Water in Spain

Water in Spain

ISBN 84-8320-219-0
9 788483 202197

45 €
(I.V.A. incluido)

MINISTERIO
DE MEDIO AMBIENTE

SECRETARÍA
GENERAL TÉCNICA

CENTRO DE PUBLICACIONES

MINISTERIO
DE MEDIO AMBIENTE

SECRETARÍA DE ESTADO
DE AGUAS Y COSTAS

DIRECCIÓN GENERAL
DE OBRAS HIDRÁULICAS
Y CALIDAD DE LAS AGUAS

BASIC INDEX

DETAILED INDEX

INDEX OF FIGURES

INDEX OF TABLES

Water in Spain

MINISTERIO
DE MEDIO AMBIENTE

SECRETARÍA DE ESTADO
DE AGUAS Y COSTAS

DIRECCIÓN GENERAL
DE OBRAS HIDRÁULICAS
Y CALIDAD DE LAS AGUAS

Edita: Centro de Publicaciones
Secretaría General Técnica
Ministerio de Medio Ambiente ©

I.S.B.N.: 84-8320-219-0
N.I.P.O.: 310-04-026-9
Depósito Legal: M-16717-2004

Imprime: V.A. Impresores, S.A.

Impreso en papel ecológico

"Just within the fortress of the Alhambra, in front of the royal palace, is a broad open esplanade, called the Place or Square of the Cisterns (la Plaza de los Algibes), so called from being undermined by reservoirs of water, hidden from sight, and which have existed from the time of the Moors.

At one corner of this esplanade is a Moorish well, cut through the living rock to a great depth, the water of which is cold as ice and clear as crystal.

Fountains and wells, ever since the scriptural days, have been noted gossiping places in hot climates; and at the well in question there is a kind of perpetual club kept up during the livelong day, by the invalids, old women, and other curious do-nothing folk of the fortress, who sit here on the stone benches, under an awning spread over the well to shelter the toll-gatherer from the sun, and dawdle over the gossip of the fortress, and question every water-carrier that arrives about the news of the city".

Legend of the Moor's Legacy
Tales of the Alhambra, Washington Irving

Whoever has been privileged enough to visit the Alhambra and the Generalife in Granada will have witnessed the exquisite care and veneration with which their inhabitants dealt with water.

The Alhambra, like many other historical monuments –such as the Aqueduct in Segovia– are a living testimony to the wealth of tradition and culture that has long existed in Spain in relation to the use, exploitation and enjoyment of water by man.

This culture of water, typical of Arabs, Romans and other civilizations who settled in the Iberian Peninsula, has survived up to the present. However, this traditional knowledge, accumulated over centuries, has been joined in more recent times with the technological development of hydraulic engineering and a significant expansion in the technological knowledge and application of water use and management. This evolution has also taken place on an administrative level, and Spain has a Water Administration which, organized around hydrographic basins, boasts considerable experience in the regulation and management of such a valued resource.

This white paper on water aims to be the heir to that knowledge and tradition. A compendium –as far as possible– of the state of the question in Spain.

It commences with a portrayal and diagnosis of the current situation and existing and foreseeable problems in water management in Spain. It continues by proposing a basis for new water policies and concludes with an analysis of the evolution of water planning from its beginnings in the 19th century up to the antecedents of the current National Hydrological Plan.

From the outset, he Environment Ministry aim to show the question of water from its multiple perspectives with the sole objective of providing a global, combined overview. The presentation of its first version (December, 1998) set off a necessary debate on water management in our country and prior to the preparation of the National Hydrological Plan. The document gave rise –as was its objective– to a large number of reactions and varied contributions, helping to enrich it. In Spain, water has always been the subject of heated debates and emotions. Probably because its scarcity has always made it a valuable resource, in a country with such an varied geography and climate.

Now, the knowledge comprised in this White Paper on Water has been edited in English, in order to share it with all those persons interested in knowing the situation of water in Spain. More southern regions will probably see the resource's scarcity problems and its efficient distribution as familiar issues; more northern regions will identify more with the problems of the resource's quality and conservation and its essential ecological functions. Everyone will find a parallel experience.

I trust that this English edition will help its readers, not just as a reference for understanding more fully the complex reality of water in Spain, but also as a broader basis for exchanging experiences, contributing to achieving, all over the world, better management –sustainable management– of such a vital resource.

Elvira Rodríguez Herrer
Minister for the Environment
June, 2003

PREAMBLE

It is a pleasure for me to be able to publicly present this final version of the White Paper on Water in Spain, prepared by the Environment Ministry.

The result of considerable effort in compiling, summarising and considering the problems of water, and of a process of refinement through lengthy public debate, this document succinctly sums up the state of a very complex issue, and outlines new, interesting perspectives for the future. Technological, social, legal, environmental and economic aspects converge naturally and comprehensively in this White Paper, achieving the harmonious –and difficult– integration of so many varying points of view.

However, apart from its intrinsic value, this document is a symbol of ongoing work through legislatures and administrative changes, and effectively shows how state policies, such as in those on water, should mature and develop continuously, without abrupt modifications, in a permanent labour of investigation and self-criticism.

Beyond circumstantial events, progress should be made collectively, on the solid foundations inherited from the past, incorporating innovations and modifications to the old methodologies, and encouraging new directions, respecting what is positive in the inheritance, but without the inefficient encumbrances of the past, is the aim in water policy.

Jaume Matas Palou
Environment Minister
September, 2000

FOREWORD

The river is an image of life: its crystal or muddy waters, its calm flow or turbulent course bearing land to the sea from all the districts it runs through, are essentially mobile and fleeting. Their only permanency is variety.

Enrique Becerril, "The River, Image of Life and Source of Energy". Speech given in February, 1947, on the presentation of the "Alfonso el Sabio" Award by the Upper Council of Scientific Research.

Water in Spain. With this title or something similar, numerous articles, books, pamphlets and, in general, all kinds of publications have been written, each aiming to reflect in its own style some of the countless facets of Spain's water problems. We can only refer to water in this country by highlighting the plurality that characterizes modern Spain as a whole.

In May, 1996, after the general elections, the government of José María Aznar took office, and as one of its members, I had the honour and the pleasure of taking over the Environment Ministry, and through it, the powers the state holds on waters.

A draft of the National Hydrological Plan existed, written in 1993, and amended in 1995, together with a series of recommendations, standards, allegations and opinions for all opinions, on the problems involved with the non-conclusion of the approval process for the basin hydrological plans, exacerbated by the drought that had just occurred in 1994 and 1995.

Furthermore, the implementation of the Water Act under the above-mentioned conditions clearly showed a number of deficiencies, on physical and administrative issues, for which an immediate response was impossible, as was simultaneously shown by our commitments with the European Union and in compliance with Community Directives.

In short, it was obviously necessary to accurately diagnose the nature and consequences of the difficulties arising from the multi-faceted problems of water administration in Spain, while the need arose to promote a significant, qualitative change in the traditional viewpoint that, for over a century, had influenced our hydrological circumstances: to outline, from the recently-created Environment Ministry, new water administration policies, highlighting water's condition as a natural element, instead of fiercely maintaining the principle of increased storage capacity and resource supply above any other consideration.

This diagnosis of the water situation can only be defined by clearly indicating the results obtained from applying scientific and technical analysis methodology in multiple disciplines, which had to be specified for this purpose. These systems and technological instruments, designed by the Directorate General of Hydraulic Works and Water Quality, and carried out by the CEDEX Centre for Hydrographic Studies, together with consideration and contributions by specialists in various aspects of the problem, produced the document that the reader is holding: the Environment Ministry White Paper on Water in Spain.

The year 2000 has just begun. We may state, without fear of error, that a historical cycle is closing with respect to water policies, strongly influenced by regenerationist ideas and by the role its supporters ascribed to water in solving national problems, after the crisis of '98. Although with some qualification, such positions have existed throughout the whole 20th century, and may be said to persist in modern times, to a certain extent, although the situation today is very different from that of the past. Both in economic and social and in technological terms, the context in which water administration is currently implemented has undergone far-reaching transformations.

Society's priorities have evolved considerably over time, in virtually every field, something especially noticeable in the case of water. Suffice to mention the growing environmental consideration given to water-related issues and the importance of appropriately conserving natural resources.

Moreover, the economic zone our country forms a part of, after joining the Economic Monetary Union, and the rapid globalisation process that we are undergoing, creates an environment that has little to do with the start of the century, when the foundations of the water policy that most of us know were laid.

At the same time, the spectacular technological development in all sectors has also had considerable influence. This development has had a double effect; on one hand, it allows actions to be carried out that were unthinkable for our forbears, because they saw barriers in nature, for them insurmountable; on the other hand, however, it makes other actions unnecessary, considered unquestionable until very recently, because innovations in other fields easily compensate for them. This is the case, for example, of the continuous improvement in productivity registered in the agricultural sector, in general, and in irrigation in particular, referring to sectors very directly related with Public Water Administration.

All of us, to a greater or lesser extent, accept these changes, although, as usually happens with those events that take place without attracting a great deal of public attention, we are not aware of their implications, and even less have we been able to assimilate and integrate all their consequences. Finally, they become so evident that they escape our perception.

In reality, the main objective of this White Paper on Water in Spain is bring these issues into the open, to act as a turning point in administrative thinking and debate on water, and to encourage full awareness of the times we are living, essential in facing the new period that, without a doubt, is beginning in administration and management of the resource.

From this point of view, all analysis elements considered necessary have been provided with the aim of accurate diagnosis. As will be seen after reading the document, an enormous effort has been made to summarise, streamline and homogenise data which up to now was scattered throughout various organisations and institutions, so as to offer all data systematically, objectively and coherently, both on water resources and on their different uses.

In short, and notwithstanding the errors and mistakes that it may contain, it is document that has been prepared without bias, and with demanding scientific, technical and methodological rigor. But this is not the result of simple academic or research enthusiasm, without a practical vocation, although contributions in this respect have certainly been made, but rather it arises from an interest to be useful in creating a better-informed criteria for all interested parties in water problems in Spain.

Starting with the identification of new references, it ultimately seeks to facilitate decision-making and help to successfully overcome the crossroads we now stand at. Aspects are described, up to now not sufficiently taken into account by public opinion, whose neglect or ignorance could have been preventing a balanced, pondered position from being adopted, with respect to water-related issues. Furthermore, they are appropriately based on the arguments presented, in the hope that these are shared by most of the society.

As a consequence, the document is an open work that allows different interpretations: it may be seen as a source of ideas or as a table of data, as an encyclopaedic summary or as a guide for identifying priorities and for political and administrative action.

In the Environment Ministry, we are convinced that the solution of water-related problems requires broad national consensus. There are so many aspects converging and such a variety of interests involved, all of them legitimate, that it is not reasonable to propose that solutions should be settled in one single area, whether economic, environmental, territorial or cultural.

With these premises, the White Paper on Water in Spain also aims to act as source of assistance in drawing up the National Hydrological Plan and thus culminate regulatory development laid down in the Water Act. Although approval of the said plan is not the only instrument in the service of water policies, and in particular of the Water Administration in implementing its functions, it does have a special significance.

Finally, we should highlight that, in short, its aim is fundamentally to solve a common problem. The better and more available information about it, and the larger the number of people with access to it, the better the possibilities of coming to appropriate decisions, shared by all. This White Paper has therefore incorporated all the constructive comments received from different levels of Spanish society, whether or not directly or indirectly represented on the National Water Council, and which have involved modifying, specifying, clarifying or completing the different issues dealt with here.

It only remains for me to thank all those who have participated in its preparation, for their effort and work, which, as always when a job well done comes to its conclusion, I can qualify largely as a disinterested party. I am convinced that the Environment Ministry White Paper on Water in Spain will soon become a text for study and consultation, and an essential work of reference for many years to come.

Isabel Tocino Biscarolasaga
Environment Minister
February, 2000

PRESENTATION

This document, the White Paper on Water in Spain, has been edited, under the Secretariat of State for Waters and Coasts of the Environment Ministry, by the Directorate General of Hydraulic Works and Water Quality, with the collaboration, assistance and technical support of the CEDEX Centre for Hydrographic Studies.

In its development and preparation, different administrative departments have taken part, both from the Environment Ministry and from other Ministerial Departments, in addition to numerous specialists from professional and academic fields.

The first version was presented in December, 1998, as a working document to be put to discussion and social debate. From that moment on, the Paper was the subject of numerous presentations and public discussions in a wide variety of forums, lasting for months, taking shape as the large number of comments and suggestions finally received. So many contributions, together with the attention the document received in Spain and internationally, corroborate how expedient the work was, and how successful the Environment Ministry was in promoting it.

The document's editing team would like to give very sincere thanks for the collaboration and effort made by everyone who has contributed their comments and suggestions. They have all been analysed and taken into account in the process of writing this final version.

Furthermore, we should note that this White Paper has not been conceived as an isolated action, resulting from a circumstantial impulse that appears like a flash and then fades away: notwithstanding its spot use as source of ideas and data for water-related issues at the end of the century, this document aims to last as a basic, up-dated work of reference on the situation of water resources in Spain. This will require periodic review, improvement and up-dating, which we undertake from this moment on.

In short, it is our hope, and that of everyone who has worked on the document, that the effort made may contribute modestly to a better understanding of water-related problems in Spain. Knowledge of the complex hydrological reality and rationality when facing this reality are the basic requirements so as to effectively deal with the problems of the present and the challenges of the future.

Francisco Cabezas Calvo-Rubio
General Sub-director of Hydrological Planning

1. INTRODUCTION

1.1. WHY A WHITE PAPER ON WATER?

Water represents an essential element for life and for economic activity. This insistently-repeated, standard statement, the starting-point for countless books, conferences and publications since it was formulated in 1968 in the European Council's Water Charter, in spite of being exhaustively reiterated, encloses a truth that the cliché has been unable to dissipate. In reality, nobody doubts that at this time, faced with the panorama that can be seen around the world, and specifically in modern, developed societies, that the issues associated with water availability, its access, preservation and protection, represent one of humanity's main challenges in the coming century, and one of the most serious latent sources of regional and international conflict.

In this problematic global context, Spain is facing similar difficulties, though in a framework of peculiar, particular experiences and situations of its own, often difficult to extrapolate. A country with considerable background in water use, in organising its model institutions and water regulations, in developing infrastructures, in productive, exemplary irrigation ..., it is facing the challenge of modern times with the weight of an intense, extended background, and perplexity with respect to the new challenges, the far-reaching, accelerated social transformations, the changes in traditional uses and methods, the perceptible degradation of aquatic landscapes, the rapid appearance of technologies, far-reaching economic changes, the transformation of the countryside, uncertainty about climatic change...

This is not, of course, a new issue, requiring our attention for the first time. However, reflection on water problems and values lay within an old tradition, which, at least since the end of the 19th century, has even been explicitly formulated, as a relevant subject for intellectual attention, considering it, in the succinct language of the period, a fundamental problem of the nation.

It is then, a long-debated issue, and never definitively resolved, in which realities have often been mixed with good intentions, rigor with banality, general interests with individual ones, dissatisfaction with achievement, mutual ignorance with misunderstanding. So much has been said, so much has been publicised, and often, clichés and slang have been abused so much that, it seems, water issues have become a veritable ceremony of confusion.

Many different players take part in this ceremony, although its main driving force and cause is the crisis of which, for the purposes of understanding, we may describe as the traditional model of Spanish water policy. A persistent model for decades, and which, originating from the regenerationist ideas of the 19th century –in turn inherited from previous experiences, and which they tried to surpass– survived social change and political regimes, and became to a large extent a primary driving force in Spain's economy and modernisation.

The implementation of major hydrological structures to promote transformations into irrigation and into hydroelectric production have historically had multiplying effects on employment, the settlement of populations, the development of industries, food production, and self-sufficiency. All desirable, unquestioned objectives, and which governments, companies, farmers and the administrative organisation adopted and undertook to resolutely and unreservedly promote.

There are many varied combined circumstances that have led to the crisis in this model, and this Paper gives an opportunity to analyse them in detail. What must be stressed immediately is the highly dubious efficacy of its fundamental inspirations and, as a consequence, the inevitable need for comprehensive review and reorientation. Furthermore, there is no sudden worsening of this historical development; what has occurred is rather a progressive deterioration in the situation, a gradual adaptation to changing circumstances, a growing feeling of inadequacy with respect to new or emerging realities, and for which an effective response has not yet been found, and the feeling of witnessing the end of a cycle, without the features and aspects of the future yet being fully and clearly outlined. Perhaps these are the historical circumstances of today with respect to water, and perhaps this is the moment to explicitly and openly formulate this situation from the closest, most sensitive position, that of the public water administration itself.

Naturally, this White Paper is not the first document to consider these questions, and the concerns expressed have been perceived by the water administration for decades. Furthermore, in recent years, there has been a surge of countless meetings, workshops, conferences, studies, symposia and publications, where these concerns have been reiteratively described, in very different institutions, with greatly diverging degrees of knowledge and rigor, and from equally varying perspectives.

The Water Act of 1985, which includes numerous previous ideas and work from ongoing consideration since the 1960s, notwithstanding the actual results produced by their application, is simply an attempt –explicit in its motivation– to provide an effective legal response to the new technical and social model as regards water, and the new demands of the times, although it is clear that it fell a long way short of achieving the ambitious objectives that inspired it, and it is more than questionable that a mere legal provision is, or can be, enough to achieve them. Furthermore, there exist numerous recent works of theoretical reflection, in the fields of professional research and of the water administration, which have considered these problems and have often provided interesting new perspectives from different, illustrative positions in the technology, legal, economy, environmental or sociology sectors.

The fundamental reason why it was decided to draw up this White Paper is precisely the clear verification that, at this time, and after experiences in the recent past, it is necessary to promote, from the water administration itself, a calm, collective effort in joint reflection, in unifying points of view, in integration, that contributes to clarify the present confusion, and which, without the status of a formal statutory or regulated text, but open and flexible, aiming for accuracy, dialogue and mutual approach, provides appraisals that are useful for the whole, and informs with the most reliable, up-to-date technical data on water-related situations, criteria and problems that are often unknown or, at least, not systematically and critically compiled in a text for debate, with widespread public distribution.

It is also fair to say that, unlike recent years, when very serious drought gave rise to extraordinary social, territorial and political tension in sectors involved with water utilisation, the current relative normality allows this reflection to be carried out calmly, with a certain sense of perspective, and without the logical animosity and lack of focus that water scarcity brings about, always demanding immediate action more than a discussion on the basis for this action.

It should also be mentioned that any discussion on such a basis must in no way be considered as procrastination with regard to the necessary actions nor as an obstacle for action. Quite the opposite, there is no effective action without solid, mature underlying ideas, and there is no real progress in the simple repetition and unsatisfactory routine of things. All time used in public information, clarification of data, definition of ideas, and explanations and proposals for public policies is used in strengthening those policies, making them visible, providing major consensus on fundamental issues, transforming them into collective goals, and definitively, making them genuinely legitimate, and genuinely effective.

1.2. OBJECTIVES OF THE WHITE PAPER

The above-mentioned reasons for drawing up this White Paper basically mention what its main objectives are. Without aiming to be comprehensive, some of the proposals specifically pursued in drawing up the document are presented below.

Firstly, the need and usefulness of compiling basic water data in Spain is clear. This basic data is widely scattered throughout numerous administrative and private institutions, and the complicated task of simply summarising and bringing it together, is in itself intrinsically interesting. Moreover, the tremendous work in compiling and unifying the data allows it to be processed systematically and uniformly, organising it and up-dating it, creating common, consistent archives, allowing it to be stored in homogenous data banks. A major by-product of this task will be the electronic edition of a database on water which, containing this basic spatial and temporal information, will be made freely available to the public.

Another of the White Paper's objectives is to lay the basis, once the current situation has been described, for estimating the foreseeable evolution, and establishing options and priorities, in water utilisation. It is a common feeling that some recent forecasts planned actions should be subjected to comprehensive reconsideration. The changes in collective interests, the major socio-economic trends, and the unavoidable environmental requirements call for a re-orientation of traditional policies of water promotion towards other methods of greater social utility and future sustainability.

Furthermore, there exist no documents on water in Spain that systematically incorporate the basic experience of the last drought. The need to re-assess resources in accordance with this significant event gives rise to new results, and creates new concerns and uncertainties which, for obvious chronological reasons, were not able to be considered in current Hydrological Plans. As shall be seen, the implications that this has on the perception of our water systems, their vulnerability, and their dimensioning and expansion possibilities, are a long way from being banal.

The controversies and old arguments over the treatment of subterranean water, the evaluation of their importance, and the need for them to be considered correctly, belong, in our opinion, to the past. The correct conceptual treatment of the whole hydrological cycle is a very simple problem from a technical point of view, and of course, has been rigorously dealt with in this document. The same is true of the considerations on water quantity and quality, and the need for its integrated treatment. A different question is the historical praxis as regards these issues, the bitter controversies and the disagreements that, for a long time, and not without justification on both sides, they have given rise to.

Another explicit objective has been the permanent effort in considering and focusing water problems from multiple positions, with different perspectives, sometimes complementary, occasionally divergent, always enlightening.

In dealing with water problems it is essential to understand, from the outset, that there is no such thing as an abstract water problem, and what in fact exists is the sum of many different, partial problems, which often overlap, diverge, old problems that disappear, and new problems that arise.

This multi-faceted, relativist vision is an essential requirement in approaching water issues with any degree of solvency. A river crosses a landscape, and there is someone who sees its future as irrigated crop fields, someone else the bend for a head diversion, someone else sees himself fishing while another sees the sediment of the river and plans to exploit it, someone else sees the riverbank and the species that inhabit it, along with someone who imagines a house on the bank, and another person who finds a spot to dump and dilute his waste, while someone else sentimentally contemplates the river and landscape of his youth. They are all seeing very different things, although they are all seeing the same landscape, and the same river.

Several different visions, all valid; different interests, all legitimate. The need for balance, for unification, for priorities, for agreements, for consideration. Technological, legal, economic, environmental and anthropological aspects: sides of the same object, faces of the same polygon. There is no other possible approach than from different angles, and there is no one single path that covers the field of water.

In this White Paper, there has been a deliberate effort to remain faithful to that idea, and to transmit this to the reader. A naturally complicated task and which will probably not be fully achieved, although that is the orientation we aim for, with conviction: not a juxtaposed variety of disciplines, but an effort towards comprehensiveness and global understanding.

This variety of perspectives must furthermore ensure that the discussion on water policy does not fall, as happens with significant frequency, into a discussion on marginal, specific, local and sectorial aspects, which are given disproportionate relevance. It is true that ideas and intentions are demonstrated and implemented on a day to day basis, with specific actions (the implementation of certain works, the resolution of certain proceedings, a certain line of research, etc.), but it is no less true that such specific issues must not make us lose the perspective of the whole, that its possible local interest is not necessarily general, and that it may even be the contrary. Prudence and rigour are, then, what the reader requires, a capacity to perceive the vast extent and complexity of the issue, the need for appropriate consideration of contents, the relativity of what seems important, and the importance of what is sometimes ignored or underestimated.

From the point of view of public opinion, this White Paper aims, as mentioned above, to provide an ordered, comprehensive and accurate material basis for discussion and social debate. The processes of internal development and contrast of opinions thus takes on greater transparency, since they are founded on objective, explicit documentary bases. Obviously, this document's main recipients will be among the upper institutions of political representation and the advisory offices of the administration on water issues, although the discussion in these essential domains does not wholly exclude the potential for public debate on water in Spain. This debate requires an open, public audience, neither regulated nor restricted, and sufficient terms for studying the data, suggestions and proposals contained in the White Paper.

Finally, it is clear that, once it has been debated, perfected and a reasonable consensus has been reached, this White Paper will express a common majority sentiment as regards water issues, and in this respect, may represent an genuine document of guidelines for the National Hydrological Plan, providing this Plan with the initial conditions for technical development, debate and consensus of considerable importance for its socio-political feasibility.

1.3. STRUCTURE AND SCOPE OF THE DOCUMENT

It is clear that a document aiming to deal with such complex problems and from such diverse perspectives comes up against a serious initial, simply formal difficulty, in its internal arrangement and structure. Any index or explanatory order is subject to different alternatives, and there is no one clearly preferable formula.

After evaluating different possibilities, it was decided to structure the White Paper in five large, basic, well-differentiated parts.

The initial introduction, as a motivation, explains the reasons and objectives that gave rise to the decision to draw up and present this document.

A second part will deal with describing the three aspects of the overall geographic context – physiographic, socio-economic and institutional, where water issues are relevant. This description provides the basic reference frameworks that comprise the situations and problems, allowing better understanding of their basic conditioning factors.

A third, basically technical and explanatory part will reflect the latest developments as regards the present situation of knowledge on water issues, including a description of the basic existing and foreseeable problems, incorporating documentary contributions and perspectives from different sectorial administrative offices. As we shall see, these latest developments are not limited to a simple compilation and exhibition of documents, but incorporates particular technological developments, specifically prepared for this White Paper. Logically, this third part on descriptions of data, situations and water problems in Spain is considered absolutely essential, and will occupy a major proportion of the document.

As far as possible, this third part of the White Paper will be limited to the description of facts, understanding this word in a broad sense (that is, physical data and legal situations, or existing administrative and economic regulations), thus referring to what may be demonstrated, and should therefore not be subject to conceptual or ideological discussion.

In the light of this technical description of facts (situations and problems), a fourth part will deal with the basis on which future water policy should be founded, oriented towards overcoming these problems and observed deficiencies. There should therefore be consideration of the different legal, environmental, economic, socio-political and technological aspects that converge in water matters, and which, in accordance with the ideas expressed previously, must be considered globally and jointly. Naturally, the subject is so extensive and complex that we are necessarily limited to pointing out some basic ideas. Public discussion will offer identification and development of those aspects considered most relevant and which require greater reflection and development.

The delimitation between these third and fourth parts arises from an organisational reason which has been considered necessary in a document such as this White Paper, since it is clear that these possible ideas or solutions generally allow for differing conceptual orientations and policies, and these policies must not, as unfortunately occurs so often, be confused with facts. As a simple example, there may be discussion on the most appropriate destination for the water from a river, and it is a legitimate discussion because it arises from different interpretations or socio-political perspectives, but how much water to supply should not be discussed because this is physical data, not ideological, which may be accounted for by specialists, after a strictly technical analysis.

Lastly, a fifth part will refer to water planning as the main –although not only– material expression of water policy, and a basic instrument for implementing it.

Obviously, faced with such a complex and inter-related matter as the present one, partial overlapping, crossed references and certain marginal repetitions between the different chapters is inevitable, and despite the effort to be rigorously systematic, cases of overlap will probably to remain. In spite of these possible occasional effects, it is estimated that the document is globally coherent and comprehensively explanatory.

As regards the style and scope of how things have been presented, the White Paper aims to achieve a balance between vulgarisation, which, compared with the advantage of making it easier to read makes it superficial in a number of aspects, and excessive academic formality, which would bring about the opposite effect. The aim has been to preserve a general educational tone, allowing greater distribution and public participation among non-specialists, without abandoning technical accuracy nor concealing the complexity of the problems described, and the difficulty involved in their possible solutions. As a consequence, some sections may seem rather dry for readers unaccustomed to the issue in hand, while others may seem trivial to specialised readers. Readers as a whole will finally judge the degree of success in seeing balance.

Finally, it should be mentioned that, due to its characteristics, this is an open White Paper, and a collective work. As mentioned above, the text presented simply represents the basis for permanent dialogue on water problems –as changeable and flowing as water itself– that specifies and incorporates, honestly and accurately, contributions made from very different perspectives. Collective, interested social participation must be, in the final instance, its true inspiration, and the water administration its destination and foundation.

2. THE PHYSICAL, SOCIO-ECONOMIC AND INSTITUTIONAL REFERENCE FRAMEWORK

As mentioned in the previous chapter, this second part generally describes three aspects –physiographical, socio-economic and institutional– in the global context of water issues. This description offers basic reference frameworks for situations and problems regarding water resources, and gives an understanding of their fundamental conditioning factors.

2.1. INTRODUCTION

As mentioned, it seems appropriate that, before describing the current situation of water issues, a brief introductory reference is given on the framework or overall context in which this resource's availability and utilisation operates. It is true that the border between the framework of the problem and the problem itself is, at the very least, unclear and rather artificial. Nevertheless, for presentation purposes, it seems relevant to consider that there is some external data provided or conditioned by mechanisms that are basically outside the area of water problems, and which, to give the necessary perspective, must be known from the outset. Naturally, describing this characteristic as "outside" is merely a convention in many cases, but it is useful from the point of view of explanatory layout and clarity.

This is the case of features that we may describe as physiographical (climatic, geological, edaphological, hydrographic and biotic), which make up a basic substratum of crucial importance since it is associated with problems of spatial irregularity in climatic variables, runoff regimes, aquifer formations, biological diversity, natural water quality, etc. As we shall see, the implications of these questions go beyond the mere explanation of water irregularities, and point directly at the fundamental problem of territorial organisation and regional development, conditioned, at least initially, by these circumstances.

Furthermore, at every given moment there exist socio-economic circumstances that, operating upon the physical environment described, and impregnated by this environment, in turn condition the current and foreseeable situation of water problems. Therefore, even briefly, they should be made known first. This way, there can be no doubt that the population situation in Spain and its foreseeable future trends, the implications of tourism, territorial agricultural and industrial trends, or the European and international context, represent *de facto* situations that may significantly determine the problems and solutions for water issues. It is, in this case, a conditioning factor that can in turn be conditioned, thus referring us to the basic technical problem of the feasibility of models of overall regulation and the scope of concept of planning itself, which we will logically have the occasion to deal with in detail.

Finally, it is necessary to refer, however briefly, to the institutional and organisational framework of hydraulic management. Although this explanatory order may seem unorthodox, it is our feeling that a brief prior reference to the institutional framework of water management in Spain gives a better understanding of what is happening with its availability, its use, its demand and its exploitation. Furthermore, this institutional and administrative situation, as we shall see, is of critical importance (certainly greater than other conditioning factors traditionally considered to be key players) in the make-up of water problems in Spain.

Note that all the above merely organises the description in hand –water issues– initially formulating the different reference frameworks in an approach that may be classified as geographical: description and explanation of terrestrial landscapes, that is, of the physionomic aspects of the land surface arising from a combination of factors, both physical (climate, geology, biology, etc.) and human (population, tourism, agriculture, industry, etc.) that act upon landscapes and shape them dynamically. It is after this short geographical description, oriented towards a better understanding of water issues, that the necessary perspective is achieved, providing a basis to deal with subsequent levels of the problem's complexity and particularity.

2.2. PHYSICAL AND BIOTIC FRAMEWORK

Under this concept, we shall review the main features of the climate, geology, edaphology, land use, hydrography and biota that makes up and frames the Spanish hydraulic situation.

2.2.1. Climatology

The Iberian Peninsula, given its location between two major sea masses (Atlantic and Mediterranean) and two continental masses (Europe and Africa), has a climate whose basic defining feature is diversity.

The northern area, including Galicia, Cordillera Cantábrica and the Pyrenees, is characterised by a temperate climate, with storms from the Atlantic appearing almost all year round, giving rise to a high relative humidity level and mild temperatures, temperate in winter and cool in summer.

On the Mediterranean coast and part of inland Andalusia (basically the Guadalquivir basin), the climate is temperate, with dry summers and mild winters. In the rest of the Peninsula, the predominant climate is characterised by dry summers and cold winters, features that reflect its continental character. Winter anticyclones are habitual in this area, a situation that causes inversion of temperature gradient (inversions of normal temperature decrease with increase in altitude).

In the Canaries (especially in the eastern islands, since Atlantic air masses affect the western islands more), and the coastal strip of Murcia and Almería, the climate is dry, with little precipitation, very mild winters and very warm summers.

The spatial distribution of average annual temperature is closely linked to the mountain systems we describe briefly in the next section. Minimums lower than 8 °C are located in the mountain ranges in the northern half of the Peninsula, while the warmer areas, delimited by the isotherm of 18 °C are located in the Guadalquivir valley, the south and south-east coast, and Levante. Figure 1, included solely for visual purposes, shows the spatial distribution of mean temperatures, superimposed on a shaded relief analysis, giving a qualitative idea of this relationship.

In a similar way to mean annual temperature, mean annual rainfall is also significantly influenced by the mountain systems. Precipitations increase with altitude and are greater on mountain systems located to the windward side of humid fronts than those located to the leeward side.

In its spatial distribution, there is a significant positive latitudinal gradient –that is, precipitation diminishes from North to South– and considerable longitudinal asymmetry that gives rise to precipitation on the Atlantic side being greater than on the Mediterranean side. In order to get a visual idea of this behaviour, notwithstanding its detailed description, given in the next chapter when we refer to water resources, figure 2 shows, like the previous one on temperatures, the spatial distribution of mean precipitation, superimposed on a shaded relief analysis, allowing, as above, a qualitative appreciation of its inter-relationship.

As for temporal distribution of precipitation, it may be delimited into a first area of strong Atlantic influence and which, together with the basins corresponding to this watershed (with the exceptions of the central area of the Douro and the upper basins o the Tagus and Guadiana), would include the upper Ebro basin, the Basque-Navarre Pyrenees and the South basin as far as Cabo de Gata. In this area, the period of greatest rainfall is seen between the end of autumn and the beginning of winter, with a relative minimum at the end of winter and a relative maximum in the months of April-May.

A second area comprises the Mediterranean watershed, from Cabo de Gata as far as the French border. There, a perfectly differentiated absolute maximum can be seen in autumn (September - October), and a secondary maximum, in the northern half, in spring.

The rest of the Peninsula is mainly characterised by its continentality, with a noticeable maximum in spring and another lesser one at the beginning of the winter season, and a winter minimum in January - February.

In the Canary Islands, distribution is clearly monomodal: winter maximum in December and a minimum in summer.

According to the moisture index, defined (UNESCO, 1979) as the coefficient between precipitation and potential annual evapotranspiration according to Penman (which we shall see in detail in the analysis of water resources), there exist arid, semi-arid, sub-humid and humid regions in Spain, as shown by the figure below. The arid regions occupy a small surface area and are located partly in the Canary Islands and in the region of the Tabernas Desert (Almería). The semi-arid zones mainly affect the Ebro Depression, Almería, Murcia, the southern Júcar basin, headwater of the Guadiana and part of the Canaries. Sub-humid areas are basically located in the Douro basin, the south of the Catalonia Inland Basins, the Balearic Islands, Guadalquivir

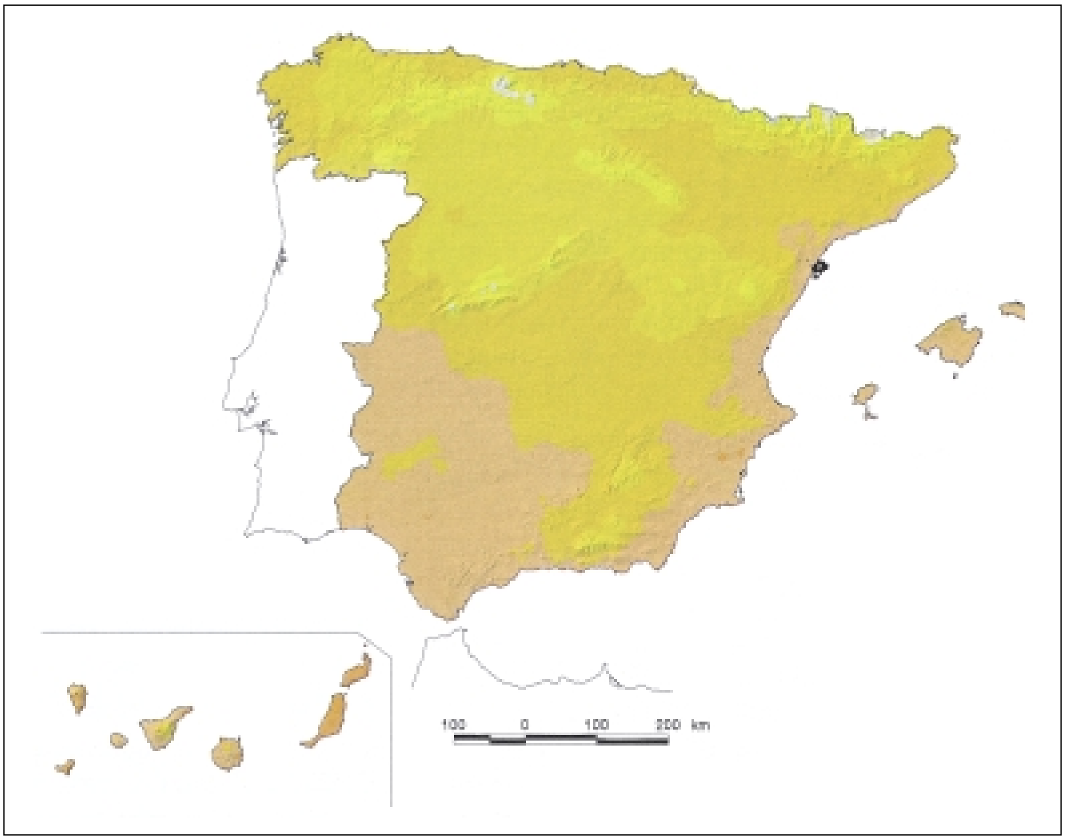


Figure 1. Map of spatial distribution of mean temperatures, superimposed on the relief.

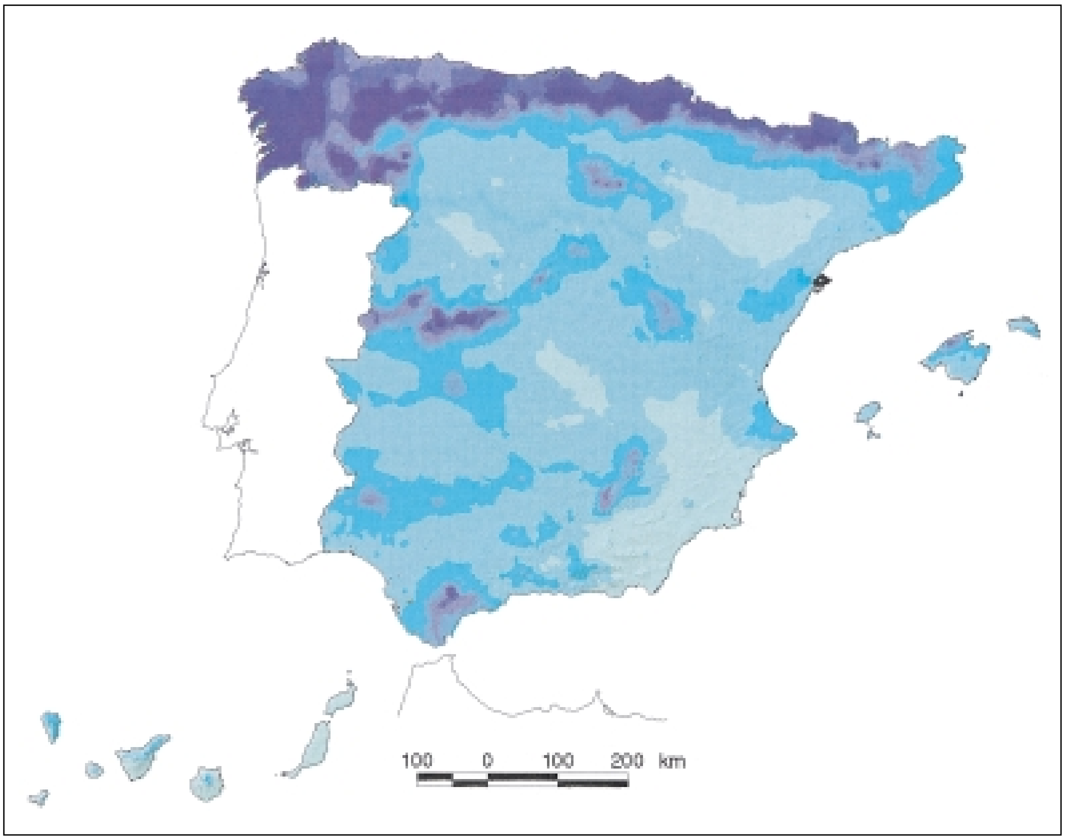


Figure 2. Map of spatial distribution of mean precipitation, superimposed on the relief.

and along the mountain ranges of lesser altitude. Finally, the humid zone affects the rest of the country (fig. 3).

In summary, and as stated above, Spain shows a particular diversity of climate that, extended over its equally diverse geology, gives rise to a large variety of aquatic environments, as we shall see.

2.2.2. Geology

Since ancient times, when its relief began to shape Iberia's closed, solid and peninsular outline (Strabo's "stretched hide", the bull-hide according to the symbolic vision of Spain), other unique features that make up Spanish territory are equally striking.

The first and, possibly, fundamental, is the central nucleus of the plateau, flat lands which at an average altitude of 600 m above sea level cover nearly half the peninsular area, with a backbone of the granite-slate Cordillera Central along its central axis. The southern sub-meseta, slightly lower than the northern one, loses monotony with the broken, grey slate-quarzite alignments of Montes de Toledo, whose low hills distribute water toward the sub-meseta's major collectors: the Tagus and the Guadiana. The plateau's formation lies in the paradoxical existence of two, Hercynian depressions which were filled by hundreds of meters of sediment from the adjacent mountain ranges; marl-clay sediment and also gypsum, adding to its endhoreism, a characteristic common to many continental sedimentary basins.

Another major feature of the meseta is its ramparts. The Cantabrian and Iberian mountain ranges enclose it to the north and east, and the Sierra Morena to the south, while to the west it is generally open toward the Atlantic, with a clear threshold. This arrangement of isolation influences its continental climate, mentioned above, and as a consequence, its hydrographic regimes.

The two triangular depressions adjoining the enclosed central area, Ebro and Guadalquivir, with their perimeter walls of the Catalan Coast Pyrenees Massif, and Cordillera Bética, make up the basis of Spanish geography. Two deep depressions filled with Tertiary material offer little resistance to erosive agents, and two major mountain systems with the highest points on the Peninsula, both of which are genuine peninsular alpine mountain ranges arising from the orogeny of the same name.

These two alpine-style ranges, Bética and Pyrenees, together with the Cantabrian and Iberian ranges, also raised by the same orogeny, are mostly formed with calcareous materials, formations that join up to create the classic inverted Z of calcareous Spain. These four basically permeable structures are drained by large, abundant springs that provide significant base flow for the collecting channels they run into. Conversely, the siliceous base that makes up the Central System, Galician Massif, Sierra Morena and Extremadura territory, of low-permeability Hercynian material, have a very quick runoff response and more moderate, continuous base flow.

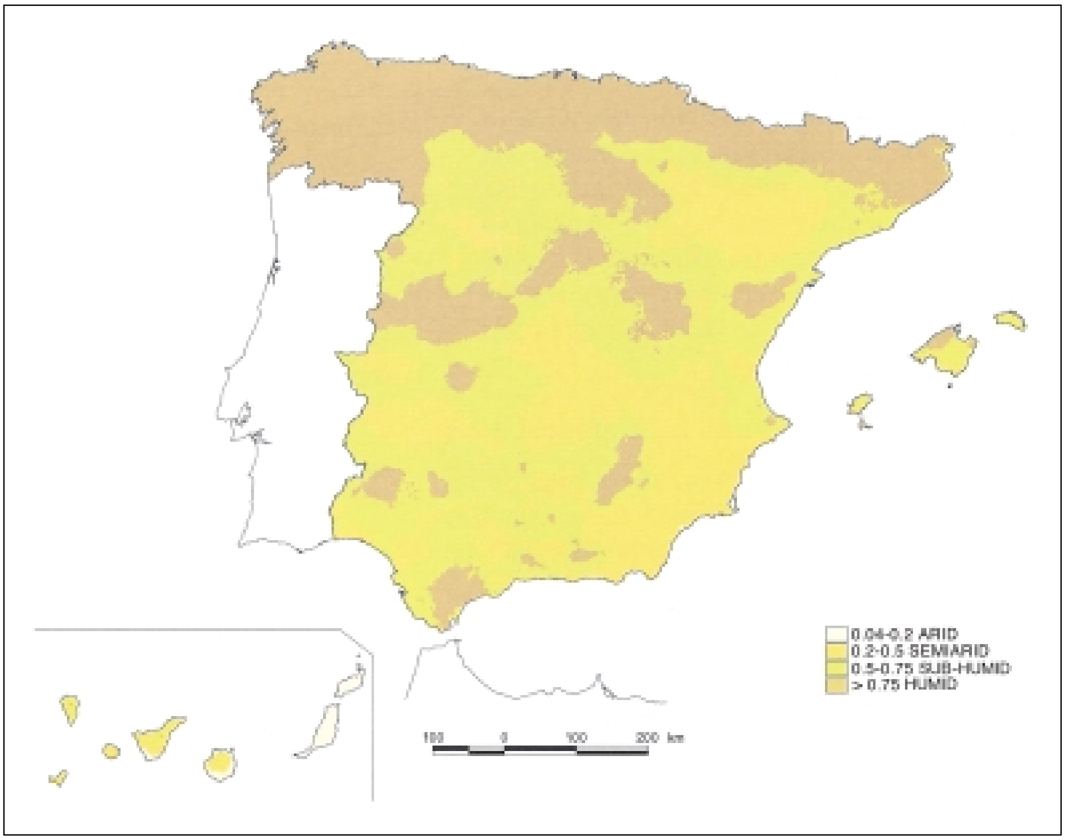


Figure 3. Map of climatic classification according to the UNESCO moisture index

Figure 4 shows the different lithology observed, according to the EUROSTAT digital land map, on a scale of 1:1,000,000, which does not include the Canary Islands.

When the orogenic changes that raised or rejuvenated the mountain systems came to an end, with varying results, the meseta structure did not remain passive. At the end of the Miocene, it tilted, in one piece, westwards, creating the significant asymmetry of the peninsular fluvial network by orienting the major peninsular channels in that direction, with the exception of the Ebro. The meseta's decline towards the Atlantic, with the confluence of the peripheral mountain ranges, leads to the other channels with mouths on the Bay of Biscay and the Mediterranean being short and torrential.

The narrow Mediterranean coastal plains –the Cantabrian plains are scarcely relevant– complete the scenario of Spain's geography, monotonous in contours but varied in content, and even further enriched by the Mediterranean and Atlantic island territories. The first, the Balearic Islands, is no more than a north-eastern continuation of the Andalusian System as regards characteristics; the second, the Canary Islands, is remarkable for its volcanic origin, and both are characterized by the virtual absence of permanent river flow, as we shall see further ahead, when describing hydrography.

Figure 5 shows a digital model of land elevations (reprocessed to a resolution of 1×1 km from a basic model of 80×80 m), together with the contours of the main dividing rivers, illustrating the mountain features described.

To summarise, and reiterating the above, geological multiplicity, variety of materials, structural complexity and, in short, the repetitive feature of vast diversity and heterogeneity.

2.2.3. Edaphology

The same variety in structures and materials that characterizes the geology, contributes primarily to the fact that the main feature of Spanish soil is also diversity.

The thickness of the soil that plant roots grow in, as a structure situated between the lithosphere and the biosphere, and in a way belonging to both, is the result of climatic effects on the land surface, under the influence of the mountain systems and the action of living organisms. Its role in the hydrological cycle is fundamental, by acting as a distributor of precipitation between runoff and infiltration. If, as shown in sections above, the initial material and the factors determining its evolution are characterized by variety, the result can only be the tremendous diversity of soils to be found in national territory. This diversity is seen by reviewing the most relevant aspects of Spanish soil on the basis of the largest-range category, orders, established by Soil Taxonomy, the world-wide classification proposed by the US Soil Survey Staff (USDA [1960]; USDA [1967]).

Accordingly, considering the soil's level of evolution, there are examples ranging from very young soils (entisols) and undeveloped soils (inceptisols), to soils that have reached

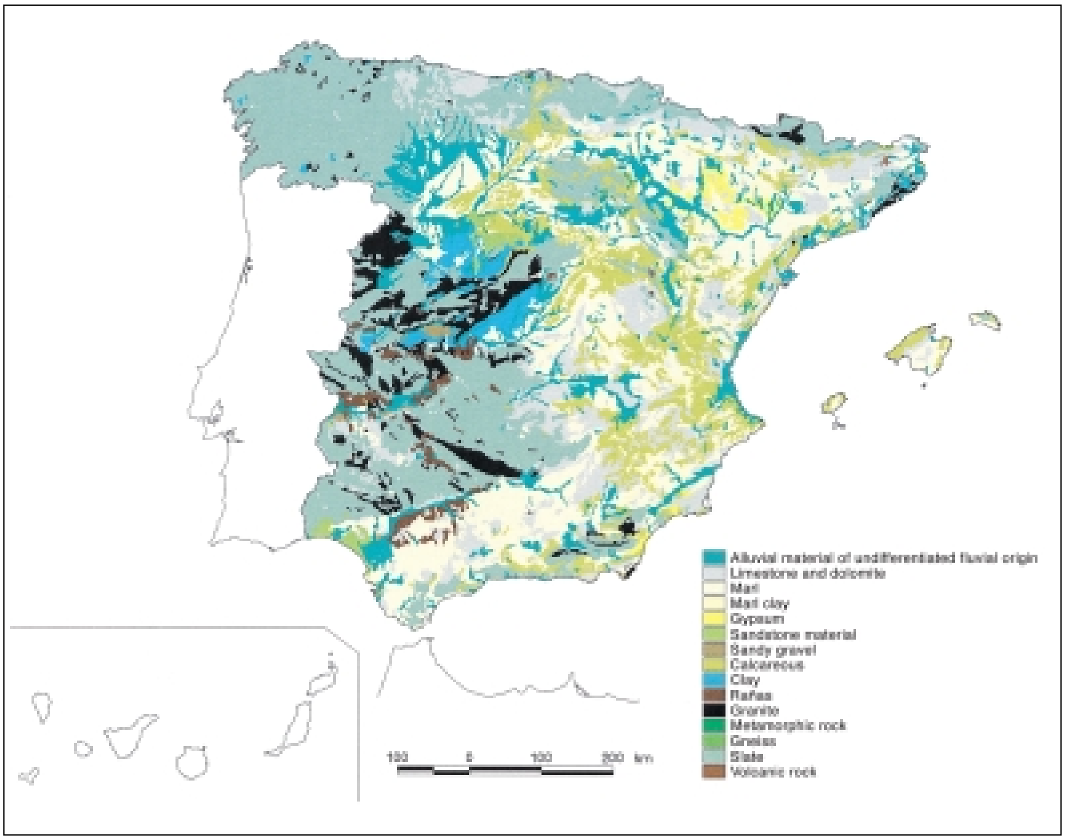


Figure 4. Lithology map.

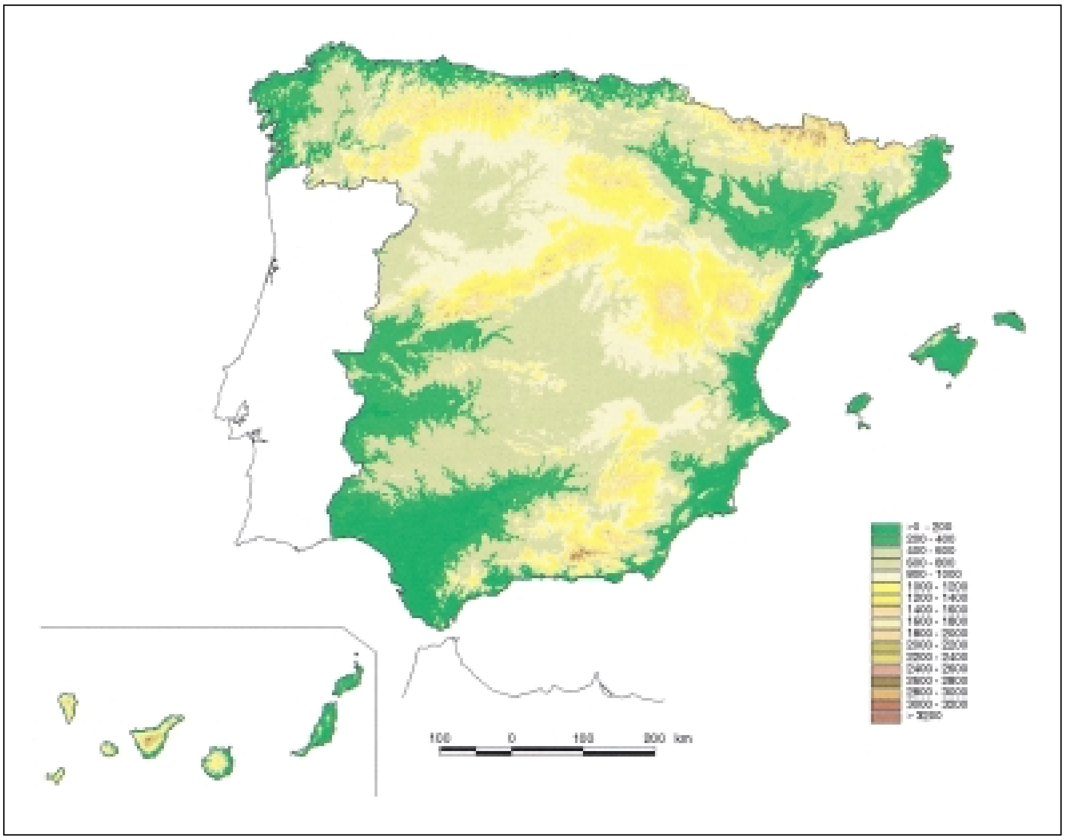


Figure 5. Relief map. Digital model of the terrain.

the last stages of meteorisation and evolution (ultisols); as regards texture, from sandbanks of eolic origin, in some entisols, to the expansible clays of the Andalusian seasonal lagoons (vertisols); as regards soil reaction (pH), there are soils with a high base content (mollisols), those with high to average (alfisols) and acid soils (spodosols). Additionally, there are also soils with abundant gypsum (gypsiorthids) and saline content (salorthids), both of the aridisol order; and even, on the Canary Islands, dark soils developed from volcanic materials (andosols).

As for thermal regimes and moisture, which are the two fundamental diagnosis characteristics used in the Soil Taxonomy, their variety is also their most illustrative feature. Accordingly, the thermal regime ranges from the cryic layer, where the mean annual soil temperature at a depth of 50 cm is between 0 and 8 °C, up to the thermal layer, where this temperature is between 15 and 22 °C. With respect to soil moisture conditions, these are also represented, from the histosols of some lagoons, to the aridisols with marked water deficit.

It is significant that the above paragraphs have included references to ten of the total eleven orders which, according to Soil Taxonomy, the Earth's soils can be grouped into. We may therefore apply, also in relation to edaphology, the idea of some geographers that the national territory is virtually a miniature continent. Of the ten mentioned orders, those that cover the greatest area are the inceptisols, entisols, aridisols and alfisols, as shown in the adjoining figure. Diversity is, again, the dominant characteristic.

Figure 6 shows a map of the main soil types, adapted from the National Atlas of Spain of Edaphology, of the National Geographical Institute (MOPT, 1992a).

2.2.4. Soil uses

As seen in figure 7 on soil uses, drawn up here from the leaves 1:100.000 CORINE LAND COVER in digital format provided by the National Centre for Geographical Information (CNIG), of the National Geographical Institute, a large percentage of Spain's surface area, about 50%, is covered with agricultural land.

The main use corresponds to agricultural land, which includes cereals, vegetables, tubers and fallow land. Another group consists of permanent crops, including fruit, olives and grapes. A last group corresponds to heterogeneous agricultural systems, where annual and permanent crops coexist.

The agricultural land is located mainly in the two big depressions of the Ebro and the Guadalquivir and on the flat surface areas of both plateaus, occupying 26% of the territory. Heterogeneous agricultural systems are distributed over the whole territory in small areas and occupy 18%, while permanent crops (6% of the total) are mainly found in the south of the Peninsula, the Mediterranean coast and the Ebro basin.

Shrub or herbaceous vegetation covers 27% of the country's surface area. It consists of natural pastures with low productivity and scrubland, with low-lying, thick vegetation.

The forests, transformed over time by agricultural land, presently cover 17% of the territory. This amount, despite its moderate size, is certainly very significant, and shows the existence of an important natural heritage which, in spite of historical reduction, continues to have considerable extension and importance.

The areas of meadow occupy just 1% of the country. They are located mostly in the north of the Peninsula and in mountain areas over the whole territory. Their final destination is, in many cases, forage production for livestock.

A very small area, which does not even represent 1% of the territory, is covered by humid areas and water bodies, including wetlands, marshy areas, reservoirs, marshes, peat-bogs and salt flats.

Lastly, we could distinguish those areas (4% of the total) where the vegetation barely covers the surface, either because they are rocky areas, tundra, fallow land, beaches, burnt areas... or because they are artificial surfaces such as urban areas, highways, etc.

From the point of view of forests, the map in figure 8, drawn up here from information generated by ICONA in the National Forestry Inventory, shows the different soil uses. It distinguishes the following categories: tree-covered forest (forest surface area with a fraction of over 20% of space covered by projecting tree-tops), understocked forest (forest surface area with fraction of between 5 and 20% of space covered), open forest (fraction of less than 5% of space covered), crop and non-productive.

Seen from the air, Spain is basically a rural country, with very little urban surface area , and a very uneven relief, creating a rough, hard landscape, dominated by sharp edges and brown tones.

2.2.5. Hydrography

In the same way as the Peninsula's mountain systems are characterized by having their main mountain ranges oriented to follow the parallels, the biggest Spanish rivers also reflect that orientation, as may be seen in the map showing relief and main rivers (fig. 9).

The Rivers Douro, Tagus and Guadiana run over the Meseta, enclosed by the Cordillera Cantábrica and the Cordillera Ibérica and by Sierra Morena,and leave towards the sea in the area furthest west, on the border with Portugal. Furthermore, the two major exterior valleys –Ebro and Guadalquivir– follow this general direction pattern, hugging the Meseta.

The exception to this orientation pattern of the major rivers takes place in those which, like those on the Cantabrian and southern peninsular watersheds, have their sources in

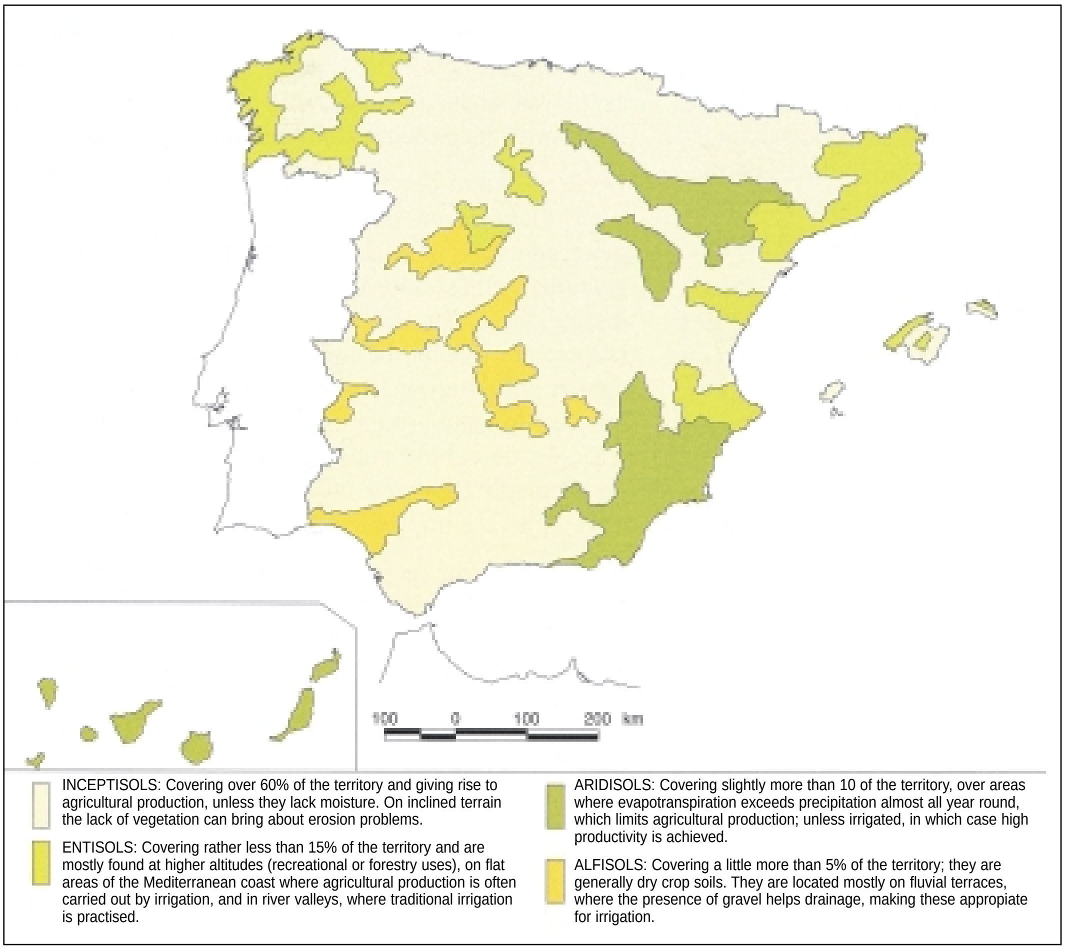


Figure 6. Map of basic soil types.

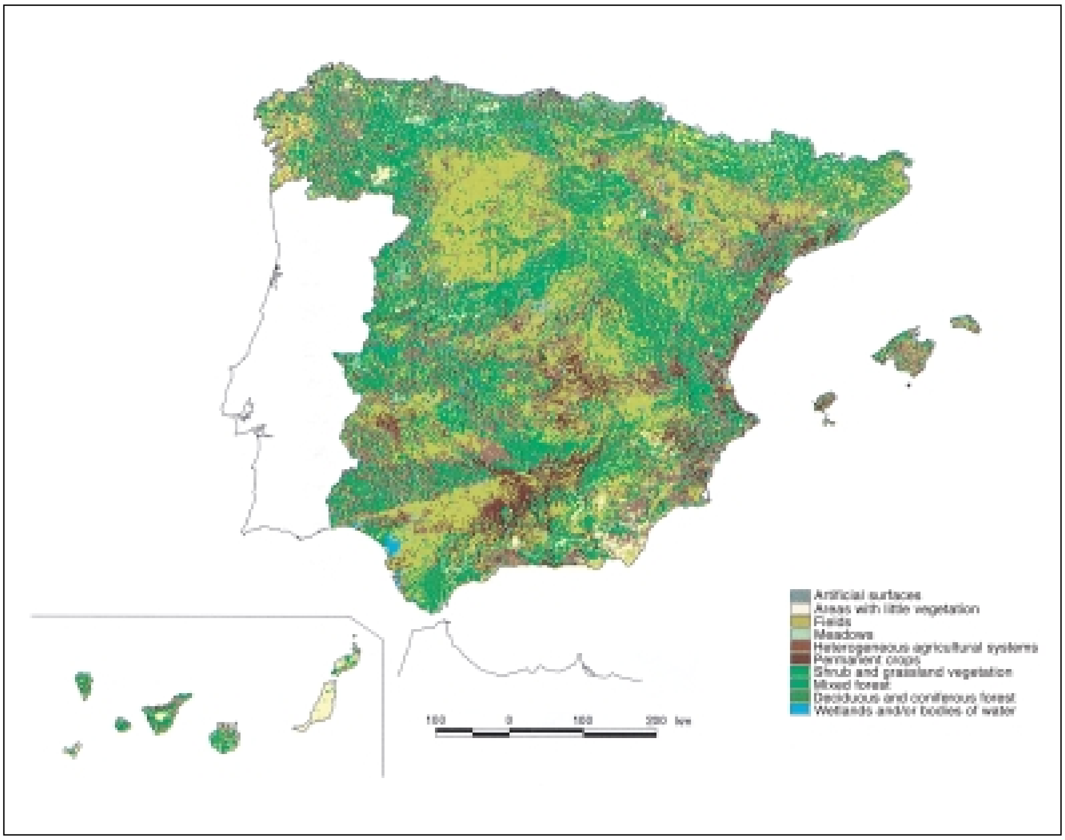


Figure 7. Map of soil uses.

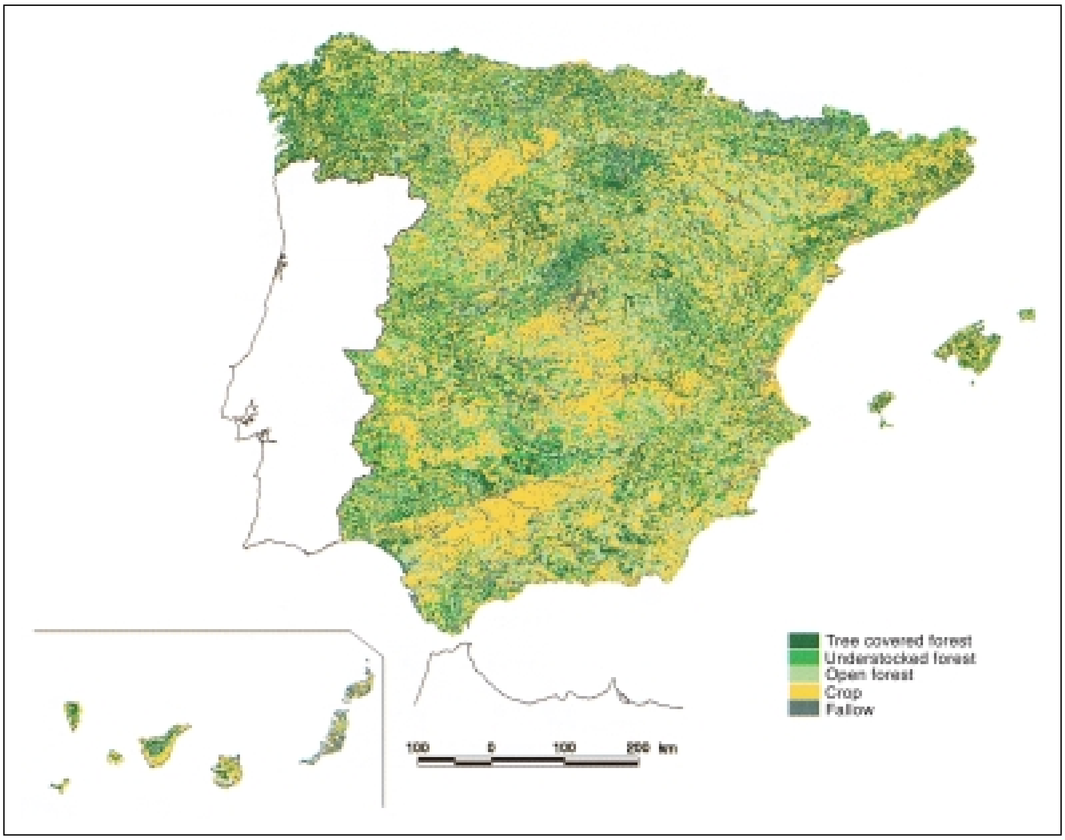


Figure 8. Map of forestry uses.

Figure 9. Relief map and main rivers.

mountain ranges near the sea, following a southward direction.

The Catalonian Coast mountain range, at the Mediterranean end of the Ibérica, and the Cordilleras Béticas, all near the coastline, give rise to relatively small basins, with the exception of those corresponding to rivers with significant torrential effects. These are the cases of fluvial invasion, such as the Llobregat, which has captured basins originally belonging to the Ebro, the Júcar, whose headwater lies very near the source of the Tagus in the Montes Universales, or the Segura, whose source lies within the Bético range (Arenillas and Sáenz, 1987).

The insular channels of the Balearic Islands and the Canaries are characterised by their intermittent nature and steep gradients. In the former, the presence of numerous karst zones means that a large part of the water is infiltrated before reaching the lower channels and subsequently appears as springs. In the latter, the steep gradients of the hillsides and the historical abundance of groundwater withdrawal, has led to the virtual absence of surface currents (there is presently only one river in La Palma and another in Gomera, and there used to be one in Gran Canaria).

Figure 10 shows longitudinal profiles (height in metres above sea level compared with distance in kilometres from source) of Spanish rivers with the longest courses.

Normally, these longitudinal profiles distinguish three differentiated reaches: the headwaters, where the river proceeds between steep banks, favouring its erosive capacities; the middle reach, of a considerably greater length and uniform gradient along the channel, whose characteristic action is transport; and a final reach, or mouth, where the river deposits load carried to the basin, often forming deltas and coastal deposits, if tidal and current conditions allow (one of whose most spectacular examples is the Ebro Delta). The combination of characteristic actions, erosion, transport and sedimentation, tends to shape a gentle longitudinal profile between the source and the mouth level which acts as an indicator of its degree of geomorphological maturity.

The longitudinal profiles given show, as a striking aspect compared with the general pattern described above, the step that exists on those rivers that collect water from the Meseta, and particularly on the Douro when it leaves the high plain, on the Tagus and the Guadiana more gently, or on the Júcar when it leaves the plain of La Mancha. Logically it is these reaches, where there is a succession of steep gradients once there is significant flow collected from the basin upstream, which are the most appropriate for energy uses and, in fact, it is on these where a large part of Spain’s major hydroelectric stations are to be found. It is worth mentioning the dams on the upper part of the Douro or on the Júcar between the reach at Cofrentes and Embarcaderos or El Naranjero.

A peculiar feature of Spanish hydrography is the frequent presence of temporary currents, or water courses that are not permanent in time and only carry water occasionally, after storms. Arising from the aridity of the climate and from the relief, the geomorphology and the permeability of the terrain, they dry up shortly after the rain stops, giving rise to cases of continuous reaches co-existing with permanent flows and other, intermittent ones with temporary flow in the same river, especially in calcareous zones.

Figure 11 shows the hydrographic network together with the major river divisions and their mean peaks (Hernández-Pacheco, 1956). The Pico de los Tres Mares can be seen, the high point of the three major seaboards that surround the Peninsula.

Furthermore, not all runoff flows into the river network, as there are numerous enclosed, endorheic or semi-endorheic areas. They are usually areas of small dimensions consisting of depressions in land with low permeability, where water is retained, forming pools, later to be lost through filtration or, more commonly, through evaporation. They are irregularly distributed all over Spanish territory, with an abundance of small, shallow lagoons (Arenillas and Sáenz, 1987).

One of the areas where there is the largest number of lagoon complexes is the upper Guadiana basin, known as Mancha Húmeda, and especially the areas along the river basins of the Záncara and the Gigüela. This area could be extended, as regards the phenomenon of enorheism, to the eastern plain of La Mancha, in the Júcar basin, and the most northern areas of the Segura basin, bordering the Júcar (Yecla, Corral Rubio and Pozohondo areas). The topography of this whole area is formed by temporary channels that run into semi-flooded plains, lagoons and marsh areas. A good example of this situation is the María Cristina Canal, built in the 18th and 19th centuries precisely to provide a way out for the water stagnated around Albacete.

In the Ebro basin, specifically on the left bank of the River Jiloca, lies Spain’s largest lagoon, the Gallocanta. Other zones with notable endorheic behaviour can be found in Santillana del Mar, in Cantabria, Ruesga, between the Rivers Asón and Miera, in the Norte II territorial area, Osuna on the Guadalquivir, or those of Fuente de Piedra and Zafarraya in the south.

In short, the Spanish hydrographic system shows, like the other environmental elements examined so far, numerous peculiarities and significant contrasts. In subsequent chapters, there will be opportunity to describe these contrasts and precisely quantify their flow in great technical detail. For the moment, it is sufficient to indicate that the variety of runoff regimes is the cause of difficulties in research and the lack of general hydrological behaviour rules, although it also gives rise to a tremendous diversity in river, environment and landscape values.

2.2.6. Biotic Environment

The variety of the abiotic environment described above (geological, climatic, edaphological, hydrographic), combined with palaeo-geographical and palaeo-climatic varia-

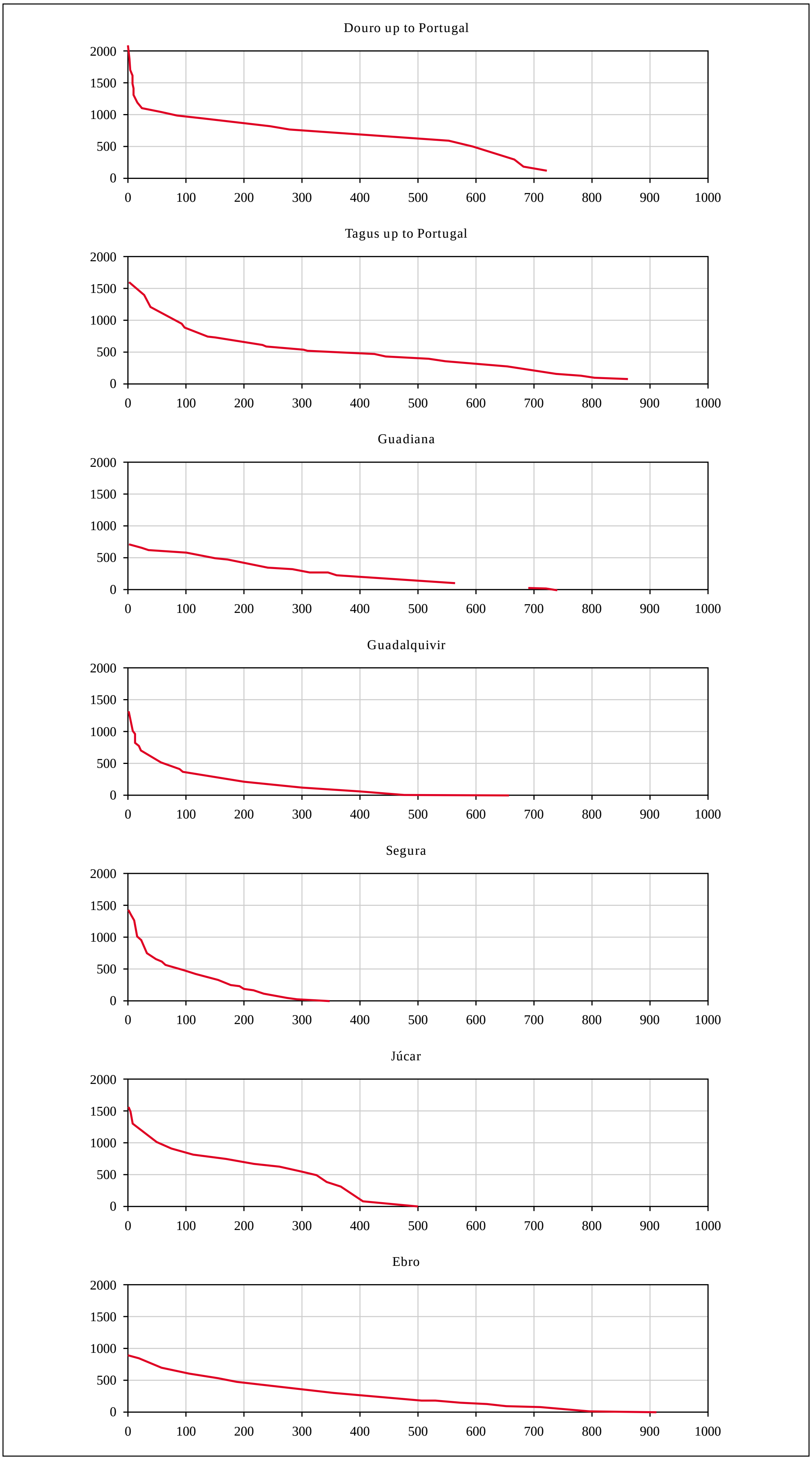


Figure 10. Longitudinal profiles of the longest rivers.

Figure 11. Map of the basic fluvial network and border divisions of the main basins.

tions and the major role that the Iberian Peninsula has played –and continues to play– as a geographical bridge or crossroads between two continents for the movement of species, together with the historical shaping actions of humankind, has given rise to a large number of ecosystems in Spain, biogeographically divided into in three regions: Eurosiberian, Mediterranean and Macaronesian, regions in which up to fourteen bio-climatic levels are defined, in addition to the fourteen provinces distinguished by botanic levels.

As mentioned, this diversity has given rise to the consideration of the Iberian Peninsula as a mini-continent, together with the fertile Island ecosystems. The wealth of ecosystems is intuitively obvious, without the need to resort to scientific descriptions, to travellers, who can differentiate a considerable variety of landscapes while moving around Spanish territory, from the Almería deserts, to the high-mountain peaks of Sierra Nevada, the Pyrenees or the Teide, through the meadows of the mesetas, the northern deciduous forests of beech and oak, the Canarian Laurisilvas, the continental steppe and the gallery forests of the river courses.

This landscape variety contains different biological communities adapted to them, and considerable biological diversity, shown by over 7.000 species of vascular flora (with around 1.300 endemic species); 66 species of land mammal, including remarkable zoological specimens such as the Iberian lynx, the European bear, the wolf, the Iberian ibex and Cabrera's vole; 27 species of bat with one endemic species, the Tenerife long-eared bat; 30 species of amphibian, with endemic varieties like the Majorcan midwife toad, and 55 species of reptile, not counting marine turtles, including the Hierro giant lizard, Bedriagai's skink or the Iberian viper; 368 species of birds, classified as breeding, wintering or in migration, among which, although it is difficult to pick out any one in particular, we could mention the great bustard, the Spanish imperial eagle, the black stork and owls. Finally, and without entering the numerous group of invertebrates, the 61 species of fresh-water fish, of which 17 are exotic, native ones including the European chub, the different species of barbo and the Spanish killifish. All this makes our country a European territory where, unlike others, it is still possible to find landscapes with a high level of natural conservation and varied, valuable flora and fauna.

This short description simply aims to point out a noteworthy situation of biological diversity, in spite of degradation suffered over recent decades, that remains in Spanish territory.

From our point of view, it is important to retain, in maintaining this natural asset, the rivers, ravines and water courses that play an extremely important role by acting as corridors for fauna to move along, and as a refuge housing, both within them and on their banks, a large part of the Peninsula's total species. The role of the rivers lies in addition to that of the wetlands, whether inland or coastal, as a refuge for many biotic species which otherwise could find no place to live in our territory. Bodies of fresh water (lakes and reservoirs) also have a fundamentally important role to play and, although they cover a relatively small part of the surface area, contain a considerable level of biodiversity (Margalef, 1981).

These are the reasons why environmental factors (fauna, vegetation, ecological processes) require particular attention in dealing with hydraulic systems; any programme affecting these systems must explicitly consider, beyond a simplistic hydraulic vision, such environmental factors from the outset.

In recent decades, the clear perception of a generalised deterioration in water quality, and the gradual degradation or disappearance of major natural systems –which definitively contribute to maintaining ecological and environmental diversity–, merely demonstrates the problem presented, and shows a confrontation between water uses and resource conservation, which, as we shall see, is one of the central problems faced by modern water policy.

2.2.7. Conclusion

In the light of the above paragraphs, if a basic defining feature were to be given to characterise our territory's physical and biotic framework, it is certain the said feature is quite simply diversity. Diversity of climates, of geological substrata, of river regimes, of animal species, of vegetation, of lands, of landscapes...

From a hydrological perspective, this diversity of environments means the existence of very different aquatic environments, of significant aridity gradients, islands of humidity in dry contexts, of considerable runoff variability, of a hydrogeology with major regional differences, of variability in processes on different scales, of –as we shall see– a high level of heterogeneity in the storage and flow of water in our territory.

The implications for hydraulic systems of these characteristics of the physical and biotic environment go far beyond explaining the reasons for circumstantial space-time irregularities in their hydrological regime and the natural quality of their water. Firstly, is there a place for general solutions to such different situations? Can the same system of regulatory procedures be satisfactory for the whole territory? Would it not be better to think of different models for different areas, of different vocations for the different basins? How far can, and should, inter-territorial water management go? What would be the limits of interconnection?

Important, complex questions, which we simply suggest for the moment, and which we shall return to in other paragraphs of this White Paper.

2.3. SOCIO-ECONOMIC FRAMEWORK

As we have seen, reflection on the mentioned basic features of the Spanish physical and biotic environment leads to fundamental questions, whose answers, to a large extent, are related to the socio-economic framework acting on that physical environment.

It is clear that, environmental conditions being equal, the level of social development and the general trends of population and economic activity can give rise to very different responses and situations. How to compare, for instance, the state of things at the beginning of the century, with an essentially rural, impoverished Spain, with serious lack of social cohesion and economic deficiencies, with modern-day Spain where, unquestionably, apart from other current problems, the overall situation is utterly and radically different?

As a result, and in relation to water, the physical sub-stratum, the basic conditioning factor for supply, is significantly comparable, although in view of the far-reaching socio-economic changes conditioning demand, how could the interests of then, the hydraulic aspirations, the problems perceived, the old idea of modernity, still remain in force?

2.3.1. Introduction

Very briefly, it may be said that, unlike the old rural countryside societies, with subsistence economies associated with working the land, and for whom achieving self-sufficiency in foodstuffs was a big enough objective, modern societies, after the historical experience of industrialisation, technological innovation, and the structural and institutional changes created, have reduced the importance that natural resources –and among them water– have traditionally had in economic growth and the welfare and wealth of nations.

Furthermore, in developed countries, the territorial location of human activities whose implementation requires water resources follows its own sectoral dynamics, in general –and in principle– regardless of the location of these water resources, even though in the past urban settlements and some economic activities –irrigation, industry– have been related with expedient water availability.

Following this general pattern, in the case of Spain, a marked time-space disassociation has been increasing over recent decades between demand requirements and the location of resources, which has led to major development of hydraulic infrastructures –including the inter-connection of hydraulic systems– and a differing level of exploitation of own resources in different hydrographic basins, sometimes virtually exhausting them. We will have an opportunity to study both questions in detail in forthcoming chapters, although it is appropriate to point out here that territorial development trends have played a decisive role in bringing about recent hydraulic transformations.

Moreover, it would be naive to think that scarcity problems –imbalance between supply and demand– are a new issue in our hydrualic history. A brief review of the economic history of the semi-arid regions immediately shows how water availability and the conflicts around its use have been highly significant factors since the beginning of the century. The basis of the water problem, then, is not new, although the dimension reached certainly is, and the fact that, for the first time, the observation of the negative impact that productive activity has on the natural environment has given rise its increasing evaluation by society, and a demand for the conservation of the main environmental assets, whose enjoyment is associated, more and more, with greater levels of welfare.

Having made these considerations, the following sections provide a brief description of those variables in the Spanish economic-productive and territorial system that make up the context of water resource utilisation and show a greater influence or have a highly significant role in the composition of total water demand. As is logical, in no way is the intention to make a general study of Spain's socio-economic structure or its production system, but rather simply highlight some basic features of this structure, relevant from the point of view of water resources.

With this criteria, and from the perspective of the general socio-economic framework, attention has basically focused on the following issues:

Population and Tourism. Both show their effects on water resources through demand aimed at satisfying people's basic needs (consumption in supply). In the case of tourism, additionally, the circumstances are double: firstly, it is a fundamentally important activity, within the services sector, and one of the most dynamic in the Spanish economy; secondly, it is beginning to incorporate –beyond simple seasonal movement and increase of population– new forms of demand for water resources associated with leisure, enjoyment of the environment, and in short, the tertiarisation of natural resources.

Irrigation, hydroelectric production and industry. The first two are economic activities that use water as a fundamental input in their production process, and without which they would be unfeasible. Both sub-sectors are, with some difference from the rest, the major users of water resources, although with the basic difference that the first of them, unlike the second, is of a consumption type (it consumes most of the resources allocated to it). Industrial activity is of moderate importance on a global scale, but is fundamental in some territories.

It is worth mentioning that the rest of sectors or activities, in first or last instance, must also use water in some of their production stages; however, they do not do so in such an intensive way, nor do they combine the characteristics mentioned, so they have not been given specific attention in this descriptive framework.

With the general perspective of this socio-economic context, subsequent chapters will analyse in detail some of the issues mentioned here, from more concrete and specific points of view.

2.3.2. Population

As regards water resources, it is interesting to consider what the Spanish population currently is, where it is located, and what the general trends are in its evolution. This interest is directly related to the fundamental demographic aspects of water demand, conditioned and influenced by the situation of the population, its occupational and territorial dynamics, and its future trends.

2.3.2.1. Current situation and recent dynamics

2.3.2.1.1. Evolution over time

The recent evolution of the Spanish population, with respect to the most immediate past, may be characterised by marked stagnation and lack of dynamism, in amounts that may unquestionably categorised as historic. The graph in figure 12 shows the Spanish population's evolution (de facto inhabitants) since 1700, a date that marked the demographic transition into the modern age, overcoming to a large extent the major epidemic mortality that had given rise

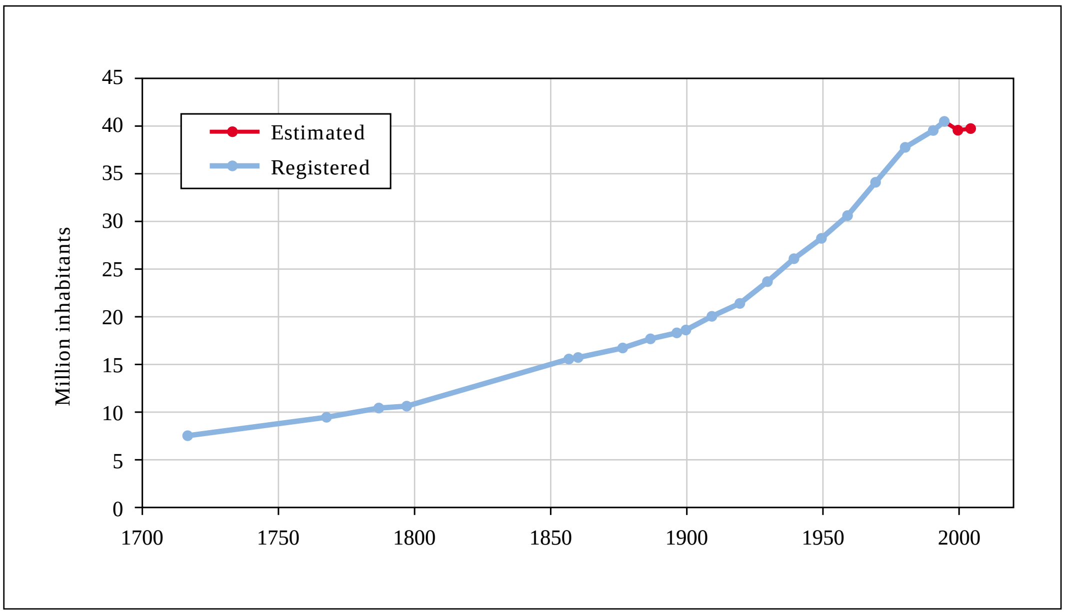


Figure 12. Evolution of the Spanish population since 1700 and short-term projection.

to zero or negative natural growth for long periods in the previous demographic cycle.

This graph, drawn up with data from the official Census published by the INE (National Statistics Institute) since the year 1850 (Puyol [1997], page 267) and data from Nadal collected in Rodriguez Osuna (1985) for the previous period, very clearly shows the phenomenon of sustained growth as of the 18th century (with dramatic development as of 1900), the turning point around 1975, and stagnation in recent years. The small anomaly in the year 1995 stems from a rectification in the Census of inhabitants and corresponds to the resident population. The projection for the years 2000 and 2005 has also been shown, calculated from the 1991 Census.

As described by Vinuesa (1997), had the growth rates for 1970-90 continued, around three million more Spaniards would now have been born, with the highly significant socio-economic consequences of all kinds that this fact would involve.

The following graph in figure 13 shows two estimates of the annual evolution rate (percentage increase) of the resident population indicated, from the middle of the last century, obtained by linear interpolation and splines of the census values.

In view of this graph, and notwithstanding the slight differences between the two interpolation methods, it may be stated that annual population growth rates –which is the data that interests us here– range between 0.2 and 1.1% up to the year 70, and from then on clearly drop to the current virtually zero levels.

Thus, up until the seventies, our country was characterised by what one writer described as a Mediterranean birth-rate and a Scandinavian death-rate, which certainly represented a major national asset. Presently, the mortality-rate actually stands among the best levels in Europe (life expectancy of 82 years for women and 75 for men), but the birth-rate, measured by fertility rates, has spectacularly fallen not just to historical minimums, but to a world-wide low. The result is a serious stagnation, with an age pyramid, as we shall see, that is dramatically regresssive, and a foreseeable reduction in our total inhabitants in the short to medium term.

The expressive graph in figure 14 shows births, deaths and natural growth (difference between both), taking place since the 70s.

The 1991 Population Census shows results for the resident population of 38.9 million inhabitants as a national total (39,4 de facto), a high figure if compared with the rest of the countries in the European Union. Nevertheless, Spain is a country with low average density, with 77 inhab/km^2, compared to the 113 inhab/km^2 of the European Union. In relative terms, it is therefore a sparsely populated country.

2.3.2.1.2. Spatial distribution

Having indicated the basic features of the Spanish population's aggregate temporal evolution, we now turn to the structure of its spatial distribution, firstly indicating that, from this point of view, and unlike other European countries, its basic characteristic would be its irregularity.

This spatial irregularity is the consequence of a historical process of territorial concentration, originally arising from the spatial variability of natural resources, and from the fact that economic activity, fundamentally agricultural in most of the territory, requires placing large areas of land at the disposal of the work factor. The crisis in traditional agriculture, progressive industrialisation, and the appearance of the services sector, less demanding in this sense, brought about population concentration and growth in urban areas. Furthermore, and although to a lesser extent, spatially differentiated variations in the birth rate have also contributed to spatial irregularity.

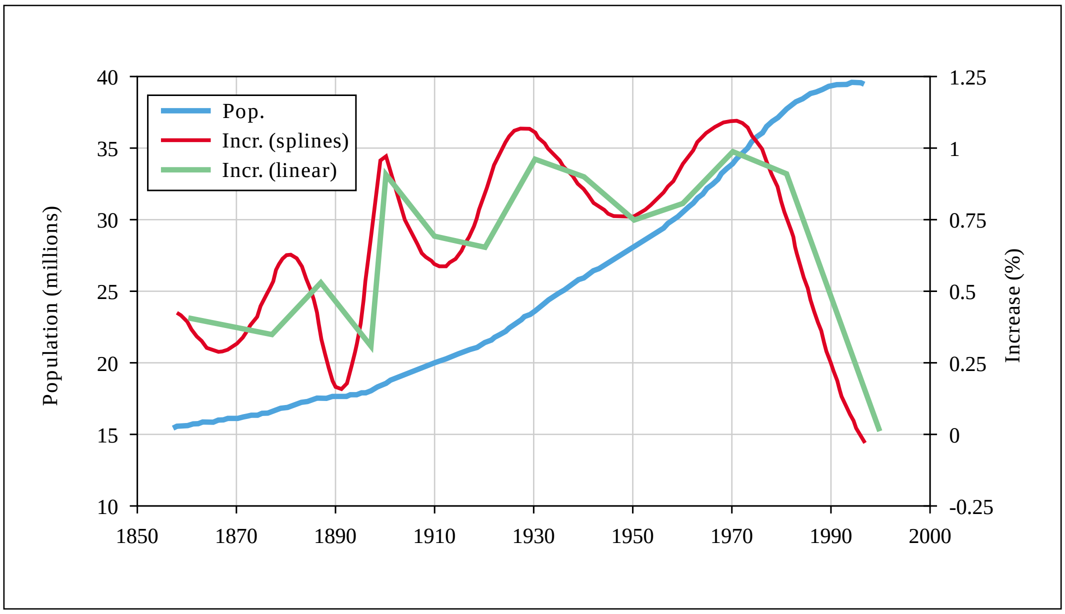


Figure 13. Evolution rates of the Spanish population since 1850.

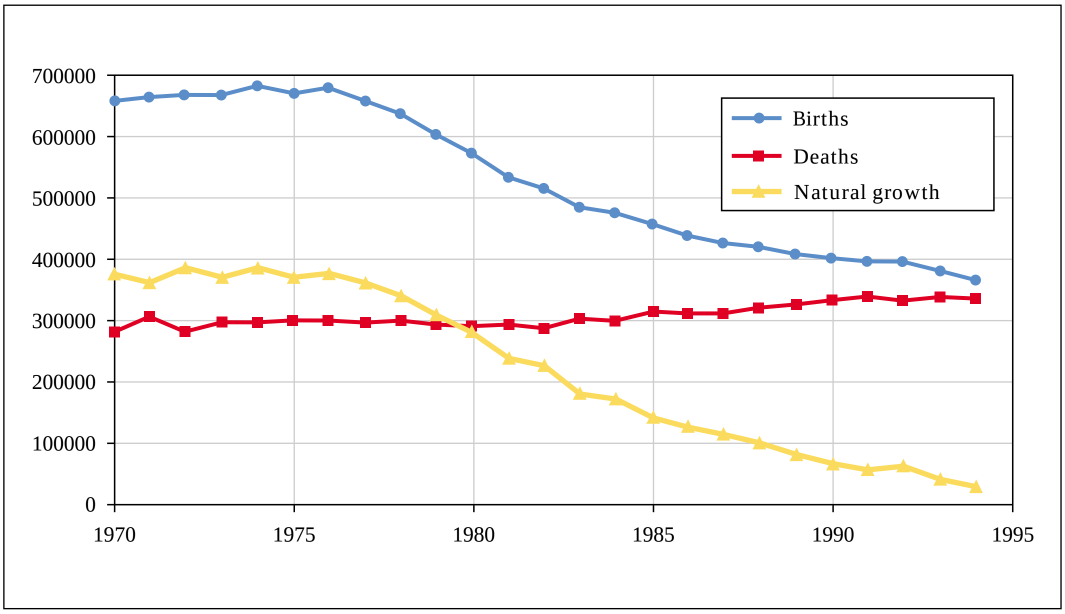


Figure 14. Births, deaths and natural growth of the Spanish population since 1970.

In summary, it may be said that the period of major growth in the Spanish economy (sixties and first part of the seventies), the process of territorial concentration of the population came about fundamentally from long-distance migratory flow, and the maintenance until the end of this period (year 1975) of a birth-rate at relatively high levels.

This migratory flow took place in the sense established by spatial differences in the labour market (from south to north), and basically concentrated the population in Madrid and in the coastal areas –Bay of Biscay and the Mediterranean– of the north and east, firstly giving rise to a displacement of the population's centre of gravity towards the north-east and later towards the south , with a final result of displacement towards the south-east. This displacement is even more marked if it includes the tourist population. Alongside this process, there was also another creating concentration in some medium type cities.

As of the second half of the seventies, changes took place in the circumstances of the two demographic variables determining the population's spatial distribution. Long-distance migrations almost totally disappeared (the cases of the Basque Country and Barcelona even showed negative balances) and the birth rate underwent significant regression in the territorial areas that concentrated the greatest economic activity, while the turning point for the rate in the rest of the territory, especially in the southern half. In this period short-distance migrations continued, which, together with the high death rate in rural areas, arising from the ageing of the population –especially on the northern meseta– contributed to drastically accelerating the depopulation process in rural areas.

These recent processes of population growth and change –probably the most significant in the history of Spain– have given rise to a current situation in which, as clearly shown by the 1991 Census, almost half of Spanish people live in a district different from the one they were born in, and around a quarter do so in a different province.

The considerable present irregularity is, therefore, the result of both historic circumstances of the population –relating to physical conditions of the territory: relief, climate or access to natural resources– and the described process of massive migrations and urban settlement (between 1950 and 1975) in the areas of attraction. The imbalance initially caused by the natural environment has been radically and increasingly accentuated in recent decades.

The indicative map in figure 15, on population density (DGPT [1995a] pp. 519), very clearly shows the overall result of these processes.

This map, which reflects municipal figures for real population by surface area, in inhab/km^2, according to the Census of Population and Housing of the INE in 1991, gives a clear demonstration of how the majority is concentrated in a small number of geographical areas: the Mediterranean and southern Atlantic coast (from France to Portugal, including the Balearic Islands), where even in 1991 over 20% of the Spanish total lived only in districts located less than 5 m from the coast and over 30% within 25 km; the Cantabrian coast (with three centres: concentration of the Basque Country and its prolongation towards Santander, Galician north-south corridor and the central Asturian area), where nearly 8% and 13% live in both areas, respectively, the urban area of Madrid and its zone of influence where around another 14% of the national population has settled; the Ebro valleys (up to Zaragoza) and the Guadalquivir, and, finally, the Canarian island territories.

These intense trends towards population concentration in costal and peripheral parts of the Peninsula can be seen clearly in figures 16 and 17.

The first shows the temporal evolution of population concentration on the coast (at distances less than 5 km from the coast). The unequivocal trend can be appreciated, from the decade of the 60s, towards coastal concentration of the peninsular population on the Mediterranean seaboard (from

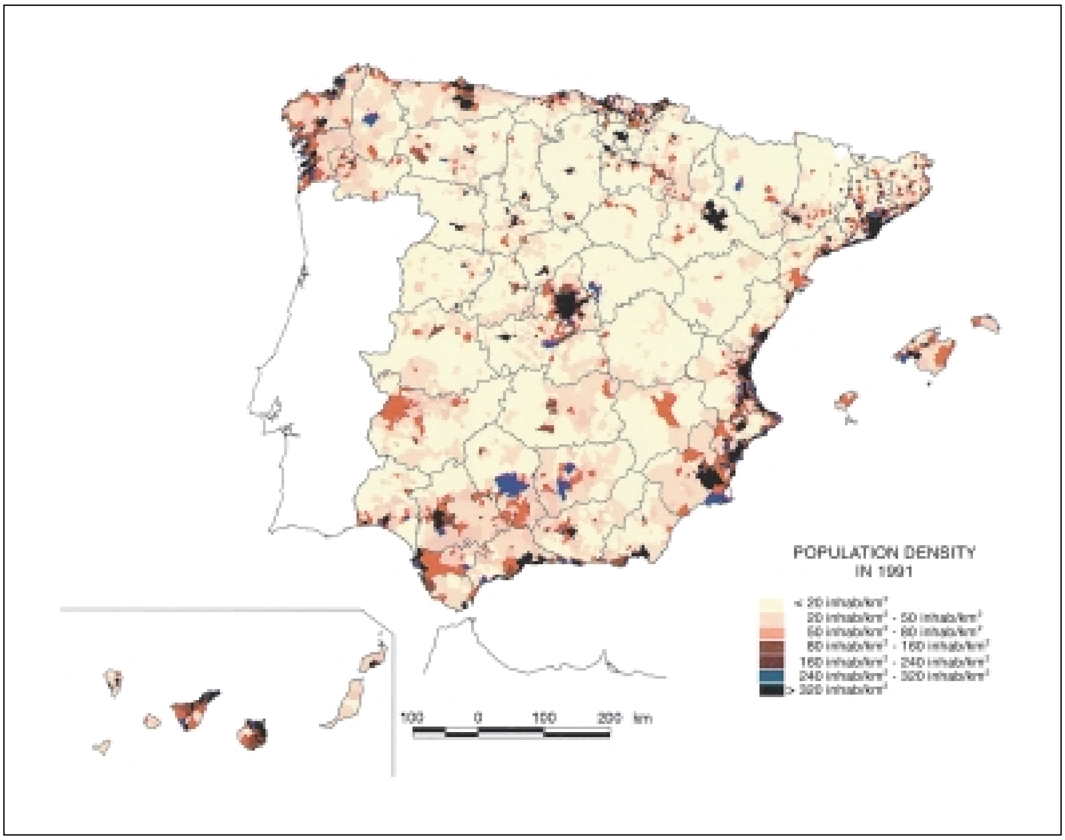


Figure 15. Map of population density in 1991.

15 to 20%), compared with the relative stability of the Bay of Biscay coast.

Furthermore, the second population concentration in 1991 according to distance from the coast shows how over half the total Spanish population (56%) lives less than 50 km from the sea. If the singularity of the Madrid area is considered, the effect is even more striking.

As regards the rest of the population, outside these large areas, it may be said that in general it is concentrated in medium-type cities (provincial capitals) and small, low-density towns, widely dispersed all over the national territory.

The map in figure 18 shows the spatial distribution of populations greater than 50.000 inhabitants according to the 1991 Census, and gives a visual appreciation of this dispersion.

Additionally, figure 19 (drawn up here from data taken from the 1995 Statistics Yearbook of the INE) shows the

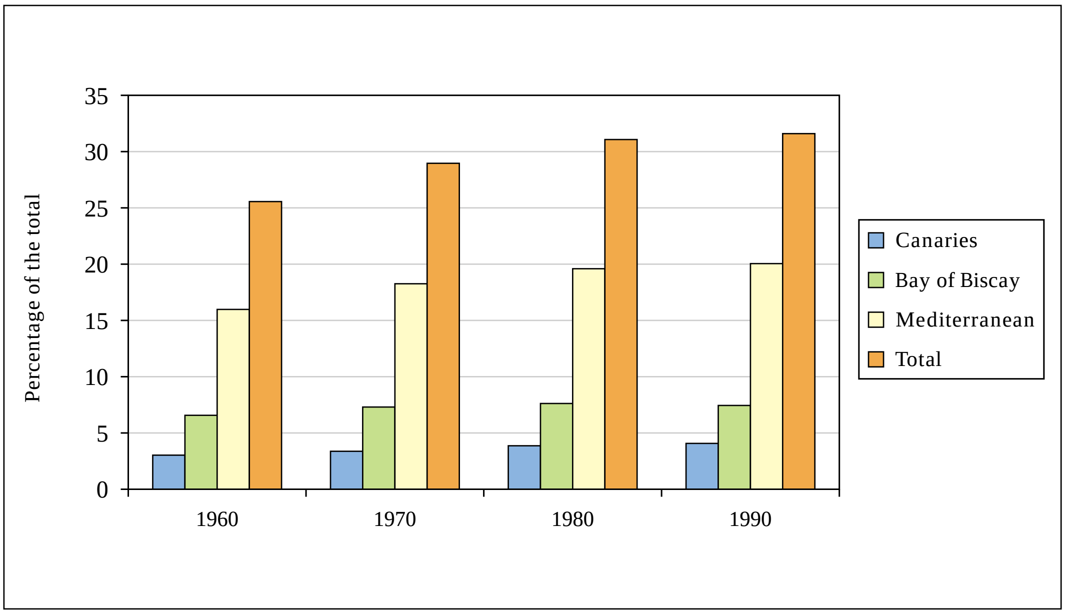


Figure 16. Evolution of the concentration of population less than 5 km from the coast.

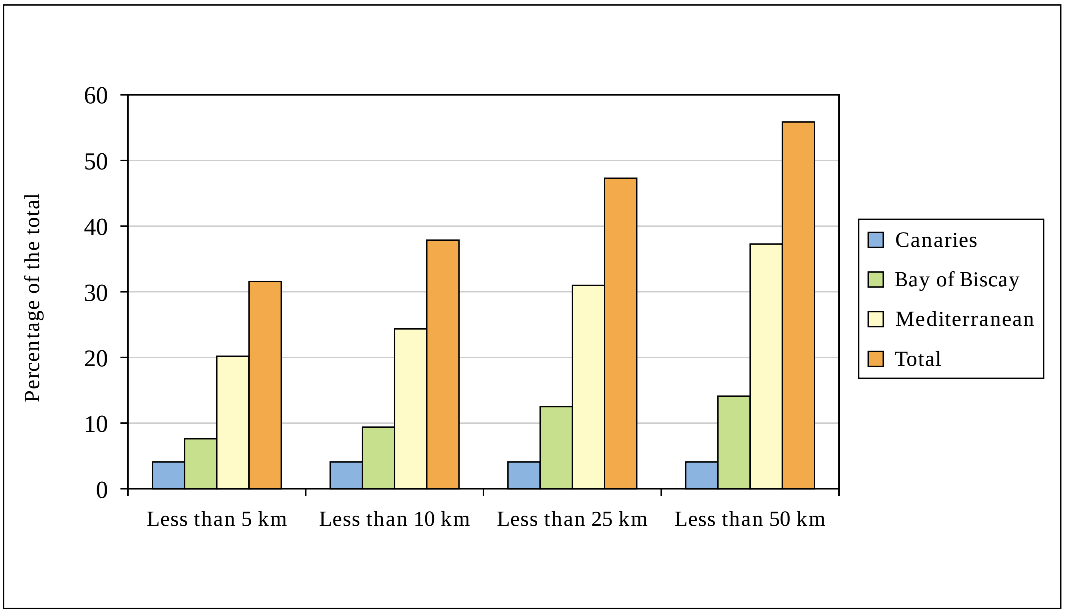


Figure 17. Population concentration on coastal strips.

evolution of the percentage of the real population resident in the different-sized districts in Spain, and clearly indicates –with transition between both– the phenomenon of drift towards medium and large cities, and small rural towns' progressive loss of relative importance throughout the century. As can be seen, at the beginning of the century, 50% of the population lived in towns of less than 5.000 inhabitants, whereas in 1991 that percentage had fallen to 15%.

Only districts with towns of sizes between 10.000 and 30.000 inhabitants maintain a level of participation in the total of around 8%, and relatively stable (with maximum absolute deviation of 3 points). This size of town is, then, the pivot around which the drifting process has been taking place during the process of urban drift throughout the 20th century.

As a simple though significant example, some data indicating the major current spatial imbalance may be the following (Vinuesa, 1997):

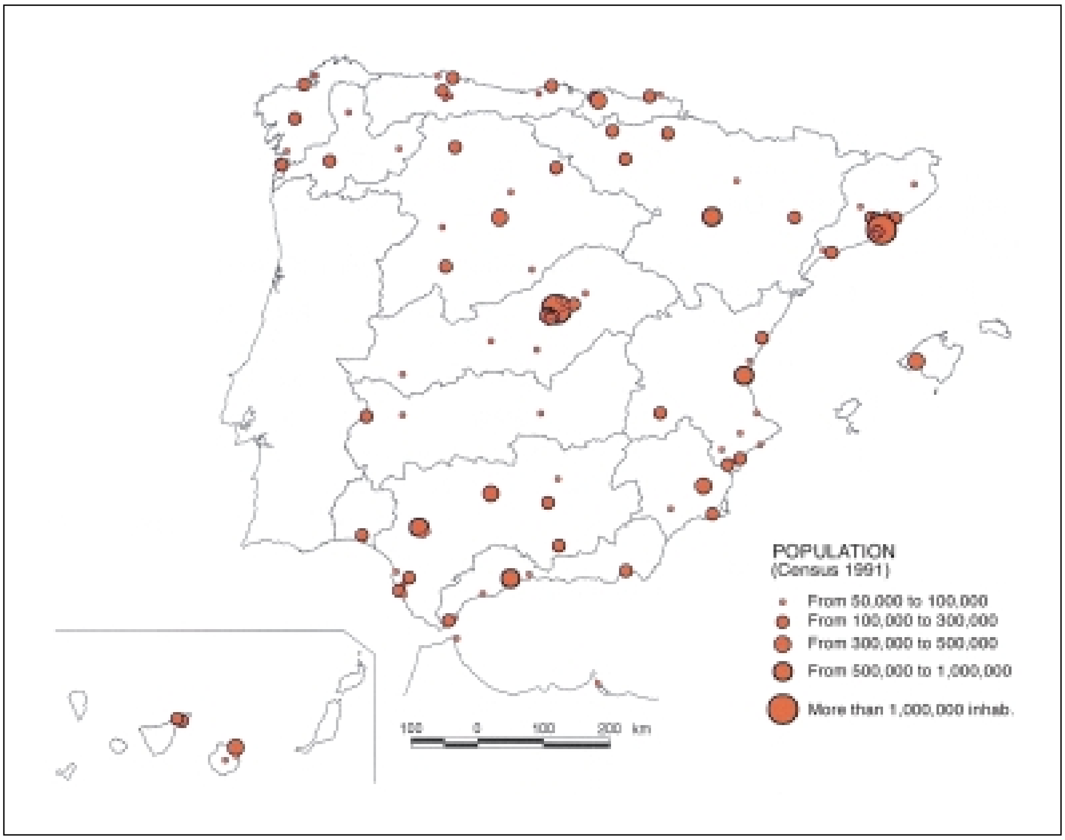


Figure 18. Map of centres of population with over 50,000 inhabitants.

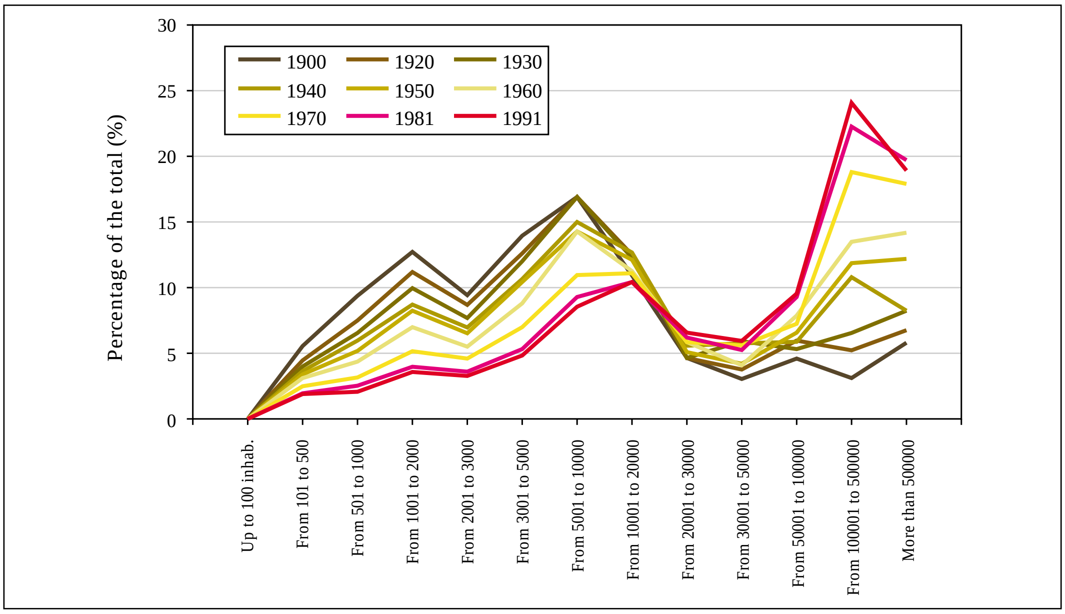


Figure 19. Evolution over the century of the resident population according to size of municipality.

In 1991, 70% of the total surface area, that of lowest population density, contained just 10% of it (80% contained 20%), whereas a surface area of less than 5%, corresponding to the most densely populated municipal districts, contained 60% of the Spanish population. The population corresponding to cities of over 100,000 inhabitants represents 42% of the national total although it only occupies 3% of the surface area. There are 14 provinces that do not have any town of this size. There are 15 provinces with densities lower than 30 inhab/km^2. Madrid is 70 times denser than Soria or Teruel...

The situation of Aragón is striking, with one of the most exacerbated macrocephalias in Spain: the city of Zaragoza, due to immigration in the past, and stagnant growth now, contains over half the population of Aragón, with a much younger pyramid than that of the surrounding Aragonese desert. The province of Teruel registers stagnant growth, Huesca approaches zero growth, and only Zaragoza, thanks to its capital, shows a positive balance, although lower than the Spanish average (Bielza de Ory [1988] pp. 200-205; Gaviria y Grilló [1974]).

In short, the physical environment, socio-economic circumstances, the town planning model, and the setup of existing communication networks have left extensive areas of the Peninsula barely inhabited and disconnected, where not only is there no expected growth, but the mere maintenance of the population is seriously threatened. The system of settlements has no capacity to facilitate exchange, commercial relationships or the distribution of innovation, which ultimately means isolation and increasingly difficult integration for these areas within the economic systems of the rest of country. Furthermore, the ageing and depopulation of these areas is one of the main problems for conservation of the rural environment where they are located.

As regards this evolution, the adjoining provincial map of population variations (fig. 20) is also very demonstrative.

This map numerically reflects the provincial population distribution in 1991, and, in terms relative to the national total, the variation that took place in that decade with respect to the census results for 1981. It clearly shows the major differences existing between southern territories, much more demographically dynamic in this period, and the interior and northern ones.

2.3.2.2. Trends for the near future

Once the population's recent evolution and current situation has been characterised, both from the point of view of aggregate magnitudes and spatial distribution, it is appropriate to make some forecast on what, supposing no dramatic changes occur in Spain's socio-economic and territorial framework, may be expected in the immediate future. In order to do this, and like before, the foreseen aggregate temporal evolution will be studied first, subsequently considering the territorial structure of these forecasts.

2.3.2.2.1. Temporal evolution

The graph in figure 21 shows the overall projection curves for the total future national population (in millions of inhabitants, Minhab), according to five different highly solvent and technically rigorous estimates recently carried out in Spain, and partially gathered by Zamora (1997): the INE forecast (1988) for the 1980-2010 period; the INE forecast (1994); the average scenario estimated by the INE (1995b) as of the 91 Census; the average forecast by De Miguel and Agüero (1986); and the average hypothesis of the Demography Institute (1994).

As can be seen, these projections give different results due to the different dates on which they were carried out, in addition to the different hypotheses (life expectancy, mortality rates, birth rates, migrations, etc.) adopted in

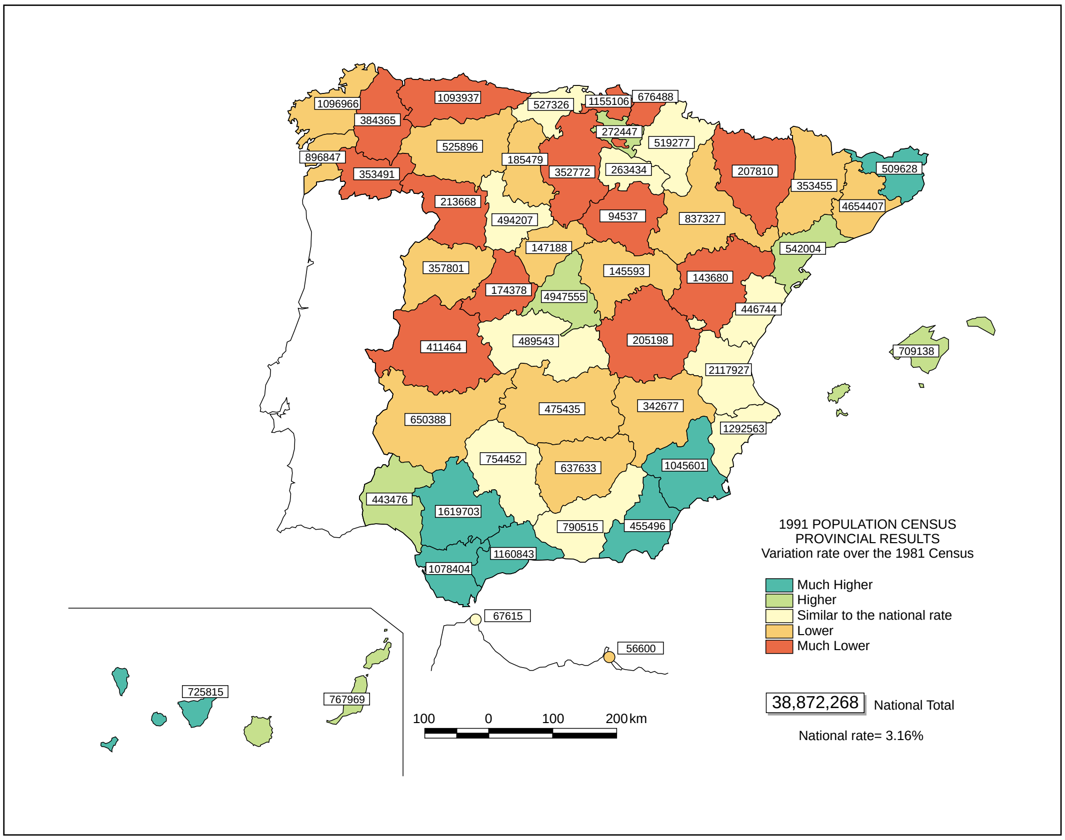


Figure 20. Map of provincial population variation rates in the period 1981-1991

each case. In summary, relative maximum differences can be appreciated of around 4-5 Minhab in the long term (20 years), equivalent to maximum differences of around 2 Minhab (5%) between the intermediate projection and the most recent one (INE 1995b, which may be adopted as a reference), and any other.

Furthermore, all the projections –and this is a fundamental common feature, which should be highlighted– foresee a drop in the population after an absolute peak which will be reached in the next few years, and this peak will not exceed, under any circumstances, the figure of 42 Minhab. It seems certain, then, that the Spanish population will decrease in number, accompanied by a growing level of ageing.

The graph in figure 22 shows jointly the reference forecast with the historical evolution given above.

Additionally, the following graph in figure 23 shows population pyramids on a national scale in the year 1991, and those foreseen for the years 2005 and 2020 in accordance with the INE projection (1995b) adopted.

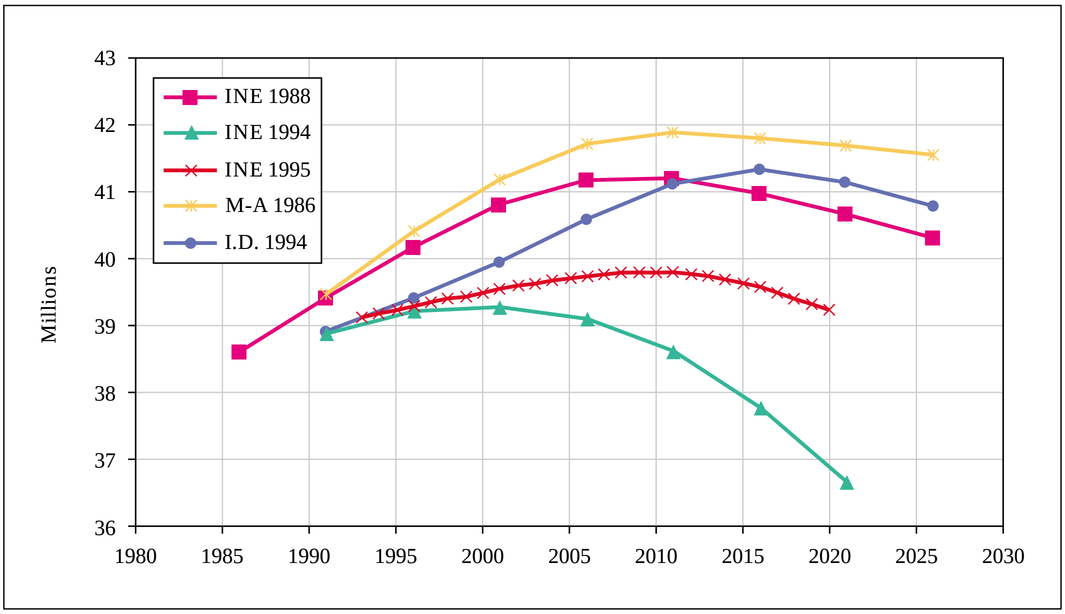


Figure 21. Different projections of the total national population.

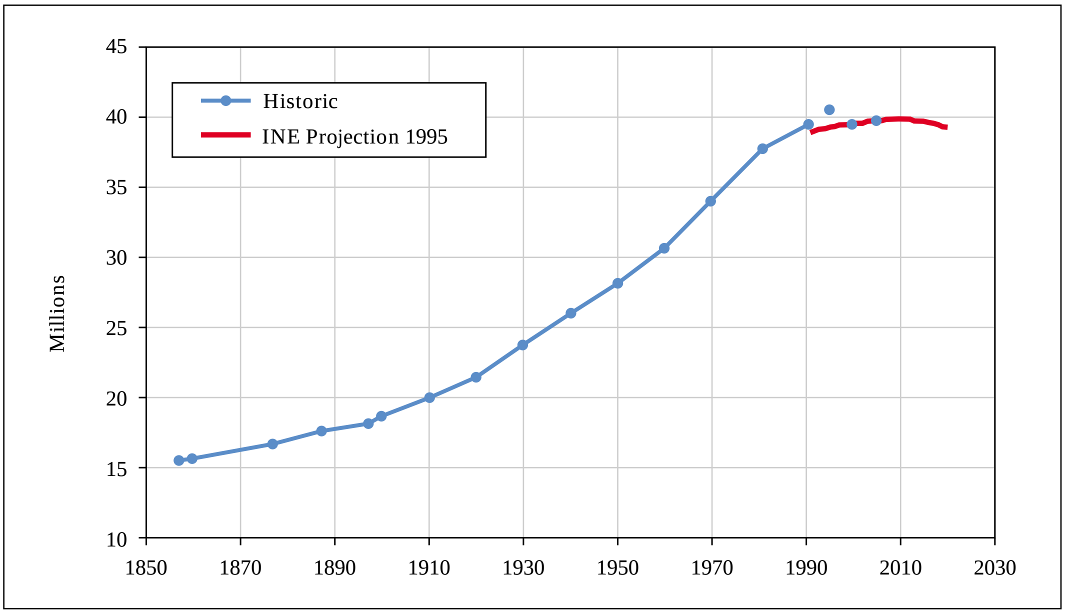


Figure 22. Spanish population since 1850 and projection up to 2050.

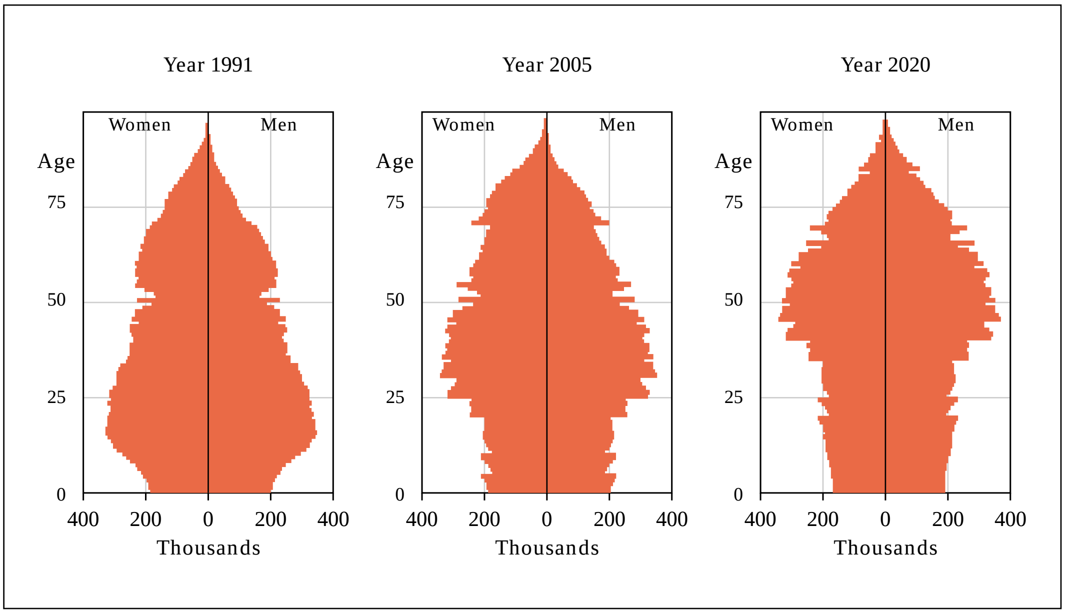


Figure 23. Population pyramid in 1991 and forecasts for 2005 and 2020.

These pyramids give a highly indicative view of the increasing level of population ageing to be expected in the medium to long term.

2.3.2.2.2. Spatial distribution

From the point of view of territorial distribution of the future population, the adjoining maps show the desegregation, on a provincial scale, of the overall forecasts indicated for the years 2000, 2010 and 2020 respectively, showing both the numerical value of the foreseen population of each province, and the rate of variation with respect to the 1991 Census (figs. 24, 25 and 26).

Such provincial forecasts are precisely the basis for the overall projection provided, in the hypothesis that the average birth and death rates observed in the 1988-1991 period are maintained.

This is the most probable hypothesis that may be postulated for the medium term, unless trends observed in the recent past are sharply modified, an unusual circumstance in demographic phenomena, characterised, at least during periods of normality, by its inertia and solid predictability in the short and medium term.

Something to notice in all the maps is, firstly, the continuation of the situation in the 1981-1991 period (shown in the previous map), and the significant long-term effect shown by the different birth rates registered in the different provinces, much lower in the north than in the south.

As a complement to this, and partly as a consequence of the phenomenon described, there will foreseeably be an inten-

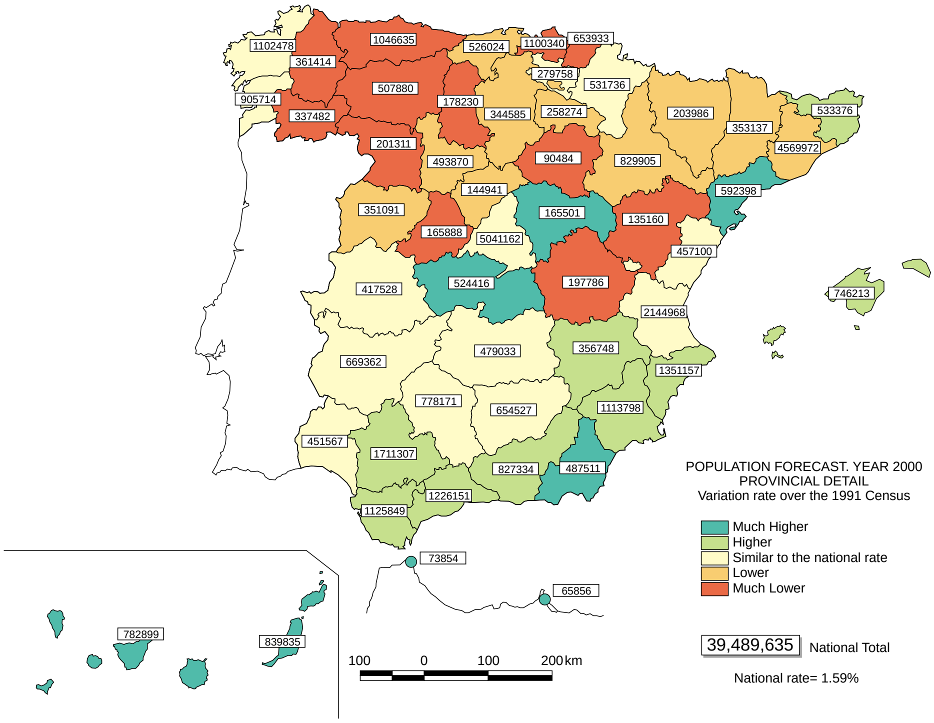


Figure 24. Map of provincial population forecasts in the year 2000, and variation rates with respect to 1991.

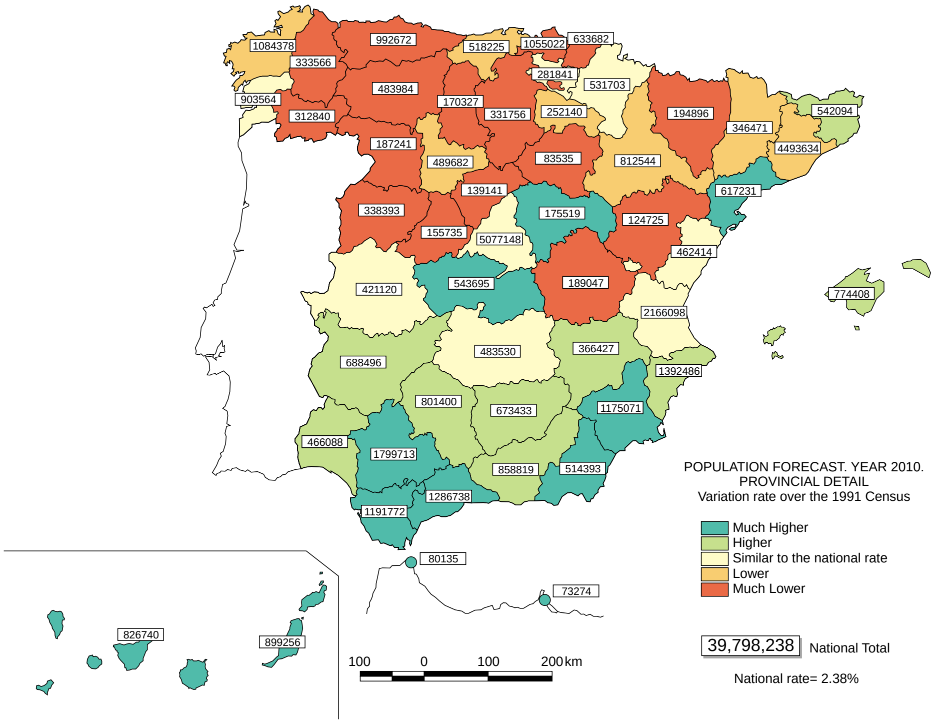


Figure 25. Map of provincial population forecasts in the year 2010, and variation rates with respect to 1991.

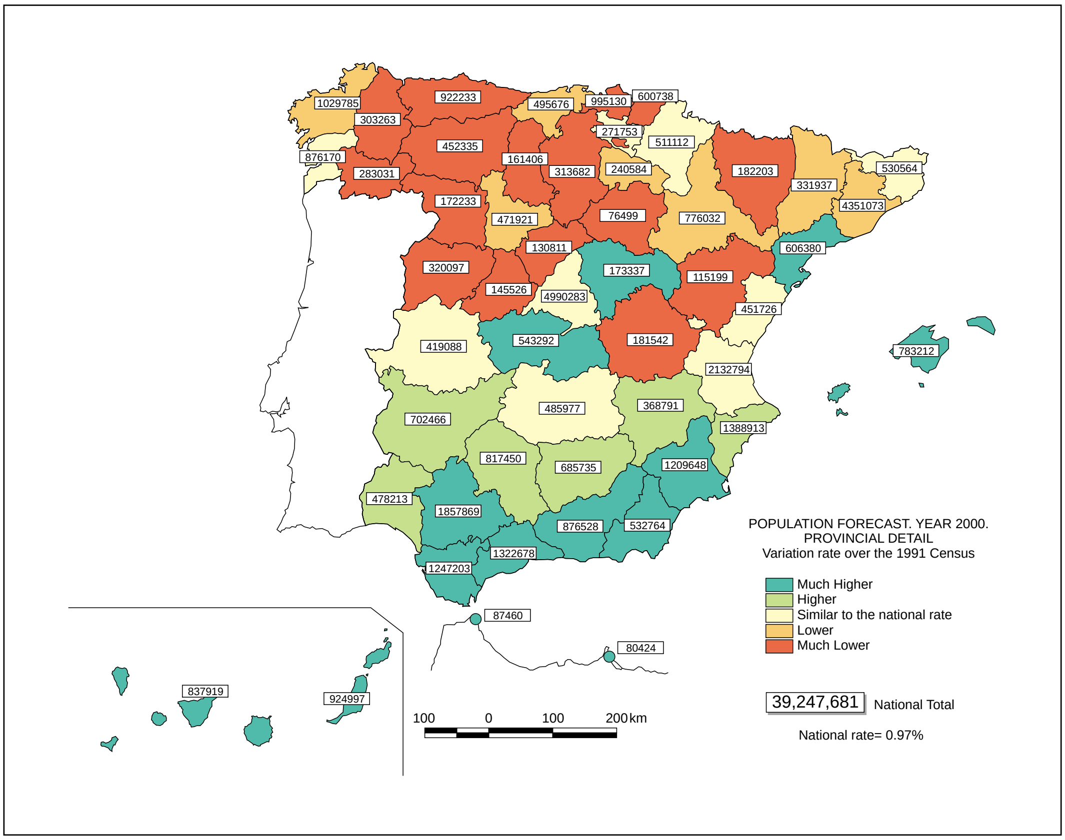


Figure 26. Map of provincial population forecasts in the year 2020, and variation rates with respect to 1991.

sification in the historical process of population concentration on the Mediterranean coastline and an emptying of inland rural Spain, especially the northern meseta and the Ebro valley.

Furthermore, the following graphs, drawn up here from previous information provided by the INE, show analogous forecasts for the future population, though here ordered according to water planning area (fig. 27).

The first graph shows these forecasts for all the areas of the basin management plans, and indicates the existence of two major groups of areas according to their population.

On one hand, and in this order, the Tagus areas (with the Madrid area), Catalonia Inland Basins (with the Barcelona area), Guadalquivir (Seville), Júcar (Valencia) and –to a lesser extent– Ebro (Zaragoza), make up the group of greatest present and future population. In all of them, the population remains stable or drops slightly, except in the case of the Guadalquivir, which shows a slight increase.

A second group, which would be made up of all the others, also shows a situation of certain stabilisation, with some territorial differences. To appreciate them better, the following graph is provided, identical to the one above, but rescaled and showing only the trends of this group (fig. 28).

Study of these graphs draws the conclusion that, on the whole, all the planning areas considered tend towards population stagnation or reduction in the long term, except those of the Guadalquivir, South, Canaries, Segura, Guadiana and Balearic Islands, that is, basically the island and southern areas. As pointed out, variations in excess of 5% are not to be expected in these results offered.

Having described the basic features of foreseeable territorial trends for the Spanish population, here we pause our explanation of the situation and perspectives of this fundamental sociological conditioner. In subsequent chapters, when looking at population supply, these trends' implications on the corresponding water demands will be looked at in detail, but, in view of the results provided, we can already observe that there is little expectation of any significant future increase in water requirements for this concept. What is more: the relative demographic stability may enable the implementation of policies to preserve the hydraulic environment, since greater urban pressure upon it is not generally foreseeable in the future.

2.3.2.3. Conclusions

In short, and summarising the terms of above paragraphs, the fundamental features of the current situation, and the trends that will foreseeably characterise population-territory relationship in the medium term are as follows:

1. The current situation and recent dynamics of the Spanish population are characterised by an extraordinary retreat in aggregate magnitudes, which began around the middle of the 70s, and which has, in recent years, become serious stagnation, with virtually zero overall population growth rates. The old image of a country of booming birth rates and of emigrants has given way to a radically different

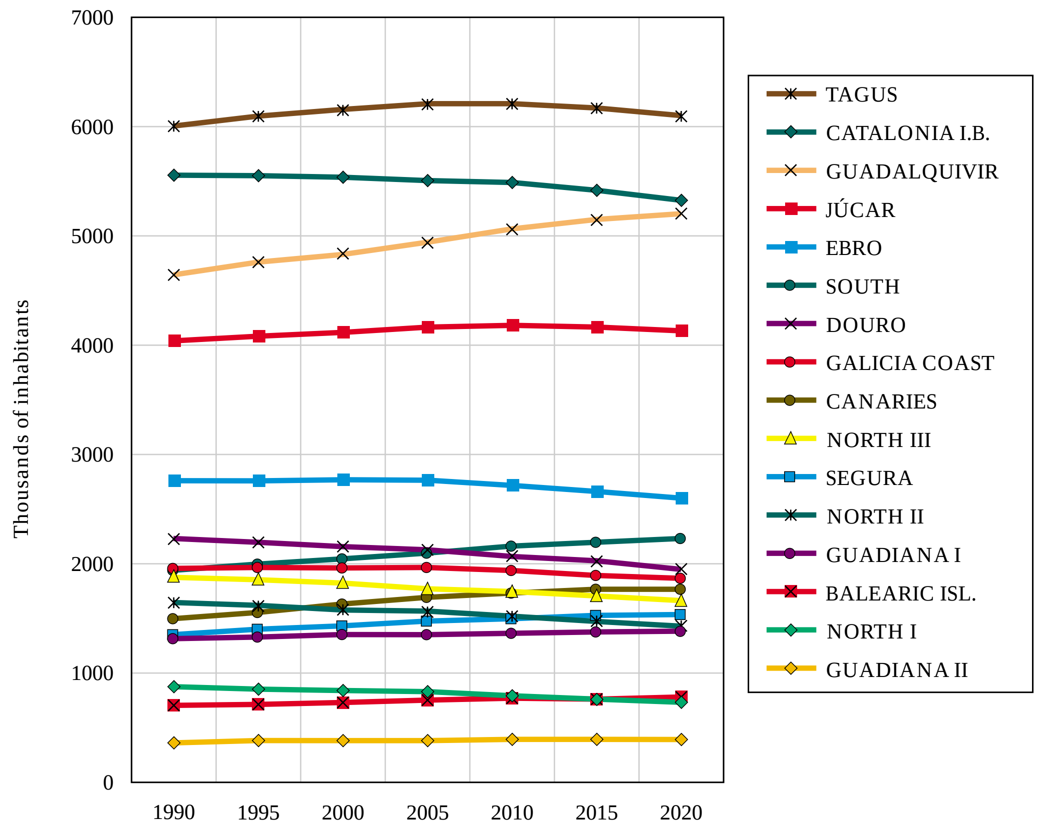


Figure 27. Forecasts of population evolution by water planning area.

situation, characterised by minimal birth rates, increased ageing, and a turnaround in emigration. The medium-term perspectives give no signs of significant corrections to this model.

2. As regards the population's spatial distribution, there is considerable territorial irregularity, with unequivocal trends, at least since the 60s, towards coastal concentration and the depopulation of the interior. The major migratory flow from south to north has disappeared, with only short-distance migrations remaining (from the country to the city), contributing to drastically accelerate the depopulation process of rural areas. With these major currents gone, population variations on Spanish territory are explained basically by reasons of better climatic and natural conditions, which would contribute, as mentioned, to the relative concentration of the population in coastal and southern territories.

3. Temporal delay and less intensity is taking place in the fall in birth rate in southern territories, which is giving rise to slight growth in the south and fall in the north. Its most relevant effects refer to the degree of ageing in the population, which will increase in the medium term, and which could even worsen further than indicated if we take into account that in some northern regions the Synthetic Birth Rate –number of children per woman– is lower than 1, when at least 2.1 is required merely to maintain the existing population.

4. The central territories of low intensity are undergoing a severe drop, which is especially intense in the northern meseta, Aragón –except the Ebro axis– and slightly less in the southern meseta, and in general over all the highlands. This could lead the process of abandon and de-population of interior Spain to its ultimate consequences.

5. In conclusion, it should be pointed out that the current process of southern concentration in the Spanish population, the drift towards lower altitudes, more exaggerated in coastal areas, and the consolidation of the system of medium-sized cities.

Contemplating these facts from the point of view of considering water, the demographic panorama described suggests some ideas, poses major questions, and leads to relevant consequences. This is not the appropriate place for its detailed description, since this chapter is dealing with the generic, overall perspective of the socio-economic context, and not specifically hydraulic. Since these consequences lie expressly within the field of water problems,

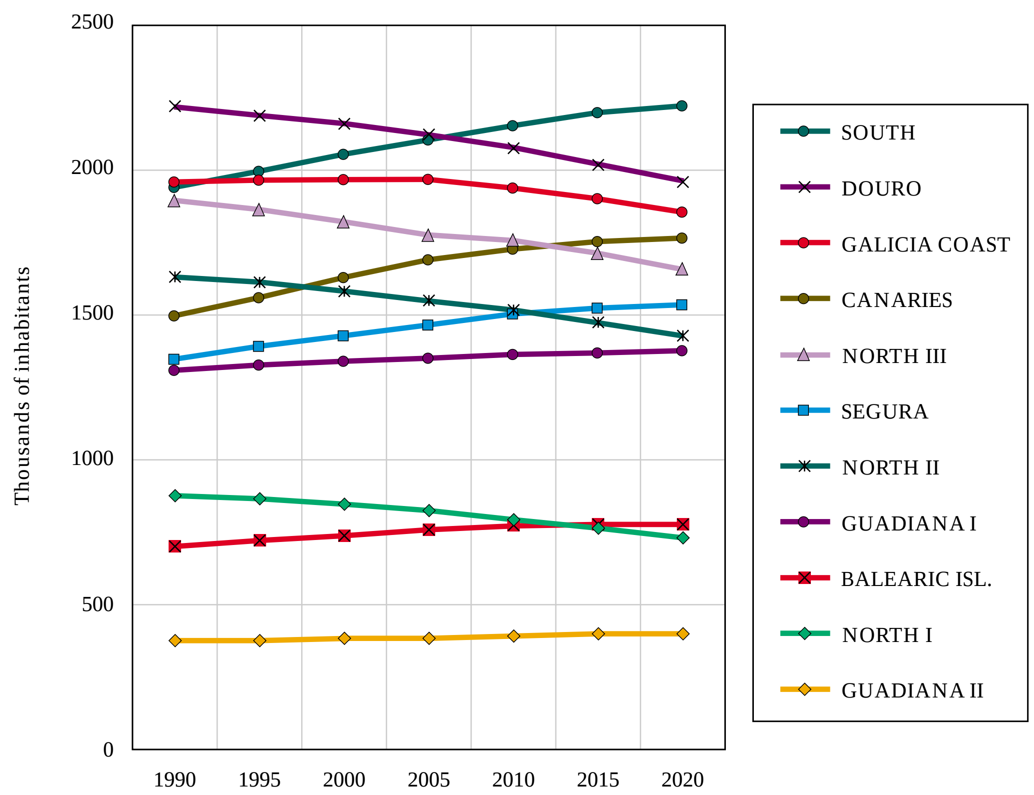


Figure 28. Forecasts of population evolution by water planning area (detail).

we will refer to them in detail in dealing with supply, population and irrigation, and other various questions. Nevertheless, and notwithstanding a return further ahead to this topic, it may be appropriate here to mention some considerations.

Firstly, it is a noteworthy fact that the socio-economic movements that have given rise to the current circumstances of population and territory in Spain have in no way been associated with water problems. Rather, the most recent flow and trends seem to have taken place, in broad terms, from areas which, as we shall see, have more abundant water (mesetas) towards areas with greater scarcity of this resource (south and Mediterranean coast).

Thus, having happily overcome the historical famines which, associated with adverse climatic cycles, caused genuine de-population and massive migration, the conclusion seems to be that recent population movements in the past decades are the result of other driving forces, of other economic causes of a different nature. Once technology has allowed large-scale regulation and transport of flow, the historic role that water has played as a fundamental instrument in configuring territory has been significantly reduced. We could even say that it seems to have been lost forever.

However, it is necessary to make some kind of qualification: despite the fact that it would be theoretically feasible to entrust major hydraulics (large water storage and transport infrastructures) with the solution to any problems of future imbalance, there are reasons both strictly technical (containing foreseeable demand and the relative maturity of Spanish hydraulic equipment) and reasons of economic and environmental costs associated with these large operations, it seems to be initially advisable, notwithstanding some kind of specific action, to discard this option as a generalised, large-scale solution.

Furthermore, and as already suggested, it is not foreseeable that significant overall increases take place in water needs for supply to population in Spain, with the expected scenario being, under the supposition that current availability remains stable, that in the long term it is maintained, or even reduced. Maximum deviations expected in quantifying these phenomena, according to the different projections used, are around 5%, and a currently reasonable objective for water planning would be to set the maximum target population to be attended in the long term at 42 million inhabitants. The possible increase in supply as a consequence of improvement in the standard of living will be compensated by the increasingly greater efficiency and better management of supply networks, a field in which, as we shall see, major improvements are being made, and more are expected in the future.

The southern regions escape this general scenario, where demographic increases do seem to be expected in the medium to long term, which will involve an increase in water demand. The fact that these regions are the least favoured as regards resource availability, for strictly demographic reasons, and without entering into other considerations, a future worsening of current water resource deficit problems is foreseeable in the southern half of Spain.

This worsening must be considered, however, as qualified, in view of the little effect, in terms of volume, that this urban component has on total water demand in these territories, but it will be necessary to take a very important aspect into account, which is service guarantee: the massive concentration of population in large southern and coastal areas will necessarily require a quality, stable, guaranteed urban supply, unaffected –as far as technically feasible– by hydrological irregularities and climatic uncertainties.

Moreover, from a territorial point of view, we should also mention the situation of many small towns in the peninsular interior, which will tend to worsen in the future. In these towns, since they do not reach the population thresholds required to make use of the necessary economies of scale, problems will arise in efficiently financing and managing water supply services, both as regards the extraction, treatment and supply, and the treatment of effluents to required quality levels. Public intervention to this effect seems obligatory in order to contribute to the subsistence and improvement in the quality of life in these rural towns.

Furthermore, the possibility of fomenting and extending irrigation as an instrument for consolidating rural population, an idea deeply rooted in the regenerationist thinking of the late 19th century (MAPA-MAP-MOPU, 1988, vol.1, pp. 41-47), has been the subject of intense controversy and is presently, at the very least, questioned. Analyses carried out maintain that it is not clearly demonstrated that this effect has been achieved in the past, and especially, it is dubious that it will do so in the future, particularly in a scenario of costs and markets that seems to be appearing (Escobar Gómez [1995] pp. 825-840; Pérez Pérez [1997] pp. 336-337).

Cases like those of some districts in the Ebro valley in the 19th century, or Plana d'Urgell, where a colonisation of traditionally unpopulated areas did in fact take place, thanks to the conclusion of the irrigation Canal in 1862, these contrast with others where the colonisation experience did not mean significant settlement nor appreciable improvement in the quality of life in the affected areas. Irrigation can, in fact, be the basis for agro-industrial development, though not as requisite or necessity, of other contributory factors are not present (Arrojo y Bernal, 1997).

Moreover, the phenomenon of agricultural production's loss of influence on the rural world's economic reality has been taking place in Spain for years (Naredo, 1996), and, from a demographic point of view, in those districts where recently, since the decade of the 80s, a stagnation or even a slight recovery has been observed in the rural population, this phenomenon has not in general resulted from traditional agrarian activity, which continues descending overall, but from other sectors and areas of rural life. The non-agrarian activity of the rural world is expanding, and may be the element that contributes most in the future to population settlement (García Sanz [1996] pp. 39-40).

Merely mentioned here, we will return to these issues further ahead, in examining the socio-economic problems of irrigation and population settlement, forecasts for demand, resource availability, the crisis of traditional water policy, and the bases for new water policy and water planning.

2.3.3. Tourism

Having analysed the recent evolution, present situation, and foreseeable trends in the Spanish population, it is expedient to examine the phenomenon of tourism (that is, temporary population movements outside their place of residence) as a seasonal modifier of water demand and a generator of requirements on inland water considered as a recreational element.

From an economic point of view, and continuing an old, consolidated tradition, tourism is becoming an increasingly important activity in the Spanish economy, exhibiting a performance that could be described as excellent, not only thanks to its contribution to the total product –which stands at around 9% (5% for domestic and 4% for foreign tourism)–, but thanks to its sustained evolution after the boom at the beginning of the 60s, registered in recent decades, as graphically shown by the adjoining chart on the evolution of tourism (foreigners with passport and general total), and on the number of hotel spaces. As can be seen, the number of these spaces has practically doubled in the last 25 years, which gives some idea of how dynamic the sector is (Tamames and Rueda [1997] pp. 554-559; and data from the Secretariat of State for Tourism) (fig. 29).

Similarly, figure 30 gives the evolution of currency income from tourism in the last 40 years, and demonstrates this activity's extraordinary importance and development.

In fact, the tourist sector has traditionally played a fundamental role in contributing to even out the trade balance, and will foreseeably continue to do so in the future. From our point of view, as we have mentioned, it is also and obligatory consideration: its seasonal and spatial displacement effect on the population, with the resulting highly circumstantial and concentrated increase in water demand, with increasingly greater force, from leisure, tourist and recreational activities, associated with the public water domain (trekking, sailing, river fishing, bathing, etc.).

Below, magnitudes and fundamental effects are given according to the information provided by the Institute of Tourist Studies under the Economy and Treasury Ministry.

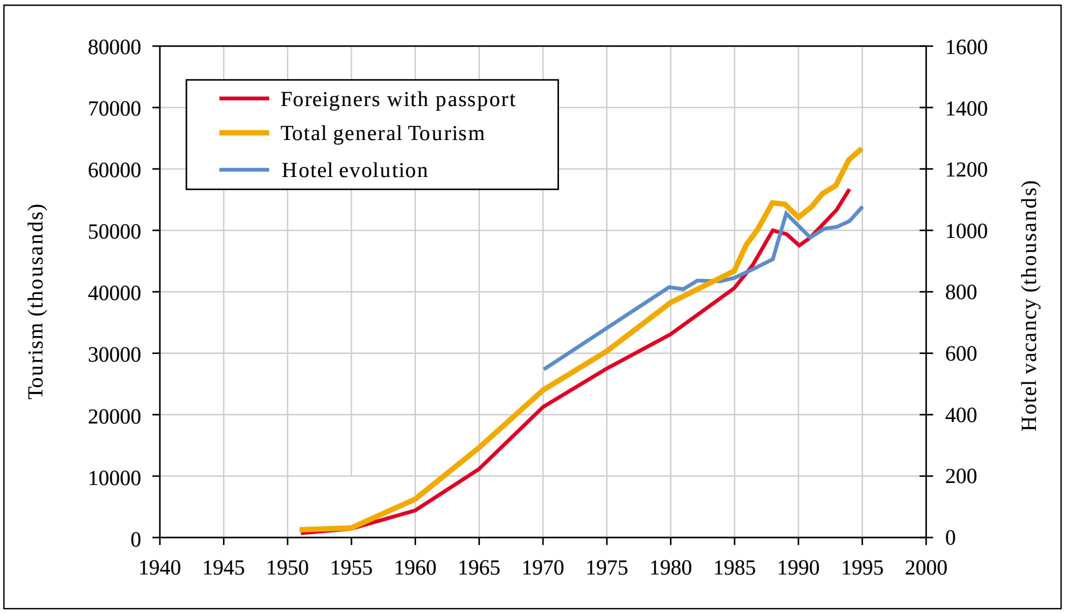


Figure 29. Evolution of tourists and hotel accommodation.

Foreign Tourism

In 1996, 61.8 million visitors were recorded, of which 67% (about 41.4 million) were strictly tourist, that is, visitors who stayed at least one night in Spain. Other visitors, in the category of excursionists, represent 33% of the total and 20.4 million people in absolute terms.

The summer season (months of June to September) concentrates almost half the annual total (28.7 million visitors and 19.6 tourists), which demonstrates this population's considerable seasonality. The average stay for tourists in this period was 12.6 days.

Spatial distribution of this affluence responds, as is known, to the attraction of the classic natural resource of sun and sand, with the insular territories standing out in this sense (Balearic Islands, which receive 34% of tourists, and the Canaries, with 19%), followed by Andalusia and Catalonia (14% each). The rest of the Communities stand at less than 10% of the total.

Domestic Tourism

In absolute terms, domestic summer tourism produced figures similar to foreign tourism in 1996. The number of travellers during the months of June to September was around 20 million, half of which corresponded only to the month of August, and had Spain as a main destination in 93% of cases, while the remaining 7% went abroad. Domestic tourism also saw a spatial distribution similar to that indicated for foreign tourism (sun and sand), although in this case located preferen-

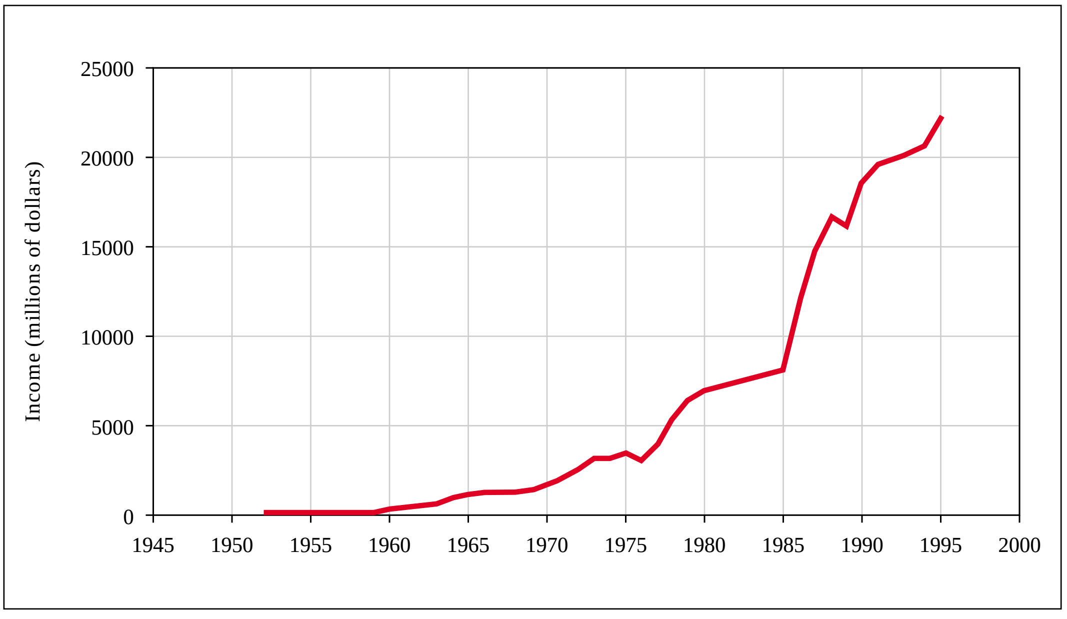


Figure 30. Evolution of currency income from tourism.

tially on the peninsular Mediterranean coastline (mainly Catalonia, Valencia and Andalusia).

An indicator that clearly shows the territorial concentration that characterises tourism in general is the presence on the Mediterranean coast of the majority of Spanish real estate property involved in the tourist industry, both in terms of second homes and total tourist spaces, as can be seen in the adjoining maps (DGPT [1995a] pp. 525) (fig. 31 and 32).

In the light of these maps, the spatial distribution of this phenomenon is clear, coinciding substantially, as can be seen, with the population trends mentioned in paragraphs above.

As regards its magnitude from the point of view of water demand, the effect of tourism with respect to total demand does not seem very relevant, at least on a national level.

In fact, generalising to the whole year, the data regarding seasonal behaviour observed in foreign tourism (the only one for which average stay is available), it is possible to estimate that foreign tourism adds, in total, about 1.5 millions people, in equivalent permanent annual population. Although the exact figure for domestic tourism is not known, it is reasonable to suppose, in the light of available information for 1996, that this population also stands at around a similar number to the one mentioned, resulting in an approximate total of 3 million people, in terms of equivalent annual population, meaning definitively an average population increase of around 10%. Naturally this is just an initial estimate of the phenomenon, but is useful for situating its order of magnitude. However, it should be pointed out that despite these moderate quantities on an overall scale, in certain areas the limited availability of water resources may represent a serious conditioning factor for the development of tourist activities and a source of tension between alternative uses (Vera Rebollo [1988] pp. 115-124; Marchena Gómez [1988] pp. 101-114).

A very important aspect of tourism from the point of view of water demand is its seasonality. The adjoining figures –prepared here with data from Tamames and Rueda (1997) p. 557– very clearly show this effect, and its evolution since the year 1960 (fig. 33).

As can be seen, there is significant seasonality concentrated in the months of August, July and September, but a tendency towards gradual decrease has been detected since the 1970s. The overall monthly rate for these three months has passed from 210 to 166% in that period, which means that the significant seasonality of sun and sand is tending –still very moderately– to fall off in favour of other forms of tourism, not in summer, but spread over the rest of the year.

As regards the other factor in demand, unitary supply, it is to be expected that it will be considerably above habitual home consumption, considering sporting and recreational activities that usually accompany the holiday and leisure period, the main motive behind tourism.

This certainly makes the increase in water demand greater than the 10% that would correspond to the simple

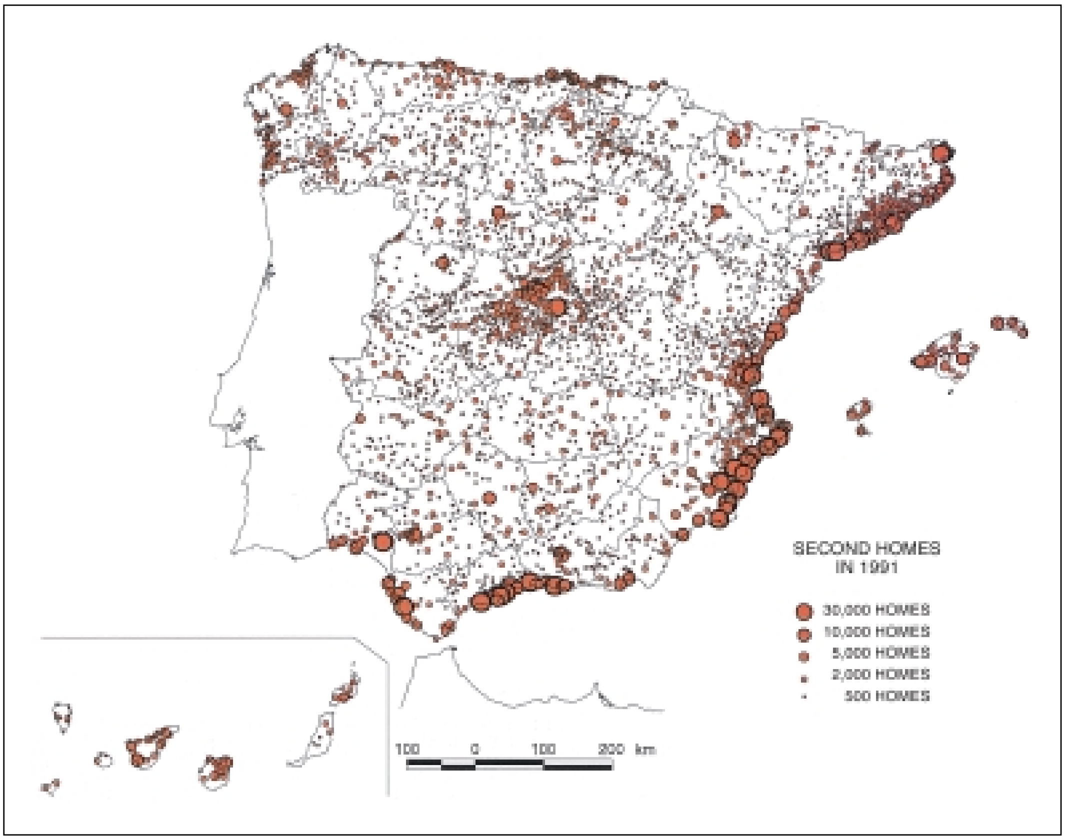


Figure 31. Map of distribution of number of second homes in 1991.

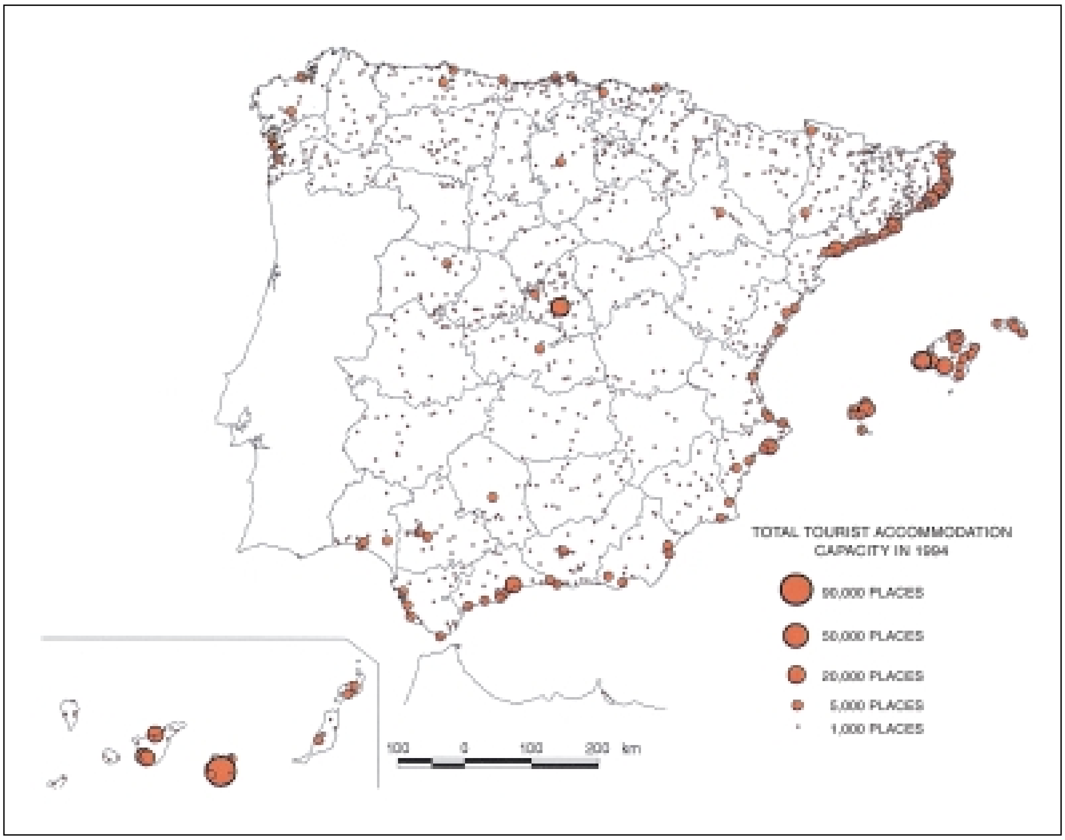


Figure 32. Map of distribution of number of total tourist accommodation capacity in 1994.

increase in user population. Suffice to point out, for example, demand associated with golf courses, whose number has jumped from around 90 in 1988, to over 200 in the year 1995, distributed as shown in the adjoining map. In this respect, two questions should be highlighted: the feedback and multiplying effect of these facilities, since they add tourist attraction to those places where they are set up, and the solvent demand implied, allowing major costs to be assumed that cannot be borne by other activities (fig. 34).

Finally, there should be some mention of new trends observed in relation with tourist demand for natural resources associated with water (wetlands, river landscapes, mountain sites, springs, sources, etc.), whose socio-economic importance will certainly grow in the future, and which means not only seasonal increase in supply needs for these areas, but also the need to consider water as an environmental and leisure element. Not attending to this demand could mean losing a major niche market in the tourist sector, in full development in countries around us.

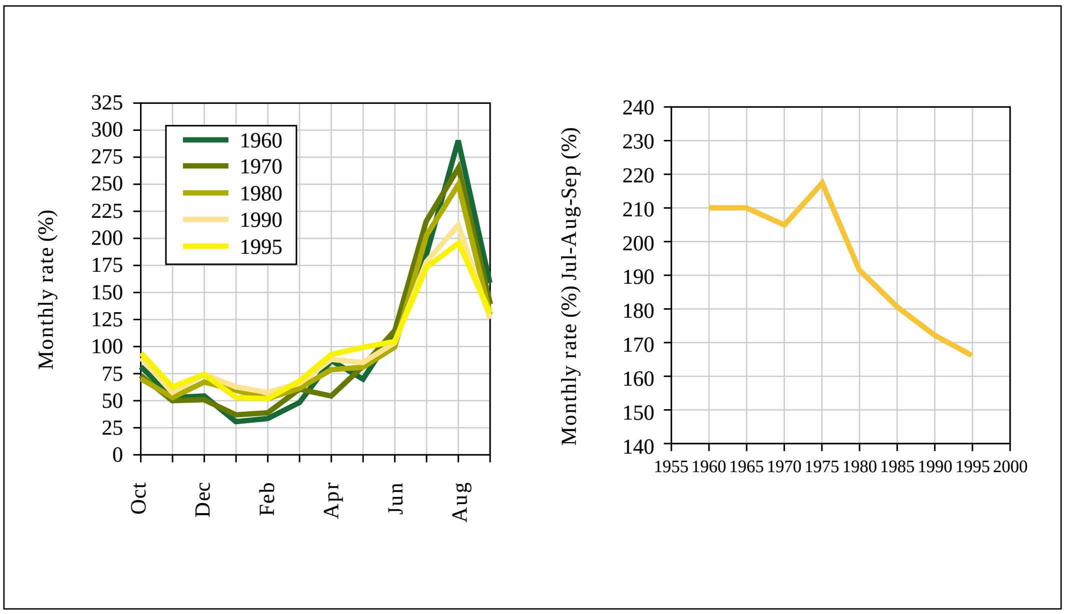


Figure 33. Evolution of seasonality of tourism.

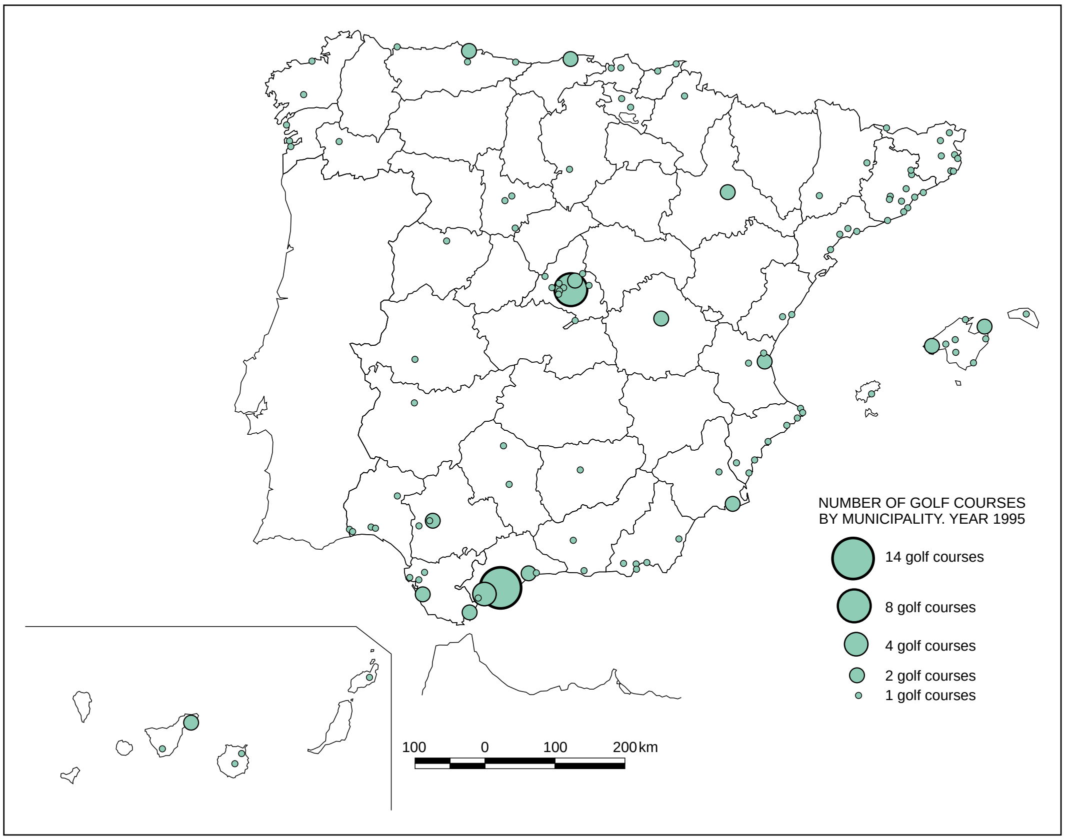


Figure 34. Map of distribution of number of golf courses in 1995.

This is a segment of demand that seeks the most direct contact with nature, so it has been adopted as an indicator for comparing the number of existing campsites. The map in figure 35 gives the location and number of these facilities existing in the year 1995.

It may be seen that their distribution tends to be concentrated in coastal areas, preferentially seeking the attraction of sun and sand. Nevertheless, if instead of looking at the current situation, we look at what has been the trend registered over the past few years, the panorama is the one shown in figure 36 on provincial variations in facilities in the period 1980-94.

A study of this figure clearly shows that the saturation of coastal areas has meant that inland territories and rural areas have enjoyed greater relative development in recent years, tending, together with a somewhat greater pressure on channels, towards a positive increased territorial balance. Although water consumption in these facilities is irrelevant, such trends are significant as indicators of a foreseeable greater pressure with respect to recreational uses in inland areas, associated with aquatic landscapes.

In short, and notwithstanding the foreseeable increase in the recreational uses of rivers, the Mediterranean and southern coastal areas are the main receivers of tourism, and additionally, this phenomenon of spatial concentration fundamentally takes place during the summer months.

Although its impact on water consumption is not very significant, especially if it is considered alongside the very important economic activity brought about by tourism, it gives rise to significant seasonal and local effects in areas that today are problematic as regards water availability, not to mention the need for overdimensioning of infrastructures with relation to what would be necessary to attend to the permanent population. As a result, the availability of water resources in appropriate quantity and quality may be, in the near future, a limiting factor for tourist development and the maintenance of economic activity associated with those territories.

The trends and problems of territorial imbalance in the Spanish population, which we have already referred to, are therefore exacerbated by tourism. In view of its strategic character for the Spanish economy, it will be essential to provide those territories with the necessary guarantee and supply security, and in view of the relative situation of greater water deficit, there must be an effort to economise water to the maximum by re-utilising urban waters devoted to irrigation, which, considering the zones' characteristics, will generally be perfectly possible from both a technical and a financial point of view.

2.3.4. Irrigation

Irrigation is a fundamental element in the landscape structure, a basic activity in the country's socio-economic structure, and one of the territorial variables that decisively influences total demand for water resources. It is the most relevant sector, both in terms of occupying surface area

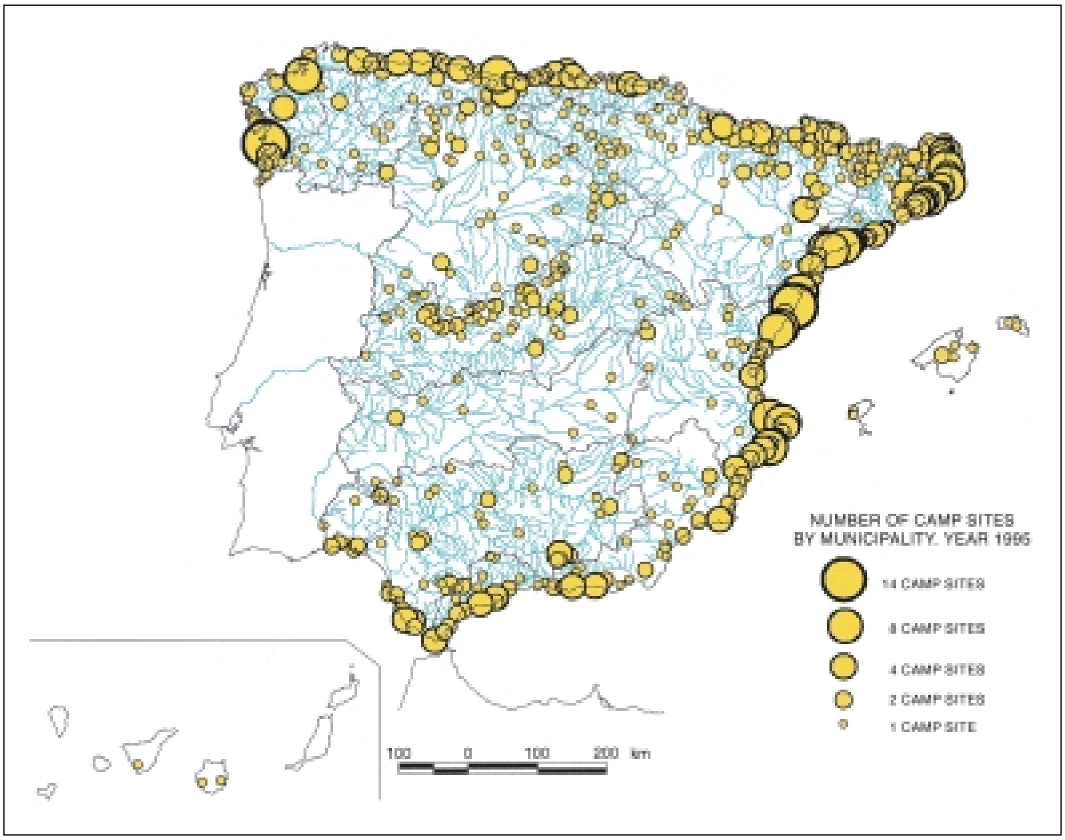


Figure 35. Map of distribution of number of camp sites in 1995.

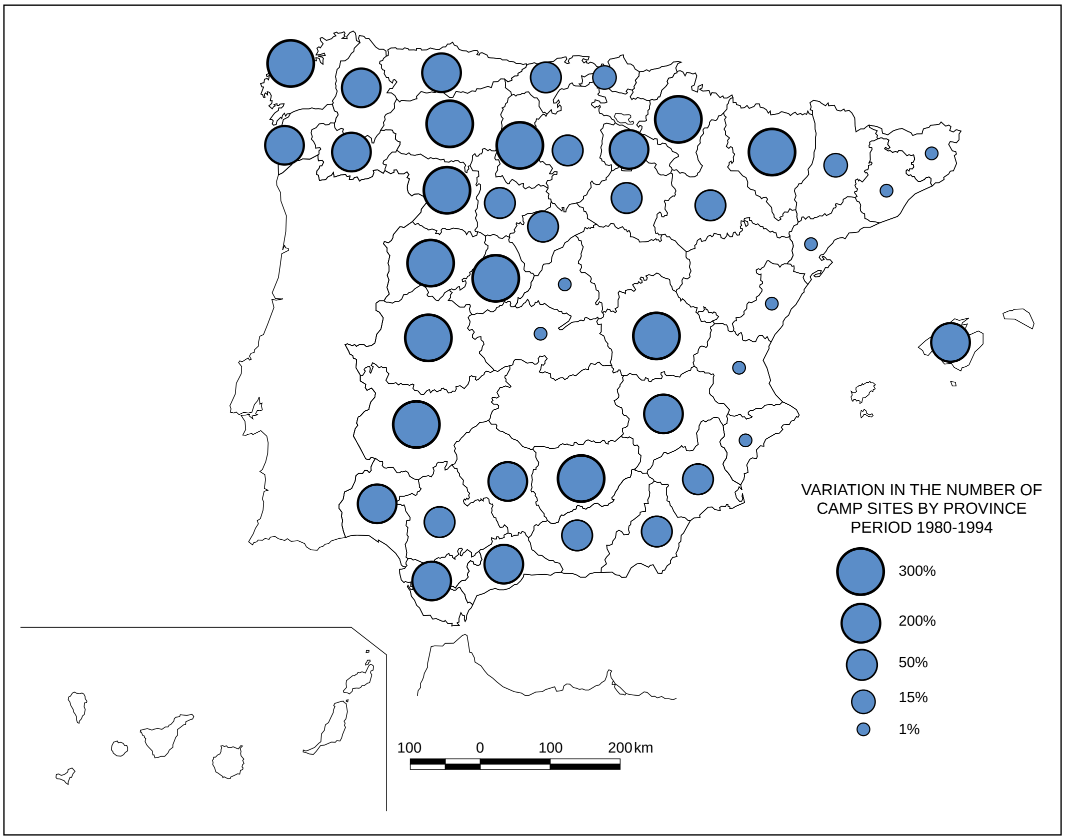


Figure 36. Map of provincial variation in number of camp sites in the period 1980-1994.

(over 3 million ha., representing 13% of usable agricultural land (UAL) or 6% of the total Spanish surface area), and in demand for water (around 80% of demand corresponds to main consumption purposes and around 68% if refrigeration is considered). Its current spatial distribution, which can be seen in figure 37, obtained by teledetection techniques, is the result of a long, complex series of public and private transformation actions, dispersed all over national territory.

We will study this situation in detail in later chapters, on examining water uses and demand for irrigation, although we can state here, in line with this chapter on general description of the reference framework, some of the basic features that condition and make up this highly important socio-economic activity.

It is clear that irrigation activity requires certain natural conditions in order to be implemented, although it is also true that, in certain cases, this activity takes place in situations of low dependency with respect to the physical environment. With historical origins certainly associated with immediate natural conditions, the major technological progress made in the agricultural world is gradually leading to a reduction, in modern irrigation, of physical factors' importance, and giving greater weight to social and economic conditions (Sáenz Lorite, 1990).

Thus, physical medium initially explicative, certainly a determining factor in extreme circumstances (e.g. the unfeasibility of irrigating at 3,000 m, or with sub-zero temperatures), though with somewhat qualified influence outside these limits, and tending to give way to socio-economic conditioners. Below, we will briefly describe these basic factors and conditioners.

2.3.4.1. Natural conditions

Lucas Mallada has already described the considerable difficulty that the layout of our geography represents for irrigation, lands below an altitude of 200 m are uncommon (just 11% of the whole territory), and high plains or mountains are the norm. To illustrate this situation, the adjoining graphs have been drawn up, showing hypsometric distribution (affected surface area in thousands of km^2 - m above sea level) of the whole territory and currently existing irrigation, both on a global scale and separated into the scale of the different basins. The levels of the territories, the levels of irrigated land, its extension relative to the total, and its relative magnitude among the different basins, can be immediately and graphically observed (fig. 38).

Furthermore, and so as to better appreciate this effect, figures 39 and 40 show, in the first graph, the accumulated percentage curve of total surface area of the territory compared with irrigated surface area –with a point on the curve for each of the levels given in the above figure–, and in a second graph, the percentage of territory surface area and irrigation which is under each level.

It can be clearly seen that irrigation is concentrated towards lower levels, compared with what would be a perfectly uniform distribution over the country's entire geography (blue

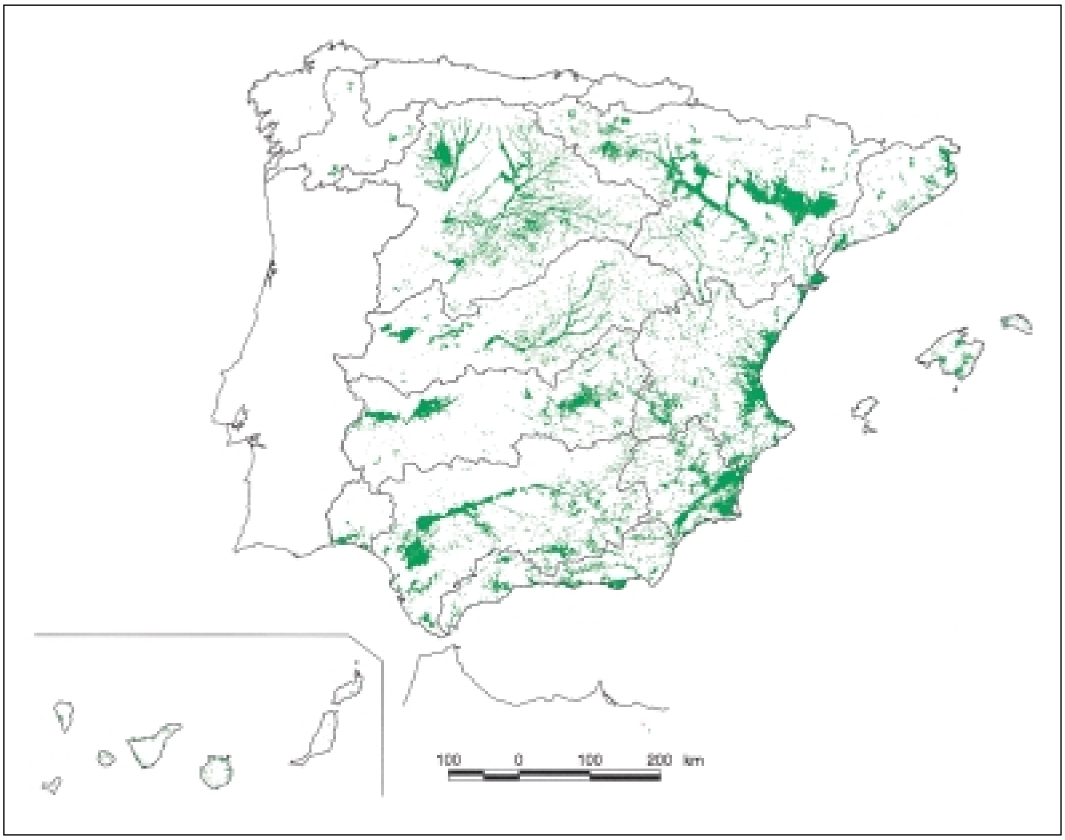


Figure 37. Map of irrigated areas identified by tele-detection (years 1984, 1987, 1991, 1995).

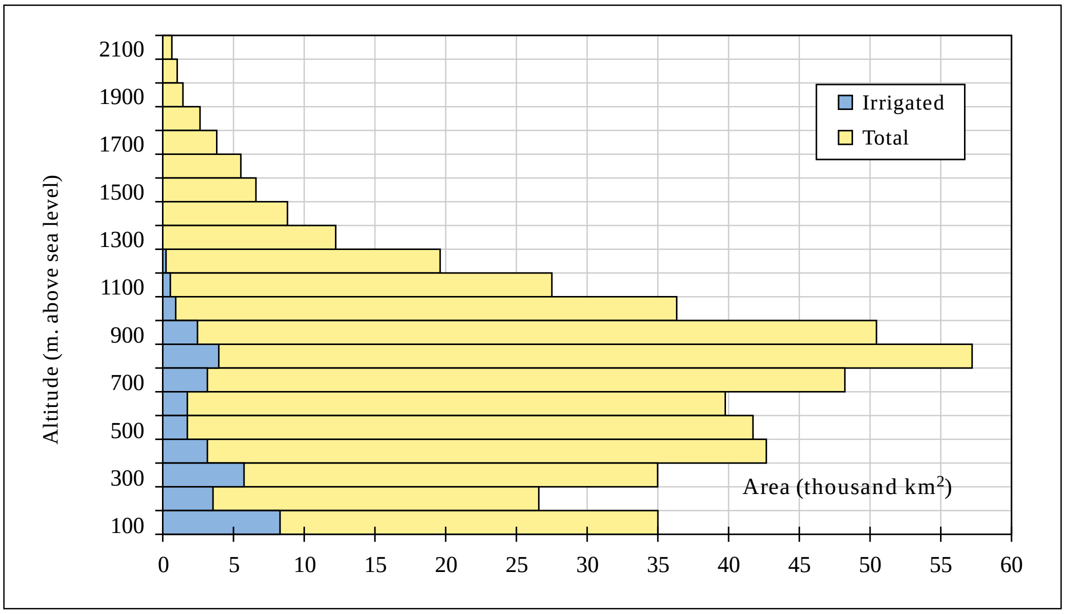


Figure 38. Hypsometric curve and altitude of irrigated areas in Spain.

line at 45° on the first graph, or both distributions superimposed on the second graph). Therefore, whereas half the territory of Spain lies below the 700 m level, almost 80% of its irrigated land lies under that level, and in the 20% of lowest-altitude land, over 50% of all irrigation is concentrated.

It is worth highlighting the major surface area occupied by irrigated land up to the 100 m level. This belt concentrates the greatest surface area due fundamentally to the better climate and, generally speaking, greater profitability at such levels. In the Douro basin and in the upper zones of the Tagus, Guadiana, Júcar and Ebro basins, there exist major extensions of irrigated land at greater altitude, with predominant levels situated between 600 and 900 m.

Between the 100 m level and the 300 m level, there is a jump in surface area due to the effect of Portugal, whose territory lies fundamentally in that altitude range.

Another important natural factor for agriculture is the soil, whose basic types from an edaphologic point of view and their use were briefly mentioned in the relevant paragraphs. In accordance with what was mentioned there, it is expedient to outline the fact that over calcareous Spain there is usually little-evolved, basic land, together with black soil, of the best agricultural quality, compared with poor soil of mediocre aptitude in siliceous Spain. This is influenced by other factors such as the greater evolution of soils in humid Spain, conditioned by the climate, or localised alluvial types, over which Spain's best-known cultivated valleys and traditional croplands are usually established (such as those of Valencia and Murcia).

Moreover, another decisive natural factor is, obviously, climate, whose diversity and peculiarities were mentioned in previous paragraphs.

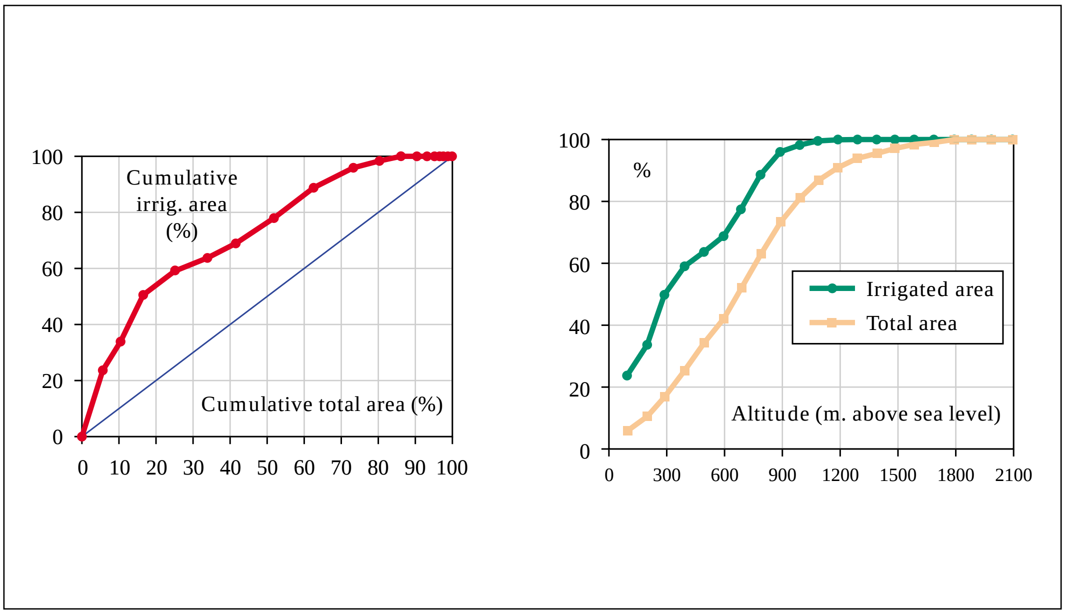


Figure 39. Cumulative percentage curve of area of territory compared with irrigation at different altitudes.

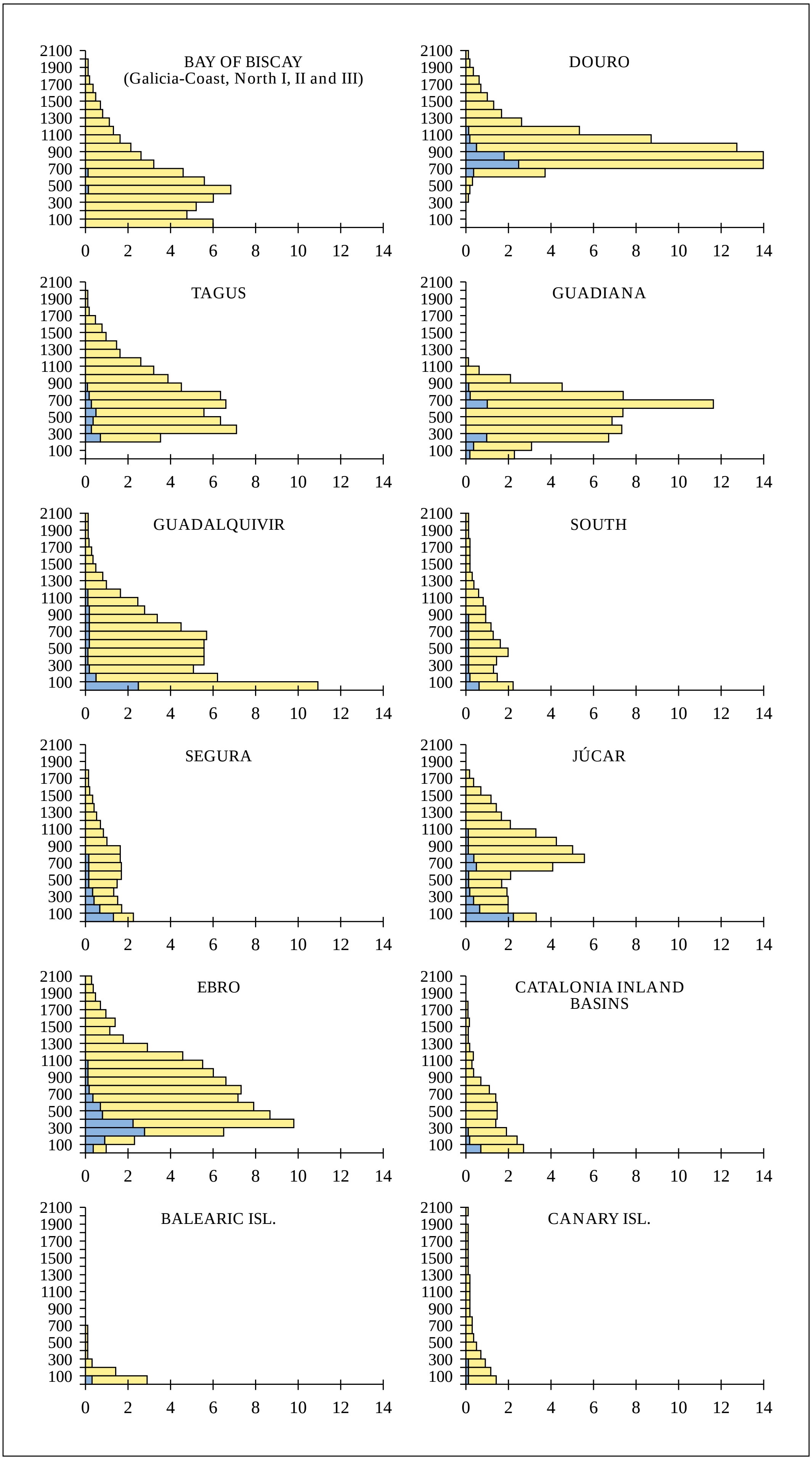


Figure 40. Hypsometric curve and altitude of irrigated areas in different water planning areas.

Finally, in relation to the above, the factor of water availability is a basic conditioner that has influenced the evolution of irrigated land and its possibilities for development. We will have an opportunity to refer to this issue in detail when analysing the water requirements of agriculture and the historical evolution of irrigated surface areas, although we may say here that the major development of irrigation in Spain took place during the second half of the 20th century, and that the major transformations from public initiatives run parallel to the implementation of hydraulic works for water extraction, storage and transportation (that is, what we will call in another chapter of this White paper, in contrast with traditional methods, major hydraulic structures).

In fact, as we shall see, the spectacular increase in river regulation and the massive expansion of groundwater also too place in those decades, and the water availability factor was a decisive conditioner in the dynamics of the process.

Notwithstanding a return, further ahead, to these questions, we may point out two very significant facts here: that the implementation of hydraulic exploitation in Spain is a very recent phenomenon (for barely two decades) and very rapid progress, and that this rhythm of growth seems to have subsided in recent years to much more moderate rates.

2.3.4.2. Population occupied in the agricultural sector

The social aspects involved are frequently used as arguments when trying to evaluate new public actions in hydraulic infrastructures for transformation into irrigated land. The theory is that of these transformations' function in achieving social results in demographic maintenance, population settlement, territorial organisation, and, in short, generating employment to make rural life associated with irrigated agriculture sustainable.

In view of the obvious socio-political importance of this proposition, it is essential to analyse the issue, however briefly, assessing its real scope and its effective possibilities. Obviously, the complexity of the problem far surpasses the scope and objectives of this document, but it is possible to provide some basic data that focus the problem and help to objectivise necessary reflexion.

The graph in figure 41 shows the absolute evolution and percentage distribution of active population (that is, all persons over 16 years of age providing labour for the production of goods and economic services, or are available and are taking steps to participate in this production), according to different activity sectors, as of data from the INE Population Census (Olivera and Abellán [1997] pág. 336).

The same graph also represents the evolution of the general rate of activity (active persons with respect to population in active age [15-64 inclusive, and from the year 1981 16-64]), and of the activity rate (active persons with respect to total population).

The following graph from the same source as the previous one also shows detail of this relative evolution, but here separating active persons by professions (fig. 42).

As can be seen clearly in both graphs, the drop in agricultural activity and the rise in services seems, obviously, unstoppable. Except the industry and construction sector, with a long cycle and a basically stabilised situation with its peak in the decade of the sixties, all activities show permanent, moderate growth, at the expense of continued drop in agricultural activity from the fifties onwards.

Without comparison with other sectors, in absolute terms, the temporal evolution of the active agrarian population is what is shown in the adjoining graph, which also includes the evolution of dry-crop and irrigated surface areas. The contrast between both is interesting, since it shows the enormous development undergone by irrigated land from the

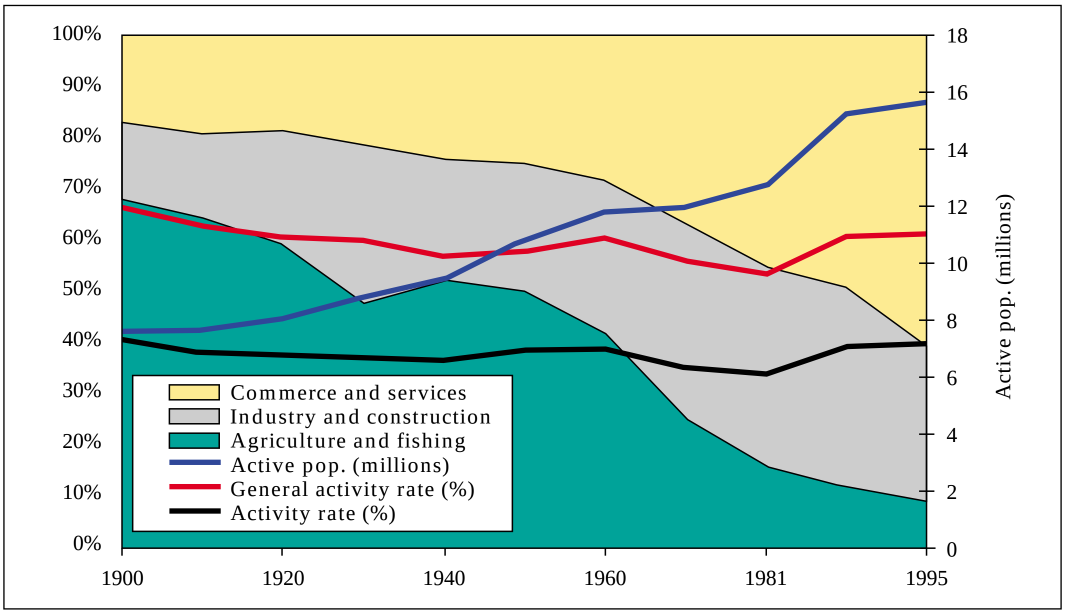


Figure 41. Evolution of active population by sectors of activity since 1900.

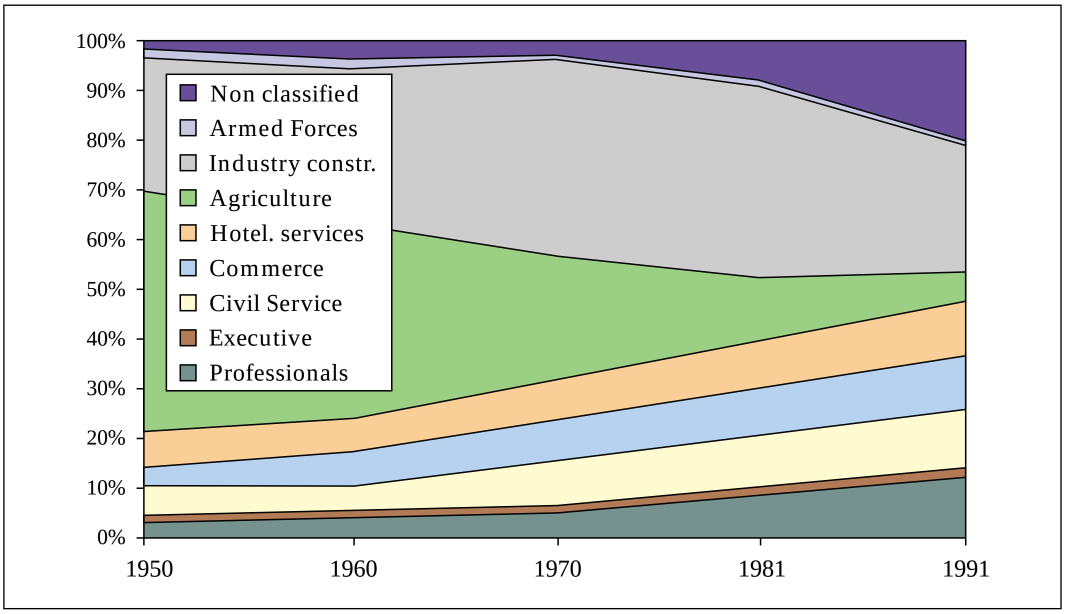


Figure 42. Evolution of active population by professions since 1950.

beginning of the century has not had a clear correlation with agricultural work. Rather the opposite: when the major expansion of irrigated surface areas began in the 50s, the active agrarian population began to diminish.

Among the multiple reasons that explain this is the fact that a great deal of transformation into irrigated land came from original dry crops, in which agrarian employment already existed; intensification and specialisation, which has often given rise to less employment per unit of productive surface area; agricultural mechanisation and technological improvement, which appeared in those years and significantly reduced labour work in the field, etc. (fig. 43).

It is necessary, however, to point out that, in certain territories, the population drop in irrigated areas has been clearly less than in non –irrigated areas, so these general observations should be qualified in each specific case, appropriately considering local circumstances.

It is also interesting to see what has happened not just with active population, or those willing to work, but with that which is actually working. The following graph shows the evolution of occupied population (that is, the fraction of the active population that, during the reference period, have been employed or self-employed) in the agricultural sector in the period 1983-1997, according to the Yearbook on Agrarian Statistics (MAPA [1991] p. 16; MAPA [1997] p. 16), and clearly shows, like the above graph, the intense process of adjustment undergone in these last years (fig. 44).

As can be seen, occupation has fallen, in barely ten years, to almost half, and with an annual variation rate that has always been negative, ranging between 1 and 11%.

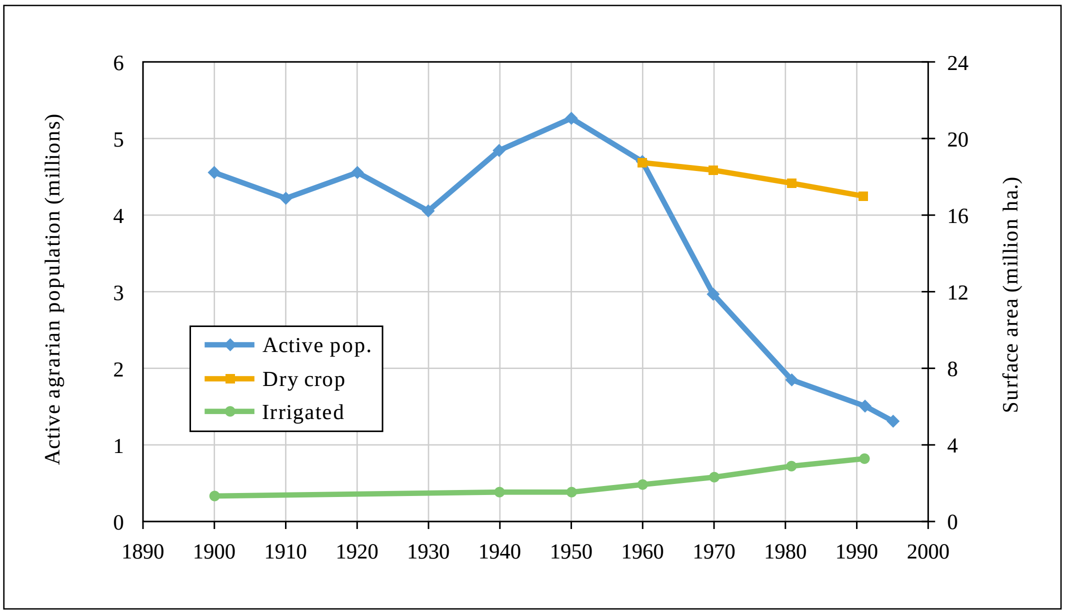


Figure 43. Evolution of active agrarian population and surface areas of dry crop and irrigated land.

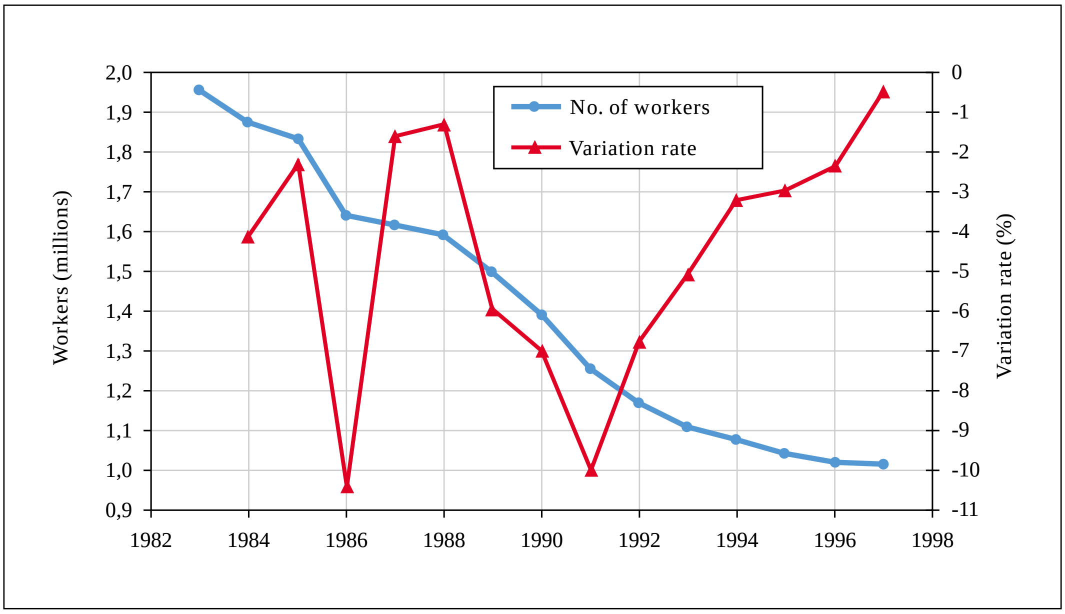


Figure 44. Recent evolution and variation rate of employment in the agricultural sector.

Apart from the considerable numerical drop, the high level of ageing among agricultural employees is also a significant fact, with an average age of 44, an especially intense effect in interior and higher-altitude territories, as can be clearly seen in the map in figure 45, on the ageing of the agrarian population (above 64 years old /total family workforce) in 1989, on a municipal scale (DGPT [1995b] pag. 553).

It may be predicted, without much risk of error, that these trends and adjustment processes will continue in the future horizons of water planning, and that, foreseeably, in the medium term the occupied agrarian population will not exceed half a million jobs.

Furthermore, and due to the physical, demographic and economic reasons mentioned above, this general decrease on a national scale will, probably be more intense in inland and northern regions of rural Spain.

In spite of the somewhat unfavourable panorama described, and the serious future uncertainties, we should highlight the

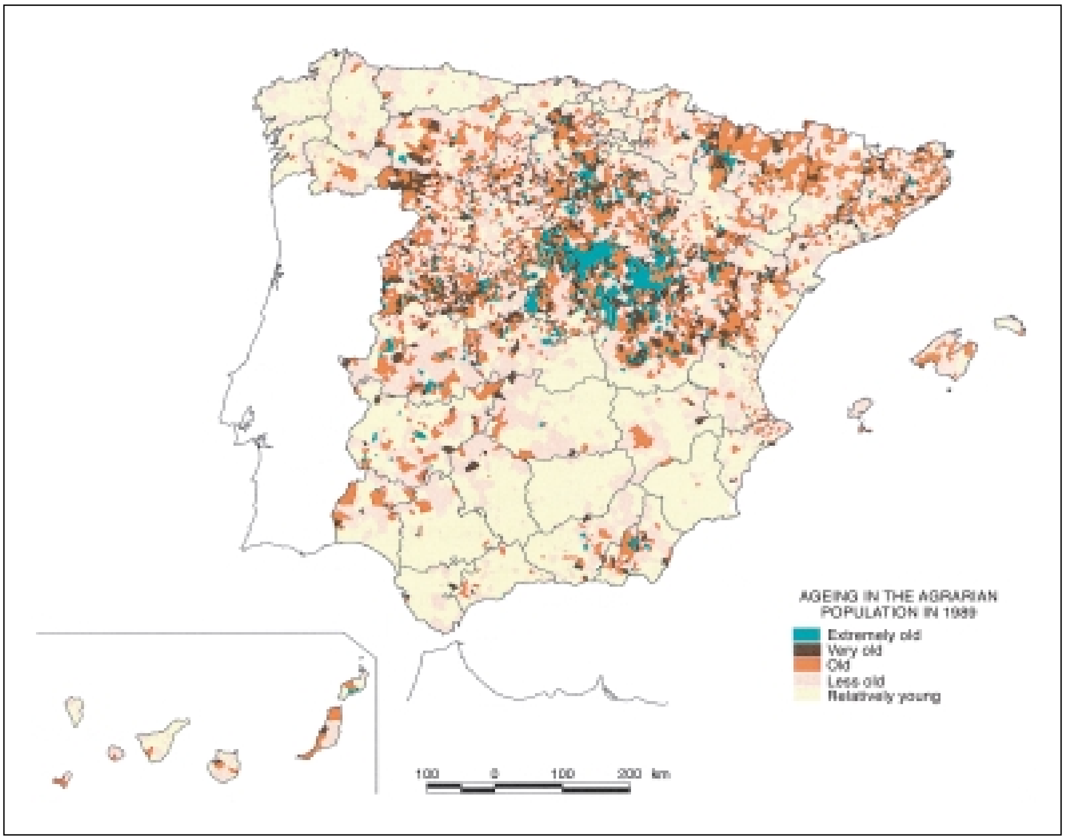


Figure 45. Map of ageing in the agrarian population.

relatively high dependency of a large part of Spanish territory on the primary sector, which is really no more than a reflection of the traditional agrarian vocation of an appreciable part of our country's production structure. This factor will have to be taken very much into account in the near future, considering the foreseeable social and territorial effects to be expected from the substantial adjustment processes looming over this sector.

Details of these economic magnitudes will be seen further ahead, in examining water economy from a sectoral point of view, although it is worth mentioning here, underlining its importance.

2.3.4.3. Conclusions

Generally speaking, and notwithstanding the unique characteristics of some especially productive and competitive territories, it seems highly improbable that commercial activity associated with agricultural production markets is able by itself, without resorting to subsidies, to generate enough added value to sustain the population levels of previous decades. As a result, if this negative situation is to be moderated, there must be decisive, explicit public intervention. Nevertheless, and in view of trends and experiences of the recent past, it should be pointed out that, unfortunately, there is no guarantee that even with such public intervention, these objectives may be met.

In fact, it is undeniable that younger generations would only be willing to continue in this activity if their income expectations were not clearly lower than those offered by other activities. At present, over 30% of agricultural income comes from EU subsidies, with the erratic, precarious factor that this involves, so there is no guarantee that it could react favourably if faced with adverse circumstances outside these dependency relationships.

What is more, and as a prior issue, it would have to be demonstrated that this satisfies the best interests, both of the territories themselves with respect to other development alternatives, and the general interests of the national economy, both questions which, conceptually and theoretically, are far from being resolved.

2.3.5. Industry

In accordance with the denomination of water legislation, which refers to industrial uses differentiating them from energy uses, we shall use these terms to refer to all those sub-sectors within the greater sector of industrial activity, not specifically devoted to energy production.

From the point of view that interests us, this activity sector involves a situation of spatial concentration in water demand, whose correct supply –in quantity and quality– is of fundamental importance in maintaining production activity. Likewise, and according to the specific activities carried out, it may pose a serious risk of water pollution in these areas of concentration.

After the development of the traditional Catalan and Basque industrial focal points –followed later on by Madrid– from the mid-19th century to the mid-20th century, and in a predominantly rural context, Spain's transition towards and urban–industrial society basically took place as of the Stabilisation Plan (1959) up to the 70s, with very high expansion rates during barely two decades. Industrial activity's evolution in most recent years has been characterised by a drop in previous expansion rates, increasing trans-nationalisation –culminating with European integration– and rapid technological improvement. All this has forced the restructuring of numerous production sectors and companies, exhausted some accumulative processes in traditional areas of industrialisation, and displaced certain activity segments to other peripheral zones (Méndez Gutiérrez del Valle [1990] p. 13), though without this having significantly modified the location of the country's dominant economic-industrial areas.

Thus, in the last decade of, Spanish industry has maintained, and even increased, the level of spatial concentration, since the 10 most industrialised provinces provide 61% of the industrial Gross Added Value (GAV), and just the four most important –Barcelona, Madrid, Valencia and Vizcaya– represent 43%.

Four spatial areas currently concentrate 73% of industrial added value: the Mediterranean coast, from Gerona to Murcia, which concentrates 37,8% of GAV; Madrid and its axial area of influence –Toledo and Guadalajara– with 13,5%; the Bay of Biscay coast, from Guipúzcoa to Asturias, with 12,5%; and the Ebro valley –Álava, Navarre, Rioja, Zaragoza and Lérida– with 8,8%.

On the next level is the area of Seville-Cádiz-Huelva and Málaga –5,4% of industrial production– which corresponds to territories without industrial preponderance and, in general, dominated by mature technology industries.

The adjoining map, drawn up from statistics on a municipal scale, shows the territorial distribution of industrial activity, and gives a visual appreciation of the areas mentioned (fig. 46).

We may highlight the fact that the Mediterranean and southern Atlantic areas, affected by water resource limitations, concentrate over forty per cent of Spanish industrial activity, and that in the period 1988-91 a slightly greater industrial growth was detected in them. This agrees with what has already been commented in relation to urban supply.

As a medium-term forecast, and in view of the relatively autonomous character with respect to political-administrative decisions, it seems possible to state that the continuity of this territorial development has greater probabilities than other alternatives, which would require, in order to be accepted, an economic and regional political framework very different from the present one and the one foreseeable in the short term.

Figure 46. Map of territorial distribution of industrial activity.

2.3.6. Energy

We shall use the term energy sector, in accordance with the denomination of water legislation, to designate, within the greater group of industrial activities, that which is specifically devoted to electrical energy production.

Within this sector, we should differentiate, in turn, two different situations: the production of hydroelectric energy by pumping water flow to exploit its potential energy (hydroelectricity), and the use of water for refrigerating thermal power plants (refrigeration). Furthermore, both types of power plant complement each other in electricity supply: thermal power stations (conventional or nuclear) are usually large power and continually operating, covering the base of the demand curve, while the hydroelectric stations, given their enormous operative flexibility, can adapt continually to demand variations, ensuring stability of frequency and power, and providing the running load (generators operating at reduced load, able to increase it instantly), to compensate for failures in other power plants in the system.

It is clear that, within the greater sector of industrial activities, the electrical energy production sector (or energy sector) has a unique importance from the point of view of water resources, since the hydroelectric component of this sector has, as mentioned, the feature of needing massive water supply, in quantities that are incomparable with the rest of industrial activities for which water is just another input –and not the most important– in the production process. Moreover, this water is not consumed but returns in full to the hydraulic system after use, which is also a peculiar feature within the greater sector of industrial activities that require water resources.

2.3.6.1. Sectoral structure of electrical production

Within the electricity sector, hydroelectric energy has been a fundamental contribution to Spain's energy balance for decades, although it has been stationary and even decreased since the mid-60s (when it represented 70-80% of the total), a situation that may be attributed both to the implementation of nuclear production, as of the year 1980, and the unfavourable hydrological conditions registered in the country. This evolution is shown in the following graph, drawn up here from UNESA data (1998a), where the structure of energy production is registered from the year 1940 to the present day, expressed by the percentage of participation of its different basic components: hydraulic, conventional thermal and nuclear (fig. 47).

The electricity sector supplies a major part of the energy finally consumed in Spain, with a participation that has evolved from 12.7% in 1973 to rather more than 18% as of 1990, a figure that has remained stable since then (with UNESA data, in 1994 petroleum products provided 68.9%; gas 8.4% and coal 4.5%). At present, the sector's contribution to the total Spanish GAVmp (Gross Added Value at market price) stands at around 2.6%.

These basic figures therefore show that at present hydroelectricity provides, depending on the year, between 15%

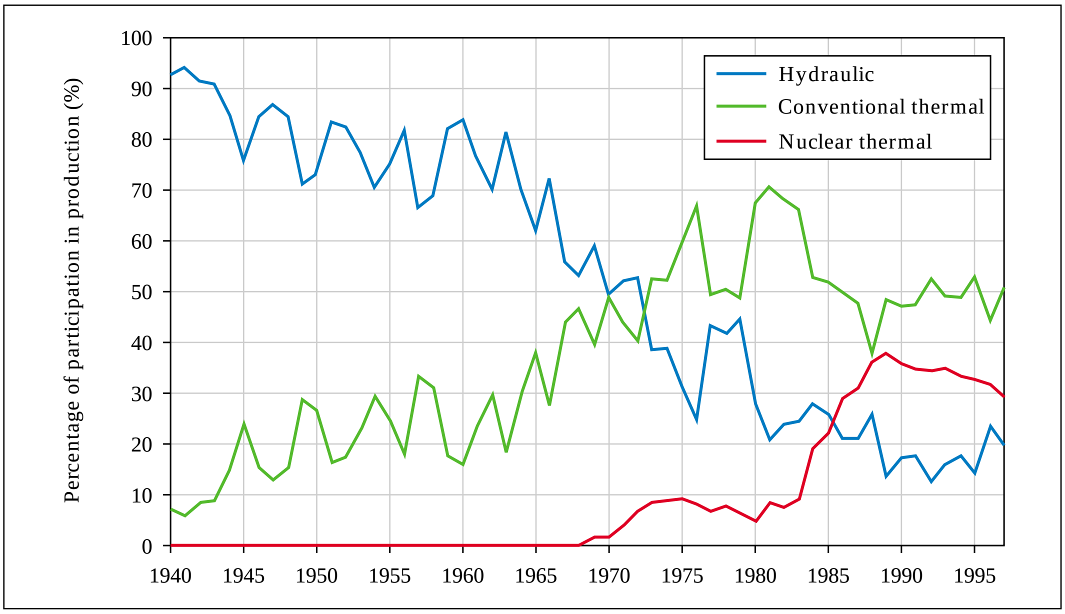


Figure 47. Evolution of the sectoral structure of electricity production since 1940.

and 25% of electricity production (much more in years with excellent hydrological conditions), which represents between just 3% or 3,5% of the final energy consumed in Spain. However, for the purposes that interest us here hydroelectricity has two significant characteristics that highlight, from an economic point of view, its role in the sector. In fact, firstly, it is the primary source of clean, renewable energy, and secondly, it operates covering the peak hours of the electricity load curve, allowing a continuous quality service. These two circumstances mean that, despite its relatively modest contribution to the total national energy balance, its considerable importance from an energy point of view should be highlighted.

Finally, and in conclusion, in terms of GAV, its production function, more favourable than that of other major sources, and its better sale price allow the hydroelectric sub-sector's contribution to be estimated at around 0.7% of the national total.

2.3.6.2. Territorial structure of hydroelectric production

From the point of view of territorial distribution, hydroelectric production is very unevenly localised as a consequence, obviously, of water resource availability, and of the territories' different topographical possibilities to exploit the potential energy of water. The following graph reflects the average values of this participation structure, on total hydroelectric production, of Spain's different basins (fig. 48). It may clearly be seen that the basins of Cantabria, Ebro, Douro and Tagus are absolutely predominant as regards production, and to a much lesser extent, the Júcar.

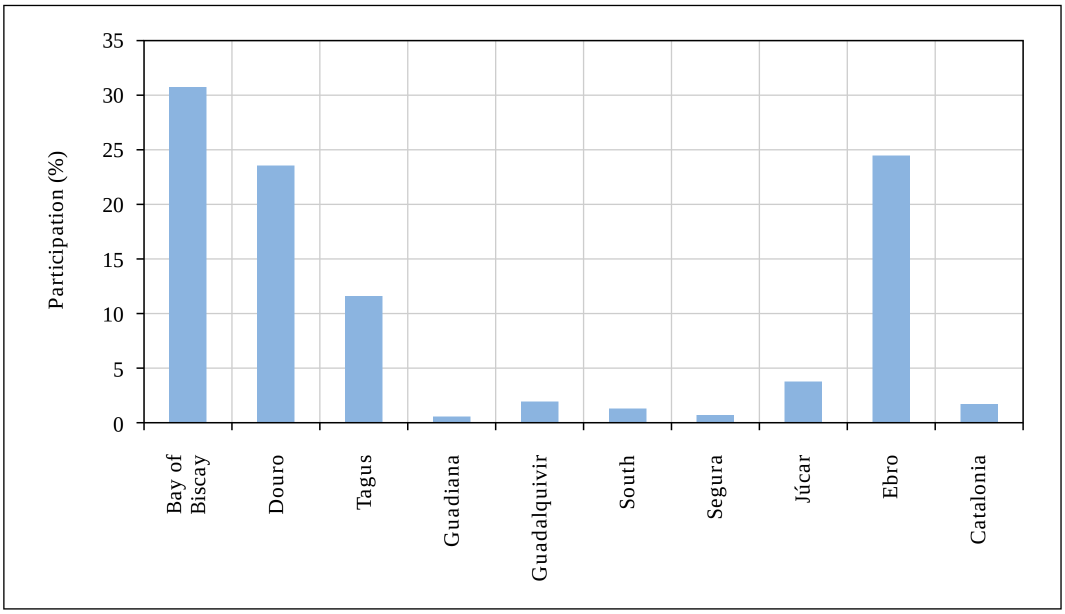


Figure 48. Participation of hydrographic basins in total hydroelectricity production.

Compared with these, the rest (Guadiana, Guadalquivir, South, Segura and Catalonia) have an absolutely marginal hydroelectric contribution, as a result of their worse natural conditions (flow and relief) and of their historically dominant agricultural vocation. This is simply an obvious expression of basins' different territorial specialisation, and the result of developing their different relative potential.

Obviously, there exists a different degree of competition between both sectors for the use water in the different basins according to their production capacities and the volumes of water that can be used. Thus, insofar as the Douro and Ebro seem to have resources for both uses, the same does not happen with the Guadiana, Guadalquivir, South, Segura and Júcar, whose opportunity costs should be analysed in the necessary detail, as outlined further ahead, in studying the sectoral water economy. In any event, and advancing data that will be seen later in detail, the existing territorial differences and the different production profiles can be seen in figure 49, representing the percentage of participation by the different basins, over the national total, in surface areas and water consumption in irrigated land, installed hydroelectric power and, as before, hydroelectric production.

As may be seen, in some basins participation in surface area is greater than in consumption (Guadiana, Guadalquivir, South, Segura, Júcar, Catalunya and archipelagos), while in the rest the opposite occurs. Simultaneously, there exist basins with greater participation in hydroelectric production than in installed power (Bay of Biscay coast, Douro and Ebro). These relative participation differences are due, in the case of irrigated land, to the differences in hydraulic needs of crop alternatives and in efficiencies, whereas the differences between power and production capacity are due to the different equipment and utilisation hours of the power stations.

If the relative percentages of surface area and power capacity of each basin are represented in Cartesian coordinates, the graph in figure 50 is the result, giving an even clearer appreciation of the different production typologies.

In fact, as mentioned above, only Ebro and Douro show relatively significant amounts for both uses (of around 15% in both cases). Tagus and Júcar also show –although to a lesser extent– major joint use, while the Cantabrian basins register a net hydroelectric use, and those in the southern Peninsula (Guadalquivir, Guadiana and Segura) are fundamentally agricultural.

Notwithstanding a later return to these differences in territorial orientation in later chapters, it is appropriate to remember these basic features here, since they help to understand the reiterated complexity and diversity of situations that our country offers in the field of water utilisation.

2.4. INSTITUTIONAL FRAMEWORK

After the brief examination of the physical reference framework (climate, geology, soils, biotic environment, etc.) and socio-economic reference framework (population, tourism, industrial activity, energy, etc.), it is appropriate to briefly present some basic features of the third major pillar that supports water management and makes up water problems, which is organisational and institutional conditions, referring both to domestic organisations and regulations and to the increasingly important international conditions.

As in the case of the physical environment and the socio-economic substrata, the institutional framework can also justly be considered an infrastructure, that is, a prior condition that supports and influences water management and use. What is more, unlike what occurs with other natural resources, much less subjected to these conditioning factors, it is through institutional constructions that, to a large extent, water policies are implemented, and these institutional constructions, as we shall see, play a particularly relevant role in their development.

This section, then, will generally describe such conditions dealing first with the territorial organisation of the State

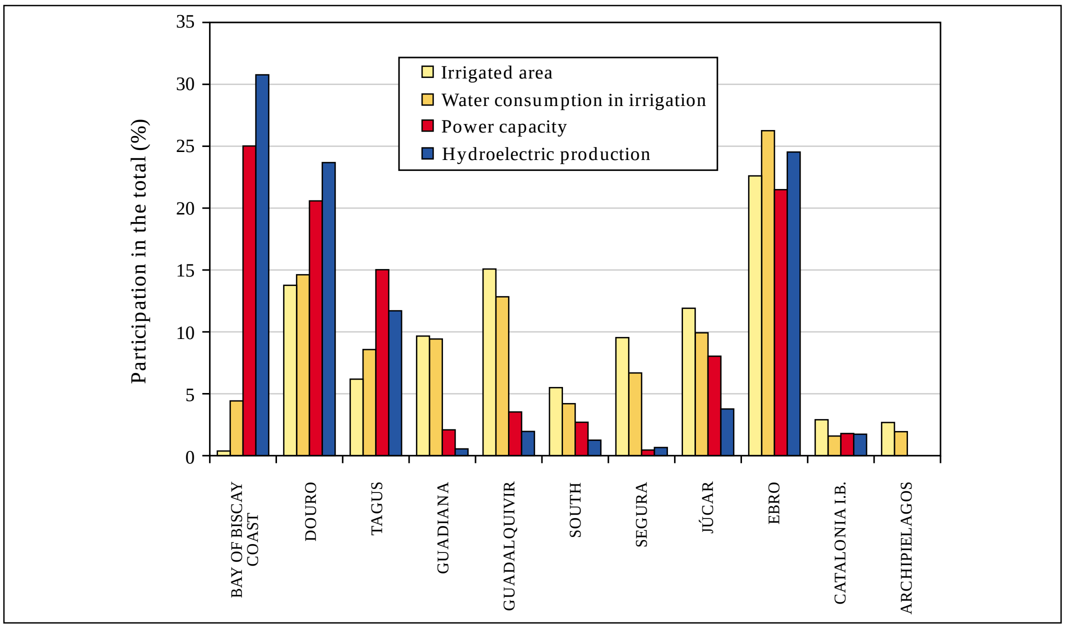


Figure 49. Relative participation of the different basins in surface areas and water consumption in irrigation, power capacity and hydroelectric production.

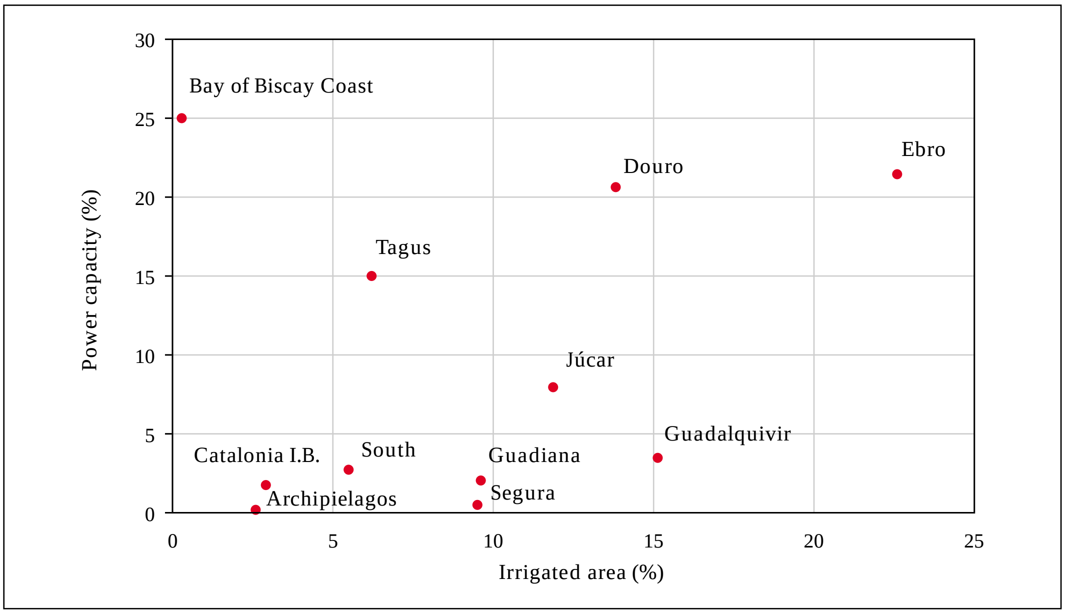


Figure 50. Relative participation of irrigated areas and power capacity by hydrographic basin.

and, as a consequence, the conditions that this organisation involves as regards water. We will then continue with the historical background that has led to the legal regulations in force, and the most significant aspects of these regulations, briefly noting some considerations on the basic organisations in water management. Finally, we will conclude with some other particular questions that deserve a mention.

It has been stated and reiterated that the field of law impregnates water, penetrates it and regulates it. As a result, as we have mentioned, we will simply note here the basic features of the current institutional context, leaving some specific issues for later consideration, together with other technical aspects, and combined with them. Thus legal reflections appear mingled with and combined with other considerations, running through the whole text, and avoiding the need for a specific isolated and separable chapter. This leads to the multifaceted character that this study on water should present, and which it has been intended to give this document.

Furthermore, the presentation of the current situation and difficulties detected in this situation does not require, for the moment, a description of possible solutions or ideas for future action. Such possible ideas or solutions generally allow for different ideological and political orientations, so, as generally outlined, they are reserved for another chapter in this White Paper, which presents conceptual bases and actions considered appropriate for the future.

2.4.1. Territorial organisation and the Autonomous Communities

An element of great importance in the formation of the current Spanish institutional framework is certainly the new territorial organisation arising from the State of Autonomies.

This organisation has posed, as we shall se, some new legal problems regarding competence on water issues, which will be examined in other sections of this document. Apart from these specific legal problems, however, an important basic question has also been posed, possibly even more significant since it is the cause, on the limits of sovereignty, territoriality, administrative organisation... decisive questions from the points of view of water policies and authorities.

The legislative development and the adaptation, interpretation, and progressive refinement of the relevant legislation, in the light of the constitutional text, has gradually created a complex reality in which both the central government and the 17 Autonomous Communities and 2 Autonomous Cities enjoy considerable power and assume shared and concurrent responsibilities in environmental matters and the management of resources, matters in which municipal powers also bear an influence.

Tables 1 and 2, with data from Tamames and Rueda (1997) p. 897, show the main characteristics of the different Autonomous Communities (both from the point of view of population and economic activity) in the years 1985 and 1995, showing both the relative specialisation and their recent evolution.

In order to provide an initial overview of the organisational situation, the adjoining figures jointly show the territorial areas of the Autonomous Communities, together with the different Basin Plans. Figure 51 distinguishes the water planning areas created by the General State Administration agencies, and those created by the Autonomous Communities.

Figure 52 jointly shows both concepts, clearly demonstrating the overlapping and existing relationships.

All of this (overlapping areas, concurrent powers, regulatory differences...) has meant a substantial change in political-administrative territorial organisation, whose influence on water is decisive, and has given rise to particular problems which, as we shall see, and despite regulatory efforts implemented, is far from being satisfactorily resolved.

	Surface Area	Population 1995	Population density (inhab/ km²)		GDP per km² thousands of € 1985		GDP per capita thousands of € 1985			GDP per capita 1995	
	(km²)	(thousands)	1985	1995	1985	1995	1985	1995	% cum. var. annual	thousands of €	Index Spain = 100
Andalusia	87,218	7,056	77.3	80.9	238.96	386.89	3.12	4.78	3.3	8.03	80.8
Aragon	47,669	1,182	24.9	24.8	121.10	176.72	4.85	7.13	3.2	11.97	120.4
Asturias	10,565	1,082	105.7	102.4	442.50	565.22	4.25	5.52	2.2	9.27	93.2
Balearic Isl.	5,014	714	135.3	142.4	866.13	1,513.95	6.23	10.63	3.7	17.85	179.5
Canaries	7,273	1,523	201.6	209.4	810.52	1,466.05	4.11	7.00	4.0	11.75	118.2
Cantabria	5,289	527	98.7	99.6	422.75	595,83	4.29	5.98	2.7	10.04	101.0
Castile-La Mancha	79,226	1,671	21.1	21.1	70.71	120.35	3.45	5.71	3.8	9.58	96.4
Castile-León	74,147	2,543	27.4	34.3	107.32	201.62	4.00	5.88	2.9	9.87	99.3
Catalonia	31,930	6,106	187.5	191.2	1,012.50	1,566.73	5.44	8.19	3.3	13.75	138.4
Valencia Community	23,305	3,884	159.9	166.7	732.41	1,121.23	4.51	6.73	3.1	11.29	113.6
Extremadura	41,602	1,069	26.0	25.7	74.49	115.86	2.98	4.51	3.4	7.57	76.1
Galicia	29,434	2,717	96.5	92.3	334.45	521.22	3.61	5.65	3.3	9.48	95.4
Madrid	7,995	5,014	597.5	627.1	3,433.20	5,207.01	5.73	8.30	3.0	13.94	140.2
Murcia	11,317	1,068	88.5	94.4	323.75	512.43	3.65	5.43	3.0	9.12	91.7
Navarre	10,421	521	49.5	50.0	236.60	386.62	4.80	7.73	4.0	12.98	130.6
Basque Country	7,261	2,110	29.5	290.6	1,430.75	2,186.30	5.00	7.52	3.0	12.63	127.1
La Rioja	5,034	263	51.5	52.2	246.10	407.32	4.74	7.80	3.6	13.09	131.7
Ceuta	18	67	3,611.1	3,722.2	--	--	--	--	--	9.02	92.3
Melilla	12	60	4,333.3	5,000.0	--	--	--	--	--	6.32	92.3
Total Spain	**504,750**	**39,178**	**75.9**	**77.6**		**330.89**	**4.40**	**6,23**	**3.5**	**9.94**	**100.0**

Table 1. Some basic data on the Autonomous Communities.

	Total GDP 1995 (M€)	% of national total 1995	GDP Structure (Regional total = 100)							
			Agriculture and Fishing		Industry		Construction		Services	
			1985	1995	1985	1995	1985	1995	1985	1995
Andalusia	56,652.64	13.0	13.6	9.3	18.0	13.9	6.8	10.3	61.6	66.2
Aragon	14,143.18	3.2	8.8	6.9	32.0	27.5	5.2	7.5	54.0	57.9
Asturias	56,652.64	13.0	13.6	9.3	18.0	13.9	6.8	10.3	61.6	66.2
Balearic Isl.	10,025.66	2.3	4.4	3.4	39.8	31.3	4.3	7.3	51.5	57.8
Canaries	12,744.44	2.9	2.6	1.4	11.0	7.8	6.5	6.5	79.9	84.1
Cantabria	17,901.41	4.1	5.1	3.3	10.9	8.9	9.6	7.9	74.4	79.7
Castile-La Mancha	5,290.78	1.2	6.2	5.0	30.7	23.8	4.8	7.0	58.2	64.0
Castile-León	16,007.72	3.7	16.9	12.4	23.9	23.5	8.8	11.9	50.4	52.0
Catalonia	25,097.87	5.7	12.6	10.7	27.2	24.6	6.3	8.3	53.9	56.2
Valencia Community	83,988.03	19.2	2.5	1.8	34.1	28.2	4.3	7.1	59.1	62.8
Extremadura	43,870.08	10.0	5.1	3.2	28.4	26.1	5.7	7.6	60.8	62.8
Galicia	8,092.39	1.9	16.9	14.2	16.2	15.6	8.2	11.8	58.8	58.2
Madrid	25,757.03	5.9	11.4	7.7	23.8	20.2	7.4	11.7	57.4	60.2
Murcia	69,892.68	16.0	0.3	0.2	19.7	16.7	4.2	6.1	75.8	76.9
Navarre	9,763.20	2.2	11.9	8.6	23.8	20.4	7.0	9.9	57.3	61.0
Basque Country	6,764.24	1.5	7.3	5.0	35.3	35.7	5.5	7.2	51.9	52.0
La Rioja	26,652.04	6.1	2.3	1.8	11.0	34.7	3.8	6.7	49.9	56.5
Ceuta	3,442.46	0.8	12.4	11.8	29.7	28.8	5.4	6.7	52.5	52.5
Melilla	1,250.45	0.3	1.4	0.6	6.2	3.8	5.2	6.4	87.2	89.1
Total Spain	**4,373,093.04**	**100.0**	**6.4**	**4.7**	**26.5**	**22.1**	**5.6**	**8.1**	**61.5**	**65.0**

Table 2. Some basic data on the Autonomous Communities (GDP structure).

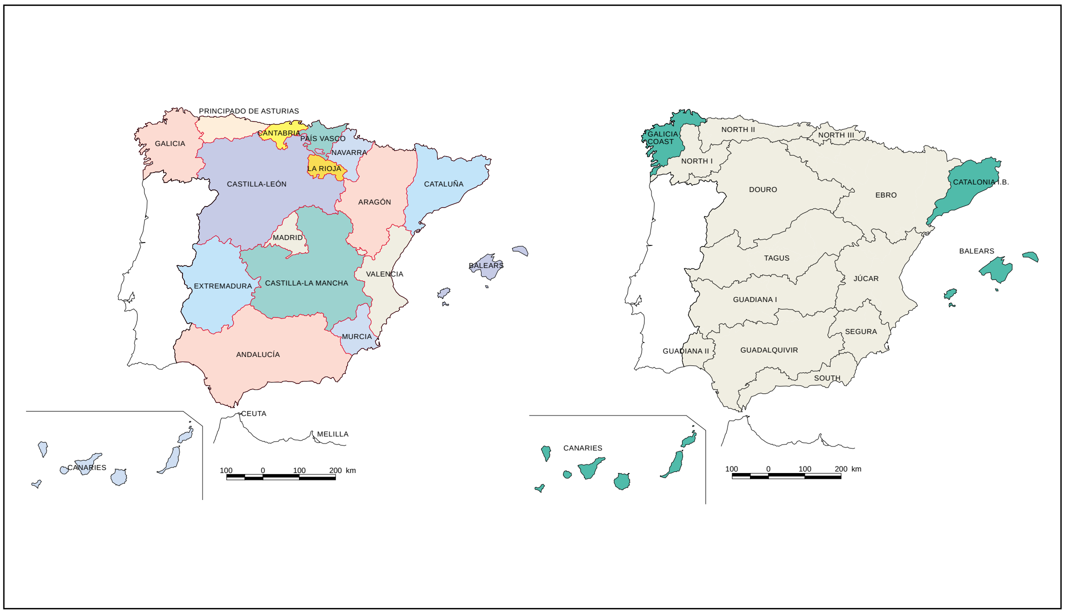


Figure 51. Maps of territorial areas of Autonomous Communities and Basin Plans.

2.4.2. The Current Legal Framework

After describing the situation of territorial organisation that makes up our current political-institutional organisation, we shall now deal briefly with describing the overall current legal framework, including its basic provisions, and noting some existing problems.

The complex and specific nature of the norms and regulations regarding water has justifiably led to consideration of a differentiated discipline within legal-administrative science, with specific criteria, jurisprudence and doctrine on water resources and their use, which may be called Water Law. This level of development and specification means that the criteria and regulations that make up and form the basis for water administration and management in Spain are very numerous and with great diversity of scope and content.

Here we will exclusively examine the fundamental texts that these regulations are presently based upon, considering

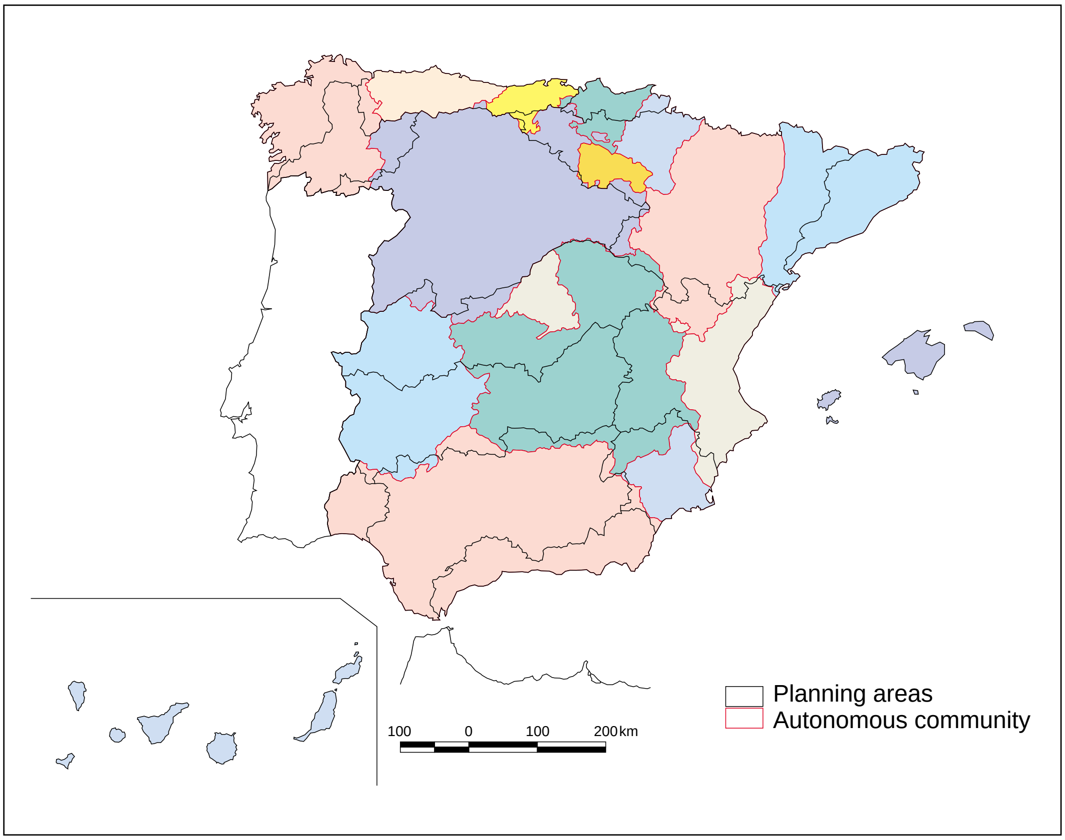


Figure 52. Combined map of territorial areas of the Autonomous Communities and Basin Plans.

these to be the constitutional text, the Statutes of Autonomy of the Autonomous Communities, the basic state sectoral legislation –Water Act of 1985 and the Regulations that develop it–, the Water Act of the Canaries of 1990, and various provisions on water passed by the Autonomous Communities.

2.4.2.1. Spanish Constitution

Within the major general regulatory framework laid down by the constitutional text, there are various references relevant to water management and administration. Among these, we should mention those that refer to the fundamental question of competence between the State and the Autonomous Communities, both on water and on other sectoral aspects, and those referring to the actions of the public authorities in relation to water.

2.4.2.1.1. Distribution of competence on water issues

Article 149.1.22 of the Constitution reserves for the State exclusive competence on matters of legislation, regulation and allocation of water resources and utilisation when the water runs through more than one Autonomous Community, whereas, in accordance with the terms of article 148.1.10, the Autonomous Communities may assume competence on projects, construction and exploitation of water uses, channels and irrigated lands of interest to the Autonomous Community; mineral and thermal waters.

Thus, the Constitution itself gives different treatment to state and autonomous competence, since as the criterion for assuming autonomous competence regarding uses, channels and irrigation is interest (article 148.1.10), state competence is governed by territorial criteria (when the water runs through more than one Autonomous Community).

In the intermediate area that may lie between the two provisions it is possible for Autonomous Communities to assume statutory competence beyond the terms of article 148.1.10, but always with the territorial limitation stipulated in article 149.1.22. In the framework of these constitutional provisions, the Autonomous Statutes have laid down competence on the subject of water as follows:

- Water uses, channels and irrigated land:

  The Autonomous Communities which achieved autonomy through article 151 of the Constitution assumed, in their Statutes, exclusive competence on matters of water use, channels and irrigation when the water runs wholly through the territory of the Autonomous Community.

  The Autonomous Communities which achieved autonomy through article 143 of the Constitution, originally limited by article 148.1.10, assumed competence on projects, construction and exploitation of water uses, channels and irrigated lands of interest to the Autonomous Community, although all the Statutes added a territoriality clause: when the water runs wholly through the territory of the Autonomous Community.

  Subsequently, Organic Law 9/1992, of the 23rd of December, on the transfer of competence to Autonomous Communities which achieved autonomy through article 143 of the Constitution, transferred to the Autonomous Communities of Asturias, Cantabria, La Rioja, Region of Murcia, Aragón, Castile-La Mancha, Extremadura, Balearic Islands, Madrid and Castile and León, exclusive competence on matters of regulation and allocation of water resources and uses when the water runs wholly through the territorial area of the Autonomous Community, competence subsequently laid down in the amendements of all the Statutes of Autonomy of the affected Communities.

  The cities of Ceuta and Melilla have only assumed executive functions on projects, constructions and exploitation of water uses.

- Mineral water, thermal water and groundwater

  At present, all the Autonomous Communities have exclusive competence on mineral and thermal water.

  As regards groundwater, the following Autonomous Communities have assumed exclusive competence: the Basque Country, Catalonia, Galicia, Andalusia, Valencian Community, Navarre, Murcia, Aragón, Castile-La Mancha, Extremadura and Madrid.

  Nevertheless, in all the texts that amend Statutes which are pending approval in parliament, except those of the Balearic Islands (that is, in Asturias, Cantabria, La Rioja, Extremadura and Castile and León), such competence is also included.

  The Statutes of Andalusia, Murcia, Castile-La Mancha and Madrid, in addition to the texts pending parliamentary approval of the Statutes of Cantabria and Extremadura, include a territoriality clause reagarding groundwater when it runs wholly through the territorial area of the Autonomous Community.

  The Statute of the Canaries refers to water, of all types, including this concept, whether mineral water or thermal water or groundwater.

  This complex jurisdictional mesh has been clarified by the Water Act, especially after its constitutional judgement through CONSTITUTIONAL COURT SENTENCE 227/88, which contains fundamental determinations for delimiting state and autonomous competence in the matter of water:

- Only the State may, by law, transfer of inland water to public property, as a category of natural assets. In legal basis 14 of Sentence 227/88, the Court passed judgement on the relationship between the ownership of public property ans competence in matters of water:

In article 149.1.22 of the Constitution there is no express implication that the legislator may include in the public domain only those waters that run through more than one Autonomous Community, and neither does this provision lay down, nor does any other provision of the Constitution or the Statutes of Autonomy lay down that the Autonomous Communities have competence over public property or, where relevant, to act as owners of the inland water that runs wholly through their territory (...) neither is it evident that the jurisdiction on public property and the ownership of public domain assets constitutes an implicit or inherent extension of the competence that the Autonomous Communities have assumed on water uses (...) Quite the contrary (...) on the basis of the text of the Constitution and the Statutes of Autonomy, the regulations that distribute powers between the State and the Autonomous Communities regarding public domain assets do not necessarily prejudge that their ownership corresponds to one or another (...) in principle, the public property of an asset and the exercise of public powers that use it as a natural support are, in principle, separable.

The Constitution has accordingly provided that some kinds of assets which by doctrine have been defined as belonging to the "natural" public domain form part of the State public domain. Nevertheless, with flexible criteria, the intention has not been to exhaust the list of types of assets which, by virtue of their natural characteristics, may be included in the state public domain (...) though there has been an intention to explicitly reserve for the Law, and precisely State Law, jurisdiction to complete this list.

...it is the exclusive competence of the state legislator to generically exclude inland water from the traffic of private law, considered a as a unitary type of natural asset or natural resource, and to integrate it within the public domain of the State.

- The criteria used by the Water Act for delimiting competence, based on the concept of basin, is in accordance with the Constitution:

  The criterion of hydrographic basin as a management unit allows a balanced administration of the water resources that make it up, attending to the series of affected interests which, when the basin covers a territory of more than one Autonomous Community, are clearly super-community (...) It is also clear that the water of one basin forms an integral whole that must be managed homogeneously (...) In order to delimit the exclusive powers of the State, the constitutional regulation allows us to refer to the integrated whole of a basin's water which, through main and subaltern currents, surpass the borders of an Autonomous Community's territory (LB 15).

- As regards groundwater, the Court also applies the criterion of hydrographic basin: it is not possible to ignore that renewable groundwater has a direct relationship of reciprocal connection or communication with surface water courses, and that, in the case of the so-called phreatic water or in that of some currents that disappear from the surface in some sections, form an inseparable part of these same courses. As a consequence, such groundwater flow, insofar as it converges in the channel network of a hydrographic basin,(...) belongs to the said basin and thus form a part, through it, of the hydrological cycle.(LB 16).

- From there, the distinction between inter-community basins and intra-community basins is created, the latter being autonomous competence if their Statutes have so assumed -,which comprises the faculty of legislating on use of public water in intra-community basins, with the only exceptions that arise from other State powers, such as those referring to basic legislation on administrative contracts and allocations and on the environment or to the bases of the mining and energy regime (articles 149.1.18, 23 and 25 of the Constitution), among others. With these exceptions, it is in order to state that, in these Autonomous Communities and in relation to intra-community basins, State legislation on the exploitation of public water can only be supplemental to the legislation of the said Communities. By contrast, in the remainder of cases, the State may regulate the use and exploitation of inland water, provided there is safeguarding of the powers assumed by the Autonomous Communities regarding projects, construction and use of hydraulic exploitations, canals and irrigated land of interest to them, in addition to the others they may have regarding associated matters, when priority must be given to other competence rights (LB 23). A particular case is that of the South Hydrographic Confederation, an administration under the Environment Ministry, and whose hydrographic basins lie wholly within the area of the Community of Andalusia, with the peculiarity of the Canales ravine, excluded from its territorial area by Royal Decree 650/1987.

- As regards the scope of the concepts of water resources and uses, the Constitutional Court stipulates that if the State has assumed the ownership of public inland water, it is logical that they should also be responsible for protecting the public water domain, in order to ensure the integrity of that ownership over all the assets that it comprises, in implementation and development of the principles laid down by article 132 of the Constitution (LB 18). This criterion is therefore applicable to both inter-community and intra-community basins.

  In the latter of these, the Autonomous Communities, by virtue of their competence on uses, are responsible for everything to do with the regime on water use, including policing the public domain.

Subsequently, Constitutional Court Sentence 161/96 has outlined the question further, confirming the principle of unitary management of water administration by hydrographic basins, and highlighting the participation of the Autonomous Communities in this:

the most direct way for the Autonomous Community to influence interests affected by the administration of water in basins that (...) spread outside their territory, is by taking part on in the governing bodies of the Hydrographic Confederations, in the terms laid down by state legislation (...), always respecting the constitutional framework, which includes the principle of collaboration between the State and the Autonomous Communities as an essential principle (...) The actions that each of the Autonomous Administrations may directly carry out on the water of hydrographic basins that runs through several Autonomous Communities is no more than a complement to what they implement participating in the administration and management of the Hydrographic Confederation itself and are only feasible insofar as they do not disturb nor interfere in its activity.

The organisation arising from the distribution of competence has been the subject of study and criticism by doctrine, not always with a favourable evaluation (see, e.g., Martín-Retortillo [1992]; Moreu Ballonga [1990]).

Furthermore, it should be noted that articles 137 and 140 stipulate constitutional guarantee of local autonomy, which, although without specifically referring to water, alludes to the necessary respect granted constitutionally to the core of local interests, which include some aspects associated with this resource.

2.4.2.1.2. The distribution of other competencies

The description of specific criteria governing the distribution of powers on water issues –in which the concept of hydrographic basin is decisive, as has been shown–, would be incomplete without mentioning that, at the same time, water also represents the physical foundation of plural, activities in which both the State and the Autonomous Communities have sectoral powers. That powers of different Public Administrations concur in the same physical space with different legal purpose is a common phenomenon in different fields and is also reflected the Sentence of the Constitutional Court 227/1988, which in its judgement 14 states that: ...the regulations that distribute powers between the State and the Autonomous Communities on public domain assets do not necessarily prejudge that their ownership corresponds to one or the other, and that, in principle, public ownership of a property and exercising the public powers that use it as a natural support are separable.

The organisation of this concurrence, in inland water, is seen by the Constitutional Court thus:

"The projection upon one same physical medium or natural resource of different powers in favour of the State or the Autonomous Communities calls for collaboration between both Administrations; a collaboration that «is essential for the correct functioning of the State of Autonomies» (...) Furthermore, this cross-over of powers obliges, as said, coordination between the Administrations involved, also according to that Sentence; a coordination that corresponds to the State insofar as economic planning objectives are affected. This established, it is appropriate to state additionally that neither competence on planning matters nor competence on planning bases authorise the State to include within its scope of activity any of the Autonomous Communities' powers merely due to the fact that its implementation could affect the development of state powers on certain matters. Coordination does not mean "a withdrawal or impairment of the powers of the agencies subject to it: rather, it logically presupposes the granting of competence to the agency coordinated" (Constitutional Court Sentence 27/1987, of the 27th of February); so it may not be used as an instrument to assume autonomous powers, not even with respect to a part of the subject they affect.

The coordination of basin management plans which corresponds to the State Administration or its dependent agencies to organise with the different plans that affect them must be mainly carried out through the procedure of their preparation, as laid down in section 38.4 of the Water Act; for which purpose, it is necessary for the Autonomous Communities participation as the Act regulates. However, notwithstanding this participation, the State Administration cannot unilaterally make the basin management plans lay down any binding limitations for urban planning or other public actions of autonomous competence by virtue of a general authority over coordination, but only insofar as it has a specific competence granted in this respect (judgement 20.e).

In this framework, below we summarise the distribution system for those matters that show clearer influence on the system of managing inland water.

2.4.2.1.2.1. Environment and wastewater

In accordance with the terms of articles 148.1.9 and 149.1.23 of the Constitution and by the Statutes of Autonomy, the State is responsible for laying down basic legislation on environmental protection, and the Autonomous Communities have competence for legislative development and implementation, together with the faculty of laying down additional protection regulations.

Constitutional Court Sentence 227/88 particularly deals with this area in Legal Basis 25 to 27, of which it is appropriate to highlight the following pronouncements:

- The Act is limited, in general terms, to laying down some fundamental principles, in order to guarantee the quality of inland water and its environment, without impairing the competence of Autonomous Communities to develop or complement those general regulations and to implement them in the scope of their administrative powers on the public water domain. These principles fit in easily with basic legislation on environmental protection, which the State is responsible for passing according to article 149.1.23. of the Constitution, so sections 85, 89. d) and 91 cannot be deemed unconstitutional
- Within this series of protective measures on water quality, one that stands out is the faculty conferred on the government by section 88.1 of establishing a protection area

around the beds of lakes, reservoirs and lagoons, where land uses and activities carried out will be conditioned. This is a competence of implementation that is not supported by article 149.1.23 of the Constitution, nor by article 149.1.22, when referring to water that runs wholly through an Autonomous Community. Consequently this conferral may not correspond to the government in relation to intra-community water or water beds. Furthermore, when it is exercised with respect to lakes, lagoons or reservoirs in inter-community basins, the governmental decision may influence the exercise of autonomous powers on territorial organisation. State competence on organisation of water resources and uses in this water does not justify such an intervention in the Autonomous Communities' scope of competence, especially in view of the lack of definition which, as regards the conditioning of land use and activities on those areas, arises from section 88.1.

- It has already been mentioned that section 6 of the Water Act is not unconstitutional, subjecting the borders of public channels to a policing area of 100 metres, since it may be considered as a general environmental protection regulation. Section 88.3 extends this policing area to the borders of lakes, lagoons and reservoirs, and may be similarly classified. It has also been said that, with respect to these areas, basin management plans may also lay down basic environmental protection regulation. Nevertheless, additionally conferring the government with the vaguely defined jurisdiction granted to it by section 88.1 involves a transgression of competence, in detriment to the authority that all Autonomous Communities have assumed on territorial organisation and environmental management.

The regulation of wastewater may be similarly considered, where we may see a cross-over of powers regarding environmental protection and water:

- Chapter two of the V Heading (sections 92 to 100) includes certain regulations on wastewater in inland water that affect the policing of the public domain, but have the character of basic environmental protection regulations, whose legitimacy arises from the terms of article 149.1.23 of the Constitution. Nevertheless, some of the disputed provisions confer powers of implementation. Those that grant such powers to basin organisations (sections 96 and 99) are not unconstitutional, since they are understood to be granted to the water administrations of Autonomous Communities with general competence on water use with respect to water that runs wholly through their territory (fourth additional provision of the Act). Alternatively, the powers of implementation conferred on the government (sections 95, second paragraph, 96 in fine and 98) correspond to those Autonomous Communities with respect to intra-community water, and may only be exercised by the State, as expressly laid down by section 98, when they may be considered as included within the scope of executive state powers, in accordance with the provisions of article 149.1.22 of the Constitution.

2.4.2.1.2.2. Agriculture

In the framework of article 148.1.7 of the Constitution, the Autonomous Communities have assumed excusive competence on agricultural matters, in accordance with the general regulation of the economy.

Directly associated with the competence assumed by the Autonomous Communities regarding irrigated land of autonomous interest, they are responsible for programming and implementing hydraulic works for transformation into irrigated land in intra-community basins, although there is scope for state intervention when the work is classified as of general interest (article 149.1.24 of the Constitution), since this competence, as noted by the Constitutional Court Sentence 227/88, is not based on territorial criteria.

If it is an issue of inter-community basins, autonomous projects will be included in basin management plans which must be approved by the government (sections 38.5 and 39.1 of the Water Act). In this case, the State is responsible for approving work that is indispensable or additional to exercising powers on the protection and use of water resources they are responsible for regulating, that is, hydraulic work necessary to prepare new territory as irrigated land, or to grant new concessions for irrigation. Thus, among the mandatory determinations to be included in the basin management plans, section 40 f) of the Water Act includes basic regulations on improvements and transformation into irrigated land, which Constitutional Court Sentence 227/88 justifies because as a basic provision it lies within basic state competence on the bases and coordination of economic planning, provided that the regulations referring to the legal provision are strictly oriented towards an improved or more rational use of inland water, as an essential economic resource, and are not extended to other provisions on agricultural policy.

With the value granted to them by constitutional jurisprudence, we should mention the Royal Decrees on concessions regarding supply, drainage, channelling, defence of borders and irrigation, by which the Autonomous Communities are allocated functions on programming, approval and processing, up to the payment of certifications, of investments in work of interest in irrigation matters, adding that they may have studies carried out, projects drawn up and work implemented by the Hydrographic Confederations, and specifying that irrigated land must comply with the basic regulations on adopting irrigation systems and production guidelines that must be encouraged within the framework of general irrigation planning, general economic organisation and the regulation of the national economy's basic resources.

2.4.2.1.2.3. River fishing

In accordance with the provisions of article 148.1.11 of the Constitution, the Autonomous Communities have assumed exclusive competence on river fishing. Since it is an exclusive competence on an activity necessarily carried out on the river basins themselves, the complex integration of two competence holders, it has been studied by the Constitutional Court, among others in Constitutional Court Sentence 15/98, legal basis 3 and 4, stipulates the general approach for dealing with such concurrence as follows:

- The overlap and occasional collision between these rights of competence arises from their referring to one same area or physical reality: that consisting of super-community river basins. In these, there lives fish fauna subject to fishing, and upon them the basin organisations exercise their competence, in accordance with the terms of the Water Act (...) conferring a competence on a certain physical area does not necessarily mean that other powers can be exercised upon that same area, provided that both have a different legal object, and that the exercise of autonomous powers does not interfere with or impair the exercise of state powers, so it is often essential to lay down collaboration mechanisms allowing the necessary coordination and cooperation between the Public Administrations involved (...). In short, the concurrence of powers cannot be resolved in terms of exclusion but must be referred to a register of alignment and integration of state-autonomous rights of competence that converge upon the same area and which, as a result, are required to act in coordination.
- The doctrine laid down by Constitutional Court Sentences 243/93 and 161/96 adds that the only way to guarantee autonomous competence is exercised on river fishing and the ecosystems where it is carried out lies in autonomous intervention in the procedure of granting hydroelectric use rights preceding the act of granting (...) in order to ensure that water uses do not endanger fish life and the ecosystems where they exist.
- The importance of collaboration formulas such as those described above must be especially emphasised here, since, in many cases, only by means of joint, coordinated action –whether through procedural intervention formulas, or through sectoral policy integration instruments, such as conceptual planning– will it be possible to exercise autonomous competence on river fishing without impairing the concurrent powers of the State and the principle of unity in water regulation and management in the area of the basin.

2.4.2.1.2.4. Sport and leisure

By virtue of the terms of article 148.1.19 of the Constitution, which enables powers to be assumed on the promotion of sport and the appropriate utilisation of leisure, all the Autonomous Communities have assumed exclusive competence on this matter.

As regards sports, activities that would be considered in association with water resources refer to sports activities that can be carried out on rivers, reservoirs, etc.

In the same way, sports facilities or facilities for practising sports on water bodies would be associated with competence on water resources.

2.4.2.1.2.5. Energy

Article 149.1.22 of the Constitution reserves exclusive competence for the State regarding authorisation of electrical facilities when their utilisation affects another Autonomous Community or the transportation of energy leaves their territorial area, and article 149.1.25, the basis of the mining and energy regime.

In their Statutes, the Autonomous Communities have assumed:

- Exclusive competence on energy production, distribution and transportation facilities when utilisation does not affect another Autonomous Community or transportation does not leave its territory.
- Competence on legislative development and implementation on energy matters.

In both areas there are references to energy, within which hydroelectric energy would be included. The practical transfer of the constitutional precept on exclusive State competence represents the two determining factors in this competence: the limit of 50 MW (special treatment according to the new Electricity Sector Act), and that the generation station is located in one single Autonomous Community. Hydroelectric energy production facilities would be associated with powers on water when they did not affect another Autonomous Community, which would lie within the scope of autonomous competence.

2.4.2.1.2.6. Civil Protection

Within the scope of civil protection, the State Administration, the Autonomous Communities and Local Corporations intervene in relation with their respective territorial areas. The State and the Autonomous Communities exercise their respective powers on this matter, within the framework laid down by Act 2/1985, of the 21st of January, on Civil Protection and from the interpretation in constitutional jurisprudence (Constitutional Court Sentences 123/84 and 133/90).

The regulation of actions that must be carried out is structured via the corresponding plans.

The preparation of these plans is carried out in the framework of the essential guidelines laid down by Basic Civil Protection Regulations.

As regards water resources, it should be taken into consideration that the contents of Basin Plans must comprise the criteria on studies, actions and works to prevent and avoid damage from flooding, spate and other water-related phenomena.

The measures that the Basin Plan may lay down and contain require action that must take into account state and autonomous competence on civil protection, and even the amendments to take into account hypotheses where damage or catastrophe take place, with the interventions by the respective Administrations.

This is confirmed by Constitutional Court Sentence 227/88: the mandatory inclusion in water plans of criteria on studies, action and works to prevent and avoid damage due to flooding spate and other water-related phenomena, may be extended to questions of civil protection , and in this sense, if such criteria are understood to be simply general guidelines on coordination and do not involve provisions on specific actions and works, they cannot be deemed to invade autonomous powers, since they represent general competence on public safety reserved for the State by article 149.1.29 of the Constitution, in accordance with what has already been stated by Constitutional Court Sentence 123/1984, of the 18^{th} of December.

2.4.2.1.2.7. Health

The Constitution attributes the State with competence on bases and general coordination of health (section 149.1.16), insofar as, under article 148.1.21, regarding Health and Hygiene, and the Statutes of Autonomy, the Autonomous Communities in general have assumed exclusive competence on health and hygiene.

The different areas that may be associated with competence on questions of water resources would be:

- Water quality from the scope of health conditions.
- Conditions of water salubrity.
- Wastewater discharge and health conditions.

In this case it should be taken into account that from the scope of competence on public health, it is the Autonomous Communities that hold competence of these questions.

With respect to this, Constitutional Court Sentence 208/91 should be noted, on quality testing of drinking water:

- ...the tests in question are clearly oriented for human health (...) which leads to extending this essentially executive activity (application of criteria prior to specific cases of surface water sampling) to competence regarding health protection. (...) This means that quality tests on surface water samples (...) shall be the competence of Autonomous Community authorities, regardless of the fact that such surface sampling corresponds to hydrographic basins situated on Community territory, or hydrographic basins that lie in several Autonomous Communities (Legal Basis 6).

2.4.2.1.3. The basic mandate of public authorities

A highly relevant constitutional reference, and which deserves a specific mention, is that of article 45.2, laying down that the public authorities shall safeguard the rational use of all natural resources, in order to protect and improve the quality of life and defend and restore the environment, supported by the necessary collective solidarity.

As applicable here, the constitutional mandate to the public authorities is therefore that of rational water use, which, together with the precept of article 128.1, by which all the country's wealth in its various forms, whoever is the owner, is subordinate to the general interest, creates a major conceptual duality (rational use of resources and subordination to general interest), in the light of which, and balanced by which, the question of water use must be considered in relation with the environment.

In fact, as these precepts have been interpreted (see Constitutional Court Sentence 64/1982) and as shown by Pérez Pérez (1997), article 128.1 means that economic resources that the State deems to be of general interest cannot be extracted from the country, producing other objectives like environmental protection. Therefore, such protection is not –as sometimes claimed– a maximum, absolute value, which any other public action must submit to, but rather must be considered and balanced by the mandate of rational use of all resources (both public and private domain), harmonising environmental protection with the exploitation of economic resources.

It is important to remember these basic, general precepts when discussing, also often in general terms, environmental limitations, the compatibility of development with conservation or the priorities of water use.

2.4.2.2. Basic autonomous regulation

In this section we consider the different Statutes of Autonomy, Organic Act 9/1992 and the Transfer Decrees.

2.4.2.2.1. Statutes of Autonomy

A study of the different Statutes of Autonomy of the Autonomous Communities reveals a lack of a general conceptual model to distribute powers on water and its related issues, conceived to apply the general constitutional precepts mentioned above. The accumulation of nuances and peculiarities is such that not only is this general model not perceived, but it has given rise to an extensive proliferation of regulations, whose legal logic and overall effectiveness to satisfactorily regulate water has caused serious doubt.

It is curious that the first Statutes (corresponding to the three historical territories, which had a potentially higher limit of powers) had almost identical contents, in line with article 148.1.10 of the Constitution, in comparison with which the inclusion of groundwater (together with mineral and thermal water) is noteworthy among the matters of exclusive competence. It may thus be thought that the intermediate area of issues between 148 and 149 (and which may be assumed from the first moment by the special regime Communities, but not by those of common regime) consisted precisely of groundwater. In any event, it is worth noticing the separation between groundwater and surface water, and the complete conferral of groundwater to autonomous competence, which may lead to holding that the Communities have competence on water resources, since at least groundwater would be allocated to them. Subsequent sentences of the Constitutional Court have maintained that this competence would be limited to non-circulating groundwater, which, in any event, and notwithstanding its legal validity, does not seem to be a logical or technically satisfying solution.

A detailed study of the statutory precepts will show the existing differences more precisely, and which, although often are merely nominal and not as significant as may at first appear, justify the above statement in the sense that the Statutes have not helped to clarify the problems of defining powers on water-related issues. Thus, and even at the risk of the description being excessively prolix in a text like this, or omitting some subsequent modification, it is worth listing and numbering the following statutory powers.

1. Competence on questions of water utilisation when the water runs wholly through the territory of the Autonomous Community:

   1.1. Communities that have assumed exclusive competence:

   - Galicia (section 27.12. S.A.).
   - Asturias (section 10.7 S.A.).
   - Andalusia (section 13.12 S.A.).
   - Valencia Community (section 31.16 S.A. and Organic Act 12/1982, of the 10th of August, on transfers of state-held powers to the Valencia Community).
   - Basque Country ((section 10.11 S.A.).
   - Catalonia (section 9.16.S.A.).
   - Navarre (section 44.5.LORAFNA).
   - Canaries (section 29.6 and 34.a.2 S.A.; Organic Act 11/1982, of the 10th of August, on complementariy transfers for the Canaries).

with the following noteworthy peculiarities:

a) The Andalusian Statute includes, together with the concept of utilisation, that of resources, also regarding intracommunity water.

b) Competence is conferred notwithstanding the provisions of article 149.1.25 of the Constitution (Basque Country, Catalonia and Valencia Community) or article 149.1.22 of the Constitution (Galicia).

c) On the same day the Canaries' Statute of Autonomy was passed, the above-mentioned Organic Act 11/1982 on complementary transfers was also passed, with the result that, on water-related issues, the question of constitutionality in the Canaries is made up of the indivisible union of both regulations. Section 1 of this Organic Act transferred legislative authority to the Canaries Autonomous Community on water-related issues that are not constitutionally reserved for the State, and a number of sentences (Constitutional Court Sentence 227/1988, Constitutional Court Sentence 17/1990) have confirmed the constitutionality of this transfer. A result of this peculiar regulatory capacity is the water legislation specific to the Canaries, which we will refer to in due course.

   1.2. Autonomous Communities with deferred competence:

   - Cantabria ((section 25.1.b.S.A.)
   - Region of Murcia ((section 13.1.e.S.A)
   - Castile-León ((section 29.1.6.S.A)

   The statutory wording differs in these texts. While the Statutes of Cantabria and Castile-León include the regulation and allocation of water utilisation on those fluvial courses than run wholly though the Autonomous Community, the Statute of Murcia stipulates the regulation of traditional water utilisation with respect for habits and customs that are typical to the region.

2. Competence on projects, construction and exploitation of water uses, canals and irrigated land of interest to the Autonomous Community.

   Exclusive competence on this subject has been assumed by the Autonomous Communities which gained autonomy through article 143 of the Constitution:

   - Principate of Asturias (section 10.1.g.S.A.).
   - Cantabria (section 22.8 S.A.).
   - La Rioja (section 8.1.4 S.A.).
   - Region of Murcia (section 10.1.g.S.A.).
   - Aragón (section 35.1.11 S.A.).
   - Castile-La Mancha (section 31.1.g.S.A.).
   - Extremadura (section 7.1.7 S.A.).
   - Balearic Islands (section 10.6 S.A.).
   - Community of Madrid (section 26.8 S.A.)
   - Castile and León (section 26.1.7 S.A.)

   As regards content, it may be noted that:

a) The Statutes of Aragón, Extremadura and the Balearic Islands contain a broader formula than other statutory texts, by conferring regulation of water uses (Aragón and Extremadura) or the water regime and water uses (Balearic Islands).

b) All of them except those of Aragón, Castile-La Mancha, Balearic Islands and the Community of Madrid, include, together with the criterion of interest, the question of territory as a limit of exercising autonomous competence, with formulas such as when the entire water channel lies inside the territory of the Autonomous Community or when the water runs wholly though the territory of the Autonomous Community.

3. Competence on groundwater.

   3.1. Autonomous Communities with exclusive competence:

   - Basque Country (section 10.11 S.A.).
   - Catalonia (section 9.16 S.A.).
   - Galicia (section 27.14 S.A.).
   - Andalusia (section 13.12 S.A.).
   - Valencia Community (section 31.16 S.A.).
   - Aragón (section 35.1.11 S.A.).
   - Canaries (section 34.a.2 S.A. and Organic Act 11/1982, of the 10th of August, on complementary transfers)
   - Navarre (section 44.6 LORAFNA).
   - Extremadura (section 7.1.7 S.A.).

   The Statutes of the Basque Country, Catalonia, Valencia Community and Navarre stipulate article 149.1.25 of the Constitution as the limit of autonomous competence (basic State legislation on mining and energy regime), while the Statute of Galicia assumes it, as mentioned, without prejudice to the provisions of article 149.1.22 of the Constitution.

   3.2. Autonomous Communities with deferred competence:

   - Cantabria (section 25.1.a S.A.).
   - Region of Murcia (section 13.1.j.S.A.).
   - Castile-La Mancha (section 35.1.a.S.A.).
   - Castile and León (section 29.1.7 S.A.).

2.4.2.2.2. Organic Act 9/1992

Organic Act 9/1992, of the 23rd of December, regulates the transfer of Powers to the Autonomous Communities that gained autonomy through article 143 of the Constitution.

This Act gives substantially similar treatment to the powers of the Autonomous Communities in article 143 as to those whose Statutes have been drawn up in accordance with the provisions of article 151 of the Constitution, since its section 2 confers the Autonomous Communities of Asturias, Cantabria, La Rioja, Region of Murcia, Aragón, Castile-La Mancha, Extremadura, Balearic Islands, Madrid and Castile-León exclusive competence on regulation and allocation of water resources and uses when the water runs wholly through the territorial area of the Autonomous Community.

Note that the generalised application of this principle would give rise to all the coastal Autonomous Communities assuming exclusive competence on the water-related issues of small coastal channels comprised wholly within their territory, which, notwithstanding its constitutionality, would contribute to increasing the current dispersion, would further complicate the territorial mosaic, and would hamper –if not make practically impossible– the objective of integral and unitary management of water resources.

2.4.2.2.3. Transfer decrees

The service transfer decrees passed so far have been limited to recognising the certain powers of the Autonomous Communities regarding works (specifically, in supply, drainage, channelling and defence of banks), though none on resources, from which it may be inferred that article 148.1.10 is understood to refer only to works. Nevertheless, this argument is not at all decisive, since the reiterated doctrine of the Constitutional Court on the legal value of service transfer decrees, which do not confer powers but merely define the results of the delimitation already made by the Constitution and the Statutes.

2.4.2.3. Water legislation

Once the diversity and complexity of the basic regulation of powers has been briefly examined, this section will refer specifically to both the State Water Act and the Canaries Act, and the various sectoral provisions passed by the Autonomous Communities.

2.4.2.3.1. The Water Act of 1985

Act 29/1985, of the 2nd of August, on Water, is the basic state text regulating the subject. We will summarise its structure and basic principles.

The preamble to the Act –which is simply its declaration of intentions– lays down concepts and defines the economic, social and legal bases that inspire it. Particularly noteworthy among these:

Water is a scarce natural resource, essential for life and for carrying out the immense majority of economic activities; it cannot be replaced, nor increased merely by human will, it is irregular in the way it appears in time and space, considerably vulnerable and may be used repeatedly...

...This availability must be achieved without deteriorating the environment in general, and the resource in particular, minimising socio-economic costs and with an equitable allocation of duties generated by the process, requiring prior water planning and the existence of appropriate institutions for the resource's effective administration in the new State of Autonomies...

...All the particular characteristics, unquestioned from a scientific point of view and included in the doctrine of international organisations and agencies, involve the need for legal instruments to regulate, with the necessary institutions modernised, on the basis of the essential water planning and recognition, for the resource, of one single legal classification, as an asset of the state public domain, in order to guarantee its unitary treatment in all cases, whatever its immediate origin, surface or subterranean.

...New legislation is therefore necessary on the subject, that makes maximum use of the unquestionably appropriate measures in preceding legislation... but which takes into account the indicated transformations, and particularly the new autonomous organisation of the State, for which the exercise of the different Administrations' jurisdiction takes place within the required framework of collaboration, achieving rational use and appropriate protection of the resource.

All such basis or objects of the law are developed in its articles. Thus, the preliminary heading mainly states the object of the law as the regulation of the public water domain, the use of water and the exercise of powers conferred on the State on matters associated with the said domain within the framework of powers defined in article 149 of the Constitution (section 1.1).

It also resolves the problem of the public domain of surface water and groundwater by stating that continental surface water, and renewable groundwater, all forming part of the hydrological cycle, represent a unitary resource, subordinated to the general interest, that forms part of the state public domain as public water domain (section 1.2).

Heading I of the Act defines the elements that make up the public domain of the State, and includes groundwater. In previous legal regulation (Water Act of 1879) private water (mostly groundwater) could co-exist with public water. Since the Water Act came into force in 1985, all water has been considered public, with the exceptions laid down in the Transitory Provisions, oriented towards preserving rights and legal situations prior to the Act coming into force.

Heading II, on mentioning the general principles that should govern the public administration if water, lays down the functions that correspond to the State: water planning in all cases, and the implementation of water infrastructures that form part of it (section 3 and 15.a); adopting the measures necessary to comply with the international agreements and conventions on water-related issues.(section 15.b); granting allocations in inter-community basins (section 15.c); safeguarding the public water domain (section 15.d) and, finally, granting authorisations in the same basins, notwithstanding the fact that these may be processed by the Autonomous Communities (section 15.d).

The exercise of these functions is governed by the following principles (section 13): unity of management, integral treatment, water economy, deconcentration, decentralisation, coordination, effectiveness, and the participation of users; respect for the hydrographic basin unit, of water systems and the hydrological cycle; compatibility of public water management with territorial regulation, environmental conservation and protection, and the restoration of wildlife.

The Act only regulates State powers, and states that in hydrographic basins that surpass the territorial areas of an Autonomous Community, basin organisations will be set up with the functions and duties regulated by this Act (section 19). These organisations are named Hydrographic Confederations and are authorities established under public law with legal personality different from that of the State, depending for administrative purposes on the Public Works and Town Planning Ministry (now the Environment Ministry) with full functional autonomy (section 20.1). Recognising the unity of the hydrological cycle, the State is conferred authority over surface water and renewable groundwater. The State is entrusted with planning for this resource, though these functions are decentralised to the Confederations. This Heading defines two major elements in the new organisation of Public Water Administration: the above-mentioned Hydrographic Confederations and the national Water Council. It should be noted that the new Hydrographic Confederations are in a certain sense successors of the autonomous organisations previous to 1959 (before the separation of functions and the creation of Water Commissions) in which, also called Confederations, similar functions were carried out, with the significant exception of the new figure of President, with authority to implement decision by executive action. We shall return further ahead to this organisation, on examining the basin organisations and the Water Administration.

Heading III deals with water planning, which we will refer to extensively in other sections of this White Paper, and which here we simply mention that it represents one of the most important innovations introduced by the 1985 Act, still pending to be fully developed and put into practice.

Heading IV deals with the utilisation of the public water domain, and particularly in its chapter II, common and private uses, stipulating the rights of common use of surface water without altering water flow and quality (section 48.1 and 2), and private uses of this resource are regulated.

A basic foundation for designing water policy is, unquestionably, this legal regime on private use, and especially concessions. According to section 57.1, and provided that its use is not included in section 52 (pluvial water on an estate or groundwater up to 7,000 m^3/year), all private use of water requires an administrative concession, eliminating lapse of time –admitted by previous legislation– as a possible way of acquiring this right.

The 1985 legislator provided for use of concessions as an economic instrument in prioritising and rationalising the use of the resource, in keeping with the legislative tradition, considering that in no way does it represent a fixed subjective right. Thus, section 57.2 states that concessions are granted taking into account the rational joint exploitation of surface water and groundwater, without the concession authorisation guaranteeing the availability of the flow granted.

Furthermore, a clear correspondence is established between concessions and water planning, since section 57.4 states that all concessions shall be granted in accordance with the provisions of the Water Plans, temporarily and with a term no greater than sixty-five years. They will be granted discretionally, though all decisions will be considered and taken according to public interest. Section 58.1 also gives priority to planning, stating that... concessions will comply, in order to be granted, with the order of preference laid down in the management plan of the corresponding basin, taking into account the protection and conservation requirements of the resource and its environment. Furthermore, it states that the procedure for granting concessions must respect the principle of competition, since it expressly mentions that the ordinary procedure for granting concessions shall comply with the principles of publicity and processing in competition, with preference, in equal conditions, for those that plan the most rational use of water with best environmental protection. The principle of competition may be eliminated when dealing with water supply to populations.

The regime for use of the public water domain may be classified, in short, as a continuation of the one defined by the previous Water Act of 1879. From that Act, it basically respects the fundamental principles whose origins date back to the early 19th century, as shall be seen when examining the historical background and current situation of water concessions.

Heading V highlights this Act's preoccupation with water quality, including most of the diverse regulations on this matter, and which were not included in the 1879 Act. It especially regulates the regime on wastewater and lays the basis for reuse of treated water.

Heading VI regulates the economic-financial regime of the public water domain. This regulation, practically taken from previous provisions, maintains that water is basically free, and stipulates that the collection of tariffs, irrigation duties and, where relevant, corresponding rates, must be carried out by the new Confederations, incorporating the collected amount into their budget, as with tariffs for discharge and for occupation of the Public Water Domain. A certain innovation in the in the spirit of the new regulation is the idea of recovering public investment through fees and tariffs, aiming to eliminate public subsidies to beneficiaries of hydraulic works.

Heading VII regulates the regime of default and penalties, and the jurisdiction of the Courts on this matter, basically stating what has been established previously.

Finally, it should be noted that the transitory and additional provisions aim to provide solutions to the problems that regulation change involves, especially the complex and much-discussed issue of the regime of water that was under private ownership when the Act came into force.

2.4.2.3.2. The Canaries Water Act of 1990

The singularity of the Canary Islands regarding water rights has, as may be expected, a deeply-rooted historical background. In fact, when they joined the crown of Castile, the system of land and water distribution on the islands consisted of a hand-over –which was verified in favour of colonisers– of land and water. Water was initially distributed with the land, though subsequently, as water grew increasingly important due to growing scarcity, the distribution of water frequently included the stipulation... with the land that may be irrigated with it, finally ending up in a total separation of land and water, which persists today. In this they are unlike the rest of the State's s islands, where these old separation regimes, having existed in several places, were eliminated many years ago.

Its hydrological particularity and its legislative capacity, therefore, already mentioned when referring to the Statutes of Autonomy, have given the Canaries a specific legal regime on water issues. The Act 12/1990 in force, of the 26th of July (Official State Journal 18th of September), revokes the previous Act 10/1987, also on water, and which, continuing a regulation regime that began particularly in the 1950s, underwent a number of incidents during its processing stage and was the subject of intense political and legal controversy (see e.g. Pérez Pérez, 1998).

At present, and after the Canaries Act came into force, there exists a somewhat complex system by which the order of priority of regulations governing water on the islands is as follows:

1. The precepts of the State Water Act that are applicable by defining the state public domain or involve an amendment or revocation of the provisions of the Civil Code.
2. Act 12/1990 on water in the Canaries, and the regulations that develop it.
3. State legislation on water, consisting of:
   a) The State Water Act and the precepts of the Civil Code under which this Water Act is established, provided that they are not amended or revoked by it.
   b) The regulations of the State Water Act.
   c) The Civil Code.

The specific Act 12/1990 has the purpose of regulating terrestrial surface water or groundwater, whatever its origin, natural or industrial, on the Canary Islands, and to exercise the powers of the Autonomous Community on matters relating to the public water domain. It also regulates Water Planning, with specific figures in the scope of the Autonomous Community of the Canary Islands (Heading III, sections 29-49), and confers responsibility on the Government or Parliament of the Canaries to approve Water Plans.

The Government of the Canaries has competence on the preparation of the Canaries Water Plan, and the definitive approval of Island Water Plans, different to those laid down by the State Act.

Furthermore, the Act states that the Autonomous Community of the Canaries is responsible for organisation and regulation of its existing water resources in order to protect them, both in terms of quality and in terms of its present and future availability.

2.4.2.3.3. Provisions on the water of Autonomous Communities

The diversity of provisions on water laid down by the Autonomous Communities is quite considerable. By way of example, some significant ones are mentioned below, promulgated around the same time as the Water Act, giving an idea of this diversity.

1. Catalonia:
   - Act 5//81 of the 4th of June on legislative development on the evacuation and treatment of wastewater. It confers collection planning on the Generalitat (in the framework of general environmental protection planning that it approves).
   - Act 17/1987, of the 13th of July, regulating the Water Administration of Catalonia, conferring, among other functions, the preparation of Water Planning on this Administration, in relation to basins comprised entirely within the territory of Catalonia.
   - Legislative Decree 1//1988, of the 28th of January, approving the combination of the precepts of Act 5/1981 and Act 17/1987, into one single text.
   - Act 4/1990, of the 9th of March, on regulation of water supply in the Barcelona area.
   - Act 19/1991, of the 7th of November, reforming the Sanitation Board.
2. Community of Madrid:
   - Act 17/1984, of the 20th of December, regulating water supply and collection in the Community of Madrid. It confers upon the Community:
     a) General planning, drawing up plans for infrastructures and definition of criteria on levels of services given and quality levels that may be required from receiving affluents and channels, in accordance with State and Community Water and Environmental Plans and Territorial and Urban Planning.
     b) Definitive approval of plans and projects referring to these services.
     c) Preparation of plans and projects, in addition to construction and exploitation of work that it directly promotes.
3. Valencia Community:
   - Act 7/86, of the 22nd of December, of the Generalitat of Valencia, on water use for irrigation. The Generalitat is conferred competence on irrigation planning. This competence is exercised without prejudice to that which corresponds to the State on questions of Water Planning.
4. Galicia:
   - Act 8/1993, of the 23rd of June, regulating the Water Administration of Galicia.
5. Aragón:
   - Act 13/1990, of the 21st of December, regarding the representation of the Autonomous Community of Aragón in basin organisations.
6. Navarre:
   - Act 10/1988, of the 29th of December, on the collection of waste water in the Autonomous Community of Navarre.
7. Extremadura:
   - Act 3/1987, of the Autonomous Community of Extremadura, on irrigated land.
8. Cantabria:
   - Act 2/1988, of the 26th of October, on the promotion, regulation and utilisation of spas and mineral-medicinal and/or thermal water in Cantabria.

2.4.2.4. Autonomous and local sectoral regulations

Apart from the provisions mentioned in the above sections, all referring specifically to water, there is a tremendous variety of other autonomous and local sectoral provisions which, both water-specific (supply and waste issues), and non-specific, directly or indirectly bear an influence on its regulation. An example of analysis of local administration functions in water management, from the perspective of integrated management, can be seen in González-Antón (1997).

Here we merely mention this diversity, indicating that, as pointed out, the proliferation of existing regulations has led to problems with jurisdiction, coordination, and regulation interpretation that have not been definitively resolved, and which, in some cases, after some time, may turn out to be impossible to res olve in practice.

2.4.2.5. International regulations

In addition to all the state, autonomous and local regulations mentioned, there also exists a considerable quantity of international provisions, especially from Europe, regarding water, and to a greater or lesser extent associated and interrelated with Spanish regulations.

As may be seen, these regulations basically refer to water quality, and have been, or are being, incorporated into our legislation.

The European Union has recently drawn up a proposal for a Water Framework Directive which has an integrating function, on one hand, since it covers within one single legal figure all the water regulations that were previously dispersed, and on the other hand, a clear innovative spirit, since it proposes derogating obsolete directives and substituting them with others. Political approval for this proposal on the 17th of June, 1998, in the Council of Environment Ministers, and with the consensus of all Member States, represents a landmark in the Union's water policy.

One of the Directive's main objectives is that the Member States achieve the so-called good state of water, which involves not only good physical-chemical state of water, but also ecological. We shall return to all this further ahead, in specific sections.

2.4.3. Institutions and organisations

Among the elements that make up the institutional framework for water use, those referring to administrative organisations responsible for the implementation of water policies are of crucial importance. As has been said, and will be repeated throughout this White Paper, the institutional component is decisive in the field of water, and administrative structures that support it are crucial in that respect.

Of the different organisations involved, we shall refer briefly to two fundamental ones: the basin organisations and the Irrigators' Associations. The former for being the basic administrative authority on the subject, and the latter for being the destination of most of water consumption in our country.

2.4.3.1. Basin Organisations

The basin organisations provided by the Water Act are agencies of the State Administration with powers over this question.

Heirs of a long-standing, exceptional tradition, of over 70 years, their most relevant characteristic, with respect to organisation prior to the new legislation, is integration, within the same organisation, of the Water Commissions and the old Hydrographic Confederations, an integration that was carried out by Royal Decree 1821/1985.

The reasons for this integration are explained in the preamble to this Decree, and focus on the need for united water management, concentrating powers in one single body, and overcoming the problems of competence among the different ministerial departments and organisations on questions such as groundwater (with the well-known corporative, administrative and even legislative conflict that had been taking place since last century), water quality (with interventions by the Water Commissions, Health, Industry, ICONA and the Local Councils), etc.(see, e.g., González Pérez et al. [1987] pp. 705-708). The problems that have given rise to this integration are commented further ahead, when describing Water Administration.

It is important to highlight that the water administration, as it is conceived by the regulation in force, fundamentally concurs with Central and Autonomous administration, and only to the extent that such concurrence is effectively and harmoniously achieved will the legislator's provisions be fulfilled.

There will later be an opportunity to examine if the objectives have been satisfactorily met or not, and to analyse, where relevant, the reasons for this. For the moment, we shall simply summaries this organisational model, which is the context for current water management.

In short, and from this organisational point of view, public water administration is carried out in inter-community basins by the basin organisations, under the name Hydrographic Confederations (sections 19 and 20 Water Act), and in intra-community basins by the Water Administrations of the corresponding Autonomous Communities (section 16 WA).

The functions of these inter-community basin organisations are (section 21 WA) the preparation of the basin management plan, in addition to monitoring and reviewing them; the administration and control of the public water domain; the administration and control of utilisation of general interest or which affects more than one Autonomous Community; the planning, construction and exploitation of work carried out and paid by the organisation's own funds, which may be commissioned by the state and which may arise from the agreements with Autonomous Communities, Local Corporations or other public or private organisations, or signed with private parties.

Basic organisations consist of the following bodies (section 24 WA):

- Governing bodies: the Board of Directors and the President.
- Management bodies, in participation regime, for carrying out the functions specifically conferred to them by the Water Act: the Users' Assembly, the Withdrawal Commission, the Exploitation Boards and the Works Boards.
- Planning body: the basin Water Council.

The territorial scope of the basin organisations was determined by Royal Decree 650/1987, of the 8th of May (Official State Journal 22nd of May, 1987).

As regards their incorporation, the basin organisations denominated Hydrographic Confederations of the North, of the Douro, of the Tagus, of the Guadiana, of the Guadalquivir, of the Segura, of the Júcar and of the Ebro, were incorporated, all of them under Section 19 of the Water Act, by Royal Decrees 930/1989, 929/1989, 927/1989, 928/1989, 926/1989, 925/1989, 924/1989 and 931/1989, all dated 21st of July (Official State Journal 27th of July, 1989). The basin organisation of the Hydrographic Confederation of the South was not incorporated.

Finally, Royal Decree 984/1989, of the 28th of July (amended by R.D. 281/1994, of the 18th of February), established the organisational structure under the Presidency of the Hydrographic Confederations, which is made up of the following four administrative units:

a) The Water Commissions.

b) Technical Directorate.

c) The General Secretariat.

d) The Water Planning Office.

It is worth pointing out the peculiarity that the Hydrographic Confederation of the South is not incorporated as a basin organisation per se, as defined by the current Water Act, as a result of which, and in accordance with the ninth transitory provision of this Act, it continues to be governed by the terms of Royal Decree 1821/1985, of the 1st of August, by virtue of which the functions of the Water Committees were integrated into the Hydrographic Confederations and its organisational structure was modified (Official State Journal 9th of October, 1985). As a consequence of this, the South Hydrographic Confederation does not have a basin Water Council and Water Planning Office, whose functions are carried out by the Board of Directors and by the Technical Director, respectively, with the existence of a Planning Area responsible for the work in which the Confederation may carry out the functions laid down for basin organisations in the Water Act and which is stipulated therein in the ninth transitory provision.

As regards the Water Administrations in intra-community basins, although they must be incorporated by the corresponding Autonomous Communities with their organisational structure determined, their legal regime must conform with the bases for applying the principles laid down in section 13 of the WA, and with the representation of users' in associated organisations of the Water Administration shall amount to less than a third of the members who make it up.

At present, the Water Administrations consist of the following five intra-community basins: Catalonia Inland Basins (1985); Balearic Islands (1985); Canary Islands (1985); Galicia Coast (1986); and the Basque Country Inland Basins (l994). A description of these Administrations can be seen in Fanlo Loras (1996).

The adjoining map show the territorial areas of the basin management plans, both inter- and intra-community. Examining it alongside the one shown above, overlaying the areas of Plans and Autonomous Communities, the mentioned relationships of intra- and inter-territoriality can be appreciated (fig. 53).

2.4.3.2. Irrigators' Associations

The role of these organisations in the proper use and management of water is tremendously important. To appreciate this, suffice to consider that, as mentioned above and as will be seen in greater detail further ahead, the majority of the resources consumed in the country are used in irrigated agriculture, for which they have these organisations as managers and administrators. The total amount of water demand depends to a large extent on their attention and rigour.

Numerous achievements have been made although these organisations also have a number of problems, and we will have an opportunity to refer to these further ahead, when describing the situation of the Water Administration. Suffice to mention here that it is as important to have an effective public water administration as it is to have effective, modern users' associations which, as public corporations, carry out functions of an administrative nature. Water management is certainly, and increasingly, a shared responsibility, and requires greater effort and cooperation from all the agents involved.

2.5. THE INTERNATIONAL CONTEXT

As mentioned, international conditions are tending to become a fundamental element in water management and regu-

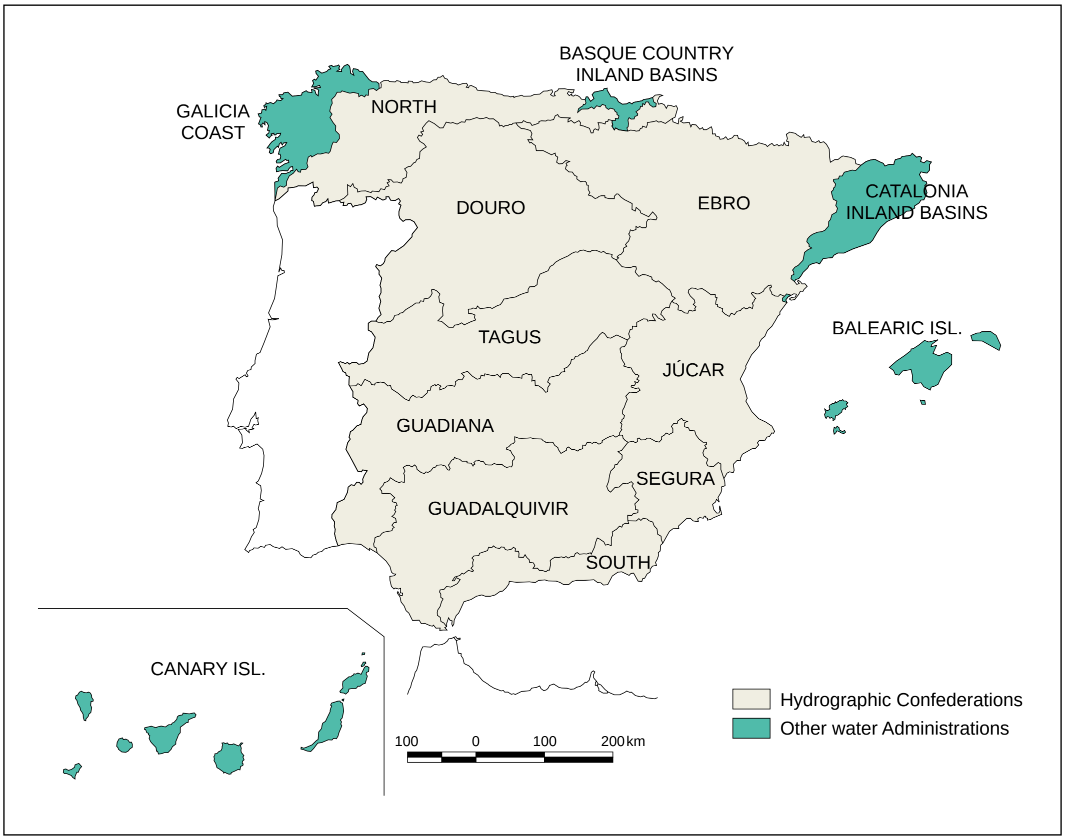


Figure 53. Map of territorial areas of the Water Administrations.

lation in Spain, in varying degrees and at different levels. It is a relatively recent phenomenon, one which past water plans could ignore, but which nowadays, and in the future more so, considerations of international context and cooperation are essential parts of our country's water regulation, and which are destined to give our water policies a clearly cross-border character.

Foreign influence generally affects territorial structure whose basic features have been described in sections above, so, indirectly, it affects water; though additionally, and specifically, it decisively influences some fundamental questions directly related with water resources, as we shall have an opportunity to comment upon in more detail further ahead. Similarly, the overall objective of European convergence gives rise to major considerations, also relevant from our point of view.

2.5.1. Convergence

The major political-economic process of European convergence has an overall importance of such magnitude that its effects also influence water policies, both directly and indirectly. This is obviously not the most appropriate place to give and exhaustive description or analysis of the consequences of the Maastricht Agreements and the meaning of the convergence conditions, though it does seem necessary to at least point out the basic features of this new framework, and take stock of what it may signify for Spanish water policy in the near future.

As is well-known, a long process of economic integration, which part of the European countries began years ago, culminated quite recently. Spain had a commitment with the objective of meeting the convergence criteria laid down by the Maastricht Treaty, and managed to satisfactorily achieve these objectives, thus opting to join the group of countries participating in the euro zone and reaching the third phase of Economic and Monetary Union (EMU) on the 11th of January, 1999.

It should be said that fulfilling these objectives is not an end in itself, but the instrument the EU has chosen, given the current situation of each economy, to offer some guarantee of successfully facing both the transition to EMU and, fundamentally, the period after, within the context foreseeable for the economy in the rest of the world. In this new world economic order, the EU must define its place, which must inevitably be based on balanced growth, capable of generating sufficient employment. It may be deduced that, to achieve this objective, Maastricht correctly decided to create the necessary conditions of macro-economic stability to stimulate a process of investment, sustained by part of the private sector.

In this sense, nominal convergence (fulfilment of established macro-economic objectives) must lay the foundations for leading to real convergence of member countries' economies (established as per capita income), which must be considered a genuine socio-political objective, and although it involves sacrifices and risks of certain instability in the short term for those which are currently worst situated.

It is clear that Spanish economic policy in this new scenario will be significantly modified with respect to previous decades. Without the possibility of resorting to monetary policy nor exchange rate policy and with the foreseeable need to come to some kind of harmonisation among the fiscal policies of the different countries, it seems clear that the State will be obliged to reorient its role towards other kinds of actions, fundamentally aimed at encouraging efficiency in production activities and in resource utilisation. In short, aimed at improving productivity, guaranteeing sustainability. Competing in a global economy, this is the only way to guarantee the population's welfare and, at the same time, converge with the advanced countries of the EU.

In this new stage, the drive for investment from the public sector must continue to be significant, though the trend towards budgetary balance and, in general, strict control of the EU's public finances, forecast a margin of action for public investment being limited on one hand and conditioned on the other by fulfilling the objectives mentioned above. It may be possible to anticipate a greater role for the measures aimed at correcting the structural problems of some sectors in the Spanish economy.

Among public investments, the role played by infrastructures stands out due to the positive externalities involved in the productivity of private investment. The issue now is to determine what kind of infrastructure best fulfils this function and therefore is best aligned with the criteria mentioned. It should be taken into account, however, that in water issues there are also other investments as relevant as infrastructures (hydrological restoration of forests, for example).

In any event, the need arises immediately for reconsidering the rules of action on water applied by the State in the recent past, and which, under the denomination of traditional water policy model, will be examined in detail in other chapters of this White Paper. Furthermore, it is necessary to pose the question as to whether the current general regulation framework for water resources in Spain is the most appropriate for the new situation, or whether, if not, it would be convenient to introduce certain measures to correct the problems detected and increase the effectiveness and rationality of the mechanisms by which it is used, in harmony with the environment and other natural resources, whose conservation should be assured in any event.

This is, in short, the significant challenge that the new water policy faces in coming years, conditioned by European convergence and by the intrinsic need to restrict spending. As a result of all this, and in view of the complex network of conditioning factors, it is appropriate to make some specific considerations and to introduce basic ideas that, although they will be described in detail in other sections of this White Paper, have already been outlined and should be taken into account from here on.

Firstly, as regards demand, water is an asset that affects people's basic necessities; for this reason part of it is dedicated, with high priority, to population supply so that meeting this demand is, except in exceptional situations, practically guaranteed by means of appropriate infrastructures and facilities.

Additionally, it is also a fundamental component in the production processes of economic sectors. Some of these, such as irrigation or hydroelectric activity, for example, stand out above the rest due to the intensive use they make of water as a production factor and the amount of demand associated. Others, such as the industrial sector, although requiring certain quantities of water in order to carry out their activity (power station refrigeration, for example), do not reach the figures of the former. In some cases, hydraulic infrastructures have been financed by private initiative, and in others not, although in all of them, water is a just another input, subject to micro-economic decisions arising from business strategies. How each one contributes to the Spanish production system varies greatly, showing a widely-ranging casuistry that arises from multiple causes: territorial location, field of activity, age, etc. It would be preferable for this economic-productive role to be carried out with the greatest possible equity and rationality.

Secondly, many kinds of hydraulic infrastructures exist, of highly varied typology. From the point of view of convergence, it would be necessary to analyse which ones make a greater contribution to its objectives, because, obviously, it is not the same in all, and it depends on the purpose they are devoted to. They may be infrastructures for regulation, transport and distribution for sectoral purposes, infrastructures for the supply of drinking water to populations, for collection and treatment of waste water, and many more. The results of the assessment are very heterogeneous, but, as above, contribution and costs should respond to principles of rationality.

Thirdly, if all of the hydraulic infrastructures in Spain are studied, it may be stated that the positive externalities arising from them, although highly significant in some cases (possibly more than in any other sector of public works), are generally speaking less than those detected in other types of infrastructures such as transport and communications. This should be taken into account when programming public policies.

Fourthly, it should be pointed out that in hydraulic matters, on average, our country does not have an imbalance similar to what exists in the provision of other infrastructures such as those just mentioned, with respect to other European countries. A case in point is the greater level of development achieved in Spain by traditional regulation works, required due to their hydrological peculiarity. Nevertheless, there are still some infrastructural deficiencies, and a serious deficit in the maintenance of this major existing asset.

Fifthly, this hydraulic heritage accumulated over history arises mostly from the Mediterranean location of our country, and in the differences that this fact creates with respect to Central European countries. It is not necessary reiterate the already-mentioned hydrological characteristics of arid or semi-arid regions, as are found over most of our territory, to justify the corrective actions that Spain has been obliged to undertake, in order to reach levels of security and guarantee similar to European averages.

Sixthly, this circumstance, representing a major comparative disadvantage with respect to countries of Central and Northern Europe, with Atlantic climate, involves significant differential costs for the whole Spanish economy for sectors that base their activity on the use of water resources in particular.

Seventh and last, we should mention the empirical evidence that the approximation of per capita income levels among member countries does not seem to occur spontaneously in response to the process of European integration and liberalization of transactions, but rather on the contrary, there exist risks that trends of spatial concentration of income prevent reduction of the imbalance that currently separates us from the EU's most advanced countries.

These last two reasons (competitive disadvantages and the need to encourage real convergence) should be reason enough for the EU to undertake a decisive policy in the community area regarding water resources, especially considering the fact that these concentration trends arise not only from the market, but rather they are also caused by the community's own policies in other fields.

2.5.2. Specific impact

Apart from the major global socio-political effect caused by convergence, community sectoral policies affect how many sectors of our economy operate, so indirectly, and to the extent that these sectors need water or contribute to its degradation, the water regime is being affected in our country. Besides these poorly-defined, widespread and indirect effects, however, and associated with production sectors and territorial structure, there is other direct impact both from the point of view of water supply and demand.

Thus, as an example, agrarian demand is more and more strongly affected by the foreign conditions of international markets and European agrarian policies, as described in the corresponding sections on agrarian demand. The potential for tourism and its territorial orientation can also have, as mentioned, major consequences from the point of view of water, and not only as seasonal demand in traditional coastal areas, but as possible causes of changes to the orientation of uses in inland areas, in those that often associate tourist and recreational activity with river zones and of water bodies.

Similarly, and from the supply side, it is clear that the community economic framework and convergence objectives introduce fundamental conditioning factors to the country's financial possibilities, and consequently, to the pace and manner in which the development of hydraulic infrastructure can be undertaken. Quality requirements generated by mandatory compliance with European directives also condition the characteristics of water supply.

In short, purely institutional or political international issues, such as convergence, common agricultural policy, GATT, etc. affect internal activity to such an extent that we may state, without exaggeration, they are shaping and determining its basic features. The issue is therefore of decisive importance, so we shall study it in greater detail in other sections of this document.

3. THE CURRENT SITUATION AND EXISTING AND FORESEEABLE PROBLEMS

As we mentioned in the introductory chapter, and with the second chapter giving a description of the global context, and geographical context in its three physiographical, socio-economic and institutional aspects, which characterise and condition water problems, this third part will carry out a technical description on the present circumstances and situation of water in Spain from a primordially descriptive point of view.

This description will deal firstly with the basic data on how much water there is, where it is, and how it is –water resources in quality and quantity–, and then review the situation of utilisation, demand and allocations that affect these resources, the exploitation systems that include resources and demand, the mechanisms for protecting the public water domain, the economy, water protection and administration, infrastructures and extreme phenomena of droughts and floods. The chapter concludes with specific reference to the international context and to cooperation with Portugal, and with comment on the current situation of research and development in water resources in our country.

3.1. THE SITUATION OF WATER RESOURCES

3.1.1. Introduction. The concept of resource

In the paragraphs below, and after a presentation of the general reference frameworks, we will describe the situation of water resources in detail, from a specific and quantitative point of view. The considerable extension devoted to this study is certainly justified, since the resources are no less than the water there is, and it is understood that this data is essential, a basis and conditioner of nearly all the rest.

Prior to this analysis, however, it is appropriate to make some terminology clarifications. Thus, the consideration of water as a resource, which gives this section its title, refers to its perception as something that can carry out different functions, though these should be understood in an abstract sense, in now way directly associated with trivial utilitarian or directly economic connotations.

It is clear that the most obvious functions of water are those that refer to its possible utilisation by humanity for various direct uses (drinking, irrigation, moving wheels or turbines, bathing...), though these functions in a strict sense do not exclude other maybe less directly perceptible functionalities but which are as important as the former. This is the case of environmental functions (supporting ecosystems, receiving waste ...) or other not strictly utilitarian functions, associated with recreation, contemplating the landscape, or the feeling of experiencing a primary element, like earth or fire, anthropologically intertwined deep down with the awareness of the human species. We shall refer in detail to these different hydraulic functions in presenting the environmental basis for water policy, although it is appropriate to mention this initial appreciation here.

Furthermore, we should also draw attention to the extremely narrow border between what we have called utilitarian and non-utilitarian functionalities, and how basically artificial this separation is, because, is there any doubt at this time that water's environmental function is a necessary utility for the continuity of the human race, or that the preservation of the environment is our main need in the long term, without which the others do not even have the chance of existing?

Having clarified this, we will firstly present the basic concepts of the hydrological cycle in a natural regime and the cycle in an affected regime. Subsequently, and since the quantitative knowledge of these resources is gathered by the observation and measurement of their components, we will present the situation of hydrological data measurement networks. Better knowledge of water resources and better measurement networks necessarily go hand in hand, so this question is of strategic importance. Once the networks have been described, we will directly deal with the assessment of water resources, in both a natural and affected regime, and also considering what have been called non-conventional resources, and which, as we shall see, deserve this name less and less.

After this physical description of the water in the biosphere, we will then introduce an initial appreciation of water resources oriented towards their possible utilisation in meeting human needs. Thus, then concept of available resources arises in contrast to natural resources, fundamentally important concepts, which have sometimes given rise to confusion and incorrect technical interpretations, and which will be meticulously explored in detail in these document.

Finally, we have included an illustrative comparison of our situation with that in other European countries, and an analysis is made on what could be the result of natural hydrological variability and the uncertainties of climatic change for our water resources in the future.

We should insist that, initially, this chapter refers to water resources under this global physical perception, functional in a broad sense, without entering into details of its aptitude or utility for the specific satisfaction of human needs. Quantitative description must respond, therefore, to the most elementary questions: How much water is there? Where is it? How does it move? Where does it go? How far can it be controlled?... apparently simple questions –but only apparently– and whose answers are the matter of hydrological science.

Moreover, questions relating to water quality cannot be conceptually separated from those on quantity. It has been said and repeated that quantity and quality go hand in hand, cannot be dissociated, and cannot be correctly understood separately. The elementary questions which, continuing from the above, should be answered now are: Can it be drunk? Can it be used for irrigation? Can it be improved?

This White Paper fully assumes –obviously– this integrated proposal, although, after analysing the possibility of a hybrid presentation –very innovative, of course, but which, with the knowledge available, would have been feasible–, reasons of presentation and better understanding of both complementary aspects advised a formal, though not material, separation of issues concerning water quality and pollution, laying out an extensive specific section with them..

This introduction could conclude by closing the questions which, in a process of gradual curiosity and learning were posed above by our hypothetical philosopher. Thus, it may now be imagined, with enough knowledge on where it is and what can be done with it, that is, once water's immediate utilitarian functions have been satisfied, what the next question would be: Since I now have enough to cover my needs, what role does water play in nature? What other things, apart from myself, is it supporting? What is my relationship with those other things?

The answers to these questions lead directly to a study of the environmental functions of water resources and, in a final analysis, to considering the root of the problem of humanity's relationship with the environment that surrounds it.

3.1.2. The quantitative consideration of the resource

Water moves in nature according to a sequence of physical processes that make up the hydrological cycle, and which it would be appropriate to describe so as to take into account water's relationships with its surroundings, and find out how modifications due to water resource utilisation can affect the various components of the cycle, and the environment in general.

In spite of its apparent simplicity, understanding the basic features of the hydrological cycle's mechanism is a relatively recent situation. Ideas that now seem trivial, such as the fact that the ocean is the main source of the cycle's water, that the contribution of rivers is associated with rainfall, or that spring water comes from the recharging of aquifers, were not clearly understood until modern times. The first effective explanation of the hydrological cycle, by experimentation and quantitative measurement procedures, took place in the 17th century, when Perrault showed, from observing and registering data, that the contribution of the River Seine, in Francia, was related to precipitation falling on its basin, and was around 1/3 of this precipitation. Perrault's measurements (from October, 1668 to October, 1669, from October, 1670 to October, 1671, and from October, 1673 to October, 1674) were the first systematic register of rainfall during at least one complete seasonal cycle (Solís, 1990, pp. 93).

Below, we give a brief description of the hydrological cycle in a natural regime, and after that show the basic impact, from a quantitative point of view, that human action causes on this natural cycle, giving rise to an affected regime which is, except in virgin basins, what can be seen in reality. Even an elementary consideration of these processes is fundamentally important for an overall understanding of water problems.

3.1.2.1. The hydrological cycle in a natural regime

In order to provide some basic notions on the hydrological cycle in a natural regime, we shall firstly present this cycle's technical concepts and basic components. Comprehending them allows us to naturally introduce the concept of water balance in a territory, something fundamental to understanding water resources from a quantitative point of view. Finally, and associated with the concept of balance, the concepts of renewable resources and reserves will be introduced.

3.1.2.1.1. The concept of hydrological cycle

Hydrological cycle is understood to mean the series of water transfers between the atmosphere, the sea and the land, in its three states: solid, liquid, and gas. The driving force for these transfers is the Sun. The hydrological cycle takes place on a planetary scale, although its continental phase is the one that incorporates the resources used for meeting human needs, the one that causes disturbances in cases of flooding, and the one on which the main anthropic effects are caused.

The series of hydraulic processes that have taken or will take place naturally in total absence of human intervention (that is, as if humanity did not exist on the planet) represents the hydrological cycle in a natural regime.

Figure 54 generally shows this cycle in concept form, giving the different water states, flow and storage.

The basic processes included in the hydrological cycle are evapotranspiration, precipitation, infiltration, percolation and runoff. Evapotranspiration is the joint effect brought about by the evaporation of water on the surface of the land and on seas, rivers and lakes, and transpiration from the land through living things, especially plants. This evapotranspiration determines the formation of atmospheric vapour which, on condensing, under certain conditions, partly returns the continental surface as liquid or solid precipitation. Part of this precipitation infiltrates the ground, from where it evapotranspirates back, or percolates into the sub-soil, and another part runs over the surface drainage network (direct surface runoff) into the fluvial system. Water infiltrated into the sub-soil, and which does not evapotranspirate, accumulates in the pores, cracks and fissures of ground material which, due to its physical characteristics, is able to store water. The geological formations able to store and transmit water are called, in a general sense, aquifers. The part of the water which, by percolation, recharges the aquifers and comes back out, after some delay, to the fluvial system, is called groundwater runoff. It is common to associate groundwater runoff with the so-called base flow of rivers, although there may be other components of the flow with relatively slow temporal variation, such as melting snow, and we should therefore distinguish a base flow from other faster flow in discharge from springs, both being groundwater runoff.

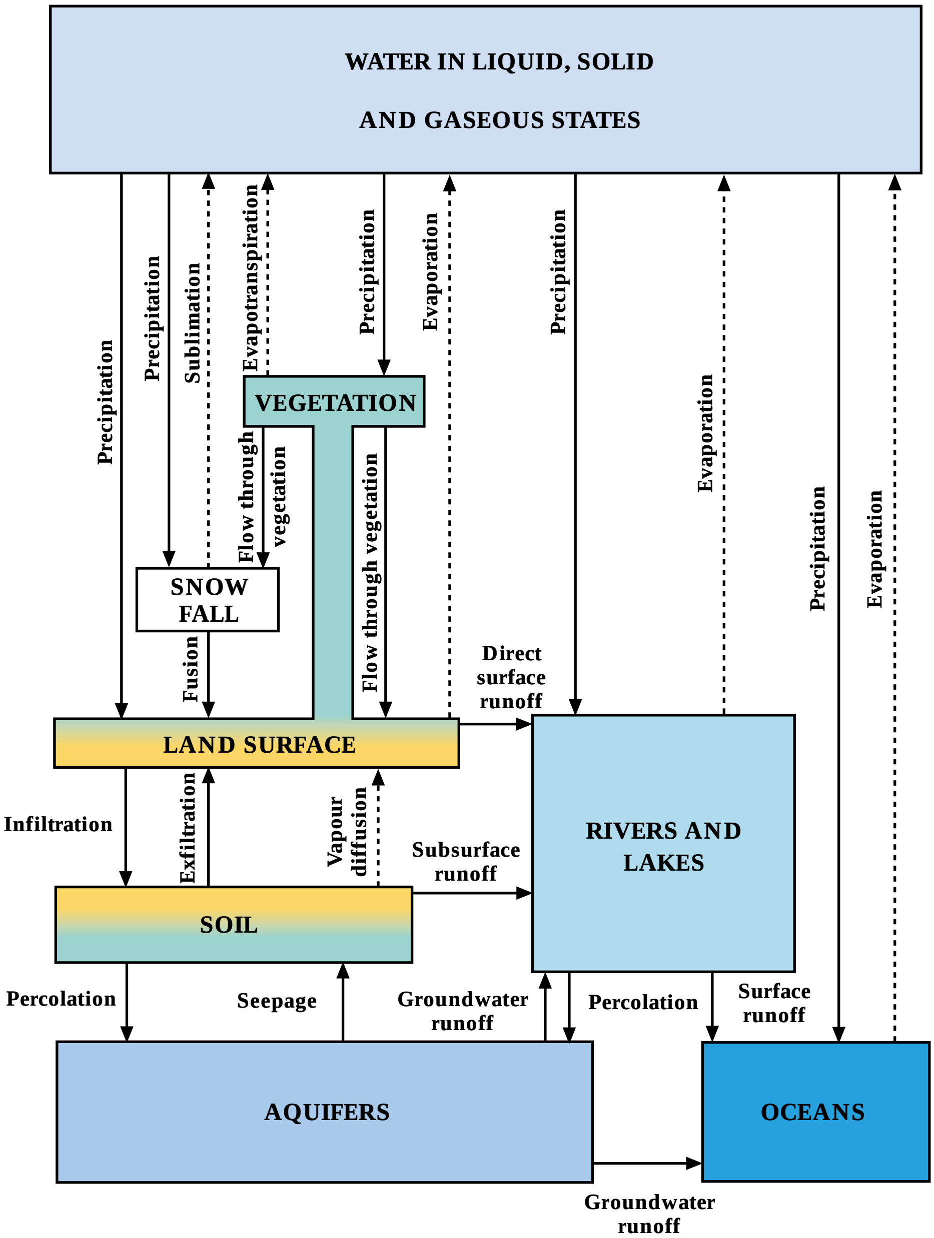


Figure 54. Conceptual diagram of the hydrological cycle.

Cumulative flow may be defined as the volume of water corresponding to the flow which passes a given cross-section of a watercourse during a given period of time. In the natural regime this cumulative flow comprises, then, the sum of direct surface runoff from the whole basin located upstream, and the groundwater runoff which joins the watercourses upstream from that point.

The water that recharges the aquifers (and which, since we refer to natural regime, is not pumped out) and does not evapotranspirate when the phreatic levels are near the surface, ends up joining the aquifer drainage channels, or seeps up through springs. The exception takes place in coastal aquifers, where the groundwater may leave directly into the sea, partly or wholly.

It is clear that the processes described operate with differing intensity on very different spatial and temporal scales, so rather than a unitary, mechanicist hydrological cycle, we should think more of an inter-related series of processes which, operating on different scales, create an aggregate final result which is observed in a simplified way as the subject of study and assessment.

Thus, a characteristic aspect of the hydrological cycle, and one often referred to, is the variability caused by its dependency on meteorological factors influencing terrestrial atmospheric circulation. This variability is related to time scale and means that, in different periods of time, the magnitudes of the cycle described may have very different values.

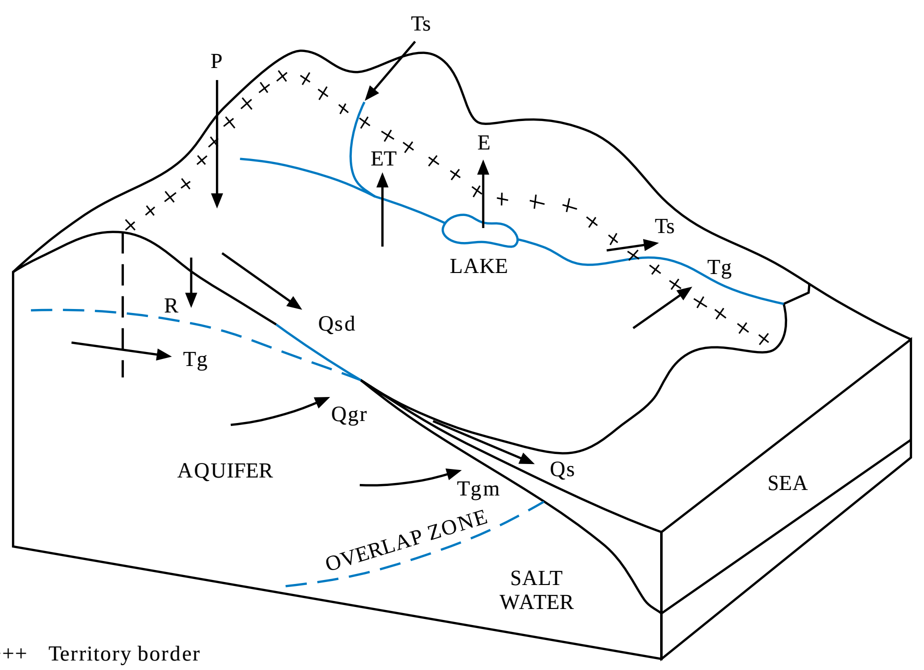
One consequence if this temporal variability is that water may pose problems both due to scarcity, in times of drought, and due to excess, in floods which causes damage and loss of human life. Hydrological variability and its extreme situations, floods and droughts, are phenomena that may be characterised, which we refer to later, and which must be taken into consideration for correct water planning.

Furthermore, this description of the hydrological cycle has only referred to quantitative aspects of the resource, but it is clear that, as water passes through the cycle's different phases, it carries or deposits chemical substances from the environments it crosses through, and therefore modifies its conditions of natural quality, which will be studied further ahead in relation with the resource's qualitative aspects. Although it is reasonable, as a final point, to associate the concept of quality as aptitude for the use the water is to be given, it may also be understood in an abstract way, regardless of possible uses, as the series of physical-chemical parameters that characterise it.

A common confusion is to associate poor quality water with problems of pollution from human activity. However, it is perfectly explicable that, in accordance with the above, there is water unfit for any use due to entirely natural causes, and without any form of anthropic contamination whatsoever. For example, this is the frequent case of water that is saline or sulphated from contact with calcareous or evaporitic material.

3.1.2.1.2. Water balance of a territory

The hydrological concepts and process being presented may be considered, as mentioned, on very different time-space scales, so they do not necessarily have to be restricted to the spatial area of a hydrographic basin, and may refer to any territory (such as a country, a province or a property). In fact, the internally-generated natural resources in any territory are those caused by precipitation and, specifically, comprise direct surface runoff and aquifer recharge. These resources do not have to coincide exactly with the cumulative flow of the fluvial system, since surface and groundwater transfers may take place to or from other neighbouring territories, as is graphically shown in the adjoining figure, adapted from Erhard-Cassegrain and Margat (1983). With this conceptual layout the concept of water balance may be considered for any territory, which does not necessarily have to be a hydrographic basin, and which would be –for any period or in long term average values– the result of considering input and output of the territory shown in the diagram (fig. 55).



+++ Territory border
P- Precipitation
E- Evaporation
ET- Evapotranspiration
R- Recharge of aquifer
Qsd Direct surface runoff
Qgr Groundwater runoff to the river
Qs Supply from river
Ts Surface transfers from / to other territories
Tg Groundwater transfers from / to other territories
Tgm Groundwater transfers to the sea

Figure 55. Diagram of the main flow in the hydrological cycle in a territory.

Hydrographic basins are, in short, simply a particular type of territory, whose peculiarity lies in the fact that they do not receive, in a natural regime, surface transfers, and the groundwater transfers they receive are usually, in general, of little importance. This hydraulic independence with respect to neighbouring territories is what makes hydrographic basins appropriate as territorial units in managing water resources.

Figure 56 –prepared here from diagrams by Erhard-Cassegrain and Margat (1983) adapted to Spanish data– shows the overall aggregate figures of main flows in a natural regime for Spanish territory (in km^3/year), and, therefore the fundamental elements of their water balance.

Further ahead, in sections dealing with natural resources, we will break this subject down in detail and, though it is useful to note here the major basic magnitudes: total cumulative flow of the Spanish river network is around 109 km^3/year (about a third of the km^3/year of total precipitation), of which three quarters (82 km^3/year) is direct surface runoff, and a quarter (29 km^3/year) is groundwater runoff. Overall external transfer, both surface and groundwater, is very low compared with considerable own flow, which is logical considering the geographic character of the peninsular territory –separated by mountain ranges– and island territory, and, therefore, its considerable hydrographic isolation with respect to neighbouring countries.

3.1.2.1.3. Renewable freshwater resources and reserves

It is commonly accepted that an area's water resources coincide with its total renewable resources (surface and groundwater), that is, with the balance of its territory. In our case, these total resources would be around 111 km^3/year (109+2), a slightly higher value to total cumulative flow from rivers.

Apart from these renewable resources, there may be aquifers in a territory with very substantial reserves of water stored in them, and which may take tens or hundreds of years to be replenished. In a natural regime, such reserves must be considered as permanently stored, and not as a renewable resource. In affected regimes such reserves may allow for greater temporal water availability during a limited period, but they would not increase resources permanently. The volume of existing reserves in our country is certainly considerable, but its quantification –and its very concept– poses some problems which we will refer to in due course.

It should be noted that the renewability of water, like all the cycle's characteristics, is not a fixed, immobile attribute, but can be affected by human action.

3.1.2.2. The hydrological cycle in a modified regime

Having described the basic features of the hydrological cycle in a natural regime, we shall now consider this cycle in current real conditions, that is, affected by human action. To do this, we will present the classic concept of modified or affected cycle and show different cases of influence, then turning to the basic problem of assessing natural flow from observed flow, which is known as restoration to a natural regime. Finally, we will describe the new concept of modification on a global scale.

3.1.2.2.1. Anthropic effect on the hydrological cycle

Water has always been an essential element for the development of civilisation, and humanity has progressed in this

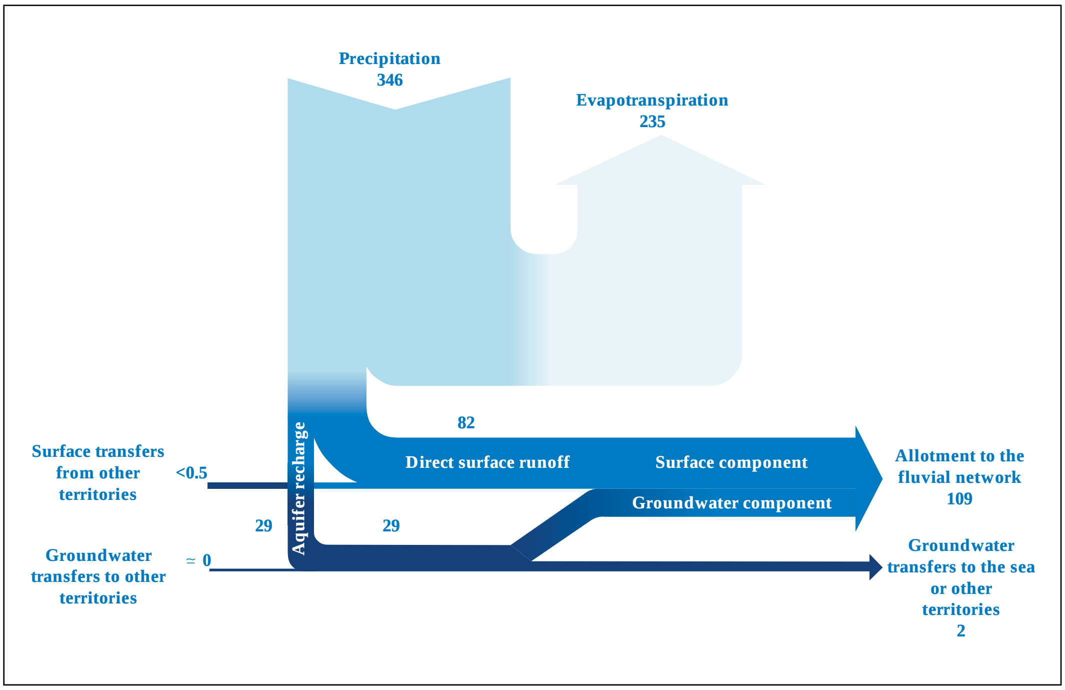


Figure 56. Diagram of the main water flow (km^3/year) in a natural regime for Spanish territory.

development by modifying the regime of natural water flow and storage. In the hydrological cycle. Thus, the establishment of cities, or the production of foodstuffs by irrigation agricultural, or energy production, has involved diverting water from its natural locations –rivers, lakes or aquifers– and applying them to these uses, modifying the circulation it would have had without human intervention.

In many regions of the planet, and particularly in our country, these local interventions have been very intensive, and have given rise to a cycle circulation, in many cases, radically different from that which would exist in a natural regime. This real circulation, arising from the natural flow and storage modified by anthropic action, forms the hydrological cycle in a modified regime.

Figure 57 outlines different examples of influence on the natural regime, in its classic sense, due to the presence of a regulation reservoir, of some wells on an aquifer, of a thermal power station, of a city and of an irrigated area.

The regulation reservoir means a modification to the fluvial hydrological regime to adapt it to demand and reduces its cumulative flow as a consequence of evaporation. The wells pumping water from the aquifer give rise to a reduction in piezometric levels, which will affect the river flow and may in turn cause penetration by the front of the saline wedge, due to the wells' proximity to the coast. The thermal power station will divert flow for refrigeration, which may have increased in temperature on return to the river. Water applied to irrigation and used by plants involves a reduction in the resource, while that which is not consumed will return to the rivers and aquifers with altered quality, by acquiring new elements from fertilisers, insecticides, pesticides, etc. Water abstracted to supply the city will also be partly consumed, with the rest returning to be purified and evacuated into the sea.

As the figure illustrates, and as may be deduced from the above comments, the alterations that the hydrological cycle can suffer are many and with very varied effects, and different sections of this White Paper will be devoted to them.

A good example of the classic anthropic effect of pumping from an aquifer on the flow of the river it drains is provided by the aquifer of East La Mancha and the River Júcar. Figure 58 clearly shows how the process of annual pumping from the aquifer and the water gain in the associated river section have evolved in the period of the last 50 years. As can be seen, there is a considerable volume of water that, up to the seventies, left naturally to the river, and is now abstracted by pumping, thus affecting the cumulative river flow, although it should be noted that, in recent years, this modification effect overlaps with that of pluviometric drought.

Another illustrative, anecdotic example of anthropic influence, much less common and important than the above, is that which is caused by a reservoir whose evacuation and filling leads to the response of a hydro-geologically associated spring, thus modifying the aquifer's natural runoff conditions. This is the case, for example, of the Valdeinfierno Reservoir on the River Guadalentín (Segura basin), and the

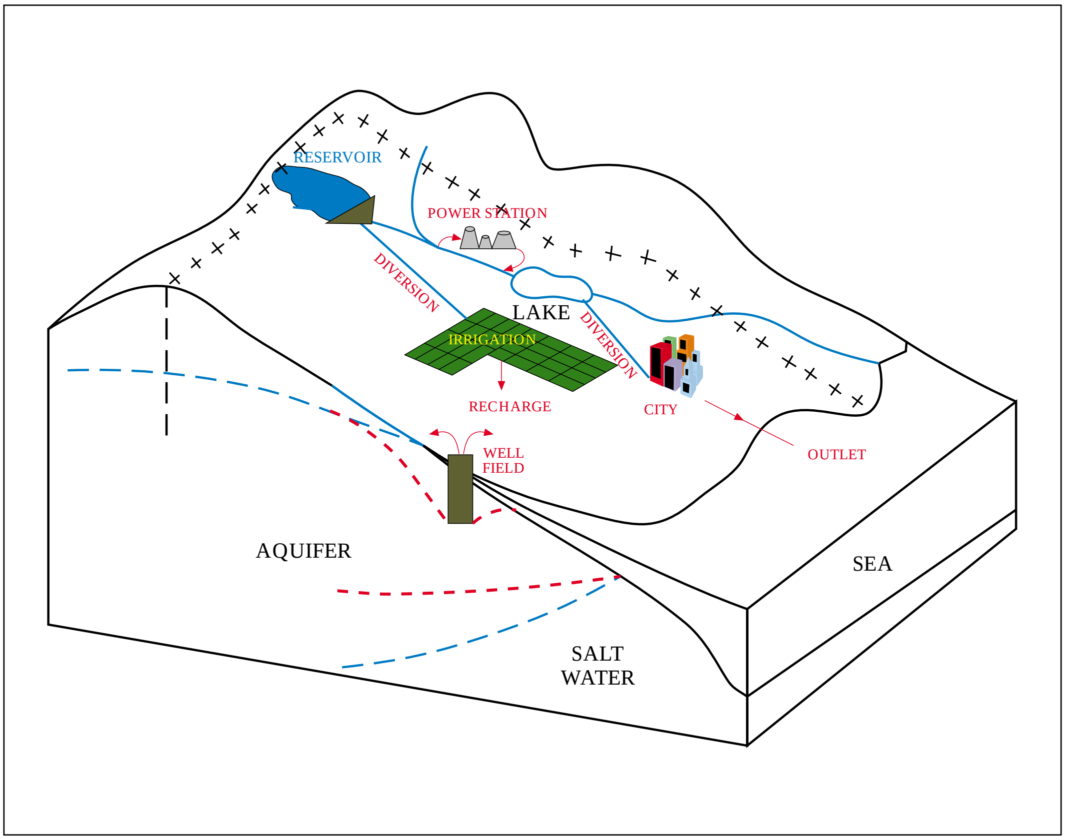


Figure 57. Some examples of anthropic alterations to the hydrological cycle.

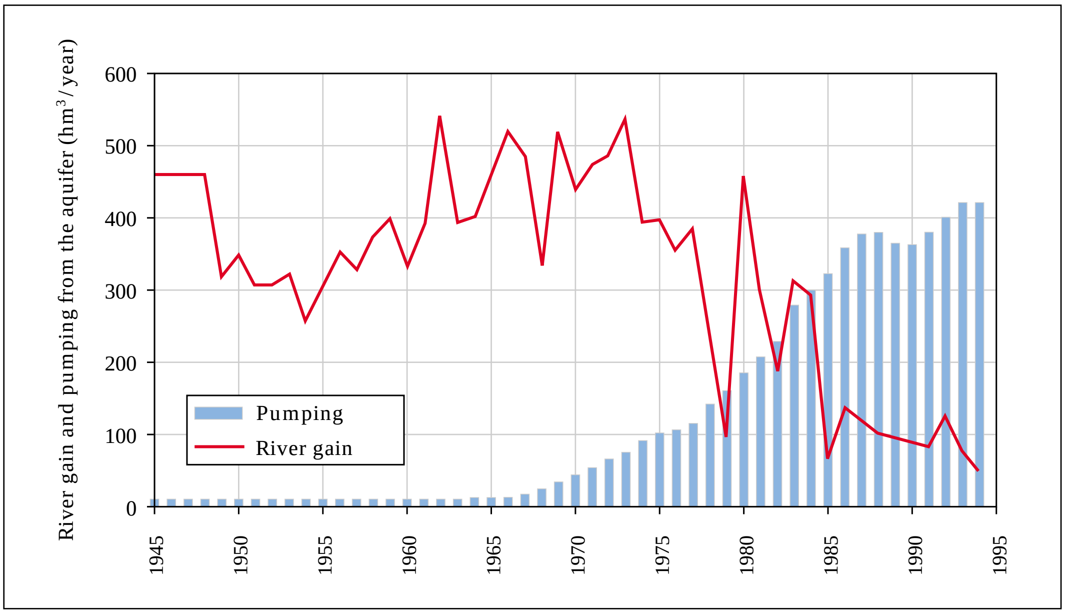


Figure 58. Effect of pumping in La Mancha aquifer on flow in the River Júcar.

major Los Ojos de Luchena spring, from which there has been discontinuous discharge since the 17th century. The adjoining graph clearly shows –for available discharge in the period 1981-1993– the mentioned influence (fig. 59).

It should be pointed out that that fact anthropic influences like those shown take place on the hydrological cycle is neither intrinsically negative nor positive, simply different. They are simple other functioning models, whose pros and cons with respect to the initial situation will depend upon many local circumstances and must be determined in each specific case.

From a quantitative point of view, the most significant influence is certainly the reduction in natural flow due to water abstraction for consumption. As is well known, the greatest use as consumption in Spain is for irrigation, with a high percentage of that water being returned to the atmosphere through evapotranspiration from irrigated areas. Urban and industrial uses in Spain represent a much lower proportion of consumption uses than agricultural ones, while energy utilisation, mainly for refrigerating power stations, uses very little.

On the understanding that this is simply an initial view, notwithstanding the descriptive presentation that these issues will be given later on, we may state here, as an initial indicator of anthropic influence on the natural cycle, the quotient between average flow currently circulating, and therefore in a real, modified regime, and that which would be circulating were it not for human influence, that is, in a natural regime. This indicator’s values for some major Spanish rivers are shown in the adjoining graph, which also represents the overall average value for these rivers, and clearly indicates the effect of anthropic influence (fig. 60).

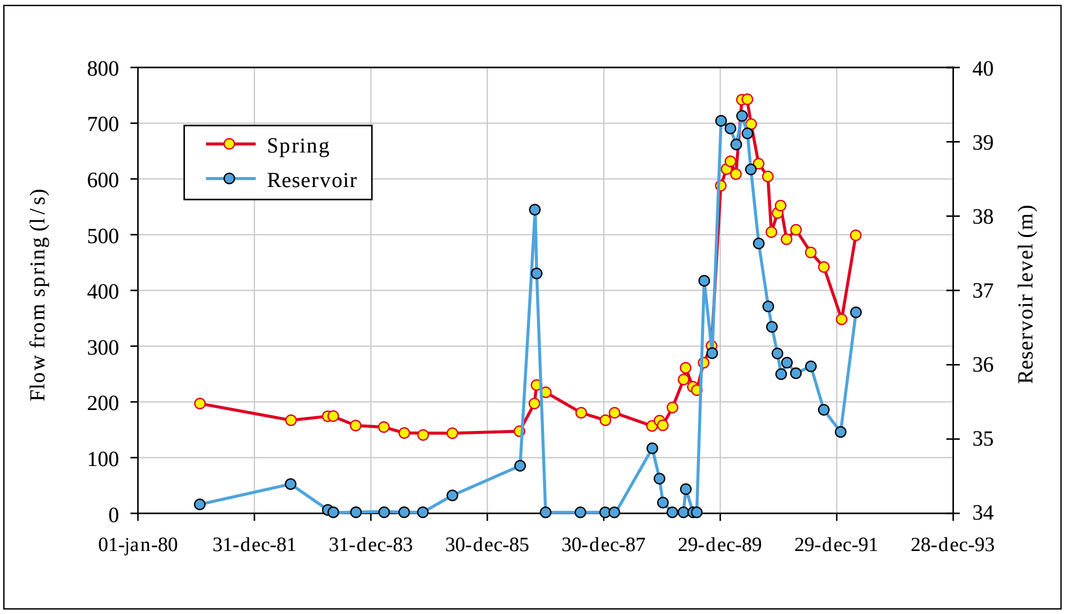


Figure 59. Effect of the Valdeinfierno Reservoir on the Ojos de Luchena Spring.

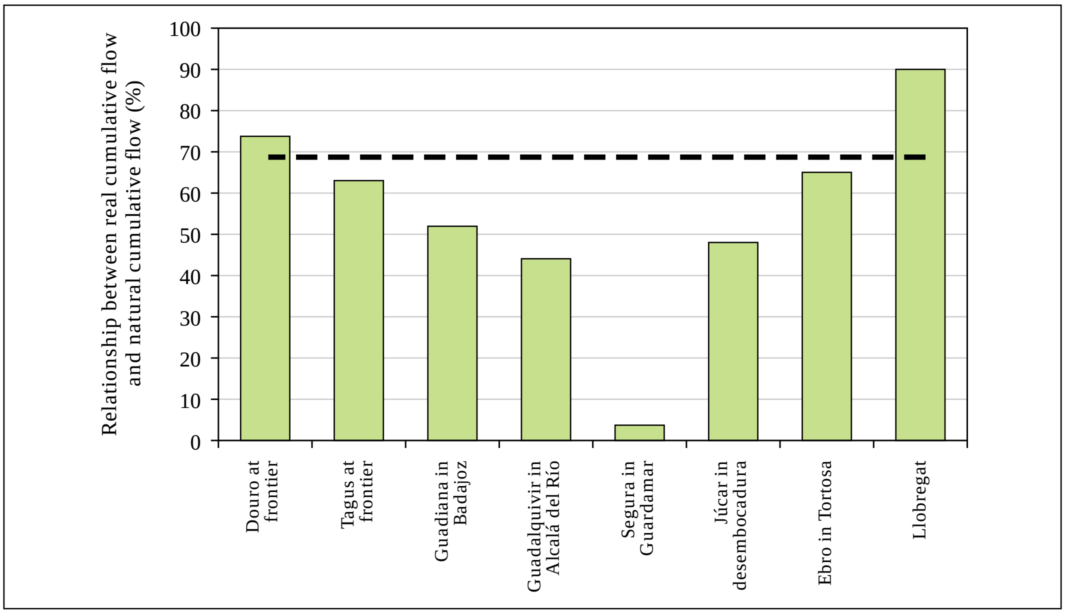


Figure 60. Real cumulative flow and natural cumulative flow for different Spanish rivers.

As may be seen, the relative effect of abstraction for use upstream is greatest on the Segura (what reaches the sea is 4% of what would reach without exploitation), revealing extreme use for water consumption in this basin. This effect is also important, although to a lesser extent, in the basins of the Rivers Guadiana, Guadalquivir or Júcar, and less on the Tagus, Ebro and Douro.

As has been mentioned, this breakdown is just an initial indication of the influence, though in no way fully describes it. Consider, for instance, that there may exist substantial modifications to the circulation regime of basin water that do not involve appreciable consumption (such as hydro-electric production or industries with high return) and, therefore, are not reflected in the ratio given.

Furthermore, and above all, very significant modifications may take place to water quality conditions that would be invisible for this ratio. In practice, however, it is common for both conditions to go hand in hand, and places with more intense levels of use also show higher levels of degradation. On the other hand, from the point of view of temporal flow regime, the most important influence is certainly caused by regulation reservoirs, whose objective is precisely that – to modify the natural flow regime for its adaptation to human requirements.

From this perspective, the level of alteration caused at a point on a river will depend basically on the volume of the reservoir existing up-river from that point, of the relative magnitude of that reservoir with respect to circulating cumulative flow, and the exploitation regime of these reservoirs up-river.

The exploitation regime may be such that natural circulation is reproduced, so alteration would be nil. Conversely, maximum disturbance would be caused by mobilising the whole volume of an up-river reservoir. To mitigate this extreme effect, and to have an initial quantitative idea of what the alteration of flow regimes, as a consequence of regulation, could mean for our country, a map has been drawn up showing reservoir volumes upstream from each point on the fluvial network, as shown in figure 61.

As can be seen, the greatest volumes exceed 5,000 hm^3, and are obviously to be found on the lower courses of the major rivers (Guadalquivir, Ebro, Tagus, Douro and Guadiana). Conversely, there are some basins that barely reach 1,000 hm^3 (North, South, Catalonia Inland Basins, Galicia Coast and Segura).

If the map of natural circulating accumulated flow is divided by this map of up-river reservoir volume, the interesting new map of maximum potential regime alteration is obtained, shown in figure 62.

As may be seen, potential alterations due to the effect of regulation show a very different appearance to that of the up-river reservoir. Basins with a very high absolute storage capacity, such as the Ebro, have regimes with generally little alteration due to their considerable natural accumulated flow, while others which also have large accumulated flow show much greater alteration possibilities (Tagus or Guadalquivir), due to their greater availability of reservoirs.

Moreover, it should be remembered that we are referring to maximum potential alterations, and actual ones may be substantially less than these. Think, for instance, of the frequent case of a hydroelectric reservoir with very high capacity, but with little operating run. Potential downstream alteration may be very high, but that which actually takes place may be very small.

3.1.2.2.2. Restoration to natural regime

The restoration of river flow and aquifer drainage consists of estimating the natural regime –which is defined by exist-

Figure 61. Map of up-stream stored volumes (hm³).

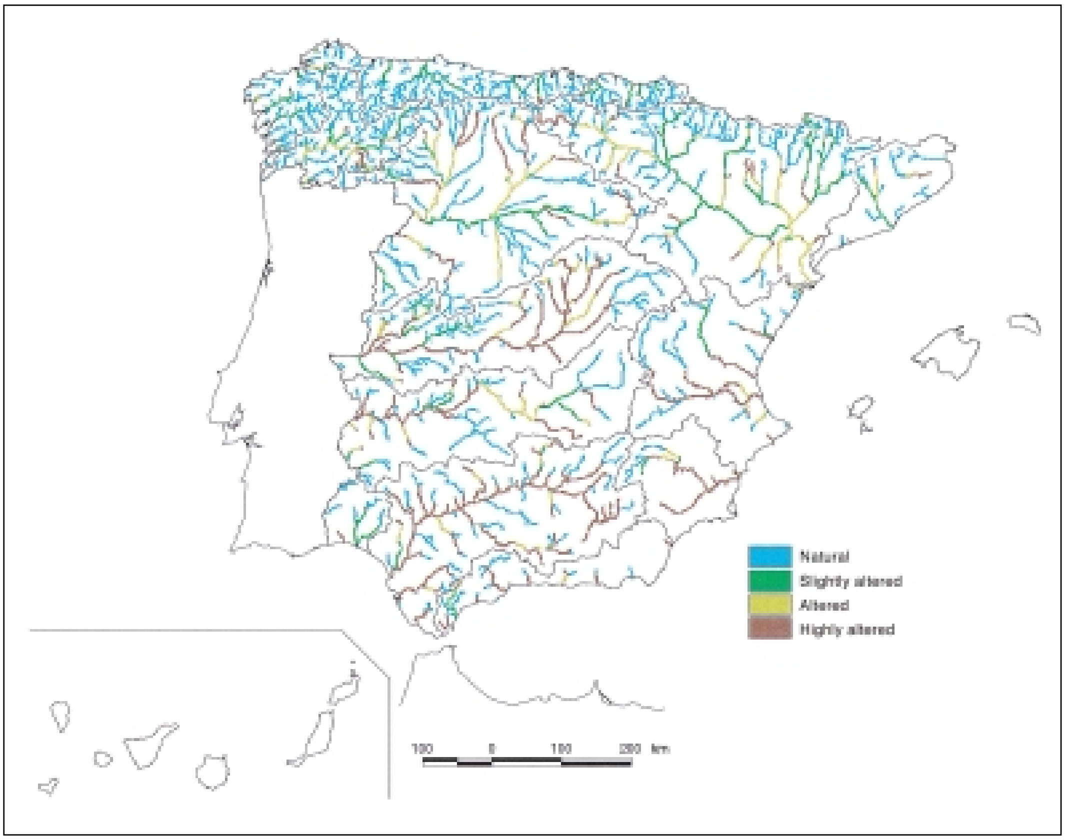


Figure 62. Map of maximum potential alteration of the natural regime by effect of existing regulation.

ing resources– from the modified regime, which is what can be observed and measured. To estimate this natural regime it is necessary to know the abstraction of water from rivers and aquifers, returns to the river, reservoir management, and evaporation and filtration that may take place upon them, artificial transfers between basins, etc. In short, information is required on the evolution in time of all the significant human actions that have taken place in the basin.

In general, water uses and diversions are not satisfactorily known in our country. Logically, this knowledge is greater in those areas where scarcity has required greater control and public intervention for water distribution, but, in any event, and on the whole, it is essential to encourage fundamental progress in this direction, which can only come from intensifying and reinforcing measurement networks, a fundamental aspect that we mention here and will deal with further ahead.

Returns of diverted water, which are quantitatively even less known, depend on the type of use and the utilisation point's distance from the take-up and return point. Return of surface water to rivers takes place with a delay in relation to the take-up, usually hours or days, though it may reach up to about a month. If the return takes place through aquifers, the delay may be much greater, even years. This is important when interpreting data on historical flow registered at gauging stations on rivers, and particularly those with low flow when they are affected by irrigation canals of an unknown amount. The same happens with pumping of groundwater of an unknown amount and temporal distribution on small alluvial aquifers, which may rapidly affect river flow.

In short, the level of anthropic alteration is sometimes so intense and complex that it is practically impossible to restore natural flow with any reliability, as from the imperfect knowledge of influence caused. In these cases, common on the lower courses of rivers, it is possible to resort to hydrological models of rainwater-runoff which, reasonably calibrated, allow an estimation of the basin's natural conditions. An appropriate combination of different methods and approaches, according to circumstances in each case, will be the key to success in dealing with the problem in a satisfactory way.

Restoring natural historical flow and obtaining accumulated flow values in a natural regime is a task of considerable importance for knowledge on water resources and for water planning, and it may be said that, at present, is still subject to some relatively significant uncertainties, which cannot be ignored by such planning.

3.1.2.2.3. Anthropic influence on a global scale

Apart from the classical anthropic influences described above, on the local scale of hydrographic basins, consideration of another type of anthropic influence on the hydrological cycle has recently emerged, which is that due to human impact on a global, continental or planetary scale. Thermal alterations and gas emissions due to human concentration and megalopoli in temperate latitudes, or massive felling and deforestation in the tropics, are planetary phenomena commensurable with interchange of humidity in general atmospheric circulation. The effect of feedback on the state of the surface, increasingly anthropogenically influenced, on atmospheric processes and the hydrological cycle on a global scale, is starting to be a reality whose consequences are not yet sufficiently well known (NRC, 1991. pp. 43-45). Figure 63 outlines these perspectives.

In short, a modern concept of the hydrological cycle must take into account that, in addition to classical effects on the scale of river basins, human activity on a planetary scale has reached a significant part of this global cycle, causing complex phenomena of feedback, not yet well-characterised from a scientific point of view.

3.1.2.3. Water accounting

Once the basic aspects of the hydrological cycle have been considered in both a natural and a modified regime, it is expedient to comment on the existence of methodologies to carry out formal accounting of the processes described.

The quantitative aspects of these water accounting methodologies are of great interest as a procedure for compact, methodical, structured organisation of flow and storage, and although they are limited to major aggregate balances and lack the refinement of detailed water system simulation models, they may be used as a summarised, structured expression of exits from these models, and as a formal homogenising instrument with a view to possible accounting of natural resources.

The initial background to this approach comes from the work on water accounts carried out by Margat in the 70s, and was experimentally applied in Spain in the Segura basin in 1984, and systematically over the whole national area (MOPTMA, 1996b).

The development of a statistical information system constructed with accounting tables would provide a solid basis for monitoring and assessing political actions on the management, use and saving of water in Spain, and would allow homogeneous analyses and international comparisons.

This statistical system could be based on the so-called satellite water accounts being developed by EUROSTAT in collaboration with some member states. The Spanish National Statistics Institute is taking part in these developments.

3.1.3. Water resources assessment. Measurement networks

Descriptive knowledge of processes that influence the hydrological cycle, as mentioned, is not enough, since the needs of modern society require, increasingly and in greater

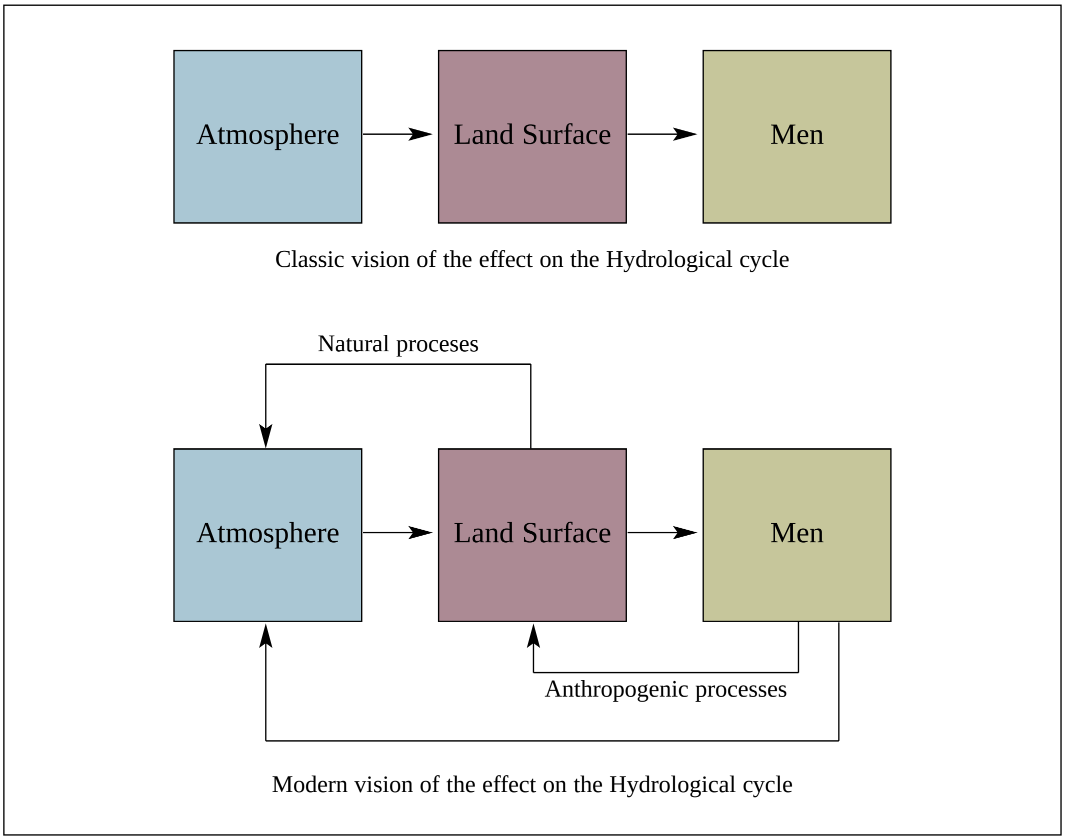


Figure 63. Different perspectives of anthropic effects on the hydrological cycle.

detail, knowledge of their magnitude in a way that is also quantitative. In order to achieve this, it is necessary to measure water flow and storage with measurement networks.

Thus, measurement networks are the basic element in quantifying water resources, and have the fundamental purpose of providing information on the state and evolution of groundwater and surface water.

There exist a large number of networks, of very different nature, objectives and typology. It may be generally stated that those affecting the quantification of water resources are:

1. Meteorological networks, since both precipitations and other meteorological variables influence the process of generating runoff
2. Surface water networks, which measure surface flow and storage, and
3. Groundwater networks, which basically provide information on piezometric levels in aquifers and spring flow

We shall refer to these in sections below.

3.1.3.1. Situation of monitoring networks

3.1.3.1.1. Meteorological networks

Although there have been periodical meteorological observations for a long time, it was thanks to Perrault, in France in the 17th century, between 1668 and 1674, when the first systematic measurements of rainwater over an annual period were made, in the context of the first quantitative studies on the hydrological cycle. From the end of the 17th century, precipitation measurement spread over western countries, and evaporation rate began to be measured (Solís, 1990, p.173).

In Spain, the first attempts made to obtain meterological data are very old, with proof of observations made for medical purposes from *Las Efemérides* by Navarrete, in 1737. Dating from the 18th century are the pioneer observations made by Salvá in Barcelona, Alonso Salanova in Madrid, Sánchez Buitrago in Cádiz, or Bals y Cardona in Mahón (Barriendos et al. [1997] pp. 47-62).

At the end of the 18th century the first true meteorological observations began, and the first data conserved is from the San Fernando Observatory in Cádiz, from 1805, and from the Madrid Observatory, from 1841. The San Fernando series, the oldest in Spain, is provided in the adjoining graph, drawn up with INM data (1996) (fig. 64).

Apart from the official observatories, there were curious particular initiatives such as those of the parish priest árroco Mosén Bodí, who compiled a detailed list of all the storms that took place in Carcagente between1837 and 1876, with concrete data on rainfall in each storm and their prevailing winds, or Rico Sinobas' compilation, with data from the first third of the century.

An early move to develop the official network took place in 1860, when Isabel II promulgated a Royal Decree commis-

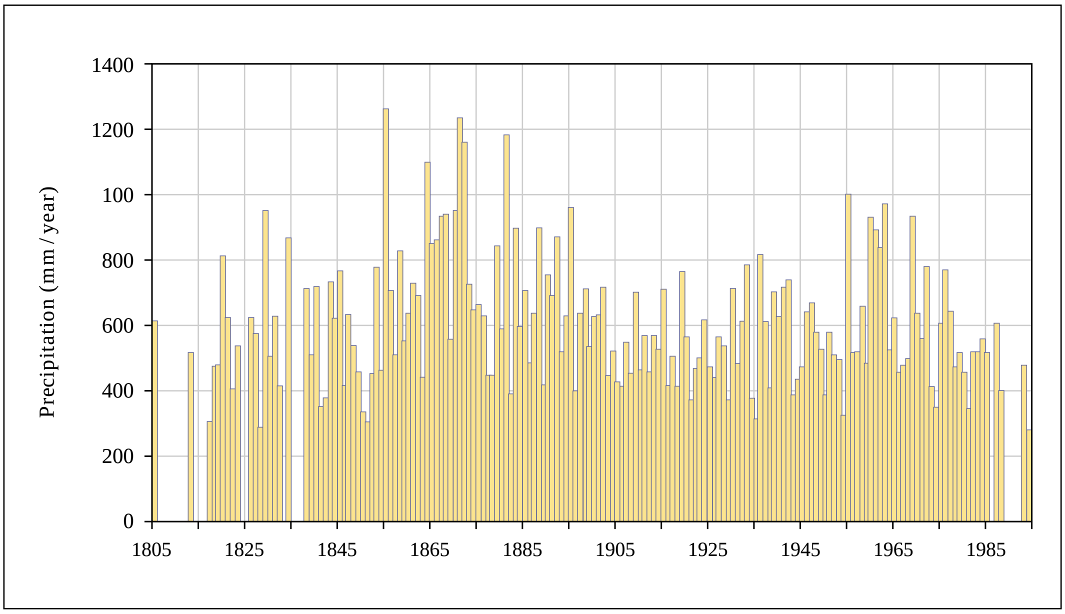


Figure 64. Series of annual precipitation in San Fernando (Cádiz) as of 1805.

sioning the General Board of Statistics of the Kingdom to set up 22 meteorological stations, which brought about a spectacular increase of the number of observation points, as shown in figure 65 –drawn up with data from the National Meteorology Institute–, on the evolution of the number of stations throughout the 19th century. As can be seen, at the end of the century the network consisted of around 40 weather stations.

During the last century, the network's growth was irregular, and although in the second decade (starting in 1912-1913) there was an initial take-off, with a significant increase in stations reaching a number around a thousand, it was really the year 1940 when uninterrupted series began to be widespread, or at least with few gaps. This is the main reason why the data in hydroclimatic studies in our country often starts with those dates.

As can be seen in the adjoining graph, drawn up with data from the INM, this growth reached a peak at the end of the seventies, stabilising or even dropping up to the present time, with an approximate number of 5,000 meteorological stations existing in service (fig. 66).

At present, the Environment Ministry is responsible, through the National Meteorology Institute, for acquiring, managing and publicising meteorological data.

The nation-wide network, shown in figure 67 and described according to planning areas in table 3, consists of approximately 9,200 stations with historical registers available, of which about 5,200 only measure precipitation (P); 3,700 measure precipitation and temperature (TP); 200 are complete stations (C) registering data on precipitation, temperature, atmospheric humidity, sunlight, wind speed, etc.; and

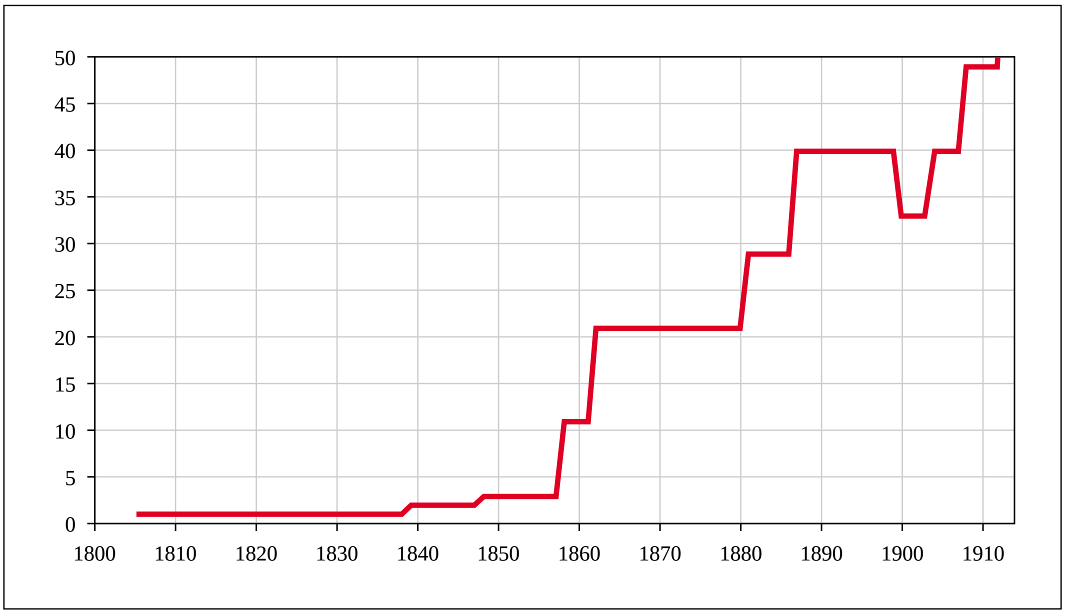


Figure 65. Evolution of the number of meteorological stations in Spain during the 19h century.

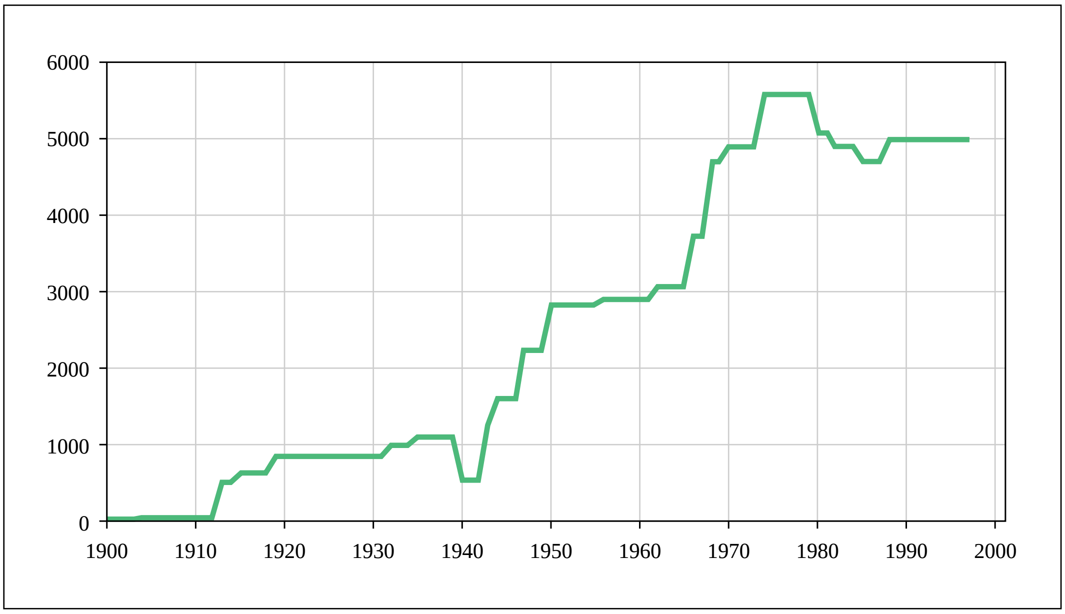


Figure 66. Evolution of the number of meteorological stations in Spain during the 20th century.

80 are automatic. This last type of station is very recent. They register the same type of data as complete stations and their main characteristic feature is that they transmit the information automatically over the telephone network.

The data registered historically in all the meteorological stations is stored in the INM climatology database, as described in the corresponding section.

Of the nearly 9,200 meteorological stations shown in the above table, about 5,080 are currently in service, of which 2,520 measure rainfall, 2,320 measure thermal rainfall, 160 are complete and 80 are automatic. Distribution according to hydrographic basins is shown in table 4, drawn up with INM data.

The rainfall and thermal rainfall stations register data daily, of great value in estimating resources, but insufficient for flood studies that require information in smaller time periods. Intensity of data by the hour, and even by the minute, is only registered in complete and automatic stations which number very few over the national territory as a whole. This fact means that, as we shall see further ahead, information gathered by rainfall detectors of the SAIH network (Automatic Hydrological Information System) is of special interest for the high flow monitoring, and as a complement to the INM's complete and automatic stations.

Another nation-wide meteorological network is the network of evaporation stations on reservoirs, which has been historically implemented and maintained by the Directorate General of Hydraulic Works and Water Quality (DGOH-CA).

Apart from registering information on different meteorological variables, it measures in-tank or Piche-type evapo-

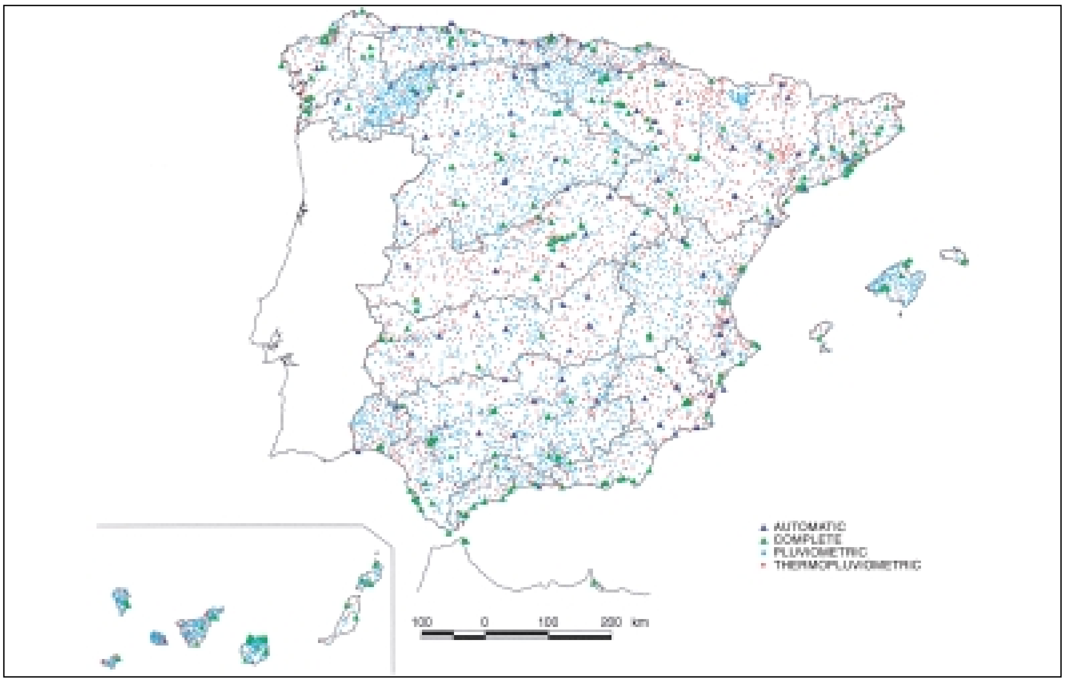


Figure 67. Map of the network of meteorological stations with historical registers of the INM.

Area	Rainfall	Thermal Rainfall	Complete	Automatic	Total
North I	326	74	8	3	411
North II	241	169	8	12	430
North III	74	88	3	2	167
Douro	757	355	15	10	1,137
Tagus	257	355	18	6	636
Guadiana I	344	298	6	8	656
Guadiana II	124	74	3	2	203
Guadalquivir	782	382	23	7	1,194
South	215	147	14	1	377
Segura	110	182	6	8	306
Júcar	447	318	18	5	788
Ebro	663	748	34	14	1,459
Galicia Coast	82	97	10	1	190
Catalonia I.B.	170	242	30	4	446
Balearic Islands	130	38	7	0	173
Canaries	435	164	23	0	622
Total	**5,157**	**3,731**	**226**	**83**	**9,197**

Table 3. Number and distribution by planning area of meteorological stations with historical registers.

ration data . Although it used to have a larger number of stations, the network presently consists of the 75 points shown in figure 68, whose monthly data is included in the Capacity Yearbooks that the DGOHCA regularly publishes.

Apart from those mentioned, there exist other meteorological networks, covering smaller areas, which are managed by the basin organisations themselves or by other organisations of the Central or Autonomous Administration, and which fulfil specific purposes to complement the national network.

There also exists a programme, called ERHIN (Study of Water Resources from Snow Covering), which began in the Pyrenees, and whose purpose is to quantify the contribution of melting snow to the water resources of different basins (MOPU [1988]; MOPT [1992b]).

The varied number of existing networks and their different scope, clearly shows the problem of dispersion and the need for coordination that should exist between all the Administrations and Organisations involved.

3.1.3.1.2. Surface water networks

The concept of river flow has been known for a very long time, but determining it in its channels posed many problems in practice, and it was not until the 19th century when the necessary techniques for such an estimate were ascertained and mastered. While rainfall began to be registered in Europe at the end of the 17th century, flow measurement was not developed until the 19th and 20th centuries.

Although spot flow data is known from some Spanish rivers prior to this, it was in the last third of the 19th century when continuous series began to be available, as shown in figure 69 on annual accumulated flow of the Guadalentín at the Puentes dam, and which is –like the San Fernando register for rainfall– the longest known series on daily capacity in Spain. The usual case was that, as has been mentioned, little more than occasional capacity data was available throughout the 19th century widely dispersed over time and space (see: Bentabol, 1900), without systematic registers –although in a small number of stations– until the beginning of last century.

Area	Rainfall	Thermal Rainfall	Complete	Automatic	Total
North	213	268	23	18	522
Douro	339	215	12	10	576
Tagus	105	177	15	6	303
Guadiana	153	206	6	10	375
Guadalquivir	385	198	13	7	603
South	166	54	14	1	235
Segura	70	156	5	8	239
Júcar	180	193	15	5	393
Ebro	214	498	16	14	742
Catalonia I.B.	70	132	15	4	221
Balearic Islands	134	43	7	0	184
Canaries	485	183	18	0	686
Total	**2,514**	**2,323**	**159**	**83**	**5,079**

Table 4. Number and distribution of meteorological stations currently in service.

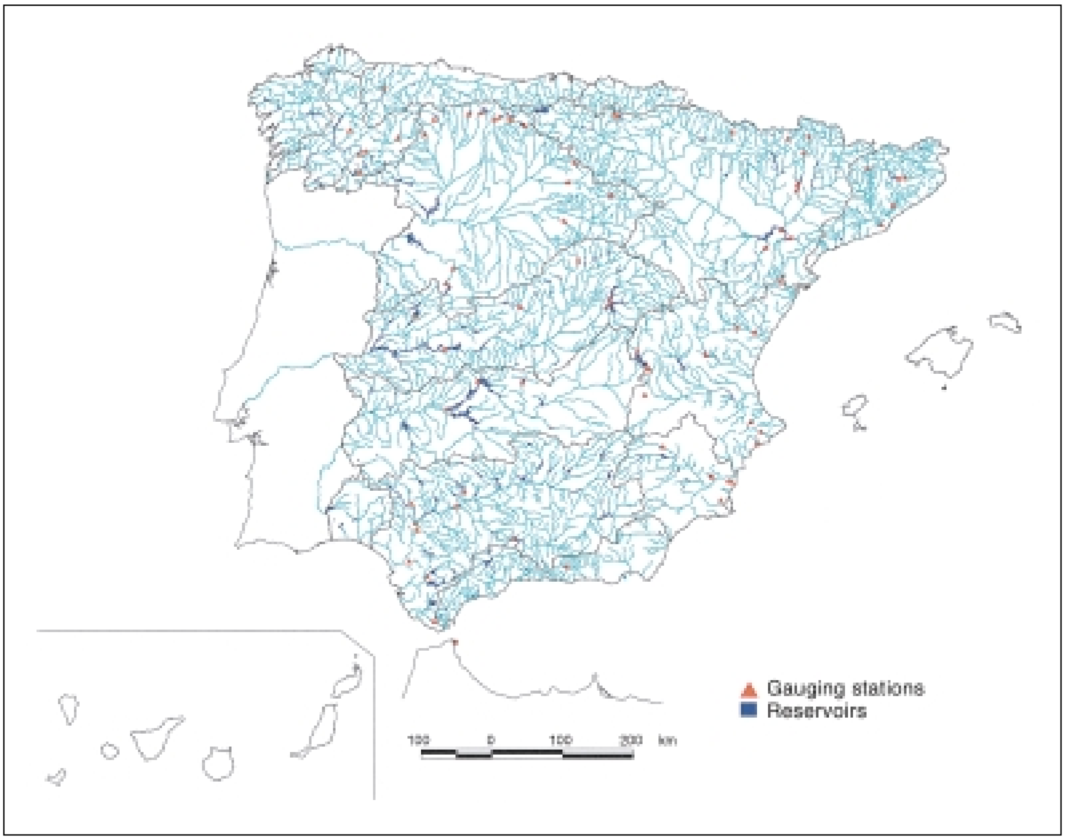


Figure 68. Map of the reservoir evaporation measurement station network.

The first official regulation on flow measurement networks dates from 1941, when the then Ministry of Public Works approved a Ministerial Order to find out flow used by grantees of public water use.

This Ministerial Order was complied with partially and late, so in 1963, the then Directorate General of Hydraulic Works (DGOH), in view of the fact that stations were not functioning as expected, approved a General Improvement and Extension Plan for Gauging Stations, which led to the Official Network of Gauging Stations (ROEA) being set up. This major Plan was carried out between 1963 and 1972 and, as can be seen in figure 70, gave rise to a very important growth of the number of gauging stations on rivers, which reached a peak at the beginning of the eighties, stabilised then fell slightly up to the present day.

In the current organization, basin organisations are responsible for the operation and maintenance of these measurement networks, while the organisation responsible for gen-

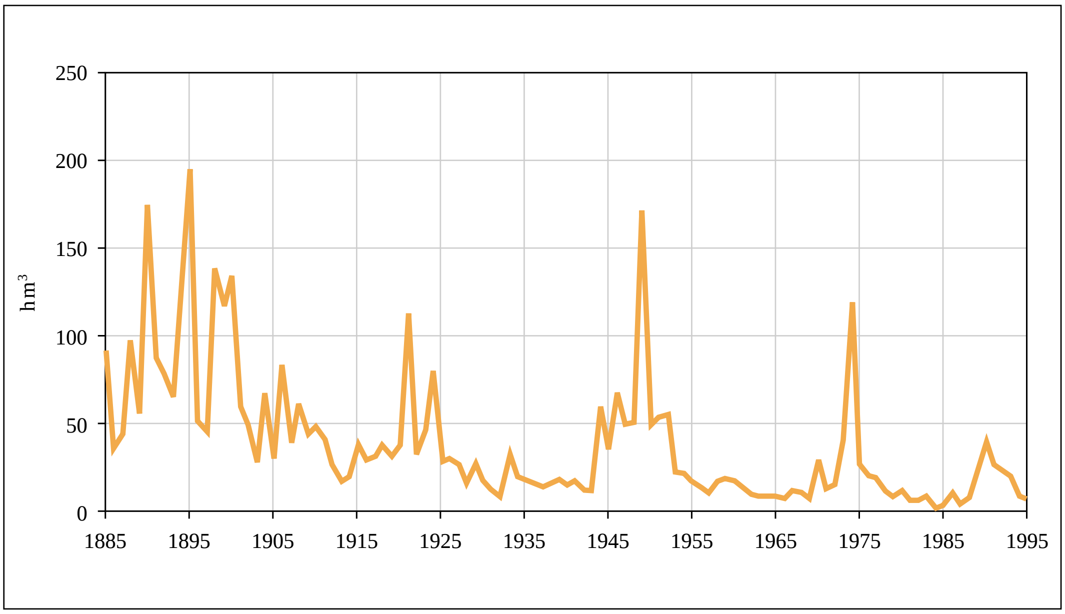


Figure 69. Series of annual cumulative flow of the river Guadalentín at the Puentes Dam as of 1885.

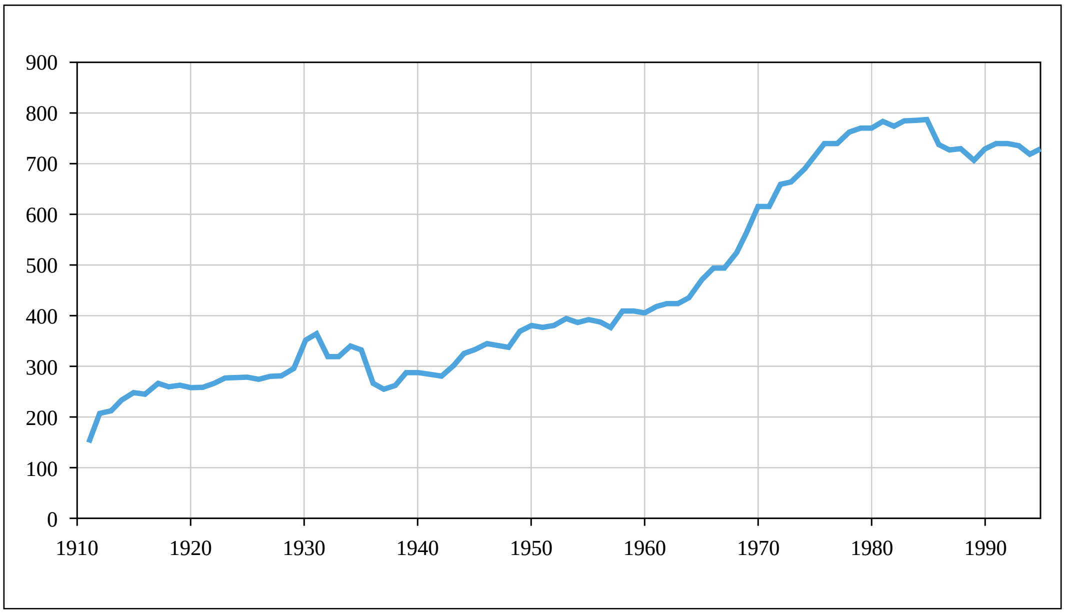


Figure 70. Evolution, as of 1910, of the number of gauging stations on rivers.

eral filing and publicising of data is the Environment Ministry, through the DGOH-CA. In the Catalonia Inland Basins, Galician Coast, Balearic Islands and the Canaries, the responsible organisations fall under their respective autonomous governments.

The ROEA provides information on level and discharge data at selected sites on the rivers and on the main reservoirs and channels. It consists of around 1,200 gauging stations on the rivers (of which about 730 are in service), about 300 control sites on reservoirs larger than 10 hm^3, and about 180 control sites on channels, as shown in figure 71 and table 5, drawn up with information from the Hydrographic Confederaciones and other organisations.

Most of the data from these stations is stored in the HYDRO database, designed and maintained by the Centre for Hydrographic Studies of the CEDEX (Quintas, 1996), an organisation that is commissioned by the DGOHCA to file and publish this information periodically. The data is stored

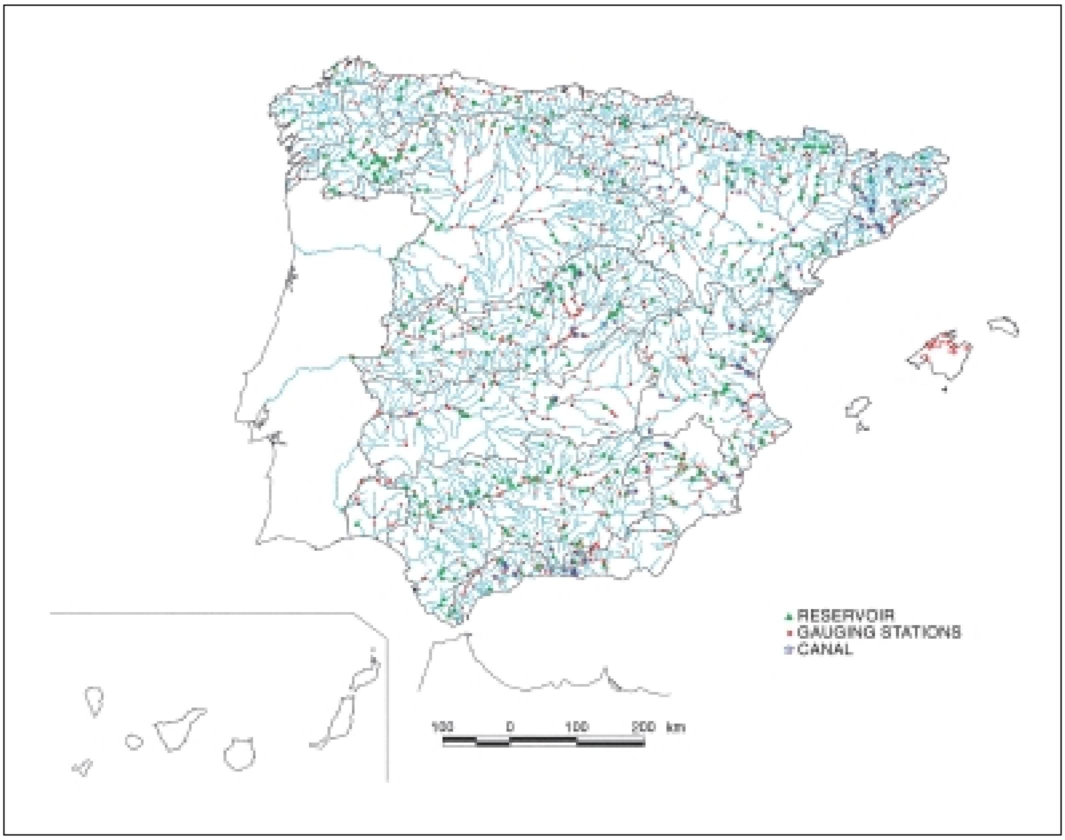


Figure 71. Map of the surface water measurement network.

Surface	Area (km^2) (1)	River gauging stations	Density of river gauging stations (1/km^2)	Monitoring sites on reservoirs < 10 hm^3	Gauging stations on canals
North I	17,600	14	1/1257	25	2
North II	17,330	32	1/541	8	1
North III	5,720	10	1/572	4	0
Douro	78,960	104	1/759	27	1
Tagus	55,810	96	1/581	46	36
Guadiana I	53,180	29	1/1.833	24	8
Guadiana II	7,030	11	1/639	6	0
Guadalquivir	63,240	71	1/891	57	6
South	17,950	48	1/374	12	22
Segura	19,120	17	1/1.125	13	11
Júcar	42,900	44	1/975	19	22
Ebro	85,560	171	1/500	46	35
Galicia Coast	13,130	14	1/938	10	1
Catalonia I.B.	16,490	40	1/412	6	31
Balearic Islands	5,010	31	1/162	0	0
Canaries (2)	7,440	--	--	--	--
Total	**506,470**	**732**	**1/692**	**303**	**176**

Table 5. Monitoring sites in service in the Official Network of surface water gauging stations.

(1): Surface area of different zones resulting from combining the polygonal unit defined by each, obtained from the digitalization of topographical leaves to a scale of 1:50.000 by the Army Geographical Service in UTM coordinates transformed to huso 30.
(2): The ROEA does not currently incorporate information surface water monitoring sites in the Canaries.

and published on a daily basis, although many of the network's stations can register data almost continuously.

The stations that form part of the ROEA have, in general, permanent facilities, and can be supplemented with stations operating over short periods, for example during the study and project stages of hydraulic work, and are later abandoned. In any event, this should be carried out in a very selective and programmed way.

There exist other types of network, such as the Automatic Hydrological Information Systems (SAIH), promoted by the DGOHCA, and implemented in the installation stage in basin organisations. The SAIH represent a useful tool in providing knowledge on the hydrometerological and hydrological situation of basins in real time, and allow, with the appropriate models, predictions on certain short term variables to be made (MOPTMA-CHE [1995]; Aldana et al. [1996]).

At present, the SAIH network only partially covers Spanish territory, although its expansion to all peninsular basins is planned in the short term, and it provides, among other things, real time data –on a time-scale of a few minutes– on level and flow in rivers and channels, reserves and outflow from reservoirs, precipitation, etc. At present, networks in operation are those corresponding to the hydrographic basins of the Júcar, Segura, South, Ebro, Catalonia Inland Basins and Guadalquivir, as shown in the adjoining figure, and in different development stages are those of the Tagus, Guadiana, North and Douro. The oldest official data registered by this network dates from 1988 and corresponds to the Júcar basin, which was the first one where the system was set up (Pedrero, 1996).

Precipitation and flow intensity data on rivers provided by the SAIH is of great interest in the study of storms, and should act as a complement to the daily data from the INM rainfall station network and from the DGHOCA official network of gauging stations on rivers (fig. 72).

Although previous networks arose with a different purpose –the ROEA is a nation-wide, general purpose network, and the SAIH was set up as a specific, real-time network oriented towards floods– at present their objectives and scope are tending to converge and to be conceived not specifically for floods or exploitation, but as instruments for research and monitoring of the public water domain.

3.1.3.1.3. Groundwater networks

With regard to groundwater, piezometric and hydrometric networks are respectively those that provide data on water levels in aquifers and flow in springs. The hydrometric network also includes, occasionally, measurements of some water courses apart from springs.

In Spain, the first data on piezometric level measurements on record date back to the 19th century (when artesianism was being developed), and correspond to the first supply and irrigation wells. However, it was not until the decade of the 1960s when greater planning of systematic research programmes began, with massive development starting at the end of the decade (Caride de Liñán [1992]; Martínez Gil [1994]; Cabezas [1994]).

Apart from the general networks, and as in the case of surface water networks, there are specific networks operated and

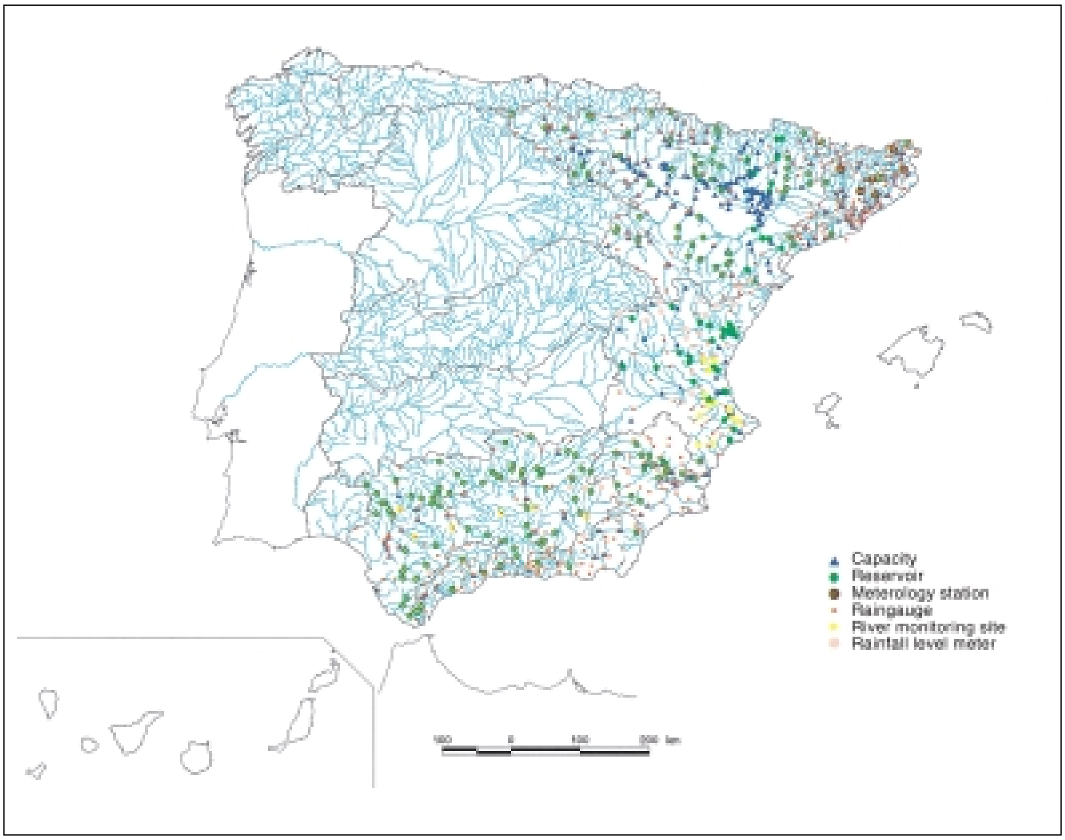


Figure 72. Map of the SAIH Network in operation.

managed by public or private organisations. This is the case of the Eastern Pyrenees network, with about 400 sites, some dating from 1966, and with monthly registers, operated at present by the Water Board, or of some Provincial Delegation networks, such as the Provincial Delegation of Alicante monitoring Network, which has signed an agreement to exchange data with the Júcar Hydrographic Confederación. This network consists of 130 piezometric sites, 200 quality and penetration sites and 20 to measure springs.

Standing out among the existing networks, due to their greater approximation to the objectives of a general-purpose, nation-wide network, are the piezometric and hydrometric networks operated by the Technological Geomining Institute of Spain (ITGE) since the end of the sixties until the present time. In recent years they have been operated jointly by the ITGE and the DGOHCA.

The piezometric network covers about 135,000 km^2, around 80% of the territory's permeable surface area. It consists at present of about 3,000 observation sites (see adjoining table, with ITGE data from 1996), where at least two measurements are made a year, the most common case being to establish quarterly, in some cases, monthly tests. Figure 73, drawn up with MOPTMA-MINER-UPC data (1993), shows some selected sites from these networks (table 6).

Basin	Surface area of permeable boundaries (km^2)	Number of piezometric network sites (1996)	Density of piezometric network (1/km^2)	Number of hydrometric network sites (1996)	Density of hydrometric network (1/km^2)
Douro	52,798	284	1/186	--	--
Tagus	14,473	84	1/208	75	1/223
Guadiana I	14,740	228	1/65	18	1/819
Guadalquivir	15,157	433	1/35	109	1/139
South	5,215	779	1/7	134	1/113
Segura	7,023	170	1/41	35	1/201
Júcar	23,787	334	1/71	22	1/1.081
Ebro	17,047	237	1/72	72	1/237
Catalonia I.B.	6,596	257	1/26	12	1/550
Balearic Islands	3,675	150	1/25	--	--
Total	**163,511**	**2.956**	**1/55**	**477**	**1/343**

Table 6. Number of piezometry and hydrometry network observation sites.

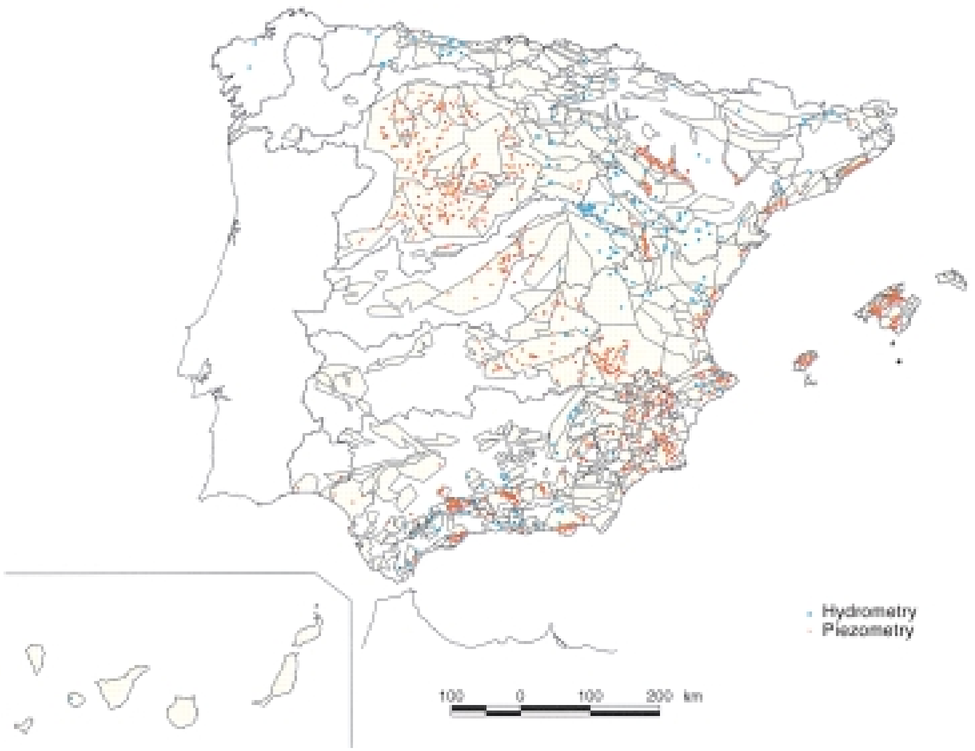


Figure 73. Map of selected sites in the piezometric and hydrometric networks.

The hydrometric network (gauging of springs) covers a surface area of around 42,000 km^2 and consists of almost 500 observation sites. In recent years the number of sites on these networks has fallen, as shown by the drop from 4,500 sites in the piezometric network in the period 1980 to 1985, to less than 3,000 at present. Figure 74 shows the amount of piezometric data registered in the Segura basin as of 1960; although it refers to a specific territory, it clearly illustrates the overall process.

As may be seen, gathering systematic data began at the end of the 60s. Groundwater research really took off in the first half of the 70s, producing almost 4,000 data entries a year, while from the mid-80s the figure decreased to about 1,000, and with ups and downs and a downward trend in the 90s.

Recently, the Administration has programmed a series of actions in order to implement new measurement networks to make up the Official Groundwater Monitoring Network in the future (MOPT, 1992).

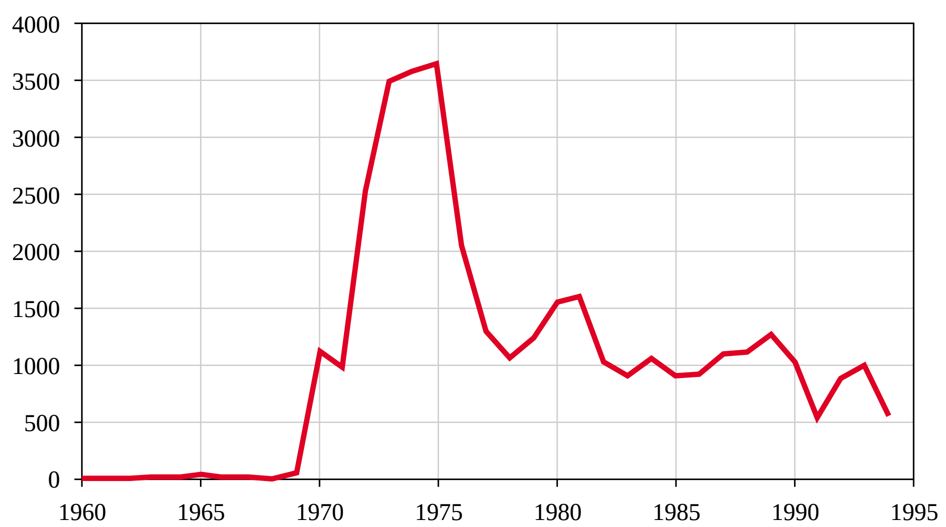


Figure 74. Evolution from 1960 of the amount of piezometric data in the Segura basin.

Table 7 shows the proposed measuring sites, differentiating pre-existing and newly-implemented sites, selecting the former to gather the characteristics to be required from network monitoring sites.

There are therefore 1,910 monitoring sites, with a permeable monitored outcrop area of approximately 160,000 km^2. The average density is one monitoring site per 85 km^2, with extreme values corresponding to the Duero basin and the Balearic archipelago, with one per 142 and 30 km^2, respectively.

This implementation programme for groundwater monitoring networks began in 1994 with a planned duration of 6 years, currently in execution. As of 1996, responsibility for publishing data from these networks, together with surface water data, corresponds the DGOHCA of the Environment Ministry.

3.1.3.2. Comparison with other countries

Having described the situation of our basic networks, it is interesting to compare this situation with that of other, neighbouring countries.

According to a study by the World Meteorological Organization (WMO, 1991) the density of rainfall gauging stations in Spain is well above the minimum recommended by the WMO and, in relation to other countries, stands at an acceptable level. The same does is not true of the density of surface water measurement networks, where Spain numbers among the last, some distance from other countries around us.

The adjoining table –drawn up with EEA data (1996a)– shows the number of stations in the surface water networks in different countries of the European Union (UE), for which average density is around one station per 270 km^2 (table 8).

The number of operative stations in the official river capacity network in Spain (732) represents a slightly lower density rate than the average (approximately one station per 600 km^2) recommended by the WMO (1981) for mountainous-type regions, but it is significantly lower –about 1/3– than the European average of one station per 270 km^2, only standing higher than rates in the Scandinavian countries, which have extensive areas of lacustrine and uninhabited territory.

These figures highlight the very low comparative level of the surface water capacity network, even less explicable bearing in mind the greater resource scarcity in our country, as will be seen later on.

As for groundwater, table 9 shows average densities of piezometric monitoring networks in some European countries, taken from the EEA.

The figures in the above table show that Spain has similar densities to Portugal, clearly lower than Germany, Austria, Holland or the UK, and only higher than Denmark, a country with the largest percentage of groundwater resource use as regards the total in the whole European Union, as we shall see later on.

3.1.3.3. Problems, conclusions and proposals for action

Generally speaking, and without reserve, it should be stated that the issue of measurement networks is one of the main pending issues as regards water resources in Spain.

In fact, after a major official drive in the decade of the 60s, with the recently created Water Commissions, under the Geology Service of Public Works, and the major hydrogeological research programmes promoted by the Industry Ministry through the Geomining Institute of Spain (IGME), in the 80s and 90s, stagnation may be seen –and even reduction– in the number of existing monitoring sites, showing some indifference to improving and promoting these networks. This reveals, in the final analysis, how the Water Administration's priorities were oriented towards other objectives at that time, and not towards monitoring and

Hydrographic basin	Permeable boundary area	Number of monitoring sites			
		New execution	Pre-existing	Total	Mean density (1/km^2)
North	5,548	58	20	78	1/71
Douro	52,798	280	93	373	1/142
Tagus	14,473	93	38	131	1/133
Guadiana	14,740	118	86	204	1/72
Guadalquivir	15,157	184	122	306	1/50
South	5,215	76	67	143	1/36
Segura	7,023	75	41	116	1/61
Júcar	23,787	121	137	258	1/92
Ebro	17,047	107	71	178	1/96
Balearic Islands	3,675	57	66	123	1/30
Total	**162,463**	**1.169**	**741**	**1910**	**1/85**

Table 7. Foreseen national piezometric network (intercommunity basins and Balearic Islands).

Country	Surface area (km²)	Number of stations	Mean density (1/km²)
Austria	83,850	861	1/97
Denmark	43,092	417	1/103
Spain	506,470	732	1/692
Finland	338,130	322	1/1050
France	543,965	3,500	1/155
Ireland	70,285	1,243	1/56
Italy	301,277	969	1/310
Portugal	92,389	213	1/433
United Kingdom	244,410	1,339	1/183
Sweden	449,960	420	1/1071
Total	**2,673,828**	**10,016**	**1/267**

Table 8. Comparison of surface water measurement networks in different European countries.

measuring water, which should unquestionably represent one of their main, undeniable functions.

Even the SAIH network, which is the exception to this trend and a major effort in promoting data-collection, is conceived initially as associated with exploitation and floods, and not as a modernisation of the official monitoring networks for the public domain.

This drop in recent years which, as mentioned, contrasts with the promotion of networks up to the early eighties, is additional to a serious lack of means in managing and processing information generated, and, in some cases, major delays in publishing it.

The varied number of existing networks and organisations in charge of their administration, necessarily requires that procedures be set up for unification and exchange of information, which presently does not happen. With this White Paper, an initial effort has been made to collect a large part of the existing information, with the intention by the DGOHCA of unifying and publishing it in the short term.

Specifically with respect to meteorological networks, the main observation that can be made, as regards the assessment of water resources, is that the number of stations is very low in higher-altitude areas, as shown in figure 75.

Figure 76 additionally shows, in the first graph, the accumulated percentage curve of surface area of the territory compared with number of stations, with a point on the curve for each of the levels given in the above figure, and, in the second graph, the percentage of surface area and stations that exists under each level.

It may be clearly seen that stations are concentrated at lower levels, in comparison with what would be a perfectly uniform distribution over the whole relief of the country (45° blue line in the first graph, or both distributions superimposed in the graph second). Thus, while half of Spanish territory lies below the 700 level, 65% of stations is below that level, and almost 50% of all stations is concentrated in the third of the land with lower altitude.

A large part of the water resources in Spain is generated at basins headwaters, where a high percentage of reservoirs are located, while rainfall gauging stations are located mostly in valleys and beside channels, as shown in figure 77, illustrating a region of the Bay of Biscay Coast. Direct use of the data registered in stations gives rise to significant under-evaluation of precipitation volume, due to the considerable growth rate of rainfall with altitude.

As for the official surface water capacity network, their density may be described as very low in some basins, as is the case of the Guadiana I area, where, on average, there only exists one gauging station per 1,800 km². Bringing the Spanish network up to the European average would involve practically tripling its current density.

Another deficiency of the official network is that it does not consider some points that are key issues in researching ands managing water resources.

Additionally, there is often no precise idea of the uncertainty of flow data. This is indirectly estimated from water levels and from the stage discharge, which relates level and flow. This curve is obtained through direct gauging, which requires the gauging station's up-keep and maintenance,

Country	Mean density by permeable surface area (1/km²)	Mean density by country surface area (1/km²)
Germany	1/3	1/7
Austria	1/8	1/27
Denmark	1/216	1/216
Spain	1/55	1/171
Holland	1/9	1/10
England	--	1/45
Portugal	1/51	1/149

Table 9. Average density of piezometric monitoring networks in European countries.

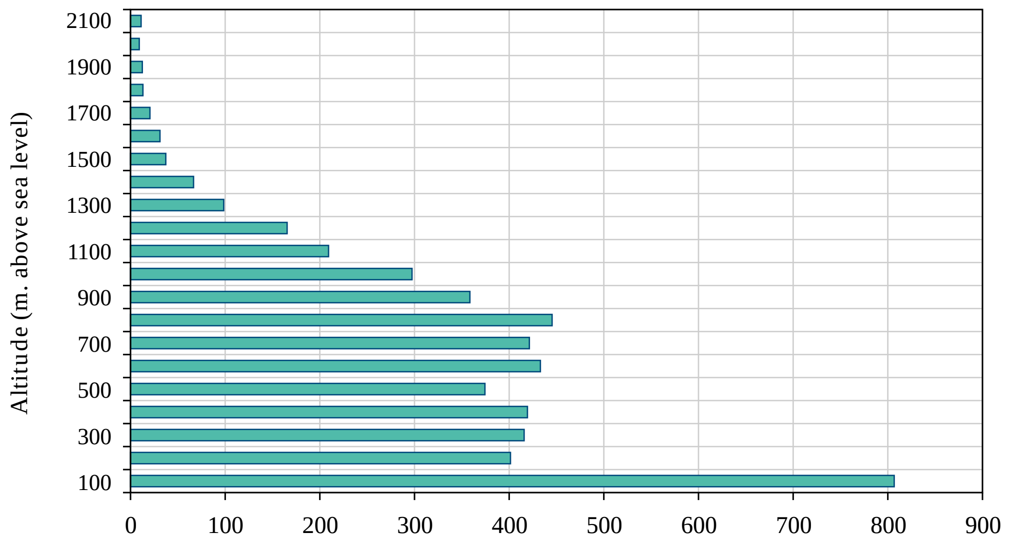


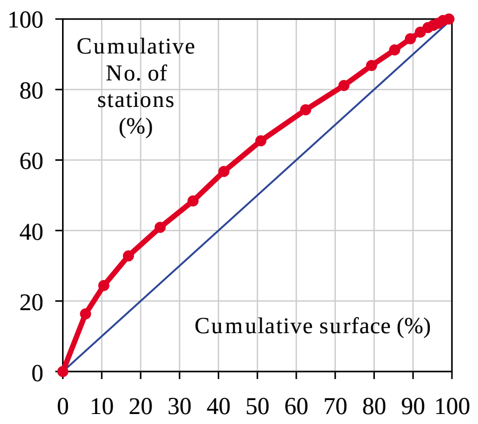
Figure 75. Distribution of meteorological stations according to altitude.

something that does not always happen due to lack of funds. It is common for flood flow data to be estimated from extrapolations of the stage discharge curve not supported by direct gauging of high water nor by hydraulic models of the station's operation, which sometimes leads to low reliability of these estimates.

Although improving this network should be a priority for most of the basin organisations, a programme does not presently on a national scale that considers the coordination, modernisation, optimisation of monitoring sites, densification of the network and improvement in its administration.

A programme like this should contribute to new stations complying with the basic objectives of a general-purpose network, which are, among other things: to measure surface water flow and storage, both in natural and affected reaches, to evaluate the river flooding, to supplement the interpretation of groundwater and quality data , to provide information for the planning and administration of resource exploitation systems and to support hydrological investigation. The need for such a program is patent.

The SAIH network also registers surface water data at a large number of sites and transmits it in real time. Greater coordination is desirable between this network and the ROEA, whose responsibilities, in most cases and as a result of the above-mentioned initial orientation given to the SAIH network, falls into different departments within the same basin organisation. Furthermore, it is not always taken into account that data reliability is much more important that its transmission in real time, and that this is only achieved with appropriate maintenance and with specialist hydrology and hydraulic technicians, who are not always available in these organisations.



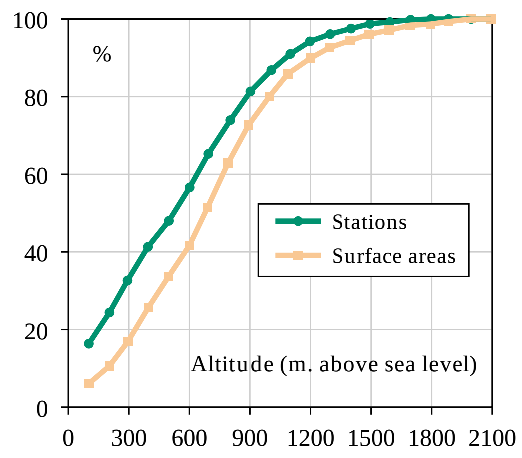


Figure 76. Cumulative percentage curve of territorial surface area compared with number of meteorological stations at different altitudes.

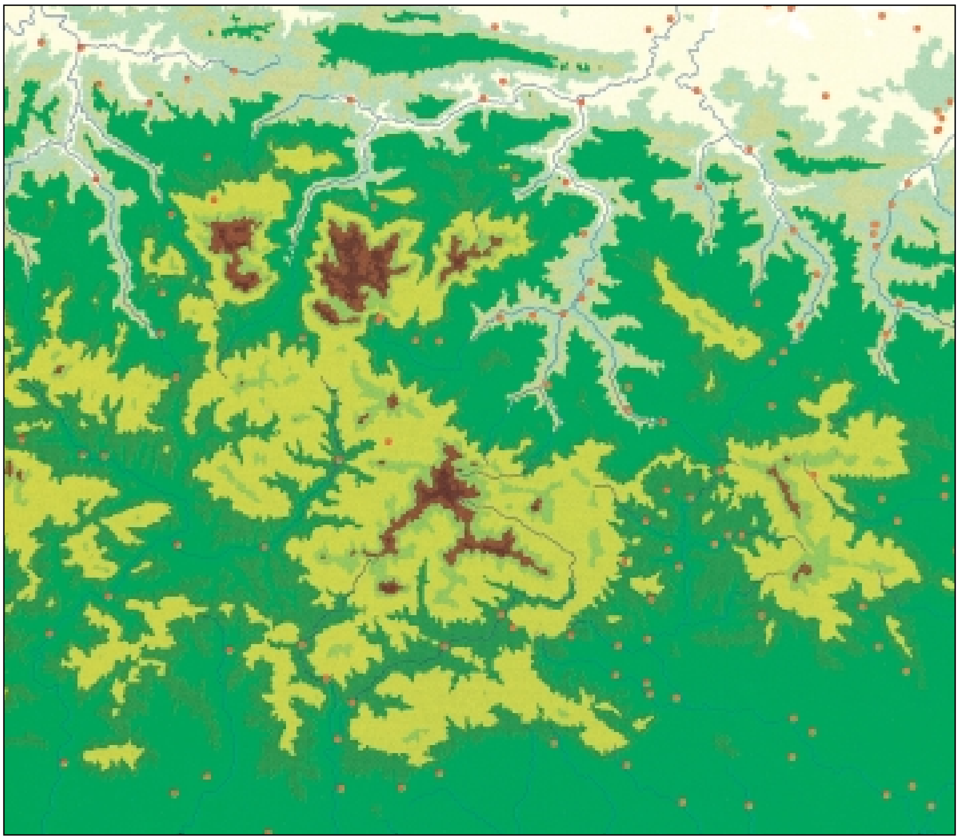


Figure 77. Map of spatial distribution of rainfall gauging stations in Picos de Europa, on a digital land model.

Obviously, the functionalities of the SAIH networks would have to be extended to all the hydrographic basins, completing their nation-wide coverage, and promoting the development of utilities that this type of real-time network can provide (hydro-meteorological alert for civil protection and emergency plans, good reservoir administration in flood situations, etc.).

In short, although different organisations or departments develop and manage their own networks, it is a good idea for a general database to be set up, integrating all existing hydrological information (conventional, SAIH, territorial, etc.) and making it easily accessible to the public in a simple, homogeneous format.

In view of this question's major importance and the need to improve the official network, the real basic measurement network for water in Spain, it will also be necessary, in the immediate future, to intensify maintenance and improvement efforts on this network, to integrate data from other networks and to publicise the important environmental information generated.

As for groundwater, the main observations that can be made on the piezometric and hydrometric networks are the low density of stations, already mentioned above, and that they are not designed with technical criteria in accordance with the objectives that a nation-wide network should pursue. So far, barring small exceptions, monitoring sites are located on wells or bore holes built for supply or irrigation, generally private property. This gives rise to lack of precision in information, which, in a sense, is the information that has historically been available instead of what is desired and expected.

Also, and as already mentioned, there has been a drop in recent years in the number of sites in these networks, as shown by the reduction from over 4,500 piezometric network sites in the period 1980 to 1985, to less than 3,000 at present. We should remember that in 1985 a Water Act was passed which included, among its major decisions, the consideration of groundwater as public property. However, and surprisingly, not only were administrative reforms and decisive action not taken with a view to improving knowledge of these resources, but instead this knowledge has progressively deteriorated from then on.

The fact that available information is generally scarcer and of poorer quality now than what was available twenty years ago is difficult justify, and it cannot be understood except in the context misguided idea of the Water Administration's objectives and functions.

3.1.4. Natural resources

Assessing water resources in a natural regime is a complex task that, technically, is still not definitively resolved. It should be supported by the data registered in gauging stations that usually measure affected regimes.

As mentioned, restoration of this data to a natural regime, although theoretically simple, involves major difficulties in practice, because it is not common to have enough information on the temporary evolution of flow abstracted from rivers, on pumping from aquifers, on returns from irrigation or supply, or on the operation of the hydraulic infrastructure. For that reason, there should be combined use of mathematical simulation models of the hydrological cycle, whose purpose is to reconstruct the natural hydrological regime from meteorological data, from the basins' physical characteristics and from data registered in the gauging stations. As we shall see, such a combined approach is the one carried out in this White Paper and, for first time, in a massive, distributed way for the whole country.

3.1.4.1. Total runoff in a natural regime

To study total runoff that takes place in our territory we shall firstly analyse the regime of precipitation and of evapotranspiration. These are the two basic climatic variables that, with geological monitoring established by the terrain, make up the runoff regime. After this, we shall offer an evaluation of this total runoff, and present the procedures used and results obtained in the evaluation process.

3.1.4.1.1. Precipitation

On an inter-annual scale, the spatial variability of precipitation in Spain is shown on the adjoining map, presenting the average annual values for precipitation (in mm) for the 56-year period comprised between the hydrological years (from October to September) 1940/41 and 1995/96. The values shown on the map have been obtained by interpolating the data registered in the INM network rainfall gauges by means of the inverse square method (fig. 78).

Annual precipitation values vary greatly, from over 1,600 mm in extensive areas of the territory, where levels can even exceed 2,000 mm, to 300 mm in wide areas of the peninsular southeast and less than 200 mm in some areas of the Canary Islands. The average for Spain is 684 –equivalent, as we have seen, to 346 km^3/year– and its intra-annual distribution, on a monthly scale, is shown in figure 79, illustrating that, overall, the rainiest month is December, and the least rainy is July.

In this figure, it is also interesting note the similarity of values in the period between January and May, probably arising from the effect of overlapping and average of different rainfall regimes in different parts of the country.

Furthermore, and complementing the description of spatial variability, average area values from a sufficiently long rainfall series is generally used to characterize temporal rainfall variability in an area. Figure 80 shows annual values for average area precipitation in Spain in the 56-year period between 1940/41 and 1995/96, together with the global average for that period.

A study of the previous series highlights the fact that runs of dry years are longer than wet ones, as corresponds to non-gaussian data with positive bias. The two longest dry runs, understanding these to be when the series average is not exceeded, have a duration of 8 (period 1979/80 to 1986/87) and 5 years (1990/91 to 1994/95), while the two

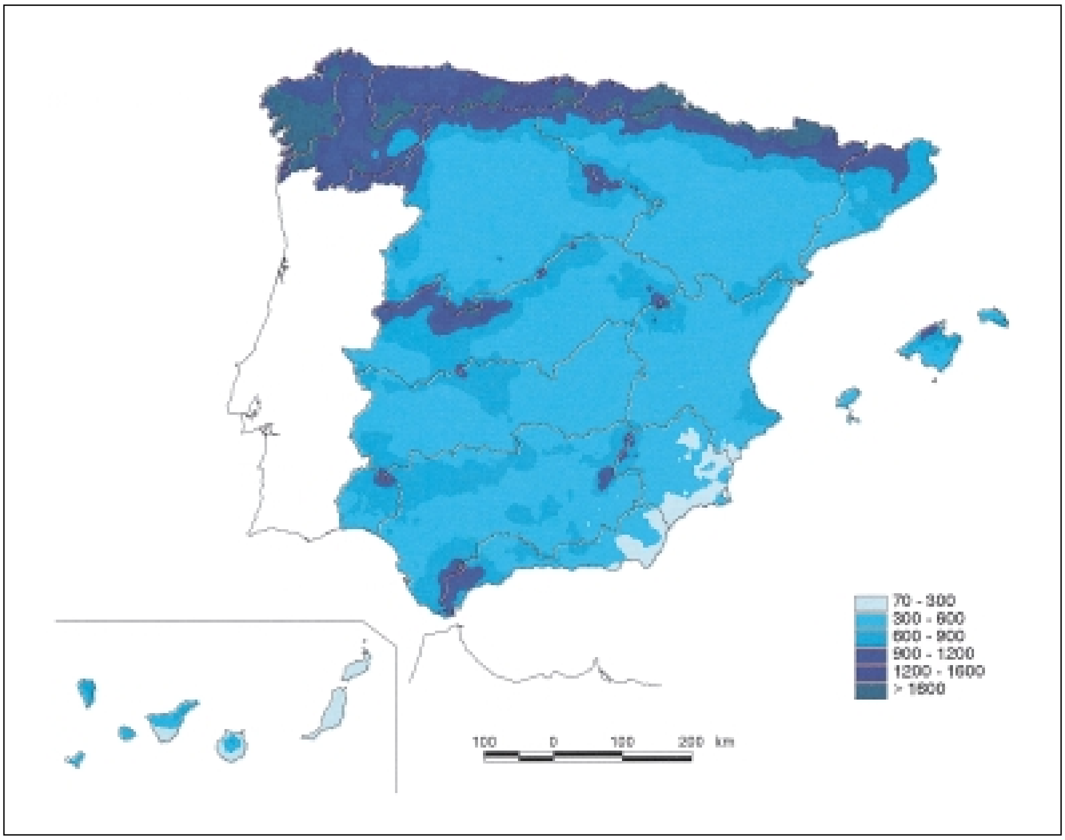


Figure 78. Map of average annual precipitation values (mm) in the period 1940/41-1995/96.

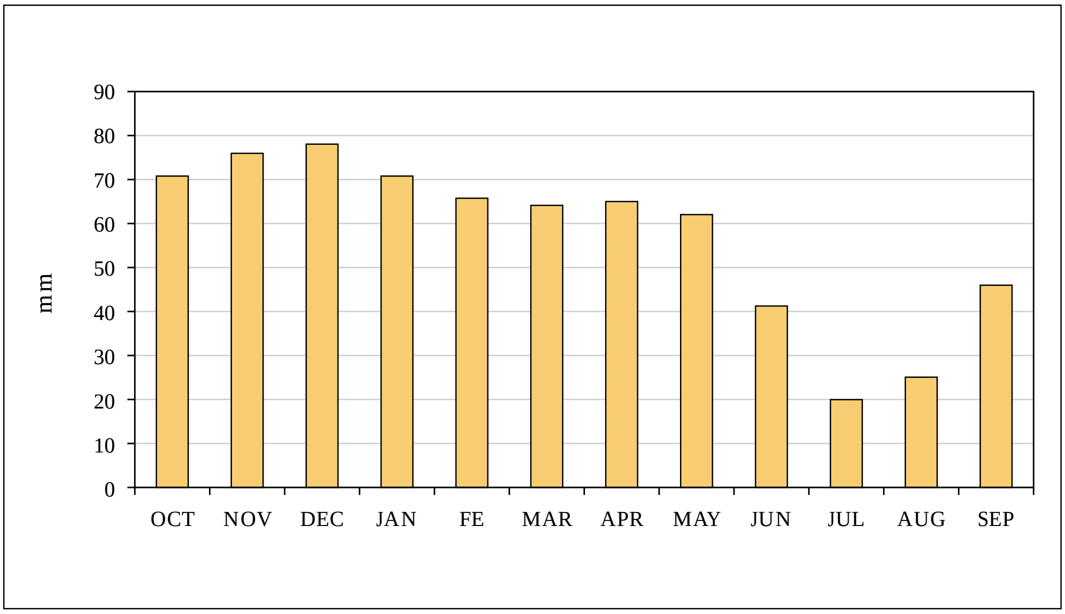


Figure 79. Monthly distribution of average precipitation in Spain.

longest wet ones are of 6 (1958/59 at 1963/64) and 3 years (1976/77 at 1978/79). It is also interesting to highlight that during the 17-year period comprised between 1979/80 and 1995/96, the series average has been exceeded on only 3 occasions, which is very illustrative, as we shall see, of the serious water shortage problems that have taken place in recent years in many parts of Spain.

To have a better overall understanding of these periods, a series has been drawn up on accumulated unitary deviations (deviation is a value's difference with respect to the series average, and unitary deviation is the deviation divided by the average), shown, together with its centred moving average for 5 years, in the adjoining graph. Ascending trends will reflect wet runs and descending trends will reflect dry runs (fig. 81).

As may be clearly seen in the previous figure, 3 different periods exist: one generally dry from 1940 up to 1957, followed by a generally wet one from 1958 up to 1978 (possibly with two sub-periods of different intensity separated by 1963), which is finally followed by another dry period from 1979 up to 1995. To what extent such overall runs are representative of the different territories will be seen further ahead, when we return to these interesting questions in the analysis of other hydroclimatic runs, regional differences, and the problem of how representative hydrological registers are.

An interesting aspect is the autocorrelation structure of annual rainfall (that is, the dependence relationships of rainfall in one year with respect to those of previous years). To contrast them, figure 82 shows the functions of the series' autocorrelation and partial autocorrelation, together with their confidence intervals of 95%.

Both functions clearly show the non-existence of temporal dependence of annual precipitation, which means that it

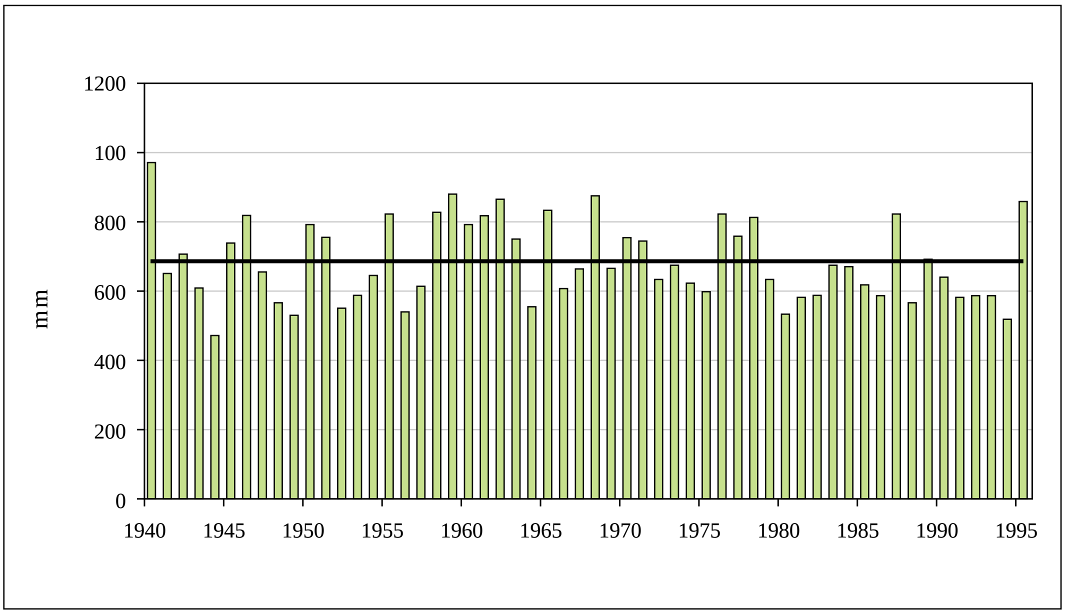


Figure 80. Series of average annual precipitation in Spain in the period 1940/41 -1995 /96.

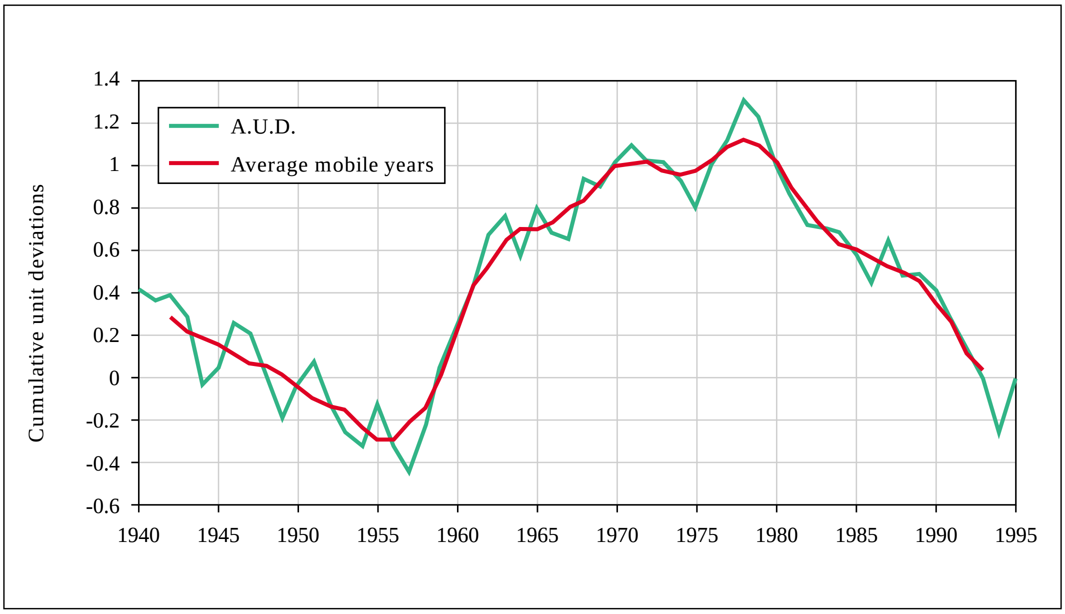


Figure 81. Runs of average annual precipitation in Spain in the period 1940/41-1995/96, as of accumulated unit deviations.

cannot improve rainfall prediction of the following year by considering previous ones, because every year is entirely independent of the previous one, and it is a phenomenon without memory.

Furthermore, pluri-annual rainfall cycles of a periodic nature are not observed. Phenomena such as solar activity cycle (related with sunspots, which have periods of about 11 years) do not seem to affect average precipitation registered in Spain. It is curious to see that this hypothetical relationship, closely studied in registers all over the world since the decade of the 60s, was anticipated in our country by Bentabol (1900), concluding –after study of Almería, the Ebro, Valencia, Guadalquivir Valley, Castile, Murcia and France– that the frequency of droughts and floods seemed to occur according to the solar cycle in a generalised way and, very especially, in Murcia. As may be seen, modern analyses of rainfall registers do not support this old hypothesis at present.

Considering the different territorial areas now, table 10 gives different basic statistical measurements of the series of annual areal precipitation, for the period 1940/41 to 1995/96, in each of the territorial areas of water planning.

As can be seen, not only are there major inter-territorial differences in average annual rainfall quantities, but also in their relative variability, measured by the coefficient of variation (ratio between typical and average deviation). The map in figure 83 shows the spatial distribution of this coefficient, expressed as a percentage. It can be seen that, notwithstanding the simplification of using areal averages for different regions, reducing extreme inland peaks, the areas with least precipitation (South, Southeast, Canary Islands, etc) have a coefficient of greater variation, adding greater temporal irregularity to scarcity in precipitation. The opposite is true of areas with greater precipitation, where the variation coefficient is smaller.

Figure 84 gives a visual, qualitative idea, by simple colour coding, of this opposition effect between rainfall quantity and variability, on the spatial scales of planning areas.

Similarly, the graphs in figure 85 show this opposition effect, which also seems to appear –with the due reserve for their high sampling variability– with the bias coefficients, indicative of positive asymmetry and, therefore, of a greater presence of high extremes.

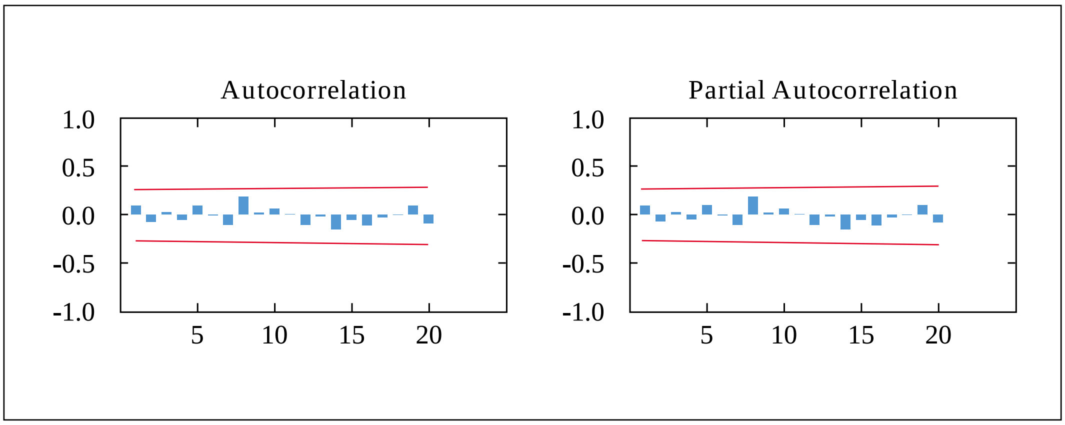


Figure 82. Autocorrelation and partial autocorrelation functions of annual average precipitation in Spain in the period 1940/41-1995/96.

Planning Area	Minimum	Average	Maximum	Max/Min	Coef. of variation	Coef. of bias	1st coef. of autocorrelat.
North I	797	1,284	2,017	2.5	0.22	0.62	0.08
North II	899	1,405	1,888	2.1	0.14	–0.24	0.07
North III	958	1,606	2,282	2.4	0.16	–0.15	0.03
Douro	381	625	931	2.4	0.21	0.40	–0.02
Tagus	374	655	1,037	2.8	0.23	0.32	0.05
Guadiana I	261	521	755	2.9	0.25	0.07	0.19
Guadiana II	278	662	1,142	4.1	0.30	0.31	0.14
Guadalquivir	272	591	1,026	3.8	0.28	0.40	0.27
South	247	530	908	3.7	0.27	0.71	0.17
Segura	221	383	643	2.9	0.26	0.36	0.27
Júcar	302	504	805	2.7	0.21	0.61	0.19
Ebro	526	682	925	1.8	0.16	0.54	0.12
Catalonia I.B.	437	734	1,147	2.6	0.22	0.64	–0.18
Galicia Coast	929	1,577	2,324	2.5	0.20	0.27	0.01
Peninsula	472	691	985	2.1	0.17	0.40	0.11
Balearic Islands	381	595	975	2.6	0.23	0.76	0.20
Canaries	119	302	574	4.8	0.33	0.55	0.05
Total Spain	**469**	**684**	**970**	**2.1**	**0.17**	**0.39**	**0.10**

Table 10. Basic statistics of the series of annual area precipitations corresponding to the period 1940/41-1995/96, by basin planning area.

In fact, studying the table of basic statistics shows that the bias coefficient, although small, in a large part of areas takes on positive values significantly different from zero, indicating a certain degree of asymmetry in the distribution of annual precipitation, with a greater probability of lower-than-average values than higher, as mentioned above. As for temporal autocorrelation, it can be seen that the value for the first autocorrelation coefficient is very small and not significant in all the areas, confirming the above-mentioned temporal independence of annual precipitation.

Going on to study the space-time structure of this rainfall, table 11 shows the correlation matrix for annual precipitation, for the period 1940/41-1995/96, in the different areas. In summary, and since this matrix is symmetrical, correlation coefficients are shown in the lower, diagonal half, and

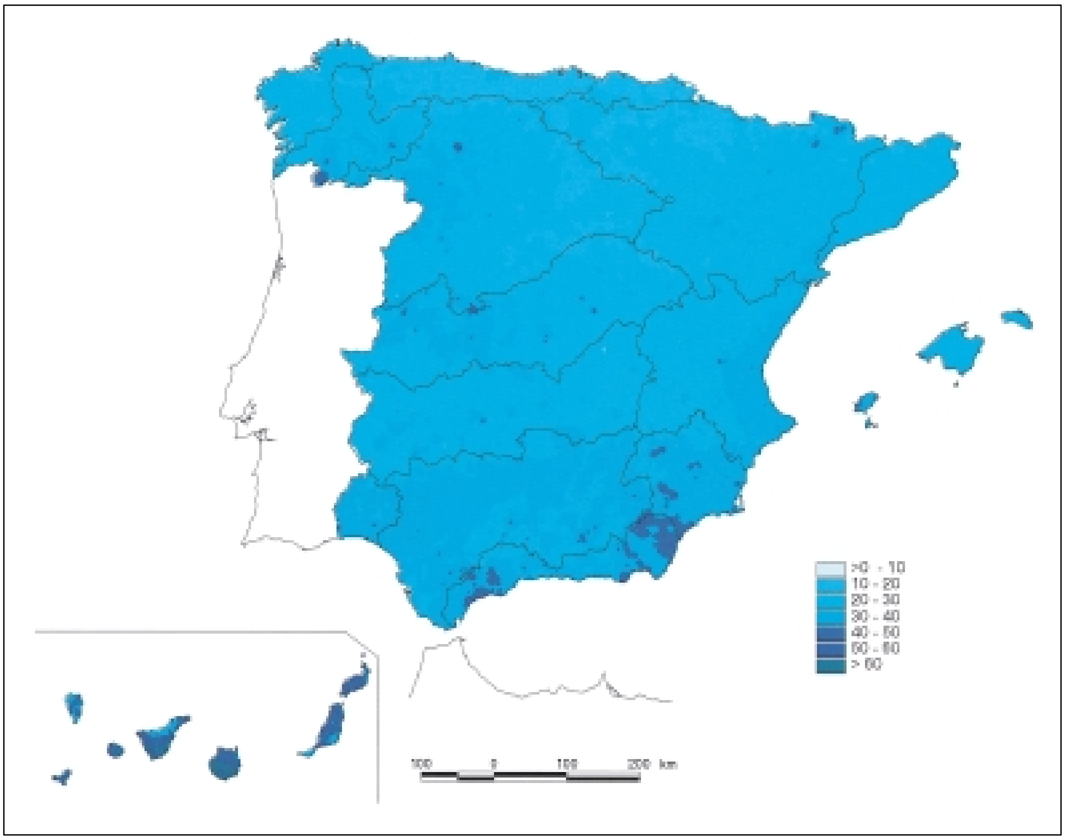


Figure 83. Map of coefficients of variation (%) of annual precipitation in the period 1940/41 - 1995/96.

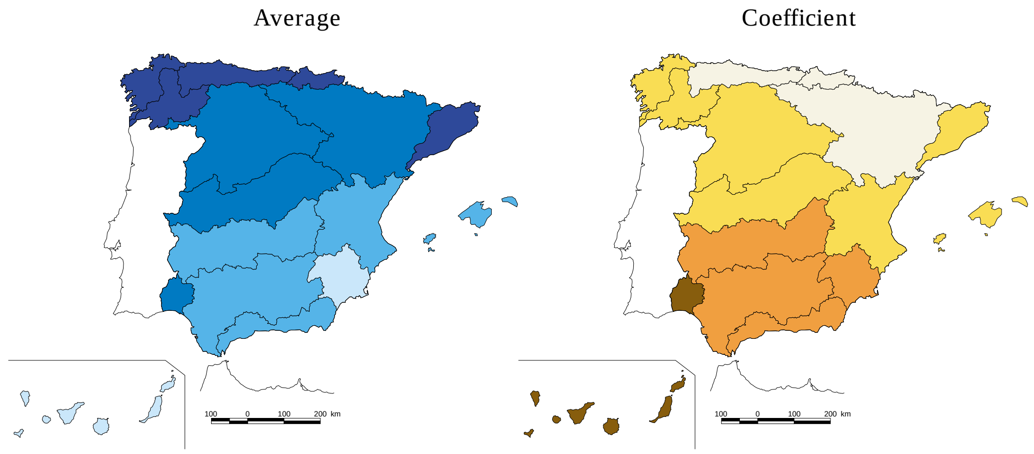


Figure 84. Maps of averages and coefficients of variation in annual precipitation by planning area.

the upper part shows an estimate of the probabilities associated with these coefficients (1 implies no correlation and 0 implies significant correlation).

A study of this table leads to the interesting conclusion that significant correlations exist between groups of areas, but not all with each other. This means that in Spain there exist areas with independent rainfall regimes, without significant cases of dry and wet runs simultaneously in the whole country, underlining, once again, the hydrological variety of Spanish territory.

Furthermore, all the correlations are zero or positive, and there are no cases, between any area pair, of any significant negative correlation. This implies that either there is no simultaneity or there exists a certain simultaneity of drought and abundance, although, significantly, there are no droughts in one area while there is abundance in another, and vice versa.

Taking this study of the space-time structure of precipitation further, and exploring its relative behaviour in different territories, the observation of significant correlations between areas suggests studying its possible affinities, reducing them to similar areas from the point of view of annual precipitation.

If a hierarchical cluster analysis is carried out, some very persistent groupings of areas are obtained. As a result, North II and North III always appear grouped together, as do the Júcar and Segura; the Tagus and Douro; and the Guadiana I and Guadalquivir. Considering these four basic groups globally, their relative proximity, and the rest of grouping obtained, it is possible to put forward a very solid regionalisation of plan-

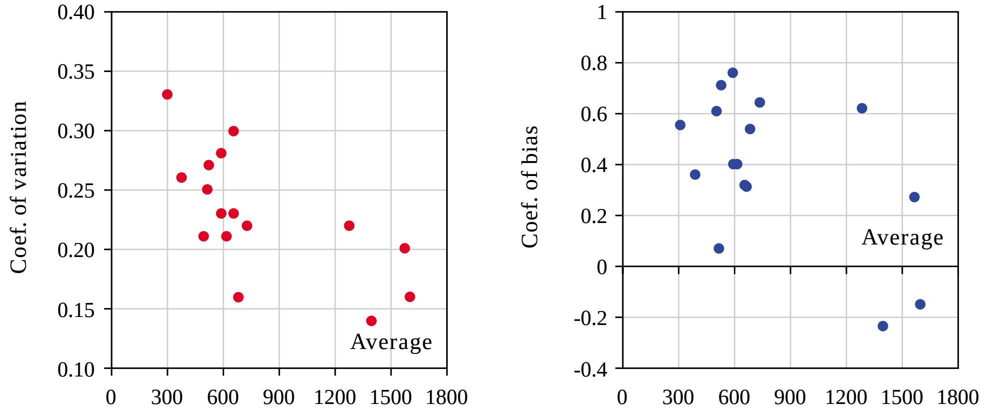


Figure 85. Average precipitation compared with variation and bias coefficients by planning area.

	GAC	NO1	NO2	NO3	DOU	TAG	GN1	GN2	GUV	SOU	SEG	JUC	EBR	CIC	BAL	CAN
GAC	1	0	0	1	0	0	0	0.08	0	1	1	1	0	1	1	1
NO1	0.84	1	0	1	0	0	0	0	0	0.87	1	1	0	1	1	1
NO2	0.58	0.62	1	0	0.1	0.61	1	1	1	1	1	1	0	1	1	1
NO3	0.3	0.23	0.82	1	1	1	1	1	1	1	1	1	0.13	1	1	1
DOU	0.73	0.85	0.43	0.06	1	0	0	0	0	0	1	0.48	0	1	1	1
TAG	0.59	0.78	0.37	0.03	0.92	1	0	0	0	0	1	0.1	0	0.96	1	1
GN1	0.59	0.71	0.33	0.02	0.85	0.92	1	0	0	0	1	0.02	0	0.56	1	1
GN2	0.44	0.53	0.14	–0.14	0.75	0.83	0.87	1	0	0	1	0.17	0.01	1	1	0.16
GUV	0.55	0.67	0.33	0.02	0.8	0.87	0.95	0.87	1	0	1	0.03	0	0.11	1	1
SOU	0.19	0.36	0.11	–0.14	0.54	0.67	0.73	0.78	0.83	1	0	0	0.08	0.45	1	1
SEG	0.01	0.04	0.02	–0.03	0.18	0.22	0.31	0.24	0.32	0.53	1	0	1	1	1	1
JUC	0.19	0.21	0.15	0.05	0.38	0.43	0.48	0.42	0.47	0.54	0.84	1	0	0	0.18	1
EBR	0.58	0.68	0.65	0.42	0.73	0.7	0.67	0.5	0.67	0.44	0.33	0.59	1	0	1	1
CIC	0.21	0.24	0.25	0.13	0.32	0.35	0.37	0.3	0.43	0.38	0.32	0.52	0.71	1	1	1
BAL	–0.07	0.09	0.22	0.14	0.03	0.1	0.06	–0.02	0.12	0.18	0.34	0.41	0.25	0.33	1	1
CAN	0.08	–0.02	0.04	–0.01	0.2	0.24	0.21	0.42	0.23	0.34	0.16	0.25	0.17	0.21	–0.11	1

Table 11. Correlation matrix of the annual area precipitation by planning area.

ning areas, from the point of view of annual precipitation, into seven types, which would be those shown in figure 86.

A large area is the central or Atlantic zone (blue) which can be subdivided into north (C_N: Douro and Tagus) and south (C_S: Guadiana, Guadalquivir and South); another area is the east (L: Júcar and Segura); another would be the north-east (N_E: Ebro, Balearic Islands and I.B. Catalonia); another is the north or Bay of Biscay (N: North II and North III); another the northwest (N_O: Galicia Coast and North I); and, lastly, another would be the Canaries (CA).

The regional organization proposed allows for a review of the question regarding wet and dry rainfall runs, but here coming down to regional level instead of the country's global average, and using rigorously established regions.

Thus, and as above for global areal average, the curves for accumulated unit deviations of regional rainfall have been created, shown jointly in figure 87.

An initial study of this graph shows that, in fact, there apparently exist regional differences leading to the run sequences in the different basins not being the same. A

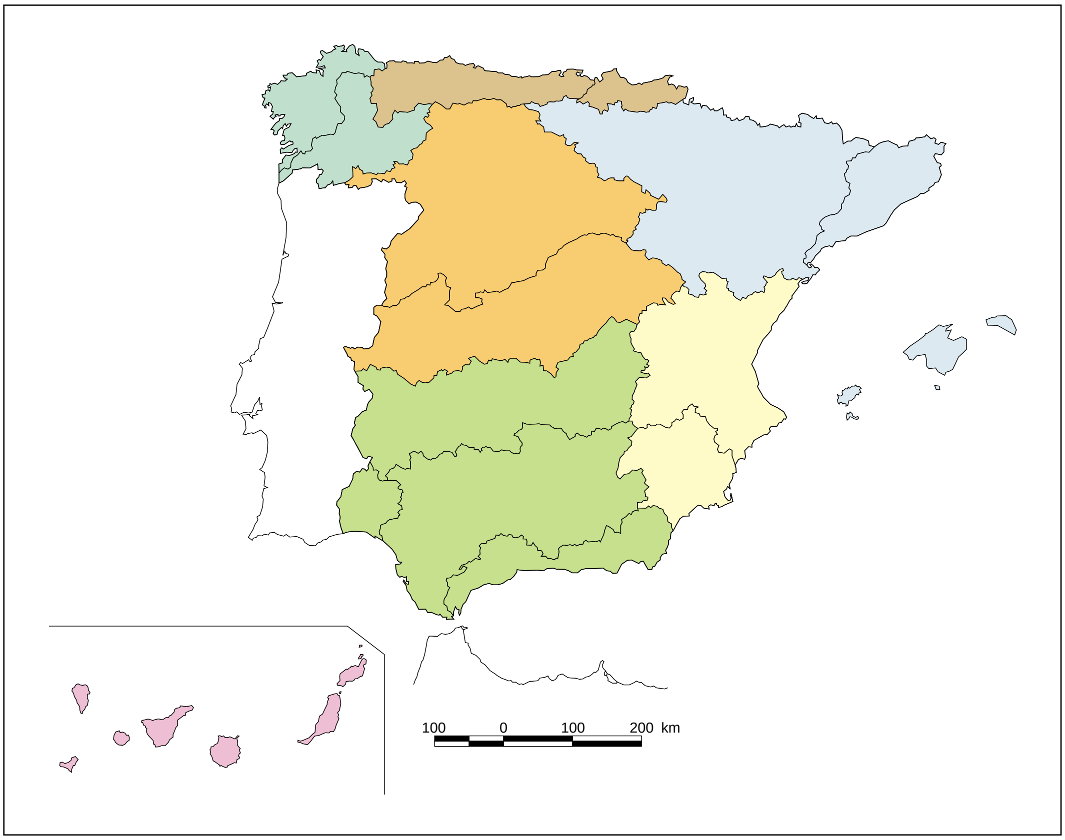


Figure 86. Rainfall regions of territorial planning areas.

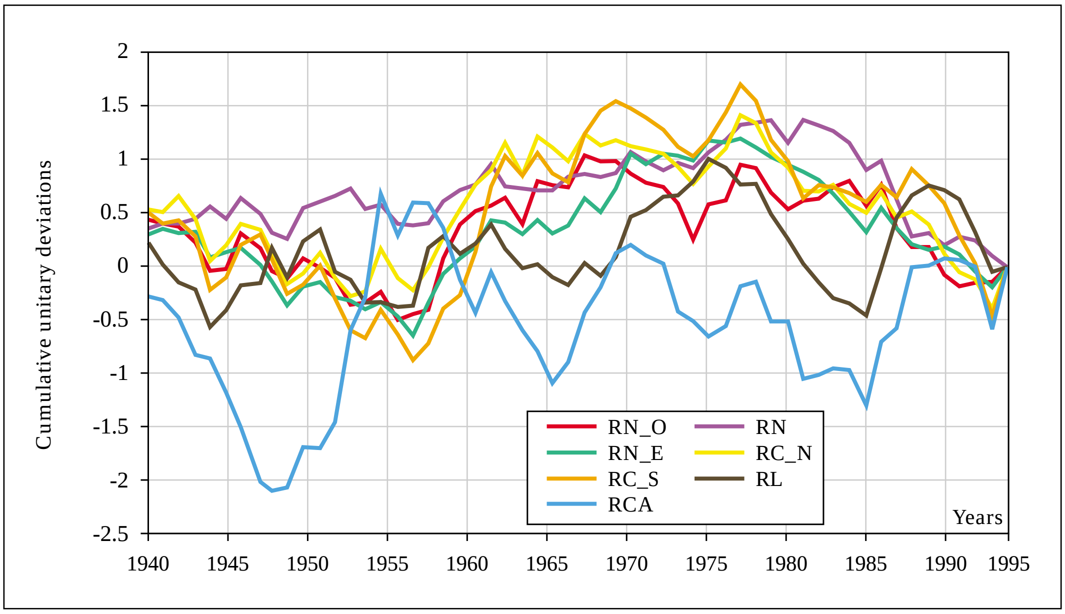


Figure 87. Runs of average annual precipitation in the period 1940/41 - 1995/96, as from cumulative unitary deviations.

detailed inspection shows differentiation between the situations shown in figure 88.

As may be seen, most of the basins (Douro, Tagus, Guadiana, Guadalquivir, South, Ebro, I.B. of Catalonia, North I, Galicia Coast and Balearic Islands) have followed a very similar pattern, which is basically the one offered above as representing the country's global average, although there are three regions (Levante, North and Canaries) that seem to have followed patterns different to this one, and different to each other.

Also, it can be seen how there has been a more or less exacerbated dry run since the late 70s, in all regions, with some fluctuations in the period 1985-90, after which it has been completely widespread. As mentioned, this, among other reasons, explains the serious water supply crisis in many places in Spain in recent years.

The level of detail in all the above analyses is justified by a basic fact, which is that, as mentioned above, precipitation is the origin of water resources, it causes and governs the hydrological response, and its variability is the main source

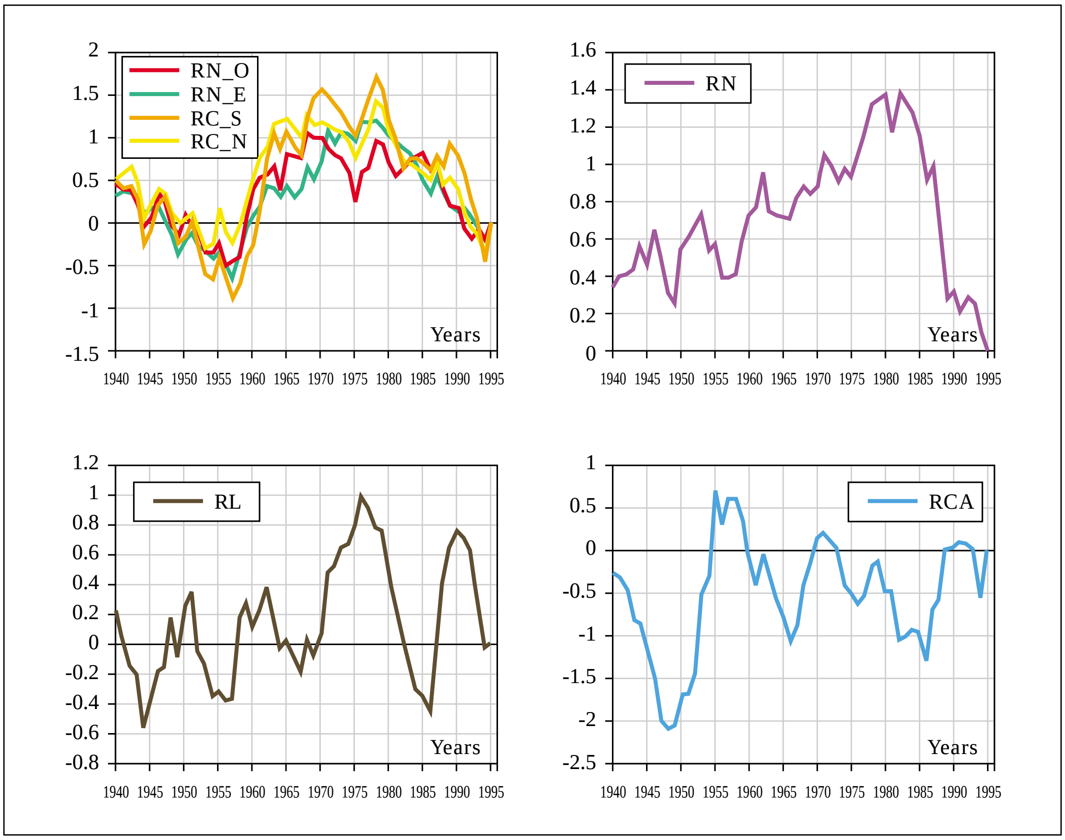


Figure 88. Different situations of average annual precipitation runs by rainfall region in the period 1940/41 - 1995/96, from cumulative unitary deviations.

of river flow irregularity. In fact, rainfall variability is transmitted, and more sharply, amplified, to runoff data, as we shall see later on. Regions of similar rainfall behaviour will probably also be regions with similar hydrological behaviour, and wet or dry rainfall runs will be converted, with greater or lesser delay, into flow runs of an identical type.

Furthermore, if instead of annual data we use data on a smaller scale (e.g. monthly, daily or hourly), this irregularity effect is even more greatly heightened.

3.1.4.1.2. Evapotranspiration

As shown in the above section, average annual precipitation (P) in Spain is 684 mm, equivalent to about 346,000 hm3 /year, a figure which, as also seen, is subject to considerable temporal and spatial variability.

Furthermore, average annual potential evapotranspiration (PET) in Spain, shown in figure 89, is 862 mm in the same period, with maximums in the southern half of the Peninsula, the Canary Islands, and the central Ebro valley. This PET map has been obtained by applying the Thornthwaite method and correcting the results for some monthly factors, regionalised for the whole territory, deduced by contrasting the Thornthwaite and Penman-Monteith methods.

Real evapotranspiration (ET), shown in the adjoining figure, presents an average global value of 464 mm/year in the same period, somewhat lower that PET, since optimum land humidity conditions are not always present for evapotranspiration to take place up to its potential rate. Logically, the greatest relative differences will be seen in the driest territories, and the smallest differences in wetter ones.

This evapotranspiration has been obtained by means of the distributed hydrological model described in sections below (fig. 90). The difference between ET and PET can be seen in the map in figure 91, showing the percentage fraction ET/PET, which is an average of 0.54 for the territory as a whole, and that it varies from 0.18 in the Canaries to 0.97 in the North III area.

It is easy to see the above-mentioned effect of increasing the quotient with greater humidity in the area.

3.1.4.1.3. Effective rainfall

Remembering the hydrological cycle's conceptual description and the graph of main water flow in a natural regime, offered in above sections, it can be seen that if evapotranspirationis subtracted from precipitation, what is left is the water that, either as surface or groundwater, will contribute to total runoff and may therefore be used.

The concept of effective rain as the difference it from precipitation and real evapotranspiration has been widely used in our country in hydrological and regional hydrogeological studies.

The map in figure 92 obtained by subtracting the above two (P-ET), shows this value's spatial variability, and a basic

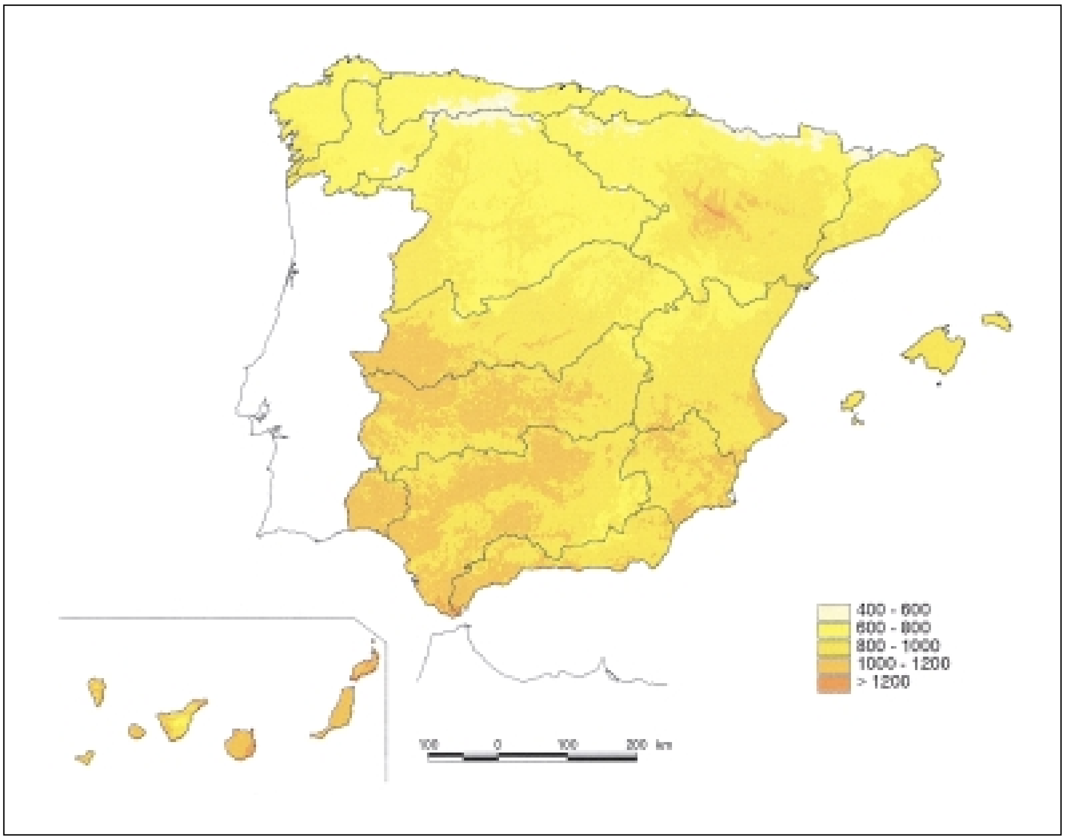


Figure 89. Map of average annual potential evapotranspiration in mm (period 1940/41 - 1995/96)

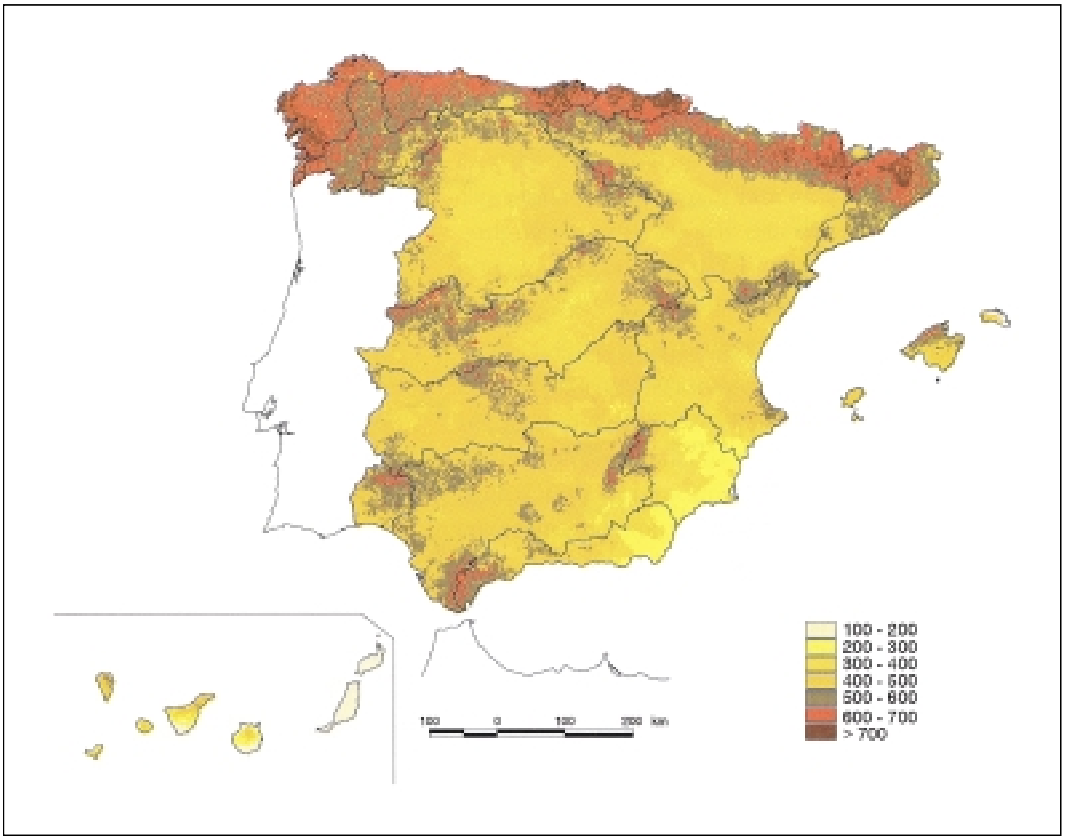


Figure 90. Map of real average annual evapotranspiration in mm (period 1940/41 - 1995/96).

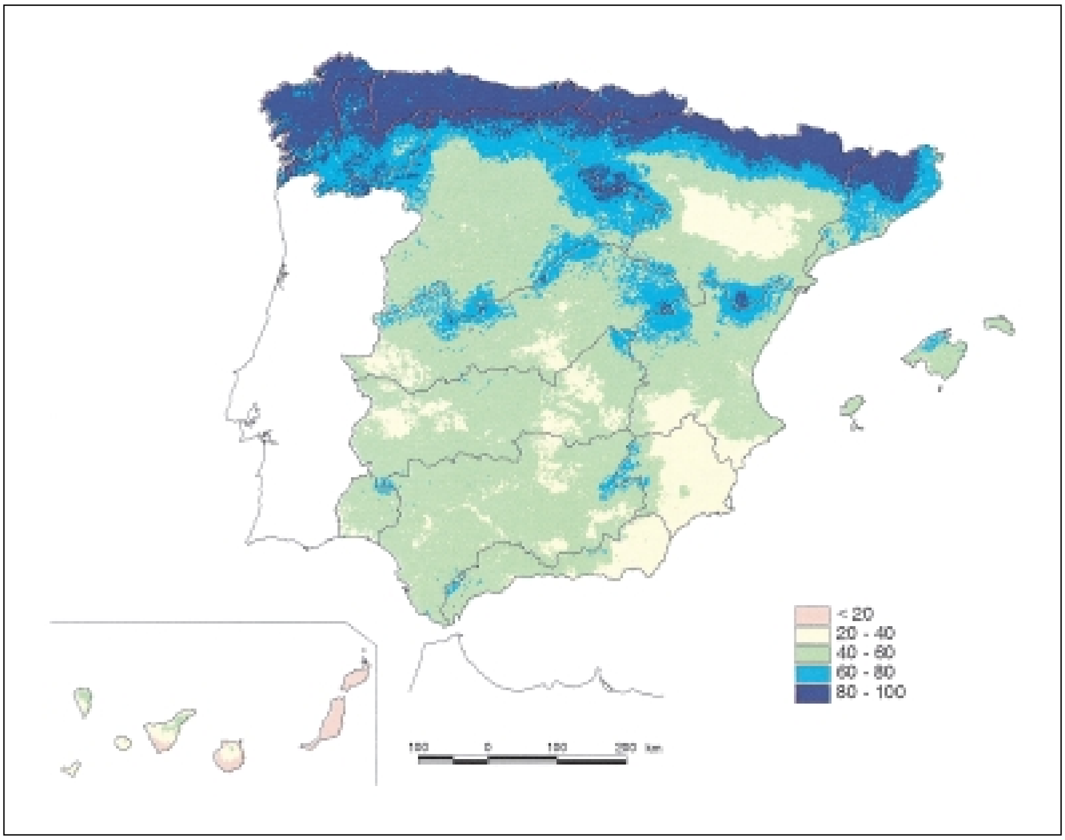


Figure 91. Map of relationship ET/PET (%) (period 1940/41 - 1995/96).

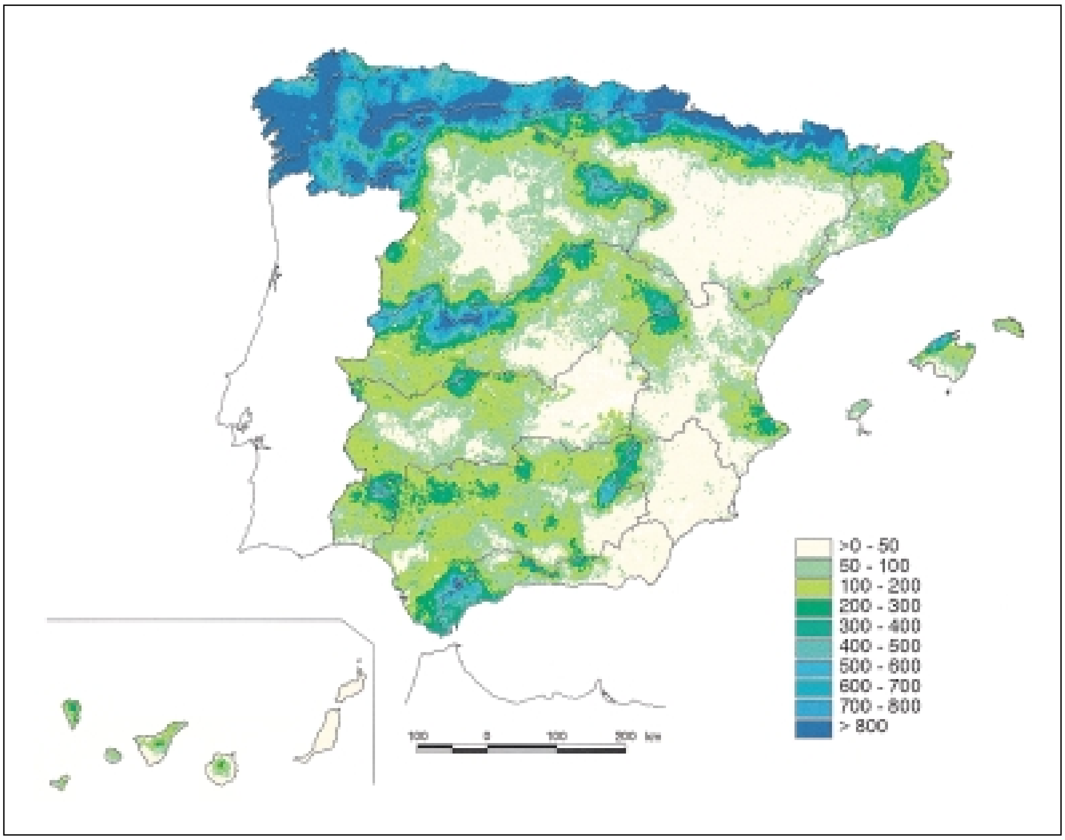


Figure 92. Map of average annual useful rainfall in mm (period 1940/41 -1995/96).

overview of greater or lesser water abundance in different Spanish territories.

In spite of their obvious proximity, the concepts of useful rain and total runoff should not be confused.

The difference between them is that while the first just expresses the difference between precipitation and evapotranspiration, runoff represents total flow by surface unit, and therefore takes into account how useful rain is distributed over ground storage, surface runoff and aquifer recharge, and how it discharges with greater or lesser delay into the drainage network.

Although the differences between the values associated with both concepts may be significant when considering more detailed time scales –days, months or even years–, in average inter-annual values such differences are much smaller (see adjoining figures), and are only due to spatial redistribution that takes place in the discharge of water infiltrated into the aquifer.

3.1.4.1.4. Total runoff

As a consequence of the effect caused by climatic variables, together with land characteristics, average annual total runoff in Spain follows a pattern of spatial behaviour similar to that of precipitation, although with greater variability, as may be seen in the adjoining figure. This total runoff (resource by surface unit or total specific cumulative flow) is the sum of direct surface runoff and groundwater runoff, and we will be explain below how it has been obtained for any point of the country.

The average annual runoff value in Spain is 220 mm, equivalent, as seen, to about 111,000 hm^3. As regards spatial distribution, the major territorial differences that it shows are obvious, ranging from areas where runoff is less than 50 mm/year (southeast of Spain, La Mancha, the Ebro valley, the Douro plateau, and the Canary Islands), up to others where it exceeds 800 mm/year (basins of the North and mountainous areas of some basins) (fig. 93).

This runoff is generated almost entirely in our territory from precipitation. Some irrelevant flow is excluded with respect to total runoff from Andorra and France in the River Segre headwater (about 300 hm^3/year according to estimates by the Ebro basin management plan), as well as from some very small basins on the Portuguese frontier.

Having obtained the map of total runoff for the whole country, total runoff (natural resources) for any territory is simply obtained by total runoff integration is, within territory boundaries. The results obtained this way for water planning areas will be given later on.

Furthermore, the map of cumulative runoff at each site is obtained by summing up the runoff at all upstream sites. This map is a fractal representation of the fluvial network, where the value corresponding to each site in the network is its inter-annual average cumulative flow. Total runoff in any territory will now not be the sum of its interior sites, but of the sites in its periphery, positive if the site contributes to the territory, and negative if it drains it. In formal terms, this

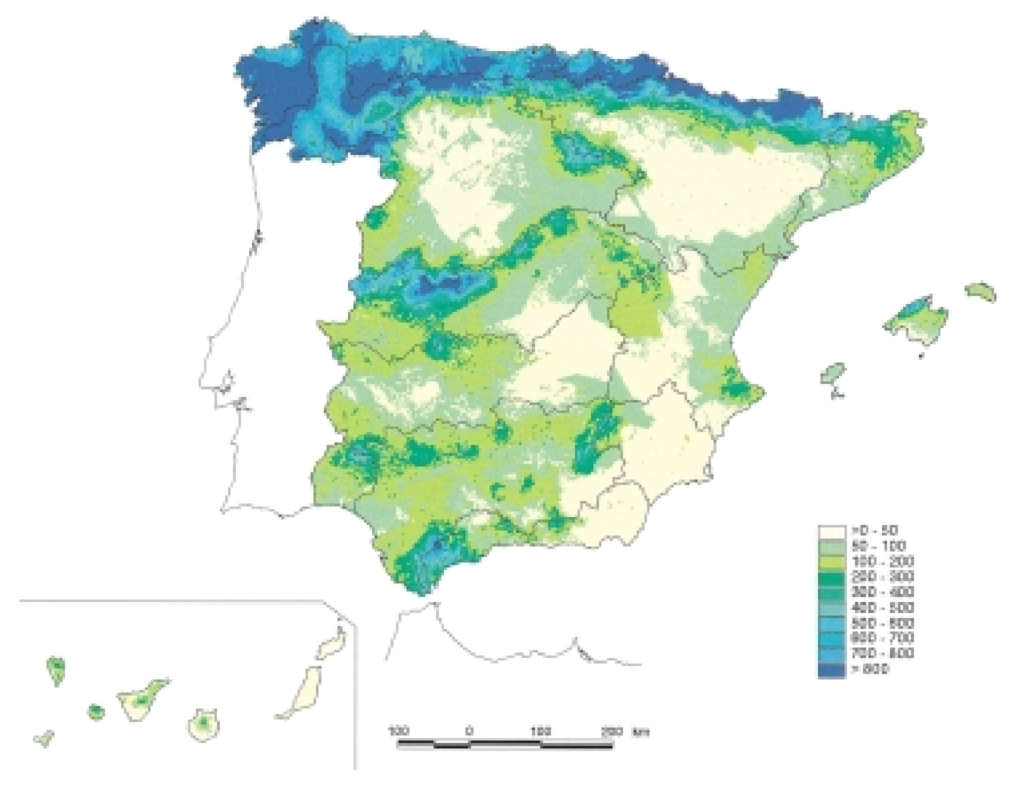


Figure 93. Map of total annual average runoff in mm (period 1940/41 - 1995/96).

is equivalent to the curvilinear integration along the boundary.

Figure 94 shows this accumulated flow map for the whole peninsular territory, representing the fluvial sections with en estimated cumulative flow higher than 25 hm^3/year.

For example, this map illustrates the contrast between fluvial network densities of basins in the North of Spain and in the Southeast. In some hydrographic basins, there are also clear differences between flow from the different drainage basins, as is the case of the Ebro, where flow from the left bank, mostly generated in the Pyrenees, is much greater than the right bank. Generally speaking, it can be seen how in most basins a very significant proportion of resources is generated at the headwaters. An exception is the Guadiana basin, where resources are generated in the tributaries running into its middle section.

Seasonal or inter-annual distribution of average runoff in Spain is shown, together with precipitation and that of potential and real evapotranspiration, in the adjoining figure.

It clearly illustrates the existing time delay between precipitation and potential evapotranspiration, giving rise to soil moisture deficit. It can also be seen that maxim global runoff production takes place from December to February, with the minimum in August; or that maximum potential evapotranspiration is registered in July.

It is also interesting to highlight the effect that water storage has on the soil and on aquifers, which in the dry months of May to July enables real evapotranspiration to be greater than precipitation, or flow to circulate in rivers (fig. 95).

As mentioned above, evaluating natural cumulative river flow is not an easy task, and an example of this is it how, over time, these estimates have varied according to the author that presents them and the compilation dates, as shown in the adjoining table on estimates of total water resources in natural a regime (expressed in hm^3/year). The differences are to be expected considering, firstly, the different dates and periods (different series) when the evaluations are carried out; secondly, even using the same series, different technical procedures can be used, giving rise to different results; and thirdly, that basin is not always understood to mean the whole administrative area defined as such –particularly in older estimates, only considering the resources the river or main rivers, and not of all water channels.

In any event, we should bear in mind that, as mentioned, natural resources cannot be directly measured, and must be estimated, which always involves a certain level of uncertainty (table 12).

The most recent figures are those from the basin management plans (which although approved in 1998, are generally based on data from the period comprised between the hydrological years 1940/41 and 1985/86), and those corresponding to the new assessment of natural resources carried out in this White Paper, for the period between 1940/41 and 1995/96.

As may be seen, in no case do the differences between these last two estimates exceed 20%, and they are usually downward, which is logical considering the different periods used

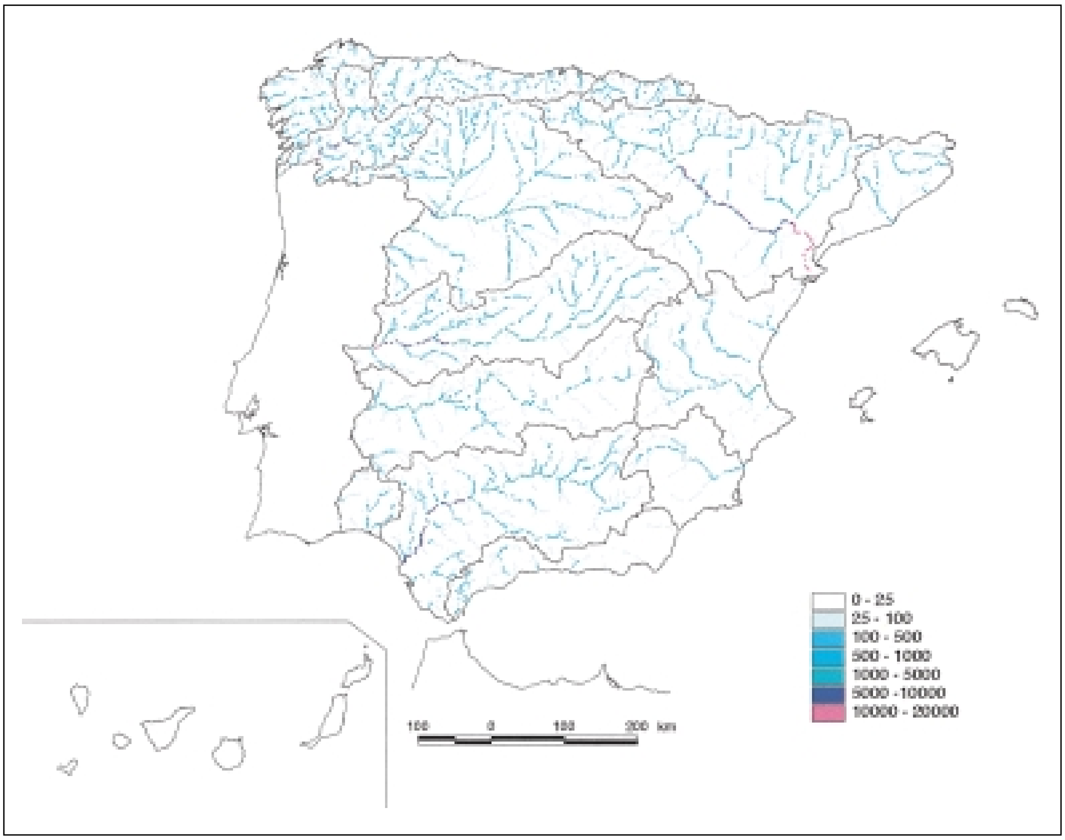


Figure 94. Map of total annual average cumulative flow (hm^3/year) in the period 1940/41 - 1995/96.

and the effect of latest drought. It can also be seen that the oldest evaluations are generally adjusted, and the global estimate of peninsular resources –around 110 km^3/year– stable for almost 20 years. The most recent evaluation, carried out for this White Paper, will be detailed in sections below.

3.1.4.1.5. Water resources evaluation procedure

Having presented the basic concepts of hydrological cycle and water balance, and having characterised their basic meteorological variables, we should detail the procedure of evaluating water resources in a natural regime that has been implemented in this White Paper, and which has entailed the massive, distributed modelling of the hydrological cycle's basic components on a nation-wide scale.

In order to evaluate water resources in Spain, a rainfall-runoff model has been developed and refined. This model allows having homogeneous methodology, in all basins, for updating the time series up to the hydrological year 1995/96, which have been used not only in the present work, but also

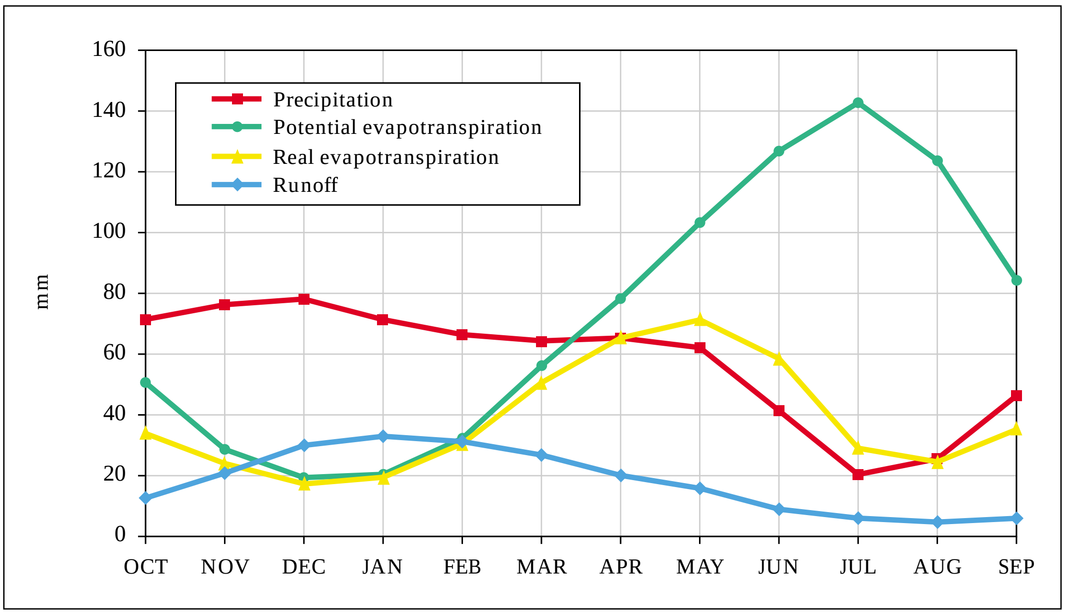


Figure 95. Average annual distribution of the main global hydrological flow in Spain

Planning Area	1967 (a)	1980 (b)	1993 (c)	1998 (d)	1998 (e)
Galicia Coast	--	--	12,504	12,642	12,250
North I	--	--	11,235	11,235	12,689
North II	--	--	12,954	13,000	13,881
North III	--	--	5,395	5,381	5,337
North	37,500	38,700	42,088	42,258	44,157
Douro	13,200	15,900	15,168	15,168	13,660
Tagus	8,920	10,250	12,858	12,230	10,883
Guadiana I	--	--	4,872	4,875	4,414
Guadiana II	--	--	1,293	1,293	1,061
Guadiana	4,895	5,100	6,155	6,168	5,475
Guadalquivir	7,300	9,400	7,771	7,978	8,601
South	2,150	2,690	218	2,483	2,351
Segura	884	960	1,000	1,000	803
Júcar	2,950	5,100	4,142	4,142	3,432
Ebro	17,396	18,950	18,198	18,217	17,969
Catalonia I.B.	1,700	3,250	2,780	2,780	2,787
Total Peninsula	96,895	110,300	112,588	112,424	110,116
Balearic Islands	--	690	745	562	661
Canaries	--	965	965	826	409
Total Spain	**--**	**111,955**	**114,298**	**113,812**	**111,186**

Table 12. Different estimates of total water resources in a natural regime (hm^3/year).

(a): PG (1967), Water Resources, 2nd Economic and Social Development Plan, Government Presidency,
(b): MOPU (1980), Water in Spain, CEH, DGOH, Also in Heras (1977),
(c): MOPT (1993) PHN report
(d): Data from basin management plans (1998)
(e): Data from the evaluation carried out in this White Paper that will be presented later on (1998)
Notes: North comprises the areas of Galicia Coast and North I, II, and III; Guadiana comprises the areas of Guadiana I and II, The figure for the Ebro basin plan (column d) does not include resources of the Garonne and Gallocanta,

in the preliminary work for the National Hydrological Plan. (Estrela and Quintas, 1996b; Ruiz, 1999).

This model uses data registered in the gauging stations, meteorological information, and basin and aquifer characteristics. It is a conceptual, distributed hydrological model - it considers the spatial variability of all hydrological information - that simulates average monthly flow in a natural regime at any site in Spain's hydrographic network. To do this, it reproduces the essential processes in water transportation that take place in the hydrological cycle's different stages. In each one of the approximately half million cells, measuring 1,000 m x 1,000 m, into which the Spanish territory has been discretized, it outlines the principle of continuity and lays down, on a monthly scale, laws on distribution and water transfer between different storage points (see figure 96).

Input to the model is the monthly data on precipitation and temperature at meteorological stations and data on historic flow observed at simulation or gauging sites. Precipitation maps have been obtained by interpolating the data registered in rainfall gauges, taking mountain environment into account. To calculate potential evapotranspiration, it uses a combination of the Thornthwaite and Penman-Monteith methods, and introduces a reduction factor for vegetation. Other information required by the model is data on the geometry of the sub-basins considered, which, taking into account the early river classification work carried out in the sixties (MOP-CEH [1965]; MOP-CEH [1966]), have been digitalized from Military Geographical Service maps to a scale of 1:50.000, and are shown in figure 97.

The model's parameters are the maps of maximum soil moisture storage capacity, of maximum infiltration capacity and the aquifers' recession rate.

Figure 98 shows maps the parameter of maximum soil moisture storage capacity, estimated from information on land uses according to the criteria in table 13. Figure 99 maps the parameter of maximum infiltration capacity.

This parameter has been regionalised according to lithology, as shown in the following table. Firstly, lithological types on the EUORSTAT digital land map were assigned a maximum infiltration capacity value from the infiltration estimates for lithological groups compiled by Sanz Pérez (1995). These reference values were later adjusted during the model's calibration process (table 14).

Finally, figure 100 maps aquifers' recession rate. The model estimates aquifer recharge in a distributed way, and obtains an area value for the hydro-geological unit for every month. Water exchange between each hydro-geological unit and the fluvial network is carried out by means of a unicellular model (López-Camacho, 1981), aggregated to the whole unit, and whose parameter is the recession or discharge rate.

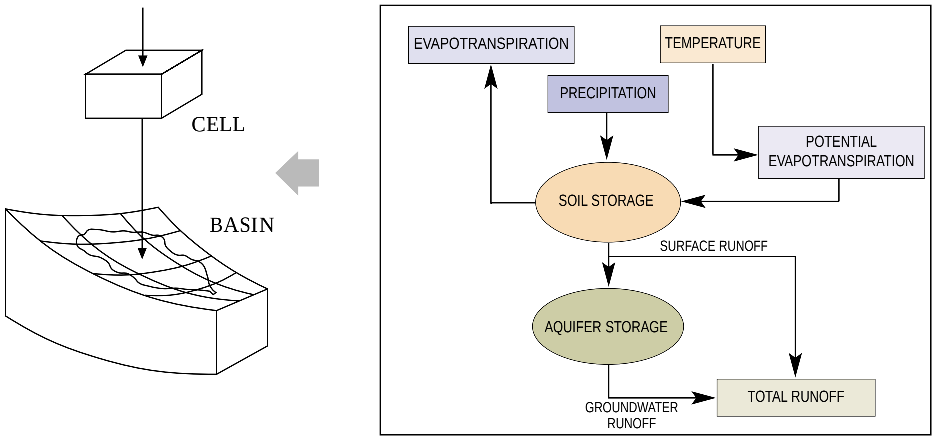


Figure 96. Outline of the distributed model used.

This map has been estimated by introducing certain initial values in each hydro-geological unit according to the aquifers' size and lithological characteristics, and later adjusting them in the model's calibration process from depletion hydrographs registered in gauging stations.

The model's calibration has involved obtaining the maps of the parameters that lead to adequate adjustment between observed values and those simulated by the model, understood to be the reproduction, as far as possible, of monthly, annual and inter-annual mean cumulative flow, plus other properties of the series, such as flow variation or persistence.

Most of the calibration data correspond to gauging stations where flow is measured in a natural regime. For the purposes of contrast, series restored to natural regime from basin management plans have also been used, mostly in areas where the above-mentioned stations are low in number, and at the main river mouths, ensuring the global adjustment of basins.

Figure 97. Map of sub-basins in Peninsular Spain.

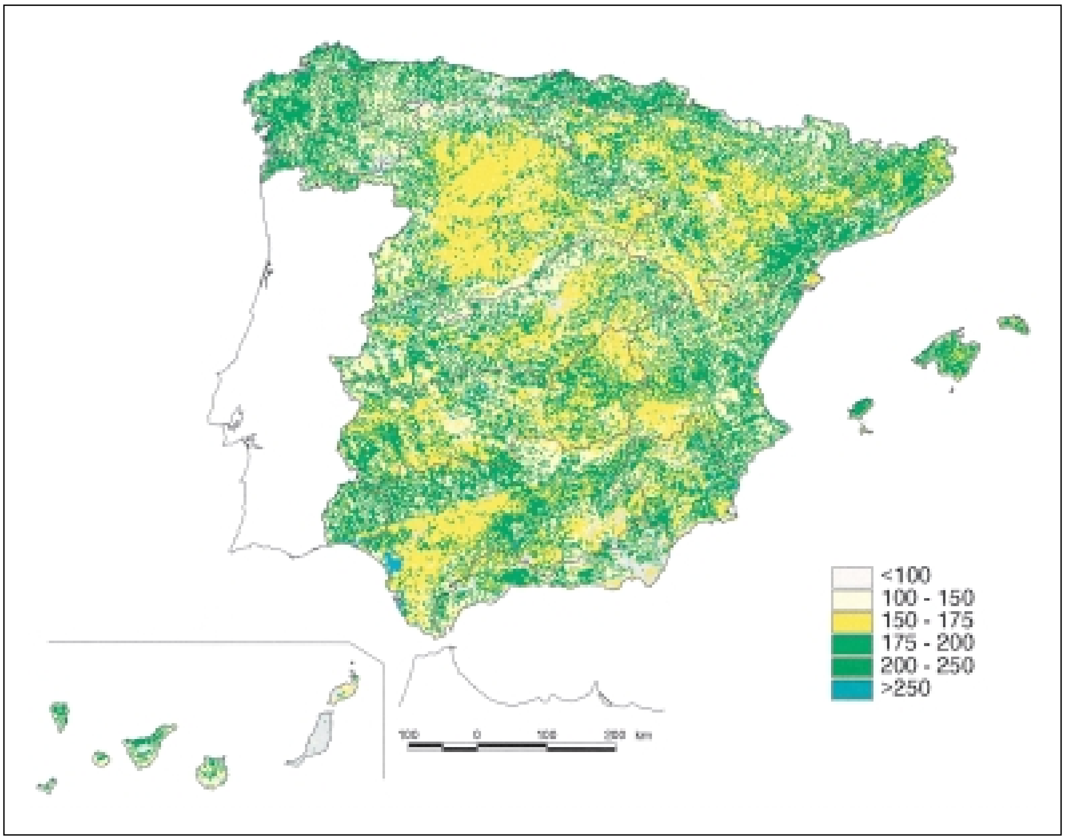


Figure 98. Map of maximum soil moisture storage capacity (mm).

Figure 101 shows the monitoring sites selected for calibration, as well as the situation of reservoirs and irrigated zones, information used to carry out this selection.

As mentioned above, in order to adjust the model the parameters of gauged basins have not been mathematically calibrated, but rather their values have been regionalised for the whole territory, from the basins' physical characteristics (land uses and lithology). Although it is more difficult to achieve near-zero error with this method, it has the advantage that the parameters estimated in non-gauged basins, which cover a large proportion of the territory, are consistent with their characteristics and can be more reliably estimated. In the case of the Canary Islands, it has not been possible to verify the parameter regionalisation carried out, due to a lack of flow registers. Similarly, it has been impossible to accurately determine the parameter regulating distribution of surface water and groundwater cumulative flow, because it is volcanic terrain barely represented in other areas of Spanish territory.

The results of the simulation are the maps of different storage, soil moisture and aquifer volume (drainable by gravity according to unicellular model), and of the variables of outflow from the hydrological cycle, real evapotranspiration and total runoff, the last item obtained from the sum of surface water and groundwater. Figure 102 shows an example simulation of runoff in millimetres in a specific month, for which maps are created for precipitation (top, left), evapotranspiration (top, right), groundwater runoff (bottom, left), and total runoff (bottom, right). Monthly flow, in each time interval, is obtained by combining total runoff in drainage areas with the simulation points. The simulated flow is contrasted with historical data, when they are available.

Table 13. Regionalisation of maximum soil moisture capacity from land uses.

Land use	Maximum soil moisture capacity (mm)
Artificial surface areas	40
Zones with little vegetation	100
Agricultural dry crop lands	155
Agricultural irrigated lands	215
Natural meadows and pastures	150
Heterogeneous agricultural systems	195
Permanent crops	210
Shrub vegetation	135
Mixed forest	220
Deciduous and coniferous forests	230
Humid areas, water masses and artificial zones	300

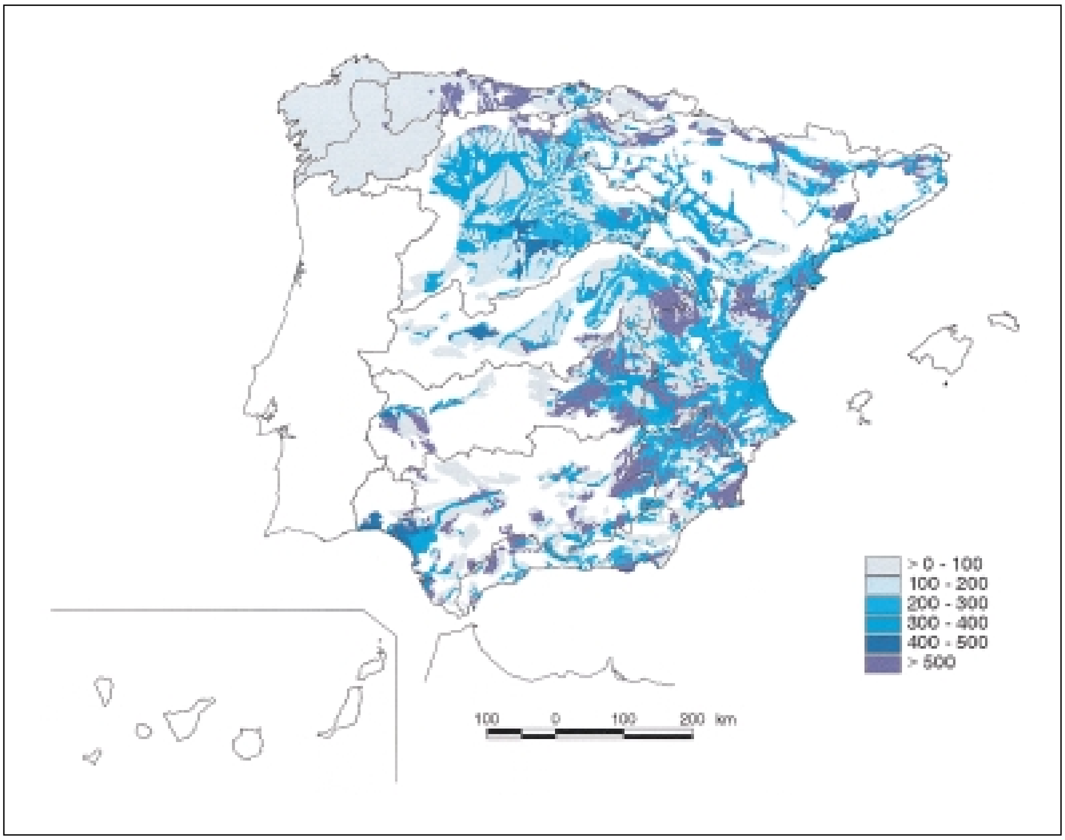


Figure 99. Map of maximum infiltration capacity (mm/month)

To give an idea of acceptable level of adjustment achieved, figure 103 shows the mean annual values of specific cumulative flow, simulated and observed, at all selected monitoring sites.

Figures 104 and 105 also present the complete series of monthly cumulative flow (in m^3/s), simulated and observed, in different monitoring sites. We could state that the calibration is highly acceptable, and that it is sufficiently reliable to allow the model to be generally implemented over the whole territory.

Also, it may be seen that the apparent downward trends for natural resources (such as the Tagus in Entrepeñas) can simply be explained by variability in precipitation, with control parameters for the hydrological response considered as stationary, at least in the period analysed, as of the year 1940. Accepting this hypothesis involves admitting the invariability of land uses. Although, as is obvious, changes in uses have occasionally taken place in recent decades, their global effect on cumulative river flow is not significant, as is demonstrated by the fact that wastewater does not show drift over the simulation period. Land changes are certainly significant on the scale of hillside, plot or small basin, but they are irrelevant on the scale of the river basins considered in this White Paper, and their effect is generally absorbed by

Lithology	Maximum infiltration (mm)
Alluvial material of undifferentiated origin	400
Calcareous and dolomite	1,000
Marl	85
Marl clay	75
Gypsum	64
Sandy material	450
Gravel-sandy material	500
Calcarenitas (Macignum)	250
Clay	150
Rañas	95
Granite	65
Metamorphic rocks	20
Gneiss	55
Slates	40
Volcanic rocks	275

Table 14. Regionalización of maximum infiltration capacity of infiltration from lithology.

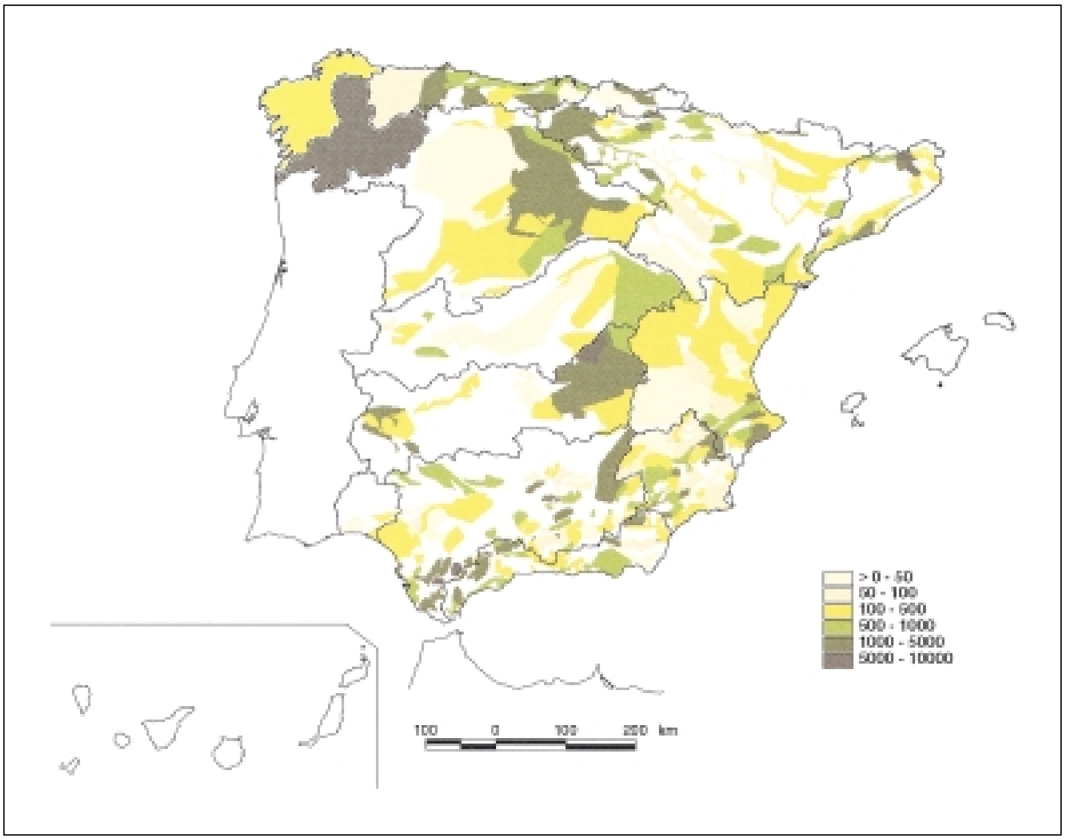


Figure 100. Map of recession rates (days^{-1} x 100,000)

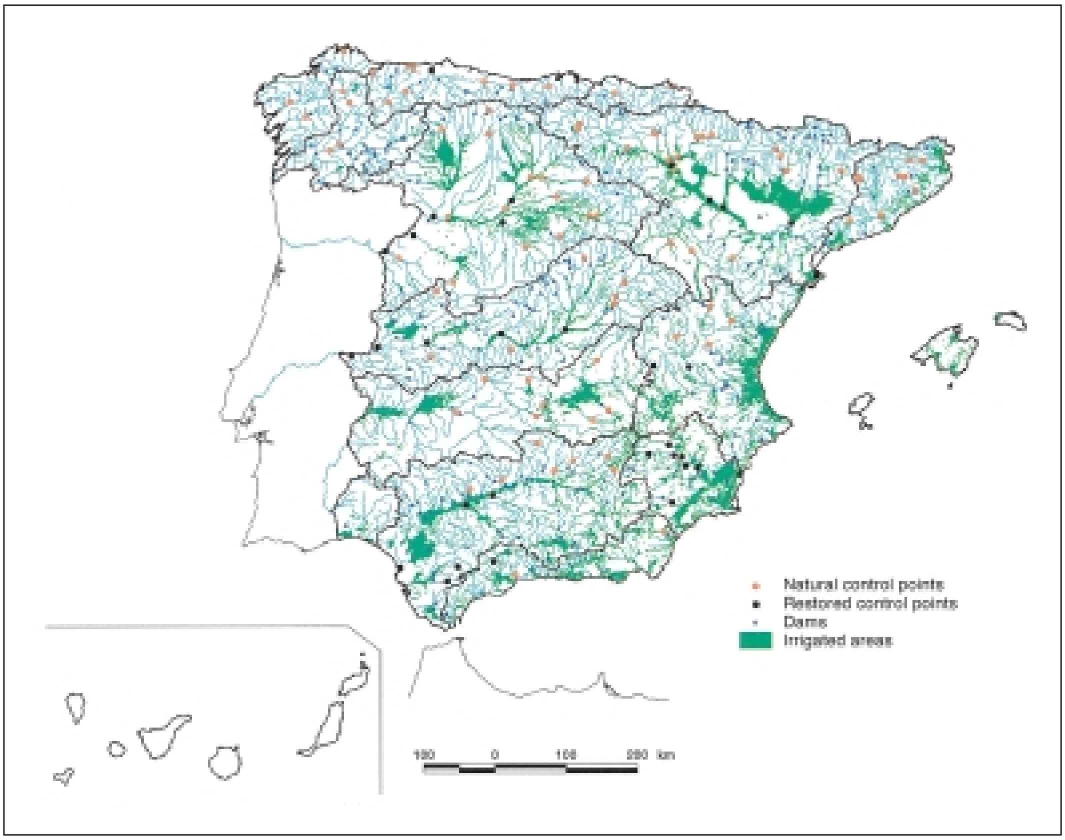


Figure 101. Map with the selection of monitoring sites for calibrating the model.

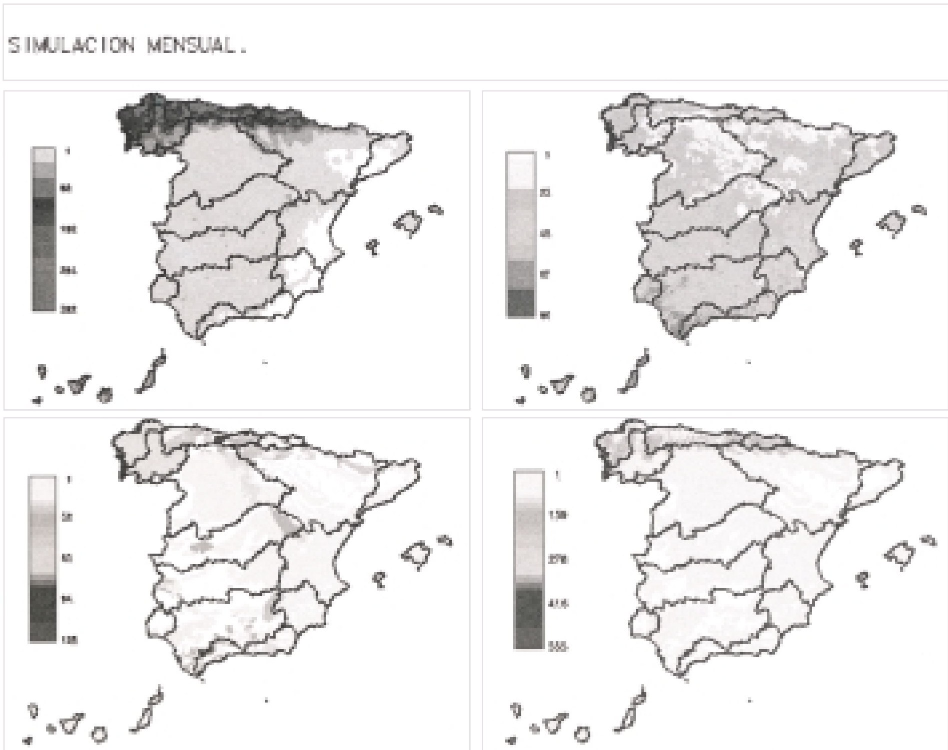


Figure 102. Example of maps generated in runoff simulation in a time interval (February 1970).

the uncertainties and noises characteristic of hydrological models, even the most complex and parametrised ones.

Figure 105 shows three of these adjustments with greater detail, in order to better appreciate the results obtained.

3.1.4.1.6. Results obtained

Having concluded that the model used is generally valid, it was then massively implemented for the period 1940/41-1995/96, obtaining the results summarised in table 15. It may be seen that annual mean values for precipitation (shown above), potential and real evapotranspiration, total runoff (which is similar to useful rain), the percentage of this runoff in comparison with the average for all Spain, runoff coefficient, and total cumulative flow in each of the areas, and in the country as a whole. For comparison purposes, it also shows values for precipitation and total cumulative flow obtained by the model for the period 1940/41 - 1985/86, which is the one usually used in basin management plans.

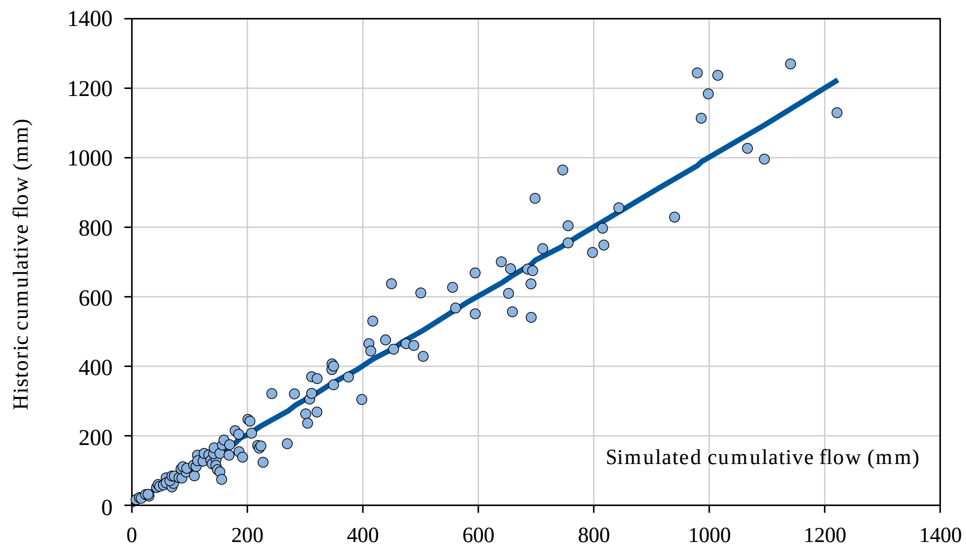


Figure 103. Contrast of the model in annual mean values.

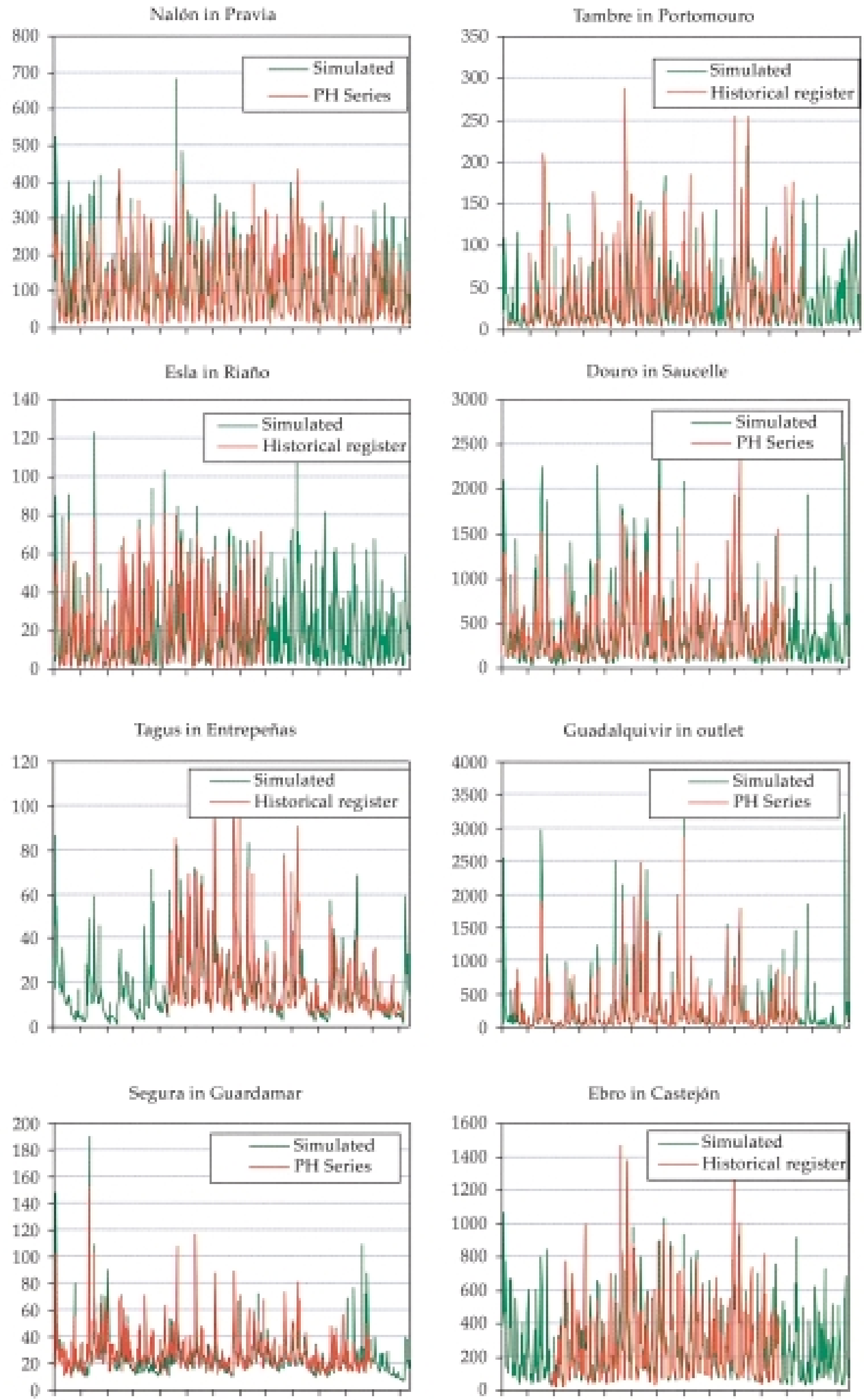


Figure 104. Simulated and observed monthly cumulative flow (m^3/s) at various monitoring sites in the period 1940/41-1995/96.

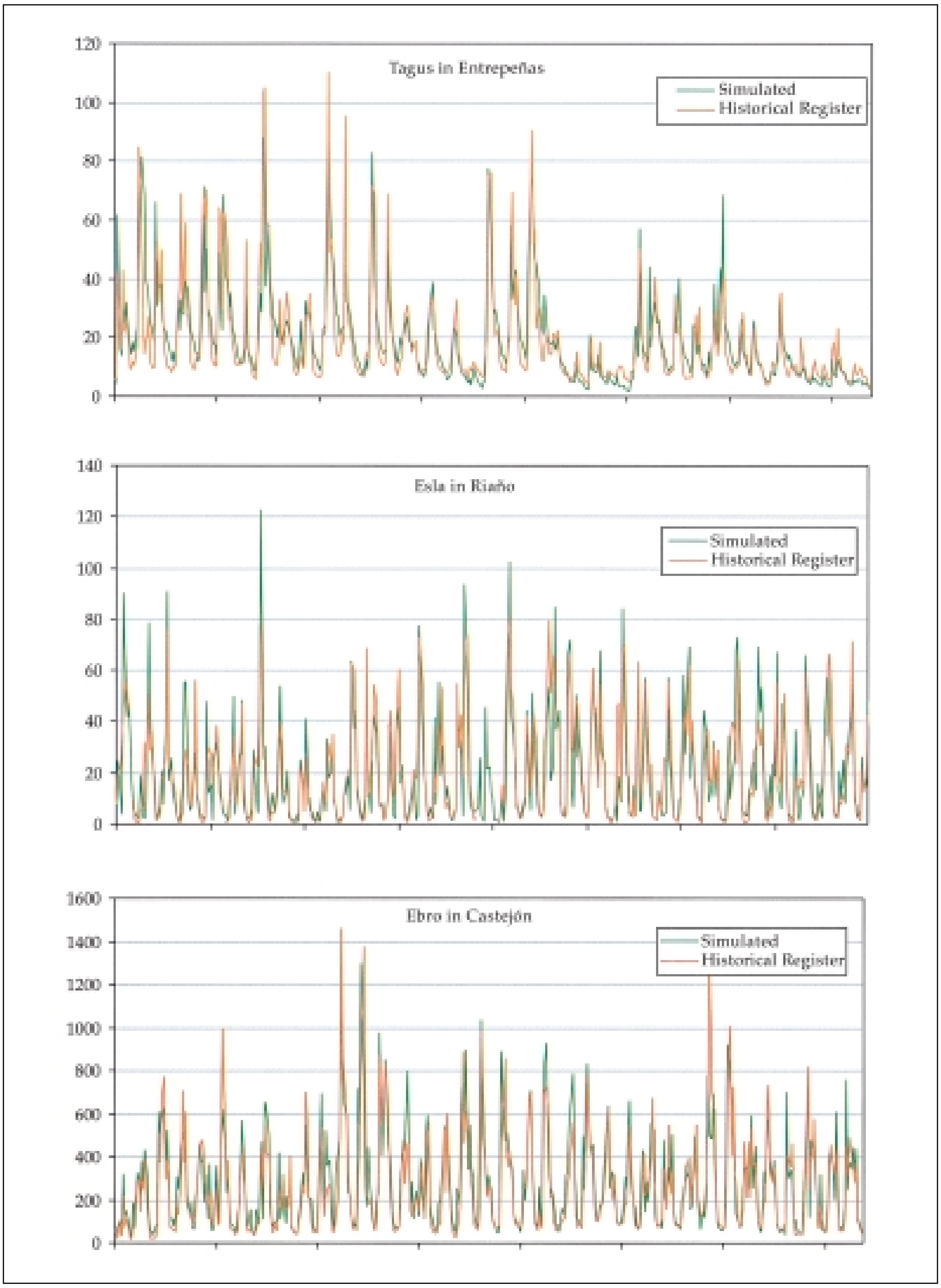


Figure 105. Detail of simulated and observed monthly cumulative flow (m^3/s) in the period 1940/41-1995/96

Figures for total cumulative flow include flow corresponding to the fluvial network (direct surface runoff and aquifer recharge) and underground runoff to the sea. The latter of these is proportionally unimportant, at about 2,000 hm^3 /año including the islands, as will be seen in a later on.

Examining this table, it is interesting to note that the inclusion of the last 10 years –that is to say, using the 1940/41–1995/96 series instead of the standard 1940/41-1985/86 –means an average decrease of almost 4% in total natural resources.

This decrease has taken place, in different percentages, in almost all the environments except Galicia Coast and Guadiana II, where it is practically the same, and in the Júcar and Catalonia Inland Basins, where a slight increase has taken place. These exceptions are explained by a detailed analysis of spatial distribution of drought in the early nineties, which although quite widespread, did not affect the whole national territory equally, as will be clearly shown in the sections on droughts.

Area	Surface Area (km^2)	Precip. (mm)	Precip. (mm)	PET (mm)	ET (mm)	Run. tot. (mm)	Run./Md (mm)	C. Run. (%)	Fl. tot. (1) (hm^3/year)	Fl. tot. (hm^3/year)
North I	17,600	1,284	1,316	709	563	721	328	56	13,147	12,689
North II	17,330	1,405	1,440	653	604	801	364	57	14,405	13,881
North III	5,720	1,606	1,650	695	673	933	424	58	5,614	5,337
Douro	78,960	625	631	759	452	173	79	28	14,175	13,660
Tagus	55,810	655	666	898	460	195	89	30	11,371	10,883
Guadiana I	53,180	521	531	977	438	83	38	16	4,624	4,414
Guadiana II	7,030	662	661	1,075	511	151	69	23	1,053	1,061
Guadalquivir	63,240	591	602	991	455	136	62	23	9,090	8,601
South	17,950	530	531	969	399	131	60	25	2,359	2,351
Segura	19,120	383	379	963	341	42	19	11	911	803
Júcar	42,900	504	500	881	424	80	36	16	3,335	3,432
Ebro (2)	85,560	682	692	792	472	210	95	31	18,647	17,967
Catalonia I.B.	16,490	734	727	792	565	169	77	23	2,728	2,787
Galicia Coast	13,130	1,577	1,590	737	644	933	424	59	12,245	12,250
Peninsula	494,020	691	700	859	468	223	101	32	113,604	110,116
Balearic Islands	5,010	595	603	896	463	132	60	22	696	661
Canaries	7,440	302	297	1,057	247	55	25	18	394	409
Spain	**506,470**	**684**	**693**	**862**	**464**	**220**	**100**	**32**	**114,694**	**111,186**

Table 15. Simulated mean annual values for precipitation, evapotranspiration and runoff by planning area, corresponding to the period 1940/41-1995/96.

(1): These figures, unlike the others, correspond to the period 1940/41-1985/86
(2): These figures do not include runoff from French territory, estimated at about 300 hm^3/year.

In short, average cumulative flow in those areas in the period comprised between 1985/86 and 1995/96 was slightly larger than the average for the whole analysis period, although this high cumulative flow basically occurred in coastal areas, where it could not be regulated to offset drought in those territories and upstream. This is, for example, the case of the Júcar, with high precipitation in the Marinas and very low precipitation at the headwaters and middle reaches of the Rivers Júcar, Turia and Mijares.

These effects can be seen in the graphs analysing regional pluviometric runs, showing that the global result of the Levante pluviometric region was very wet in the period 1986-90 and, to a lesser extent, dry in 1991-95.

In any event, and on a global scale, the mentioned reduction in total natural resources should be clear, around 4%, with respect to resources in the periods usually considered by Basin Plans.

Furthermore, as may be seen, and illustrated in figure 106, the total annual mean cumulative flow varies vastly from some basins to others, with values ranging from almost 18,000 hm^3/year in the Ebro (the biggest in Spain), over 10,000 in the basins of North I and II, Douro, Tagus and Galicia Coast, and the minimums between 400 and 800 in the islands and the Segura.

The same figure presents the global inter-annual runoff coefficient (the relationship between cumulative flow and precipitation) in each area. As may be seen, global runoff coefficient varies between figures around 60% in the basins of the North, and 11% of the Segura, which, from the point of view of resources, further exacerbates their rainfall differences.

Figures for total cumulative flow are very different, due to hydrological reasons, and to the basins' relative sizes. The consideration of runoff –total cumulative flow divided by the area of the basin– allows this scale effect to be eliminated, and therefore gives a better idea of cumulative flow's irregularity in the different areas. Figure 107 shows this runoff (also called specific cumulative flow) together with runoff coefficients, and provides a truly illustrative image of Spain's hydrological diversity.

It may be seen that the territories with greatest water abundance per surface area are, at some distance from the rest, those of the North and Galicia (that is, strictly wet Spain) with values in excess of 700 mm/year, while in the rest (dry Spain) they do not go above 250 mm/year. Spain's smallest specific cumulative flow takes place in the Segura basin, which does not even reach 50 mm/year, that is, about 20 times less than Galicia, 5 times lower than the national average, and 3 times lower than the average of dry Spain.

It may also be seen that, as was to be expected, a clear relationship exists –although non-linear– between runoff (or specific cumulative flow) and the runoff coefficient, an obvious consequence of the approximately linear relationship from a certain threshold, between runoff and long term average precipitation in the different areas, as shown in figure 108. This data has been adjusted by Budyko's regional law, structured so that where P is precipitation, PET is potential evapotranspiration and R is runoff. In the expression above, a constant PET value has been adopted, equal to the Spanish average.

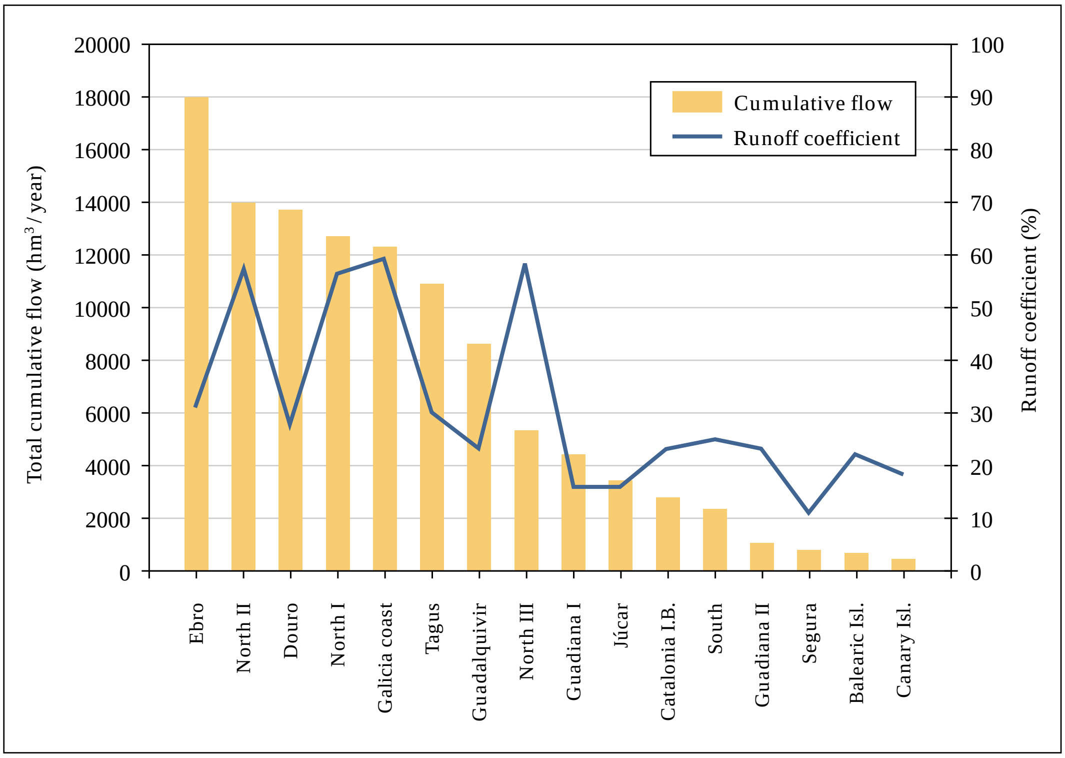


Figure 106. Total annual mean cumulative flow (hm^3/year) and runoff coefficients in a natural regime in the Basin Plans' different territorial areas.

As happens with the marked spatial variability of runoff, temporal irregularity is also very significant. Parallel to the case of precipitation, figure 109 shows the annual values of total mean cumulative flow in a natural regime for peninsular Spain in the 56-year period comprised between 1940/41 and 1995/96, together with the average for that period (about 111 km^3/year).

Logically, the cumulative flow in every year must bear a close relationship with precipitation for that same year, as in fact is clearly shown in figure 110.

Nevertheless, the temporal irregularities of precipitation seem now to be amplified, as indeed is the case when contrasting the variation rates of both series that we will see later on.

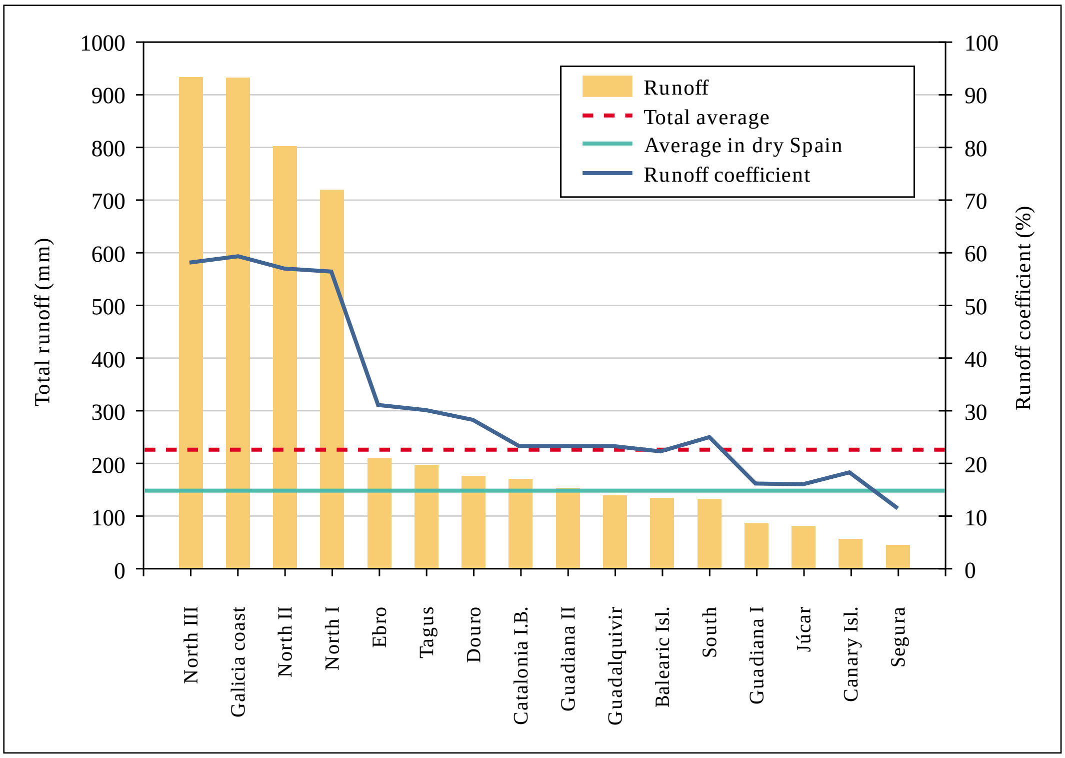


Figure 107. Annual mean cumulative flow (mm) and runoff coefficient in a natural regime in the Basin Plans' different territorial areas.

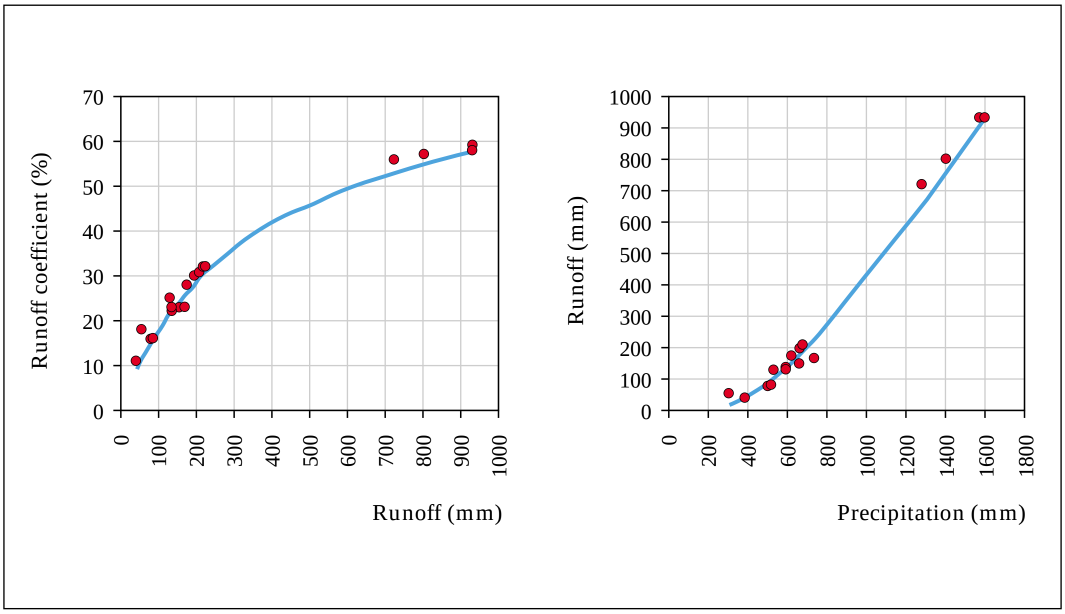


Figure 108. Relationships between precipitation, total runoff and runoff coefficient in the Basin Plans' different territorial areas.

Moreover, the relationship between both variables on a global scale and with yearly data does not seem to show time dependence structures beyond the year, as may be seen in figure 111, showing the function of crossed correlation between both variables, together with their confidence level of 95%.

As may be seen, a high correlation exists in the same year (corresponding to the previous graph), but the effect of one year's precipitation on cumulative flow in the following year does not reach a significant factor, although not far from it, and, as expected, no other significant correlation exists with a longer cycle.

Similarly, it is foreseeable that the dry and wet runs of cumulative flow on a peninsular scale show similar patterns present to those of the precipitation that generates them. To verify this hypothesis, the graph in figure 112 has been drawn up, similar to the one given above on precipitation, showing the accumulated unit deviation series, together with their 5-year centred mobile average, and the deviation previously obtained for precipitation.

It may be seen that, on a peninsular scale, runs of dry and wet cumulative flow are, as expected, the same as those for average precipitations, notwithstanding, as before, possible territorial differences.

Furthermore, and as in the case of precipitation, an interesting aspect is that of the autocorrelation structure of annual cumulative flow (that is, the relationship of one year's cumulative flow's dependence on those of previous years). For the purposes of contrast, figure 113 shows the functions of the series' autocorrelation and partial autocorrelation, together with their confidence intervals.

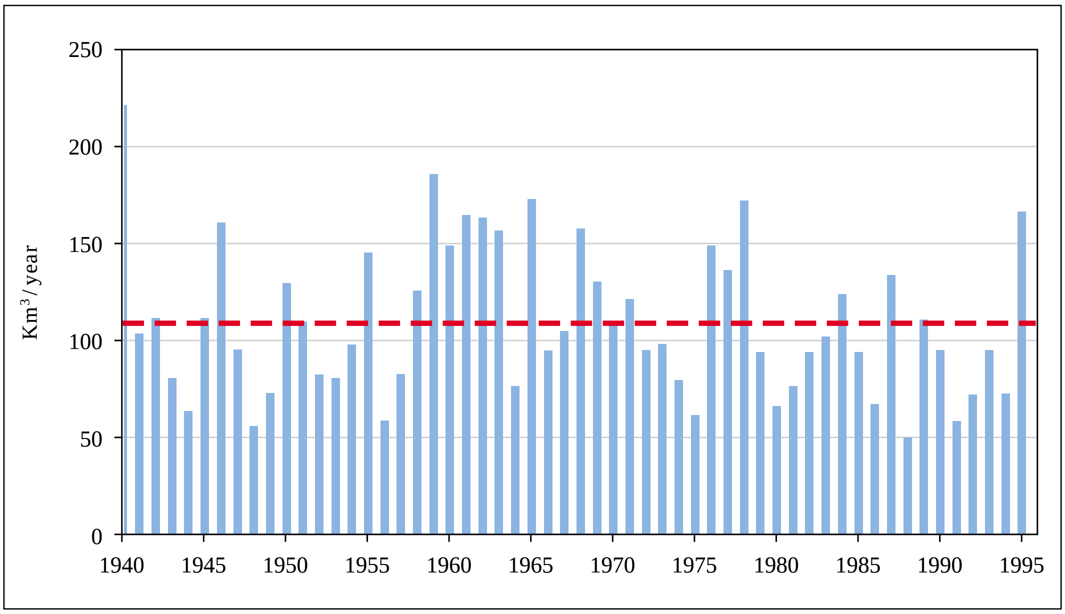


Figure 109. Series of total annual cumulative flow in a natural regime in peninsular Spain (period 1940/41-1995/96).

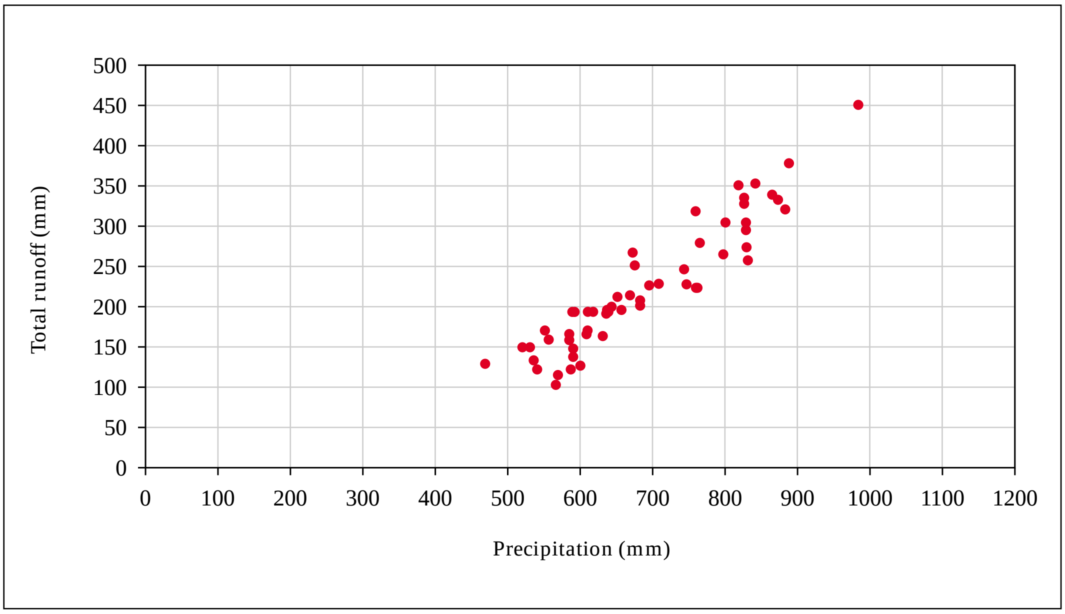


Figure 110. Total precipitation-runoff relationship on an annual scale in peninsular Spain (years 1940/41 to 1995/96).

Both functions show an apparent absence of total annual cumulative flow's time dependence, meaning, as above, that the prediction of total annual cumulative flow in the following year cannot be improved by considering that of previous years, because every year is independent from the previous one, and the phenomenon has no memory. Physically, this means that the Peninsula's total hydrogeological component is not enough to generate significant flow persistence beyond one year, or in other words, siliceous Spain surpasses calcareous Spain in the production of the total runoff on a yearly scale. Logically, and we shall see further ahead, this global result has some territorial differences.

Furthermore, it has also been confirmed that, as in the case of rainfall, there are no pluri-annual flow cycles of a periodic nature, which is predictable considering that, as we have already reiterated, rainfall is what generates and controls them.

In the analysis of territorial differences in annual series, and so as to visually appreciate the relative orders of magnitude, figure 114 shows the annual series of cumulative flow (hm^3/year) in a natural regime, for the different water planning areas.

To highlight them, and to stress their enormous relative differences, they have been separated into three groups, each of whose successive scales is, as may be seen, about a third of the previous one.

Furthermore, and as was done above with precipitation, the adjoining table provides different basic statistics from the series of annual cumulative flow, for the same period, in each of the territorial water planning areas.

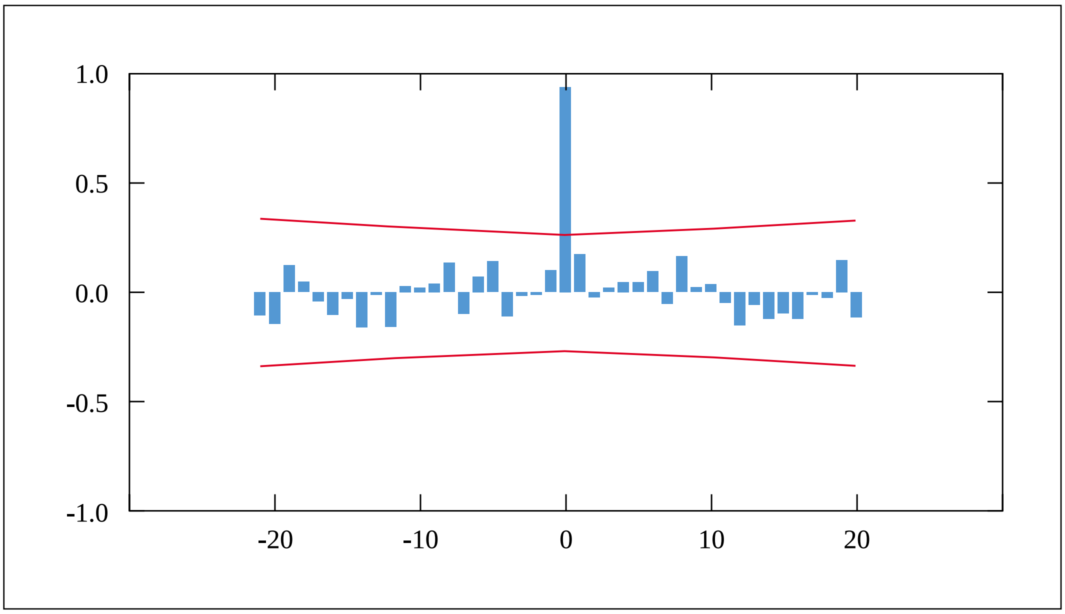


Figure 111. Crossed correlation between precipitation and annual cumulative flow in Spain in the period 1940/41-1995/96.

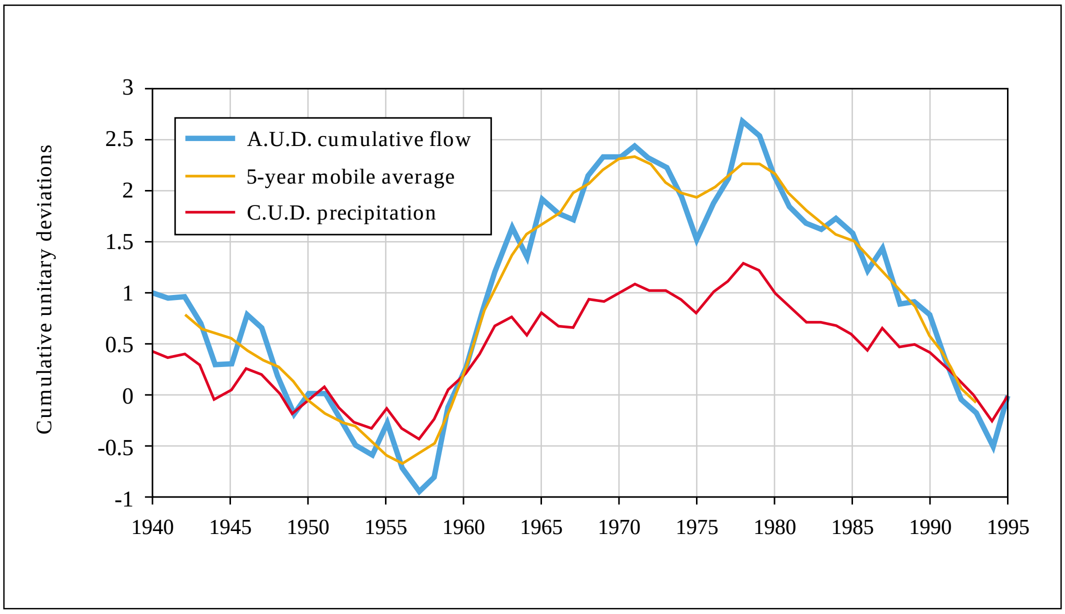


Figure 112. Runs of total annual cumulative flow in Spain in the period 1940/41 - 1995/96, as of cumulative unitary deviations.

This table highlights the considerable temporal variability of annual cumulative flow in the basins of the Guadiana, Guadalquivir and South, far higher than in other, also semi-arid basins such as the Júcar or Segura, where –despite annual rainfall variability being similar, as we have seen– cumulative flow variability is smaller due to the greater importance of their aquifers, which act as natural filters in regulating rainfall. A visual study of the series shows this effect (table 16).

Figure 115 represents the spatial distribution of the coefficient of annual rainfall variation , expressed as a percentage. The values corresponding to the territory cells shown in this figure logically give higher values for this coefficient than those obtained in each of the areas as a whole, according to table above, because by aggregating territorially, the effect of variability is reduced.

Coefficient of bias values for the annual runoff shown in the table above have generally larger, positive values than those for precipitation, which indicates that their asymmetry is even greater and, therefore, are more likely to have lower-than-average annual values.

As regards temporal autocorrelation, we have already mentioned that it was not seen on a global scale, but if coefficients of autocorrelation in the different areas are studied, it may be observed that four basins exist where they turn out to be significant, and they are, by order of persistence, Júcar, Segura, Ebro and Guadalquivir. The comment above regarding calcareous Spain is here clearly visible, because these are basins with a significant underground component that filters precipitation and delays it in time, generating greater temporal autodependence of its series, and, in short, greater persistence and predictability.

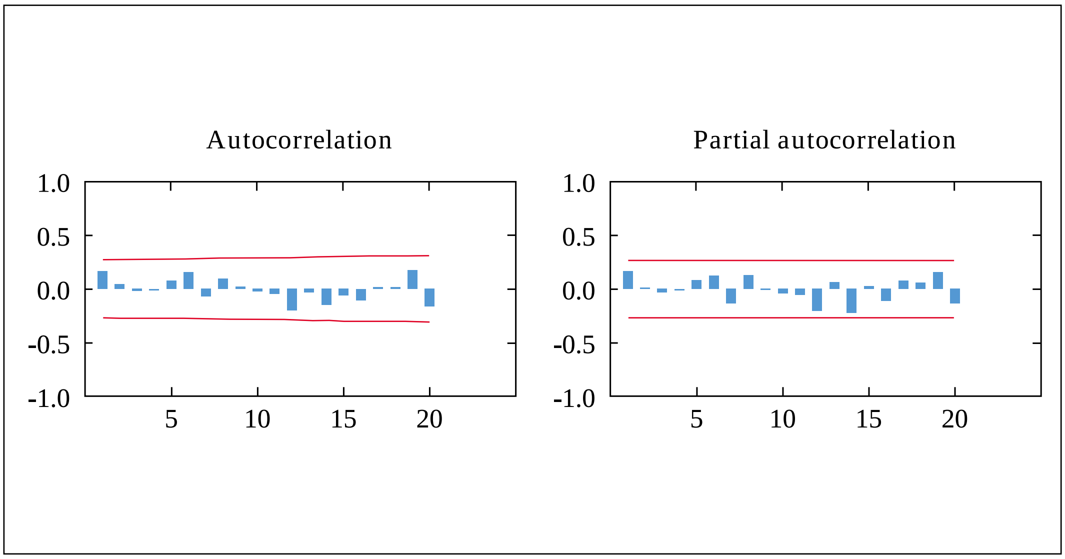


Figure 113. Functions of autocorrelation and partial autocorrelation of average annual cumulative flow in Spain in the period 1940/41-1995/96.

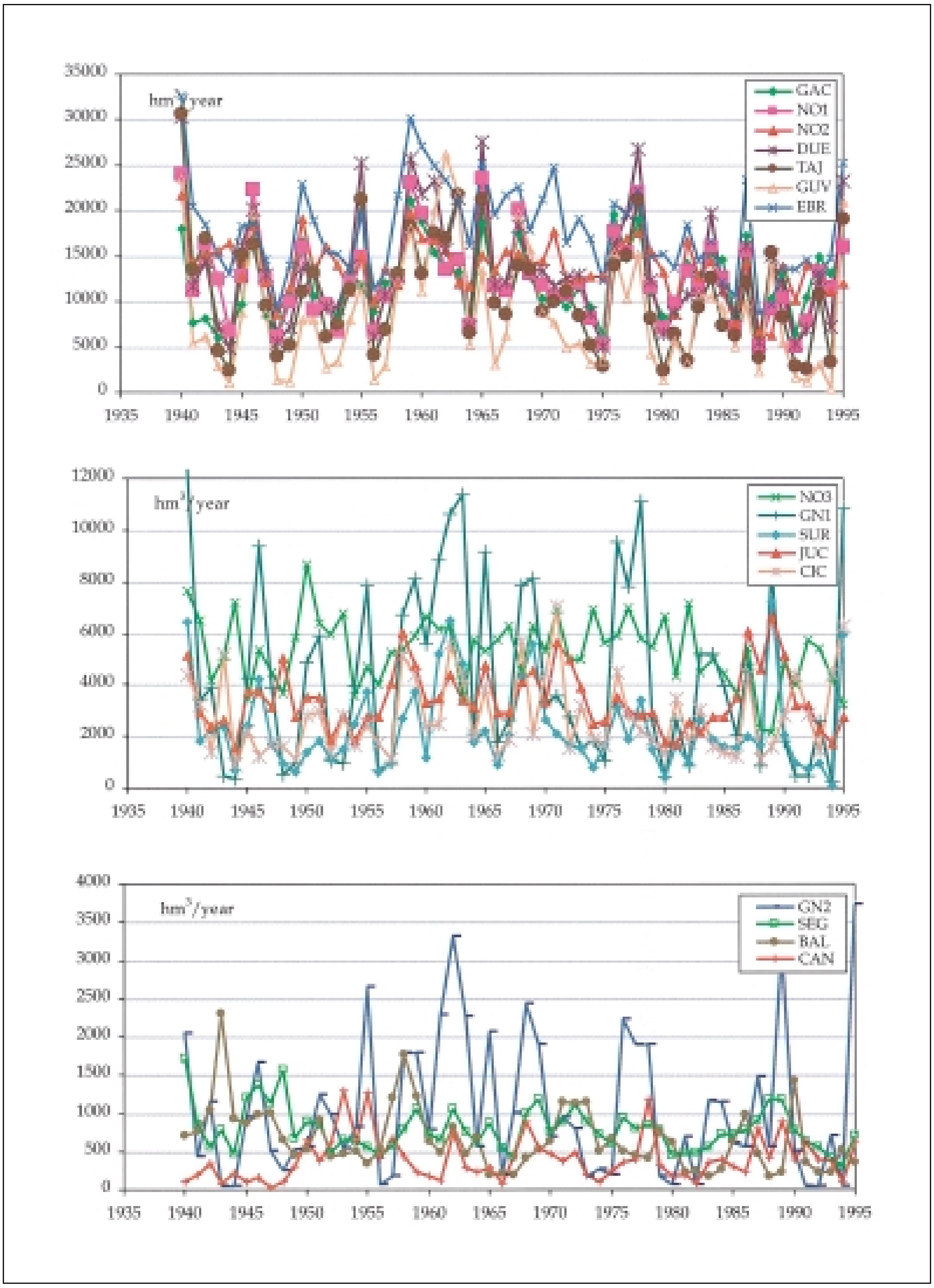


Figure 114. Series of annual cumulative flow in a natural regime (period 1940/41 - 1995/96) for the different water planning areas.

Figure 116 shows autocorrelation of the series of total annual cumulative flow in different territorial areas, with the above-mentioned difference clearly visible.

Obviously, these results correspond to total runoff in territorial areas, but within each area there may be significant differences. This is the case, for example, of the River Tagus, while the headwater has a dominant rainfall regime controlled by calcareous formations giving rise to monthly maximum values in March, significant autocorrelation of its annual cumulative flow and significant cross correlations with the cumulative flow of the Segura headwater (Cabezas, 1986). In Toledo, the river continues to show the same regime of monthly maximums, but with greater variability (possibly due to the absence here of the geological controls of the upper reaches). In Alcántara, the headwater autocorrelation has disappeared, and significant low water levels are observed.

Progressing in the study of cumulative flow's time-space structure, and in the same way as the rainfall analysis was carried out, table 17 shows the correlation matrix of annual cumulative flow, for the period 1940/41-1995/96, in the different areas. As before, the lower, diagonal half sum-

Planning Area	Minimum	Average	Maximum	Max/Min	Coef. of variation	Coef. of bias	1st coef. of autocorrel.
North I	5,062	12,689	24,087	4.8	0.38	0.68	0.10
North II	6,286	13,881	21,704	3.5	0.22	–0.15	0.19
North III	2,195	5,337	8,710	4.0	0.24	–0.13	0.18
Douro	4,926	13,660	30,393	6.2	0.47	0.80	0.09
Tagus	2,475	10,883	30,690	12.4	0.56	0.75	0.14
Guadiana I	260	4,414	12,403	47.8	0.81	0.67	0.18
Guadiana II	46	1,061	3,734	80.6	0.88	1.01	0.09
Guadalquivir	436	8,601	26,157	60.0	0.77	0.91	0.30
South	122	2,351	7,271	59.6	0.71	1.35	0.20
Segura	294	803	1,725	5.9	0.36	1.00	0.40
Júcar	1,564	3.432	6,669	4.3	0.34	0.79	0.46
Ebro	8,815	17,967	32,771	3.7	0.29	0.57	0.39
Catalonia I.B.	912	2,787	7,033	7.7	0.54	0.93	0.00
Galicia Coast	5,360	12,250	21,087	3.9	0.33	0.35	0.10
Peninsula	**50,178**	**110,116**	**221,166**	**4.4**	**0.35**	**0.66**	**0.19**
Balearic Islands	175	661	2,320	13.2	0.63	1.59	0.45
Canaries	37	409	1,310	35.2	0.72	1.51	0.27
Spain	**50,390**	**111,186**	**224,796**	**4.4**	**0.35**	**0.65**	**0.19**

Table 16. Basic statistics of the series of annual total cumulative flow corresponding to the period 1940/41-1995/96, in each of the territorial water planning areas.

marises the correlation coefficients, and the upper half shows an estimate of probabilities associated with these coefficients (1 implies no correlation and 0 implies significant correlation).

A comparison of this chart with the one given above for precipitation shows, as expected, considerable similarities, the regional aggregations for cumulative flow are also the same as those above.

Furthermore, and as was done with rainfall, we can now study the interesting question of the wet and dry runs from the point of view of flow, and on a regional scale. To do this, the accumulated unit deviation curves for total cumulative

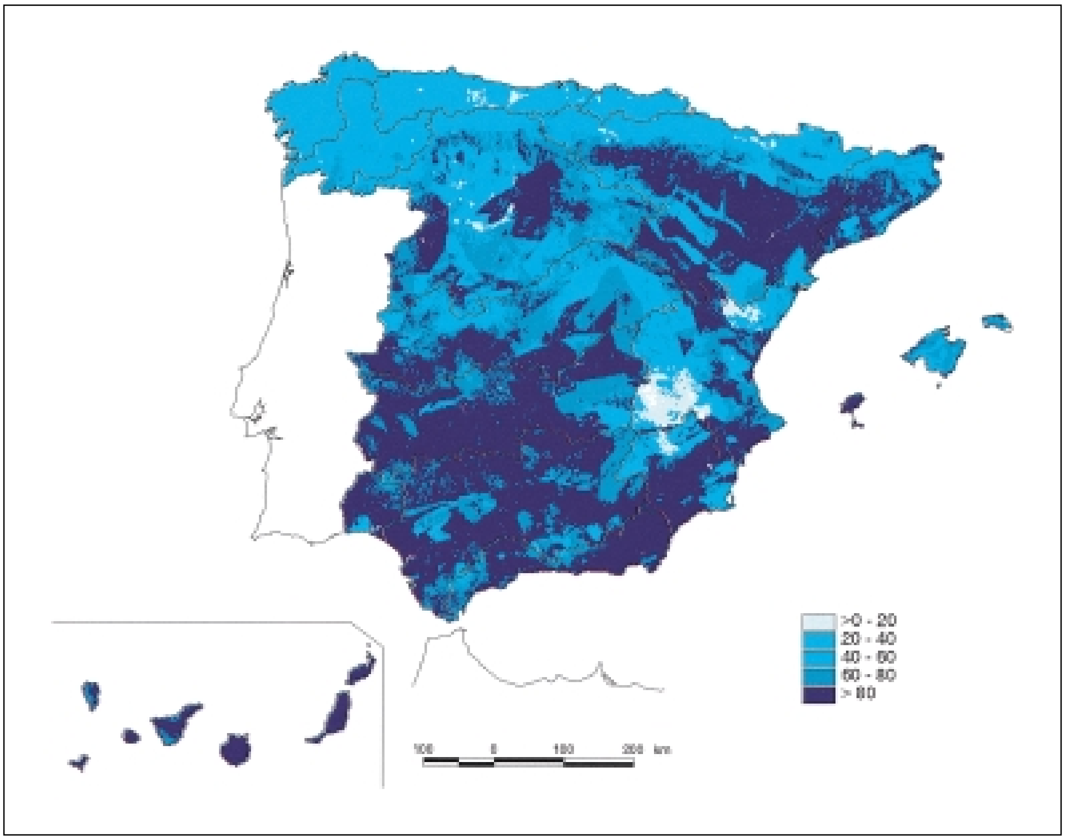


Figure 115. Map of the coefficient of variation (%) of annual runoff in the period 1940/41-1995/96.

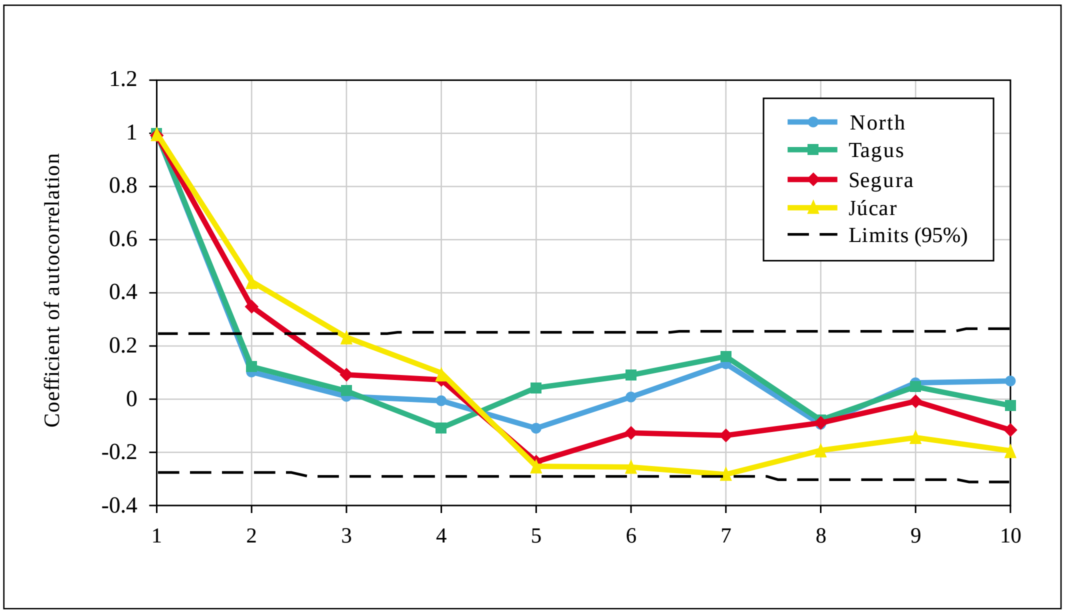


Figure 116. Corelograms of the series of total annual cumulative flow in different territorial areas.

flow have been created in a in natural regime for the different regions, shown jointly in figure 117.

An initial study of this graph shows that, as was the case with rainfall, and logically parallel to it, there apparently exist regional differences giving rise to the run sequences of flow in the different basins not being the same. A detailed inspection differentiates the situations shown in figure 118 graphs, which also present the curves corresponding to regional precipitation.

Wholly parallel to rainfall, most of the basins (Duero, Tagus, Guadiana, Guadalquivir, South, Ebro, Catalonia I.B., North I, Galicia Coast and Balearic Islands) have followed a very similar pattern, which is basically the one given above representing the country's global average, but there are three regions (Levante, North and Canaries) that seem to have followed different patterns to this, and different from each other.

Moreover, it may be seen how from the late 70s there was a more or less exacerbated dry run for flow in all the regions, with some ups and downs in the period 1985-90, after which it was completely widespread. As mentioned, this demonstrates the serious drought that many places in Spain have been through in recent years.

In short, it is confirmed that, as mentioned above, rainfall variability is transmitted in a significant, amplified way to runoff data, an effect that can be seen clearly in previous series of accumulated deviations. On these time-space scales, regions of similar rainfall behaviour are also regions with similar hydrological behaviour, and wet or dry rainfall runs that are converted into identical flow runs. Also, delays in this transmission are very short, as was also seen when studying the cross-correlation of both phenomena. As representative situations, it may be seen that in the northern region responses are immediate and

	GAC	NO1	NO2	NO3	DOU	TAG	GN1	GN2	GUV	SOU	SEG	JUC	EBR	CIC	BAL	CAN
GAC	1	0	0	1	0	0	0	0	0	0.28	1	1	0	1	1	1
NO1	0.88	1	0	1	0	0	0	0	0	0.01	1	1	0	1	1	1
NO2	0.58	0.67	1	0	0	0.05	0.35	1	0.35	1	1	1	0	1	1	1
NO3	0.25	0.21	0.76	1	1	1	1	1	1	1	1	1	0.03	1	1	1
DOU	0.78	0.89	0.54	0.1	1	0	0	0	0	0	0.75	1	0	1	1	1
TAG	0.64	0.8	0.45	0.04	0.93	1	0	0	0	0	0.05	1	0	1	1	1
GN1	0.7	0.77	0.39	0.03	0.87	0.91	1	0	0	0	0.04	0.98	0	0.24	1	1
GN2	0.55	0.58	0.2	–0.13	0.73	0.8	0.9	1	0	0	0.99	0.47	0	0.11	1	0.08
GUV	0.67	0.73	0.39	0.01	0.81	0.84	0.95	0.88	1	0	0.02	0.55	0	0.03	1	1
SOU	0.4	0.5	0.2	–0.15	0.64	0.75	0.84	0.87	0.89	1	0.01	0.09	0.05	0.33	1	1
SEG	0.2	0.34	0.11	–0.09	0.36	0.46	0.46	0.35	0.48	0.51	1	0	1	1	1	1
JUC	0.22	0.2	–0.01	–0.12	0.28	0.35	0.35	0.38	0.37	0.44	0.68	1	1	1	1	1
EBR	0.68	0.77	0.74	0.48	0.77	0.72	0.67	0.53	0.67	0.46	0.24	0.27	1	0	1	1
CIC	0.3	0.32	0.25	0.06	0.3	0.33	0.4	0.43	0.47	0.39	0.14	0.32	0.58	1	1	1
BAL	–0.09	0.06	0.2	0.1	–0.05	0.05	–0.01	–0.05	0.04	0.05	0.22	0.3	0.15	0.34	1	1
CAN	0.15	0.07	0.04	–0.03	0.22	0.25	0.25	0.44	0.22	0.33	0.03	0.14	0.07	0.16	–0.16	1

Table 17. Correlation matrix for annual cumulative flow by water planning area.

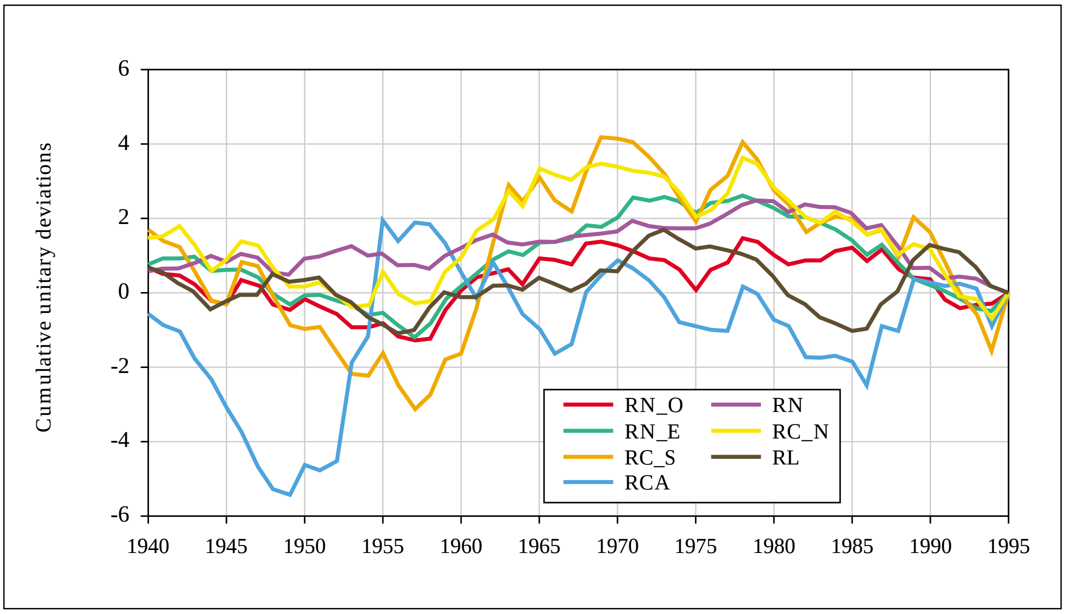


Figure 117. Runs of the annual total cumulative flow in a natural regime for regions in the period 1940/41 - 1995/96, from cumulative unitary deviations.

almost linear, while in Levante there are some effects of delay and poor adjustment due to hydrogeological persistence and redistribution.

If, instead of annual data, we use data on more detailed scales (for example monthly, daily or hourly), the effects of irregularity and non-linearity would be heightened even more.

3.1.4.2. Fraction of groundwater origin. Natural recharge

Sections above have described the situation of total water resources in a natural regime in Spain. As mentioned, this total flow consists partly of direct surface runoff, and partly of groundwater origin. So as to progress in our knowledge of water resources, we shall describe groundwater part of total

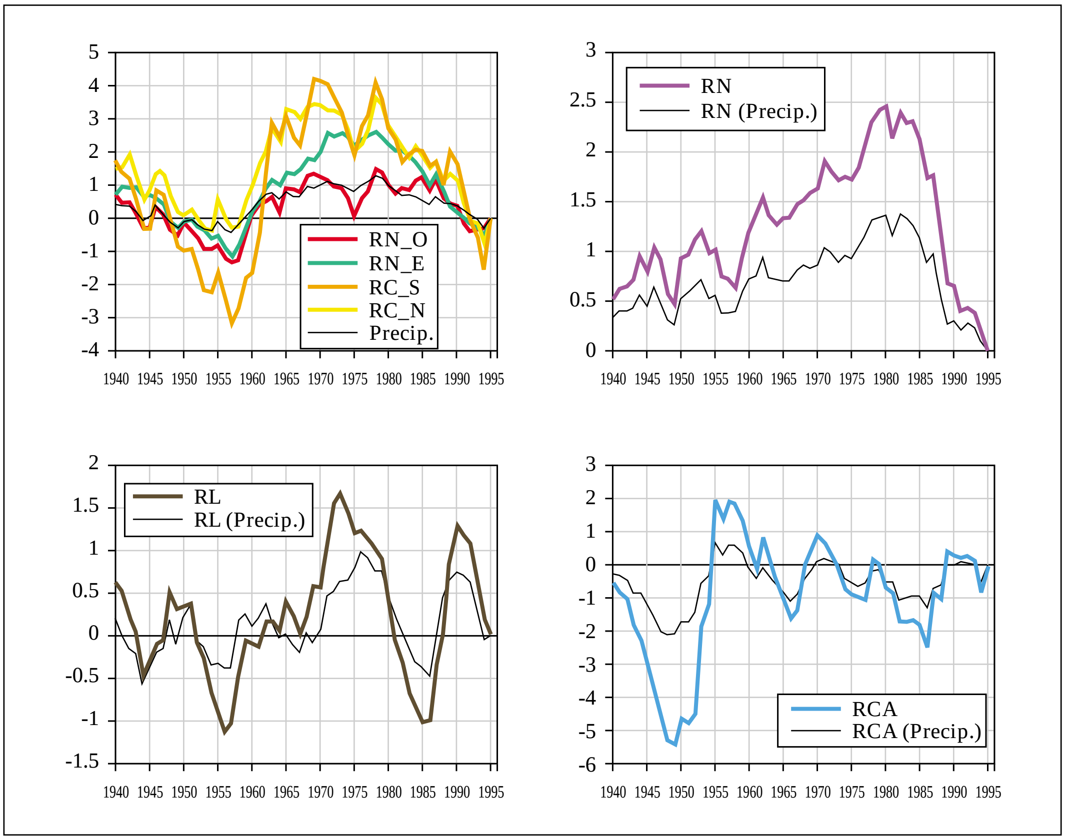


Figure 118. Different situations showing runs of annual total cumulative flow in a natural regime for regions in the period 1940/41 - 1995/96, as of cumulative unitary deviations.

runoff, which basically coincides –except the effects of external groundwater transfers– with natural recharge of aquifers.

Assessing this recharge flow is a complex task, and there exist various technical approaches. In short, it is subject to uncertainties that may occasionally be very significant. In spite of these difficulties, knowledge of recharge is of considerable theoretical and practical interest, because it delimits the long-term maximum possibilities of sustainable groundwater exploitation in an aquifer.

As mentioned, most of the water that recharges aquifers is discharged with a time difference into the fluvial network, diffusely or through springs, and in many basins it is one of the basic components of cumulative river flow. Another part of recharge, in general much smaller, is transferred underground to other aquifers or, in the case of coastal aquifers, discharges into the sea.

To assess natural aquifer recharge it is necessary to know their geometric delimitation. In Spain, aquifers have been grouped into different hydrogeological units. Here we should differentiate between the physical concept of aquifer, understood to be a geological formation capable of storing and transmitting water, and the administrative concept of hydrogeological unit, made up of for one or more aquifer, grouped together for the purposes of achieving rational and effective water administration, and whose boundaries may also include parts of territory where aquifers do not exist.

The White Paper on Groundwater (MOPTMA - MINER, 1995) included a total of 442 hydrogeological units in Spain. Of these, 422 were located entirely in one single territorial water planning area, 19 were shared by two areas, and one was shared by three.

Among the hydrogeological units defined for peninsular territory, there are four where the aquifers partly lie in Portuguese territory. These are the following: the Miño alluvial plain (HU 01.26) in the basin of the North, Ciudad Rodrigo-Salamanca (HU 02.19) on the Douro, la Moraleja (HU 03.13) on the Tagus and the lower valleys (HU 04.09) of the Guadiana. Except the one mentioned first, in all cases the aquifer's outcrop in Portugal covers a very small surface area, significantly less than on the Spanish side.

In some of the basin management plans (e.g. Segura and Ebro), and as a consequence of improvements in hydrogeological knowledge, a new delimitation of the hydrogeological units has been made where, although it generally coincides with the above-mentioned delimitation, major differences exist in some specific units, changes in coding, and new units included. In some shared units, which are defined on a national level, discrepancies also exist between the Basin Plans that share them, which are even more significant in the figures on unit characteristics (permeable boundary surface areas, recharge, hydrodynamic characteristics, etc.). It should be noted that for a unit to be considered shared it is not enough for the aquifer to cover more than one planning area.

For the above reasons, for the purposes of this White Paper, a new unit delimitation and characterisation has been drawn up, shown in the adjoining map, according to the following criteria (fig. 119):

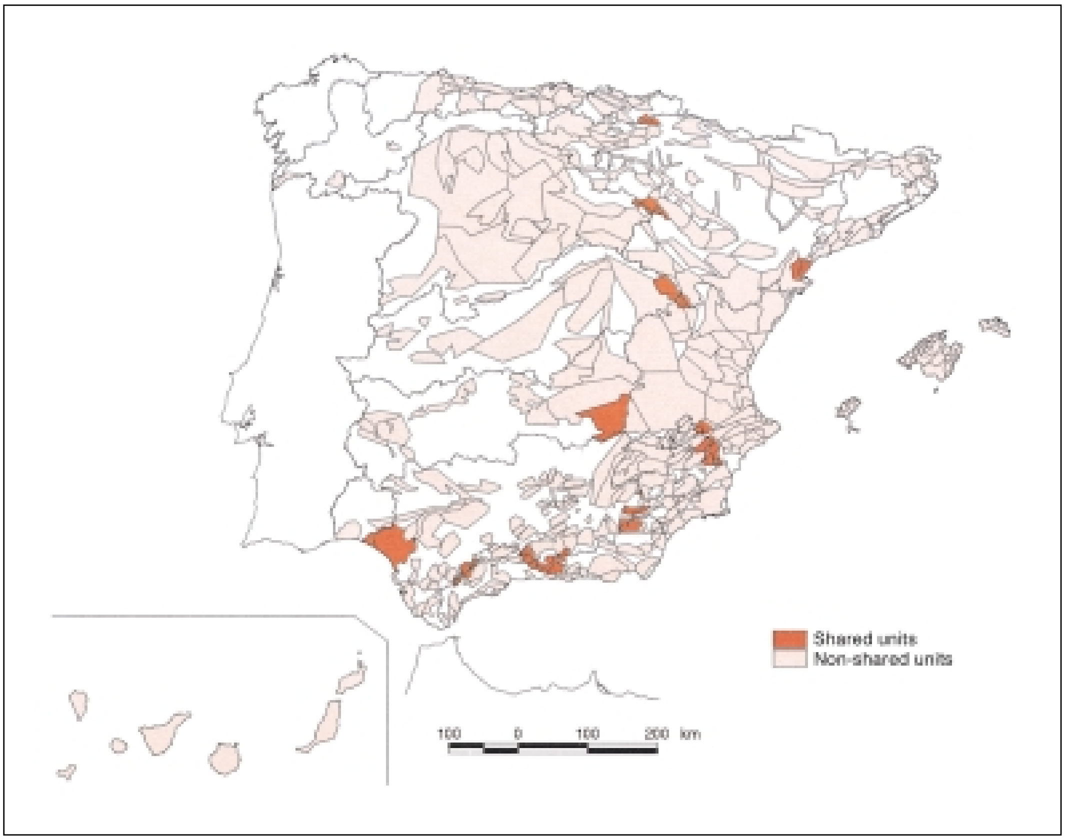


Figure 119. Map of hydrogeological units.

- The denomination and polygonal unit defined in the basin management plans are generally adopted, since these are appropriate and competent technical-administrative documents for such a definition.
- An exception to the above criterion is in shared units. In those units, there exist aquifers located within two or more territorial areas of basin management plans (BMP). In those cases, it is the National Hydrological Plan (NHP) that is responsible for delimiting and allocating resources. Provisionally, and prior to the NHP, the units adopted are those that appear in the document delimiting and summarising the characteristics of inter-basin hydrogeological units (MOPT, 1993a).
- When two adjoining boundaries of the defining polygonal unit lie on the intersection with another basin or with the coastline, the union of these boundaries shall not run along a straight line, but along the division or coastline that defines them.
- In the Canary Islands, a unit has been defined for each island, under the draft Hydrological Plan for the Canary Islands, and in the Catalonia Inland Basins, the delimitation adopted is the one that appears in MOPTMA-MINER (1995), in the absence of appropriate cartographic information on the polygonal units outlined under Decree 328/1988 on the Department of Territorial Policies and Public Works of the Generalitat of Catalonia.
- Figures on permeable boundary surface area in each unit and its typification as carbonated, detritic and volcanic have been obtained from the MOPTMA-MINER-UPC inventory (1993), after calculating the permeable surface area of each type comprised within each hydrogeological unit. This decision arises from methodological discrepancies seen in the determination of permeable surface area in the different basin plans, a heterogeneity that advised against its direct adoption.

  The surface area covered by permeable boundaries inside the hydrogeological units is about 176,000 km^2, distributed over 99,000 km^2 corresponding to detritic formations, 69,700 km^2 to carbonated formations and 7,800 km^2 to volcanic formations. The adjoining map, drawn up with MOPTMA-MINER-UPC data (1993), shows these permeable boundaries.
- The figures on each units' s basic characteristic (recharge by rainfall and channels, irrigation returns and transfers) have been taken from basin management plans, and in cases where information was not available, MOPTMA-MINER data was used (1995) (fig. 120).

In territory not covered by the hydrogeological units defined there may also exist aquifers which, in general, have low or very low permeability, and whose characteristics and balances have not yet been sufficiently evaluated. Analysis of base flow reveals that it actually exists. These aquifers and units should be included in planning inventories as they are defined and characterized.

With the above-mentioned criteria, the number of new hydrogeological units is 411, of which 391 are located

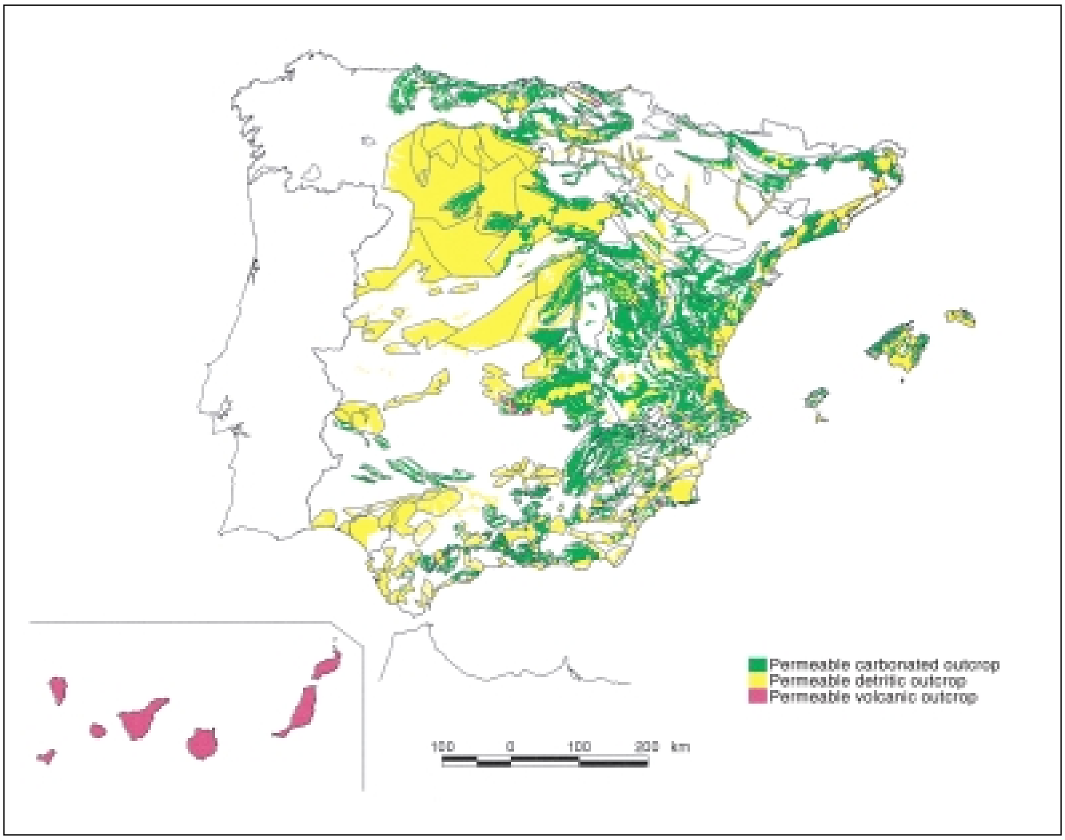


Figure 120. Map of permeable outcrops.

entirely inside one single planning area, 19 are shared by two areas and one is shared by three (CEDEX, 1998a). The difference with respect to the total number of units given in MOPTMA-MINER (1995) is, basically, due to only 7 units having been considered in the Canary Islands, one on each island. However, the number of units in the Ebro and Segura has increased, as a consequence of the new delimitation included in their respective basin plans.

The summary of these units' average basic characteristics, aggregated by planning area, and with data provided by the basin plans and MOPTMA-MINER (1995), is shown in table 18.

As may be seen, the resulting total of average natural recharge (by rainfall and infiltration in channels, and not considering irrigation surpluses that do not correspond to the natural regime), in all the hydrogeological units, according to information in the basin management plans, amounts to almost 21,000 hm^3/year. Recharge in national territory as a whole is, in fact, larger, since this estimate has only considered areas where hydrogeological units have been defined and, nevertheless, aquifers exist in certain other unclassified areas. In these areas without defined aquifers, the sum of many small abstractions, together with the uses of springs, reaches a significant magnitude, as is the case in areas of Galicia and the Canaries. In fact, as we shall show later on, in calibrating the simulation model it was necessary to include new groundwater recharge areas in the areas of Galicia Coast, North I and North II.

The units shared between different territorial areas are shown in the adjoining table, which also shows the area they are assigned to (table 19).

As was done with total cumulative flow, and so as to have an evaluation of natural aquifer recharge in a common period (1940/41 at 1995/96), and with homogeneous calculation methodology, an estimate of each unit's recharge due to rainfall has been carried out for the whole of Spain, with the distributed model of flow simulation mentioned. This estimate does not therefore take into account transfers between units which, although generally small, can be significant in certain specific units. Figure 121 shows annual average recharge values , in mm/year, for each hydrogeological unit.

Furthermore, figures 122, 123 and 124 show the series of annual recharge by direct rainfall corresponding to two specific hydrogeological units, Eastern La Mancha and Madrid-Talavera, as well as figures on the whole Spanish peninsular territory, illustrating their inter-annual variability.

Table 20 and figure 125 present the mean annual values of this recharge in each area, and the percentage they represent with respect to total cumulative flow, provided in the section above. This percentage is thus a very accurate estimate of groundwater runoff or fraction of groundwater origin of the total flow in each area.

The results obtained show, for the Peninsula as a whole, an global mean figure for groundwater component (comparable to natural recharge) of around 26% of total cumulative flow, but with considerable territorial variations, ranging between over 70% in the Segura and Júcar (as seen above and again demonstrated, the peninsular areas with the largest underground component and autocorrelation, by far)

Planning Area	Number of units not shared	Number of units shared	Area of permeable outcrop (km^2)	Recharge by rainfall and canals (km^3/year)	Recharge by irrigation (him^3/year)	Transfer from other units (km^3/year)	Transfer to other units (km^3/year)
North I	3	--	--	--	--	--	--
North II	16	0	4,672	2,587	0	94	34
North III	7	1	946	410	0	0	0
Douro	20	1	52,799	1,840	1	249	383
Tagus	12	1	17,475	1,565	0	0	0
Guadiana I	10	1	13,834	646	20	60	60
Guadiana II	2	1	920	141	0	0	0
Guadalquivir	57	11	15,140	2,573	16	27	70
South	41	7	5,305	865	69	107	31
Segura	50	7	6,958	674	83	44	0
Júcar	46	6	23,781	3,011	480	514	468
Ebro	57	4	17,057	4,433	586	19	25
Catalonia I.B.	29	1	6,616	938	45	65	54
Galicia Costa	--	--	--	--	--	--	--
Balearic Isl.	34	0	3,674	517	69	26	23
Canaries	7	0	7,384	681	0	0	0
Spain	**391**	**20 (1)**	**176,561**	**20,881**	**1,369**	**1,205**	**1,148**

Table 18. Characteristics of hydrogeological units according to planning area.

(1): The total does not coincide with the sum of parts, since different areas can share one same unit.
Note: In the Douro area, the H U. called Aluviales del Douro has been accounted for, although its polygonal unit and associated characteristics are not defined in the Douro management plan, nor in MOPTMA-MINER (1995).

Number	Hydrogeological Unit	Affected areas
1	Aralar-Ulzama	North III and Ebro
2	Araviana-Moncayo	Douro and Ebro
3	Albarracín-Cella-Molina de Aragón	Tagus, Ebro and Júcar
4	Campo de Montiel	Guadiana I and Guadalquivir
5	Almonte-Marshes	Guadiana II and Guadalquivir
6	Sierra de Libar	Guadalquivir and South
7	Setenil-Ronda	Guadalquivir and South
8	Sierra de Cañete	Guadalquivir and South
9	Sierra Gorda-Zafarraya	Guadalquivir and South
10	Tejeda-Almijara-Las Guajaras	Guadalquivir and South
11	Sierra de Padul	Guadalquivir and South
12	Sierra de las Estancias	Guadalquivir and South
13	Orce-María	Guadalquivir and Segura
14	Sierra Zarza	Guadalquivir and Segura
15	Sierra de la Oliva	Segura and Júcar
16	Segura Jumilla-Villena	Segura and Júcar
17	Serral- Salinas	Segura and Júcar
18	Quibas	Segura and Júcar
19	Sierra de Crevillente	Segura and Júcar
20	Cardó-Perelló	Ebro and Catalonia I.B.

Table 19. Hydrogeological units shared between different planning areas.

and less than 10% in the Guadiana II. In absolute terms, the largest natural recharges would correspond North II and the Ebro (around 5,000 hm^3/year), and the lowest to the Guadiana II (less than 100 hm^3/year).

This definitively shows that although groundwater is not globally and quantitatively the Spain's main natural water resource, it is a very significant one and, in some territories, without a doubt, the most important.

As may be seen, the global average obtained with the simulation model (approximately 29,000 hm^3/year in the Peninsula) is higher than that from the basin management plans (around 20,000 in the Peninsula). This is largely due to the fact that for the model to reproduce low water periods in some rivers of Galicia Coast, North I and North II, new groundwater recharge areas have been included, not reflected in the above figure because they are not administratively considered as hydrogeological units.

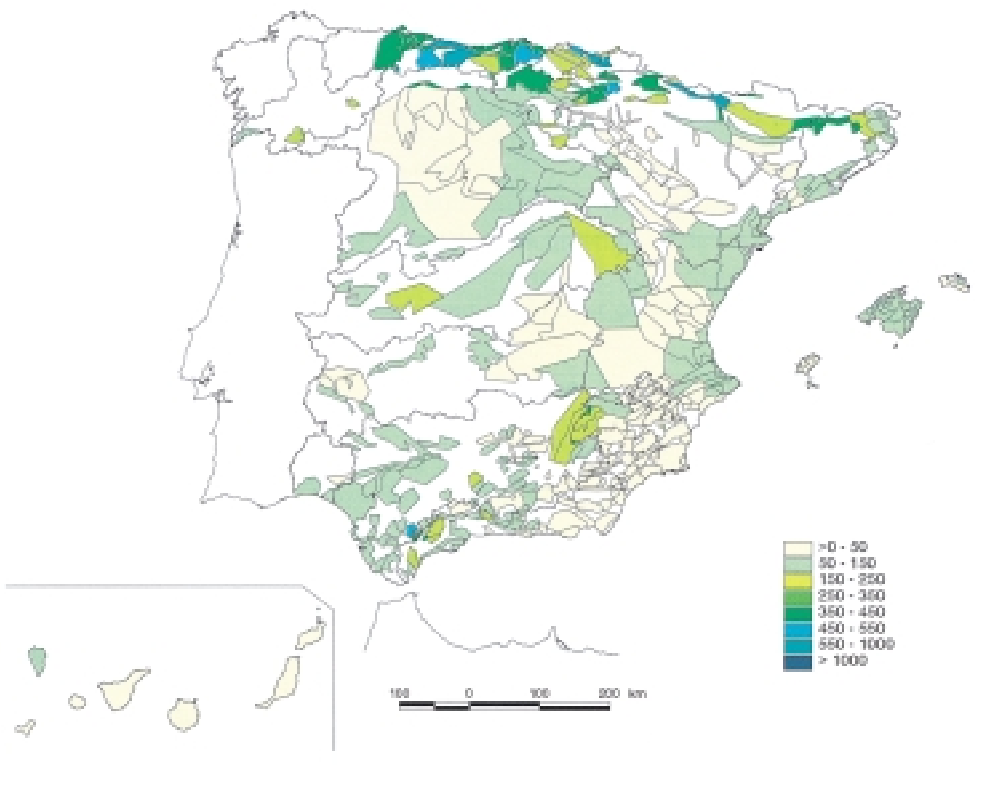


Figure 121. Map of natural recharge in hydrogeological units (mm/year).

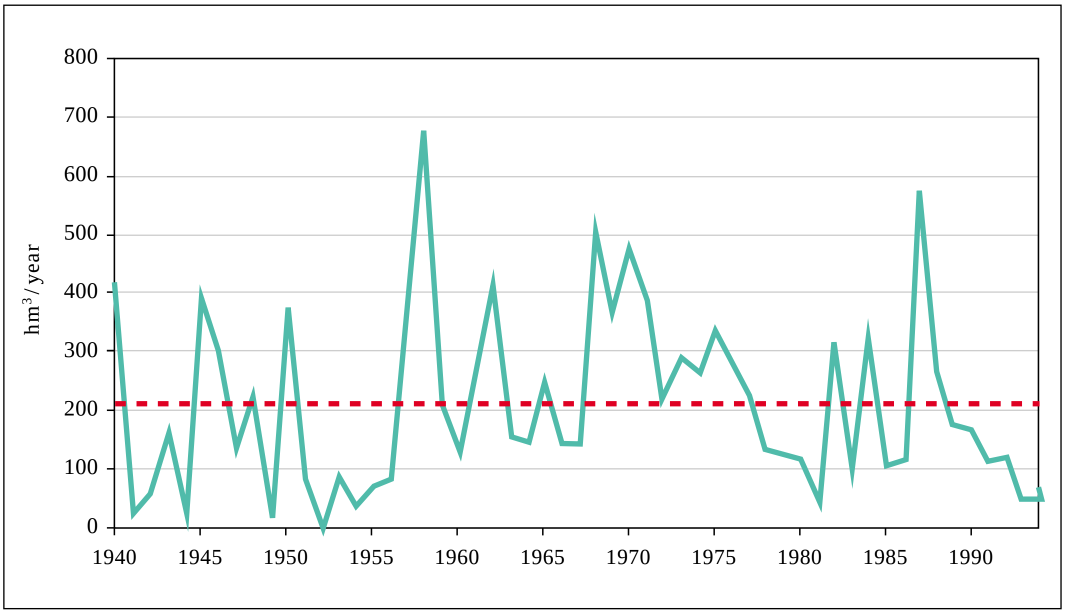


Figure 122. Recharge by rainfall infiltration (hm³/year) in the Eastern La Mancha hydrogeological unit (period 1940/41 to 1995/96).

Furthermore, although in quantitatively smaller terms, in some hydrogeological units, natural recharge given in the basin plans is higher than total runoff obtained with the simulation model, which may be due to: a) very complex situations occasionally taking place where it is not easy to separate natural recharge from irrigation returns, groundwater transfers, etc. (most of the basin plans only include the aquifer recharge figure, without specifying if it is natural or not, and if it includes transfers from other basins or not); b) the time period for calculating recharge is not known, nor if they are biased or if they are representative of the annual average; and c) as mentioned, the recharge estimate includes some uncertainty and intrinsic difficulties, so such divergences are to be expected.

Figure 126 contrasts data from both sources, illustrating that, except in these particular cases, differences do not exceed 20%.

So as to offer a general perspective of these assessments over time, table 21 shows recharge data or groundwater runoff in the basins given by different sources.

As may be seen, all the estimates carried out up to now give recharge values between 15,000 and 20,000 hm³/year, which contrasts with the 30,000 obtained in the assessment made for this White Paper. The reasons for this difference they will be detailed later on.

In any event, it shows the need to progress further in knowledge about aquifer recharge and oits distribution due to rainfall and channels, groundwater transfers, returns from irrigation, etc. This would contribute to improving our understanding and quantification of groundwater's real role in within water resources as a whole, a role that, as may be seen, it is of great importance in some of our main basins

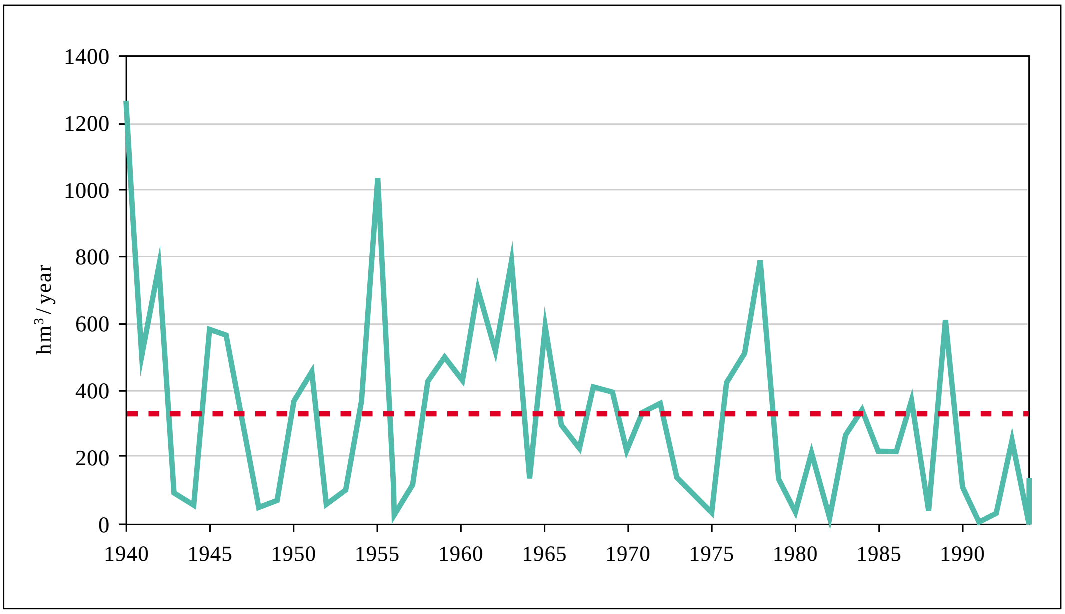


Figure 123. Recharge by rainfall infiltration (hm³/year) in the Madrid-Talavera hydrogeological unit (period 1940/41 to 1995/96).

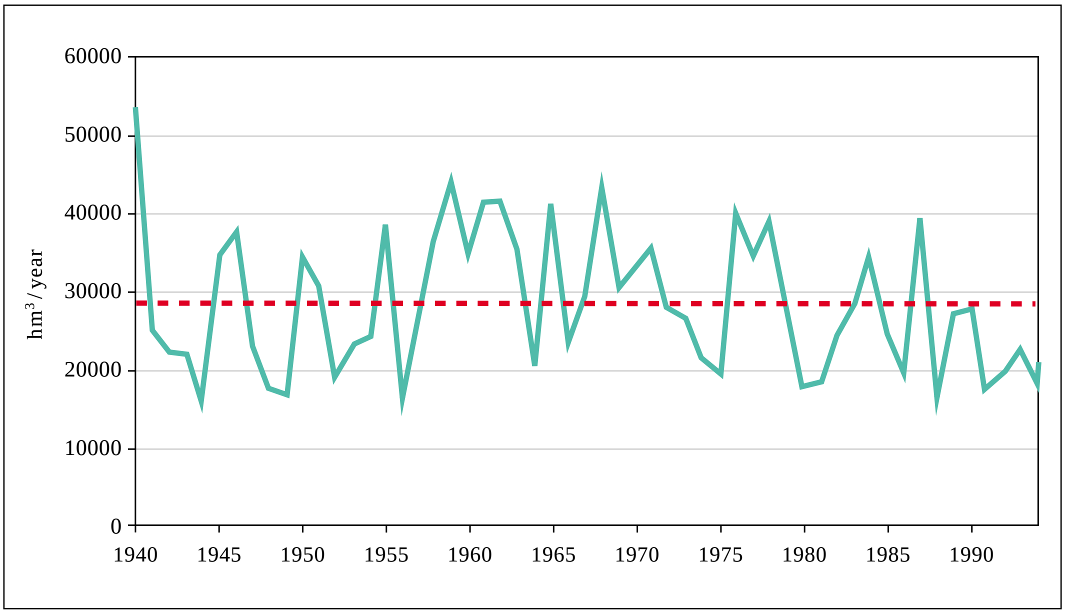


Figure 124. Recharge by rainfall infiltration (hm^3/year) in the Peninsula (period 1940/41 to 1995/96).

and it represents a strategic resource in improving supply guarantee.

As regards groundwater outlets to the sea, they are, in relative terms, very small in quantity. They have some importance on the islands, on account of the considerable length of coastal perimeter contact in relation to surface area. There may also exist singular cases of submarine upwelling due to karstic phenomena, such as the cases of Sierra de Irta (Castellón) and the area of Nerja-La Herradura (Málaga).

Table 22 gives different estimates of underground outlets to the sea (in hm^3/year), by basin or planning area. The most recent are those of the DGOH (1995) obtained for the coastal area occupied by identified hydrogeological units, and those providing the simulation model defined for the purposes of this White Paper.

As suggested by the variation of magnitudes offered by the different authors, these figures must be considered with some reservation, and they should be taken as a limited description of the problem's order of magnitude, since well-contrasted data is not available to allow for sufficient precision of underground transfers of fresh water to the sea. In any event, the differences between the figures provided by the two most recent works are moderate, excluding those corresponding to the basins of the North.

As regards aquifer stocks, the ITGE (1989) has estimated that the volume of groundwater stored in Spain, up to 200 m in depth, is around 125,000 hm^3. Of these natural groundwater stocks, approximately 120,000 hm^3 corresponds to the Peninsula, 2,500 hm^3 to the Canaries and another 2,500 hm^3 to the Balearic Islands.

Other works, such as the MOPTMA-MINER-PC Inventory (1993) estimate stocks at about 180,000 hm^3 (not including the Segura Basin not the archipelagos) with distribution according to basins shown in table 23.

It is necessary to highlight the uncertainty associated with an estimation of stocks, because there is not always agree-

Planning Area	Total Cumulative in a natural regime	Recharge in a natural regime	Relationship Recharge/ Cumulative flow
North I	12,689	2,745	22
North II	13,881	5,077	37
North III	5,337	894	18
Douro	13,660	3,000	22
Tagus	10,883	2,393	22
Guadiana I	4,414	687	16
Guadiana II	1,061	63	6
Guadalquivir	8,601	2,343	27
South	2,351	680	29
Segura	803	588	73
Júcar	3,432	2,492	73
Ebro	17,967	4,614	26
Catalonia I.B.	2,787	909	33
Galicia Coast	12,250	2,234	18
Peninsula	**110,116**	**28,719**	**26**

Table 20. Aquifer recharge and total cumulative flow in a natural regime in territorial planning areas according to the simulation model used.

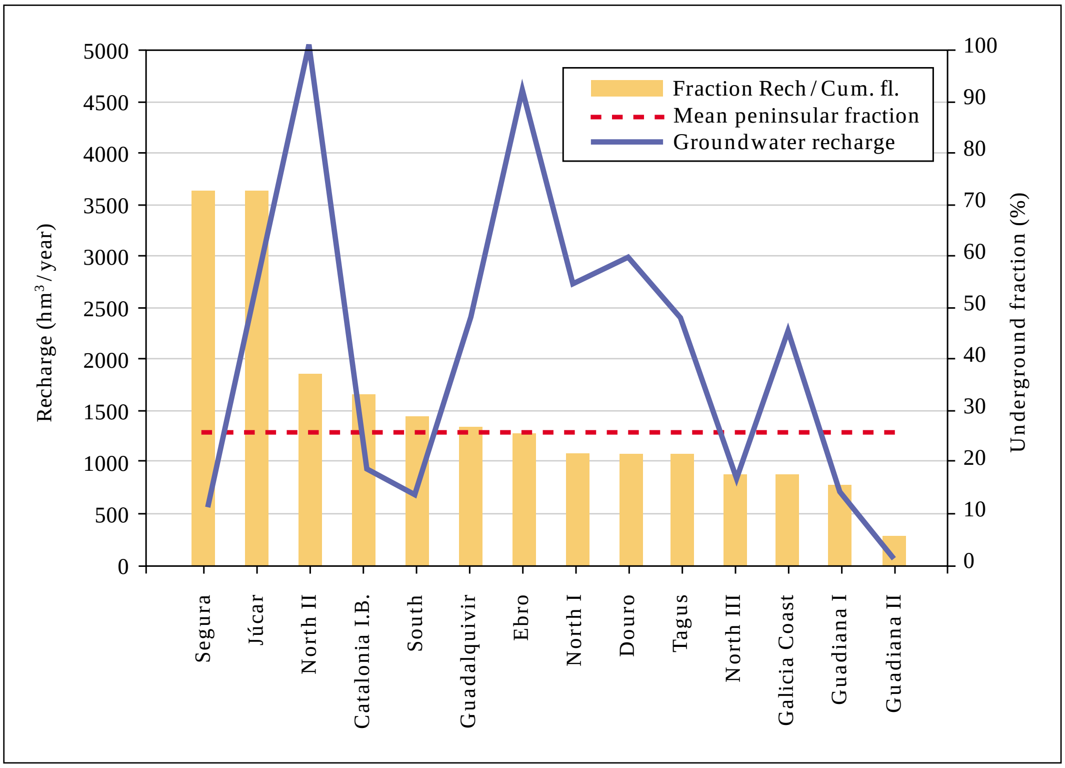


Figure 125. Groundwater fraction of total runoff and aquifer recharge in a natural regime in the territorial planning area.

ment as to its significance (consideration of the impermeable stratum, technical and economic accessibility, etc.), in addition to the inherent technical difficulties of quantifying it. In any case, these are considerable volumes (around three times the total available storage capacity through dams), which can play a fundamental role in situations of drought.

In short, natural regime resources of groundwater origin, or natural recharge of aquifers, amount to a total in excess of 29 km^3/year, of which approximately 27 is groundwater contribution to river runoff, and the remaining 2 are underground transfers to the sea or other territories.

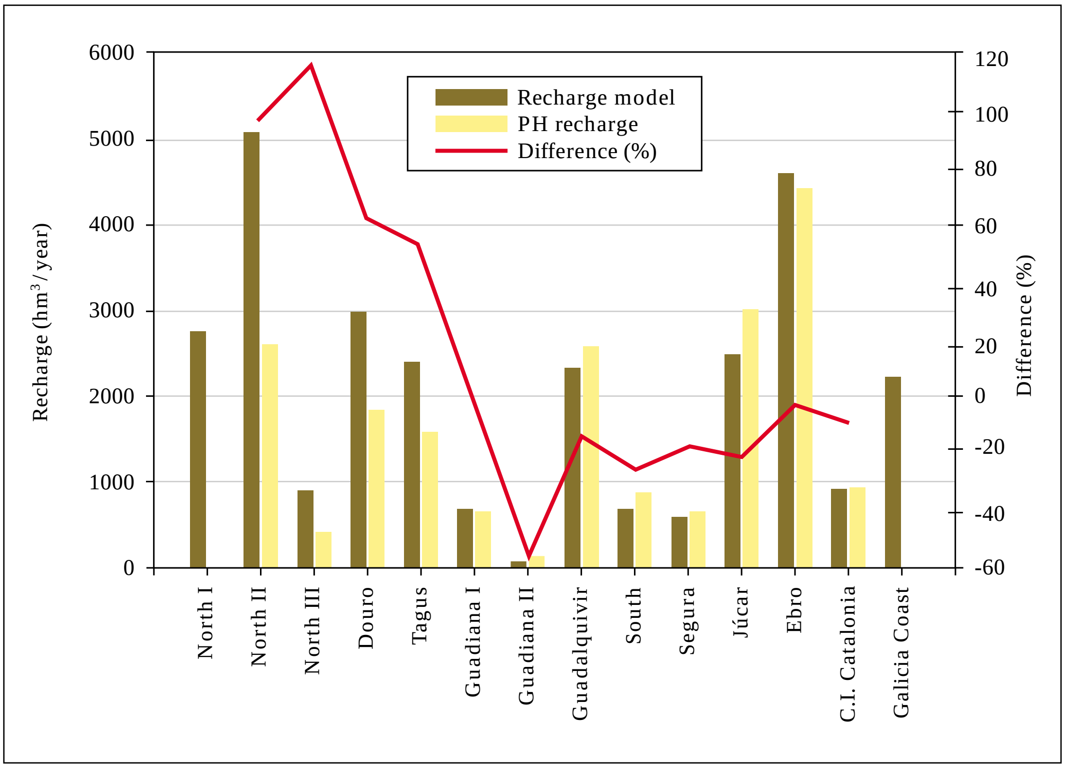


Figure 126. Contrast of aquifer recharge data in a natural regime in territorial planning areas.

Planning Area	1967 (a)	1974 (b)	1980 (c)	1986 (d)	1993 (e)	1998 (f)	1998 (g)
Galicia Coast					--	--	2,234
North I					--	--	2,745
North II					2,644	2,587	5,077
North III					331	410	894
North	5,500	5,480	4,100	4,100	2,975	2,997	10,950
Douro	3,000	1,430	1,450	1,450	1,875	1,840	3,000
Tagus	1,700	2,160	2,200	2,000	1,646	1,565	2,393
Guadiana I					656	646	687
Guadiana II					98	141	63
Guadiana	1,000	710	700	500	754	787	750
Guadalquivir	1,800	2,250	2,100	1,100	2,315	2,573	2,343
South	250	900	450	700	1,160	865	680
Segura	300	510	500	600	548	674	588
Júcar	700	2,460	1,200	1,700	3,505	3,011	2,492
Ebro	3,400	3,120	3,050	2,900	2,923	4,433	4,614
Catalonia I.B.	500	250	250	250	1,035	938	909
Total Peninsula	18,150	19,270	1,600	15,300	18,736	19,683	28,719
Balearic Isles			--	--	585	517	
Canaries			--	--	700	681	
Total Spain					**20,021**	**20,881**	

Table 21. Estimates of aquifer recharge.

(a): Prepared by Llamas in 1967. Groundwater runoff to rivers. Quoted in Llamas (1995) p. 133.
(b): Coma (1974). Total groundwater runoff (incl, flow to the sea), Quoted in Llamas (1995) p. 133.
(c): MOPU (1980). Water in Spain. CEH, DGOH, Also in Heras (1977) and others.
(d): MOPU (1986) Hydraulic panorama in Spain, in Gallego Anabitarte et al, (1986). vol, II.
(e): MOPT (1993) Memorandum of the draft NHP Act. Also in MOPTMA-MINER (1995).
(f): Data from basin management plans (1998).
(g): Data from the assessment carried out in this White Paper (year 1998).
Notes: North comprises the areas of Galicia Coast and North I, II, and III; Guadiana comprises the areas of Guadiana I and II.

Territorial Area	1967 (a)	1980 (b)	1995 (c)	1998 (d)
Galicia Coast	--	--	--	356
North I	--	--	--	--
North II	--	--	--	786
North III	--	--	--	161
North	1,100	1,500	100	1,303
Guadiana I	--	--	--	--
Guadiana II	--	--	--	8
Guadiana	60	50	25	8
Guadalquivir	600	200	70	56
South	300	440	100	65
Segura	160	10	5	16
Júcar	800	1,300	225	173
Ebro	80	100	40	--
Catalonia I.B.	250	700	125	83
Peninsula	3,350	4,300	690	1,704
Balearic Isl.	--	480	150	--
Canaries	--	610	230	--
Total Spain	**--**	**5,390**	**1.070**	**--**

Table 22. Estimates of groundwater outlets to the sea (hm^3/year) by planning area.

(a): Llamas (1967). Quoted in Llamas (1995) p. 133.
(b): MOPU (1980) Water in Spain. CEH. DGOH. Also in Heras (1977) and in MOPU (1982).
(c): DGOH (1995) I Study of the current situation and programming of future actions in groundwater-related areas in Spain.
(d): Simulation model of cumulative flow used in this White Paper (year 1998).

Basin	Reserves (hm³)
North	7,700
Douro	43,600
Tagus	4,700
Guadiana	2,800
Guadalquivir	11,000
South	5,600
Segura	--
Júcar	79,100
Ebro	12,800
Catalonia I.B.	12,600

Table 23. Estimate of groundwater reserves (hm³) in different basins.

3.1.4.3. Variability and hydrological diversity

In previous sections, water resources have been described in a natural regime, and their relative composition in direct surface runoff and groundwater runoff. In this description the great irregularity was already pointed out and hydrological diversity of the country, and since this is a very significant feature of our water resources, we will give it some specific attention here.

In fact, Spain's hydrological variability and the irregularity of its hydrological regime in space and time has become one of most insistently-repeated subjects when speaking of water problems. In reality, and as has already been shown, variability is one of the most prominent aspects of our hydrology, in such a way that, as we shall see, clearly differentiates it from the countries around it. The reasons for this lie in turn in the variability of the physical environment (climate, soil, mountains, etc.) commented in previous sections.

As was shown, precipitation is the variable that most influences fluctuations of accumulated flow in rivers, but there are other factors, such as the different soil types, vegetation, evapotranspiration and aquifers, which condition and control the basin's response to rain gauge inflow.

According to the characteristics of the precipitation pattern, but also bearing in mind other climatic characteristics, such as, for example, those arising from melted snow, we may speak of a characteristic intra-annual fluvial pattern. Figure 127 shows different examples of monthly average flow in Spanish rivers (in m^3/s), typical of these representative patterns (snow/rain fall of the Segre in Lérida, oceanic rainfall of the Miño in Puente Mayor, Mediterranean rainfall of the Guadalhorce in Bobadilla, and snowfall on the Caldares in Ibón de los baños).

Figure 128 shows seasonal variability precipitation, indicating that the seasons of the year with the largest precipitation values are autumn and winter, and that in the summer months, total precipitation in a large part of the southern half of Spain does not even reach 50 mm. A fact that further accentuates this temporary variability of rainfall is that values of average precipitation observed in some basins are taken in just a few days (see chapter on floods).

Seasonal variability of potential evapotranspiration is shown below, indicating how, contrary to what happens with precipitation, the seasons with the greatest value for potential evapotranspiration are spring and summer. However, we should bear in mind, as has already been seen

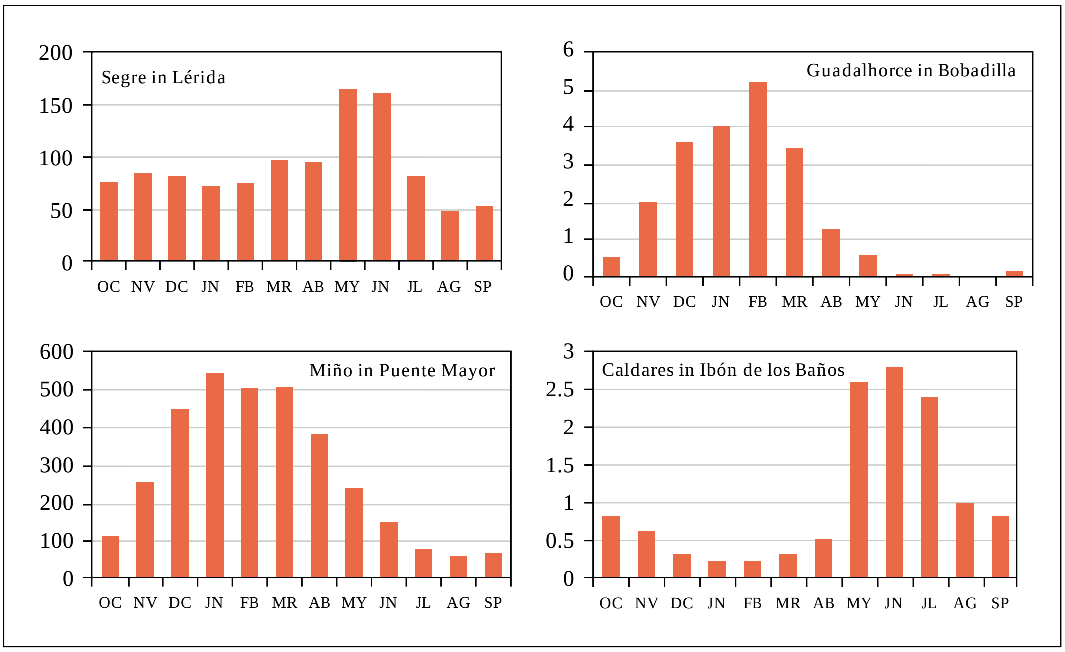


Figure 127. Mean monthly flow in rivers with different fluvial regimes.

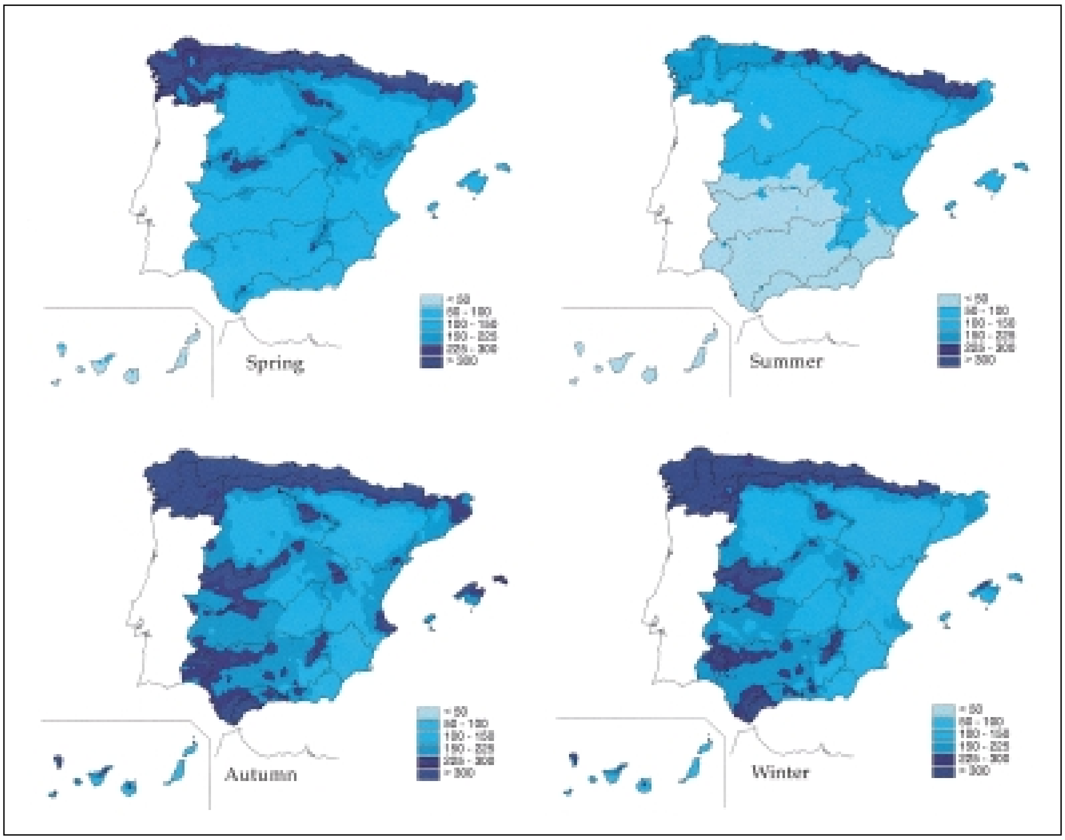


Figure 128. Seasonal distribution of precipitation (mm).

in sections above, that this is a potential value subject to the availability of water on the ground (fig. 129).

Finally, figure 130 shows the seasonal distribution of runoff, arising from precipitation and evapotranspiration patterns and from the modification caused by soil and aquifers. The potential low rainfall and high evapotranspiration of the spring and summer months determine that in a large part of the territory runoff is not generated in those months. Therefore, the water that circulates along the rivers in that time comes from aquifer discharge, and when this is not present, runoff is practically zero. Generally speaking, we could say that the water establishing a certain year's hydrological abundance in many regions of Spain is what falls in autumn and winter.

We may come to a better understanding of the relationship between the temporal variability in precipitation, the characteristics of the basin, and its consequences on temporal variability in runoff, by analyzing flow evolution in certain specific gauging stations.

As an illustrative example, figure 131 reflects evolution of monthly flow (in m^3/s) in two gauging stations in the Guadiana basin –River Guadiana at Torreblanca and River Zújar at Castuera– during 4 hydrological years 1946/47 to 1949/50, in which an almost unaffected regime can be appreciated, practically similar to a natural regime.

With a very similar precipitation distribution in both basins, it may be seen how in the first station, drained by the basin comprising the aquifers at the Guadiana headwater, circulating flow diminishes but it does not run out in the months of low water. By contrast, on the River Zújar at Castuera, which drains a basin where there are no significant aquifers, the base flow is inappreciable and in the months of low water the river is practically dry.

All these examples reinforce the idea of how diversity and variability of the factors controlling hydrological response give rise to extraordinarily diverse situations, with very different hydrological regimes, even in relatively nearby areas.

3.1.4.4. Comparison with the European context

Having described the country's water resources, both surface water and groundwater, and shown their fundamental magnitudes and their variability, it is interesting to consider the question of what the situation is like with respect to the countries in our immediate environment.

Firstly, it is necessary to indicate that water flow and reserves in the European Union (EU) represent a very small percentage of the Earth's total water. Internally-generated runoff in the EU is about 1,200 km^3/year, which represents 3% of runoff over the whole planet, as shown in table 24, drawn up here from EEA data (1995).

In the coasts furthest west and in the mountain ranges of Europe, extremely humid masses of air give rise to heavy rain. In these places, annual precipitation lies between 1,000 and 2,000 mm, with localised areas where larger values can be reached.

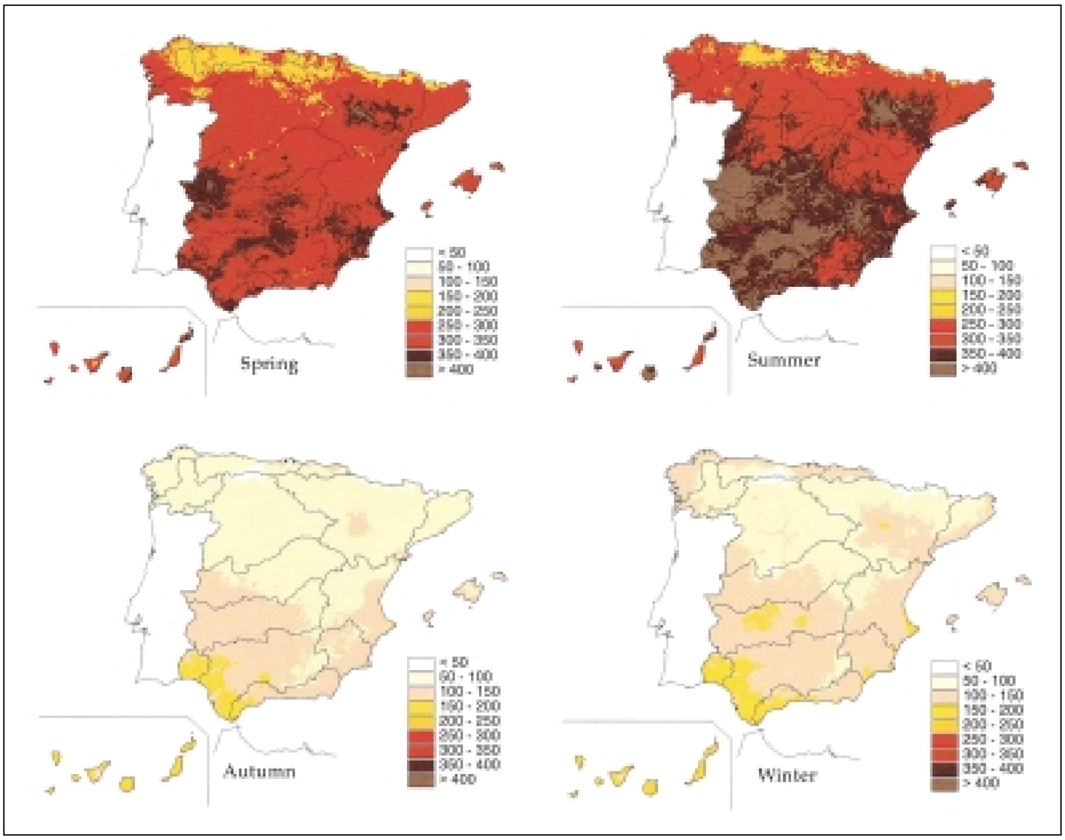


Figure 129. Seasonal distribution of potential evapotranspiration (mm).

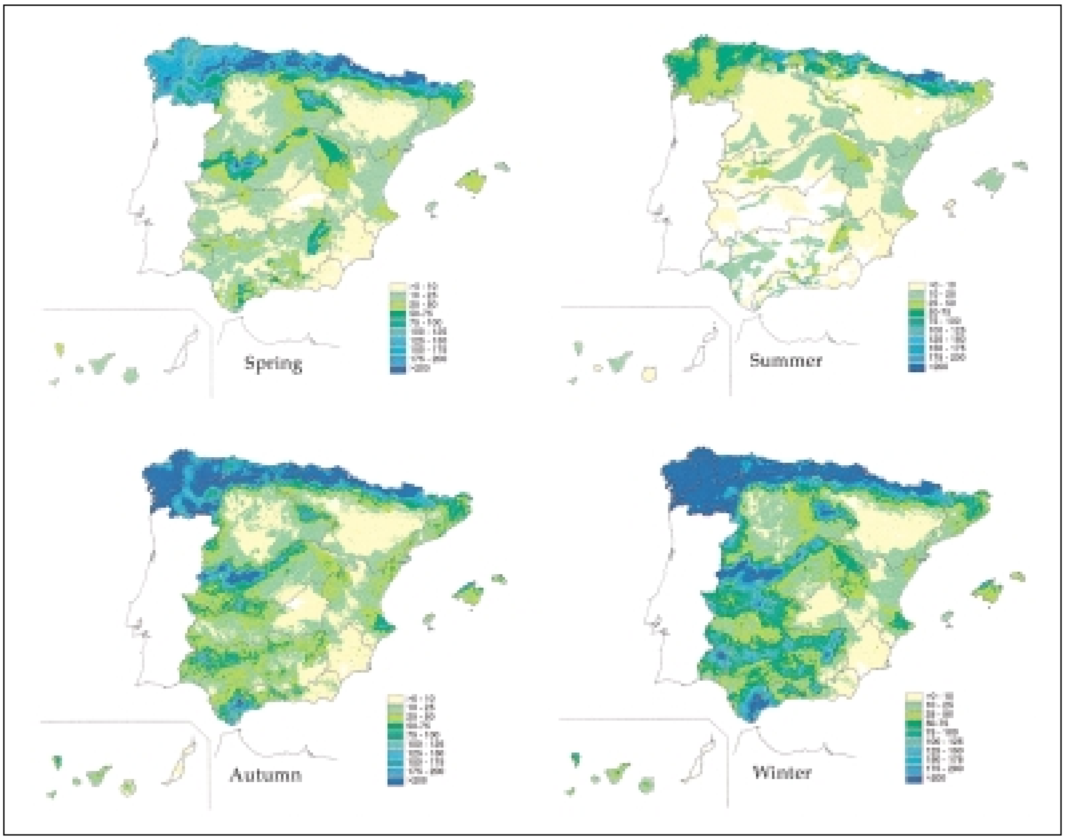


Figure 130. Seasonal distribution of runoff (mm).

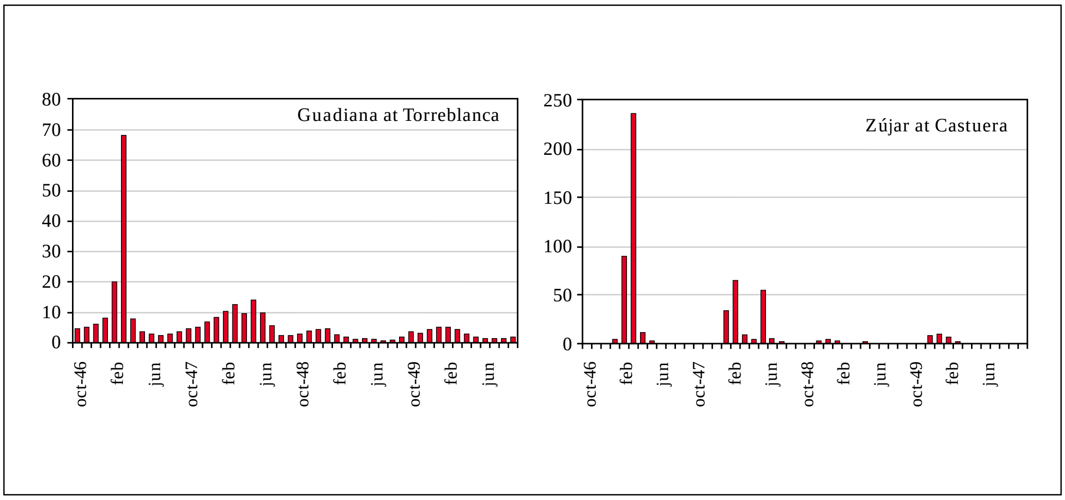


Figure 131. Monthly flow (m^3/s) in the Guadiana at Torreblanca and the Zújar at Castuera in the period 1946/47 to 1949/50.

Although annual precipitation values are common between 300 and 500 mm in the south-east of the Mediterranean peninsulas, in fact they are not exclusive to these areas and values below 500 mm can be found in Sweden, Finland, the Baltic Countries, Poland and central plain of the Danube.

Annual distribution of average precipitation, potential evapotranspiration according to Penman, and total runoff in EU countries, is shown in figures 132, 133 and 134, drawn up here from Eurostat information. The last of these figures shows runoff of internal origin in each country, that is to say, runoff generated exclusively within their own territory, without bearing in mind contributions from neighbouring countries.

Calculating the moisture index (ratio between precipitation and potential evapotranspiration according to Penman) for EU countries (see figure 135), it may be seen that most of Spanish territory, as well as the south-east of Italy and of Greece, lie in a range of values between 0.2 and 0.5, typical of semi-arid areas.

The average annual areal values for precipitation, potential evapotranspiration and internally-generated runoff, absolute and per capita, are shown, for each EU country (except Luxemburg, for which no data is available), in table 25 drawn up here from Eurostat information.

As may be appreciated, Spain shows a precipitation level amounting to 85% of average precipitation in the Union, and a potential evapotranspiration among the highest on the continent, giving rise to one of the lowest runoff values of all the countries considered (approximately 60% of the European average). If internally-generated per capita contributions are analysed in each country, Spain gives a value of about 2,800 m^3/inhab/año, which represents 90% of the average value for the European Union, considerably more than that of countries with greater population density, such as Germany, Belgium, Denmark and the Low Countries, and similar to the values of Italy, France and the United Kingdom.

These figures, however, can be deceiving. Water transfers that many European countries receive represent a very high percentage of their total resources. In fact, countries like Holland, Luxemburg or Germany receive between 40% and 90% of their resources from other neighbouring countries, so if these transfers were not considered, their demand would exceed their internally-originated water resources. An eloquent case is that of Spain and Portugal. Total resources per capita in Spain are less than 50% of those of Portugal, which receives 38% of its water from Spain.

Bearing in mind water transfers from other countries, the adjoining table –drawn up here from EEA data (1998)– total annual resources per capita are shown for EU countries, differentiating water resources generated in each country (internal origin) and transfers from neighbouring countries (external origin) (table 26).

As for the level of surface and groundwater resource utilisation, this varies greatly from some countries to others, from particular extremes such as Denmark, where practically 100% of those resources come from groundwater abstractions, to Holland, Belgium or Finland, where the use of groundwater use represents less than 10% of the total. In Spain, the percentage of groundwater use is less than 20% (see figure 136, drawn up here from EEA data 1995).

Table 24. Annual average water fluxes in the Earth, Europe and Spain.

Average annual flow (terrestrial phase)	Earth	EU	Spain
Precipitation (km^3)	110,000	2,600	346
Evapotranspiration (km^3)	70,000	1,400	235
Internally generated cumulative flow (km^3)	40,000	1,200	111

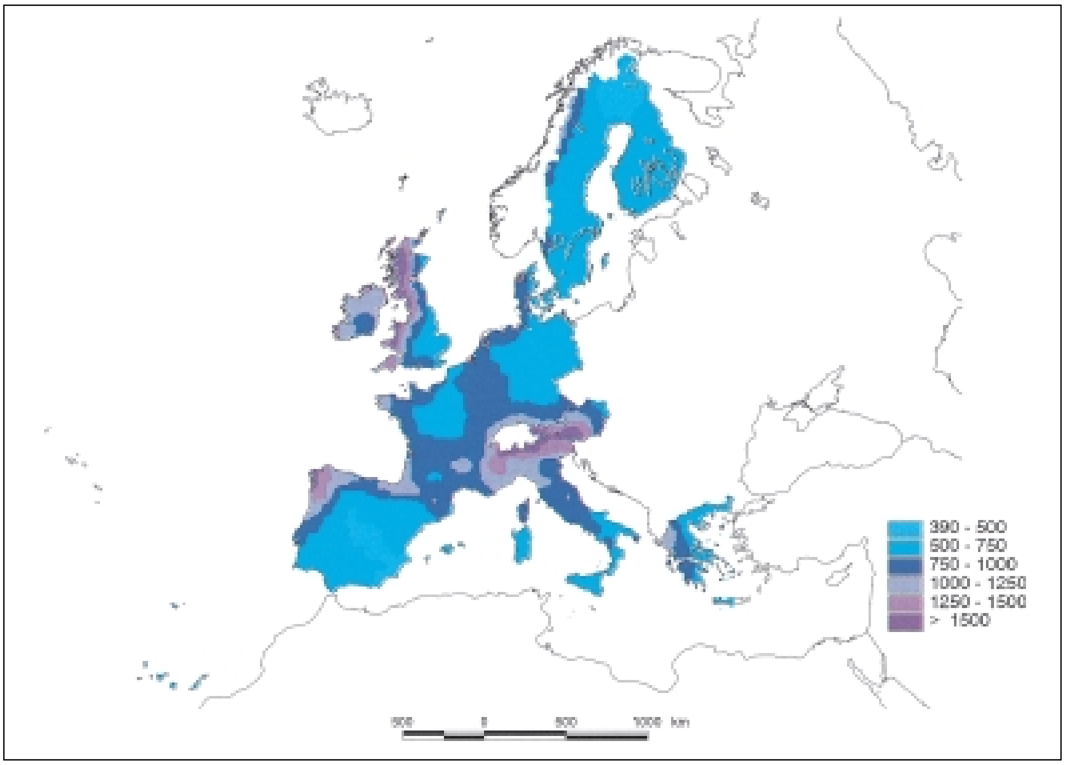


Figure 132. Map of average annual precipitation in the European Union (mm).

3.1.5. Available resources

3.1.5.1. Introduction. Previous concepts

What has been said so far has referred to resources in a natural regime, that is to say, from a hydrological, and not a functional point of view. We should now examine them from a new perspective, considering the conditions that affect them as a supply used to cover a demand for water and the limitations on their use, since logically not the entire natural resource can –nor should– carry out this function. To introduce this new perspective and for the best understanding of this water allocation system, it is necessary to present some important basic concepts (see, e.g., Erhard-Cassegrain and Margat, 1983).

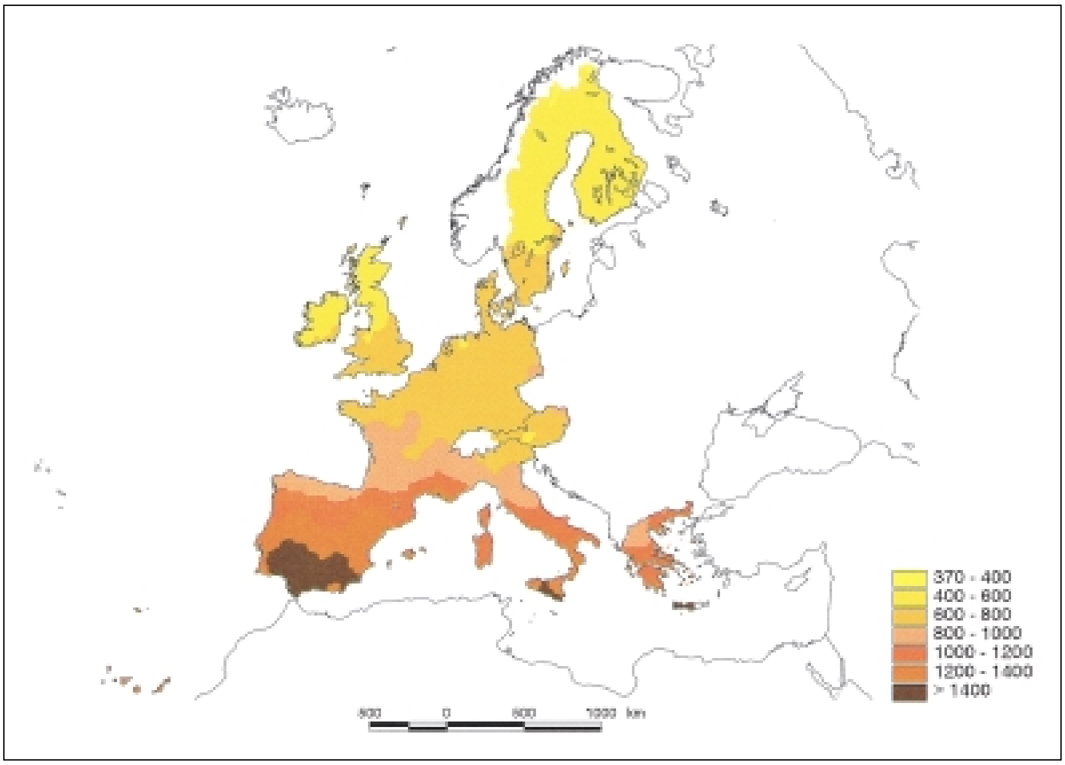


Figure 133. Map of average annual potential evapotranspiration in the European Union (mm).

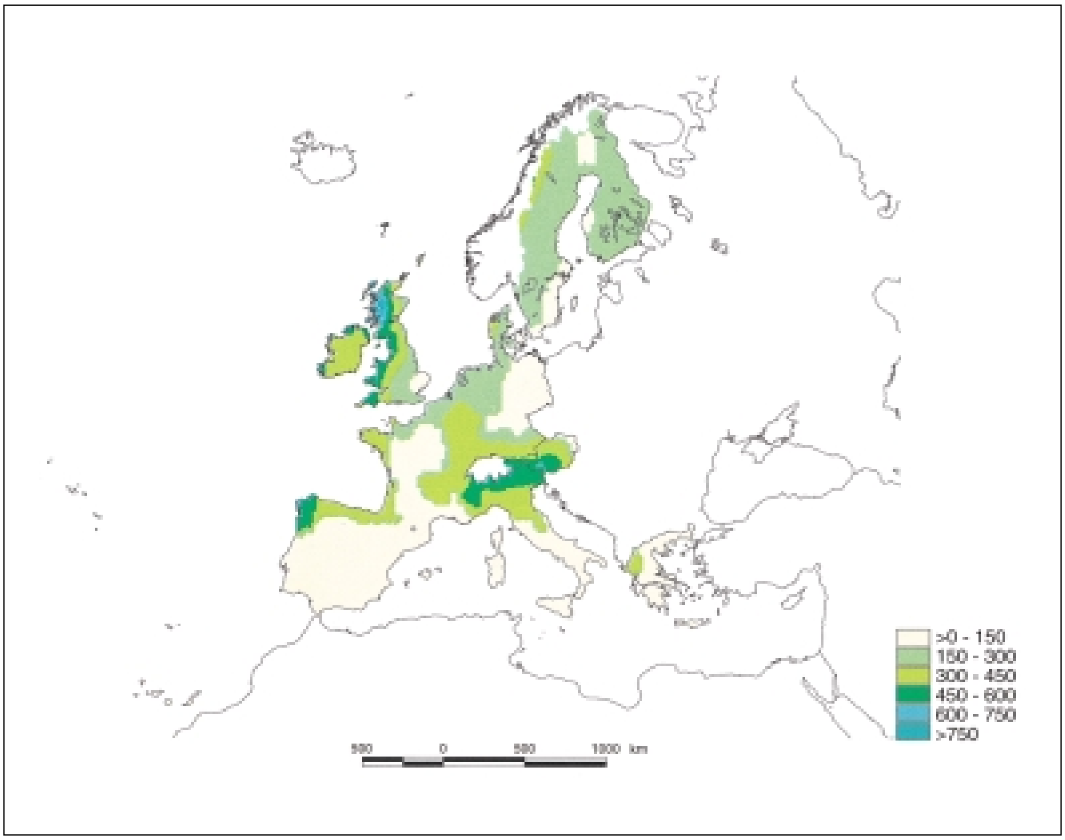


Figure 134. Map of average annual runoff in the European Union (mm).

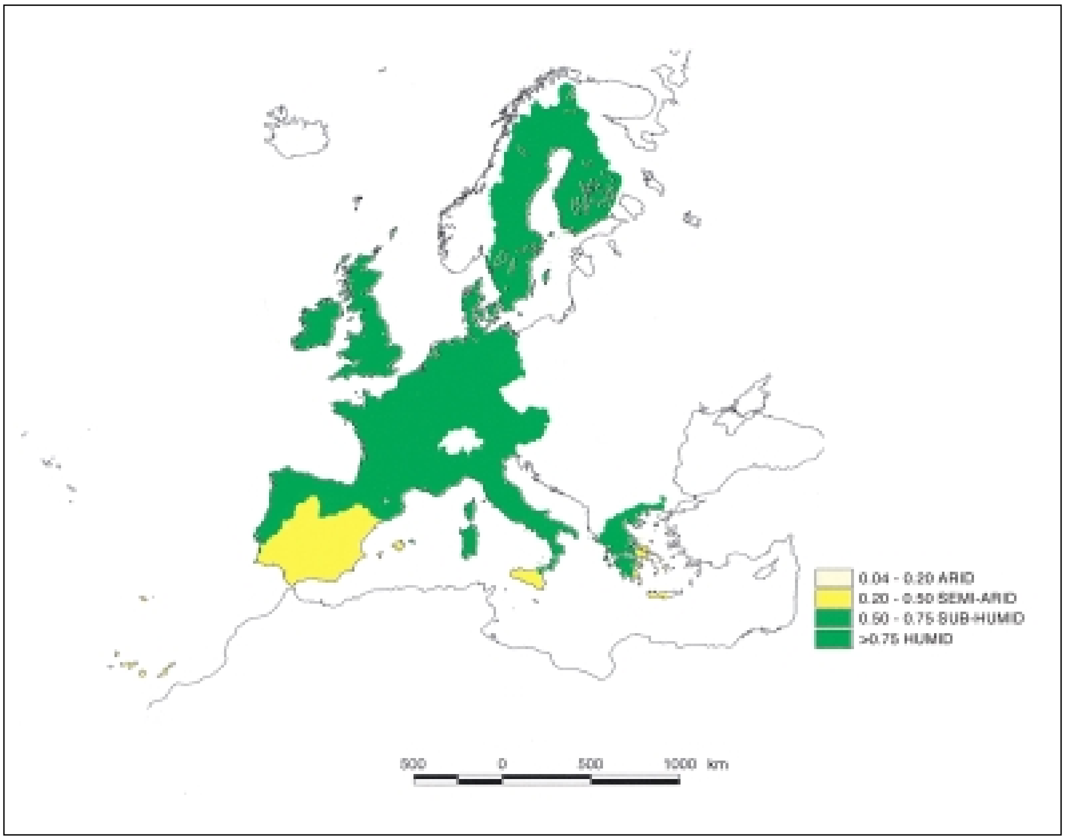


Figure 135. Map of the moisture index in the European Union.

EU State	Surface Area	Population (1995)	Precipitation		Potential evapotranspiration		Internally generated runoff		
	(km²)	(thousand inhab)	mm	km³	mm	km³	mm	km³	m³/inhab/year
Germany	356,954	82,400	768	274	493	176	266	95	1,153
Austria	83,850	7,968	1,169	98	477	40	656	55	6,903
Belgium	30,518	10,141	885	27	459	14	393	12	1,183
Denmark	43,092	5,225	673	29	441	19	139	6	1,148
Spain	**506,470**	**39,238**	**684**	**346**	**862**	**437**	**220**	**111**	**2,829**
Finland	338,130	5,115	657	222	337	114	316	107	20,919
France	543,965	58,251	809	440	601	327	313	170	2,918
Greece	131,957	10,480	849	112	765	101	356	47	4,485
Ireland	70,285	3,575	1,152	81	398	28	697	49	13,706
Italy	301,277	56,126	982	296	704	212	554	167	2,975
Low countries	41,863	15,534	717	30	454	19	263	11	708
Portugal	92,389	9,915	877	81	898	83	444	41	4,135
United Kingdom	244,410	58,204	1,080	264	413	101	593	145	2,491
Sweden	449,960	8,852	700	315	367	165	380	171	19,318
EU	**3,235,120**	**371,024**	**808**	**2,615**	**568**	**1,836**	**367**	**1,187**	**3,199**

Table 25. Average annual area values for precipitation, potential evapotranspiration and total internally-generated runoff in the EU.

It should be noted that some of the limitations or restrictions that affect natural resources as a supply included in the allocation system are external to the water allocation system itself and are prior and superior, so they limit the real potentiality of water use. In this sense, we should consider it as a potential resource that could be defined as the part of the natural resource that represents potential supply once these external restrictions have been taken into account. These restrictions may be environmental, socio-economic or geopolitical in nature.

1. Restrictions of an environmental nature aim to protect, in certain territories and time periods, the natural functions of water (aquatic ecosystems, fundamentally) by preserving flow, speeds, levels, volumes, or their physical-chemical characteristic. Given the lack of knowledge and detailed studies covering the whole national territory, a simplified way of approaching this restriction consists of reserving, as a precaution, a certain proportion of the natural resource that is not included in the exploitation system, thus being preserved from a possible economic-productive use, and continuing its natural function. This fundamental question will be dealt with again in the chapter on the current system of water use, but we should bear in mind this conceptual approach that has been proposed to deal with the problems of so-called ecological flow: not simply another use among those included in the water allocation system, but a prior, external restriction that operates over natural resources to affect the potential resource, or, in other words, a supposition prior to the administration of the public water domain.

It is important to understand that we may only consider resource supply or availability after having fulfilled

EU State	Surface Area	Population (1995)	Int. generated runoff		Transfers from other countries		Total runoff		
	(km²)	(thousand inhab)	mm	km³	mm	km³	mm	km³	m³/inhab/year
Germany	356,954	82,400	266	95	193	69	459	164	1,990
Austria	83,850	7,968	656	55	346	29	1,002	84	10,542
Belgium	30,518	10,141	393	12	131	4	524	16	1,578
Denmark	43,092	5,225	139	6	0	0	139	6	1,148
Spain	**506,470**	**39,238**	**220**	**111**	**0**	**0**	**220**	**111**	**2,829**
Finland	338,130	5,115	316	107	9	3	325	110	21,505
France	543,965	58,251	313	170	33	18	346	188	3,227
Greece	131,957	10,480	356	47	99	13	455	60	5,725
Ireland	70,285	3,575	697	49	43	3	740	52	14,545
Italy	301,277	56,126	554	167	27	8	581	175	3,118
Low countries	41,863	15,534	263	11	1,911	80	2,174	91	5,858
Portugal	92,389	9,915	444	41	271	25	714	66	6,657
United Kingdom	244,410	58,204	593	145	0	0	593	145	2,491
Sweden	449,960	8,852	380	171	7	3	387	174	19,657
EU	**3,235,120**	**371,024**	**367**	**1,187**			**367**	**1,187**	**3,199**

Table 26. Annual average value of internal runoff, external transfers, and total and per capita resources in different countries of the EU.

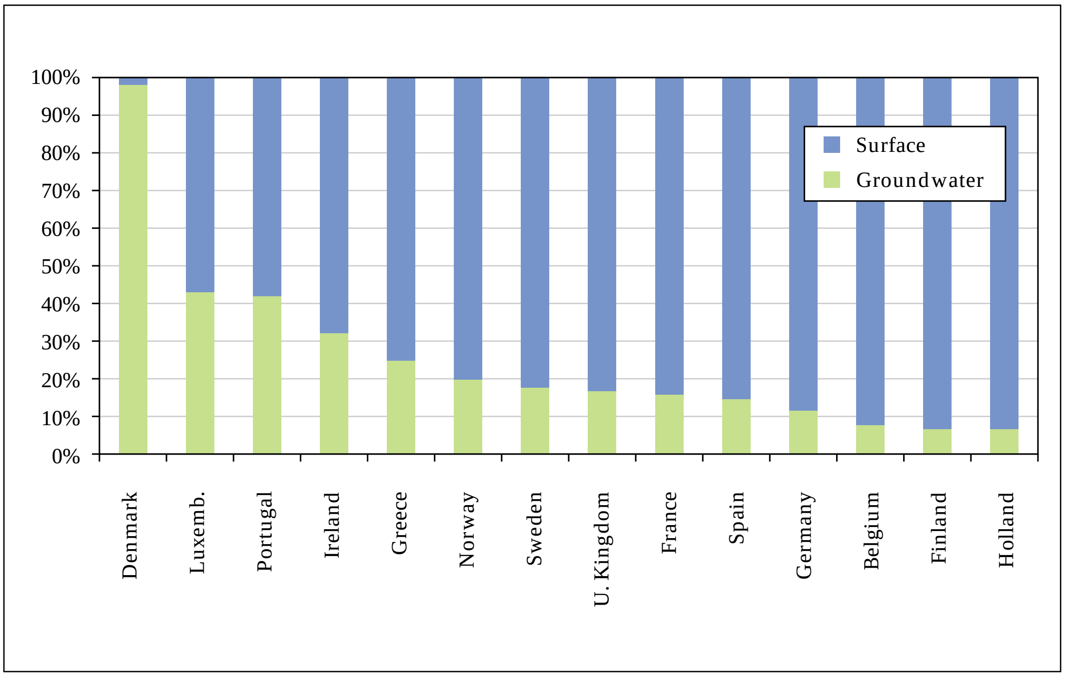


Figure 136. Percentages of surface and groundwater resource use in different EU countries.

–among others– these environmental restrictions, and only to the extent that the use of the water does not significantly distort its environmental function (biological, climatic,...), may its function as an economic-productive asset be accepted, in the service of welfare and development.

2. Restrictions of a social or socio-economic nature may come from easement arising from activities considered a priority, and which are incompatible with use of the resource, as a consequence, for example, of certain territorial regulation options. This would be the case of those facilities that, while technically and economically feasible, may create conflict with certain land occupation criteria.

3. Finally, restrictions of geopolitical nature usually refer to the case of international rivers. From the point of view of the country located upstream, certain commitments may exist to maintain a certain flow on the frontier, reducing their potential resource since this flow cannot be used. In the case of the country located downstream, their potential resources may diminish, to the established threshold, as water use increases in the country located up-stream.

Apart from these external restrictions that determine potential resource, there exist other restrictions of a technical nature that can limit the exploitation of water from the natural environment. In this sense, we may speak of resources that are really available for productive use as consequence of all the technical restrictions that limit the possible use of the natural or potential resource. The amount of these available resources depends, fundamentally, on the characteristics of the natural resource and of the technological level of the water allocation system. Thus, groundwater resources from an aquifer may be, for example, potentially profitable, but they will be really available according to the perforation and pumping technology existing at each given moment.

The concept of available resource is therefore bound to the possibilities of mobilising natural or potential resources, and as a result some authors refer to the available resource as mobilisable. In this sense, to mobilise water so that it is available for use, consists of, starting from the natural environment, putting it into circulation in the water allocation system's technical structure.

In practice, mobilisation and subsequent availability of resources can be obtained by means of various procedures:

- Direct collection of a part of the regulated flow in a natural way: direct take-up from a river or abstraction of groundwater.
- Transformation of part of the more or less irregular natural flow into a reserve for later use: regulation of a river by means of a reservoir or artificial aquifer recharge.
- Obtaining flow from a pre-existing natural reserve: use of lake water or groundwater reserves, renewable or not.
- Transformation of flow not directly usable into mobilisable flow: evaporation reduction.

These ideas are briefly outlined in figure 137.

An aspect that significantly affects resource availability is the management of exploitation systems, that is, the set of rules and regulations regarding action on the natural elements, and the works and facilities of hydraulic infrastructure that transform the regime of the natural resources to adapt them to meet demands or to avoid natural risks. Deficient management of the system can reduce resource availability considerably, while, in contrast, appropriate administration can increase it.

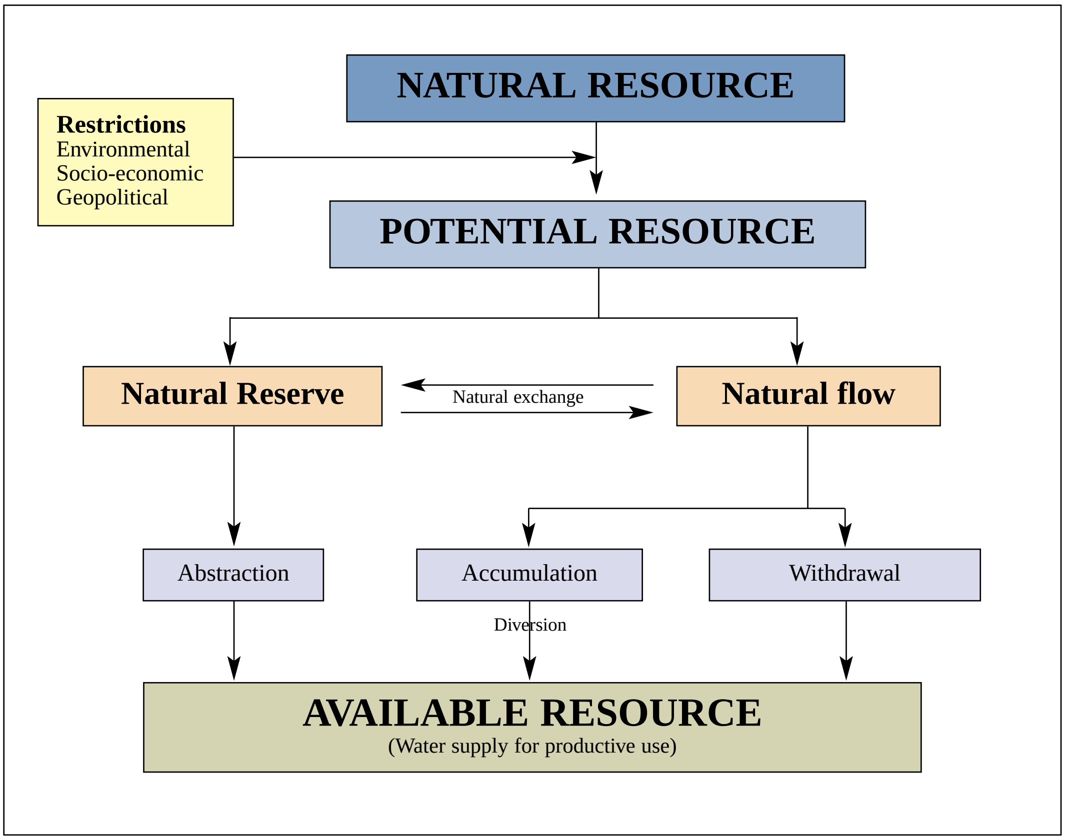


Figure 137. Conceptual outline of mobilisation of natural resources and their transformation into available resources.

From a qualitative point of view, available resources depend on the technical possibilities of treating water and correcting, where necessary, those characteristics that do not conform with the use they are intended for. Further ahead, we shall return to this question, and to the limitations that can arise from the conditions of water quality .

Another aspect that significantly affects resource availability is its reliability, that is, the guarantee of access to them. Having high guarantee or security levels in supply involves having fewer resources, while less guarantee demand would allow greater availability. In this sense, for a correct availability assessment, it is fundamental to specify the guarantee level corresponding to the resources considered available.

At the level of exploitation systems, it is also important to have the possibility of re-using water from previous supplies which is returned to the natural environment. This return water gives the possibility of remobilising part of the resources, and represents a potential secondary supply that should be included with the rest of available resources from a single use or mobilisation. This question takes on special relevance in our country, where irrigation, which gives rise to major quantities of return water, represents the largest demand by far.

As has already been mentioned, the level of technologies existing at each given moment also affects the quantity of available resources. In this sense, it is common to differentiate between conventional resources, obtained by means of implementing classical, sufficiently-proven mobilisation techniques, and non-conventional resources, obtained by means of developing new techniques, often experimental or which are implemented exceptionally. Resources traditionally considered as non-conventional are those from the desalination of marine and brackish water, the direct reuse of waste water and the modification of climatic conditions, among others.

However, the level of resource conventionality, by association with level of technology, is a dynamic concept that evolves over time. Thus, some of these techniques, such as desalination or reuse, could now certainly be considered as conventional in practice.

At this point, we should note that, unlike the natural resource, on whose technical meaning there exists a relatively widespread agreement, the concept of available resource has traditionally been given very different interpretations. This is easy to explain bearing in mind the widely-varying factors that make it up, and upon which it depends, and that some –such as the administration rules– are usually not explicitly defined nor are they easy to formulate in complex hydraulic systems.

Evidence of these differences is the different estimates that have been made in recent years in Spain (where they are sometimes called regulated or guaranteed resources). In table 27, some of the most important of these estimates are shown (expressed in hm^3/year), including those carried out in the basin management plans. In this case, a prudent interpretation should be made of the relative results, because not all the plans used the same concept of available resource, and nor were the same approaches and procedures used in

	1967 (a)	1980 (b)	1980 (c)	1990 (d)	1991 (e)	1993 (f)	1998 (g)
Galicia Coast					1,302	1,302	
North I				1,100		5,515	691
North II				1,807		1,518	587
North III				943		493	468
North	8,525	10,123	7,448		4,967	8,828	
Douro	6,405	7,713	9,111	9,465	9,269	7,797	10,229
Tagus	4,356	6,496	8,343	6,281	6,233	6,233	5,063
Guadiana I				2,610		2,592	2,591
Guadiana II				407		371	345
Guadiana	2,252	1,428	2,462	3,017	2,385	2,963	2,936
Guadalquivir	3,564	2,965	2,810	4,780	3,255	3,416	3,451
South	538	717	785	533	861	1,109	1,007
Segura	665	675	1,317	1,742	700	1,125	1,500
Júcar	1,850	2,665	3,104	2,003	2,564	3,052	3,437
Ebro	8,502	11,164	14,133	9,289	9,337	10,727	9,898
Catalonia I.B.	697	1,139	1,656		1,358	1,358	1,587
Total Península	**37,354**	**45,085**	**51,169**		**40,929**	**46,608**	
Balearic Islands	--	224	313		312	312	300
Canaries	--	496	496		496	420	417
Total Spain		**45,805**	**51,978**		**41,737**	**47,340**	

Table 27. Different estimates of available water resources in Spain.

(a): Water Resources, II Economic and Social Development Plan, Presidency of the Government, PG (1967),
(b): Water in Spain, MOPU-DGOH-CEH (1980),
(c): National Hydrological Planning, (c) National Hydrological Planning, (Advance 80), Interministerial Commission on Hydrological Planning, MOPU-CIPH (1980), Includes returns, evaluated at 6007 hm^3/año for the whole national territory,
(d): Hydrological Plan, Summary of the Basic Documentation, MOPU-DGOH (1990), These figures are presented under the term guaranteed resources and refer only to the inter-community basins,
(e): Water in Spain, Engineering Institute of Spain IIE-ITGE-UNESA, (1991), Includes resources regulated by reservoirs and those from a balanced exploitation of aquifers in a first approach, Returns or resources imported from other basins are not included, Based mainly on the Basic Documentation of the Hydrological Plans,
(f): Report of the NHP, MOPT (1993), Includes over-exploited aquifer: Guadiana I (280 hm^3/año), Guadalquivir (25 hm^3/año), South (60 hm^3/año), Segura (325 hm^3/año), Júcar (125 hm^3/año), I,B, Catalonia (50 hm^3/año), Balearic Islands (30 hm^3/año) and Canaries (160 hm^3/año), Total 1055 hm^3/año, Does not include returns (8,000 hm^3/year), nor re-use and desalination (115 hm^3/año),
(g): Basin management plans (1998), The figure for the North only includes regulation achieved in reservoirs aimed exclusively at attending to consumption demand, The figures for the Tagus and the Ebro correspond to internal demand met, lower than the available resource, The Tagus includes what it terms environmental demand and the Ebro includes 3,150 hm^3/año of minimum environmental flow at mouth , The foreseen maximum transfers are included for the South (10 hm^3/año), Segura (540 hm^3/año) and Catalonia (100 hm^3/año), The figure of the Júcar includes re-use, transfers and returns,

obtaining them. As a consequence, and in spite of the fact that they are shown in a common chart, the figures corresponding to the different plans are not directly comparable with each other.

Something similar happens if we attempt to compare some estimates with others, since in general different approaches have been used as regards modulation of demand, assessment of regulated volume in reservoirs, use of groundwater, consideration of environmental flow and return, supply guarantees, consideration of the whole environment or just of some main rivers, inclusion or not of transferred water, joint or unitary administration of the reservoirs, etc.

The table shows the disparity of the results obtained. Not counting the estimate carried out in 1967, corresponding to a very different situation from the current one (e.g as regards reservoirs), the other estimates give available resources that vary between the 38% and 47% of natural resources. However, in the scope of certain specific plans, these differences are considerable, as a consequence of the diversity of approaches already mentioned.

All this highlights the need to unify concepts and approaches in order to obtain results that allow for comparative-type analysis, helping to determine the temporal evolution of availability, and that provide an assessment of the effectiveness of the various measures aimed at improving resource availability.

3.1.5.2. Permanent flow and natural regulation

In accordance with the pattern of water flow variation over time, and from the perspective of its possible uses, it is common to consider resources subdivided in two major categories:

- Permanent, or almost permanent, regulated naturally.
- Variable, according to various degrees of irregularity.

The concept of permanent resource, or regulated in a natural regime, is closely related with rivers' base flow which, in our country, depends fundamentally on the already-mentioned accumulated groundwater flow due to drainage from aquifers and, to a lesser extent, to thaw.

It is common to interpret these naturally-regulated resources as those which, in a situation of free appropriation and absence of storage infrastructures, could be used to meet demand, that is, permanent flow that could be used. This was the value sought when, from the 18th century onwards, periodic and occasional measurements began to be made on river flow with a view to determining their possible use. Since in hydraulically mature countries –such as ours– a large number of surface regulation and groundwater abstraction works already exist, naturally-regulated resources are no more than a theoretical concept, but which is useful mainly for comparative purposes, and as an example of hydrological irregularity.

To estimate them, it is necessary to define seasonal variation in the demands that could be covered by this permanent flow, and the supply guarantees required. Traditionally, two types of demand modulation have been considered: one with uniform distribution throughout the year, comparable to the usual situation of supply demands for stable populations, and another variable, peaking in the summer months, comparable to irrigation demands.

In previous studies (MOPU, 1980) natural regulation on the Peninsula was estimated at 9,190 hm^3/year for uniform demand, and in 4,445 hm^3/year for variable irrigation demands. This estimate was carried out with data from the pioneer Inventory of Hydraulic Resources (CEH, 1971), considering reservoirs with zero capacity at river-mouths and on the Portuguese frontier. Some less important rivers and coastal inter-basins were therefore excluded from the general context. The figures shown correspond to a guarantee level of 96%, defined by eliminating the 4% of the years with less contribution and calculating the demand that could be covered without failures with the remaining series of years.

To prepare this White Paper, naturally-regulated resources have been re-assessed. In order to do this, the design of the current exploitation system has been used, described in other sections of this White Paper, and two groups of series of monthly accumulated flow in a natural regime have been used. The first of these corresponds to the series used by the basin management plans in analysing their exploitation systems. These series cover different time periods and generally do not include the last period of drought. The second group is made up of the series calculated for preparing this White Paper, which cover the period 1940/41-1995/96. These series have been obtained from the simulation model of accumulated flow described in previous sections. The series have been generated at a number of selected calculation points, (about 350) which are shown in the next chapter.

Two demand distributions have been considered: a uniform distribution with 100% guarantee and another variable distribution with standard guarantee criteria of accumulated annual deficit in annual demand of 50%, 75% and 100% for 1, 2 and 10 years, respectively. These values have been adopted as standard in this White Paper, as will be described in relation to the analytical model.

Monthly distribution adopted to characterize this representative mean variable demand –or standard demand– is the one shown in table 28, whose values have been obtained as the average of a representative region of irrigated areas in Spain.

In the case of uniform demand, no type of return has been considered, while in the case of variable demand, it has been supposed that returns of around 20% of demand covered take place. The reason for this is that, with these criteria, the results obtained for the case of uniform demand with 100% guarantee (that is, without allowing for any kind of failure with the accumulated flow series used), and without returns, represent the maximum abstraction that could be continuously made from rivers without any storage infrastructure, though this figure should not be interpreted as a possible supply source. As for the results regarding variable demand with an acceptable deficit of 50%, 75% and 100% and returns of 20%, they approach real possibilities of surface resource mobilisation for irrigation without storage infrastructures, that is, run of river. It is in this theoretical sense –as a sophisticated performance indicator– that such evaluations must be interpreted, and not as providing a quantification of water availability.

Regulated volume has been estimated with the help of a mathematical resource management model with an annual optimisation cycle. A total of about 500 demand points have been studied, distributed over the peninsular territory's hydrographic network. On each river section, water demand has been defined as take-up from one end of the section upstream and return at the downstream end. So as to represent the situation of free appropriation in the allocation of resources, demand are ordered from upstream to downstream according to homogeneous levels. Maximum priority has been given to demand of on sections located at river headwaters. Sections located immediately downstream from these have been assigned the next level of priority, and so on up to the Portuguese border or to the river mouth at the sea.

The resource regulated at each point has been calculated by means of an iterative algorithm which, at the end of each model simulation, checks compliance with guarantee criteria laid down for each demand, and increases or reduces the estimated demand value as a consequence. The modification value decreases by half in each iteration, so at the end of the process an estimate of the regulated demand is obtained with a verified precision. Each point initially sup-

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOT
3	0	0	0	0	1	4	11	18	27	25	11	100

Table 28. Monthly distribution of the standard variable demand.

poses a demand value equal to the mean accumulated flow in a natural regime at this point, and work has been carried out with a precision of 1 per 1,000 this accumulated flow's value. The initial value adopted logically involves an upper limit of maximum demand that may be covered at that point. Starting from the initial value, demand values have been delimited until the established guarantee criteria are met.

In order to reduce the number of times the optimisation model is implemented, the algorithm simultaneously adjusts demand within one same level of priority. According to the criteria for ordering priority levels, operating this way guarantees that there are no conflicts in allocating the resource, since (if there are no closed loops in the hydrographic network) demand at one same priority level cannot share the same resource.

Operatively, the process runs from upstream to downstream by homogeneous priority levels, adjusting maximum priority demand (furthest upstream) in the first stage. Demand in the following priority level is adjusted in the second phase, and so on. In each stage, demand situated downstream from demand in the priority level studied is considered to be zero, so as not to interfere with resource allocation. For demand located upstream from the priority level studied, the estimate made in previous stages is maintained.

This way, results obtained with the series of cumulative flow used in the exploitation systems analyses carried out in the basin plans are those shown in table 29 and Figure 138. The table includes, as a reference, figures for natural cumulative flow indicated in the plans and the cumulative flow for calculation used in the exploitation systems analyses. The differences are due to regulated discrepancies in the territorial area analysed, smaller than that of the plans in some areas, by excluding some small basins running directly to the sea, or to updates in the series carried out subsequent to the basin plans being drawn up. The results are given both in absolute value and in percentage with respect to cumulative flow for calculation used.

The same results, but corresponding to the series obtained in this White Paper, are those shown in table 30 and figure 139.

It is significant that the results in a variable regime are, in some cases, higher than those in a constant regime. This is explained considering the different hydrological regimes, the inclusion of returns, and the adoption of a significantly lax guarantee criterion.

These figures, which as may be seen are basically similar in the two cumulative flow hypotheses carried out, suggest different, interesting conclusions.

1. Firstly, it is clear that only a small fraction of total natural resources, around 8% or 9%, could used to meet different water needs if the natural regime were not artificially altered. This means, generally speaking, that at present only an absolute maximum of about a million hectares could be irrigated on the Peninsula, which is the surface area at the beginning of century when, in fact, the hydrological regime of rivers and aquifers was relatively similar to the natural one.

2. We may also note the generosity of estimates carried out in the eighties. In fact, the figure of 9,190 hm^3/year corresponding to uniform demand obtained at that time is similar to the 8,600 - 8,900 hm^3/year in the new estimate. The lower availability obtained now is fundamentally due to using a guarantee level of 100%, more demanding than the one used in previous assessments. In the case of variable demand, the difference is more noticeable (4,445 compared with 7,200-8,200 hm^3/year), because very different methods have been used to obtain it. On one hand, the possibility of using returns has been con-

Planning Area	Total natural cumulative flow (hm^3/year)	Calculation cumulative flow (hm^3/year)	Regulated with uniform demand (hm^3/year)	Regulated with uniform demand (%)	Regulated with variable demand (hm^3/year)	Regulated with variable demand (%)
North I	11,235	10,489	640	6	411	4
North II	13,000	10,950	546	5	708	6
North III	5,381	4,211	180	4	248	6
Douro	15,168	13,558	2,006	15	1,656	12
Tagus	12,230	12,230	644	5	505	4
Guadiana I	4,875	4,714	18	0	128	3
Guadiana II	1,293	825	0	0	0	0
Guadiana	7,978	8,021	192	2	233	3
Guadalquivir	2,483	1,076	15	1	41	4
South	1,000	857	299	35	226	26
Segura	4,142	2,580	524	20	484	19
Júcar	18,217	18,217	2,661	15	2,638	14
Ebro	2,780	1,544	282	18	284	18
Catalonia I.B.	12,642	8,137	591	7	619	8
Península	**112,424**	**97,408**	**8,599**	**9**	**8,179**	**8**

Table 29. Regulated volumes in a natural regime with the series of cumulative flow used in the basin plans.

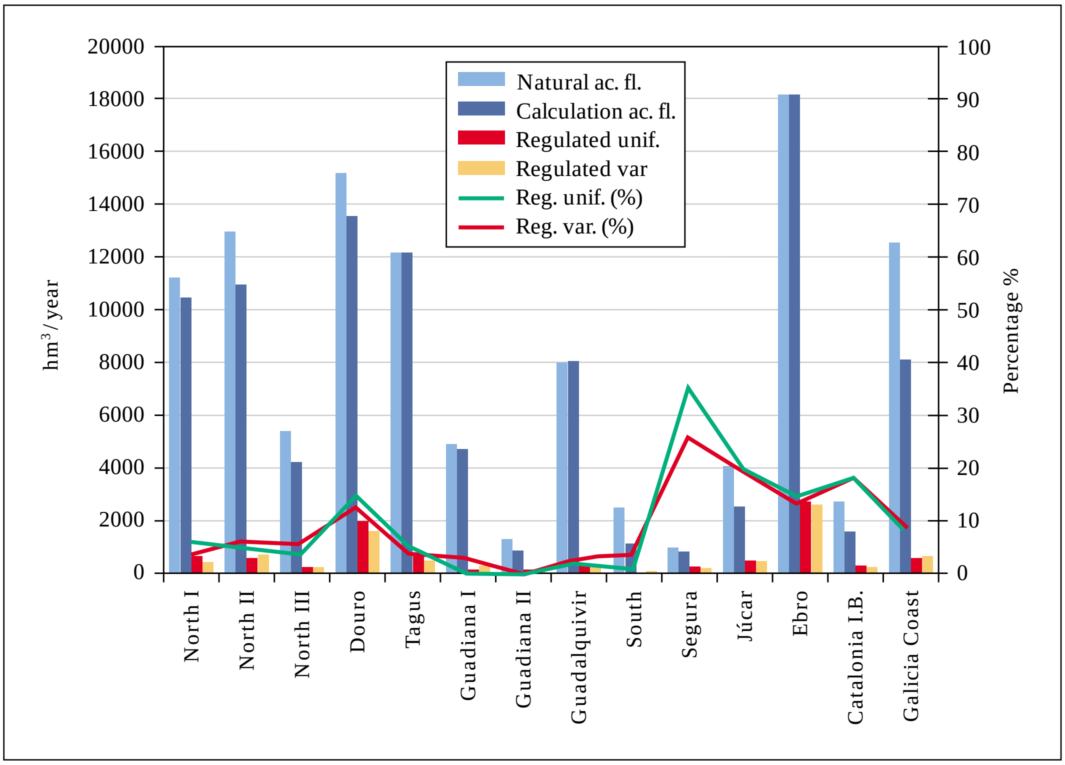


Figure 138. Regulated volume in a natural regime by planning area. Series from Basin Plans.

sidered now, generally estimated at 20% of supply. Also, different guarantee criteria have been used now, limiting accumulated deficit in 1, 2 and 10 years to 50%, 75% and 100% of the demand, respectively. This approach, in general less demanding that the previous one, leads to a greater value of volume available for use.

3. The values reached with the two groups of series used are basically similar, although some discrepancies –not very significant– may be seen the Júcar, Catalonia and Douro basins. This reinforces the general validity of the new series as an instrument for carrying out overall homogeneous analyses.

4. As was seen on examining the correlograms of cumulative flow and the fraction of subterranean origin, basins with greatest natural regulation (around 30% of total cumulative flow), due to their considerable groundwater component, are the Segura and the Júcar, which historically encouraged population settlement and the development of extensive, traditional irrigated land over their fertile plains. The Ebro follows them in relative quantities around 15%, although with much greater volume in

Planning Area	Total natural cumulative flow (hm³/year)	Calculation cumulative flow (hm³/year)	Regulated with uniform demand (hm³/year)	Regulated with uniform demand (%)	Regulated with variable demand (hm³/year)	Regulated with variable demand (%)
North I	12,689	12,603	935	7	916	7
North II	13,881	11,799	1,263	11	1,146	10
North III	5,337	4,437	352	8	251	6
Douro	13,660	12,422	892	7	742	6
Tagus	10,883	10,782	605	6	490	5
Guadiana I	4,414	4,097	26	1	44	1
Guadiana II	1,061	998	15	2	7	1
Guadiana	8,601	7,988	132	2	208	3
Guadalquivir	2,351	1,379	16	1	18	1
South	803	757	225	30	192	25
Segura	3,432	2,745	924	34	656	24
Júcar	17,967	17,089	2,795	16	1,827	11
Ebro	2,787	1,722	177	10	190	11
Catalonia I.B.	12,250	6,633	569	9	426	6
Peninsula	**110,116**	**95,451**	**8,926**	**9**	**7,112**	**7**

Table 30. Regulated volume in a natural regime with the series obtained in this White Paper.

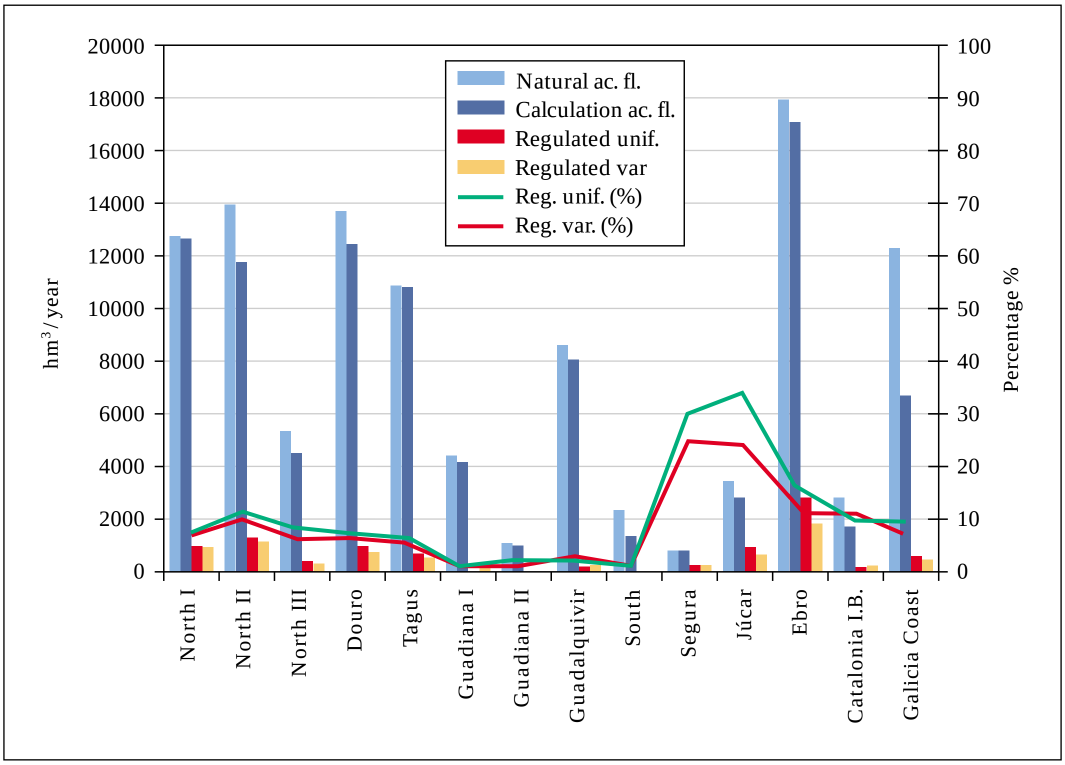


Figure 139. Regulated volume in a natural regime by planning area. Series obtained in this White Paper.

absolute terms. At the other end of the scale are the Guadiana, Guadalquivir and South basins, with a lower fraction of cumulative flow regulated naturally (less than 3%).

3.1.5.3. Regulation works and exploitation systems

As has already been mentioned, the naturally-regulated resources described in the previous section are simply a theoretical concept, certainly useful for comparative purposes and in describing of hydrological variability, but far from the current reality of the country's hydraulic maturity, with numerous works regulating surface water and groundwater abstraction that alter this natural regime and allow more regular, reliable use of natural resources.

Over time, as this level of maturity was being achieved, the role of regulation works and ways of approaching their study have evolved significantly. In his classic work *La Regulación de los Ríos*, Becerril (1959) defined regulation as the mechanism by which technique harmonises fluvial irregularity with permanent availability; it is achieved by storing water in a reservoir during the times when there is excess flow and using this accumulated water in those periods when demand exceeds river flow. This traditional definition associating regulation work with meeting a certain demand falls in stages of hydraulic development characterized by a relative abundance of resources compared with demand, in which a basin's hydraulic problems are independently dealt with and exploitation is carried out separately. Under these conditions, regulation works are programmed for each specific use proposed, without any interconnection. They are the stages that the 2nd Economic and Social Development Plan (1967) termed unconnected or opportunity use.

As water use increases, interdependence starts to form between hydraulic problems in different areas of the basins, and resource availability takes on greater importance than the implementation of specific uses. Demand is met with resources from alternative sources and interconnection takes place between different areas. At this stage, termed integral use, reservoirs become elements of a broader territorial system with greater technical complexity, in which the idea of each reservoir's independent operation is not appropriate.

To confront this new reality, the technical figure of the resource exploitation system has appeared, which in our country has even been legally regulated by the Regulation of the Public Administration of Water and Water Planning (RAPAPH). This text defines the concept of resource exploitation system as the set of natural elements, works and facilities of hydraulic infrastructure, water use standards derived from demand characteristics and regulations on exploitation which, by taking advantage of natural water resources, allow water supply to be established making up the offer of the exploitation system's available resources.

Each resource exploitation system must refer to a time horizon and its study should allow for definition and characterisation of available water resources, in accordance with the considered water's standards of use, determination of the exact infrastructure's components and basic guidelines for its exploitation, as well as natural resources not used in the system and, where relevant, those coming from external territorial areas.

Subsequently, Public Works and Transport Ministry Order of the 24th of September, 1992, approving instructions and complementary technical recommendations for drawing up basin management plans, stipulated the role that resource exploitation systems should play in water planning. Specifically, it specified that the simulation of resource exploitation systems should take into account reservoir and aquifer exploitation, aquifer-river relationships, demand modulation, supply guarantee, returns, reserves for flood storage, wetlands and their hydrological regime, minimum flow for environmental or other reasons, the exploitation regime of hydroelectric uses and, where relevant, concession-type conditions, particularly guarantee of supply for the refrigeration of existing or future thermal power stations, in addition to other factors or characteristics that affect resource availability.

It is also recommended that when several resource exploitation systems are considered in a basin, one single system for the whole basin is drawn up, to include all the partial systems, in order to carry out an overall analysis of its exploitation. If a Hydrological Plan's area comprises several hydrographic basins with a relevant degree of interconnection between the resource exploitation systems, one single system should also be created, to include those basins.

In peninsular basin plans as a whole, 125 basic exploitation systems have been considered, distributed as shown in table 31 and in figure 140.

Observing the how irregular the different plans are in defining their exploitation systems (some with a low number, and others with a very high number, almost by sub-basins) may provide some criteria for future homogenisation.

So as to have a general outline representing and analysing the different basins' exploitation systems as a whole, and with homogeneous criteria and methods, among the work carried out to prepare this White Paper it was also decided to undertake the creation of a Unified Water Resource Exploitation System model as a basic tool in drawing up the balance of resources and demands with the necessary homogeneity, methodological rigor, and resolution adapted to the scale of work in a National Hydrological Plan.

This System, which is described further ahead, has been used to evaluate the availability resulting from regulation obtained in the main reservoirs, including those that are currently under construction. The theoretical results obtained are described in the section below.

3.1.5.4. Theoretical availability obtained by means of reservoir storage

The real situation of basin operation is described in later sections. This shows the orientative result obtained from simulating basin operation under theoretical modelling suppositions and which, therefore, do not necessarily correspond to the exploitation conditions in force.

For this, results obtained in some cases differ from the observed situations of basins' real operation.

The theoretical design hypotheses used in this analysis are the same ones as those used in assessing natural storage, that is, uniform demand with 100% guarantee and without considering returns, and variable demand, with the distribution then described, acceptable deficit of 50%, 75% and 100% in annual demand and returns of 20% of demand covered. In both cases, stored volume has been determined reducing reservoir capacity by 5% to take into account the effect of minimum volume and reserves for flood control.

Also, free use of all existing reservoirs has been supposed, ignoring any concession or exploitation limitations that condition their operation, which would be particularly important in hydroelectric reservoirs, considered as free to use for any purpose. This can give rise to significant deviations in those basins where hydroelectric reservoir capacity is a very important percentage of the total. This is the case in the North I, Douro, Tagus and Ebro plans, where this capacity exceeds storage for consumption purposes. Calculations have been carried out for the two same groups of series of natural cumulative flow as in the case of natur-

Basin Plan	Number of exploitation systems
North I	6
North II	15
North III	7
Douro	4
Tagus	5
Guadiana I	4
Guadiana II	1
Guadalquivir	17
South	5
Segura	1
Júcar	9
Ebro	27
Catalonia I.B.	4
Galicia Coast	20
Total	**125**

Table 31. Number of exploitation systems per water planning area.

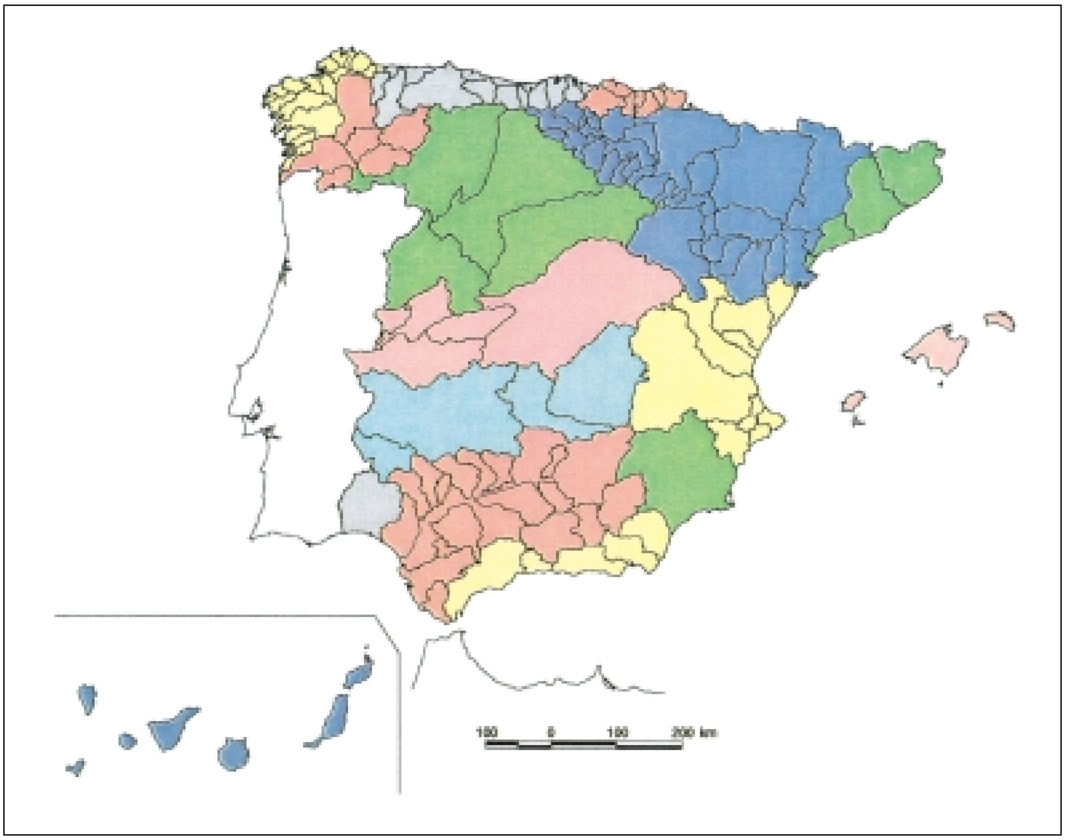


Figure 140. Map of basic exploitation systems defined in the Basin Management Plans.

al regulation, that is, those used for basin management plans in the analyses of their exploitation systems and those calculated when preparing this White Paper.

The calculation algorithm is similar to the one used in the case of natural storage, slightly modified to take into account the effect of resources stored at the end of every hydrological year. When regulation infrastructure exists in the basin, the appearance of new demand downstream, even when they have a lower priority level than existing ones, the result is that these may fail, since the water stored in the reservoirs at the end of each annual optimisation cycle modifies the resource availability in one case and another.

To solve the problem, the optimisation algorithm is carried out a second time, this time maintaining the value of the demands located downstream, with the aim of definitively adjusting demands that share the regulation of the same reservoir. Because in this case the modifications introduced are already small, at the end of this loop the resulting demands comply with the established guarantee criteria.

It should be noted that the resulting figures are merely illustrative, since they were obtained in a theoretical supposition of compulsory purchase and exclusive use of surface water, without considering any existence of groundwater pumping, without any limitation arising from existing concessions and subordinated to the reservoir management strategy of annual cycle supposed in the optimisation model used. The obtained values represent, in the absence of limitations due to water quality, a lower limit of available resources, which could, although not necessarily in all the cases, be increased with pluri-annual management strategies, techniques for joint use of surface water and groundwater, or the use of non-conventional resources. On the other hand, special cases arise, such as the Douro, in where a large part of the storage capacity (about 2/3 of the total) is located in the hydroelectric reservoirs near Portugal, and are not usable by Spain. This means that the estimates made should be significantly corrected downwards.

As a consequence of all this, and as mentioned above, the hypotheses assumed, and in consequence the results obtained, are not comparable with those observed in reality. In any case, and with the peculiarities mentioned, the magnitudes given are a good indication of the increase in availability, through regulation, with respect to the original situation in natural regime.

The results obtained with the series of cumulative flow used in the basin plans are those shown in table 32 and in figure 141. The table includes, as reference, the natural contribution figures indicated in the plans and the calculation cumulative flow used in the analysis of exploitation systems, as well as current total reservoir capacity (including reservoirs in construction) and calculation capacity used, lower by considering only the main reservoirs and discounting volume for flood control. The results obtained are expressed both in absolute value and in percentage with respect to the calculation cumulative flow used.

Similarly, results corresponding to the series obtained in this White Paper are those shown in table 33 and figure 142.

Area	Total natural cumulative flow (hm^3/year)	Calculation cumulative flow (hm^3/year)	Total storage capacity (hm^3)	Calculation storage capacity (hm^3)	Regulated uniform demand (hm^3/year)	Regulated uniform demand (%)	Regulated variable demand (hm^3/year)	Regulated variable demand (%)
North I	11,235	10,489	3,040	2,427	3,891	37	3,442	33
North II	13,000	10,950	559	384	1,579	14	1,475	13
North III	5,381	4,211	122	79	337	8	307	7
Douro	15,168	13,558	7,667	6,691	6,829	50	8,128	60
Tagus	12,230	12,230	11,135	9,887	5,860	48	7,071	58
Guadiana	4,875	4,714	8,843	7,550	2,029	43	2,711	58
Guadiana II	1,293	825	776	522	207	25	264	32
Guadalquivir	7,978	8,021	8,867	7,835	2,904	36	3,632	45
South	2,483	1,076	1,319	1,042	388	36	504	47
Segura	1,000	857	1,223	737	610	71	725	85
Júcar	4,142	2,580	3,349	2,417	1,650	64	1,985	77
Ebro	18,217	18,217	7,702	6,860	11,017	60	12,998	71
Catalonia I.B.	2,780	1,544	772	709	768	50	1,115	72
Galicia Coast	12,642	8,137	688	451	1,777	22	1,493	18
Peninsula	**112,424**	**97,408**	**56,063**	**47,591**	**39,846**	**41**	**45,850**	**47**

Table 32. Volume stored in the theoretical situation considered, with the series used in the basin management plans.

The results show the significant increase in profitable volume as a consequence of the storage infrastructure, which now stands at around 38-47% of natural cumulative flow compared with the previous 7-9%. It should be pointed out that the analysis has considered all reservoirs with major effects on regulation, including those exclusively used in energy generation. This, in some areas such as North I, the Douro or the Tagus –particularly the second–, with major energy exploitations, gives rise, as mentioned, to far higher stored volumes than those that would exist if only reservoirs devoted to covering consumption uses were considered.

The values obtained with each group of series are, in general, very similar and the observed discrepancies fall within margins that would be expected as a consequence of the different calculation procedures used and of covering different time periods.

Figure 143 summarizes the values for stored volume obtained under natural conditions and with the provision of storage reservoirs in service or in execution for the case of variable demand, acceptable deficit of 50%, 75% and 100% of annual demand, and returns of 20% (that is, a standard demand for irrigation, which is the clearly dominant con-

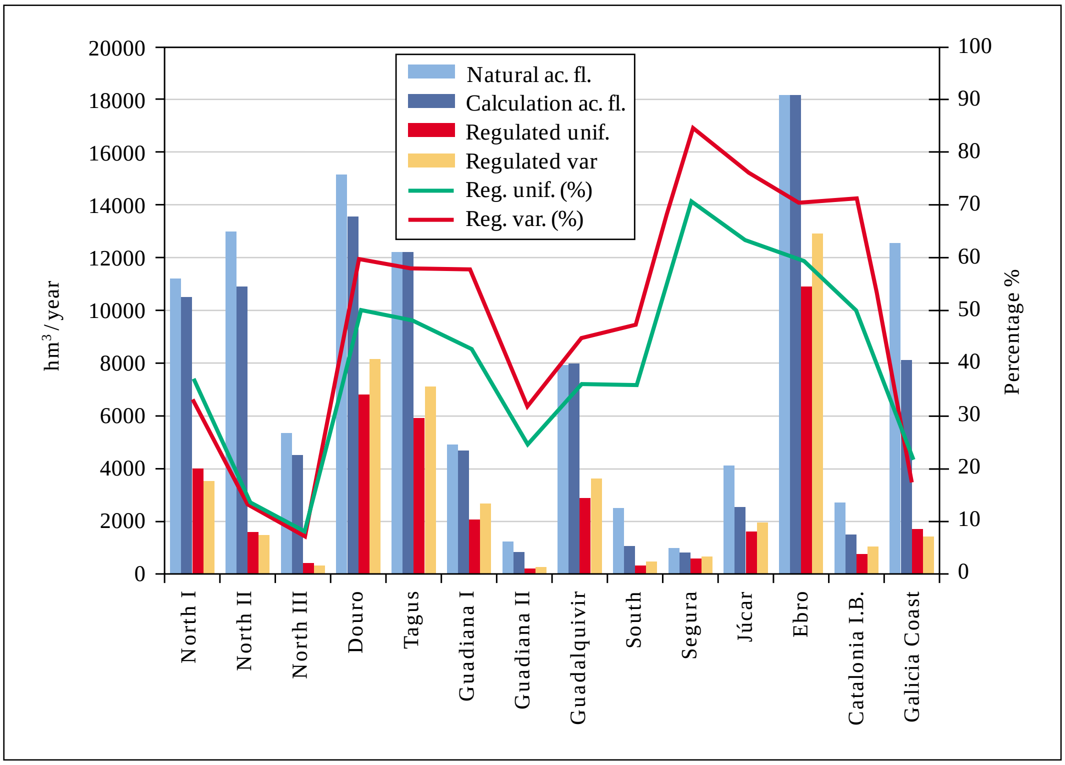


Figure 141. Volume stored in the theoretical situation considered. Series of cumulative flow from the basin plans.

Area	Total natural cumulative flow (hm^3/year)	Calculation cumulative flow (hm^3/year)	Total storage capacity (hm^3)	Calculation storage capacity (hm^3)	Regulated uniform demand (hm^3/year)	Regulated uniform demand (%)	Regulated variable demand (hm^3/year)	Regulated variable demand (%)
North I	12,689	12,603	3,040	2,427	4,735	38	3,937	31
North II	13,881	11,799	559	384	2,180	18	1,870	16
North III	5,337	4,437	122	79	471	11	353	8
Douro	13,660	12,422	7,667	6,691	5,253	42	6,095	49
Tagus	10,883	10,782	11,135	9,887	4,587	43	5,845	54
Guadiana	4,414	4,097	8,843	7,550	1,678	41	1,922	47
Guadiana II	1,061	998	776	522	188	19	228	23
Guadalquivir	8,601	7,988	8,867	7,835	2,161	27	2,819	35
South	2,351	1,379	1,319	1,042	284	21	359	26
Segura	803	757	1,223	737	519	69	626	83
Júcar	3,432	2,745	3,349	2,417	1,766	64	2,095	76
Ebro	17,967	17,089	7,702	6,860	10,145	59	11,012	64
Catalonia I.B.	2,787	1,722	772	709	615	36	791	46
Galicia Coast	12,250	6,633	688	451	1,372	21	1,223	18
Peninsula	**110,116**	**95,451**	**56,063**	**47,591**	**35,954**	**38**	**39,175**	**41**

Table 33. Volume stored in the theoretical situation considered, with the series obtained in this White paper.

sumer), using the cumulative flow series obtained for this White Paper, which, as mentioned, covers a common period and include the last drought.

As may be seen, the increase in profitable resources obtained as consequence of storage infrastructures is frankly high in some basins. In the case of the Guadiana I, for example, which has the largest reservoir in Spain (La Serena, with a capacity of 3,230 hm^3) the volume stored in a natural regime grows over forty times, reaching a usable volume of around 45% of natural cumulative flow, a similar percentage to that of areas like the Douro or the Tagus.

In the Segura, Júcar and Ebro basins, the largest percentages of surface storage are reached, particularly the first of these, which regulates over 80% of its natural cumulative flow. At the other end of the scale we find the basins of the North, South and Guadiana II with much lower reservoir stored volumes, particularly North III, where not even 10% of natural cumulative flow is regulated.

We should repeat that, to be specific, these figures and evaluations only have indicative value, because they have been obtained under certain theoretical suppositions and simplifications. In spite of this, they offer the advantage of total

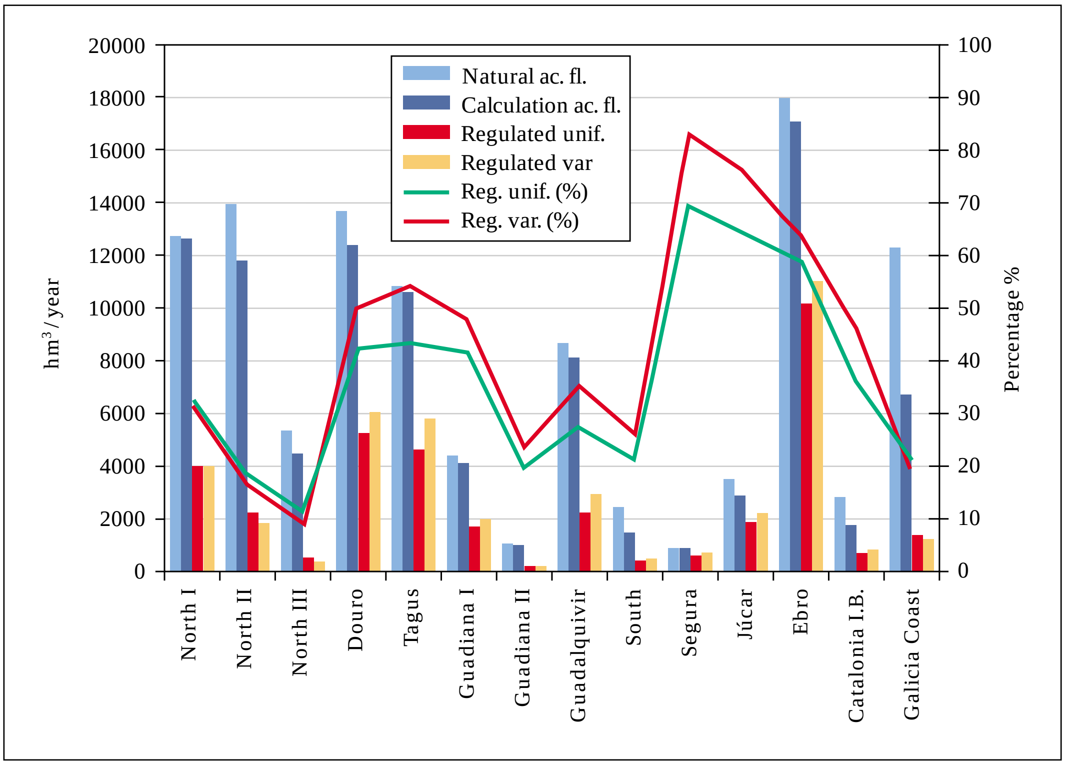


Figure 142. Volume stored in the theoretical situation considered. Series of cumulative flow obtained in this White Paper.

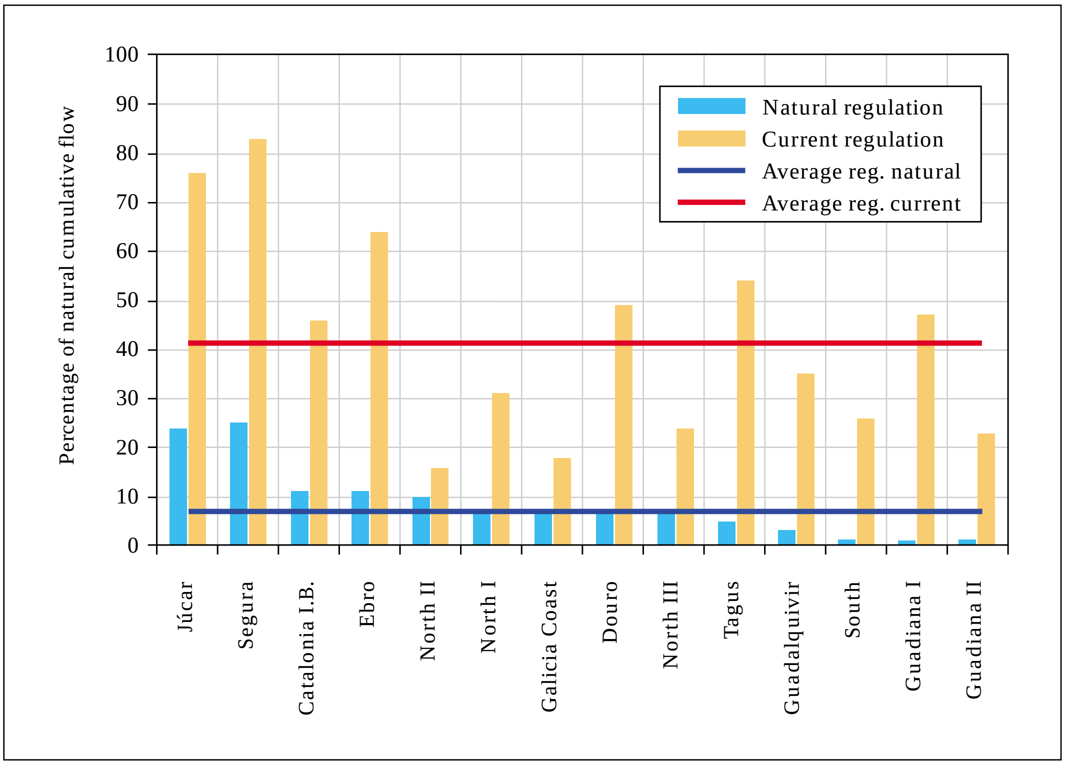


Figure 143. Storage in a natural regime and in the theoretical situation considered (in percentages of the total cumulative flow contribution in a natural regime).

homogeneity, allowing objective comparisons between basins, showing their relative situations.

In later sections, we will omit some of these simplifications and progressively introduce levels of complexity (such as the consideration of other sources of resources apart from surface storage), although always from a global perspective and on a nation-wide scale. Analyses in greater detail, fine description, and consideration of local circumstances, logically correspond to the water planning of each basin.

3.1.5.5. Groundwater exploitation

Groundwater covers a major segment of consumption demands in Spain, with about 5,500 hm^3/year being exploited, as shown in the table 34, drawn up with data on pump-

Area	Recharge in a natural regime (hm^3/year)	Pumping (hm^3/year)	Percentage of pumping with respect to natural recharge	Percentage of pumping with respect to Spain as a whole
North I	2,745	--	--	--
North II	5,077	19	0.4	0.3
North III	894	33	3.7	0.6
Douro	3,000	371	12.4	6.7
Tagus	2,393	164	6.9	3.0
Guadiana I	687	738	107.4	13.3
Guadiana II	63	76	120.6	1.4
Guadalquivir	2,343	507	21.6	9.2
South	680	420	61.8	7.6
Segura	588	478	81.2	8.6
Júcar	2,492	1,425	57.2	25.8
Ebro	4,614	198	4.3	3.6
Catalonia I.B.	909	424	46.6	7.7
Galicia Coast	2,234	--	--	--
Peninsula	**28,719**	**4,853**	**16.9**	**87.7**
Balearic Islands	**508**	**284**	**55.9**	**5.1**
Canaries	**681**	**395**	**58.0**	**7.1**
Spain	**29,908**	**5,532**	**18.5**	**100**

Table 34. Groundwater exploitation by planning area.

ing taken from basin management plans and from MOPTMA-MINER (1995), and with our own recharge data provided in previous sections of this White Paper.

It is also necessary to bear in mind, as described above, that the North I and Galicia Coast areas do not have official estimates regarding groundwater pumping. We should specify that when we refer to groundwater exploitation, we are referring to water abstracted by means of pumping from aquifers, and not to the fraction of total runoff from an underground origin. There may be major pumping exploitation in basins with a very low proportion of underground runoff, and conversely, there may be no pumping exploitation in basins with a large proportion of underground runoff. The confusion between both concepts has sometimes given rise to erroneous technical interpretations.

On the other hand, we should note that, in some cases, the pumping figures in the table provided can also include outflow from springs, since both outflows are not separately reflected in all basin plans.

Figure 144 also visually shows pumping/recharge percentages, and pumping proportion with respect to Spain as a whole, in each of the territorial water planning areas.

As may be seen, in the Guadiana I and Guadiana II areas, the abstractions are, in a mean overall value for the area, greater than natural recharge, which reveals long-term overall unsustainability. In the case of the Guadiana II, this statement should be qualified by the fact that overall unsustainability is very sensitive to data from the Ayamonte-Huelva hydrogeological unit, for which the recharge estimate made here is lower than the one included in the Guadiana II basin plan. Similarly, Guadiana I is significantly influenced by the estimate for abstractions in the upper basin in the late 80s, higher than current ones. In the Segura area, the pumping/recharge relationship exceeds 80%, and in other areas, such as the South, Júcar, Catalonia I.B. and the Islands, this relationship reaches high values, between 45% and 80%.

It is also interesting to observe how other areas exist, such as the Douro, Ebro or Guadalquivir, where, despite having major aquifers, the overall exploitation through groundwater pumping is relatively small (smaller than 25% of recharge). Obviously, this does not necessarily imply that such exploitation should be significantly increased to improve overall availability, since this will depend as much on the existence or not of surface water storage to collect groundwater discharge –as part of total incoming runoff– and the fact that it is able to regulate it appropriately, as on relative costs, on environmental effects, and on the geographical location of uses to be covered.

As for the relative amount of pumping in each area, the Júcar basin stands out , where 26% of Spain's total is concentrated, with a high level of use and allocation (Aragonés Beltrán, 1996). It is followed in importance by the Guadiana I, Segura and Guadalquivir, with figures around 10%.

It is obvious that, notwithstanding the existing difficulties in determining them (ITGE, 1999), this combined data can cover very heterogeneous local situations, because it is possible that there exists serious, occasional over-exploitation with very small global pumping/recharge ratios, and, conversely, not to have any over-exploitation with an overall ratio of 1:1. Further ahead, we shall examine these ratios separated by hydrogeological unit, but, in any event, it is certain that, at planning area scale, they are an excellent initial indicator of the basins' general situation as regards the exploitation of groundwater, and their development possibilities. We shall have an opportunity to returning to this in future sections, when referring to the possible increase of water supply by means of greater groundwater use.

As we shall see, the groundwater abstraction shown in the table, for example, covers 22% of the supply to urban areas of more than 20,000 inhabitants, a very high percentage in

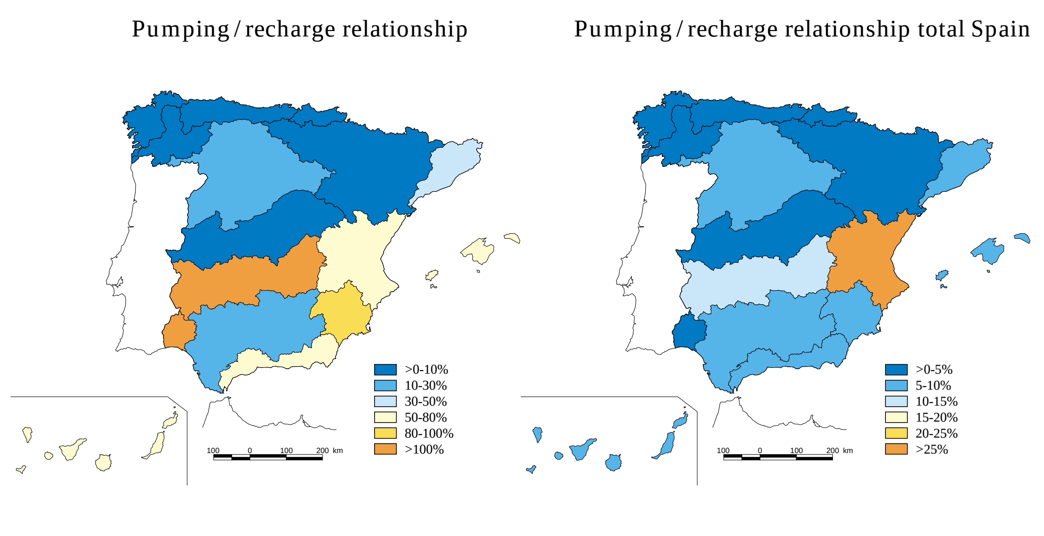


Figure 144. Maps of pumping/recharge relationship and the proportion of pumping with respect to the total, by water planning area

towns with smaller populations and around 25% to 30% of total irrigated surface area (see figure 145, drawn up from the MOPTMA [1987]). River flow in dry periods, in addition to many wetlands, among them the Tablas de Daimiel and Doñana National Parks, also depend on aquifers. Their environmental, economic and productive importance is, in consequence, considerable, as has been reiterated on many occasions (Llamas, 1995).

Aquifer exploitation causes a drop in its piezometric levels and in the flow of the rivers and springs that drain it. In the case of small aquifers, the delay in the decrease of river flow may be of some months or a few years, depending on the aquifer's characteristics and the distance from the wells to the river. In the case of discontinuous pumping, as occurs with irrigation, a significant part of the effect can be moved to months when less surface water is in demand, in which case it is possible to increase the resource's real availability. In larger aquifers, inertia is greater and it is possible to be pumping for long periods of time, even years, without significantly affecting outflow, or even, in hydrogeologically complex areas, with different rivers, without this effect every being unequivocally detected on a specific channel. In these cases, although the pumping is seasonal, reduction is distributed in a clearly uniform way throughout the year, or is spread over time and space.

Pumping in some aquifers, such as the Llobregat delta or Plana de Castellón, for example, has modified aquifer/river relationships for some time, meaning that the latter passed from receiving water from the aquifer, to losing it and feeding the aquifer. Often, the recharge induced in coastal aquifers due to pumping causes an increase in water availability by diminishing transfer to the sea.

In other cases, situations arise that, if not strictly programmed, can have negative consequences. Thus, the drop in river flow caused by intensive groundwater exploitation can cause interferences in the administration of water resources, giving rise to socio-economic, environmental or legal problems. Abstractions on the Eastern La Mancha aquifer, for example, have caused some important reductions in the flow of the River Júcar during the last twenty years as it passes through the Mancha plain, as shown in the graph in the above section. This may be acceptable if the river's different uses are regulated jointly –as this basin's management plan has done–, or it may be negative both for users downstream and for those using the aquifer, if this situation is not appropriately regulated.

In the upper River Guadiana basin (see figures 146 and 147) another important case of influence takes place on surface water flow. Abstractions carried out in the last twenty years in the Western La Mancha aquifer, also coinciding with a dry period, have caused a continuous drop in piezometric levels, which has led to deterioration in many of the existing wetlands, especially the Tablas de Daimiel National Park.

In this last figure (drawn up with CHG data, 1997) we can see how the effect of declaring the aquifer over-exploited, with the resulting regulation of abstractions, and the drop in pumping due to agricultural aid and subsidies, together with the

Figure 145. Map of areas irrigated with groundwater and water of mixed origin.

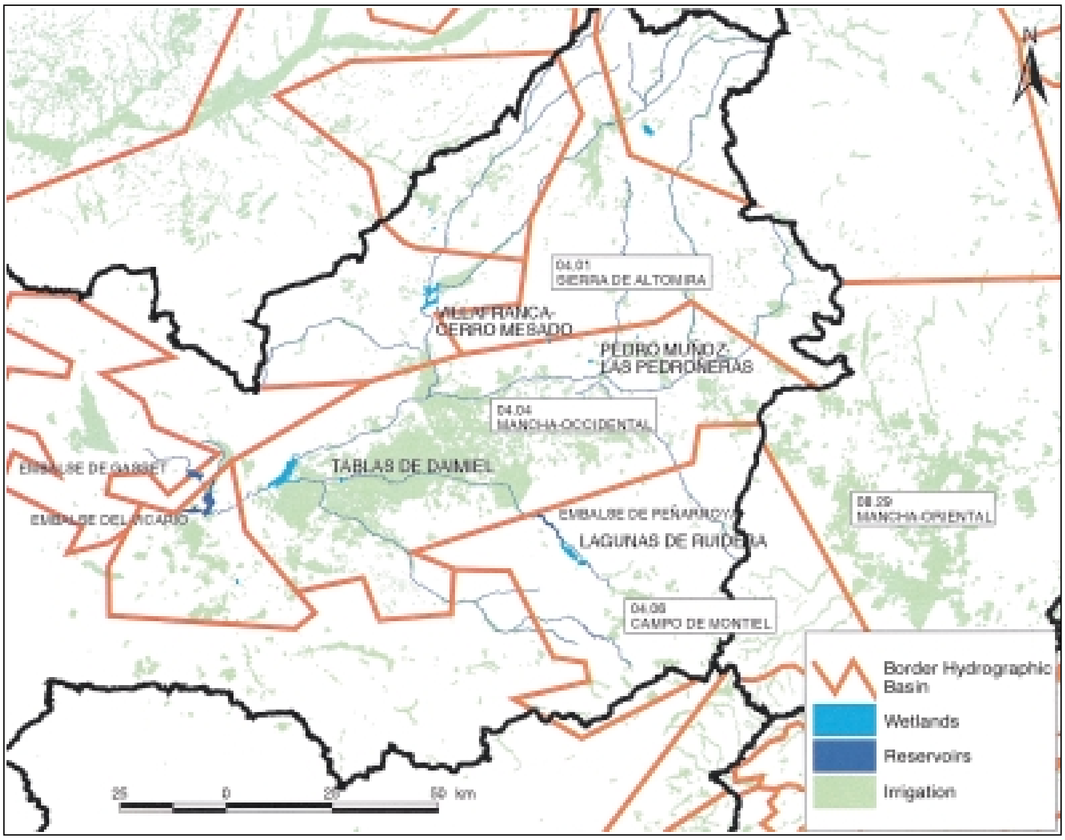


Figure 146. Map of the upper Guadiana basin.

favourable hydrological situation, is contributing to a certain recovery of piezometric levels in the aquifer (EC, 1997).

The drop of flow in rivers and wetlands and of phreatic levels in aquifers can also negatively affect aquatic fauna and some types of vegetation, as occurs in the Doñana National Park.

In other areas, however, the intensive exploitation of groundwater has allowed demands and the development of economic activities to be covered for years, and evapotranspiration has diminished in places with phreatic levels near the surface, with an unquestionable beneficial overall effect.

In general terms, the process of decreasing levels is stabilized if pumping does not exceed aquifer recharge. Otherwise, the decrease in level is progressive and can make sustained exploitation unfeasible due to exhaustion of reserves, excessive increase in costs, or deterioration of water quality by mobilising water masses with high salinity content.

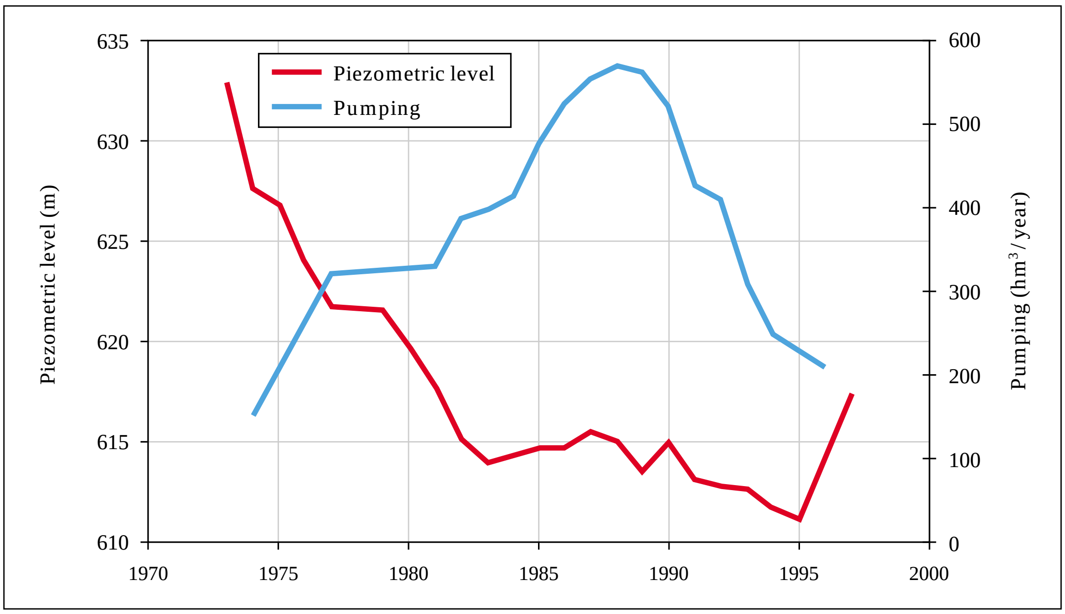


Figure 147. Evolution of piezometric levels and pumping in the Western La Mancha aquifer (piezometer 203070003 in Manzanares).

Figure 148 breaks down the information offered for Hydrological Plans' territorial area, showing the pumping/recharge relationship in the different units defined as hydrogeological. Pumping data comes from the basin plans and the White Paper on Groundwater, and recharge data is prepared here for recharge due to direct rainwater infiltration, and from the basin plans and the White Paper on Groundwater for recharge due to irrigation.

As may be seen in this figure, the most common situation is for abstraction to be much smaller than recharge, but there are a large number of units, more than 20% with respect to the total, in which abstraction exceeds recharge (ratio>1) or approaches it (ratio between 0,8 and 1). This set of units could in principle be defined as problematic from the point of view of over-exploitation, in the sense that it will be foreseeably impossible to maintain the current rates of water abstraction in the long term. This does not mean there are not other units with abstractions lower than recharge where there may also be problems, for other reasons that we shall examine later.

A study of the figure also clearly shows the spatial distribution of the phenomenon: in addition to the islands, it takes place all over the Spanish Mediterranean and Andalusia, concentrated mostly in the southeast (Murcia, Almería and Alicante) and in La Mancha plain (Ciudad Real and Albacete). In the rest of the areas, the situation only appears as a problem in the region of Los Arenales, in the Douro basin. It should be mentioned that some of these areas may also have modified the situation in recent years. This is the case of the Upper Guadiana, where, as explained, abstractions have significantly decreased with respect to those existing at the end of the 80s.

As an example of previously existing evaluations, table 35 shows estimates of the situation in problematic units, by MOPTMA-MINER (1995) and from the Report of the National Hydrological Plan (MOPT [1993]).

In the assessment carried out in this White Paper, the sum of units considered initially problematic supports total abstractions of around 3,900 hm^3/year, which represents over half the total abstractions in all the hydrogeological units in Spain.

Volumes that exceed renewable resource, and which therefore come from reserves, are abstracted by means of tens of thousands of collections, and are basically applied to irrigation and, to a much lesser extent, to supply (archipelagos, the cities of Almería and Albacete, etc.). Frequently, quantitative problems are compounded by quality problems due to marine intrusion (Campo de Dalías) or the mobilisation of brackish deep waters leaching out (Segura basin).

It should be taken into account that over-exploitation is a dynamic process. Factors like climatology, the availability of transferred water, the entry into service of desalinating plants, agricultural grants, aquifer exhaustion, etc. means that the amount of abstractions changes every year, and should be estimated at its mean current value.

Also, it should be pointed out that over-exploitation is not a recent phenomenon. Except for the islands, where the problem is very old, and only referring to the Peninsula, prece-

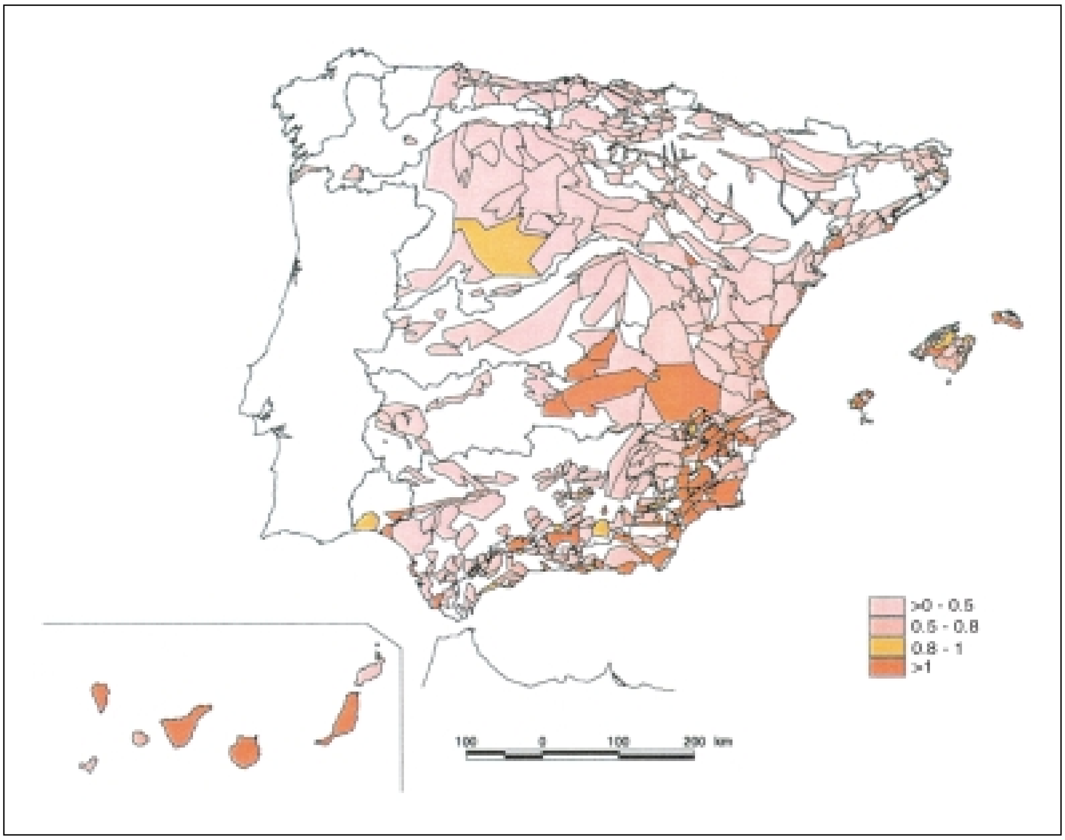


Figure 148. Map of the pumping-recharge relationship in hydrogeological units.

Planning Area	White Paper on Groundwater (1994)	Report of the National Hydrological Plan (1993)	
Num. of units with over-exploitation probs.	51	89	
	Deficit in units with pumping/recharge>1 (hm^3/year)	Strict deficit in u. with pump/rec>0,8 (hm^3/year)	Effective deficit in u. with pump/rec>0.8 (hm^3/year)
Guadiana	240.0	240	280
Guadalquivir	10.0	10	25
South	68.8	36	60
Segura	215.9	295	325
Segura/Júcar	66.0		
Júcar	54.0	55	125
Catalonia I.B.	10.0	10	50
Balearic Islands	14.0	14	30
Canaries	32.0		160
Total	**710.7**	**660**	**1,055**

Table 35. Deficit in the balance of groundwater by planning area.

dents have existed in the Southeast (not only technical but also legal-administrative) since the fifties, and the problem has been generally widespread since the seventies. This implies that it already existed when the current Water Act came into force, which has major legal consequences and signifies that, according to a certain interpretation that has received legal support, it is not acceptable to prohibit abstraction without compensation for the prohibition of the use, even though the privation is temporary, and even when there has been a declaration of over-exploitation. Obviously, this must be in the –generally uncommon– case of correct verification of rights prior to use of the aquifer's water.

Although in this current situation situations of clear imbalance are taking place in fact, it is generally admitted that, except for planned, controlled exceptions, correct use of aquifers should not be based on continuous abstraction of reserves, but on renewable resources, although this consideration should not go to the extreme of condemning all water administration that involves abstraction of reserves. In fact, any exploitation of groundwater requires transitory periods of imbalance, where part of the volume used comes from reserves. Only if the drop in reserves is prolonged excessively, without its stabilization or recovery being planned, would it be necessary to deem that over-exploitation exists.

The concept of over-exploitation applied to aquifers is not easy to define accurately. It is sometimes associated with an exploitation that causes reserves to fall, and also, more generically, to an excessive exploitation with undesirable consequences for users of the aquifer or for third parties (Margat, 1992), a line of concept that is followed, as we shall see, by our regulations.

The types of unfavourable effects that could give rise to presumed over-exploitation are varied (Custodio, 1992): a) hydrological, arising from a continuous descent in levels, which may lead to a reduction in the flow of wells, b) in water quality, deteriorated by contact with lower quality levels or by saline intrusion in coastal aquifers, c) economic, due to an increase in the cost of pumping energy, by having to abstract from greater depths and with smaller flow, and of investment costs for re-drilling wells and substituting pumping equipment, d) environmental, caused in springs, rivers, wetlands, phreatophytic masses, and associated ecosystems, due to the drop in the levels of aquifers linked with these areas and e) morphological and geotechnical, due to subsidence phenomena or sinking, caused by the drop in levels.

Under Spanish legislation, the concept of over-exploitation (defined in section 171.2 RDPH), specifies three possible situations:

- Abstractions close to or above renewable resources, immediately endangering the subsistence of existing exploitation.
- Serious deterioration of water quality as a consequence of these abstractions.
- Evolution of the aquifer, as a consequence of the amount of abstractions that endangers the long-term subsistence of exploitation.

Although this legal definition does not expressly consider, as a cause of over-exploitation, the effect of abstractions from the aquifer's natural upwelling or its piezometric levels, it is appropriate to consider some effects of this type as over-exploitation problems, especially when they involve major environmental impact. A possible interpretation of the regulations, compatible with the practical requirements of planning and administration, would be to associate acceptable exploitation levels to resource availability, with this established covering all the resource systems conditioning factors: quality objectives, ecological needs, legal situations, economic positions, rules of exploitation, users' rights, etc. (Sánchez González, 1995).

So far, in intra-community basins, 15 hydrogeological units have been declared provisionally or definitively over-exploited (MIMAM, 1998a), and whose situation is shown in figure 149 and table 36. The Cresta del Gallo unit, in the Segura area, has not been represented on the map, because it is a very small aquifer, with very circumstantial problems, not included in the new delimitation of units carried out in that plan. The Bloque de Gaia and Camp de Tarragona units have not been represented either, in the Catalonia Inland Basins, which were provisionally declared over-exploited in 1988 by the Generalitat of Catalonia, which also established limits of exploitation rights in another 21 aquifers (MOPTMA-MINER, 1995).

As can be seen in the table, of the 15 units provisionally declared over-exploited, only 2 of them have reached definitive declaration, those of Campos de Montiel and the Western La Mancha.

Not included in the previous table are the aquifers or aquifer areas of Níjar, Huércal-Overa, Pulpí and Lower Andarax, where although they have not been formally declared provisionally over-exploited, the provisions of section 171.4 of the RDPH are also applicable to them.

In order to analyse the hydrogeological units where over-exploitation or salinisation problems have been detected, and with the aim that regulation of abstractions from such aquifers may be defined and programmed, MOPTMA-MINER (1995) planned a programme on "Aquifers with Over-exploitation or Salinisation Problems."

The work carried out to draw up this Catalogue of Aquifers with over-exploitation or salinisation problems has allowed the identification of up to 77 hydrogeological units in inter-community basins –DGOHCA (1997), MIMAM (1998a)–. For all Spain, we should add to the above other problematic units in the Catalonia Inland Basins and in the Canary Islands.

It is important here to differentiate physical over-exploitation from artificial over-exploitation, because, as may be seen, it is a fact that such concepts do not necessarily occur simultaneously in the same units. Additionally, it is seen that definitive declarations are very scarce compared with provisional ones, which should lead us to ponder this important issue, and the real effectiveness that the regulation process is having in practice.

Furthermore, the fact that aquifer over-exploitation problems exist in some places does not mean that groundwater use may not be extended in others with positive effects. We will refer to this in other chapters, when studying future possibilities as regards water availability.

3.1.5.6. Joint use of surface water and groundwater

Previous sections have examined availability regulated by means of surface reservoirs and the situation of groundwater exploitation. A procedure used to increase water availability is the joint use of surface water and groundwater.

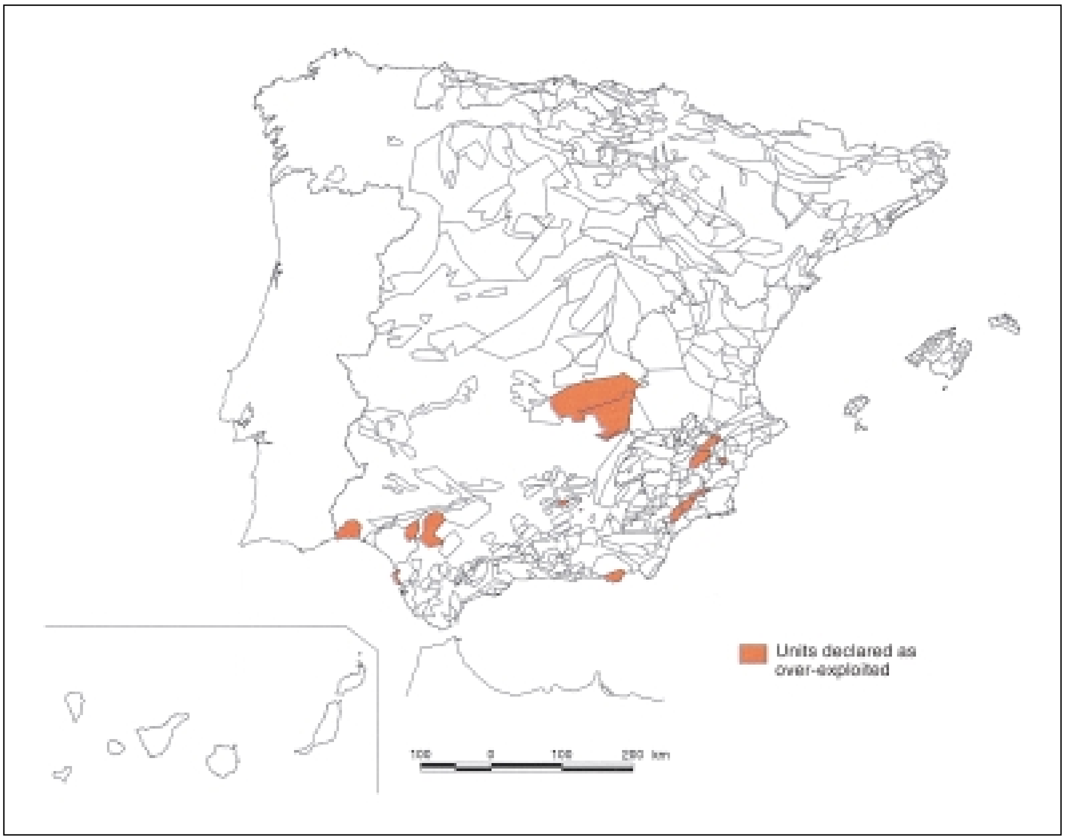


Figure 149. Map of hydrogeological units with provisional or definitive declaration of over-exploitation in inter-community basins.

Planning Area	Code	Name of Unit	Declaration of over-exploitation
Shared Guadiana-Guadalquivir	00.04	Campo de Montiel	Definitive (12/06/1989)
Shared Segura-Júcar	00.16	Jumilla-Villena	Provisional (31/07/1987)
Shared Segura-Júcar	00.19	Sierra de Crevillente	Provisional (31/07/1987)
Guadiana	04.04	Western La Mancha	Definitive (15/12/1994)
Guadiana	04.12	Ayamonte-Huelva	Provisional (12/12/1988)
Guadalquivir	05.19	Mancha Real-Pegalajar	Provisional (24/10/1992)
Guadalquivir	05.41	Chotos-Cortijo Hidalgo	Provisional (24/10/1992)
Guadalquivir	05.47	Seville-Carmona	Provisional (26/10/1992)
Guadalquivir	05.50	Aljarafe	Provisional (18/05/1993)
Guadalquivir	05.57	Rota-Sanlúcar-Chipiona	Provisional (30/11/1992)
South	06.14	Campo de Dalías	Provisional (21/09/1995)
Segura	07.09	Ascoy-Sopalmo	Provisional (07/01/1987)
Segura	07.28	Alto Guadalentín	Provisional (04/10/1988)
Segura	07.30	Bajo Guadalentín	Provisional (04/10/1988)
Segura		Cresta del Gallo	Provisional (04/10/1988)

Table 36. Hydrogeological units with a provisional or definitive declaration of over-exploitation in inter-community basins.

By combined use of surface and groundwater resources we understand the planned, coordinated use of both sources to better meet demand. The proportions in which the quantities of water from the two origins are used to cover demand are variable according to the time of the annual hydrological cycle, existing reserves in the surface storage system and in aquifers, available quality in each one, and, specifically, the objective set for the system's exploitation (SGOP-UPV, 1983).

Combined use takes advantage of the hydrological complementarity of surface reservoirs and aquifers. By exploiting groundwater when surface flow or storage is smaller, an increase in supply guarantee is obtained.

If the relationships between surface water and groundwater are considered, and the reciprocal influence of exploiting each one of them on the other, then combined use is an evident necessity in areas with supply problems that do not necessarily have to coincide with arid areas or with shortage of water resources.

An aquifer's storage capacity can be utilised if one makes more use of the surface reservoirs or of river flow in wet periods, and more is pumped from aquifers in dry periods. This type of use group, termed alternative use (Sahuquillo, 1996) is a priori the one that has most possibilities in Spain.

The best-known example of alternative use is the Mijares-Plana river system in Castellón. The system, as shown in the adjoining figure, consists of three reservoirs, two on the River Mijares, the Arenós, with a capacity of 130 hm^3, located at the headwater, and the Sichar, with 50 hm^3, and one on the Rambla de la Viuda, the María Cristina, with a capacity of 20 hm^3. The Sichar and María Cristina reservoirs, located in calcareous terrain, have considerable filtration –around 45 hm^3/year– which, together with the River Mijares, recharge the Plana aquifer. The exploitation of groundwater increases in the driest years, while in the wettest years the largest possible area of land covered with existing channels and ditches is irrigated with surface water. Variation in water stored in the Plana de Castellón aquifer, between the end of a humid period and the end of a dry one of several years' duration, has reached up to 700 hm^3. This storage capacity of the aquifer allows a very high percentage of supply guarantee. Figure 150 shows this system, with the different sources of water for irrigating the area.

It is noteworthy that this type of use is implemented by users' initiative. Subsequent studies by the Administration have aimed to rationalize and optimise an initially well-planned management. On the other hand, this system's management is complicated by the existence of an area with marine intrusion problems to the South of La Plana, due to a concentration of pumping and a lack of irrigation with channels. Exploitation simulation models, which consider the possibility of extending alternative use to wet years, demonstrate that it is also possible to offset marine intrusion problems.

Alternative use has also been applied in other resource exploitation systems in Mediterranean basins. For example, in the Júcar basin, the irrigation area of the Júcar-Turia canal, especially its right bank, uses surface water from the Júcar and from wells in a coordinated way. Specifically, the surface component of its concession is 50% of demand. Combined use has a major important element due to the greater cost of pumping, but it has taken the area to a high guarantee level during the last drought. In other systems too, such as the Campo del Turia canal system, the River Palancia-Plana de Sagunto system, River Serpis-Plana de Gandía, or Marina Baja, combined use is being implemented.

In the Segura basin, this alternative use is traditionally carried out in the Guadalentín Valley, and in the South in the basins of the Lower Guadalhorce, Vélez, Motril and Adra Delta.

A typical case of alternative use is the Canal de Isabel II supply system for the Madrid metropolitan area, which presently has a groundwater abstraction capacity of about 4 m^3/s (3

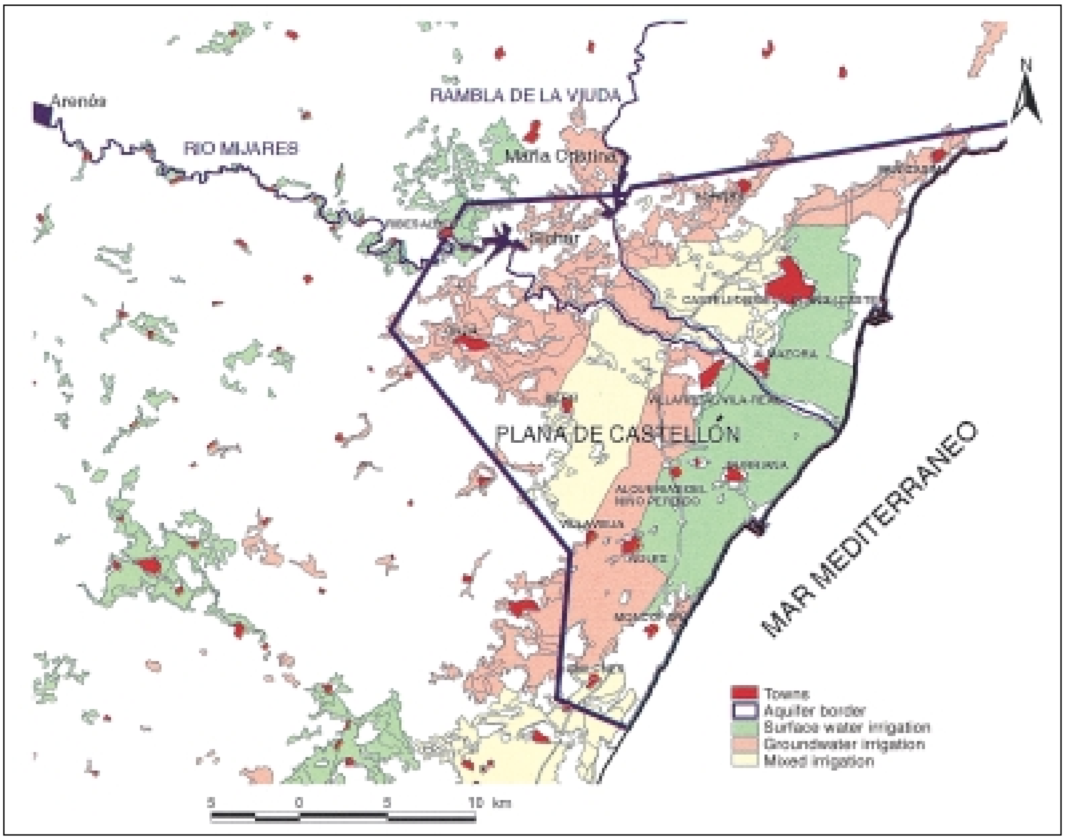


Figure 150. Map of the River Mijares-Aquifer system in Plana de Castellón.

to general systems and 1 to local systems, according to demand), so as to have emergency resources in drought situations (up to about 100 hm^3/year mobilisable, which represents about 20% of annual demand). Supplementing flow contributed by reservoirs in dry periods significantly increases the system's water availability, maintaining a high guarantee level. The same thing happens with the wells of the Llobregat aquifer for emergencies in the water supply system to Barcelona and its surrounding area.

In all Spanish basins, it is possible to make use of the alternative use concept to a greater or lesser extent. The possibilities, in any event, depend on cumulative surface flow and its variability, on the reservoirs' capacity, on the location and of quantity of demand, on the aquifers' characteristics and possibilities and on their relationships with the rivers.

Another type of combined use consists of increasing availability by taking advantage of the delay that occurs between aquifer pumping and the drop in flow of the drainage river. When pumping takes place intermittently in the driest months, when water demand is greater and river flow is lower, a part of the effect from pumping takes place in the months when river flow is greater. In this type of combined use, the influence of pumping on river flow is faster, and it is essential to know the relationships between surface and groundwater to accurately evaluate the exchange of water.

This type of combined use is termed river-aquifer and has been used in Spain, for example, in the aquifers of the Upper and Middle Segura Valley to offset the effects of drought.

Certain aquifers, when their piezometric levels fall, can invert their relationship with the river, which can go from receiver to donor. In many aquifers on the Spanish Mediterranean coast, such situations have occurred when rivers enter coastal plains. In some cases, this possibility can be exploited to recharge aquifers in times when there are no irrigation requirements. Discharges can even be programmed, for this purpose, at opportune moments, to store water in the aquifers.

A last type corresponds to the regulation of karstic springs. In Spain, a number of karstic springs have been regulated by pumping on the aquifer to supplement the flow necessary to meet demand, and different possibilities of this technique have been studied (see, e.g., Sanz Pérez, 1987).

A good example of this type is represented by the Marina Baja resource system (Alicante). This system consists of two small reservoirs (Guadalest and Amadorio) and a carbonated hydrogeological unit (Serrella-Aixorta-Algar) with two fields of high-productivity wells, one of them upstream from the Guadalest reservoir and the other one, which is used to regulate the karstic spring of the Algar, which drains the aquifer of the same name. This system covers a supply demand of about 20 hm^3/year, and the irrigation of 3,200 Ha.

Although the system is not completely integrated as a management unit, its main demands are covered indiscriminately with surface water, with the Algar spring, and with the wells.

Purified waste water is also used for irrigating timber cultivations. This system, apart from being an example of karstic spring regulation, is also an example of alternative use and has acted in compensating major droughts. The regulation of the Santos spring by pumping has allowed agricultural demand to be covered, although environmental problems have appeared due to reduced flow from the spring.

Another case of joint use with artificial recharge takes place in the system made up of the River Llobregat and the Lower Llobregat coastal hydrogeological unit, where mean annual abstraction, at about 140 hm^3, is slightly higher than the unit's average recharge. In the river's alluvial plain about 20 hm^3/year is recharged in wells located in the delta, with excess water from the Sant Joan d'Espí treatment plant. Also, by means of scarifying the river channel, it has been possible to increase infiltration in the alluvial plain. The experience of the Lower Llobregat has been very illustrative and, without being a perfect example, is a reasonable attempt of management from users, the Water Administration and the University (Custodio, 1996).

Figure 151 shows some of the main schemes where combined use is currently being implemented in Spain.

3.1.5.7. Artificial recharge of aquifers

Artificial recharge is the name given to a set of techniques that allow, by means of programmed intervention and direct, induced or stimulated introduction of water into an aquifer, an increase in the level of guarantee and water resource availability, and action upon their quality.

Artificial recharge of aquifers has been used for some time to store surface water or surplus runoff. Recently it has been used as a means of improving aquifers administration, to reduce the drop in piezometric levels, or to diminish or alleviate problems of marine intrusion by displacing saline wedges toward the sea. The possibility of storing water in aquifers has been implemented in surface and groundwater joint utilisation schemes (Custodio, 1986).

Artificial recharge is a technique that involves certain complexity in implementation. Programming actions based on this technology should be limited, with some exceptions, to areas with low regulation of water resources and high demand, to areas with well-developed agricultural exploitation and high yield, to districts where water cost is very high and to coastal sectors where it is not possible to construct classical regulation works due to topographical conditions.

The country with a highest level of development in applying the artificial recharge technique has traditionally been the United States. Just in the State of California, by means of utilising artificial aquifer recharge, a volume of 1,400 hm^3/year (CDWR, 1998) is provided. In Israel, a significant part of available resources are devoted to recharge. In the context of the European Union, Germany and Holland are the countries where it is most implemented. In these countries, the main objective is not to increase availability, but to purify water for urban supply as it passes through the ground's unsaturated zone.

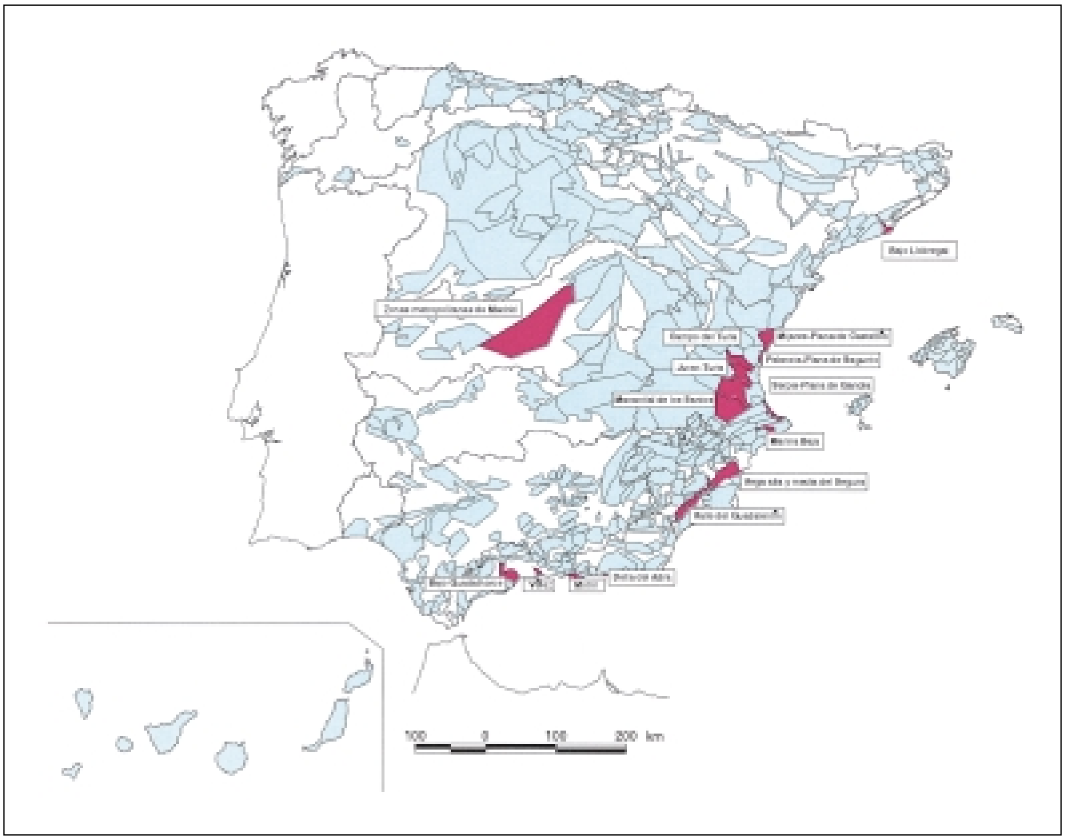


Figure 151. Map of the situation of combined use schemes in Spain.

In Spain, traditional systems of artificial recharge have existed at least since Arab times. Examples of these traditional practices are the Alpujarra pastures, or the systems of dikes, underground dams and sluices in alluvial plains of the southeast. The first modern artificial recharge facilities were located in the surroundings of Barcelona, in the alluvial plain of the Rivers Besós and Llobregat. In the latter of these, they are recharged, in some years, up to a maximum of 20 hm3, in wells located in the delta, with excess water from the Sant Joan d'Espí treatment plant, and by scarifying the river. Other interesting experiences, although not comparable with this one due to duration in time, are those of Mallorca, in Llano de Palma (MOPU, 1986), or Boquerón, in the Segura basin (Senent Alonso, 1985), or others on the Llobregat coast, Sant Pau of Ribes, etc. The total quantity of resources regularly devoted to artificial recharge in Spain is difficult to estimate, but it would probably not even reach 50 hm^3/year.

In collaboration with other organisations, the ITGE has been carrying out pilot experiences since 1984, whose main characteristics are summarised in table 37 (López Geta y Murillo, 1995).

The results obtained from these experiences are encouraging, although some failures have occurred, owing as much to a lack of planning and technology, as to insufficient interest in their possible beneficiaries, and poor economic funding to develop them.

In MOPTMA-MINER (1995), a general programme was studied with the aim of promoting effective, rational investigation into this technology.

In any event, we should mention that using artificial recharge should not give rise to expectations of significant improvements in the country's resources, though it is possible to remedy or offset some local problems, improving supply guarantee.

Location	Type of facility	Origin of recharge water	Objective	Duration of experiment	Infiltrated flow
RIVER OJA ALLUVIAL (RIOJA)	3 infiltration pools and 10 km of canals	Surface surplus from River Oja and Santurdejo	Increase water resources for irrigation and improve water quality in the aquifer where there is abstraction for urban supply	From Dec. 1986. 3 to 5 months a year	40 – 400 l/s
VEGA DE GUADALIX (GRANADA)	5 infiltration pools	Drainage from the Alquije Mine	Increase water resources for irrigation	From Nov.1984 3 to 4 months a year	200 – 300 l/s
CALCARENITAS DE CARMONA (SEVILLE)	1 "pit"-type infiltration pool	Winter surplus from the Lower Guadalquivir canal	Solve local over-exploitation problems	15 days	6.7 l/s
LOWER GUADALQUIVIR ALLUVIAL (SEVILLE)	2 infiltration ditches (300 m), 1 m diameter interior	Winter surplus from the Lower Guadalquivir canal	Increase water resources for irrigation	1 month	250 – 500 l/s
JIJONA AQUIFER (ALICANTE)	1 deep borehole and permeable deposits (5000 m^3 capacity)	Sporadic runoff and winter surplus from the Nuches spring	Increase supply guarantee for Jijona	2 years	Up to 12 l/s
ESGUEVA VALLEY (VALLADOLID)	1 deep borehole	Winter surplus from the River Esgueva	Increase water resources for irrigation	5 years	2 – 20 l/s
SETLA-MIRRAROSA-MIRAFLOR (ALICANTE)	1 large diameter well with two galleries parallel to the coast, 100 m long each. As of Nov. 1996, 3 recharge wells	Winter surplus from the River Girona	Stop marine intrusion and increase water resources for irrigation	From Dec. 1985 5 to 6 months a year	40 l/s
MANCHA REAL (JAÉN)	1 deep borehole	Winter surplus from the River Torres	Increase supply guarantee for Mancha Real	15 days	70 l/s
MAZAGÓN (HUELVA)	6 infiltration pools	Gross urban wastewater for irrigation	Increase water resources	1 year	100 – 200 m^3/day

Table 37. Experiments with artificial recharge carried out by the ITGE in collaboration with other agencies.

3.1.5.8. Reuse

Another technique to increase availability considered as non-conventional is water reuse. Although the resource volume is obviously the same, its successive application allows more uses to be covered and, therefore, increase the water allocation system's internal availability.

Reuse is an intrinsic component of the water cycle, since by means of wastewater running into water courses and their dilution in the circulating flow, waste water has been traditionally reutilised by water intakes downstream from its entry point into the channel. It is important to distinguish between indirect reuse, which is the one mentioned and the most common, and direct reuse, which is when the second use takes place after the first one, without the water entering any public channel between the two.

In fact, this direct or planned reuse, on a large scale, has a more recent origin and represents the direct use of purified wastewater with a greater or lesser degree of previous treatment, by transporting it to the point of second use through a specific channel, without entry into a public channel being involved.

Reuse possibilities are directly related with available volumes of treated wastewater, which in turn depend of the number and capacity of existing purifying stations. This number and capacity will foreseeably undergo a significant increase in view of the obligation to comply with Community Directive 91/271/EEC, on the treatment of the urban waste water, and the implementation of the National Wastewater Collection and Treatment Plan (NWCTP). The need to obtain water with certain minimum qualities for each use, and to guarantee some satisfactory sanitary conditions, usually requires purified wastewater to be given specific tertiary treatment (filtration, micro-filtration, physical-chemical treatment, disinfection, salt-elimination treatment, etc.) which should naturally be taken into account in planned reuse (Philanderer, 1994).

Apart from very frequent indirect reuse (of which an excellent example is provided by the Segura valley, where water is applied, two, three and four times to the traditionally-irrigated land by means of the irrigation-drainage-new irrigation system, or irrigation in the Jarama, with purified water from Madrid), in Spain there exist at present over 100 direct reuse actions, and it is one of the most-developed countries in this field. These actions allow a demand of about 230 hm^3/year to be covered, with irrigation the most widespread use (89% of total volume, compared with 6% for recreational uses and golf courses, 2% for municipal uses, 2% for environmental requirements and 1% for industrial uses). Facilities are mostly located on the islands and Mediterranean coastal areas with shortage of water resources –fundamentally the Júcar and Segura– as shown in the adjoining figure. These areas are also those that seem to show the greatest potential for future development.

An interesting experience that should be mentioned is that of the city of Vitoria.

Vitoria, despite being an area with abundant rainfall, must deal with the double problems of assuring urban supply and irrigating 10,000 Ha, while also maintaining some service flow in the channels. To do this, an integral reuse plan was drawn up for the purpose of achieving full reuse of the city's wastewater, calculated at about 45 hm^3/year, which mixes 27 residual with 18 of nearby streams, taken up by the network of urban collectors. After impeding this abstraction diverting flow upstream from the city, the residual 27 hm^3 is treated in the EDAR by means of tertiary treatment so that it can be added to channels in adequate conditions for fish life. It short, this is a treatment operation that allows an increase in overall availability for supply and irrigation, and maintains the River Zadorra's trout stock (López García et al. 1998).

Furthermore, other examples of interesting experiences are those of the Costa Brava (Sala and Serra, 1998), Costa del Sol (Marzo, 1998), Tarragona (Aragonès, 1988), and the peninsular southeast (Rico et al. 1998) (fig. 152).

The map in figure 153 shows municipalities with existing reuse facilities, clearly illustrating the above-mentioned spatial concentration.

The main problem affecting the direct reuse of purified water, and which represents an impediment to its expansion, is the lack of generally applicable, specific regulations, sanctioned by the health authorities, regulating quality criteria that may be required of this water and aspects regarding its administration. This situation is causing a certain lack of orientation in planning, a dispersion of criteria on the selection of precise tertiary treatment and, on occasions, the reuse of wastewater in inadequate conditions.

To solve this deficiency, and developing both the Water Act (section 101) and the Regulations on the Public Water Domain (arts. 272 and 273), a draft Royal Decree was drawn up which, basically following the health criteria of the Health and Consumption Ministry, laid down basic conditions for the direct reuse of purified wastewater. This draft Royal Decree is currently in a process of analysis, revision and consultation with the affected parties, and subject to any existing regulations there may be at European Community level.

Simultaneously, some regulations have appeared in autonomous areas, which basically lay down various health limitations for using this type of water in agricultural irrigation. An example of these can be seen in the case of those existing in Catalonia and the Balearic Islands.

3.1.5.9. Desalination

Another technique to increase availability traditionally considered non-conventional is water desalination which, as the name indicates, consists of treating salted or brackish water from the sea or from saline aquifers, and removing the salt from it, to transform it into waters suitable for uses such as population supply or irrigation.

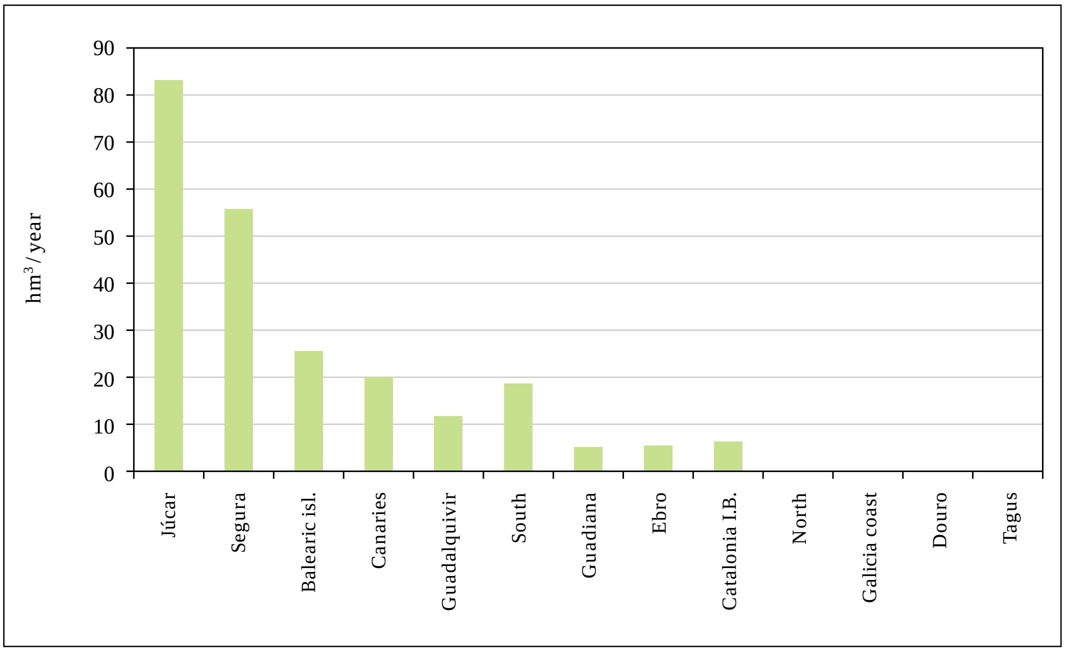


Figure 152. Volume of current direct reuse by planning areas.

The idea of using sea water for human use is very old, with references from as early as Aristotle, but it was not until the mid-20th century when massive, industrial use of this technology began to take place.

Figure 154 (Rico et al., 1998) shows two estimates of the evolution of world desalination volume in plants with a treatment capacity greater than 100 m^3/day, and of installed desalination capacity in Spain. Notwithstanding the fact that circumstantial values may be modified according to the interpretation given to the concepts represented (type and size of plants, type of treated waters, etc.), the figure shows an unequivocal, continuous growth trend from the sixties, which accelerated in our country as of the second half of the 80s.

In fact, sea water desalination has been used in Spain since the end of the 60s for urban supply to Ceuta, Lanzarote, Fuerteventura and Gran Canaria, which all have low water

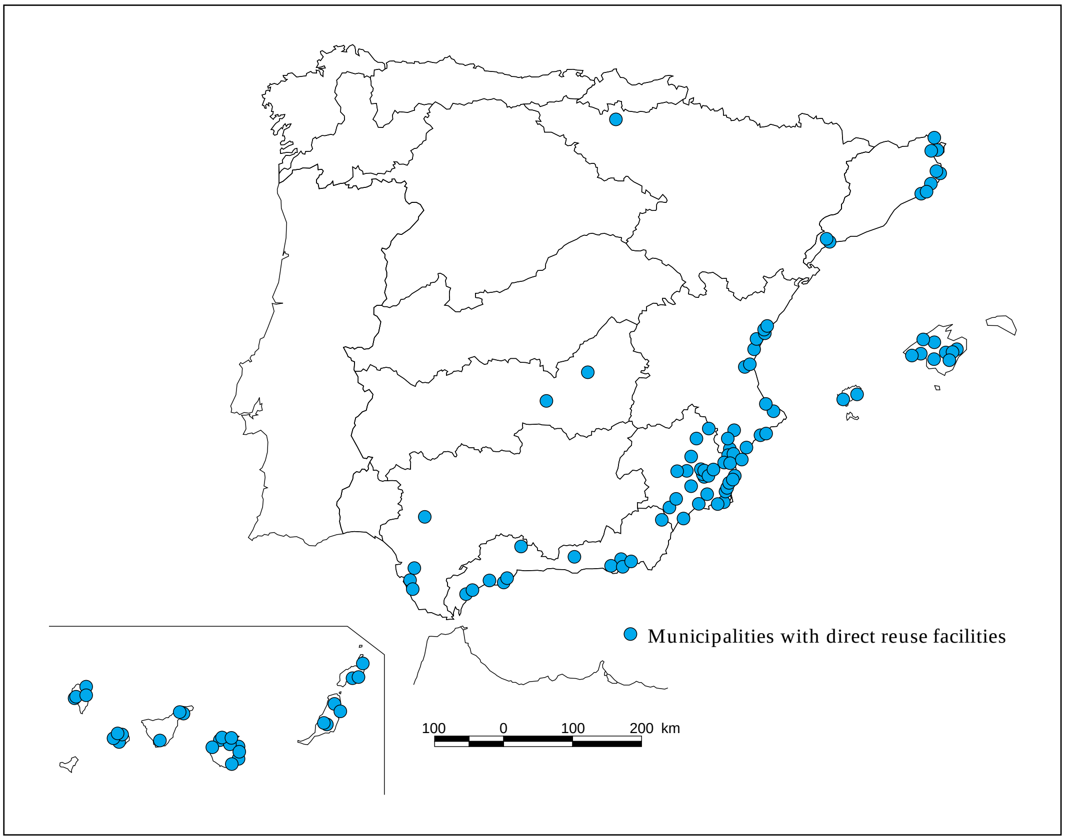


Figure 153. Map of municipalities with direct reuse facilities.

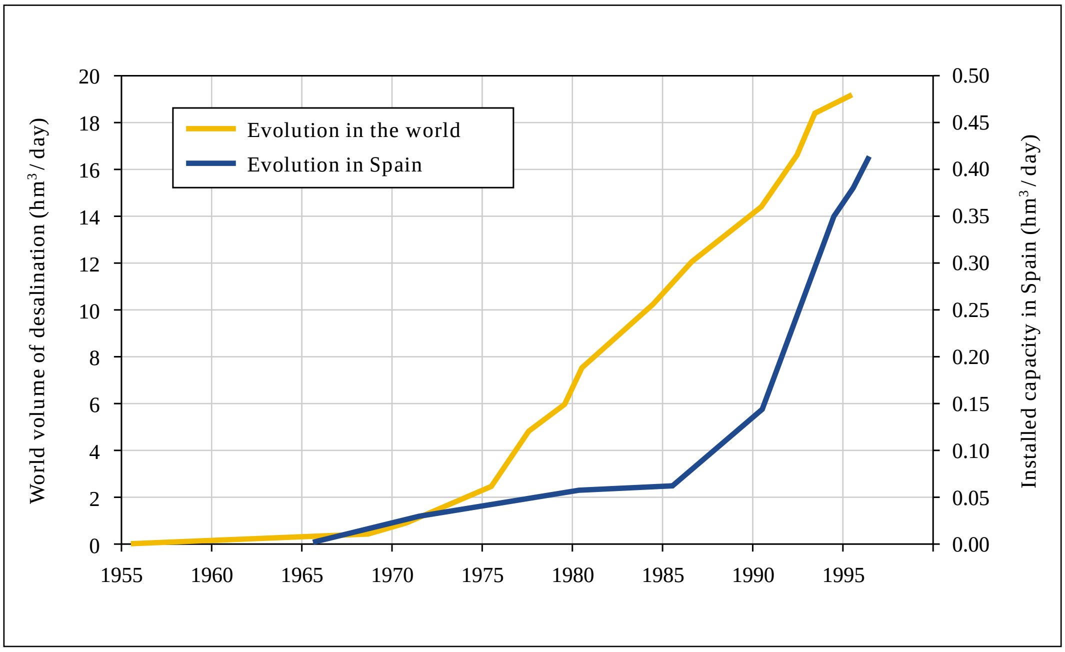


Figure 154. Evolution of desalination in the world and in Spain.

resource availability in common. In all these cases, desalination turned out to be the best solution –and in some cases the only one– to the problem of urban supply deficit. Other solutions studied (water transportation in ships or artificial rainfall increase) were abandoned after a time since they were considered technically or economically unfeasible.

The first technologies implemented were those of distillation, in varieties of multi-stage flash (MSF) and vapour compression (VC), for which energy consumption was very high –between 15 and 18 kWh/m^3–, this being the main cause for the very high cost of desalinated water, in excess of 1.20 €/m^3. The development, and market entry, of other, more efficient technologies, such as inverse osmosis (with a total consumption around 5 kWh/m^3 according to the latest projects carried out), together with a drop in energy cost, have significantly reduced the cost of this desalinated water to figures below 0.60 €/m^3, and in a clearly favorable recent trend.

As an indicator of this favorable trend to the effect of cost reduction, figure 155 (drawn up with UNESA data, 1998b) shows evolution over recent decades of the average sale price of electric power in Spain (Pta/kWh) –both in current pesetas and in constant pesetas of 1959–, in addition to the evolution of the annual percentage increases in the electricity rate and the General Consumer Price Index. As may be seen, the price of electricity has traditionally grown below the rate of inflation, leading to a drop in real terms of the kWh price of 44% between 1959 and 1997. Over recent

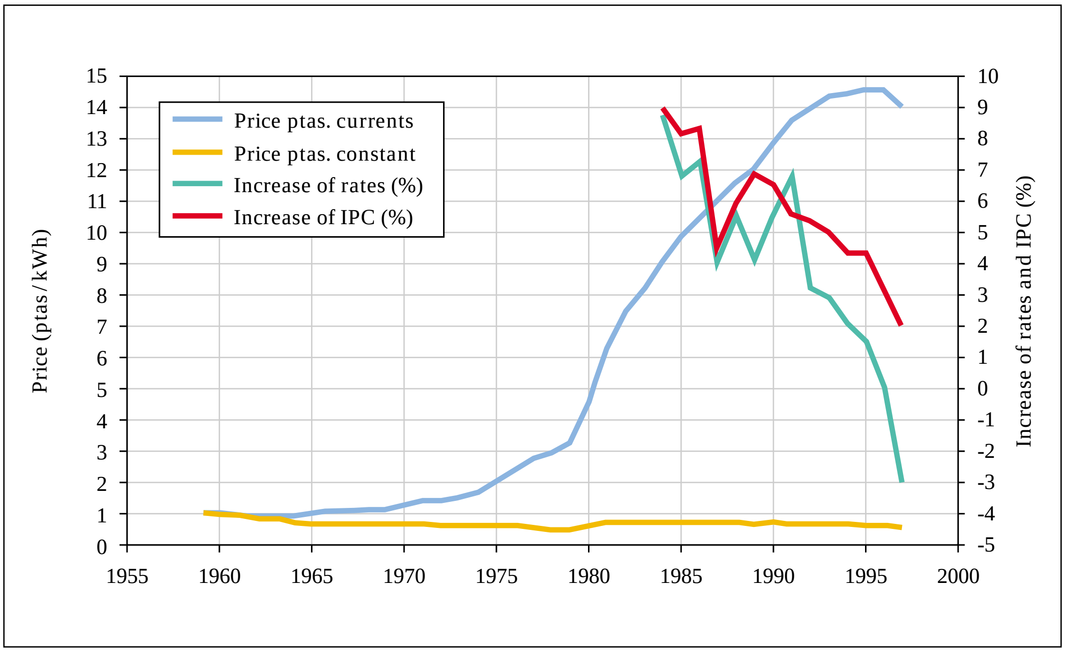


Figure 155. Evolution of the average sale price of electric power and of annual increase in the electricity rate and inflation.

years the trend of moderation in electricity prices has been significantly accentuated, as may be seen, with even negative growth taking place.

With average prices (total sales divided by energy consumed) stabilized around 0.08 €/kWh, and which drop to about half that for major industrial consumption such as in desalination facilities, the perspectives of using this technology are changing quickly, their economic feasibility is being highly favoured in recent years, and the costs traditionally involved in producing this water are falling.

Thus, we should mention how in recent evaluations carried out with the construction of new facilities, costs have already fallen below the figure of 0.60 €/m^3, including the part corresponding to full amortisation of the investment made. These are still very high figures, which do not allow their exclusive use for irrigation, but which, in certain cases of considerable shortage or lack of alternative sources, could be assumed for population supply.

Figure 156 shows an estimate of the current total costs of sea water desalination by inverse osmosis, according to plant production, in a hypothesis of amortising investment in 15 years at 5% interest, zero residual value, and an energy price of 0.04 €/kWh.

As may be seen, the basic cost component is operation and maintenance (around twice as much as amortisation), and of this, between 50 and 80% corresponds strictly to energy consumption.

Water production levels higher than the maximums shown in the graph (equivalent to about 20-25 hm^3/year) are also technically feasible, but they begin to pose serious problems both from the point of view of abstraction, if it is to be carried out through wells, and outflow of brine into the sea, since increasingly longer and more costly outlets would be required to dilute, without negative environmental effects, continuous spot wastewater, of considerable flow and high saline concentration. The costs associated with these difficulties mean that, although experiences with larger plants exist, the maximum sizes currently in use are, in practice, of the order of magnitude shown.

Furthermore, another significant component in production cost may be that required for evacuating brine to the sea by means of very long submarine outlets. If environmental values are present (such as, e.g. fields of algae) which should be preserved from excessive saline concentrations, these outlets may be an appropriate solution, although they add extra cost to water production.

The costs mentioned in relation with on-site plant production, would have to be considered in addition to transport costs from the plant to the consumption area, which would be the headwater basins in the case of irrigation, or municipal deposits in the case of population supply. In the latter case, resulting total costs (production and transport) would be those equivalent abstracting resources and transporting them to high-level deposits (high-level supply costs), so with respect to the final water price paid by the user, we would have to add all the low-level costs of distribution, maintenance and exploitation of municipal supply networks, possible treatment and intakes, personnel and administration expenses, etc.

Focusing on the transport of desalinated water from the production plant to the high-level deposits, these transport costs must include amortisation of investment for the transport infrastructure (pipelines, pumping equipment, regulation pool for incidents), plus operation costs (basically energy consumption for pumping) and maintenance costs. All these costs are parametrisable according to three basic variables, which are plant production (indicative of the flow to be transported and the regulation required), the distance to the sea (indicative of the transportation distance), and alti-

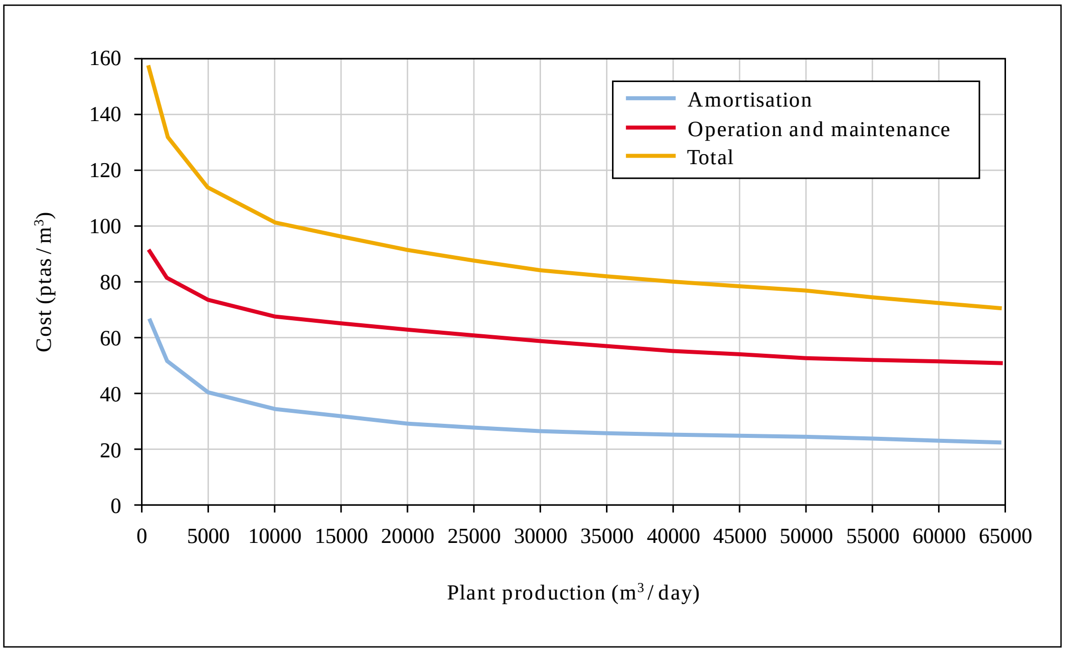


Figure 156. Costs of sea water desalination according to plant production.

tude of the consumption point (indicative of the pumping equipment and energy costs). By introducing these variables in a cartographic model, these costs can be spatially calculated.

In fact, figure 157 shows an estimate –obtained from a cartographic model– of the total cost of producing and transporting desalinated water to any point in the territory. The water would come from a plant of 10,000 m^3/day (consumption corresponding to a population of about 30,000 inhabitants) and the hypothetical conditions were, as mentioned above, amortisation in 15 years at 5% interest, and energy costs of 0.04 €/kWh.

As was to be expected, the map obtained shows a significant relationship with distance from the sea, but controlled by effects due to relief. These results are obviously simplified and merely indicative, although, in spite of this simplification, they provide an approximate idea of what would be involved, in economic terms, in satisfying the needs of a small-medium sized population, by means of desalinated sea water. As may be seen, generally speaking, only towns relatively near the coast –less than about 50 kms– could have costs lower than 0.90 €/m^3, while costs rise as of 150 km, surpassing 1.20 €/m^3.

To obtain the total price of water for supply, these high-level costs would have to include, as mentioned, all costs corresponding to low-level distribution, in addition, where relevant, to other concepts usually included in urban supply rates. Considering that, as mentioned in the relevant section, current high-level costs usually range between about 10 and 0.24 €/m^3, substituting it with desalinated sea water would imply a substantial increase in this cost, in several orders of magnitude.

The final conclusion is that, as mentioned, sea water desalination can play a significant role in urban supply for coastal towns, but as a selective, spot method, since its current costs, although clearly falling over recent years, are still generally far higher than other possible conventional alternative sources of supply. For irrigation, this water clearly stands at prohibitive cost levels except in spot utilisation due to very serious shortage, high profitability production, and availability of other water at lower cost for combination.

Furthermore, the very high dependence of production cost on energy price suggests some prudence with respect to the possible production of this water on a massive scale, and suggests strategically outlining alternative options so that the global supply system has a lower dependence on energy.

As regards brackish water, production and transport costs are considerably lower, but they involve problems of possible exhaustion and change in characteristics (that is, maintenance of their quantitative and qualitative availability), and of evacuating the brine generated in the process. As a result, studying their feasibility and costs requires detailed analyses in each specific case.

For water of this type, only membrane technologies are used, both inverse osmosis and electrodialysis, according to the raw water's characteristics. Production costs are similar with both technologies, although osmosis, with greater ver-

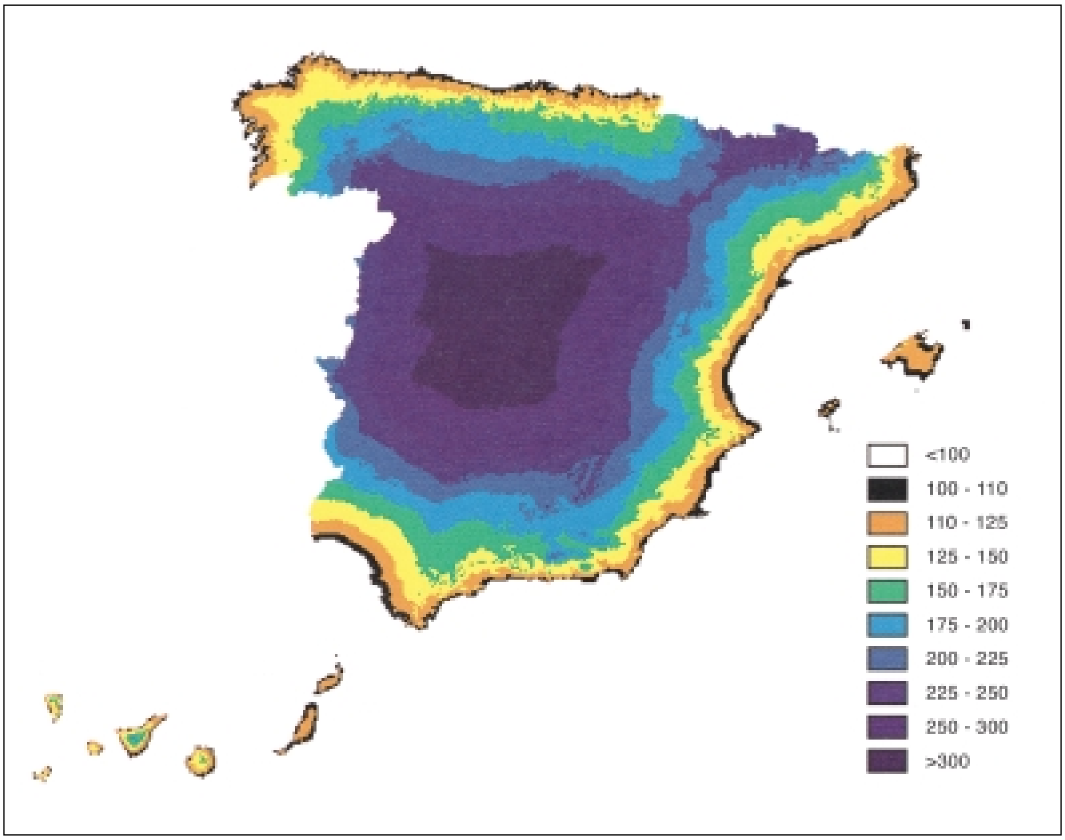


Figure 157. Map of total supply costs (production and transport) of 10,000 m^3 /day of desalinated seawater (Pta/m^3).

satility, has become more widespread. On the whole, sea and brackish water desalination currently involves a contribution to the hydrological cycle of about 220 hm^3/year, which puts Spain at the head of Europe, with 30% of all facilities in the whole continent. This production is distributed by uses as shown in table 38.

There are also major initiatives under way (such as the two sea water plants planned by the Canales del Taibilla Association, with 40 hm^3 /year for supply in the Seguar and Júcar basins, or the sea water plant for reprovisioning irrigation in Campo de Cartagena, with production of 20 hm^3/year) which, as we shall see, will increase the present figures very significantly in the short term.

Figure 158 shows volumes for current desalination by hydrological planning area.

Furthermore, figure 159 shows municipalities with currently-existing desalination facilities for urban supply.

Although the current volume of desalinated water is relatively insignificant with respect to the total figure for water resources, there are areas where it is used as a high percentage of resources. This is the case, for example, in the islands of Lanzarote, Fuerteventura and Gran Canaria, where desalinated water represents 97%, 90% and 16%, respectively, of total urban consumption.

3.1.6. Transfer of resources

3.1.6.1. Introduction

Apart from conventional and non-conventional resources internally generated within a certain territorial area, and which have been examined in previous sections, there exist situations where external, surface or groundwater transfer takes place, between different territories, giving rise to modifications in their resources.

Surface transfers between different basins increase available resources and cover existing demand in water allocation systems where they are unable to meet this objective exclusively with resources of internal origin.

Many examples of this type of transfer exist in Spain, moving resources from one basin for use in another. A particular case is transfer between territorial areas of different basin management plans, with estimating and planning for these transfers laid down as mandatory in the National Hydrological Plan, in accordance with section 43 of the Water Act.

There also exist certain fluvial exchanges with neighboring countries that may also be comparable to a natural surface transfer.

Sea water	Urban use Agricultural use	89 hm^3/year 5 hm^3/year
Brackish water	Urban and tourist use Industrial use Agricultural use	29 hm^3/year 40 hm^3/year 58 hm^3/year

Table 38. Distribution by uses of desalinated seawater and brackish water.

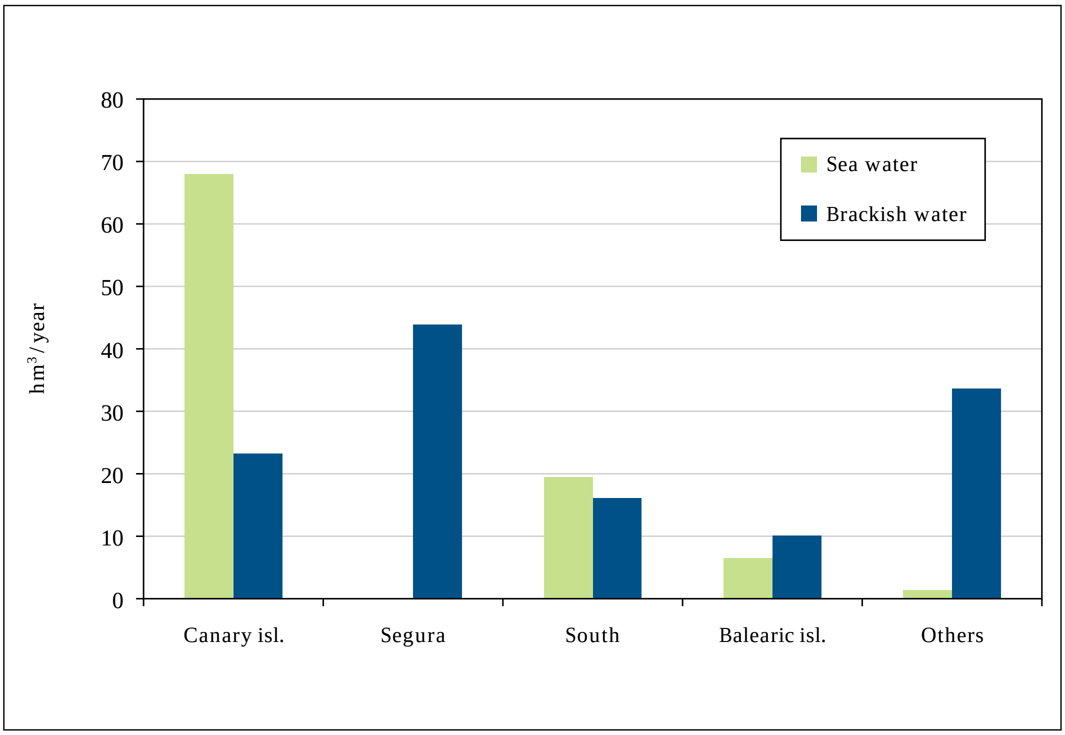


Figure 158. Volumes of current desalination by planning area.

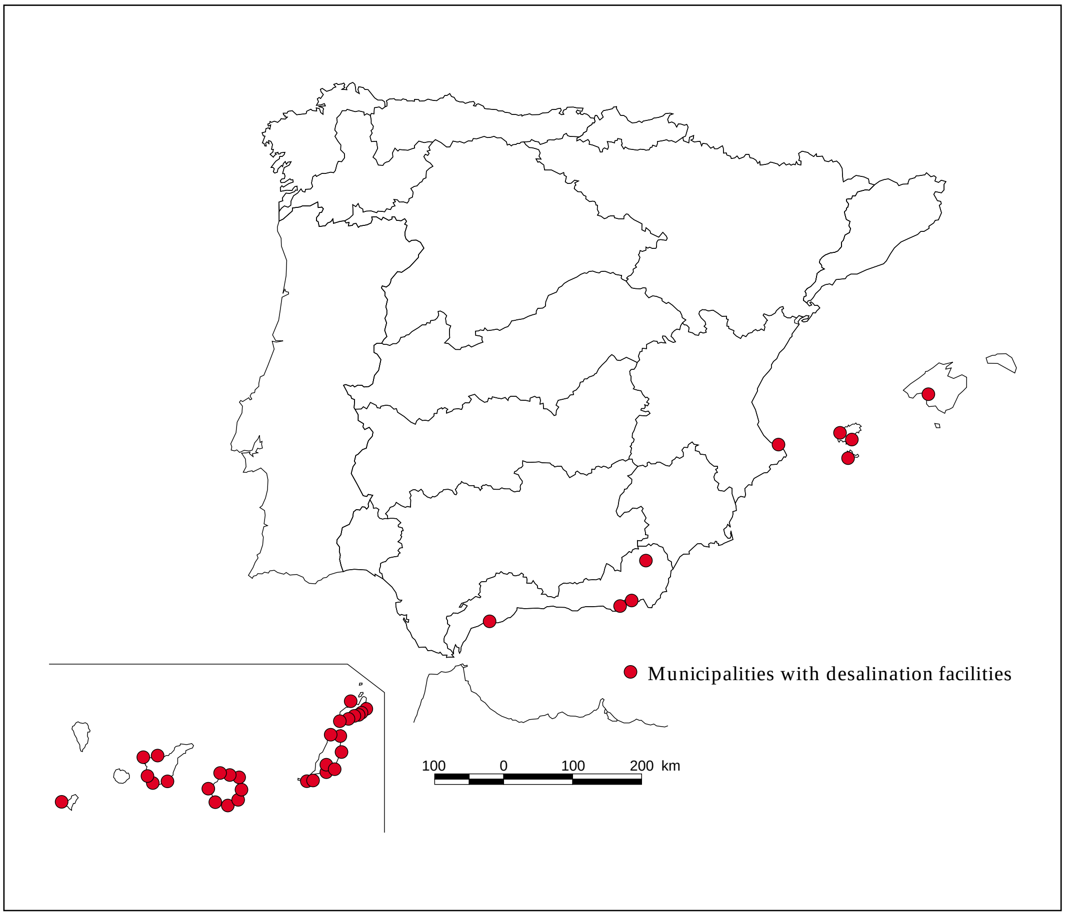


Figure 159. Map of municipalities with desalination facilities for urban supply.

In addition to surface transfers, there is also the case of groundwater flow which is naturally transferred from some hydrogeological units to other adjoining ones that may belong to different planning areas and, therefore, represent an external transfer. Although, obviously, these are very different processes, and their joint consideration is unusual, it has been considered convenient, for systematic purposes, to include them in this section.

The sections below describe the main current surface and groundwater transfers between the territories of the different Water Plans.

3.1.6.2. Surface transfers

Natural transfers with other neighboring countries will be described firstly, then presenting artificial transfers between different water planning areas.

3.1.6.2.1. Natural transfers with other countries

Planning areas with international frontiers and which include fluvial exchange is as follows.

NORTH I. The Portuguse border coincides significantly, whether with water divides, or with channels, so transfers occur rarely and in a quantity that is insignificant, except in the case of the River Limia that has a basin surface area of around 1,300 km^2 in Spain. The River Salas is noteworthy, an affluent of the River Limia, which crosses the frontier in the reservoir of the same name and to 3 km further on returns back into Spain.

DOURO. Apart from the River Douro, with a basin surface area of about 77,000 km^2, rivers crossing the frontier towards Portugal are the Manzanas (438 km^2), Sabor (110 km^2), Tuela (276 km 2), Arzoa (122 km^2), Mente (112 km^2), San Lorenzo (168 km^2) and Támega (681 km^2), all of them tributaries of the right bank. The River Bubal, a tributary of the Támega, has its source in Portugal, and on its entry into Spain it already has a considerable basin surface area. On the left bank, there are a number of streams which, crossing from Portugal into Spain, make up the headwater of the Rivera Azaba, an affluent of the River Águeda.

TAGUS. The frontier practically coincides along the left bank of the River Erjas and on the right bank with the River Sever, so the only transfer of resources is that of the River Tagus itself whose basin surface area on the Spanish side is 55,770 km^2.

GUADIANA. The River Gévora, with its tributary the Gevorete, have their source in Portugal and pass into Spain shortly before running together with a basin surface area of 55 km^2. It returns to Portugal after collecting 583 km^2 of Spanish basin, and after traveling 14 km through

Portuguese territory, returns to Spain. There is a Portuguese area of about 50 km^2 draining towards the Gévora, further downstream, through a series of streams distributed along 14 km of frontier, as far as the River Caia, a tributary of the Guadiana acting as frontier. From the Guadiana's entry into Portugal as far as where the River Chanza forms the frontier, all the transfers go from Spain towards Portugal and principally through the rivers Alcarrache (379 km^2), Godolid (260 km^2), Zaos (237 km^2), Ardila (1,837 km^2) and Múrtigas (745 km^2).

EBRO. The surface areas of Spanish zones draining into France are: at the headwater of the River Irati 78 km^2, at the headwater of the Aragon 9 km^2, and the River Garona, which has its source in Spain and on crossing the frontier already has a watershed surface area of 547 km^2. Conversely, the French part drained by the Ebro is: the headwater of the Irati with 49 km^2 and the headwater of the Segre with about 500 km^2.

3.1.6.2.2. Artificial transfers between planning areas

The most important transfer is the one that is carried out by means of the Tagus-Segura Aqueduct (TSA), regulated by Acts 21/1971 and 52/1980. It permits the transfer of water from the upper Tagus basin to the basins of the Guadiana, South, Segura and Júcar. The volumes to be transferred in an initial phase were set at a maximum of 650 hm^3/year, and in a second phase at 1,000 hm^3/year. The resources transferred between 1979, the year when transfer began, and the year 1996/97, come to an annual average of 263 hm^3 (287 not including the first two years), with a maximum of 452 hm^3 in the year 1996/97. Of the resources transferred, 25 hm^3 is devoted to irrigation in Levante Left Bank, 30 hm^3 to population supply in the Júcar basin and about 7 hm^3 to the South (the established maximum legal quantity is 15 hm^3/year). The rest is used in the Segura basin for population supply and irrigation. For accounting purposes in these transfers to be presented in subsequent figures and tables, irrigation in Levante Left Bank is included in the Júcar basin, a territorial area where it is partially located, although this basin's management plan does not include it since its intakes are in the Segura basin.

Apart from these transfers, and after Act 13/1987, by means of the TSA, resources are transferred to the Guadiana basin in order to provide water for the Tablas de Daimiel. The first transfers were carried out experimentally during a three-year period, in which a maximum of 60 hm^3 was contributed. In 1990, the Act in force was extended by another three years and with the same quantity of resources, with a new extension up to 1996 (Royal-Decree-Act 6/1990 and 5/1993). Later on, by Royal Decree 8/1995 revoking the previous provisions, a diversion of TSA resources was authorized to supply of the upper Guadiana basin with an average annual quantity, calculated on a ten-year maximum period, no greater than 50 hm^3. This volume includes the quantities stipulated in the provisions mentioned for the Tablas de Daimiel Natural Park, which were made permanent. In the period comprised between 1987 and 1993, mean annual transferred volume was around 10 hm^3/year. Furthermore, 3 hm^3/year is reserved for supplying towns next to the to the TSA line in the Guadiana and Júcar river basins.

Three transfers take place between the Ebro and North III areas. The most important is the Zadorra-Arratia transfer, for hydroelectric use (Barazar power station) and supply to the Greater Bilbao Water Consortium. The concession is for 9 m^3/s, and during the period 1985/86-1994/95, the average volume transferred was about 180 hm^3/year. The Cerneja-Ordunte transfer transports about 9 hm^3/year for supply to Bilbao, and by the Alzania-Oria transfer, a little over 1 hm^3 is moved for hydroelectric use.

There is also a resource transfer between the Ebro and North II areas by means of the Ebro-Besaya transfer, conceived to complete the resources of the River Tagus, with volume regulated in the Ebro reservoir, which is replaced in times of high waters, maintaining a zero inter-annual balance. Since 1986, volume transferred both ways has so far been about 4 hm^3/year.

There are two other transfers from the Ebro to the Catalonia Inland Basins. The Ebro-Campo de Tarragona transfer has the purpose of urban and industrial supply for the Campo de Tarragona area. The current concession is of 90 hm^3/year, and during the period 1993-1996 an average of about 46 hm^3/year was transferred. The Ciurana-Riudecañas transfer is used for irrigation and population supply in the Reus district, and amounts to around 7 hm^3/year.

The Segura basin also transfers around 30 hm^3/year of own resources to the Júcar basin: 15 for irrigation of Levante Left bank, and another 15 for population supply.

The Guadiana basin receives about 4 hm^3/year from the Tagus basin for supply to the Algodor Association and another 6 hm^3/year from the Guadalquivir for supply to Valdepeñas, Santa Cruz de Mudela and Sierra Boyera Association.

There are other, smaller-sized transfers from the Tagus to the Guadiana for supply to the Alcuéscar Association, and from the Guadiana to the Guadalquivir for supply to the Llerena and Tentudía Associations. Exceptionally, an average of 5 hm^3/year was transported by ship to the Balearic Islands (Bahía de Palm) from the Ebro Delta (Tarragona Water Consortium) during the years 1995-97.

Figure 160 outlines the main current surface transfers, showing their mean values actually transferred in recent years.

3.1.6.3. Groundwater transfers

In Spain there exist numerous examples of groundwater flow naturally transferred from some hydrogeological

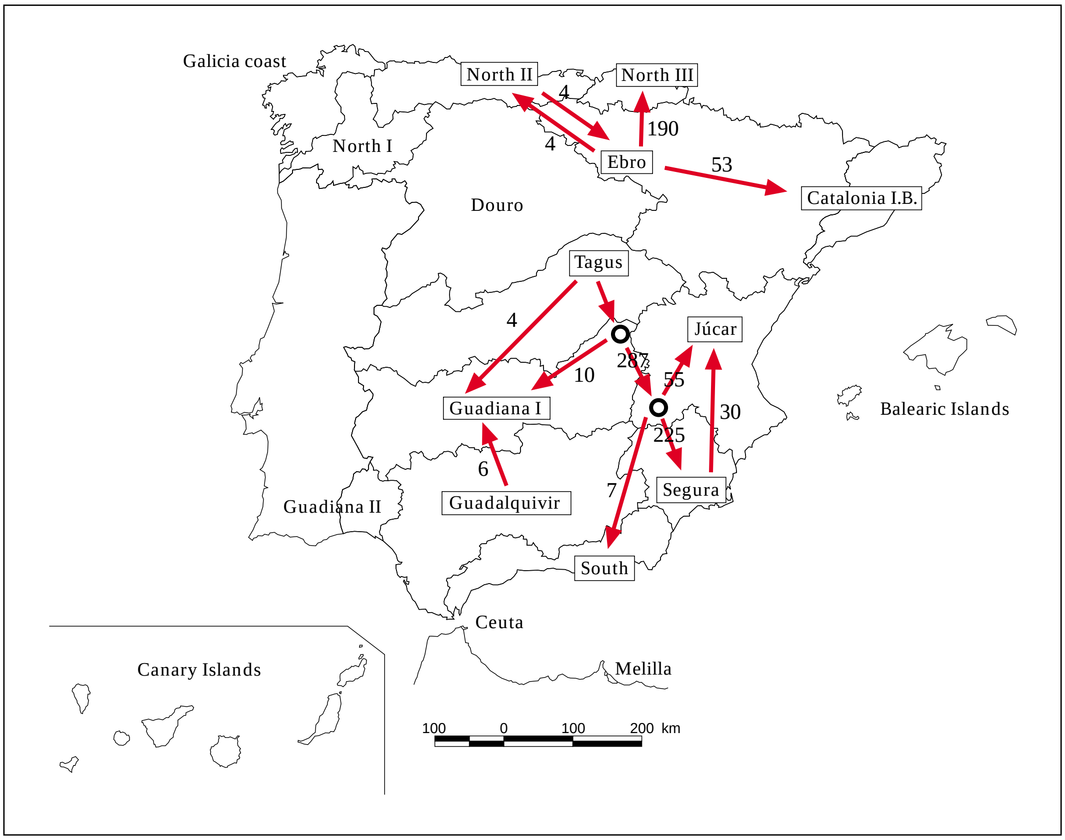


Figure 160. Map outlining the main current surface transfers.

units, generally carbonated, to other neighbouring units. We could mention those of the Vildé aquifer to the Almazán deposit, which runs into the Duero in Gormaz, the groundwater connection between the Carrión and Pisuerga basins by the Camporredondo reservoir, the Sierra de Altomira and Campo de Montiel running into the La Mancha plain, the flow received by the Granada valley from surrounding mountains, the perimeter entry flow into Plana de Valencia, the Cardó to the Ebro delta... etc. As mentioned in an above section, total water transferred between hydrogeological units in Spain is estimated at approximately 1,200 hm^3/year.

There are also several cases of groundwater transfers between different planning areas that take place in shared hydrogeological units. The flow transferred is small in size, but it is interesting to point out some of the most significant, shown in table 39.

Groundwater transfers shown in the previous table are not all the existing ones, but some of the most important. For example, more detailed estimates carried out in aquifers, such as Araviana-Moncayo (Sanz Pérez, 1987) show larger transfers (20 hm^3/year) than those reflected in this table. It is also worth mentioning the transfer of about 15 hm^3/year from the River Ebro to the headwater of the River Arlanza in the Duero basin.

3.1.6.4. Total transfers

In accordance with previous sections, transfers between the areas of different Hydrological Plans, both surface and groundwater, are those summarised in table 40.

As mentioned, these values correspond to real transfers representing what has taken place in recent years, and not to

Donor basin	Receiving basin	Hydrogeological Unit	Transfer (hm^3/year)
Douro	Ebro	Araviana-Moncayo	10
Guadalquivir	South	Sierra de Libar	5
Guadalquivir	South	Setenil-Ronda	3
South	Guadalquivir	Sierra Gorda-Zafarraya	30
Guadalquivir	South	Sierra de Padul	10
Ebro	Catalonia I.B.	Cardó-Perelló	20
Tagus	Ebro	Albarracín-Cella-Molina de Aragón	20
Júcar	Ebro	Albarracín-Cella-Molina de Aragón	10

Table 39. Groundwater transfers between planning areas.

Area	Transfers from other areas (hm^3/year)			Transfers to other areas (hm^3/year)		
	Surface	Groundwater	Total	Surface	Groundwater	Total
North I						
North II	4		4	4		4
North III	190		190			
Douro					10	10
Tagus				301	20	321
Guadiana I	20		20			
Guadiana II						
Guadalquivir						
South		30	30	6	18	24
Segura	7	18	25		30	30
Júcar	225		225	30		30
Ebro	85		85		10	10
Catalonia I.B.	4	40	44	247	20	267
Galicia Coast	53	20	73			
Balearic Islands						
Canarias						
Total	**588**	**108**	**696**	**588**	**108**	**696**

Table 40. Total transfers of resources between planning areas.

volumes that could legally be transferred according to the regulatory provisions of the different transfers.

3.1.7. Total availability

Previous sections have examined availability regulated by means of surface reservoirs, the situation of groundwater exploitation, the combined use of surface and groundwater, artificial recharge, reuse, desalination and surface and groundwater transfers.

The available internal resources in each basin, conventional and non-conventional, together with the transfers that affect it, make up the supply of total available resources with which to cover different water requirements.

Table 41 summarises part of the information obtained and presented in the sections above. The volume stored

	Volume regulated in reservoirs (hm^3/year)	Current pumping of groundwater	Direct reuse	Sea-water desalination (hm^3/year)	Surface transfers (hm^3/year)	Total current maximum limit indicator (hm^3/year)
Galicia Coast	1,223					1,233
North I	3,937					3,937
North II	1,870	19			+4-4	1,889
North III	353	33			+190	576
North	7,383	52			+194-4	7,625
Douro	6,095	371				6,466
Tagus	5,845	164			–301	5,708
Guadiana I	1,922	738			+20	2,680
Guadiana II	228	76				304
Guadiana	2,150	814	5		+60	2,984
Guadalquivir	2,819	507	12		–6	3,332
South	359	420	19	20	+7	825
Segura	626	478	56		+225-30	1,355
Júcar	2,095	1,425	83		+85	3,688
Ebro	11,012	198	6		+4-247	10,973
Catalonia I.B.	791	424	6		+53	1,274
Total Peninsula	39,175	4,853	187	20		44,230
Balearic Islands		284	26	6		316
Canaries		395	20	68		483
Total Spain	**39,175**	**5,532**	**233**	**94**	**+588-588**	**45,029**

Table 41. Summary of theoretical water availability.

in reservoirs corresponds to the standard representative case of variable demand modulation, acceptable deficit of 50%, 75% and 100% of annual demand and returns of 20% from the demand covered, with a decrease of 5% of the reservoirs' capacity to take into account the effect of storage for flood control. We should also bear in mind the overestimation effect for backwater reservoirs in some basins, which was referred to in previous sections.

The exploitation of groundwater refers to the current pumping values. The same thing happens in the case of the direct reuse and desalination. In the latter case, only sea water has been included, because total pumping includes brackish water.

Furthermore, values for the transfers correspond, as mentioned, to a representative average of the real volume transferred in recent years.

The table's figures only aim to give a reference framework for current water availability, and they are not additive (they cannot be directly added up), this being one of the errors sometimes made when trying to homogenize and present information on water resources.

In fact, the volume regulated in reservoirs has been evaluated, as mentioned, in the theoretical supposition of appropriation and sole right of the total surface flow. The use of groundwater could logically affect this volume, so they cannot be added directly. Neither has the table considered all possible indirect reuse, nor returns from sea water desalination or from transfers, which would increase availability.

For these reasons the sum of the last column has been titled not as total availability, but as indicator of maximum level currently registered for this total availability.

Thus, and dealing only with conventional resources, an initial estimate of currently regulated total conventional availability would be the sum of storage in reservoirs plus pumping of groundwater, since all groundwater exploitation is obviously regulated (pumping is activated when required).

This simple estimate is not entirely accurate, because a part of pumping regulation could be absorbed by that offered by reservoirs, although this is unlikely to happen in view of the price difference of water in both cases. Also, this pumping could diminish the incoming flow to reservoirs if they are located on aquifers that drain towards them, and, consequently, reduce the figure for surface regulation.

In any case, the sum of the two concepts is not a good estimate of conventional availability, but of their upper limit, and should be interpreted as such. The addition of non-conventional resources generally functions in the same sense, although some non-quantified effects could even increase this indicator (e.g. returns from transfers or combined use).

The figures obtained can be valid for establishing the level of currently available total resources, and its comparison with natural resources in each area provides a very general idea of the different basins' relative degree of development from the point of view of their water supply possibilities.

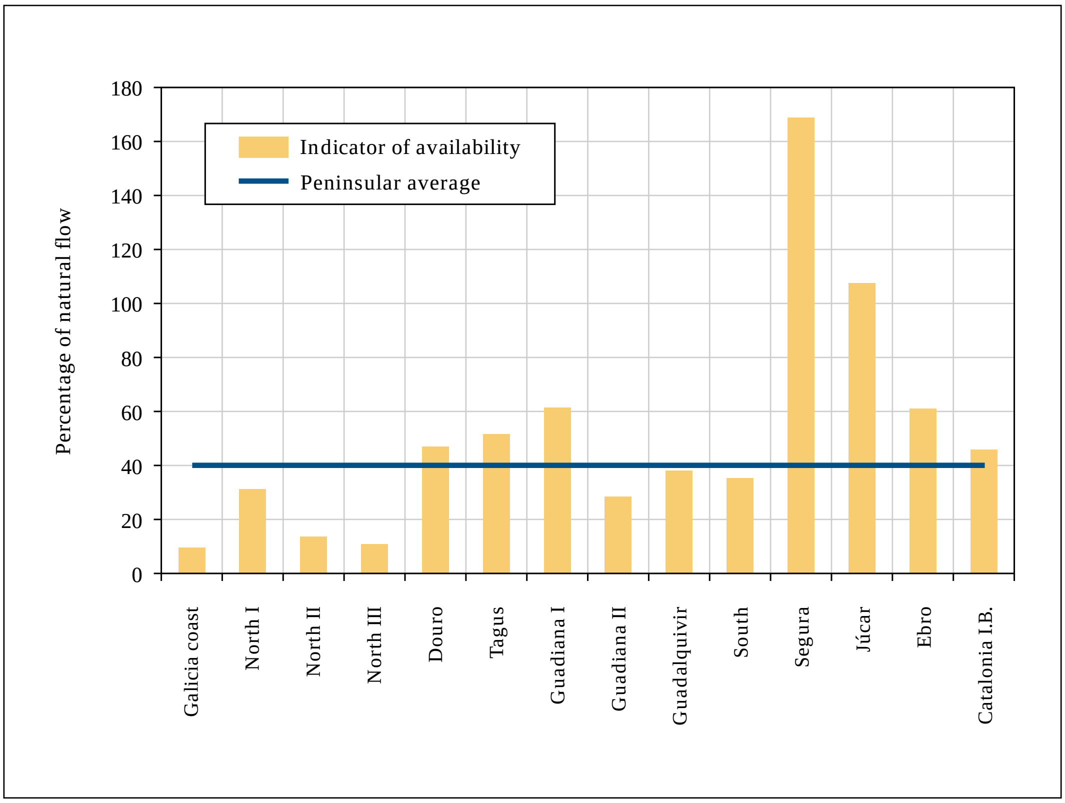


Figure 161. Relationship between indicators of maximum water availability levels, and total resources in a natural regime, by planning area.

Thus, figure 161 shows the relationship between the maximum levels of availability obtained and total resources in a natural regime, and this may be considered as another additional step to the one offered above on regulation in the theoretical situation analysed, which only considered the action of surface reservoirs.

As may be seen, average peninsular availability is similar to those above (around 40%), but differences between basins are now seen to be much more marked.

Particularly noteworthy are the Segura and Júcar basins, where the theoretical maximum availability existing is similar or higher than their natural resources, which may be accounted for by external transfers and intense groundwater and non-conventional resource exploitation. We may state that, generally speaking, these basins are well-developed as regards major regulation and groundwater pumping equipment, they use their resources intensively, and they will not require major new dams nor increases to groundwater abstraction to significantly augment availability, because they now allow for almost no increase by conventional means, and only non-conventional sources could increase it marginally.

The Ebro, Guadiana, Tagus, Douro basins and Catalonia Inland Basins are next in terms of availability level, with values around 50% of their natural resources, and higher than the peninsular average, so despite their current favourable availability level, they still have considerable margin for possible future developments or environmental reserves. We should note, nevertheless, that in the case of the major international rivers (Douro, Tagus and Guadiana) some special requirements exist, due to their cross-border nature, influencing this possibility.

At the other end, Galicia Coast, North II and North III are the areas with lower availability levels in relation to their natural flow, which may be accounted for by the considerable volume of average resources in these basins compared with their relatively low current needs. The above must be considered, obviously, as a merely indicative approach, and in no way as firm, conclusive results. Nevertheless, the homogeneity and rigor of the verifications, and the unity of treatment used, even with this indicative character, give a reasonable idea of the different basins' current relative situation from the point of view of development level of water availability.

It is important to note that these availability indicators have been obtained exclusively from the analysis of water resources, which is the analysis carried out up to now, and without considering the situation of water demand in the basins. The analysis carried out and the obtained results should therefore not be confused with analysis of possible water balance in these basins, a question that will be dealt in other sections of the White Paper.

In fact, there may be cases of areas with an indicator of very high availability, and which however show situations of deficit, since their demands exceed even such high availability. In contrast, there may be areas with an indicator of very low availability, and in which there is an abundance and surplus of resources, if the existing demands are fully covered with this availability level and even with lower levels.

The systematic analysis of availability carried out only aims, as mentioned, to show the relative degree of its development in different basins, and to indicate those where, reasonably and on a global scale, there is no scope for a significant expansion of resource supply by means of regulation elements and future groundwater abstraction. In contrast, internal redistribution elements could be required to provide redundancy and improve service guarantees, or, where appropriate, non-conventional sources of new resources (such as desalination or external transfers) if deficit situations were detected, but such analysis is, as shown, of a different nature to the one presented so far.

3.1.8. Future uncertainties

Among the different uncertainties looming in the future of water resources in our country, we shall briefly comment on the consequences of natural variability in the hydrological register, and on the possible effects of climatic change of anthropic origin.

3.1.8.1. Natural hydrological variability

As we have seen and reiterated in previous sections, hydrological registers show considerable variability in space and time. In those sections, we closely studied the space-time structure of total annual natural flow on a global scale, and in the different territorial areas of water planning, as well as dry and wet runs observed in different regions. This analysis extended to the 56-year period comprising the hydrological years 1940/41-1995/96.

In this section, existing uncertainty associated with natural hydrological variability, and the length of such hydrological samples, will be shown. In order to do so, we will firstly analyse the influence of sample size on the estimate of average resources, in periods with abundance of available data (standard period, with series since the year 1940/41). After this, the analysis will extend to longer periods but with smaller quantities of available data, studying runs from existing long series on precipitation and natural flow.

3.1.8.1.1. Uncertainties associated with the length of available registers

Focusing on total flow in a natural regime, it is important to remember that their natural random variability constitutes a source of intrinsic uncertainty, due to the length of series used and the need to infer population properties from small samples.

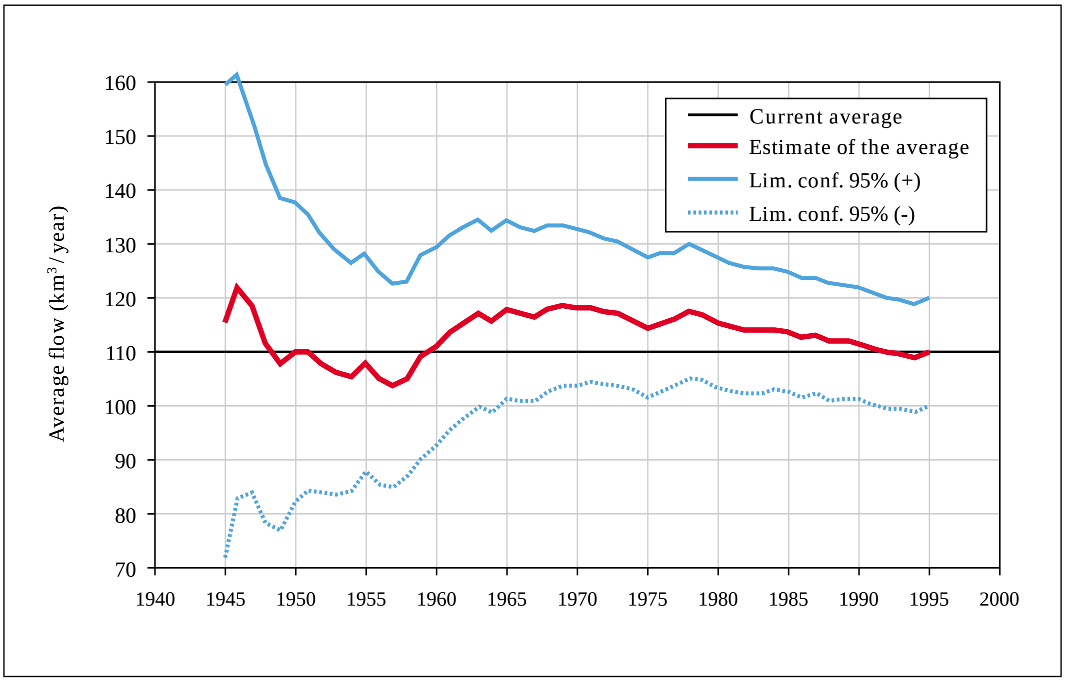


Figure 162. Evolution of the estimate of average annual total flow in a natural regime in peninsular Spain and its associated uncertainty.

To define this effect quantitatively with a significant example, and considering standard data from the year 1940/41, figure 162 shows the evolution of the estimate of mean total flow in a natural regime in peninsular Spain, and of the uncertainty in estimating that average, according to the year when this estimate was carried out. This uncertainty is expressed by confidence limits of 95%, obtained from the standard error of the average.

As may be seen, the estimate of mean resources has evolved, admitting the initial series, from 120 to 105 km^3/year, and from the end of the 70s fell every year up to 1995, when it increased slightly up to the present 110. Moreover, even this current estimate of 110 km^3/year has, as may be seen, a margin of statistical uncertainty of around +/- 10 km^3/year for a 95% confidence level, because the standard error of the average is presently about 5 km^3/year, that is, rather less than 5%.

If the same analysis is carried out on the scale of water planning areas, results show that standard errors in estimating mean resources vary between 3% in the basins of the North and 12% in the Guadiana II.

In short, there exists intrinsic inaccuracy in knowledge about resources, due to the time window of observation (available samples) of hydrological registers, which although does not modify quantities in their current evaluation, it suggests the magnitude of their uncertainty, and draws attention to the necessary prudence and considered judgement in the analysis of water systems.

Such natural variability does obviously not incorporate non-natural effects, such as those due to the hypothetical climatic change of anthropic origin, which will be studied in sections below.

3.1.8.1.2. Uncertainties associated with long term variability

Apart from this indeterminacy due to the time window of observation, the existence of multi-decade variations has been seen in the past - without anthropic climatic change, with appreciable differences between such periods, although statistical analysis of this variability, in the samples available, do not clearly reject the hypothesis of hydroclimatic series' seasonality. Historical and paleoclimatic study, before the era of instrumental measurements, also shows significant oscillation in the climate, with continuous alternations of cold and warm, dry and rainy periods. An interesting description of these climatic oscillations in Spain is given by Font Tullot (1988).

From a scientific point of view, maybe fractional noise processes, of infinite memory, or the chaotic variation in average humidity and atmospheric levels on a multi-annual scale (Rodríguez-Iturbe, 1991), can describe or help to explain these natural phenomena. The legendary old biblical effects in the story of Noah (unexpectedly high values of continuous rain for forty days and forty nights), and of Joseph (very long alternating runs –7 years– of plagues and lean years, and years of plenty), come to mind as classic expressions of this natural variability, thirty years after they were brilliantly described in modern hydrological literature (Mandelbrot and Wallis, 1968).

To attempt to define uncertainties due to the standard time window, it is necessary to analyse, at least briefly, the possibility of extending this window with the longer available series. This will involve a certain loss of spatial representation, by dealing with a significantly smaller set of registers than in the standard period, although allowing for this loss, the study is interesting because it shows effects of registers' non-homogeneity (jumps or trends), and to qualify, where relevant, our standard current estimate, upward or downward, comparing mean values for the different periods.

Without considering proxy indicators (such as sediment registers, rings of trees or other biogeophysical evidence), and focusing exclusively on available registered hydrometeorological data, we will firstly examine rainfall registers, then turn to river flow.

3.1.8.1.2.1. Rainfall variability

In the sections dealing with the analysis of meteorological networks, some graphs were presented on the evolution of number of existing rainfall gauging stations in Spain throughout the 19th and 20th century. In the graph of the 19th century, it can be seen that from 1840 there were 2 operative stations, from 1862 there were 21 stations, and from 1910 there were 44 stations. Examining these old series, compiled by the INM and completed and homogenized by this institution (INM, 1996), we have been able to select a group of 27 very complete rainfall series of sufficient quality, with data from 1910. Of these, a subset of 14 series has very complete data from 1868, and of these, one (San Fernando) has very complete data from 1839.

The map in figure 163 shows the situation of 27 rainfall gauging stations selected, demonstrating their good spatial distribution, allowing them to be considered as reasonably representative of the whole territory. Other gauging stations have also been included, which will be commented on below.

To analyze these long series' behavior, figure 164 shows accumulated unit deviations of the 4 data groups: single series in San Fernando, average series of 14 (M 14), average series of 27 (M 27), and average series of the whole peninsular area in the standard period (1940/41-1995/96), shown in sections above. Given the stations' spatial distribution, such simple average arithmetic is a reasonable estimator of the mean peninsular area value.

As can be seen, and despite the perceptible variability on different scales, the 4 groups of series seem to follow similar patterns in the time periods where they coexist, reaffirming their representativity. It may also be seen that the dry period from the year 1940 until the mid-50s, which had already been detected in the analysis of runs in the standard series, seems to be the culmination of a much longer, stable or slightly dry cycle, which would have started at the beginning of the century, with a slight wet recovery in the 30s. The last 20 years of the 19th century can be considered as wet, with similar behavior to the recent run from the mid-50s until the late 70s. The ten previous years (1870-1880) were, in turn, a dry run, and it is risky to suggest any hypothesis for the previous period, because we only have data from one station.

In summary, historical registers from the last 130 years of rainfall data seem to show major oscillations on a scale of decades, similar to or even greater than those of our stan-

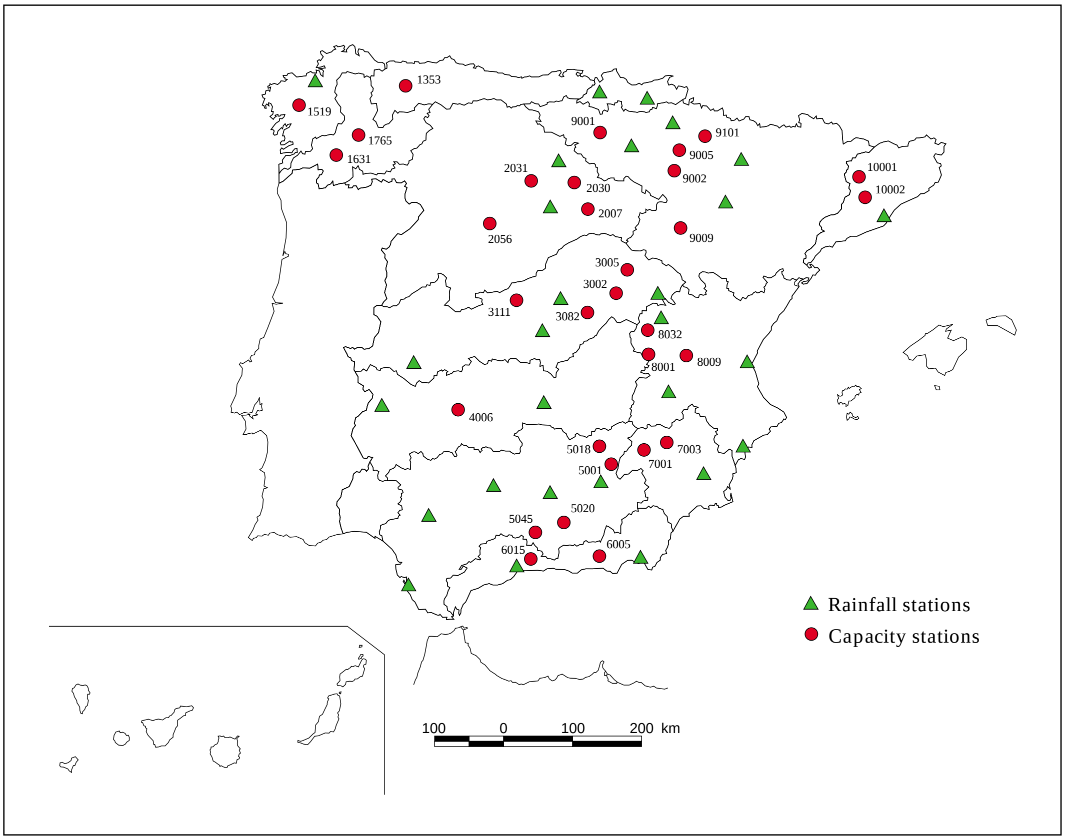


Figure 163. Map of stations with selected long series.

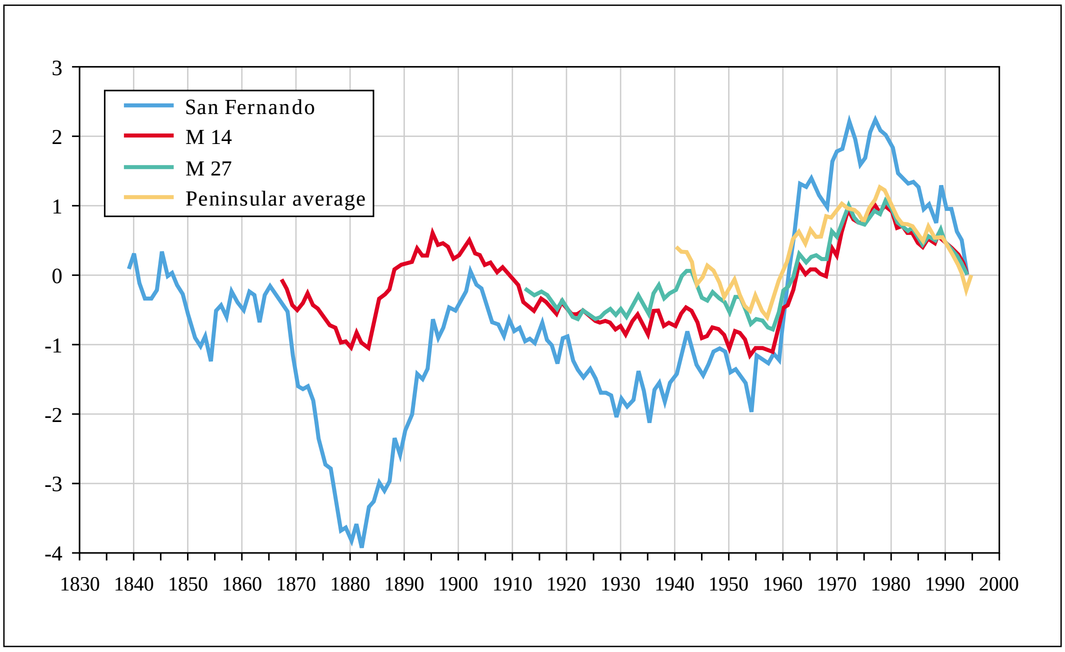


Figure 164. Runs of mean annual precipitation in Spain with long series, from accumulated unitary deviations.

dard analysis period. Additionally, the mean series value for annual rainfall in the last 130 years (series M 14) stands at about 2.5% more than the same series in an ordinary time window in basin management plans (1940-1985), and 1.3% more than the same series in the standard time window of this White Paper (1940-1995). These values decrease to 1.8 and 0.5% respectively with the 83-year window provided by the M 27 series. Taking the period 1961-90 as a comparison window (last 30 climatic reference years CLINO, according to the standard thirty-year periods recommended by the WMO), this window turns out to be 4.1 (3.3)% wetter than the M 14 (M 27) series.

In short, it cannot be discarded, on the whole, that traditional rainfall oscillations observed have caused significant hyper-annual variability in the hydrological response, higher to the one seen in the standard windows, or that such windows used in planning give inaccurate results, with higher averages than those of the full long period. In both cases the underlying problem is a possible lack of representativeness of the hydrological series.

This possibility, relevant to our water planning, is analysed the in the section below.

3.1.8.1.2.2. Flow variability

It is to be expected that dry and wet runs of natural cumulative flow, on a peninsular scale, show similar multi-annual behaviour patterns to those of the precipitation that generates them, although with differences on a smaller timescale due to the non-linear effects of the hydrological response.

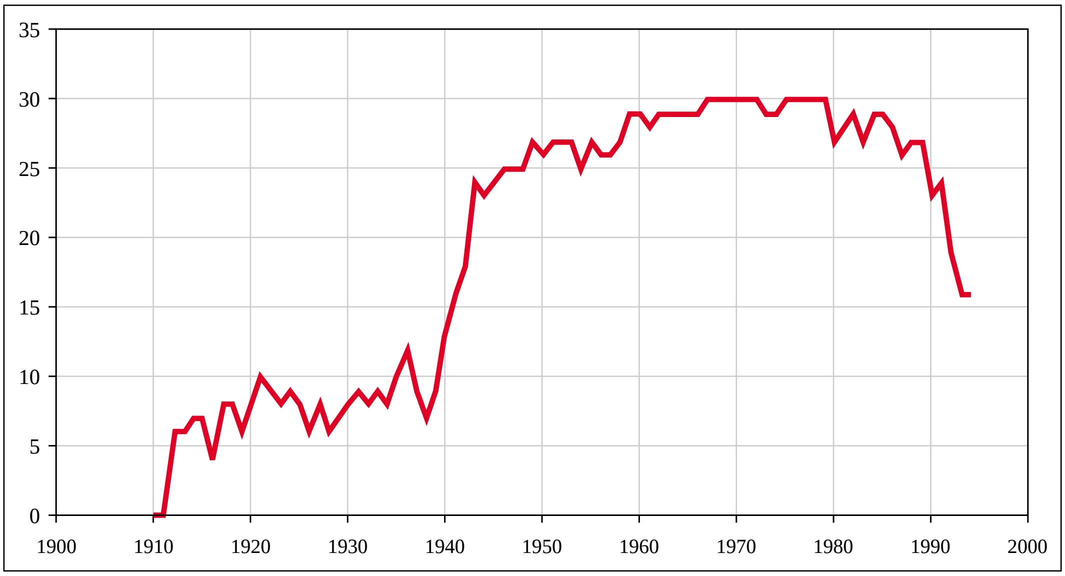


Figure 165. Evolution of the number of available gauging stations with relatively complete and unaffected series.

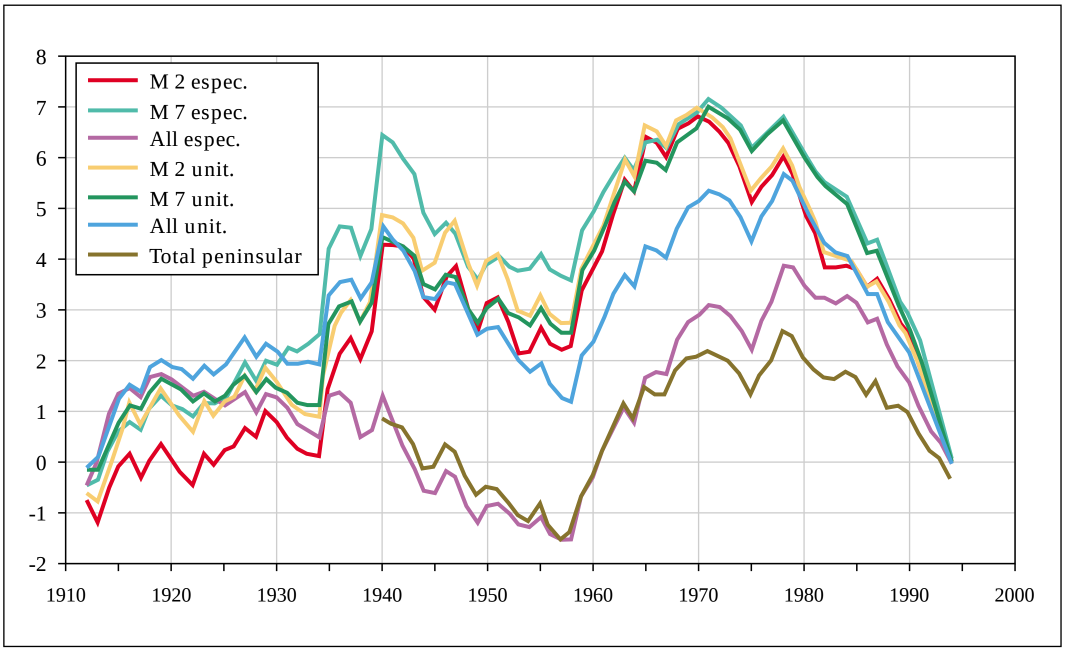


Figure 166. Runs of annual natural cumulative flow in Spain with long series, from accumulated unit deviations.

Once the general behaviour of the long rainfall series has been studied, a similar analysis will be made for cumulative flow in a natural regime. For this purpose, gauging stations with available data have been selected, not affected (at least until recent times), and with relatively complete registers, and whose evolution in number is shown in figure 165.

It can be seen that stations began to appear in 1912, and up until the forties, their availability did not significantly grow. Of them all, 2 have annual series with over 75 complete years since the year 1912, while there are 7 with 65 complete years. The map shown above presents the situation of the 30 initially selected stations. Without refining the analysis further, and aiming only to obtain an initial impression of their behavior, figure 166 represents the series of accumulated unitary deviations corresponding to the group of 2 (M 2), the group of 7 (M 7) and to the group of all those available. In the three cases, and ignoring scale problems, they provide the averages of the stations' specific data (cumulative flow/surface area drained) and unit data (divided by the average). It also shows total peninsular cumulative flow obtained with the model distributed for the standard period, given in above sections.

It may be seen that, despite how simplified and imperfect this analysis is, the multi-annual pattern fully coincides in all cases, and runs of dry and wet cumulative flow are, as was to be expected, basically the same as those of mean precipitation. In the period prior to 1940, there is no clearly marked pattern, with some stagnation observed up to 1935, when there was a short wet run. The effects of the Plans' reference window (1940-1985) do not seem to be important, because the average contrast of specific cumulative flow in the 7 longest stations is only 2% (and with considerable variability between stations), which cannot be considered significant, and it is not possible to go further back in time due to lack of data.

In short, on a global scale, and with the first simplified analysis implemented, it is not possible to draw conclusions as to whether the time window used in Basin Plans is representative or not. The overall value of 2% above the long register is not significant, although, considering it jointly with 1.8-2.5% of rainfall, it infers that it may indeed be a slightly wet window with respect to the total available for the instrumental period.

The standard window for this White Paper is thus more similar to the total one, since it includes the effect of the recent drought.

3.1.8.2. The uncertainties of climatic change

3.1.8.2.1. Introduction

Far from being a novelty, discussion on possible climatic changes has been taking place for a long time. In Spain, for example, it was a fashionable controversy by the middle of the 19th century, as shown by the classic works of Rico Sinobas (Font Tullot [1988] p. 33). However, it was not until recently that this question came to the forefront of discussions on the future of our natural resources and the sustainability of its use.

Thus, significant scientific-social concern has arisen in recent years regarding possible climatic change caused by the increase of carbon dioxide (CO 2) and other greenhouse gases (GEI) in the atmosphere. This concern has given rise to major international initiatives such as the United Nations Framework Agreement on Climatic Change, ratified by Spain in 1993 (MIMAM, 1998e).

The basis of the problem is the probable intensification of the natural greenhouse effect which would give rise to an increase in mean world temperature of the Earth's surface, known as global warming, and the complex atmospheric processes associated with this (Linés Escardó, 1990).

The problem's potential seriousness is growing as we see the pace of change in greenhouse gas emission rates has increased, in most cases. In fact, the increase of greenhouse gases in the atmosphere and variations in other factors such as incoming solar energy, volcanic eruptions or modifications to the planetary albedo (part of the incoming energy reflected into space) are quantified by means of so-called radiative forcing or alterations in net energy flow in the tropopause. Forcing associated with increase in atmospheric greenhouse gases is positive and much greater than those associated with the other phenomena, which provides the basis for existing social concern. However, negative forcing also exists. This includes the most important and capable of partially counteracting greenhouse gases, the one due to the presence of sulfurous atmospheric aerosols. It is foreseeable that its relative contribution will diminish in time since its rate of increase is limited. Moreover, its rather non-homogeneous distribution, located geographically in the major nuclei of world contamination, introduces a factor of uncertainty.

Available climatic registers indicate a trend towards global warming over the last century, with warming prior to 1940, a slight cooling during the period 1940-70 and a particularly remarkable subsequent warming during the last decade. Figure 167 (drawn up with data from the Climatic Research Unit of East Anglia University) clearly shows these thermal trends.

As may be seen, mean temperatures in the northern hemisphere, the southern hemisphere, and the Earth's surface have increased between 0,3 and 0,6°C, approximately, since the end of the 19th century. Although sufficient uncertainty exists as to whether the observed trend is a product of natural climatic variation, similar to existing ones in the past, or whether most of it should be attributed to the increase of atmospheric greenhouse gases over the last 200 years, most studies carried out reflect that the origin of the trend shown by observed warming is unlikely to be totally natural. The capacity to quantify human influence on the world climate is, at present, limited, because the signal detected is a signal that is starting to emerge from the noise of natural variability (Labajo, 1996), and is not even clearly discernible from that noise. However, according to the Intergovernmental Panel of Experts on climatic change (IPCC), the tests and studies carried out generally suggest a detectable human influence on the global climate (IPCC, 1995).

The tools used to research all these effects are the Ocean Atmospheric General Circulation Models (MCGA-OA). In most of these models, some agreement exists on the trend of some climatic variables, such as temperature and precipitation, although with greater uncertainty in the case of the latter.

A modification of temperature or precipitation would reflect upon a territory's water resources, because, in the long term, their runoff is similar to the difference between precipitation and evapotranspiration. According to scientific assessment reports carried out by the IPCC, a temperature increase of one to two degrees centigrade, together with a drop of 10% in precipitation, could cause a reduction between 40% and 70% in annual runoff in semi-arid areas (IPCC, 1995).

If, in accordance with the climatic scenarios available for Spain, mean annual precipitation drops slightly and temperatures increase, runoff will fall in the future.

Furthermore, trends predicted for Spain show greater temporal irregularity for precipitation, which would reflect

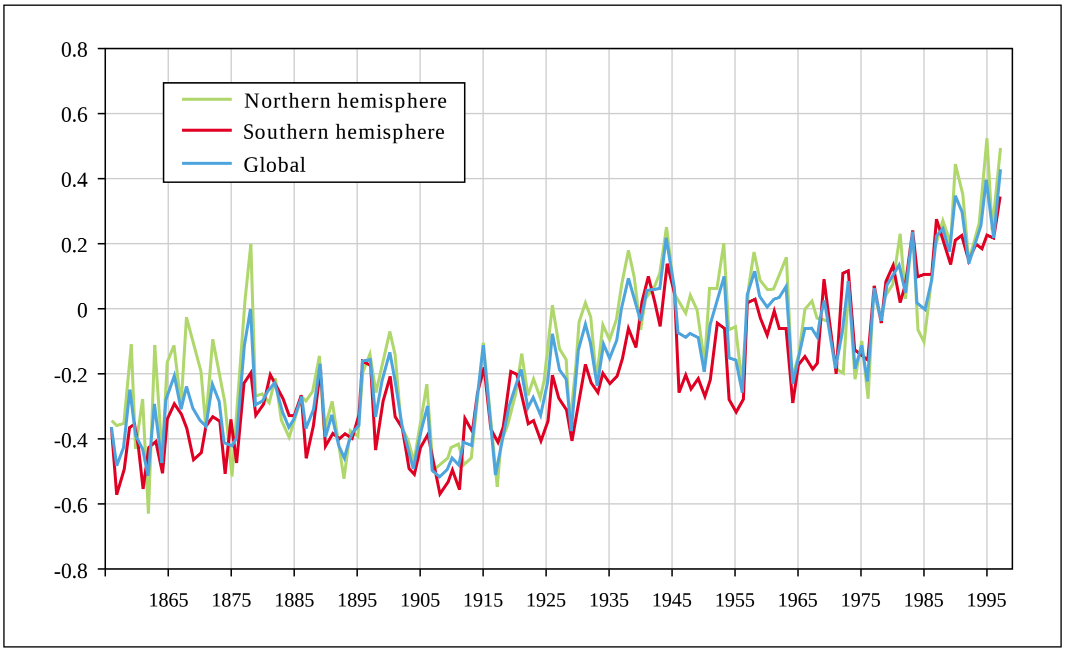


Figure 167. Evolution since 1855 of variation in the Earth's global average temperature with respect to the series average (°C).

negatively on the regime of floods and river regulation, modifying flow seasonality.

If we see climatic change with such potential impact it will probably take place gradually. Although there is considerable uncertainty and time will be required to confirm changes, we should note that the threat exists and that it is important enough to be taken into account within the framework of water planning.

3.1.8.2.2. Scenarios of precipitation and temperature

Although OAGCMs have been used to evaluate the effect on the climate caused by an increase in CO_2 concentrations and other greenhouse gases, this does not mean that in their state of knowledge they can provide the precise spatial distribution and temporal evolution of the climatic system's response to a variation in CO_2 and other greenhouse gas concentrations in the atmosphere. Nevertheless, the OACGM is at present the only tool available to obtain patterns of climatic response to various exogenous actions. Most of these models solve similar equations, but differences exist between them regarding temporal resolution, the physics of interconnections, the treatment of clouds, the representation of the ocean, etc., which explains some of the discrepancies in their results.

To respond to questions posed by the possibility of climatic change requires increasingly greater temporal and spatial resolution, as well as information on a larger number of variables (evapotranspiration, maximum and minimum temperature, runoff, etc.). For this reason, regional climatic models are being developed. At present, they are at an early stage and the results they provide are not yet sufficiently reliable to be used as future scenarios. At present, we only have regional scenarios obtained from the results of one or several OACGMs, with all the limitations and precautions that this involves.

Traditionally, these future climatic scenarios have been generated by a composition of OACGM results. This is how it is done in the document National Programme on the Climate (MOPTMA, 1995c), drawn up by the National Climate Commission, analysing the results from different compositions of models.

With these compositions, the effect of doubling CO_2 is evaluated, by means of different analysis types: of response in a state of balance, of response in transition until the new CO_2 value is reached, and as a response dependent on time. This duplication of CO_2 is foreseen as taking place approximately in the year 2030.

Notwithstanding the precautions and uncertainties associated with the problem, the most likely evolution for Spanish peninsular climate, as a result of these analyses, is summarised in the following temperature and precipitation scenarios:

- It is generally estimated that a duplication of CO_2 could cause an mean annual temperature increase ranging from 1°C (analysis of response in transition) to 4°C (better estimate analysis of response in balance), although these increases are slightly higher in summer.
- It is estimated that a general drop in mean annual precipitation values ranging between 5% and 15% could take place, being more likely in the southern half of the Peninsula. A trend has been noticed towards temporal concentration of precipitation, in addition to greater annual and inter-annual variability. This trend would involve an increase in dry periods and more torrential precipitation. The OACGM does not yet provide answers to quantify these effects.

Scientifically, these results are also exposed to the existing uncertainties as to the function of clouds and aerosols in the climatic system, which may reduce warming due to the intensification of the greenhouse effect, in the middle latitudes of the northern hemisphere.

The most recent results on precipitation in the Iberian Peninsula, based on global models, show very moderate variations in precipitation, positioning our zone in an area where the expected variation in precipitation changes direction, that is, in all the experiments the line of zero change crosses through the Iberian Peninsula.

The uncertainties in the results provided by the MCGM force us to work with scenarios and not with predictions. Conclusions obtained from the sectoral impact studies should, therefore, be more oriented towards highlighting the systems' weaknesses than to modifying their design criteria or operation.

3.1.8.2.3. Impact on water resources

The identification of impact on water resources associated to possible climatic change has taken place in our country for a long time. As a case in point, there are references from the beginning of the century to flow reduction in the Segura and its extremely low water, as a consequence of basin's deforestation and possible climatic changes (Díaz Cassou, 1900), changes which have been talked about, as we said, since the mid-19th century. Even then, Díaz Cassou concluded the natural explanation for the observed changes, putting forward what we would call today the hypothesis of seasonality of water registers.

There also exist indications of possible changes in Spain's hydrological regime in centuries past. For example, it is likely that the country's water resources in the 18th century were, as a whole, greater that those of the immediately previous Little Ice Age (1550-1700), a circumstance that may have been a factor in Charles III undertaking the major hydraulic works programme of the Illustration (Font Tullot [1988] p. 106).

Now at the beginning of the 21st century, and given the interest that is currently aroused by the hypothesis of climatic change, and increasingly greater evidence of its existence, it is appropriate to begin carrying out studies in Spain into water resource exploitation systems' sensitivity to possible variations in future climatic conditions. The existing uncertainties, of all types, do not currently allow for these studies to be anything more than simply indicative, but even so the need to investigate and analyse is inevitable.

Unlike other sectoral policies that approach climatic change with limitative criteria, as agents in causing it who should self-regulate to minimize their effects (the case of industrial atmospheric gas emissions), confronting the problem of climatic change from the perspective of water planning requires an adaptive position to be assumed. The phenomenon is taken to be external to the water allocation system, so adaptation strategies should be sought, where appropriate, to reduce adverse consequences.

The influence of climatic change on water resource exploitation systems operates in two successive phases. Firstly, modification of atmospheric conditions causes modification of the natural hydrological cycle –of natural water resources– which means changes in the magnitude and seasonality of water flow and quality. Secondly, this hydrological modification can affect different water requirements, and influence the use of water through exploitation systems, its infrastructures and its administrative regulations.

Therefore, real final impact requires identification of these two different phases. Given the diversity of existing systems (different vulnerability, guarantees, resilience, fragility of ecosystems, etc.), we cannot generalize beyond strictly hydrological results, and such subsequent analysis must be carried out, where relevant, for each single system. As a consequence, we will here analyse possible impact on water resources, leaving possible impact on sectoral water demand for other sections.

To deal with the hydrological problem, a possible option is to start from hypotheses of predicted scenarios of climatic change in Spain. An initial analysis is made by the study of how these climatic variations may affect mean annual runoff in a natural regime in the different territorial water planning areas. The estimate of this impact would allow reasonable suppositions to be made on series of natural cumulative flow or total water resources in rivers, and therefore obtain design series which, once put into system exploitation models, would allow us to assess the impact that climatic change represents for our water systems. As mentioned above, and it is appropriate to reiterate, such analyses are mostly pure theory, and are subject to considerable margins of uncertainty, although it seems appropriate to undertake them to obtain some kind of initial quantification, however dubious and uncertain it is.

Thus, by using mathematical modelling techniques to dynamically simulate the hydrological cycle's terrestrial phase we are able to make an estimate of climatic change's impact on series of monthly cumulative flow in rivers. Models of this type, like the one used in this White Paper, establish water balances for the different processes taking place from the moment it rains until the water runs off on the surface or underground, and estimate cumulative flow from meteorological data (precipitation, potential evapotranspiration, etc.) and the physical characteristics of the territory (vegetation, hydrogeology, edaphology, etc.).

At present, sufficiently detailed information does not exist on climatic scenarios to justify applying this type of model on a national scale. However, and since the first step is knowing the long-term mean values of the main hydrological variables, by applying regional laws that relate precipitation, potential evapotranspiration (function of temperature) and total runoff, in mean annual values, they can provide a general overview of the problem's scope.

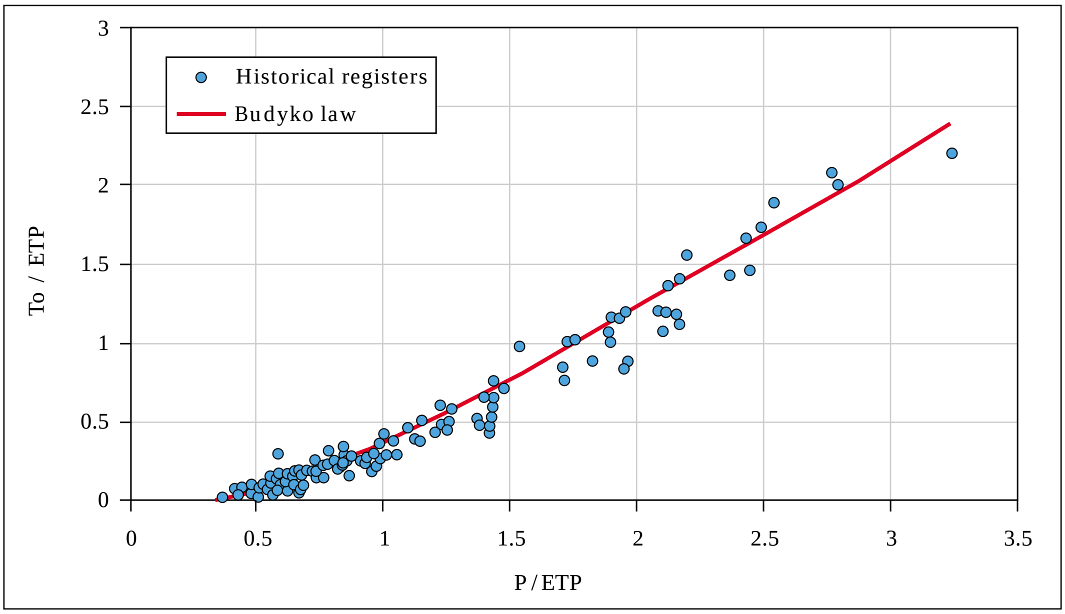


Figure 168. Relations between cumulative flow (TO), precipitation (P) and potential evapotranspiration (PET) at monitoring sites.

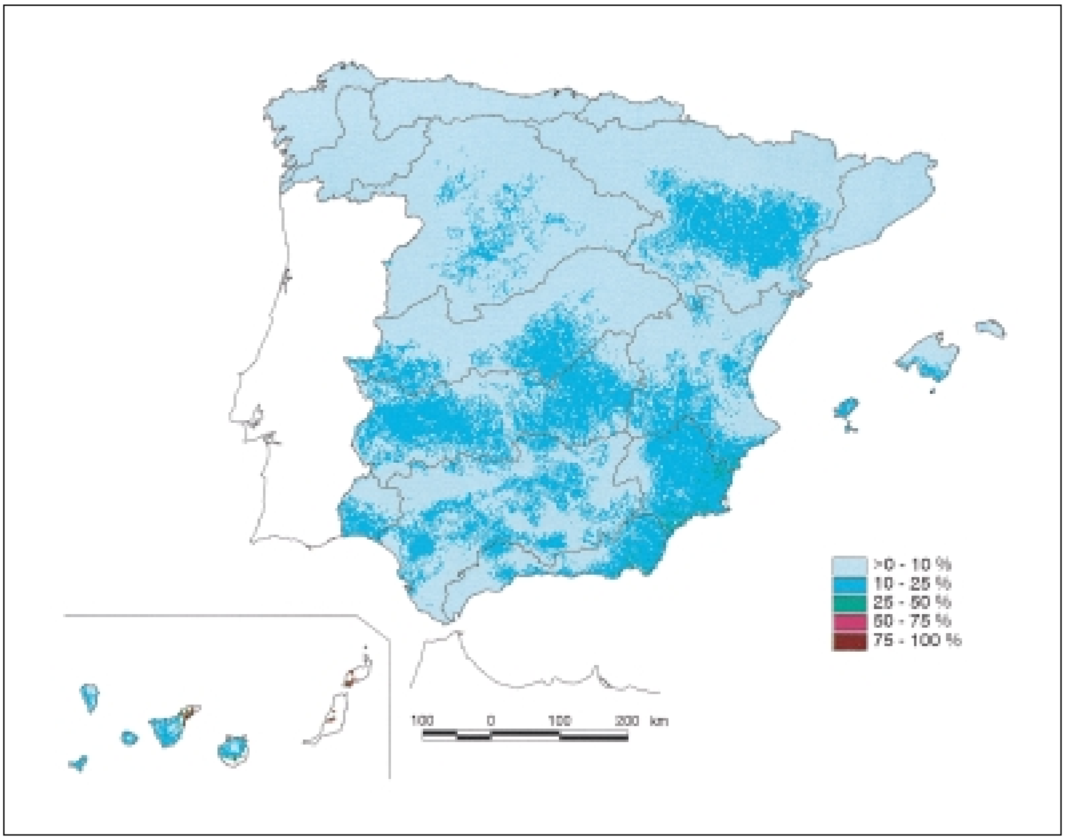


Figure 169. Map of percentage decrease of runoff for scenario 1.

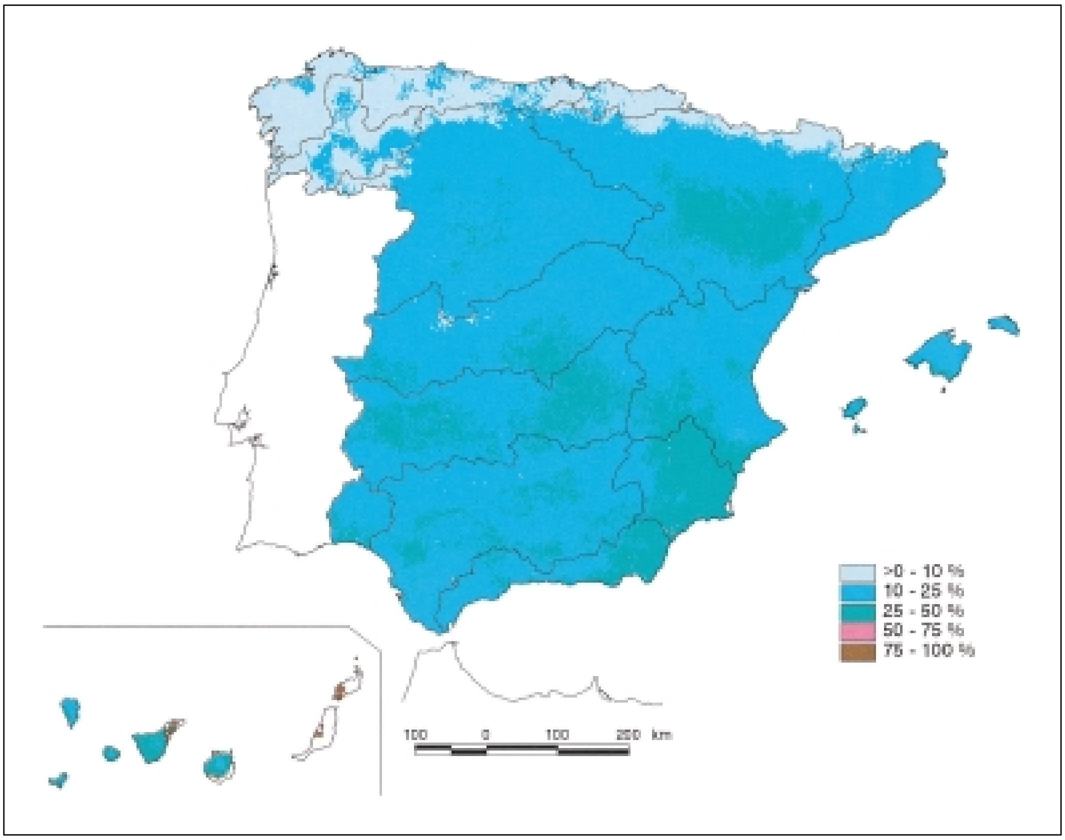


Figure 170. Map of percentage decrease in runoff for scenario 2.

Area	Scenario 1	Scenario 2
North I	–3	–10
North II	–2	–10
North III	–2	–9
Douro	–6	–16
Tagus	–7	–17
Guadiana I	–11	–24
Guadiana II	–8	–19
Guadalquivir	–8	–20
South	–7	–18
Segura	–11	–22
Júcar	–9	–20
Ebro	–5	–15
Catalonia I.B.	–5	–15
Galicia Coast	–2	–9
Balearic Islands	–7	–18
Canaries	–10	–25
Spain	**–5**	**–14**

Table 42. Percentage decrease of total cumulative flow, by planning area, for the climatic scenarios considered.

To estimate spatial impact on average annual runoff derived from different climatic scenarios, a regional law has been used, Budyko's (1961), relating runoff (TO) with precipitation (P) and potential evapotranspiration (ETP). This law was already used in an experimental analysis carried out in Spanish basins with different climatic and hydrological characteristics (Estrela et al., 1995). Here, it has also been contrasted with the monitoring sites in a natural regime selected to gauge the simulation model of monthly cumulative flow. As shown in figure 168, the adjustment is acceptable and justifies the use of this simple regional law.

In the analysis, the following climatic scenarios were supposed, considered as representative of what could happen in our country in the immediate future in the hypothetical case of CO_2 duplication, predicted for the year 2030:

- Scenario 1. Increase of 1 ºC in average annual temperature.
- Scenario 2. Drop of 5% in average annual precipitation and increase of 1 ºC in temperature.

In figures 169 and 170, the percentage decreases in mean annual runoff are shown with respect to the current situation, resulting for these two scenarios.

In table 42, these effects are quantified, with each territorial area showing the average value of percentage decrease in total cumulative flow in the two climatic scenarios considered.

An extreme, highly improbable scenario has also been analysed, involving a 15% decrease in average annual precipitation and an extreme increase of 4°C in temperature. Reductions in cumulative flow, in this case, are much greater, reaching values over 50% in some areas.

The analysis implemented allows us to conclude that the peninsular southeast, the Guadiana basin, the Ebro valley and Spain's islands are the areas where impact on water resources would be most severe.

The results obtained are of the same order of magnitude as the impact estimates on resources carried out in other regions of the world hydrologically similar to Spain, such as California. In any event, and as mentioned above, these results should in no way be taken as definitive, but as a warning, and a starting point for further, more precise impact studies. Moreover, we must also take into account that, as noted, the scenarios used correspond to the CO_2 duplication hypothesis predicted for the year 2030, and that this year lies beyond the horizons of current water planning. This does not mean that, should anthropic climatic change really occur, Spain may not face a future serious problem of worsening water shortage in some areas.

Furthermore, other climatic scenarios have been proposed which, together with temperature increase all year round, forecast a decrease of summer precipitation in our country, while they increase in winter. This means that the lower cumulative flow due to temperature increase and rainfall reduction in summer (increase in summer droughts) could by compensated by greater flow in winter, giving an uncertain final balance, which could even be favorable if enough storage is available for the greater winter runoff. This again illustrates the major existing uncertainties.

Returning to the two scenarios considered, a representative average global figure of this change, projected to the second horizon of water planning, and closely adjusted to all the ranges for the different areas, would be around 5-6%, as show by the graph in figure 171. The effect that this decrease of the natural resources could have on the Peninsula's available resources has been globally evaluated at around 4% (Garrote et al., 1999).

In view of the major uncertainties that such estimates presently involve, it does not seem reasonable to advance further –and it is already quite venturous– than these large aggregate figures (as an example, climatic models usually

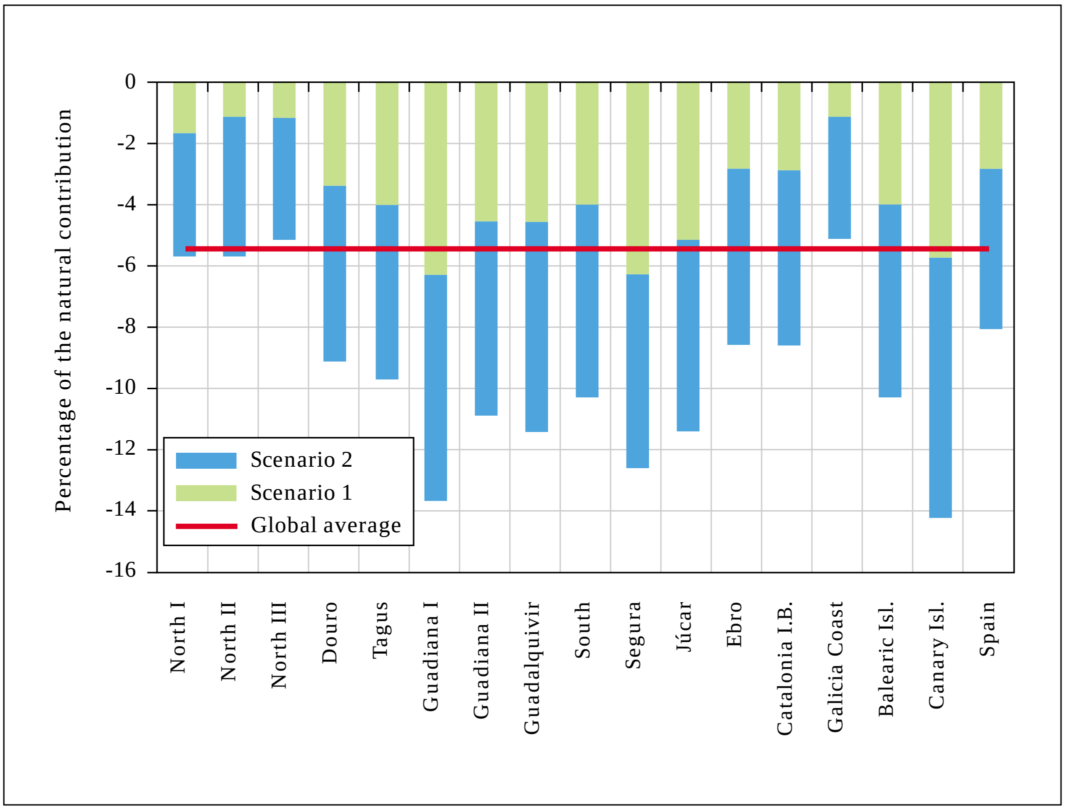


Figure 171. Percentage decrease of total cumulative flow, for the climatic scenarios considered, in long term water planning.

consider all Spain as a single climatic region), and for the time being, going into greater detail or breaking down time-space levels should be considered an illusory, purely speculative exercise.

In short, and although, as mentioned, this process's reality is not even definitively, scientifically demonstrated, if a prudent, reasonable estimate is required on the impact of possible anthropic climatic change on water resources in Spain, the whole country could globally, generally expect a decrease of 5% in total cumulative flow in a natural regime for the second horizon (or long term) of water planning.

Together with this decrease, we could expect greater annual and inter-annual variability, which would be expressed by an increase in the range of flow, and whose quantity is so far unknown.

3.1.8.3. Conclusions

Both for reasons of natural variability in hydrological phenomena, and for the possible effect of climatic change of anthropic origin, it is questionable to accept, as a design basis from a water planning and administration point of view, that future hydrological registers will be similar to those of the past, or in other words, that water flow should be considered stationary in the long term.

The intrinsic uncertainty in our current estimate of average natural flow values in Spain (standard error of average), due to the length of available samples, ranges from 3% to 12%, according to the planning area considered, and with an average value for the whole country around 5%. Additionally, in the absence of climatic change of anthropogenic origin, the European climate shows multi-decade variations, with appreciable differences between such periods, although statistical analysis of this variability, in samples available, does not demonstrate the non-seasonality hypothesis of the hydroclimatic series. In the case of Spain, there are indications to suppose that reference period used in basin water planning may be slightly wetter than the instrumental hydrometeorological period, although this does not go beyond mere hypothesis, statistically unconfirmed.

Seen in this context, possible climatic change appears to be an extra element of added uncertainty which can be absorbed within this natural variability, or be distinguished from it in a more or less remote future.

In short, and as a result of all these superimposed circumstances, it seems appropriate to reconsider how water resources are evaluated in the long term from the point of view of water planning. Perhaps a prudent reduction in expected values (e.g. around 5% on the second planning horizon), together with a certain increase in their seasonal irregularity (increase in flow range), would be good preventive practice while our knowledge of the phenomenon advances.

3.2. WATER QUALITY

3.2.1. Introduction

The description and evaluation of water quality is a complex matter, with some controversy as to the different methodologies' capacity to inform on the qualitative character of water resources. The problem lies fundamentally in the definition adopted on the concept water quality, for which different interpretations exist.

Thus, quality can be understood, from a functional point of view, as water's intrinsic capacity to respond to the uses that can be obtained from it. Or, from an environmental point of view, as defined by the Water Framework Directive proposal –which we will refer to further on in its specific section– as the conditions water must meet in order to maintain a balanced ecosystem and so that it fulfils certain quality objectives (ecological quality). Or, as the set of physical, chemical and microbiological characteristics that define it, etc.

In the sections below, the situation of water resources in our country will be studied from a qualitative point of view, attempting to combine these different approaches into an integrative, global vision.

3.2.2. General situation and regulatory aspects

Water quality is a fundamental descriptive variable in the water environment, both from the point of view of its environmental characterization, and from the perspective of planning and water administration, since it defines the water's aptitude to maintain ecosystems and to cover different demands.

Water quality can be modified by both natural causes and external factors. When the external factors that degrade natural water quality come from outside the hydrological cycle, it is described as pollution. The prevention, control and resolution of the problems arising from of water pollution is one of the objectives any water resource administration policy put forward should take into consideration.

At present, the general quality of Spanish inland water is not completely satisfactory in the light of the legislation in force, and of society's basic expectations. Our climatology's time-space irregularity, described in above sections, means that both urban and industrial wastewater have a more negative influence on final resource quality than in any other country with greater natural regulation. It is clear that, under these conditions, the self-purifying capacity of our rivers is quickly surpassed, calling for greater attention to the prevention, monitoring and correction of such wastewater, and occasionally requiring a certain minimum flow to be established, not just for environmental purposes, but also for health reasons.

As regards pollutant wastewater, the situation is diverse. Urban wastewater presents increasingly better conditions thanks to the implementation and development of the National Wastewater Collection and Treatment Plan (NWCTP), which, although it does not specifically include meeting quality objectives, is achieving an increasingly large number of inhabitants connected to treatment systems.

The situation of industrial wastewater is more worrying since a quite considerable percentage of direct wastewater still lacks requisite authorization, and much more has provisional authorization in regulation phase. That is, a great deal needs to be done as regards measures to correct this type of wastewater which, due to its quantity and characteristics, puts great pollutant pressure on water channels and masses. So far, little progress has been made in developing the Sectoral Regulation Plans for Industrial Wastewater laid down by Royal Decree 484/1995, on measures for the regulation and monitoring of wastewater, an instrument aimed at solving the worrying current situation: few wastewater authorizations, low liquidation of the wastewater charge, jurisdictional problems with industrial effluent in urban collectors and non- compliance with legislation.

Diffuse contamination from agriculture represents another major concern in our country, particularly associated with the increasing use of fertilizers and pesticides, as we shall see, which can cause serious eutrophication problems in reservoirs, and pollute groundwater. Although this situation is known, and is sufficiently characterized with respect to eutrophication in the main hydrographic basin reservoirs and the main aquifers, both cases require greater knowledge to achieve a better understanding and diagnosis of the problems outlined.

In view of the overall situation described, it is sometimes difficult to adapt water quality to the use for which it is required. This fact highlights the importance of characterising natural water quality and defining quality objectives in each hydrographic basin's river sections and aquifers. The administrative agencies responsible in each case for setting water quality objectives are different according to the territorial characteristics of the river section or sector of aquifer in question, and the very purpose for which the water is used. Resolving the jurisdictional and administrative maze in which these conflicts are settled, and in each case clearly establishing the institutional channel that will lead to declaring a quality objective for a specific section, is one of the main regulatory needs in this issue.

The management of water quality in our country must be based on the principles derived from the European Union, and which have been repeatedly assumed by the public administrations responsible for implementing them. The 5th Environmental Programme of the European Union and the Agreements subscribed by Spain on environmental issues point to the need to guarantee a design of what has been called sustainable development, a concept we will refer in later chapters, and which could compare with the constitutional principles on how natural resources should be managed in our country: general interest in their utilisation, solidarity in their distribution and rational use. As a result, Heading V of the Water Act of 1985 deals with the protection of the Public Water Domain and water quality, and stipulates, in Section 84, what thereafter are fundamental objectives: to achieve and maintain an appropriate level of water quality, to prevent the accumulation of toxic or dangerous compounds in the subsoil, capable of polluting the groundwater, and to prevent any other action that may cause its degradation. Finally, it entrusts the competent water administration with policing the surface water and groundwater, and their channels and natural deposits, easement zones and protection perimeters.

Figure 172 outlines some water quality protection actions derived from the Spanish State's legal regulations.

There also exist over 20 Community Directives, incorporated into Spanish legislation, shown in table 43, and which impose certain quality requisites that water should possess according to its use.

We should also mention other international commitments that Spain has assumed with respect to a series of Agreements, and by which it is bound to observe and respect certain aspects relating to the administration and monitoring of water quality, especially when cross-border rivers are affected: Helsinki, Oslo and Paris, Barcelona Agreements, etc...

3.2.3. Knowledge on water quality. Monitoring networks

3.2.3.1. Introduction

As mentioned, evaluating water quality is a complex matter, associated with the very definition given for this concept. Thus, depending on whether one definition or another is adopted, and which objectives are pursued with data gathering, one type of measurement and/or monitoring network or another will be required.

The main objectives of water quality measurement network would be:

- To describe the current conditions of water quality.
- To analyse long term trends.
- To identify factors affecting water quality.

In view of the specific objectives pursued in each case, the definition of a water quality network will not only consist of locating sampling sites, but of setting up water quality monitoring programmes, which must define the main objective of sampling, the population to sample, the accuracy and confidence interval of analyses, the number of samples to obtain in each case and sampling frequency. These programmes thus provide an assessment of the effectiveness of environmental policies implemented, the effects that changes in land use and production activities have on resource quality, statistically characterize pollution, and evaluate the frequencies of surplus in quality standards as regards assigned uses.

Water's aptitude to cover various uses, in general, domestic supply, bathing, development of fish life, industries and irrigation, is usually characterised according to the surplus or not, in a time period, of certain values for the different quality parameters sampled. This is the reason why the stations

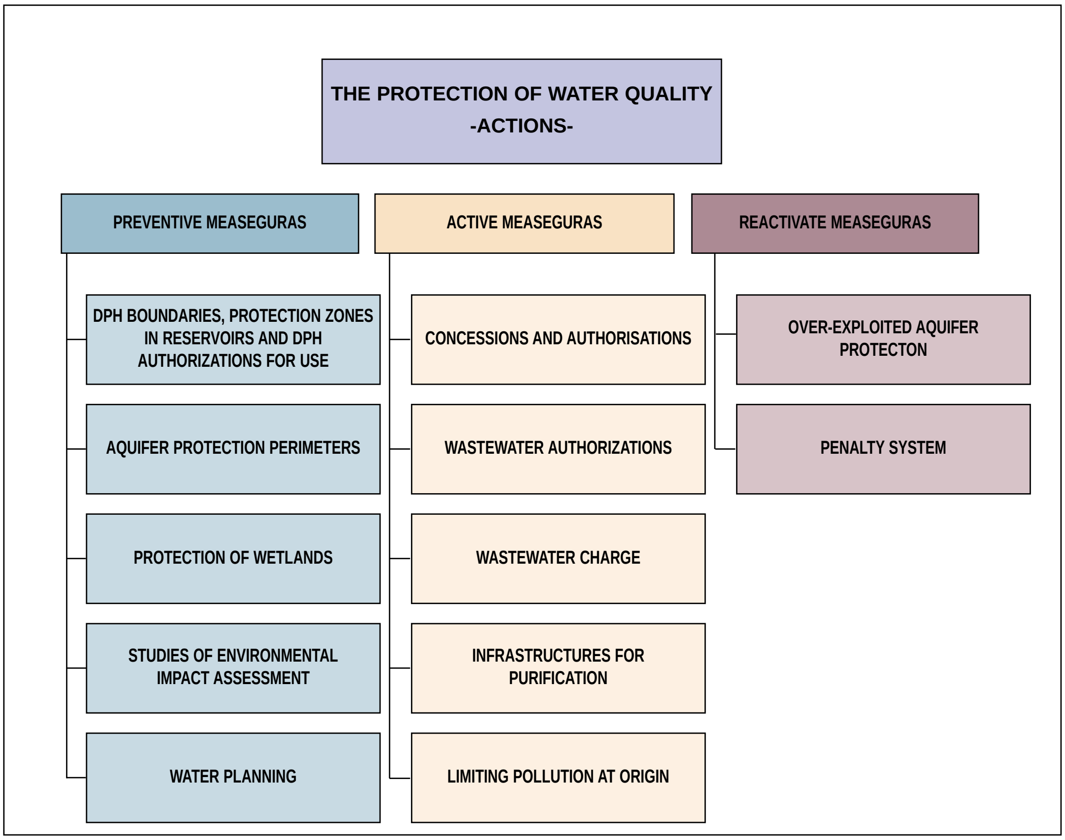


Figure 172. Actions for the protection of water quality.

EMISSION REGULATIONS		QUALITY OBJECTIVES	
DIRECTIVE	INCORPORATION	DIRECTIVE	INCORPORATION
76/464 Pollution caused by certain dangerous substances	Water Act 29/1985 (Secs. 92 to 100) RDPH (Secs. 245 to 273)	**75/440** Water intended for the production of drinking water	RAPA (Annex I) O.M. of 11/5/1988, 15/10/1990 and 30/11/1994 Royal Decree 1541/1994
82/176 and 84/156 Mercury	O.M. 12/11/1987 O.M. 25/5/1992	**79/869** Measurement methods and frequency of water analysis and sampling for the production of drinking water	O.M. of the 8/2/88
83/513 Cadmium	O.M. 12/11/1987 O.M. 25/5/1992	**80/778** Water intended for human consumption	O.M. 1/7/87 Royal Decree 1138/1990 (Technical-Health Regulation)
84/491 Hexachlorocyclohexane	O.M. 12/11/1987, 25/5/1992 and 27/2/1991		Royal Decree 734/1988 RAPA (Annex II)
86/280 Carbon tetrachloride and other dangerous substances	O.M. 12/11/1987 and 25/5/1992	**76/160** Quality of bathing water	O.M. 16/12/1988 RAPA (Annex III)
88/347 Aldrin and other dangerous substances	O.M. 13/3/1989	**78/659** Quality of fresh water needed for fish life	RAPA (Annex IV) Royal Decree 38/1989
90/415 1, 2-dichlorethane and other dangerous substances	O.M. 28/6/1991	**79/923** Waters for shellfish breeding	
78/176, 82/883 and 83/29 Waste from the Titanium industry	O.M. 28/7/89		
80/68 Protection of groundwater	Water Act 29/1985 (Art. 94) RDPH (Arts. 256 at the 258) Royal Decree 1315/1992		
91/271 Treatment of Waste and Urban Water	Royal Decree-Act 11/1995 Royal Decree 509/1996		
91/676 Protection of Water Polluted by Nitrates	Royal Decree 261/96		
91/692 Standardisation of reports			
Decision 92/446 and 95/337 **96/61** Integrated pollution prevention and control			

Table 43. Incorporation of Community Directives into Spanish water legislation.

periodically providing this information are located on river reaches where the water is used to cover different uses. In Spain, examples of this type of networks are the so-called COAS (Official Supply Control) which control urban supply and allow pre-treatment analyses to be carried out, and the Fish Life Network that aims to verify water's aptitude to harbour fish life, and which monitors 140 river sections.

The methodology of General Quality Indexes (ICG) for water has also been broadly used in Spain, which aim to define, by means of a simple numerical scale from 0 to 100, estimated from 23 analytic parameters, the general quality level of the river section in question. In this case, the sampling sites should be chosen so as to be statistically representative of a territory's fluvial network quality, and they should therefore consider both highly polluted reaches and others with excellent quality. In Spain, the water quality network fulfilling this objective has been the COCA network (Official Water Quality Control), which has periodically sampled the parameters used to draw up the ICG statistics.

At present, these networks have been included, with some improvements, into the ICA network which, covering intercommunity basins, provides information on various aspects relating to water quality.

Also, there exist several networks which, managed by the ITGE and the Hydrographic Confederations, provide information on groundwater evolution.

Sections below present, in some detail, the current situation and the basic characteristics of the water quality monitoring networks.

3.2.3.2. Situation of monitoring networks

In Spain, surface water quality has been systematically monitored since the year 1962, when the Public Works Ministry set up the above-mentioned COCA network, and the Water Commissions were entrusted with its implementation. Initially, it was made up of 50 stations, monitoring 18 parameters relating to water quality. This network has undergone successive extensions and in the year 1972 it had 221 sites, while at present it has reached 408 stations belonging to 9 inter-community basins and 45 belonging to peninsular intra-community basins.

Generally speaking, COCA network stations do not have a specific associated infrastructure, since they are sites where samples are taken with a determined frequency. These stations are generally located in easily-accessible reaches of the rivers, and where they can take representative samples of the river's mean quality on the reach. It is typical to choose river reaches where major concentrations of pollution are common, and so there are stations downstream from the most important centres of population.

At present, this network's stations monitor a total of 40 parameters, including temperature, dissolved oxygen, BOD5, etc (table 44).

Stations are classified into three major categories, differing essentially by the frequency with which they measure or analyse the four groups of parameters, ranging between a monthly, quarterly, biannual, or annual determination, as shown by the adjoining table (table 45).

The COCA network has over 30 years of data in some stations. It is therefore unquestionably a fundamental source of information in studying quality evolution over time. Additionally, like any other quality control network, the data contributes information on the polluting capacity of wastewater upstream.

In the year 1993, the Integrated Water Quality (ICA) network was designed with the aim of controlling river reaches with the frequency and intensity required by the uses existing on them. This network was included within the already-existing ones (COCA, COAS and Fish Life), due to simple, obvious statistical continuity criteria, and increased its number on some specific reaches. Figure 173 shows this network's conventional stations for systematic, periodic sampling.

Furthermore, the current ICA network does not only include conventional stations for systematic, periodic sampling, but also includes Automatic Warning Stations (EAA) which, implemented under the SAICA (Automatic Water Quality Information System) project, produce continuous information on some quality parameters, and transmit it in real time to a series of control and decision centres. The map in figure 174 shows the location of the automatic warning stations.

The EAA have been installed at sites where the presence of specially critical uses calls for the necessity to adopt immediate preventive action, and in others where it would be expedient to detect pollution points and act in consequence, with appropriate speed. An EAA's equipment is shown in figure 175, and includes, as may be seen, equipment both for specific analysis and data transmission.

At this moment, the system is undergoing revision in order to further decentralise everything related with data administration, as well as a redefinition of parameters to be measured and transmitted from each EAA.

We should also mention the implementation, as of October 1978, of a National Control Network for Environmental Radioactivity in surface water, which supplies information on several radiological parameters and their possible presence in Spanish inland waters. The results of these samples are sent to the DGOHCA and the Nuclear Security Council (CSN, authority established under public law, Act 15/1980

Group A	Group B	Group C	Group D
Solid	Dissolved flow	Silica	Arsenic
Temperature	Chlorides	Fats	Copper
Dissolved oxygen	Sulphates	Cyanides	Iron
Solids in suspension	Calcium	Phenols	Manganese
pH	Magnesium	Fluorides	Lead
Conductivity	Sodium	Cadmium	Zinc
DQO to permanganate	Potassium	Hexavalent chromes	Antimony
BOD_5	Phosphates	Mercury	Nickel
Total coliform organisms	Nitrates		Selenium
	Saltpeters		
	Ammonia		
	Carbonates		
	Bicarbonates		
	Detergents		

Table 44. Groups of parameters controlled by the COCA network.

	Groups of parameters			
Station type	A	B	C	D
Normal	Monthly	Biannual	Annual	Yearly
Preferential	Monthly	Quarterly	Quarterly	Quarterly
Special	Monthly	Monthly	Monthly	Monthly

Table 45. Frequency of sampling in the COCA network.

of 22nd of April, as sole competent authority on nuclear security and radiological protection) for their supervision and for taking necessary measures, where relevant.

Moreover, the owners of nuclear facilities, in accordance with instructions from the CSN, carry out certain Environmental Radiological Surveillance Programmes (PVRA) in the area around all their facilities.

As regards groundwater, the Technological Geomining Institute of Spain (ITGE) has carried out a gradual implementation of a Groundwater Quality Observation Network (ROCKS) to study the evolution of its different physiochemical parameters. This network, which was set up in the decade of the 70s, has been enlarged and modified up to the present, and a total of 1,650 sites are controlled, whose density by basin is shown in the table. These sites make biannual analyses of major chemical constituents.

As a complement to this network, there exists another network specifically observing intrusion (ROI), created to study the evolution of marine intrusion in coastal aquifers. This is a permanent control network, taking samples with bimonthly or biannual frequency, according to each area's peculiarities, and analyses chlorides and conductivity.

There also exist other activities in spot sampling, statistics and research of groundwater quality or other aspects carried out by the DGOHCA in the framework of agreements subscribed with CEDEX, although these activities are not continuous, systematic measurement networks. Interesting work in isotopic hydrology has therefore been carried out, from own data and from specific international networks (Plata Bedmar, 1994).

Table 46 summarizes the situation by basins of the different networks mentioned.

3.2.3.3. Comparison with other countries

As shown by table 47, the European Union has over 20 programmes evaluating the general quality of surface waters. The density of the networks included in these programs varies from one station every 10,000 km^2 up to one every 100 km^2 (the mean value in Spain is approximately one station every

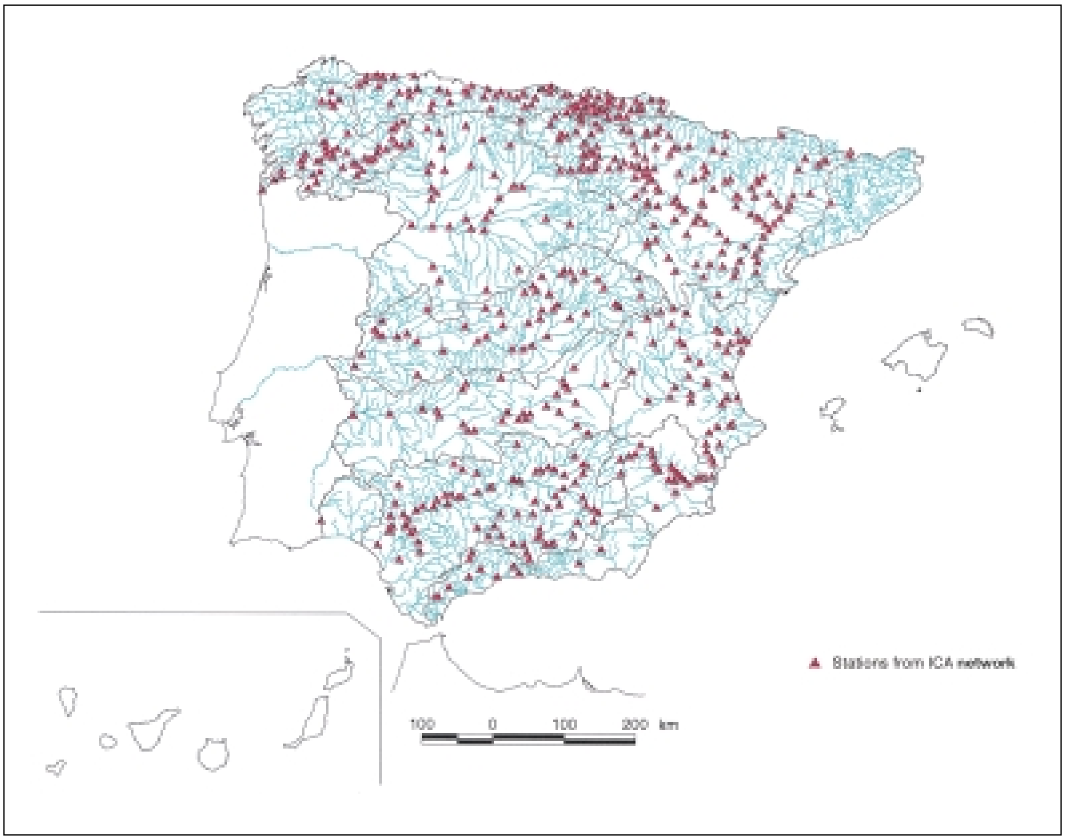


Figure 173. Map of ICA network periodic sampling stations in operation.

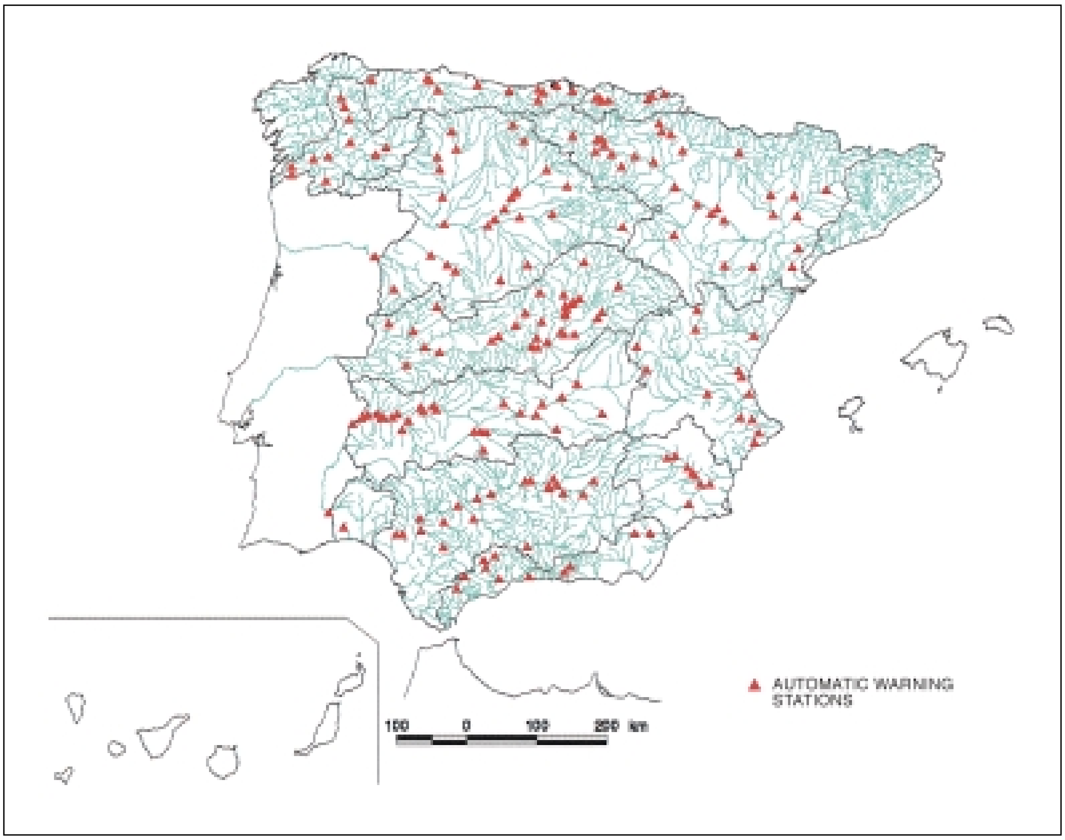


Figure 174. Map of ICA network Automatic Warning Stations.

1,000 km^2). Usually, the density is of one or two stations every 2,000 km^2. Sampling frequency also varies greatly, ranging between 4 and 26 annual samples per measurement point. Greater still are the differences regarding the number of parameters measured in each station, varying between 4 and 120. The parameters most frequently sampled are pH, conductivity, water temperature, dissolved oxygen and BOD5.

In November, 1995, the European Environment Agency (EEA, 1996d) published some initial recommendations on the quality networks which, at the very least, should exist in each Member State, under the following criteria:

1. A basic network whose main function would be to statistically characterise water quality in the territory and which would be provided with a density of one station per 2,000 km^2. At least 20% of stations should be located in reaches reflecting the area's most representative human activities, and another 20% in areas of low-intensity human activity.

2. An impact network whose objective would be to evaluate general water pollution, and which would have a density of one station per 10,000 km^2, in areas with towns smaller than 50 inhab/km^2, of one station per 3,000 km^2 in areas with towns between 50 and 100 inhab/km^2 and of one station per 1,000 km^2 in areas with towns larger than 100 inhab/km^2.

3. A fully representative network, used to detect the greatest impact caused by pollution, and to compare the resulting quality with the original water quality.

Table 48 shows the number of stations that would be obtained, with the above-mentioned criteria, for the different EU countries. It can be verified that Spain complies with minimum requirements for the total number of stations, but it is not in line with density and recommended location criteria.

As for the net of Groundwater Quality Control network, the European situation is more varied and more heterogeneous, with countries like Austria, Germany, Holland and Spain with relatively high densities, and others, such as Iceland, which do not have a quality network, or countries like Norway, with just 21 monitoring sites, or Greece with 275 measuring sites.

3.2.3.4. Proposals for Administration, Coordination and Modernisation

Information on water quality is at present difficult to manage, not just as consequence of its volume, but of the heterogeneity of sources and diversity of formats in which it is stored. There exists a significant lack of consolidated quality administration programs which, based on their corresponding database management systems, allow conclusions to be drawn on the state of rivers and aquifer quality, to detect the main pollutants' evolution and to evaluate repercussions that the different administration alternatives mentioned could have on the water environment.

Existing water quality networks and the information management carried out by them are not sufficient to provide

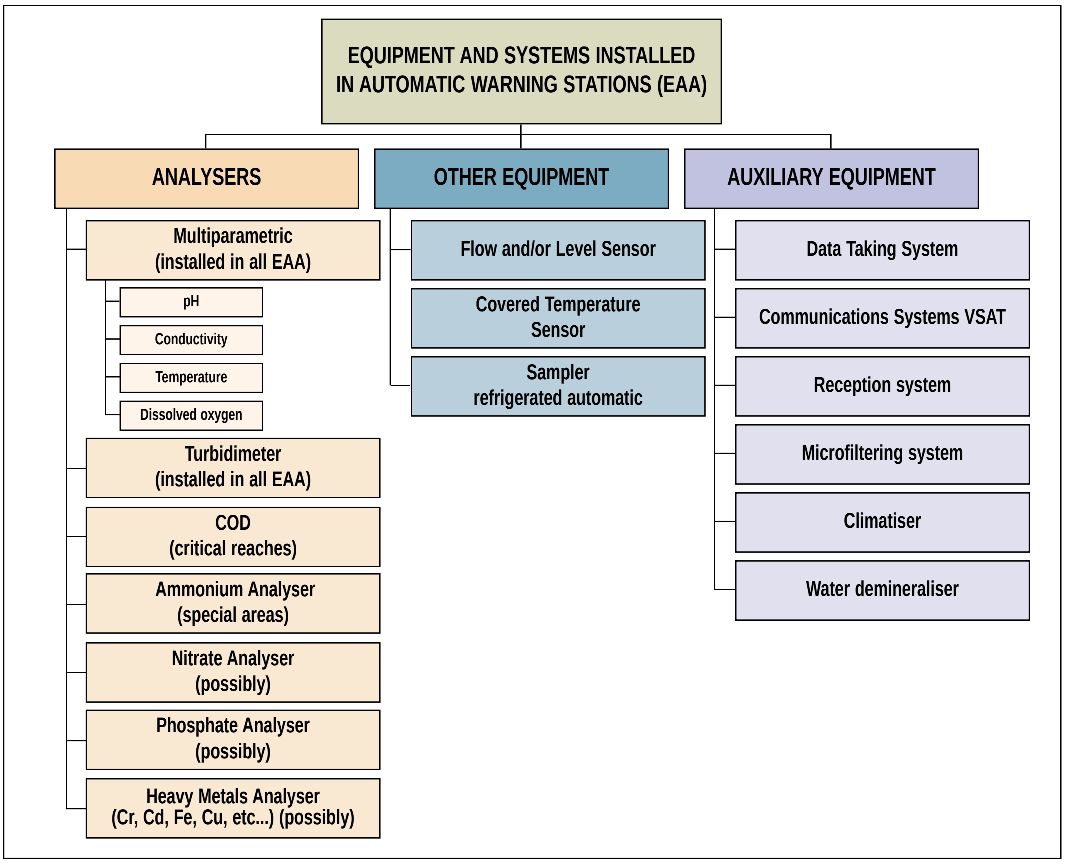


Figure 175. Equipment and systems installed in Automatic Warning Stations.

the minimum necessary information and to comply with the most recent legislation on water quality. It is therefore urgent that the necessary work is implemented to improve the existent quality networks as regards defining locations, station density, and sampling parameters and frequency.

Although in recent years surface water quality control networks have improved by increasing the number of stations in the COCA network, adding stations to monitor water intended for the production of drinking water (net COAS), including stations in areas supporting fish life (Fish Life Network) and combining all the stations within the ICA network, it is essential to increase the attention and effort devoted to this network, for the following reasons:

- The existing network as a whole covers only some river reaches or reservoirs where declared uses exist, but it does not cover virtually any of those where there are no specific uses and those where, in many cases, information is required.
- Sampling frequencies are insufficient in some cases and consequently, do not provide appropriate data to implement out adequate statistical control.

	Surface area (km^2)	N.º of stats in the ROCA network	Density of stats. in the COCA network l/km^2	N.º of stats in the ROCAS network	N.º of stats. in the ROI network
North	40,650	106	1/383	133	--
Douro	78,960	37	1/2,134	92	--
Tagus	55,810	55	1/1015	130	--
Guadiana	60,210	54	1/115	119	10
Guadalquivir	63,240	35	1/1,807	168	39
South	17,950	16	1/1,122	282	319
Segura	19,120	14	1/1,366	182	--
Júcar	42,900	25	1/1,716	106	337
Ebro	85,560	66	1/1,296	138	--
Catalonia I.B.	16,490	44	1/375	300	93
Galicia Coast	13,130	4	1/3,283	--	--
Total peninsula	**494,020**	**456**	**1/1,083**	**1650**	**798**

Table 46. Monitoring sites in the different basins of the main monitoring networks for water quality.

Country	N.º Stats.	Freq. Sample	N.º of Params.	Area km²	km²/u.	Length rivers km	Length per area	km/u.
Austria	244 48	6 12	59	83,856	343,7 1,747	47,000	0.56	192,6 979,2
Belgium	957 90	8 5	19 108	30,500	31,9 338,9	22,600	0.74	23,6
Germany	146	26	19	357,000	2,445,2	179,000	0.50	1226
Denmark	261 58 15	20 4 26	12 8 11	430,000	1,647,5 7,413,8 28,666,7	28,000	0.65	107,3 482,8 1,866,7
Spain	**456**	**9**	**42**	**505,950**	**1,109,5**	**172,000 (1)**	**0.34**	**377,2**
Finland	68 15 30 12	4 15-70 12 6-12	41 18-26 41 21-41	338,145	4,972,7 22,543 11,271,5 28,178,8	159,000	9.47	2,338,2 10,600 5,300 13,250
France	1,082	12	40	543,964	502,7	563,000	1.3	520,3
Greece	6	12	26	131,944	21,990,7			
Ireland	1,500	12	18	70,000	46,7	33,700	0.48	22,5
Luxemburg	217	1-13	20-25	2,590	12	1,330	0.51	6,1
Holland	26	13-52	120	42,000	1,615	20,100	0.48	773,1
Norway	10 20 25	12 12 12-24	14 12 5-22	324,000	32,400 16,200 12,960	210,000		21,000
Portugal	109	12	24	88,700	813,8	172,000	1.87	1,578,0
Sweden	300 35 15 49	1/5 1 12 12	25 23 25 31	450,000	1,500 12,857,1 30,000 9,183,7	315,000	0.70	1,050 9,000 21,000 6,428,6
United Kingdom	230	6-52	80	240,000	1,043,5	171,000	0.70	743,5

Table 47. Surface water quality control networks in different European countries.

(1): Does not include Balearic or Canary Islands Table 47, Surface water quality control networks in different European countries,

Country	Basic Network (1 per 2,000 km²)	Impact network (Of 1/1,000 km² to 1/10,000 km²)	Cause-effect Network		Total
			Reference	Pollution	
Austria	42	38	4	16	100
Belgium	15	31	2	10	58
Denmark	22	17	2	8	49
Finland	169	41	8	34	252
France	272	230	20	80	602
Germany	179	357	20	80	636
Greece	66	34	4	16	120
Ireland	35	23	3	9	70
Italy	151	283	15	80	529
Luxemburg	1	3	--	1	5
Holland	21	40	3	9	73
Norway	162	33	10	30	235
Portugal	46	47	4	14	111
Spain	**253**	**161**	**15**	**80**	**509**
Sweden	225	59	5	20	309
United Kingdom	122	191	15	75	403
EU	**1,781**	**1,588**	**130**	**562**	**4,061**

Table 48. Recommendations by the European Environment Agency on surface water quality control networks.

- The number of parameters sampled is insufficient in some sites, in view of the new requirements laid down by legislation and international agreements.

Additionally, the current layout of the Groundwater Quality Control network does not respond to the management demands required to incorporate this resource into the public water domain, nor to the hydrogeological complexity involved in monitoring the physical-chemical evolution of groundwater. Generally speaking, what the network is using as sampling sites are wells built for other purposes, urban supply or irrigation. Furthermore, although the network comprises the main hydrogeological units, there are un-monitored aquifers for a number of reasons, such as non-existence of wells or observation bore-holes, or the occasional lack of means to carry out sampling.

Another significant aspect is that these networks, due to their characteristics and the type of analysis carried out, generally do not detect specific pollution phenomena, as the case of the organic micro-pollutants (hydrocarbons, pesticides) or of certain heavy metals.

Sampling frequency is also a very important aspect. In general, the number of samples is low, especially in coastal areas where problems of marine intrusion exist, and whose observation requires more accuracy and greater frequency of measurement. In an attempt to overcome the above deficiencies, the MIMAM has drawn up ten projects aimed at redesigning and establishing this network in the intercommunity and Balearic basins. The resulting proposal (building new piezometers and updating existing ones) consists of 1,151 observation sites, which would mean having a network with a mean density in the controlled area of 130 km^2 permeable surface area per observation site.

3.2.4. River pollution

Pollution is defined in section 85 of the Water Act as the *action and effect of introducing substances or forms of energy, or causing conditions in water which, directly or indirectly, harmfully alter its quality as regards subsequent uses or its ecological function.*

In each specific case, the polluting processes are caused by the discharge of certain substances into the water environment, and by its negative effect on the water's aptitude to comply with certain uses or quality objectives. That is, the combination of wastewater and an unsatisfied use or ecological function gives rise to pollution as defined in Water Act. Therefore, fluvial pollution will have to be studied in connection with the implementation of existing regulations on water quality, coming mostly from legislation passed by the European Union and which have been incorporated into Spanish state law. We should also mention the close relationship existing, in many rivers of our country, between water quantity and quality. The strict limitation of circulating flow in many channels, subjected to intense exploitation, gives rise to quality problems and frequent resort to dilution with scarce water, causing frequent conflicts of interests among users.

Furthermore, the increase in diffuse-type pollution, associated with episodes of high rainfall and flow, transporting soil-based pollution, highlights the importance of planning land uses and studying measures to combat these sporadic effects. In this respect, we should indicate that contamination of channels by the storm water running from unit drainage systems, as well as runoff from highways, can contribute a similar or equal pollutant factor to that of urban wastewater in dry periods, and additionally concentrated in a very short space of time.

3.2.4.1. Water quality status. Aptitude criteria and indicators

The natural or intrinsic quality of fluvial water is what would exist in a natural environment without human intervention. In Spain, this natural quality would enable them, in general, to be used in irrigation and in population supply, although in some cases natural, non-toxic salinity could cause some quality problems, though not compromising public health. Nevertheless, the negative influence of certain anthropogenic actions has led to serious deterioration in the natural state of water.

From the point of view of its aptitude for different uses, and of some global, representative indicators, the situation of water quality is as described in the following sections.

3.2.4.1.1. Criteria on aptitude for human consumption

Criteria on aptitude for human consumption are defined in Directives 75/440, 79/869 and 98/83. As regards these regulations, almost all the basin organisations have identified and located the catchments from which towns over 1,000 inhabitants are supplied, and have classified existing purification treatment. This information was included as one of the variables in designing the ICA net work, and in locating the EAA which control the most important supplies.

Directive 75/440, concerning the quality of surface water intended for the abstraction of drinking water (and the complementary directive on the frequency of sampling and analyses to be carried out, Directive 79/869), deals with the quality that surface fresh water should have in order to be used in abstraction for use as drinking water, after being appropriately treated. This directive's incorporation into Spanish law was implemented by the Ministerial Order of the 11th of May, 1988, by Public Water Administration Regulations (Annex I), by the Ministerial Order of October 15th,1990, by the Ministerial Order of November 30th, 1994, and by Royal Decree 1541/1994.

Table 49 shows the water quality standards under this Directive 75/440, establishing three groups , A1, A2 and

Parameter	Unit	Type A1	Type A2	Type A3
PH	--	(6,5-8,5)	(5,5-9)	(5,5-9)
Colour	mg/Scale Pt	20 (10) (o)	100 (50) (o)	200 (50) (o)
Solids in suspension	mg/l	(25)	--	--
Temperature	°C	25 (22) (o)	25 (22) (o)	25 (22) (o)
Conductivity at 20 °C	MS/cm	(1.000)	(1.000)	(1.000)
Scent	dilution factor	(3)	(10)	(20)
Nitrates	mg/l NO_3	50 (25) (o)	50 (o)	50 (o)
Fluorides	mg/l F	1.5 (0,7/1)	(0,7/1)	(0,7/1)
Dissolved iron	mg/l Fe	0,3 (0,1)	2 (1)	(1)
Manganese	mg/l Mn	(0,05)	(0,1)	(1)
Copper	mg/l Cu	0,05 (0,02) (o)	(0,05)	(1)
Zinc	mg/l Zn	3 (0,5)	5 (1)	5 (1)
Boron	mg/l B	(1)	(1)	(1)
Arsenic	mg/l Ace	0,05 (0,01)	0,05	0,1 (0,05)
Cadmium	mg/l Cd	0,005 (0,001)	0,005 (0,001)	0,005 (0,001)
Total chrome	mg/l Cr	0,05	0,05	0,05
Lead	mg/l Pb	0,05	0,05	0,05
Selenium	mg/l You	0,01	0,01	0,01
Mercury	mg/l Hg	0,001 (0,0005)	0,001 (0,0005)	0,001 (0,0005)
Barium	mg/l Ba	0,01	1	1
Cyanide	mg/l CN	0,05	0,05	0,05
Sulphates	mg/l SO_4	250 (150)	250 (150) (o)	250 (150) (o)
Chlorides	mg/l Cl	(200)	(200)	(200)
Detergents	mg/l (laurilsulphate)	(0,2)	(0,2)	(0,5)
Phosphates	mg/l P_2 OR_5	(0,4)	(0,7)	(0,7)
Phenols	C_6 H_5 OH	0,001	0,005 (0,001)	0,1 (0,01)
Dissolved hydrocarbons or emulsions (after extraction in petroleum ether)	mg/l	0,05	0,2	1
Polycyclical aromatic hydrocarbons	mg/l	0,0002	0,0002	0,001
Total pesticides	mg/l	0,001	0,0025	0,005
DQO	mg/l O_2	--	--	(30)
Dissolved oxygen	% satur.	(70)	(50)	(30)
BOD_5	mg/l O_2	(3)	(5)	(7)
Kjeldahl Nitrogen	mg/l N	(1)	(2)	(3)
Ammonia	mg/l NH_4	(0,5)	1,5 (1)	4 (2) (o)
Substances extractable with chloroform	mg/l SEC	(0,1)	(0,2)	(0,5)
Total coliforms 37 °C	/100 ml	(50)	(5.000)	(50.000)
Fecal coliforms	/100 ml	(20)	(2.000)	(20.000)
Fecal Estreptococos	/100 ml	(20)	(1.000)	(10.000)
Salmonellas	--	Absent in 5.000 ml	Absent in 1.000 ml	--

Table 49. Quality characteristics of surface water intended for producing drinking water (Directive 75/440).

In parenthesis are the guideline values of the Directive.
(o) Exceptional climatic or geographical circumstances.

A3, in ascending order of necessity for treatment in abstraction for drinking water. There is also differentiation of guideline values, which appear in parenthesis, and which correspond to the limits Member States should attempt to respect, and the mandatory values, which are those they are bound to comply with.

Quality requirements must be complied with at intake points for urban supply. For every reach immediately upstream from an intake point, the Hydrographic Confederations will establish quality standards, acting on the wastewater authorizations that may impede its adaptation. These actions should be included and programmed in the basin plans.

Only exceptionally may water of a quality lower than at A3 be used in producing drinking water, provided that appropriate treatment is carried out to convert it into drinking water with full guarantees. Only in the event of floods, natural catastrophes or exceptional meteorological or geographical situations is it acceptable to surpass the parameters marked with an (o) in the Table of Directive 75/440. In such cases, the DGOHCA and the European Commission will be informed in this respect. The Hydrographic Confederations themselves will also be responsible for taking the necessary samples to pre-test the quality of the drinking water.

The Health and Consumption Ministry has set up an information system allowing coordination of supply and quality control between the State Health Authorities and the Autonomous Communities. It has also been declared obligatory to supply a minimum of 100 litres per inhabitant per day of drinking water, under normal conditions.

Figures 176 and 177 show water aptitude during the last 15 years to cover human consumption depending on whether the mandatory or guideline values of Directive 75/440/CCE are used. These maps have also represented the quality objectives regarding the use of pre-treated water in the different river reaches, giving some idea of their level of implementation.

Water's aptitude for producing drinking water has been considered good at those points of the network where, in a high percentage of years, the water quality has been A1, normal when it has been A2, regular when it has been A3 and bad when the quality has been lower than A3.

It should be pointed out that this Directive seems to be aimed at fluvial intake, and it does not always adapt well to intake conditions in our reservoirs. In some cases, it has been observed that the 4 qualities described could be obtained according to the depth the sample is taken from.

We should note that these figures only offer a general overview of water aptitude in the country's fluvial channels to be used, after abstraction, in urban supply. The analysis has been carried out at sampling points of the COCA network, which in many cases do not coincide with supply water intake points. We should bear in mind, therefore, that a large percentage of points represented in the figures as not apt for the production of drinking water are not being used for this purpose, and that the association of both concepts could lead to errors of comprehension.

In any event, and even with the bias mentioned, the results shown provide a general overall view of the situation, and valuable information on the potential aptitude of Spanish rivers to be used for that purpose.

3.2.4.1.2. Criteria on aptitude for irrigation

There are several classifications providing guidelines as to the quality that water should possess to be used in irrigation. The most commonly-used criteria to analyse water aptitude for irrigation is given by the FAO, and refer firstly to the risks of salinisation and reduction of infiltration capacity according to conductivity, of this, and of the Sodium Absorption Ratio (SAR), respectively. These variables can be obtained from data provided by the COCA network.

Moreover, the FAO criteria include information on other potential problems, arising from the toxicity of certain specific ions and oligo-elements, excess nitrogen and bicarbonate and the pH magnitude. The guidelines proposed are only applicable in certain suppositions relating to climate, land, irrigation handling and methods, drainage conditions and patterns of moisture absorption by the crop. When local characteristics do not conform to the suppositions considered, a specific study of the case is required, which may give rise to a modification of the criteria mentioned.

Table 50 gives the classification of water quality for irrigation according to this criterion.

Considering these guidelines drawn up by the FAO and the information available from the COCA network, two figures

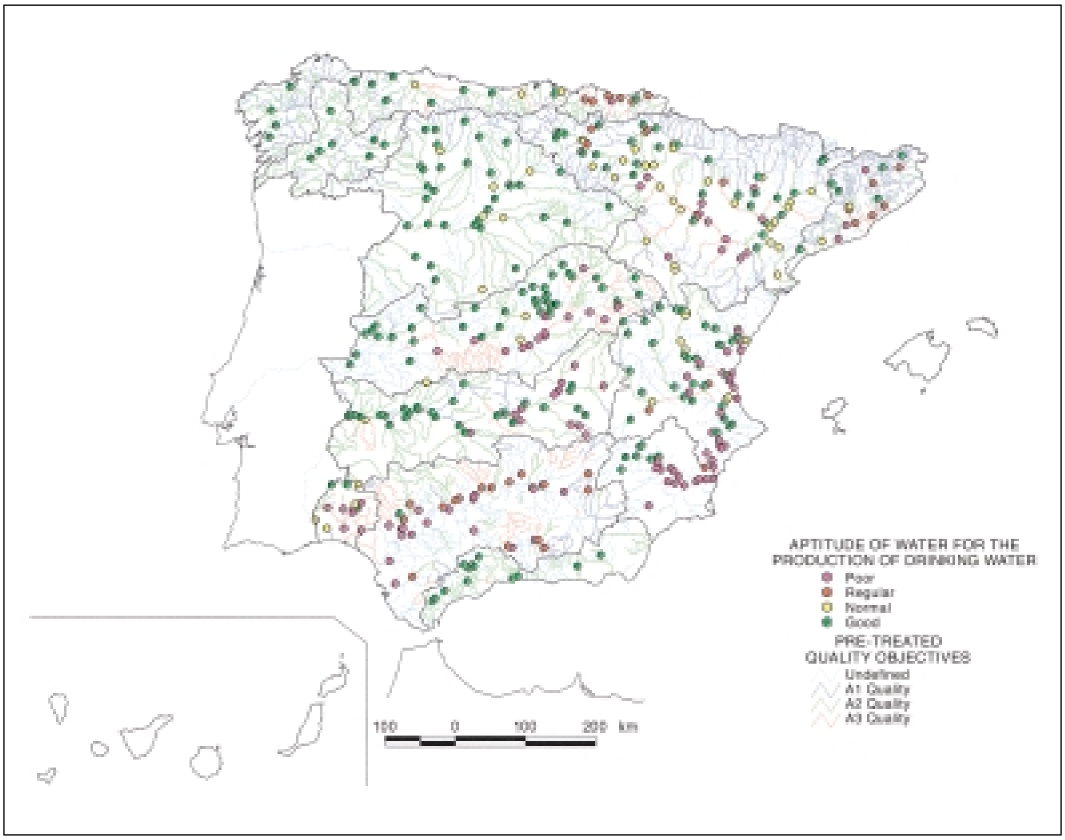


Figure 176. Map of water aptitude for the production of drinking water according to the mandatory values of Directive 75/440.

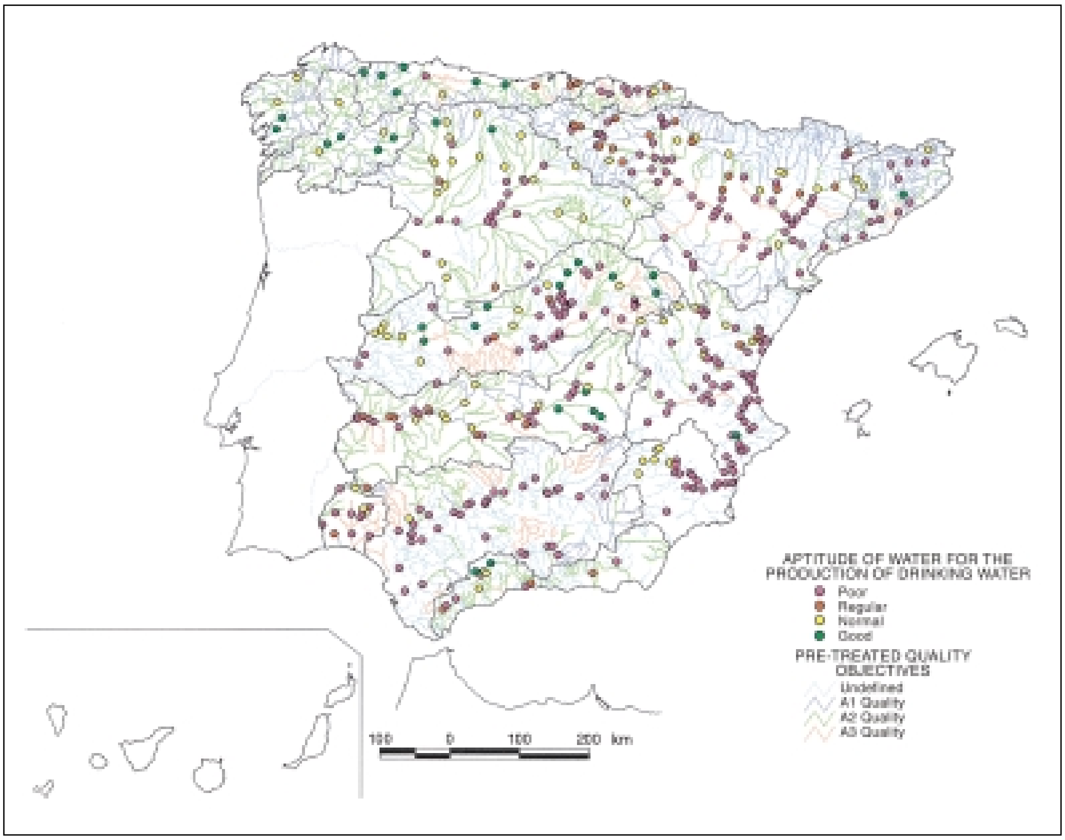


Figure 177. Map of water aptitude for the production of drinking water according to the guideline values of Directive 75/440.

have been presented showing, in each station, the mean aptitude of water for irrigation as regards risk of salinity (fig. 178) and reduction of infiltration capacity (fig. 179) during the months of July and August, which coincide with the time periods when water needs for irrigation are greater. For the purposes of contrasting their relative situation, the

POTENTIAL PROBLEM	UNITS	DEGREE OF USE RESTRICTION		
		NONE	SLIGHT OR MODERATE	SEVERE
Salinity (affects availability of water for crops)				
ECa	dS/m	< 0,7	0.7-3.0	>3.0
TSS	mg/l	< 450	450-2000	> 2000
Infiltration (reduces infiltration to evaluate using the ECa and SAR at the same time)				
RAS = 0 - 3 y ECa	=		> 0.7	0.7 - 0.2 < 0.2
= 3 - 6	=		> 1.2	1.2 - 0.3 < 0.3
= 6 - 12	=		> 1.9	1.9 - 0.5 < 0.5
= 12 - 20	=		> 2.9	2.9 - 1.3 < 1.3
= 20 - 40	=		> 5.0	5.0 - 2.9 < 2.9
Toxicity of Specific Ions (affects sensitive crops)				
Sodium (Na)				
Surface Irrigation	SAR	< 3	3 - 9	< 9
Aspersion Irrigation	me/l	< 3	> 3	
Chlorides (Cl)				
Surface Irrigation	me/l	< 4	4.0 - 10	> 10
Aspersion Irrigation	me/l	< 3	> 3	
Boron (B)	mg/l	< 0,7	0.7 - 3.0	> 3.0
Oligo-elements				
Various (affects sensitive crops)				
Nitrogen (NO_3-N)	mg/l	< 5	5.0 - 30	> 30
Bicarbonate (HCO_3) (only leaf aspersion)	me/l	< 1.5	1.5 - 8.5	> 8.5
pH		Normal Extension 6.5 - 8.4		

Table 50. Classification of water quality for irrigation according to FAO.

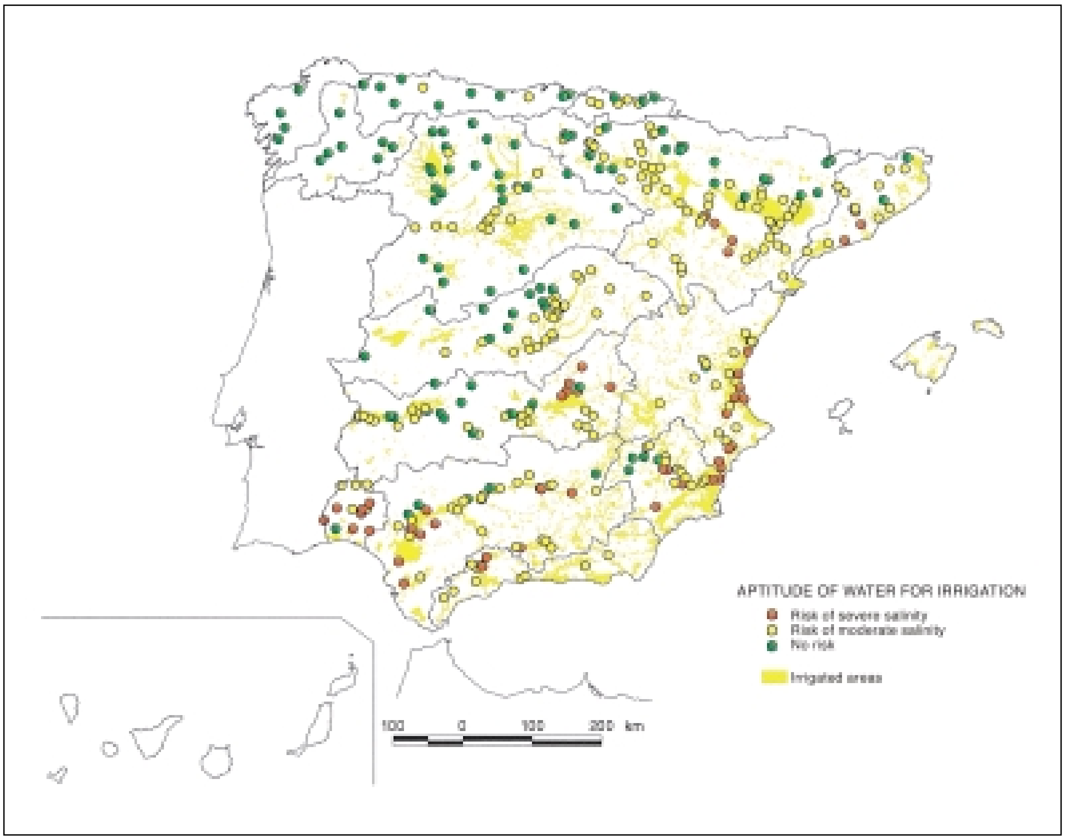


Figure 178. Map of water aptitude for irrigation during July and August (risk of salinity).

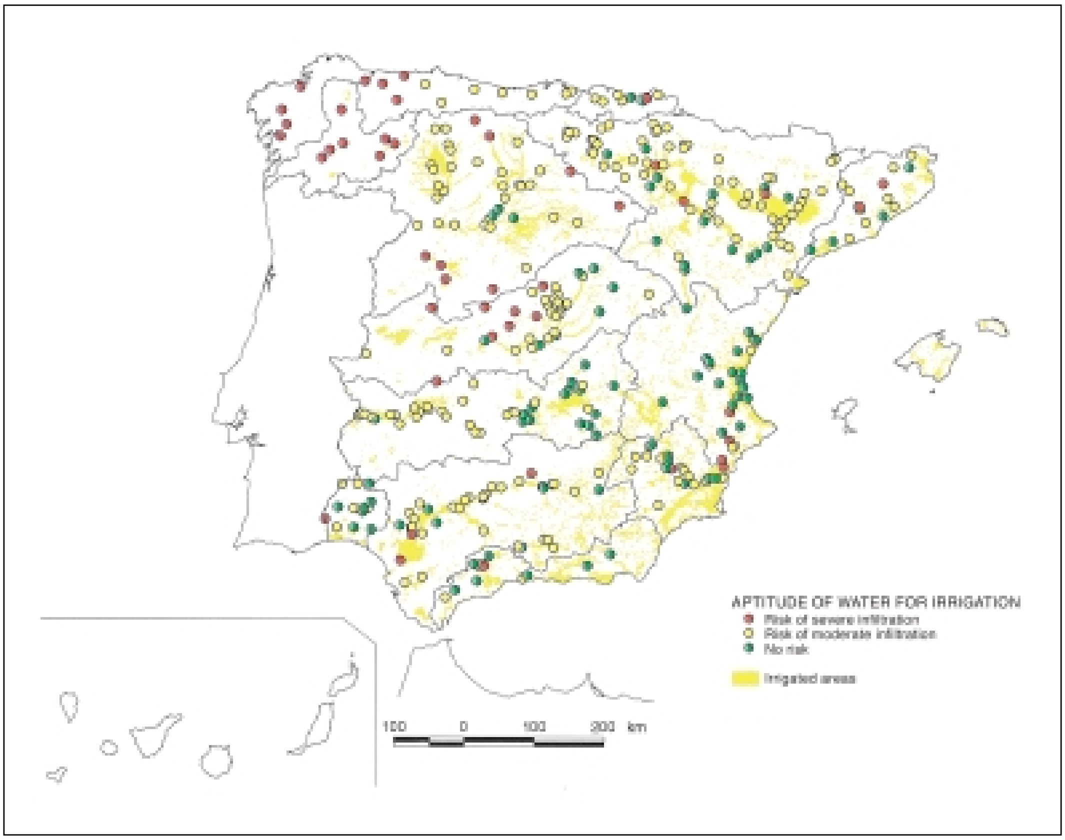


Figure 179. Map of water aptitude for irrigation during July and August (risk of infiltration capacity reduction).

same figures have also represented existing areas of irrigation.

As mentioned with respect to supply water, this aptitude does not provide information on the current quality of irrigation waters, but on the potential aptitude of Spanish river reaches to be used in water abstraction for agricultural uses, since not all the sites in the COCA network coincide with irrigation water abstraction sites.

3.2.4.1.3. Criteria on aptitude for bathing water

Directive 76/160/EEC, on the quality of bathing water, which has been incorporated into Spanish legislation by Royal Decree 734/1988 and by Annex II of the RAPAPH, which is currently undergoing review, has the objective of ensuring certain minimum quality levels in continental and coastal water intended for bathing. This set of regulations constitutes a valuable health-related instrument with respect to a water use which, as seen in other sections, has increasing social value.

Water planning should consider river or reservoir sections that Autonomous Communities have declared Bathing Areas, and assume, as Quality Objectives in them, the terms of the Annex to Directive 76/160 for this purpose, and which is presented in table 51.

To characterize water from this point of view, and under the provisions of the said Directive, the Health and Consumption Ministry draws up, and sends to the European Commission, an annual report summarising the quality of bathing water in Spain, which reflects the most relevant characteristics in the health monitoring of these waters carried out, in accordance with Royal Decree 734/1988, by the Autonomous Communities. This report is the basis for statistical control of water quality from the point of view of its aptitude for bathing, and the basic source of information in this respect in our country.

Requirements of sampling points

The requirements to assign health qualification for bathing water at a sampling point, during the bathing season, are as follows:

a) Each sampling point is representative of Bathing Area or a part of it.

b) The analytic methods used to determine each parameter are the official ones (those of the said Royal Decree 734/1988, of July 1).

c) Each sampling point has controlled, at least, the obligatory parameters: total coliforms, fecal coliforms, colour, mineral oils, tensoactive substances, phenols and transparency.

d) Sampling frequency is at least biweekly, plus a sample before the start of the season.

Health qualification

The Bathing Water Health Qualification at a sampling point has carried out in accordance with the following criteria:

"2" WATER: Water apt for bathing, of very good quality. This is water that furthermore complies with the following conditions:

a) At least 95% of samples do not exceed mandatory values for the following parameters: total coliforms, fecal coliforms, salmonella, Enterovirus, pH, colour, mineral oils, tensoactive substances, phenols and transparency.

b) At least 80% of samples do not exceed guideline values for the parameters: total coliforms and fecal coliforms.

Parameters	Guideline Value	Mandatory Value
Total Coliforms /100 ml	500	10,000
Fecal Coliforms /100 ml	100	2,000
Fecal Estreptococos /100 ml	100	--
Salmonellas /11	--	0
Enterovirus PFU /10 ml	--	0
pH	--	6-9*
Colouring	--	Without abnormal change in color*
Mineral oils mg/l	≤0.3	Without surface film
Tenso-active substances mg/l (laurisulphate)	≤0.3	Without persistent foam
Phenols mg/l $C_6 H_5$	≤0.005	≤0.05
Transparency	2	1*
Dissolved oxygen % of saturation	80-120	--
Tar residue and floating matter	Absent	--

Table 51. Guideline and Mandatory Values on the quality of bathing waters (Directive 76/160).

* Over the limits established in the event of exceptional geographical or meteorological conditions.

c) At least 90% of samples do not exceed guideline values for the following parameters: fecal estreptococos, transparency, dissolved oxygen and floating matter.

“1” WATER: Water apt for bathing, of good quality.

This water complies with the condition a), of the “2” water, but without complying with conditions b) and/or c) of the “2” water.

“0” WATER: Water not apt for bathing.

Water that does not comply with condition a) of “2” water.

“SD”: This designates those sampling points where the only existing information refers to territorial data.

“SCO”: This term refers to cases where a sampling point does not comply with requisite c) for sampling points.

“SCF”: This is assigned in cases where a sampling point complies with requisite c) but requisite d) is not fulfilled.

The Directive provides for certain exceptions in compliance with some parameters of its Annex in exceptional meteorological or geographical circumstances, not considering that under such conditions the Directive is breached provided that public health is not endangered by prohibiting bathing, with notification to the Health and Consumption Ministry and from there to the European Commission.

Current situation

Table 52 shows the results of bathing quality of inland water in Spain in the year 1997, according to the annual monitoring reports drawn up by the Health and Consumption Ministry (MSC, 1997).

As may be seen, 160 of 226 are apt for bathing, that is, 71% of the sampled whole.

Additionally, figure 180 shows, in the COCA network sampling points, a simple estimation of water’s aptitude for bathing in compliance with the Directive’s mandatory values. It also shows quality objectives existing on river reaches according to the basin management plans, and bathing areas declared to the European Union during the 1995 bathing season.

In a primary, simplified consideration, water’s aptitude for bathing has been taken as good in those points of the COCA network where the frequency of compliance in the chart exceeded non-compliance, with the same comments valid in this case as those made with respect other uses in the sections above.

3.2.4.1.4. Criteria on aptitude for fish life

Basic State Legislation on river water quality and its aptitude to support fish life is defined by the incorporation of Directive 78/659/EEC into Spanish law, on the quality of fresh waters for fish life, implemented by the Ministerial Order of December 16th, 1988 and by Annex III of the RAPAPH.

In the existing distribution of powers, Autonomous Authorities possess extensive jurisdiction on fish and environment, so the different Autonomous Communities have developed regulations on these matters which, since they fall within the scope of nature protection laws, may be mandatory as regards river quality in sections declared under special protection.

The Water Plans include the sections that the competent authorities declare to be salmon or cyprinid by virtue of Section 41.2 of the Water Act, and they contain the opportune measures to reach the quality requirements, as a minimum, shown in the adjoining summary table (table 53).

Autonomous community	Num. of Municipalities	Bathing areas	Sampling sites	“2” Water	“1” Water	“0” Water	SCF Water
ANDALUSIA	58	63	70	3	36	27	4
ARAGÓN	11	11	12	3	7	1	1
ASTURIAS	1	1	1	0	0	1	0
CASTILE-LA MANCHA	28	39	43	24	7	12	0
CASTILE-LEÓN	2	2	2	0	1	1	0
CATALONIA	9	10	11	3	8	0	0
EXTREMADURA	17	17	17	0	0	0	17
GALICIA	53	54	68	10	45	13	0
MADRID	6	6	7	0	2	5	0
MURCIA	3	3	3	0	0	3	0
NAVARRA	11	11	11	4	5	2	0
RIOJA	1	1	1	0	1	0	0
VALENCIA	2	2	2	0	1	1	0
Total	**202**	**220**	**248**	**48**	**112**	**66**	**22**

Table 52. Territorial distribution and health quality of sampling points in fresh water bathing areas.

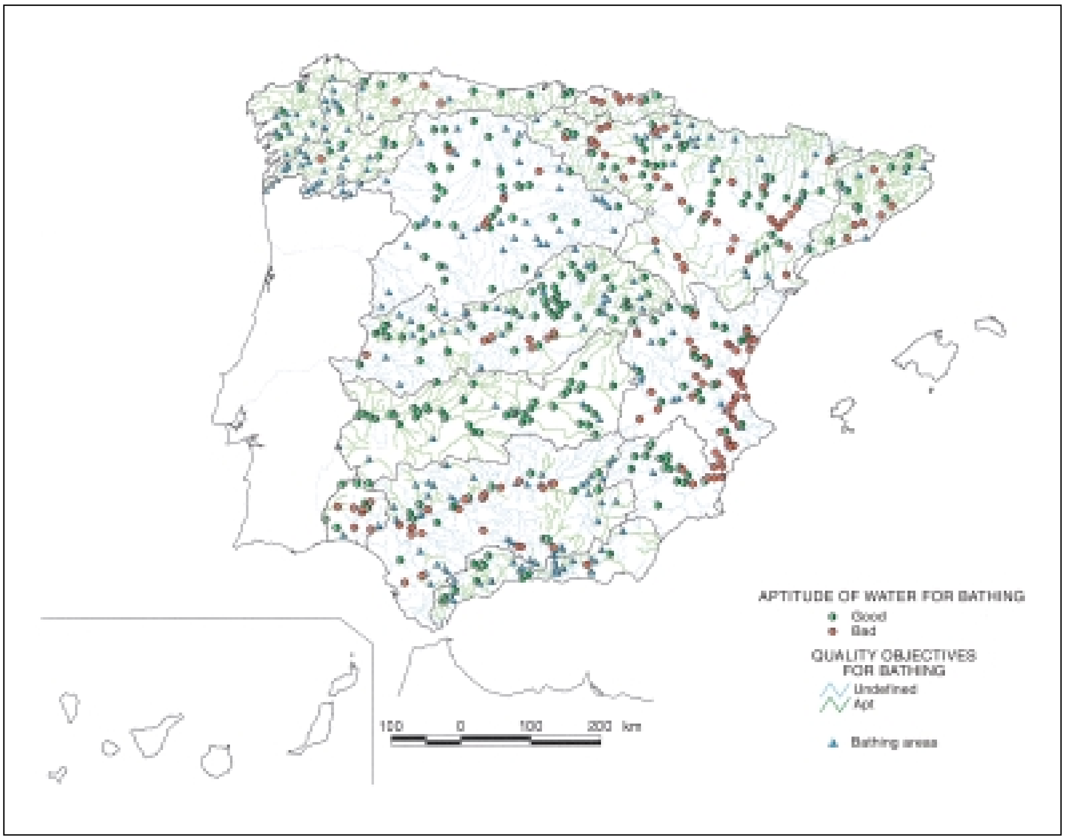


Figure 180. Map of estimative aptitude of water for bathing in the COCA network.

	Salmonid waters		Cyprinid waters	
	Guideline	Mandatory	Guideline	Mandatory
Temperature (°C)				
Increase of maximum temperature in areas of discharge	--	1,5	--	3
Maximum water temperature	--	21.5 (o)		28 (o)
Maximum water temperature during species' reproduction		10 (o)		10 (o)
Dissolved oxygen (mg/l O_2)	50% ≥ 9 100% ≥ 7	50% ≥ 9	50% ≥ 8 100% ≥ 5	50% ≥ 7
pH	--	6 - 9 (o)*	--	6 - 9 (o)*
Matter in Suspension (mg/l)	≤ 25 (o)	--	≤ 25 (o)	--
BOD_5 (mg/l O_2)	≤ 3	--	≤ 6	--
Nitrates (mg/l NO_2)	≤ 0,01	--	≤ 0.03	--
Phenolic compounds (mg/l C_6H_5OH)	--	**	--	**
Hydrocarbons	--	***	--	***
Non-ionized ammonia (mg/l NH_2)	≤ 0.005	≤ 0.025	≤ 0.005	≤ 0.025
Total ammonium (mg/l NH_4)	≤ 0.04	≤ 1****	≤ 0.2	≤ 1****
Residual chlorine (mg/l HOCl)	--	≤ 0.005	--	≤ 0.005
Total zinc (mg/l Zn)	--	≤ 0.3	--	≤ 1.0
Soluble Copper (mg/l Cu)	≤ 0.04	--	≤ 0.04	--

Table 53. Summary of Directive 78/659 conditions, on aptitude for fish life.

(o) Member States may waive this Directive for the parameters shown due to exceptional meteorological circumstances or to special geographical circumstances.

* Artificial pH variations with respect to the unaffected values shall not exceed +0.5 of a pH unit within the limits falling between 6 and 9 provided that these variations do not increase the harmfulness of other substances present in the water.

** Phenolic compounds must not be present in such concentrations that they adversely affect fish flavour.

*** Petroleum products must not be present in the water in such quantities that they 1) form a visible film on the surface of the water or form coatings on the beds of water-courses and lakes; 2) impart a detectable "hydrocardon" taste to fish; 3) produce harmful effects on fish.

**** In particular geographical or climatic conditions and particularly in cases of low water temperature and of reduced nitrification or where the competent authority can show that there are no harmful consequences for the balanced development of the fish population, the Agency may fix a value higher than 1 mg/1.

As regards this Directive 78/659, the Spanish State has defined a total of 140 areas for fish life, distributed over all the basins, except the Segura, as shown in figure 181. As may be seen, it is in the northern rivers where aptitude is greater and the number of declared areas is higher.

Figure 182 shows the aptitude of water for fish life at sampling points of the COCA network, complying with the mandatory values of Directive 78/659/CEE, jointly representing sections with defined objectives. It has been considered that water is apt for fish life when the frequency of compliance on the table exceeds that of non-compliance in the case of salmonid waters, which is the more stringent.

It may again be noticed that many points of the COCA network are not located on protected sections, so, as in the above cases, the figure should be interpreted as information on the potential aptitude of Spanish rivers to support fish life. Additionally, we should mention that if instead of salmonids, we had contrasted with cyprinids, the situation would be better than the one shown.

3.2.4.1.5. Quality according to ICG criteria, or General Quality

The General Quality Index (ICG) aims to provide a global, aggregate indicator of water quality. It is obtained by means of an aggregation formula which comprises 23 quality parameters, 9 of which, termed basic, are necessary in all cases. Another fourteen, which are generally named complementary, are only used for those stations or periods when they are analysed. Starting with mathematical weightings that evaluate each of these parameters' effect on the index total, a single, representative final value is deduced, ranging from 0 (very polluted water) and 100 (completely clean water).

The general diagnosis of the current situation in each water planning area is presented in figure 183. It indicates, for the rivers monitored in each area, the current situation of water quality expressed in percentage of fluvial network length according to the General Quality Index.

An examination of this figure quickly shows the different areas' relative situation. Thus, and bearing in mind that rates below 65 (Regular, Deficient or Poor water) are already seriously compromising the majority of possible uses, it may be seen that the situation is not completely satisfactory in some Spanish basins, mainly in those where natural cumulative flow is lower or the influence of industrial wastewater or diffuse pollution is higher.

To spatially appreciate this aggregate data, figure 184 shows the mean representative ICG of the current situation (data from 1994) in stations of the COCA network.

For better interpretation of this information, we should clarify that, as mentioned in the description of the COCA network, this network's monitoring sites have been established, in general, downstream from some discharge which should be monitored. Thus, ICG values on a river section, since they are conditioned by wastewater, are usually rather lower than they would be if the observation site was another, more representative of the river reach in question, and they should generally be interpreted as a maximum level of the true state of quality in that part of the river.

Furthermore, if the index's evolution is analysed over time, a global situation of stability or improvement can be appreciated, with some territorial worsening and various anom-

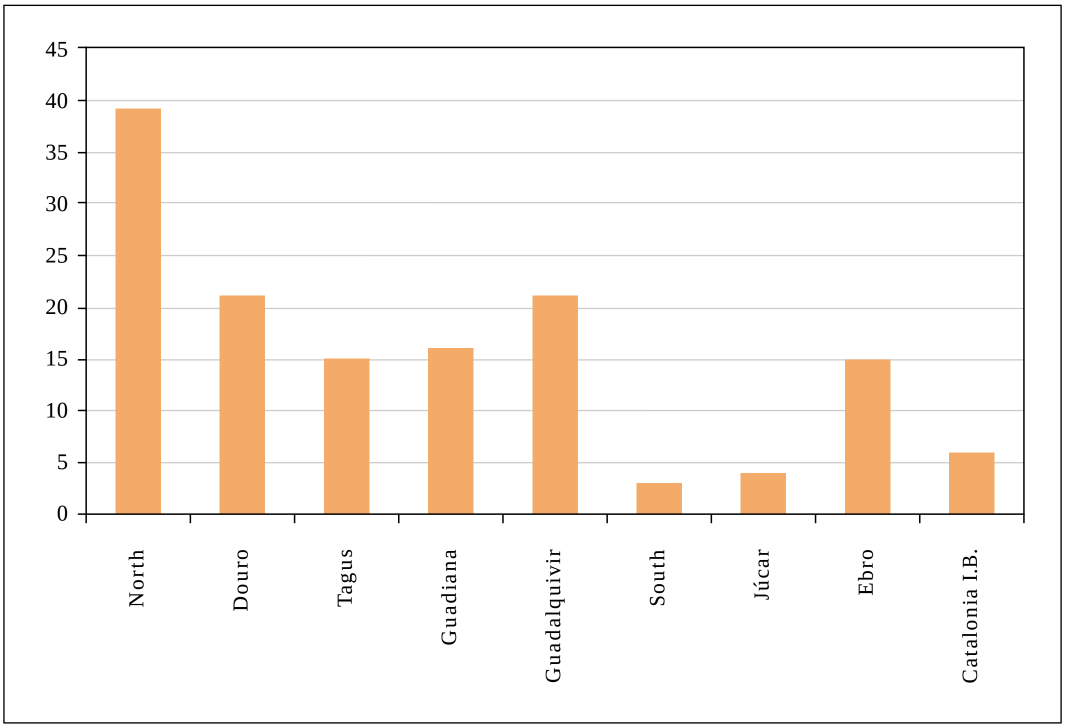


Figure 181. Number of areas declared for fish life in different basins.

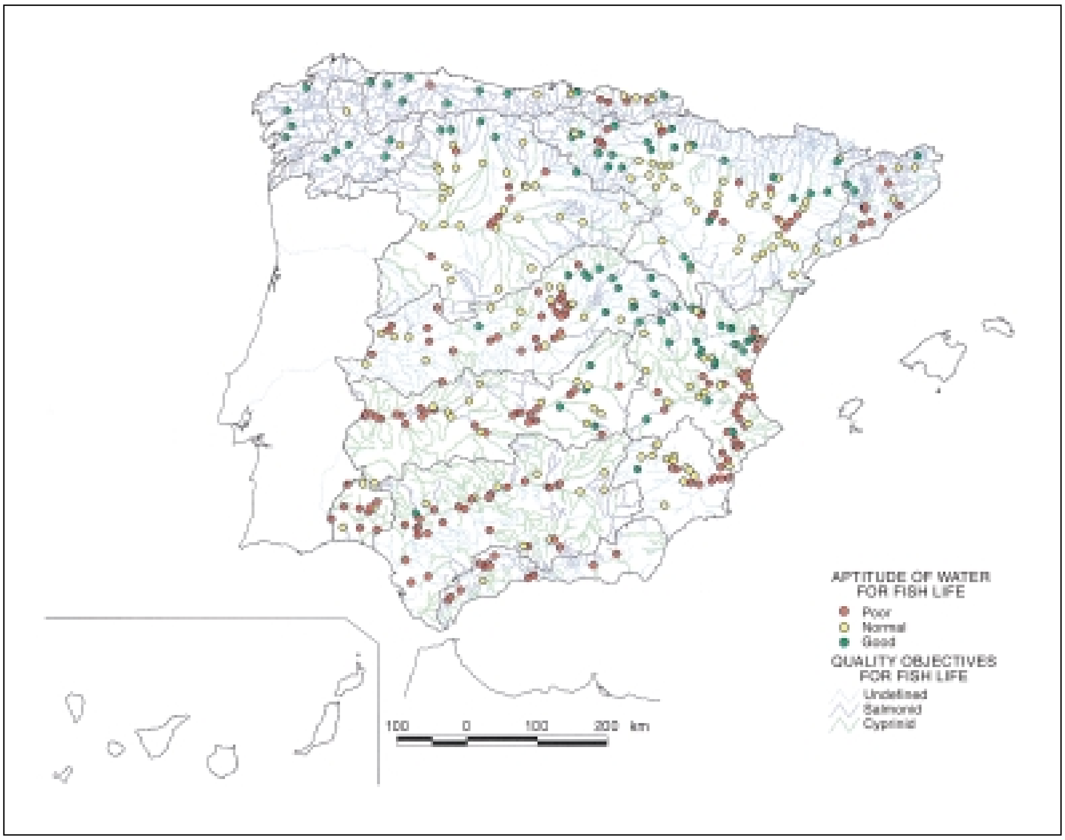


Figure 182. Map showing aptitude of waters for fish life (salmonid criteria).

alies. Studying these anomalies' causes in greater detail, the following conclusions can be made:

- Negative evolution is sometimes observed in river reaches where estimated quality is not so bad.
- The fact that water quality in some places has not evolved favourably in recent years, after significant actions being implemented to correct wastewater discharge, leads to doubts on the reliability of some old data, probably due to the handling of samples, measurement systems and apparati, etc. Although we should also point out that the magnitude of wastewater discharge has greatly increased during recent years.

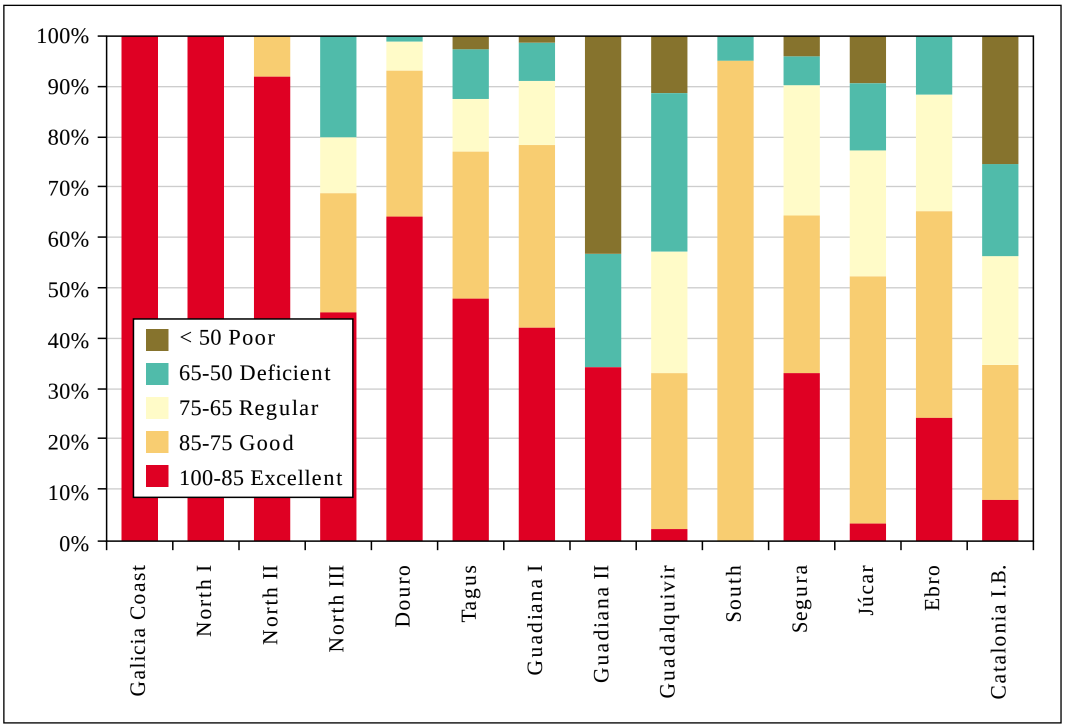


Figure 183. Current situation of water quality expressed in percentage of fluvial network length according to the General Quality Index.

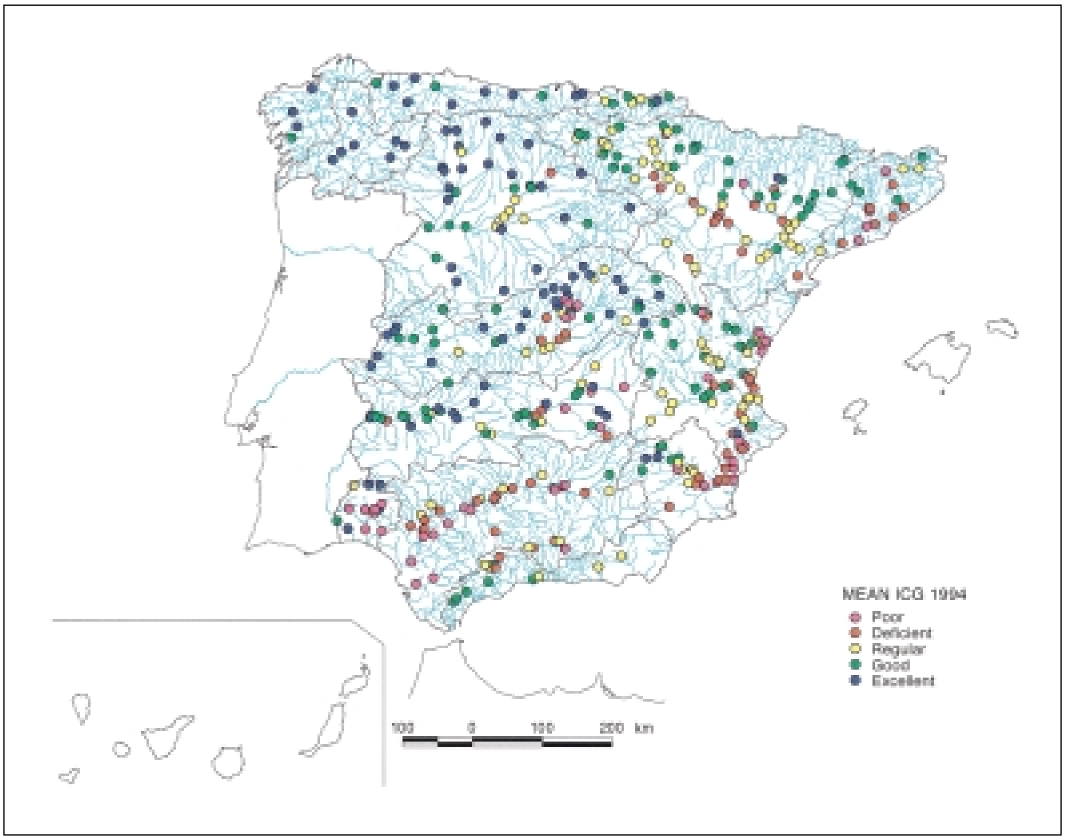


Figure 184. Map of current mean ICG in COCA network stations.

- To refine the analysis of trends it would be necessary to statistically treat the data from historical series, identifying any which show inconsistencies, filtering the possible values that lie outside the range, etc. This requires the implementation of systems to manage the analysis results, ensuring greater data reliability and verification, and, using appropriate methodologies where necessary, promoting supervised systems of automatic and continuous measurement.

3.2.4.1.6. Quality according to BOD5 criteria, or organic pollution

From the point of view of organic pollution, caused directly by urban effluent, a good general indicator is the BOD5 parameter (biochemical oxygen demand at 5 days). BOD5 values above 10 mg/l are characteristic of very polluted waters, and below 3 mg/l, pollution may be considered low.

Figure 185 shows the recent state (year 1994) of organic fluvial pollution, measured by the concentration of BOD5 at sampling points in the network.

As may be seen, the country's global situation is acceptable, although major spot problems exist on some rivers, specifically the Segura, the Guadalquivir and the Ebro.

3.2.4.1.7. Quality according to biotic index criteria

Another approach in describing water quality is provided by the biotic index. The organisms or biological communities in a fluvial ecosystem reflect the characteristics or environmental conditions of the system they are part of. Their utilisation as bioindicators generally lies in greater ease and lower cost in their observation compared with the analysis or direct assessment of the parameter they indicate. The main advantage of biological indicators is their capacity to integrate the temporary variations in the area's environmental conditions. Major spot fluctuations in the area's physiochemical parameters can go unnoticed in certain periodic monitoring if the extreme values of the altered factor do not coincide in time with the sampling moment. Bioindicators, thanks to their great diversity in fluvial ecosystems, apart from not requiring calibration cost and continuous maintenance, provide a large number of responses any level or type of alteration to the environment. They are therefore a valuable complementary tool for the automatic physiochemical water quality control networks already set up, such as the SAICA network.

In order to quantify the organisms' indicator value, numerous authors have drawn up different biological indices of water quality, based on the different tolerance levels of species or communities against polluting factors. The presence or absence of a species or family of aquatic organisms, as well as their density or abundance, are assigned a quality value according to the parameter or set of parameters intended to be assessed, depending on their tolerance level. Observations of the entire existing biological community as a whole will provide a final quality value according to the index used for each section or river studied. This type of limnological study only requires a minimum of 2-3 annual visits to the points chosen in the fluvial network.

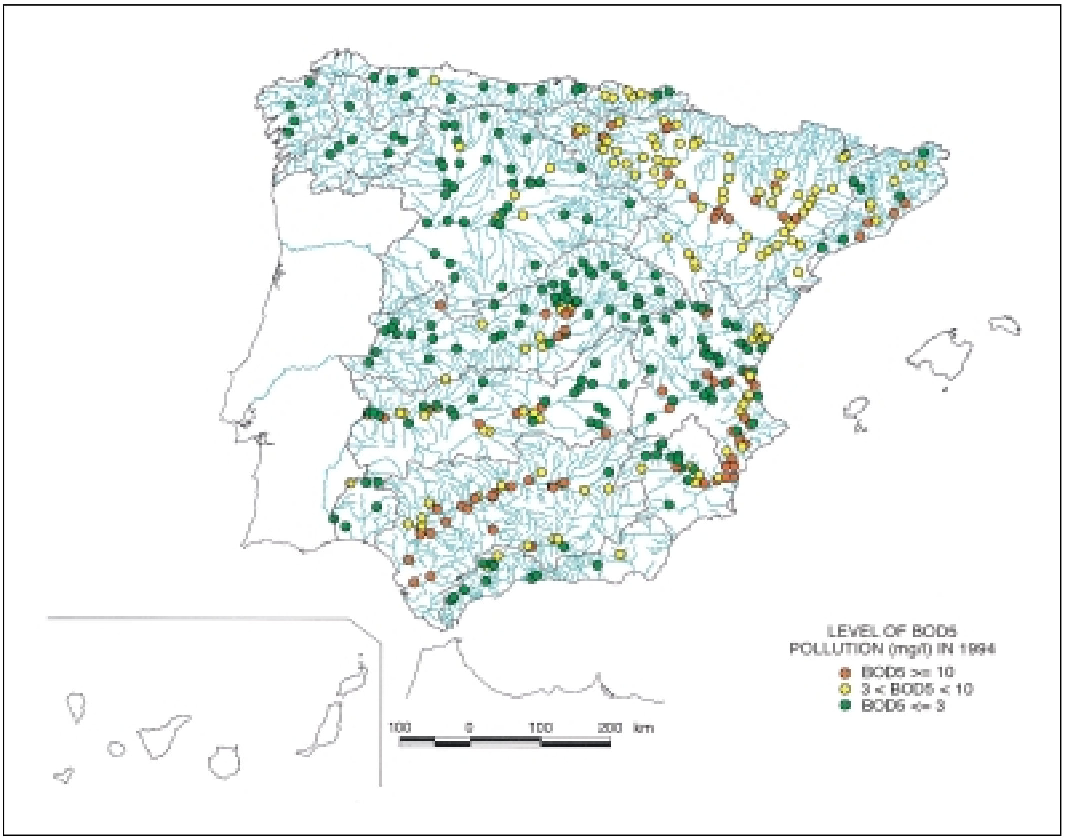


Figure 185. Map of BOD5 concentrations (mg/l) at points in the network (year 1994).

A wide variety of biological water quality indices exists for fluvial systems, and can be Typeified into the following groups:

- *Diversity* indices: based on variations in the specific composition of communities of organisms and their structure. In general, greater biodiversity corresponds to better water quality and vice versa. Examples of this type of index are those based on the information theory, such as Shannon's, or Margalef's (1951).
- *Saprobic* indices: these reflect the effects of pollution by organic matter from having urban or agricultural effluent and its degree of decomposition, upon organisms. Different approaches can be seen in García de Jalón and González del Tánago (1986).
- *Biotic* indices: these are those most used and are based on the typification of organisms according to their tolerance to pollution, assigning them points on a range varying according to the index used. The quality value for the river studied is the total sum of values for each organism present. The best-known ones are the Trent Biotic Index (TBI), the BI, the Biotic Score, or the BMWP. This last index's adaptation to existing organisms in the Iberian Peninsula gave rise to the BMWP'Index (Alba-Tercedor and Sánchez-Ortega, 1988), and is presently the most-used in our country thanks to its simplicity, accuracy and effectiveness. Its use was recommended by the Spanish Limnological Association at its National Congress in 1991.

Both the General State Administration, and some Autonomous Communities Organisations, have been developing river water quality control programmes for some time, based on the use of biotic indices, using bentonic aquatic macroinvertebrates as ecological indicators of environmental conditions. The CEDEX, for example, has been monitoring, since 1985, water quality in Spanish river basins (Avilés et al., 1997), choosing, as the most effective and applicable to greatest number of basins, the above-mentioned BMWP index (Biological Monitoring Working Party) modified to BMWP', also known here as the Alba Index, which establishes five types of biological water quality according to the index's total value. It has also been used, for example, by the Basque Government, since 1992.

The latest results obtained in recent years by different institutions from all over the national territory are shown in the map of biological quality in figure 186. The Organisations that provided this information are, apart from the CEDEX, the Hydrographic Confederations of the Ebro, the Guadalquivir and the Júcar, the Barcelona Delegation, the Generalitat of Catalonia, the Basque Government, the Junta of Communities of Castile-La Mancha and the Universities of Barcelona, Granada, León, Oviedo, Santiago de Compostela and Valencia.

The BMWP ' index assigns each family of aquatic macroinvertebrates a score from 1 to 10 according to their sensitivity to water pollution or alteration to the environment. The index value at each sampling station is obtained by the sum of points for each family found. According to the final score, each river section receives one of the following quality types shown in table 54.

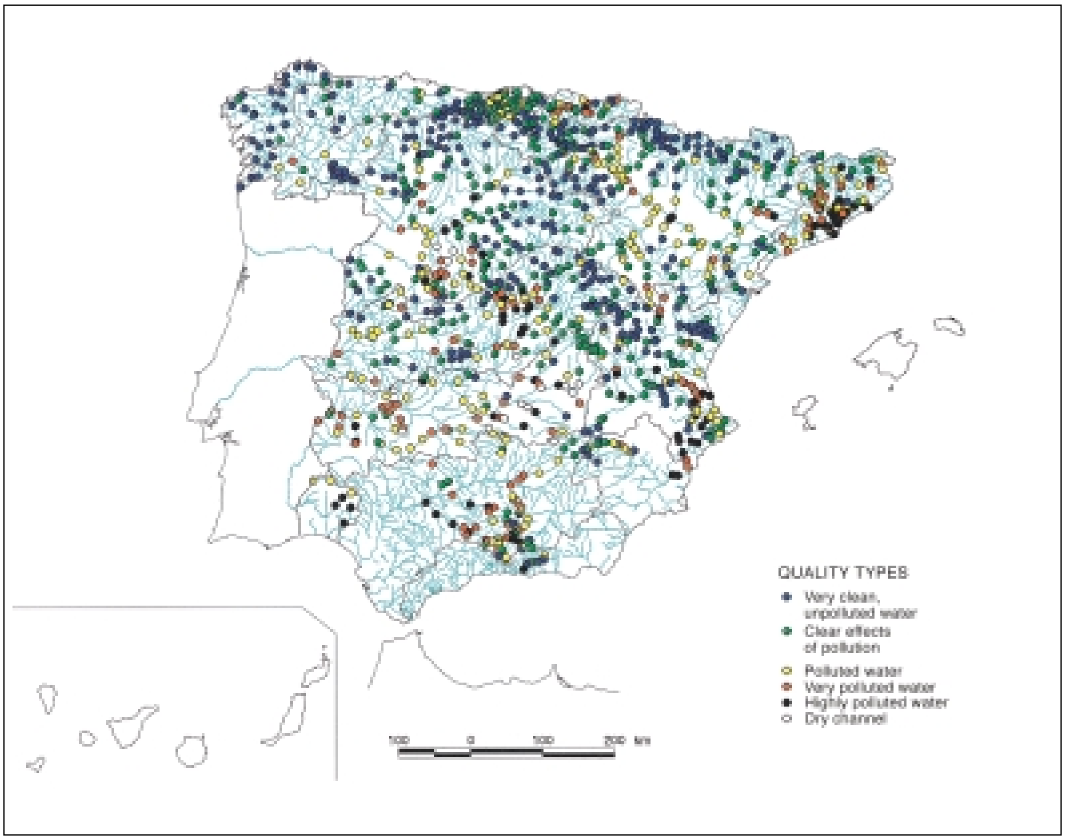


Figure 186. Map of biological quality in peninsular rivers obtained by applying the BMWP' biotic index.

So far, over 1,000 sampling stations have been monitored, distributed over 244 rivers of the major Spanish hydrographic basins. Table 55 presents the number of sampling points studied in each basin, and figure 187 shows the percentages of the different quality types in each one, and in the national territory as a whole.

It can be seen that basins with a more acceptable general state of biological water quality are those of the North, Douro, South, Júcar and Ebro, with a points percentage of polluted waters (Types IV and V) lower than 20%, and a points percentage of not very polluted waters (Types I and II) greater than 60%. Conversely, the basins in poorest condition are those of the Guadiana, Guadalquivir, Segura and you Catalonia Inland, with over 40% of points with polluted waters (Types IV and V) and less than 40% of points in a good state of conservation (Types I and II). In general, and for national territory as a whole, the number of points showing polluted water is approximately 20%, with 60% of points with water in a good state of conservation. The remaining 20% show some pollution effects (Type III).

The results provided by this index can be considered complementary to those given by the ICG. In view of the international trend of substituting the physio-chemical indices with biological indices, it is foreseeable that this type of indicator will take on greater importance in the near future.

We should mention that at present Spain does not have an official quality control network via biotic indices, although some territorial organisations have one, and this is a lack that should be corrected in the short term.

3.2.4.1.8. Ecological quality

In different rivers where intense collection and treatment work has been carried out, applying widespread secondary and tertiary treatment, and improving the water's physio-chemical quality significantly, it has been verified that this recovery is not accompanied by a similar improvement in fluvial biological communities.

In an attempt to improve this situation, overcoming the water quality's characterization in purely physio-chemi-

Type I:	>120	Very clean water
	101-120	Non-polluted or not significantly water
Type II:	61-100	Some pollution effects are clear
Type III:	36–60	Polluted water
Type IV:	16–35	Very polluted water
Type V:	<16	Heavily polluted water

Table 54. Quality types according to the BMWP' index.

	Type-I	Type-II	Type-III	Type-IV	Type-V	Total N.º of points	Total N.º of rivers
North	67	82	29	9	3	190	94
Douro	65	54	27	11	8	165	36
Tagus	38	31	25	15	8	117	31
Guadiana	1	12	24	16	11	64	23
Guadalquivir	4	9	14	13	13	53	13
South	4	2	1	0	1	8	3
Segura	1	5	3	0	1	10	3
Júcar	44	45	23	12	5	129	41
Ebro	106	73	48	11	5	243	54
Catalonia I.B.	3	18	32	32	36	121	12
Total	**333**	**331**	**226**	**119**	**91**	**1,100**	**310**

Table 55. Number of sampling points studied according to each type of biological quality.

cal-biological terms, according to its aptitude for different uses, the concept of ecological quality of a river's water responds precisely to considering a river as an ecosystem, and seeks to measure its overall good state –quality of the structure and functioning of aquatic ecosystems– from this point of view. This involves considering a large variety of aspects jointly, such as riparian vegetation, sediments, existing animal and plant communities, dissolved oxygen, the concentration of toxic and hazardous substances in the water, sediments and biota, etc. (MIMAM [1998c] pp. 33-35).

Thus, to achieve a good ecological state, reducing harmful pollution (maintaining reduced, acceptable levels of chemical contamination), is as necessary as maintaining the necessary water flow(minimum flow) and other conditions for fluvial ecosystems' preservation.

As may be expected, specifically quantifying ecological quality, thus conceived, is highly complex and extensively casuistic, comprising other previous typing, and capable of being affected by practically any action on the aquatic environment (regime effluent discharge, derivations for different uses, hydraulic works, etc.).

From a regulatory point of view, having verified the above-mentioned physio-chemical improvement –though not environmental– of some European rivers, a draft Directive on ecological water quality (94/C222/06) was proposed in 1994. After the discussion process, the regulatory focus of water policy was redirected in the European Union. In 1997, this redirection gave rise to the proposal of the Water Framework Directive, which we refer to in other sections of this White Paper, and which includes, among other issues, this concept of ecological quality. Anticipating the

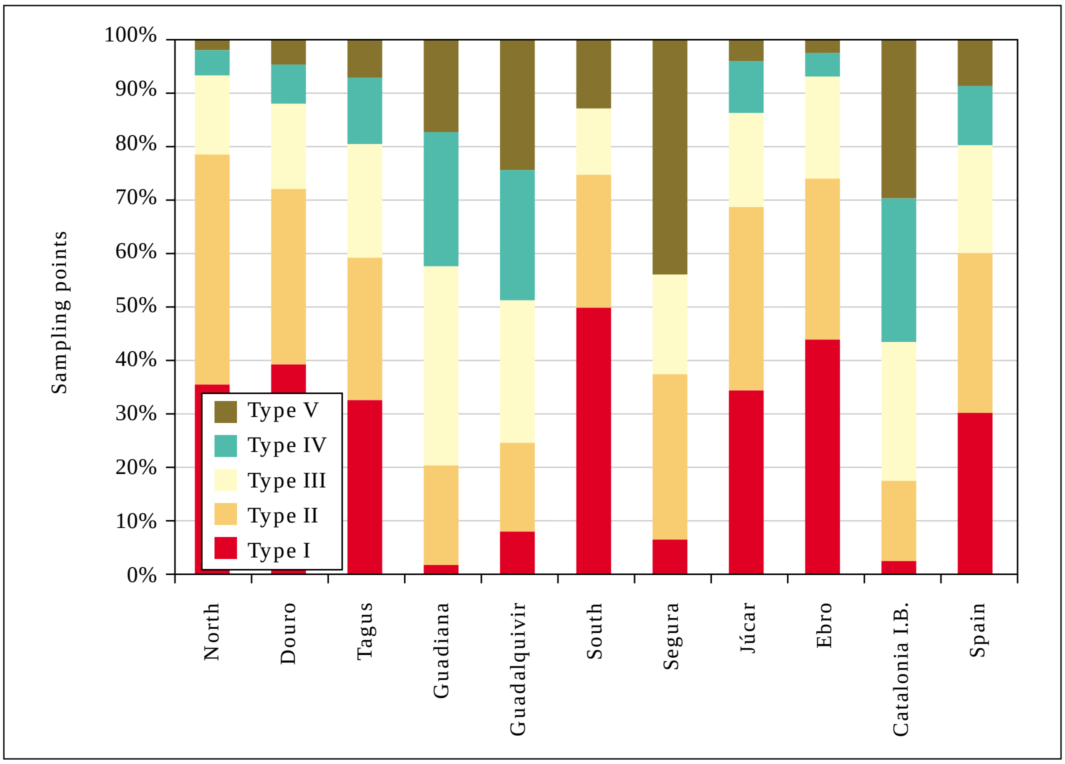


Figure 187. Distribution by basin of quality types according to the BMWP' index.

Directive's approval, the recent amendment to the Spanish Water Act has incorporated the concept of *good ecological state of the public water domain* as the primary objective of water planning.

As regards procedures for its practical application, different studies carried out have shown that, as consequence of the complexity and enormous diversity of existing fluvial situations in the European Union, there exist serious limitations when determining criteria and technical that are comparable and acceptable for all the countries within it –primary recipients of these regulations– so it has been agreed to recognise that a great deal of work needs to be done before we have feasible, appropriate technical specifications to control the ecological quality of surface waters in affected countries as a whole, and detailed studies are required to establish technical methodologies for determining ecological state in different countries with acceptably heterogeneous conditions, enabling the comparison of similar, already-existing measures in the area of the Union.

Despite these practical difficulties, which must be overcome in the near future, we have already had some interesting experiences in typing and determining the ecological state of some rivers in our country. This is the case of the annual quality control work on rivers in the Basque Country (Basque Government [1995]), or those carried out on some rivers in Catalonia (Munné et al. [1998]; Prat [1998]), experiences that will be intensified after these concepts' mandatory formal association with the specifications of water planning.

3.2.4.2. Situation of industrial wastewater treatment

Section 92 of Water Act stipulates that all activity liable to cause pollution or degradation of the Public Water Domain... requires administrative authorization, whose procedure and content is detailed in sections 245 to 252 of the RDPH. Effluent that must be submitted to the corresponding authorization is considered to be both direct discharge into channels and indirect discharge through municipal wastewater networks.

This administrative authorization also refers to effluent that can affect groundwater, on which legislation is stricter in implementing Directive 80/68, on the protection of groundwater against pollution, obliging all this effluent to have a hydrogeological study, which requires a mandatory report by the ITGE in order to be processed, and which in under no circumstances can contain dangerous substances in list I. This list I includes substances considered extremely hazardous by the European Union, and which are defined in Directive 76/464, on pollution by toxic and dangerous substances.

In Spain there exist over 300,000 discharges into surface channels, of which the majority (80%, that is, about 240,000) is indirect discharge, that is to say, running into drainage openings, sewage systems, wastewater or rainwater pipes that finally run into a channel, after the necessary purifying treatment in the municipal collection facilities. Of the 60,000 direct discharges existing (carried out directly into a water course or irrigation channel), about 10,000 correspond to municipal effluent, which is regulated by Directive 91/271/EEC, on the treatment of urban wastewater, around 40,000 discharges correspond to the stabled or semi-stabled livestock and, finally, about 10,000 direct discharges are of industrial effluent.

Prior to the Royal Decree on Effluent Regulation coming into force, and according to a study carried out in the year 1994, only 5% of companies had definitive authorization and 18% had a provisional authorization under the Ministerial Order of December 23rd, 1986. In this respect, we should mention that most of the major companies, and therefore the greatest effluent discharges, have some kind of authorization and they mostly discharge after the effluent receiving some kind of purification treatment, so the percentage of authorized polluting load is larger.

In general, authorizations for effluent discharge granted to industries are given according to the criteria laid down in the table from the Annex to Heading IV of the RDPH, which classifies discharge into three categories according to the intensity of the purification treatment, and in accordance with which the corresponding effluent charge is collected. We should highlight that these tables have the purpose of fixing an effluent charge in connection with limitations discharge depending on how the effluent is characterised. However, these are not the only limitations that discharge authorizations should consider, since both direct and indirect effluent must respect the limits set by the Directives developing 76/464/EC, on pollution by toxic and dangerous substances (list I), and the discharge limits and quality objectives included in the Substance Pollution Reduction Programmes of list II, developing article 7 of Directive 76/464, in addition to all those limits set by other Directives, which establish their own objectives of quality.

The treatment of industrial effluent can be considered not entirely satisfactory, in a general sense, since numerous unauthorised discharges take place, and a large number of substances are not subject to individual and specific regulations by industrial sector and by particular company. Direct discharge has a more exhaustive level of control than indirect discharge, but it is also true that the former usually has a higher flow and polluting load. For example, in the chemical industry just 35% of companies discharges directly into channels, but its discharge represents 85% of the sector's total polluting load.

The measures to be adopted to limit pollution should be based on the best available techniques, at a reasonable cost, within the recommendations of the V Environmental Programme of the European Union, of the contents of Directive 96/61/CEE, on integrated pollution prevention and control, and of the coming Framework Directive on Water Policies(COM(98) 76 end), which we will refer to specifically when presenting the current situation and the principles of European water policy.

In this sense, we should mention that minimising pollution comprises numerous practices, of which the final treatment of effluents is just one alternative within a global concept of the industrial process regarding pollution. That is, there exist a whole series of actions, different from treatment itself, which are set to take on increasing relevance: improvements to production processes, reduction of raw materials and final products, more environmentally and energy-efficient technological modifications, recycling and recovery of materials and of processing and refrigeration water, elimination of leakage and spillage, substitution of reagents and solvents, etc.

As regards indirect discharge, that is, that which takes place at urban collectors, Local Administrations are responsible, in most cases, for managing and granting the corresponding authorizations. As specified in the Ministerial Order of 23rd December, 1986, the Hydrographic Confederations will supervise the implementation of Reduction Plans for pollution at municipal treatment plant outlets and will verify that discharge limits and quality objectives comply with legislation. Furthermore, Directive 91/271 establishes obligations for member states with respect to regulating industrial discharge at collectors prior to December 31st, 1993. As a consequence of all this, there exist unequal regulations in this respect, with the result of possible impunity for those causing prohibited discharge and a lack of administrative mechanisms to register and authorise indirect discharge. Regulatory clarification and appropriate coordination between both Administrations is essential for these purposes.

3.2.4.3. Diffuse pollution

Most of the diffuse pollution of surface waters is related with whole series of activities, mostly agriculture and livestock farming, which are carried out over large expanses of territory, and which pollute this surface water by means of the runoff flowing over their surface area, and bearing and dissolving substances that have been deposited in the land. The most common substances found in the water in relation with this diffuse pollution belong to the categories of fertilizers and phytosanitary products, used in agriculture, of organic matter and toxic substances, associated with livestock activities and urban wastewater or certain industrial activities.

Diffuse pollution tends to take on increasing significance in degrading water resources, because the greater the level of treatment and limitation of spot discharge, the greater the increase that all distributed or diffuse pollution will represent for pollution as a whole. As an example, it is estimated that the quantity of nitrogen of diffuse origin in the Douro basin represents approximately 80% of total nitrogen quantities in the basin. In the Tagus and Guadiana basins, pollution of diffuse origin represents almost half the total quantities of nitrogen.

Nitrate pollution is described in greater detail in the section on groundwater pollution. The presence of phytosanitary products in surface waters has not yet been studied sufficiently. The COCA network does not analyse pesticides in the water, so it is almost impossible, in general, to assess its presence and effect on resource quality. Some of the possible provisions of the proposed new Directive on drinking water include more exhaustive control and more demanding limitations for this type of pollutant in water intended for human consumption. Their presence has been detected, although without being too representative, in some hydrogeological units, through spot campaigns whose results are summarised in other sections.

As for diffuse pollution caused by urban wastewater and by toxic and dangerous effluent deposited in the land without control, other sections highlight the significant negative effects that such deposits can mean for the state of water quality (very specifically, for groundwater).

We should note that a major deficit exists with respect to studies that clearly determine the diffuse component of pollution in Spanish surface waters. It is clear that the lower qualities detected in the water during many phenomena of floods and heavy rainfall are due to the disturbance of pollutants previously deposited in the land, and which are in fact mobilized during these short periods of time, causing spot pollution and significant episodes of pollution.

Limiting diffuse pollution can only be achieved by means of preventive measures such as reducing the application of fertilizers and pesticides, reducing the application of manure, and regulating wastewater in those areas with significant potential for diffuse pollution. This type of measures include those proposed by Directive 91/676, on the protection of waters against pollution caused by nitrates from agricultural sources, which was incorporated into Spanish legislation by Royal Decree 261/1996 of 16th February.

Moreover, it may be necessary to declare protection areas in reservoir catchment areas, to prevent, apart from eutrophication, possible cases of microbiological pollution that has not been halted with the conventional treatments laid down for A2 and A3 quality water. This is the case, for example, of the Giardia and Cryptosporidium protozoa due to excrement borne in the water from bovine livestock pasture areas (Torobin, 1998).

3.2.4.4. Thermal pollution

Thermal pollution refers to excessive changes in the temperature of aquatic environments, due to human activity modifying certain biochemical reactions in the water and causing physical or chemical change.

Most thermal discharge comes from thermal power stations, but they can also be caused by air-conditioning and refrigeration systems, paper industries, steel, rubber, petrochemical, and gas liquefaction and sea water desalination plants. The heat given off is a function of thermal yield (in nuclear power stations 33% and in coal, diesel plants, etc. 40%). Over 60% of the heat produced is released into the atmosphere. Refrigeration processes use a large quantity of water that is later discharged at a higher temperature than at intake. Numerous power stations have intakes and outlets in the sea, but many others use inland waters. In an open circuit, they discharge directly into an aquatic ecosystem, and they require significant flow; in a closed circuit, the water is cooled in refrigeration towers, pools, etc. and reused in the process. Thermal discharge alters water's viscosity, evaporation rate, saturation point for solids and dissolved gases, etc. affecting the metabolism, growth and reproduction of biotic communities and changing predominance toward more thermophilic species. It increases fish and macroinvertebrates' growth, but also their nutritional necessities, conditioning species' survival and migration.

In Spain, as of the late fifties, numerous conventional and nuclear thermal power stations have been built, as shown in the adjoining map (fig. 188).

The RDPH stipulates and increase thermal maximum of 3 °C in rivers, and a maximum temperature of 30 ºC for discharge into lakes or reservoirs. The RAPAPH stipulates 1.5 °C in salmonid waters, and 3 ºC in cyprinid waters, with maximum values of 21.5 °C and 28 °C, respectively. It adds that the Hydrological Plans should set no less stringent quality objectives. In concession procedures for refrigeration, if power exceeds 300 MW it is mandatory to assess environmental impact.

Spanish thermal power stations that use inland waters show a variety of problems, although generally speaking they do not usually exceed the above-mentioned limits due to the implementation of refrigeration towers (cases, e.g., of Zorita and Ascó). Some exceptions are Aceca the power station, with high discharge flow into an already highly-altered environment, or to a lesser extent, Garoña, Ascó and Puentes de García Rodríguez, because they discharge into large water bodies, or they have somewhat lower effluent flow.

3.2.4.5. Pollution by toxic and dangerous substances

This type of pollution has specific treatment in community regulations through Directive 76/464/EEC, on water pollution by toxic and dangerous substances, whose annex lists the substances, mostly of industrial and agricultural origin (phytosanitary products), considered highly dangerous by virtue of their bio-accumulation, persistence and toxicity.

This Directive defines two lists, List I of substances for which measures should be taken to eliminate their presence in the waters, and List II of substances whose water pollution should be reduced.

List II includes all the substances which, belonging to substance categories considered in List I, do not have emission limits and quality objectives specified.

In developing this Directive, a total of seven Directives have been issued, specifying the quality objectives and emission standards, for just 17 substances of all those liable to be included in List I.

Directive 82/176/EEC sets these values for mercury discharges by the chlor-alkali electrolysis industry and 84/156/EEC for the rest of mercury treatment facilities;

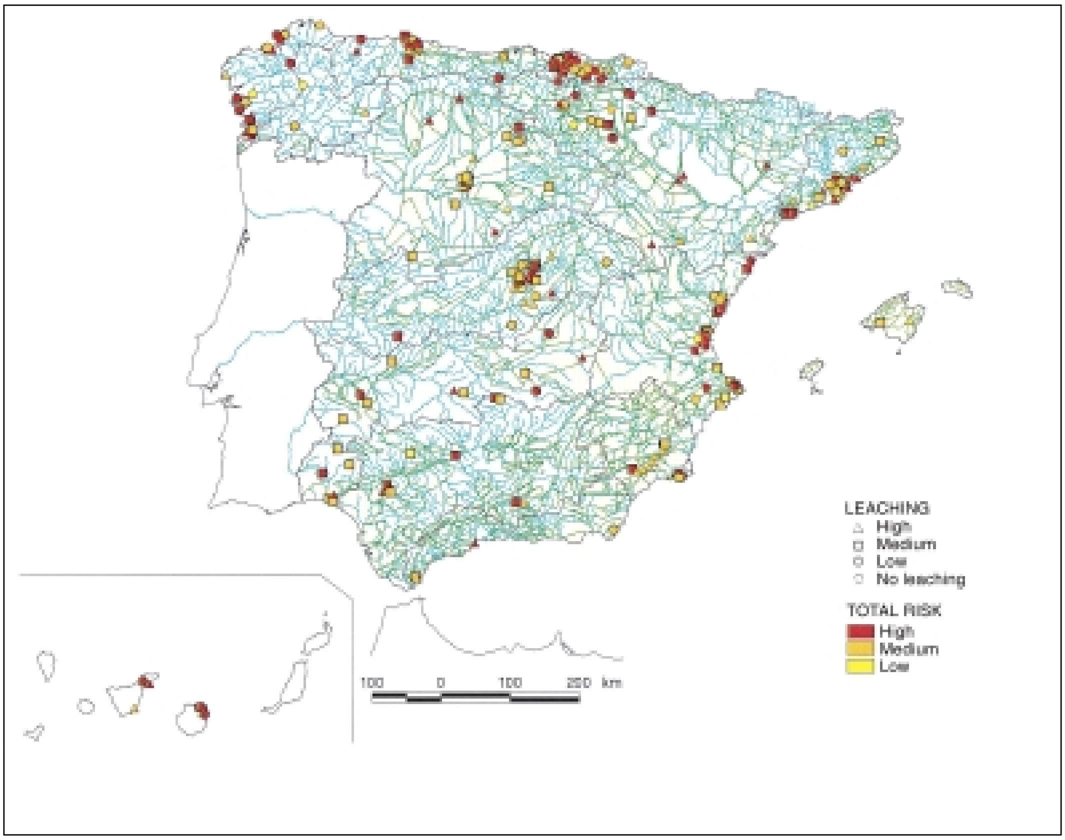


Figure 188. Map and location and main characteristics of conventional and nuclear thermal power stations.

83/513/EEC for those poured of cadmium; 84/491/EEC for hexachlorocyclohexane discharges; 86/280/EEC for DDT, pentachlorophenol and carbon tetrachloride, 88/347/EEC sets the values for discharges of aldrin, dieldrin, isodrine, hexachlorobenzene, hexachlorobutadiene and chloroform and 90/415/EEC for discharges of 1,2 dichloroethane, trichloroethylene, tetrachloroethylene and trichlorobenzene.

Furthermore, community legislation obliges each member state to set up action programs to reduce water pollution by substances in List II and those substances of List I that do not have specific daughter directives. These programs should include control and limitation by means of emission regulation for the mentioned discharges, as well as quality objectives for receiving waters, possibly including specific provisions on the composition and utilisation of substances, bearing in mind the most recent economically feasible technical advances.

In this sense, an effort is being made in Spain to acquire greater knowledge of our waters' problems regarding these substances, by means of surveillance and control, and Action Programs aimed at reducing pollution caused by these substances, as stipulated by article 7 of the Directive.

Thus, inventories on discharges of these substances are being updated, and control networks are being set up for water, silts and biota in several hydrographic basins.

As regards reduction programmes, actions are being implemented on two levels; on one hand action programmes are being carried out in industries to eliminate and reduce pollution caused by these substances in both surface water and groundwater, and on the other hand efforts are being made to set up sectoral programmes for pollution reduction and discharge regulation.

In this sense, negotiations are taking place to draw up Sectoral Discharge Regulation Plans (stipulated in Royal Decree 484/95) laying down homogeneous emission limit values for discharges in the paper, pulp and cardboard industries.

Nevertheless, Directive 76/464 will tend to disappear with the approval of the current Framework Directive, whose article 21 lays down that the Commission should define a list of high-priority substances to substitute the current Lists I and II.

Work is under way to define this List of high-priority substances, which will be common to all the countries of the European Union.

3.2.4.6. Discharge of solid waste

Pollution of water resources, surface and groundwater, by means of discharge into the soil, is regulated by section 84.b of the Water Act, which stipulates as an objective in protecting the Public Water Domain to *prevent the accumulation of toxic and dangerous compounds in subsoil, liable to pollute groundwater*; section 89.b, which generally *prohibits accumulating solid waste, rubble or substances, whatever their nature and location where they are deposited, which represent or may represent a hazard in polluting waters or degrading the environment*; sections 40.g and 40.i defining the contents of basin management plans and binds them to contain protection perimeters and measures on the conservation and recovery of the resource and the affected environment, in addition to guidelines on aquifer protection.

The Spanish legal system deals with solid urban waste separately (Act 42/1975 of 19th November, and Legislative Royal Decree 1,163/1986) plus that which is produced by industrial activity and which is deemed dangerous (Act 20/1986 of 14th May, Royal Decree Regulation 833/1988 of 20th Julio). Whatever its origin, solid waste, unless appropriately collected, treated and eliminated, can give rise to serious health and environmental problems (air, water and soil pollution) as well as high economic and social costs (MIMAM [1998d]; CEDEX [1998e]).

It has been shown that approximately half of urban waste consists of organic matter and that approximately 20% of this is paper and cardboard. Spain generates an average of 1 kg of urban solid waste per person per day. As regards treatment, approximately 14% is used as compost, 64% is deposited in controlled dumps and 18% represents uncontrolled dumping.

There exists a large quantity of solid urban waste which is deposited in the land without any kind of treatment or control, which represents a serious hazard of pollution in soils and aquifers with a certain level of vulnerability. Approximately 28% of the territory is at high risk from the pollution derived from solid waste dumping, particularly over a third of the surface area of Aragon, the Balearic Islands, Valencia and Madrid have these characteristics. The figure is greater than 30% in the basins of the Júcar, Segura, Ebro and South, Balearic Islands (84%) and the Canaries. We should highlight that at present landfills are being systematically sealed in several Autonomous Communities.

As regards toxic and dangerous waste, the scope of application of Act 20/1986, of 14th May, basically on toxic and dangerous waste, excludes "effluent whose discharge into the sewage system, into water courses or the sea is regulated by the regulations in force", but it stipulates that waste management operations should avoid transferring pollution or environmental deterioration to another receiving area, which is applicable to discharge or dumping that contains residuals classified as such.

Industries that produce toxic and dangerous waste are highly varied, but it may be stated that the chemical industry (33%), automobiles production (11%), the manufacture of metallic products (10%), the food industry (8%) and the paper industry (8%) add up to over 70% of the total production.

The National Polluted Land Recovery Plan (1995-2005), approved by the Council of Ministers on 17th February, 1995 (MOPTMA, 1995b) highlighted the importance in the existence of *4,532 locations identified as potentially polluted due to the type, concentration of pollutants and their potential dispersion, the biophysical and anthropic system in which they are located and due to these areas' level of vulnerability.*

Of the 259 locations characterized and studied in greater depth in an initial phase (in a second phase, another 120 locations were characterized) it is apparent that the *risk of groundwater pollution is high in 60% of the locations, since they are located in average to high-permeability lands* and show pollutants with high toxicity level, such as heavy metals (arsenic and mercury), mineral oils, hydrocarbons, phenols, lindane, DDT (Dichlorodiphenyltrichloroethane, a much-used pesticide in the past and today prohibited by a large number of countries due to its significant toxicity), PCB (polychlorinated biphenyl, a very toxic family of compounds, persistent and non-degradable, present in pesticides, paints, inks, etc. and which are a major component in electric transformers), etc. The possible level of surface water influence *can also be estimated equally high since almost 50% of them are less than 50 meters from the channel*.

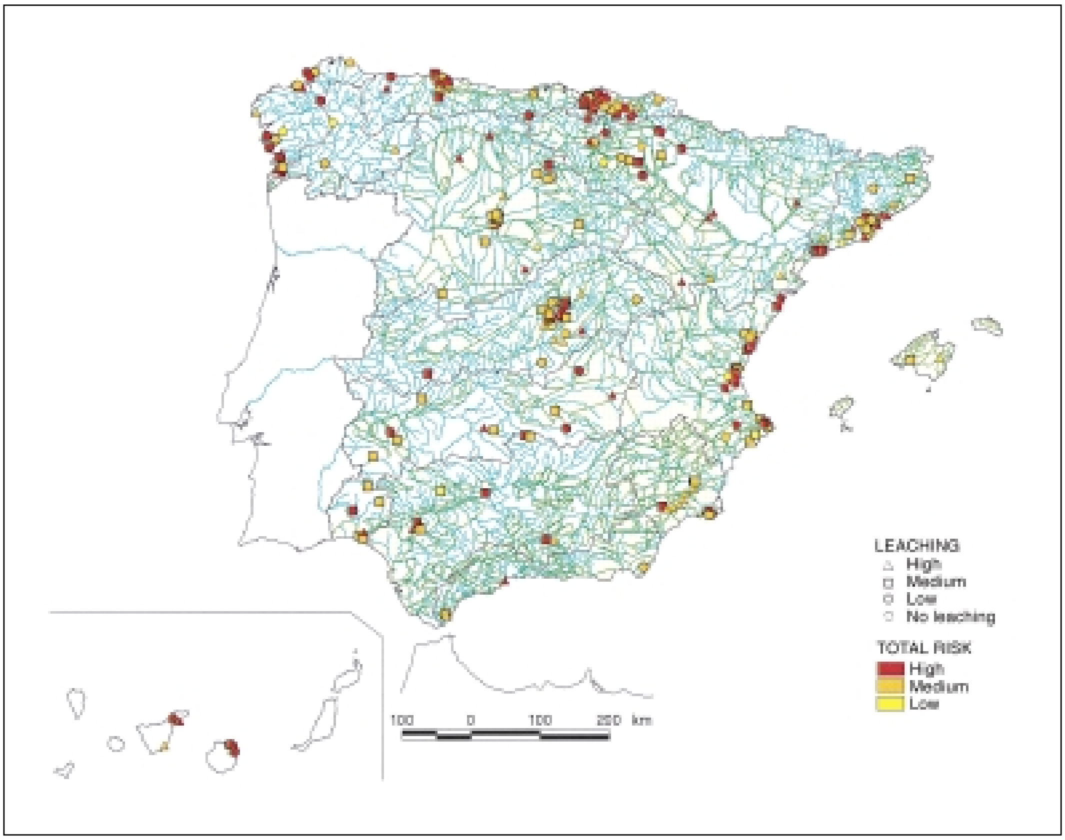
We should highlight that 61 of these locations are deemed *high priority due to the serious effects on groundwater, their imminent planning re-classification, the special hazard of the pollutants present in them, their proximity to urban zones or because they area areas of Public Water Domain or hydraulic easement*. These high-risk locations affect about 38 million m^3 of soil and about 9 hm^3 of groundwater.

The map in figure 189 shows, together with the hydrogeological units, soil contaminated by high-risk substances, according to the above-mentioned Plan.

3.2.4.7. Radioactive pollution

The presence of radionuclides in water may be of natural or artificial origin. The first case includes radiation from outer space, cosmic radiation, and radiation from natural radioactive elements present in the soil and in the rocks, associated mainly with granite formations and the sedimentary formations they give rise to. The MARNA project [Map of Natural Radiation in Spain, R+D project developed by the Nuclear Security Council (CSN) and the Empresa Nacional de Uranio S.A. (ENUSA)] has the aim of drawing up a map of natural radioactivity in peninsular Spain with data from over 30 years' sampling campaigns, in which gamma radiation was measured, providing values ranging between 1 mR/h and 30 mR/h, with the national average at about 9 mR/h. As for the second group, possible artificial radiation present in water can come from nuclear power stations, uranium mining, storage of nuclear waste, medical applications and industrial applications.

Assessing the possible radioactive pollution of water is of great importance since it can affect both the ecological functions of the receiving area and the health of people who are exposed to this potential source of radiation. The effective presence of radio-isotopes in the water not only depends on the natural or artificial sources of possible emis-



Figures 189. Map of soil contaminated by high-risk toxic and dangerous substances.

sion, but also on a series of characteristics of the physical and biological environment, in such a way that a significant part of radioactive pollution accumulates in the trophic chains and in silt. As a result, correctly characterising this peculiar form of pollution is not only determined by water analyses but should be supplemented with the study of aquatic flora and fauna (bioindicators) and of fluvial silt. This is in fact carried out in the environments of all nuclear facilities, systematically monitoring water, bed silts, bank silts, fish, indicative organisms, etc..

Regulations on radioactive pollution of water in Spain are mainly contained in the Technical-Health Regulation of Supply and Quality Control of Drinking Water for Human Consumption (Royal Decree 1138/1990), whose Annex G includes some total alpha activity indices of 0,1 Bq/l (Becquerel Bq is the activity unit in the international system), and total beta activity of 1,0 Bq/l, which should not be exceeded.

The CSN's Security Guideline 7.7 (Rev.1) also lays down that for the specific case of tritium, the activity concentration value corresponding to the research level (situation in which the continuous intake of drinking water could give rise to a dose of or above 0,05 mSv/año, calling for research into the origin of the radioisotopes present in the water) is of 4.000 Bq/l.

Furthermore, the new Directive on drinking water 98/83 EC includes radioactivity within the parameter indicators, proposing 100 Bq/l H-3 as a parameter indicator.

We should note that these regulations (Royal Decree 1138/1990 and Guideline 7.7) are only applicable to drinking water, and not, therefore, to natural surface or groundwater prior to being treated.

With this exception, the samples taken in the National Radiological Surveillance Network since the year 1978, at its approximately 100 sampling points, produce the following conclusions, reflecting the geographical and edaphological characteristics of the soil through which the water runs, and the influence of urban waste and nuclear facilities (see figure 190).

In the Douro basin, there are two nuclear facilities with radioactive waste, the Juzbado factory, on the River Tormes, and the Saelices uranium mines, on the River Águeda. Radioactivity levels detected in Vega de Terrón, on the frontier with Portugal, indicate that these facilities' influence is not significant.

In the Tagus basin, there are three nuclear facilities, the Trillo, Zorita and Almaraz power stations, plus the urban radiological influence of Madrid, causing appreciable concentrations of tritium in this group (Security Guideline No. 77 Rev.1, on the Radiological Control of Drinking Water, lays down that for the specific case of tritium, a very low toxicity radionuclide, the activity concentration value corresponding to research level is 4.000 Bq/l). A total alpha activity above 0,1 Bq/l can also be seen in the reach between Aranjuez and Valdecañas, whose origin lies in the natural uranium eroded from the receiving basin's terrain and in urban waste.

It seems to be clear that the Trillo power station has a radiological effect on the waters of the Tagus-Segura inter-basin

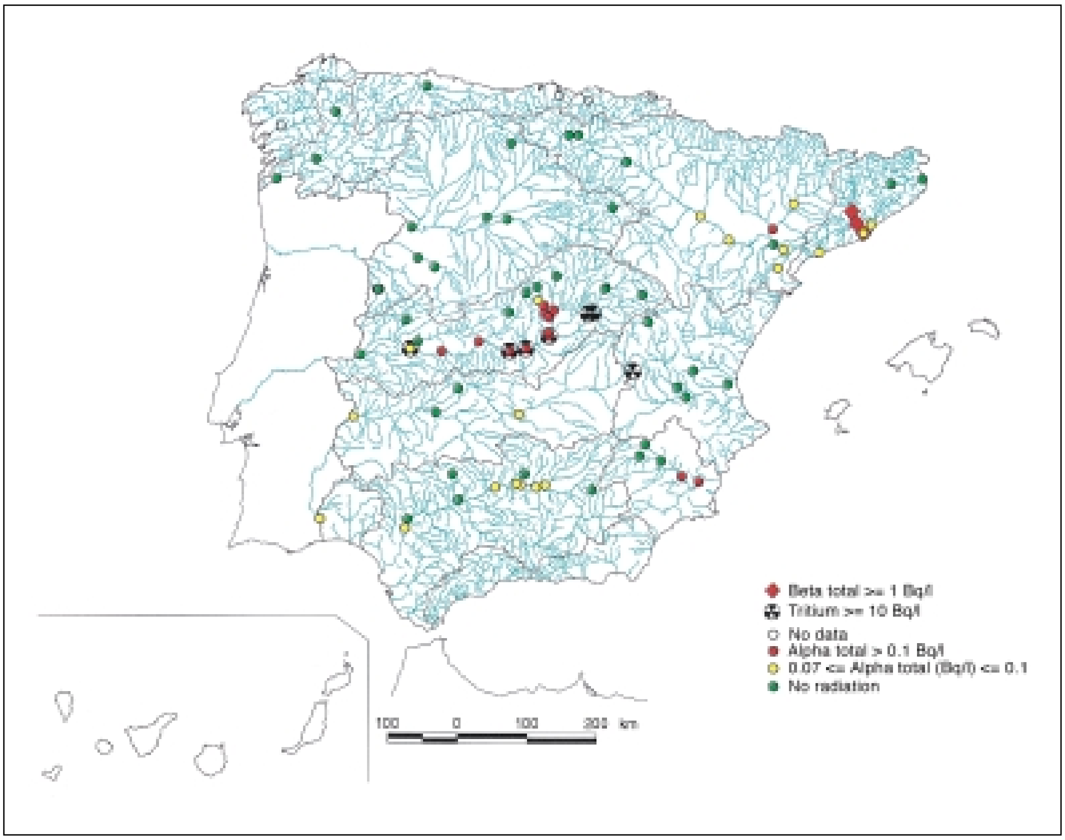


Figure 190. Map of water's radiological situation.

transfer, and in the Alarcón reservoir, mean tritium values of around 15 Bq/l are obtained, dropping to 8 Bq/l before joining with the River Mundo.

Finally, the River Llobregat shows high values of total beta activity indices due to the addition of salt as it passes through the area's mining basin.

Figure 191 shows the evolution of total alpha activity since 1990 in some of the points mentioned, illustrating the absence of clearly identifiable upward or downward trends.

It is interesting to note that in the 20 years since the National Radiological Surveillance Network began functioning, artificial gamma-issuing isotopes have never been detected above their corresponding minimum detection limits.

We should also point out that radioactive concentrations detected could only represent health risk, arising from their consumption, if such waters were actually used as drinking waters in urban supply. Generally speaking, they are not used for this purpose on the reaches studied and, moreover, analyses were carried out directly in the river channels, and not in the water that finally arrives in homes, already treated as drinking water, whose analysis and control corresponds to the Autonomous Communities.

It would also be appropriate to clarify a point of great interest when assessing the data above. The health risk can be diagnosed when it is "associated with a potential committed effective dose of 1 mSv/año" (Sievert Sv is the unit of dose in the international system). That is, the seriousness of exposure not only depends on the magnitude of the dose but also on the exposure time.

The CSN recommends that only in cases where the dose is exceeded should the public authorities take action (action level). As the CSN well advises, the health risk from consuming water with some indications of radioactivity does not by itself involve a health risk, even if the alpha and beta emission values have exceeded Technical Health Regulation recommendations. In these cases water samples would have to be closely studied, analysing and checking that a group of certain radioactive isotopes exceeds preset amounts (CSN, 1994).

3.2.5. The pollution of bodies of water

3.2.5.1. Introduction

The contamination of inland water bodies (reservoirs, lakes and lagoons) has two main sources. On one hand, the discharge of urban and agricultural wastewater, and on other hand, industrial discharge.

The first of these sources is basically organic, and its treatment is relatively easy since it is biodegradable in the short term, although the massive use of detergents greatly complicates treatment processes. The second source of pollution consists mostly of chemical products, many of them toxic, as phenols, dioxins, heavy metals, as well as hydrocarbons, radioactive substances, etc., more difficult to break down than the contents of urban wastewater.

Knowledge of the pollution level in these bodies of water is relatively good, although some less-known spot problems exist, and with aged data.

Below, the specific problem of eutrophication in lakes and reservoirs is described in greater detail.

3.2.5.2. Eutrophication of lakes and reservoirs

Eutrophication is a complex process, fertilising natural water with nutritious substances, especially nitrogen and

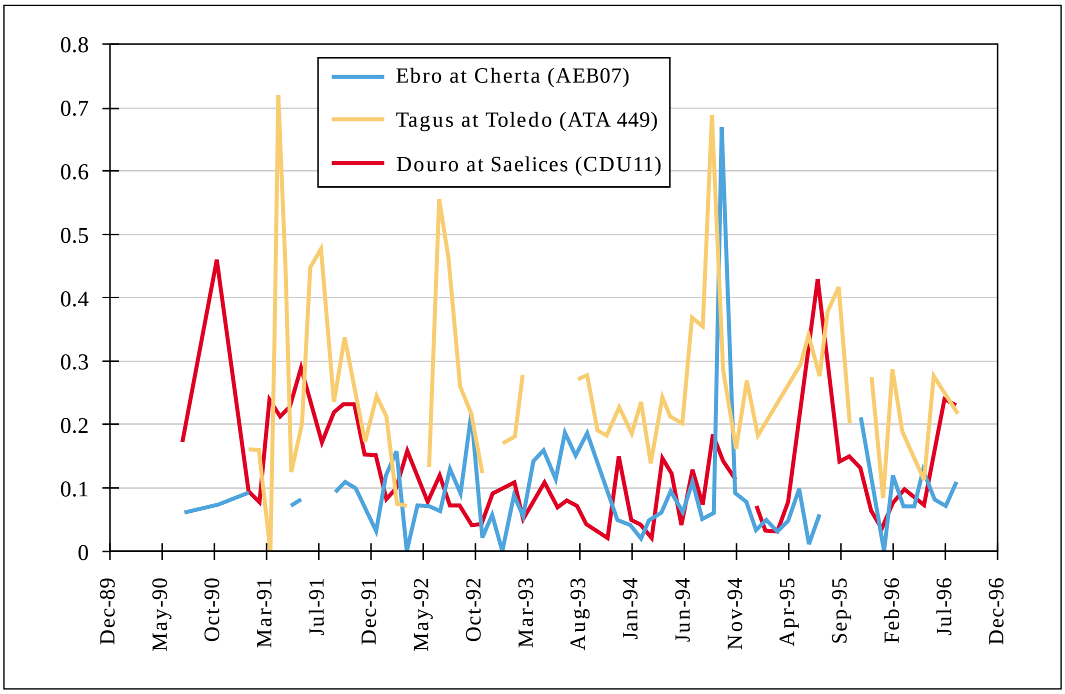


Figure 191. Total alpha activity at some points in the basins of the Tagus, Douro and Ebro.

phosphorous, in a way that the aquatic vegetation can assimilate, causing an increase in algae populations, a growth in productivity on all levels of the food chain and a deterioration of the water's initial physio-chemical characteristics. Although it can take place naturally, the main cause of this phenomenon is usually human activity.

Lakes and reservoirs are usually classified into eutrophic, mesotrophic and oligotrophic, according to their capacity to produce more or less abundant vegetable biomass.

Eutrophic waters are characterized as having high primary productivity and a large concentration of nutrients. As a general rule, they are quite shallow, cloudy in summer due to the effect of phytoplankton, and with low dissolved oxygen concentrations in their beds, tending towards anoxia during the stratification period.

Oligotrophic waters have a low nutrient content, they are not very productive, transparent, deep and with a high dissolved oxygen concentration in the hypolimnion.

Mesotrophic water lies half-way between the two.

In accordance with OECD criteria (1982), two new trophic categories can be included: ultraoligotrophic and hypereutrophic, as shown in table 56.

In Spain, the problem of eutrophication in reservoirs has been studied more, especially in numerical terms, than lakes and lagoons (Margalef et al, 1976).

To determine of trophic level of Spanish reservoirs, information has been gathered from limnological studies carried out by the CEDEX for the DGOHCA (1990-1997), and the information given by images from the Thematic Mapper sensor of the Landsat-5 satellite in teledetection work in the basins of the Ebro (1990), Guadiana (1991), Tagus (1992) and Douro (1992), also carried out by the CEDEX for the DGOHCA. Furthermore, so as to update the existing information on eutrophication, it has been completed with data from Hydrographic Confederations, Guipuzcoa Provincial Council, Añarbe Water Association, Bilbao Water Consortium, municipal companies and Universities.

Figure 192 shows one of these images, of the Torre de Abraham reservoir drainage area in the Guadiana basin.

The reservoir's total volume on which information is available amounts to 49,684 hm^3, representing over 90% of the existing total, so we would have to consider it as completely representative.

Figure 193 shows the proportions of degraded water volume (eutrophic or hypereutrophic) with respect to existing total volume in each planning area, and the average overall percentage (almost 50%), in the hypothesis that the trophic state remained at maximum capacity.

As may be seen, the basins with reservoir-stored water in the worst condition are the Tagus (68%), Catalonia Inland Basins (67%), Galicia Coast (64%) and Douro (57%), leading to almost half (48%) the total volume of Spanish reservoirs to be in an advanced state of eutrophication.

Although the figure of 48% of the dammed volume may initially seem high, it is not it actually so much since considering of eutrophic water to be bad, or oligotrophic water to be good, depends on the use that is made of it and, therefore, quality objectives will be established according to the purpose for which the water is intended. Thus, a supply reservoir should have such quality that it could be treated with conventional, low-cost methods, and of the total volume of degraded water only 14% is used for supply.

The map in figure 194 shows the current trophic level of reservoirs larger than 10 hm^3. It may be seen that the most eutrophic reservoirs are located in the lower reaches of the main rivers, after they pass through large urban zones. Others are dominated by basins with substantial populations, agriculture and livestock farming activities. Oligotrophic reservoirs, on the other hand, are mainly located river headwaters, in cold, uninhabited areas, covered with a dense vegetation.

3.2.6. Groundwater pollution

The natural quality of groundwater, understanding this to mean its original composition, is the product of infiltrated water interacting with the materials in comes into contact with during the hydrological cycle. Certain external factors, mainly of anthropic origin, can cause alterations to this

Trophic category	Chlorophyll Average	Chlorophyll Maximum	Phosphorous Total	Secchi Average	Secchi Minimum
Ultraoligotrophic	< 10	< 2.5	< 4.0	> 12.0	> 6.0
Oligotrophoic	< 2.5	< 8.0	< 10.0	> 6.0	> 3.0
Mesotrophic	2.5 - 8	8 - 25	10 - 35	6 - 3	3 - 1.5
Eutrophic	8 - 25	25 - 75	35 - 100	3 - 1.5	1.5 - 0.7
Hypereutrophic	> 25	> 75	> 100	< 1.5	< 0.7

Chl. average = yearly average of chlorophyll concentration in surface water (µg/m^3).
Chl. maxim = yearly peak of chlorophyll concentration in surface water (µg/m^3).
Total phosphorous = yearly average concentration of total phosphorous in the water (µg/l).
Secchi average = yearly average Secchi depth transparency (m).
Secchi minimum = annual minimum Secchi depth transparency (m).

Table 56. Limit values for a trophic classification system.

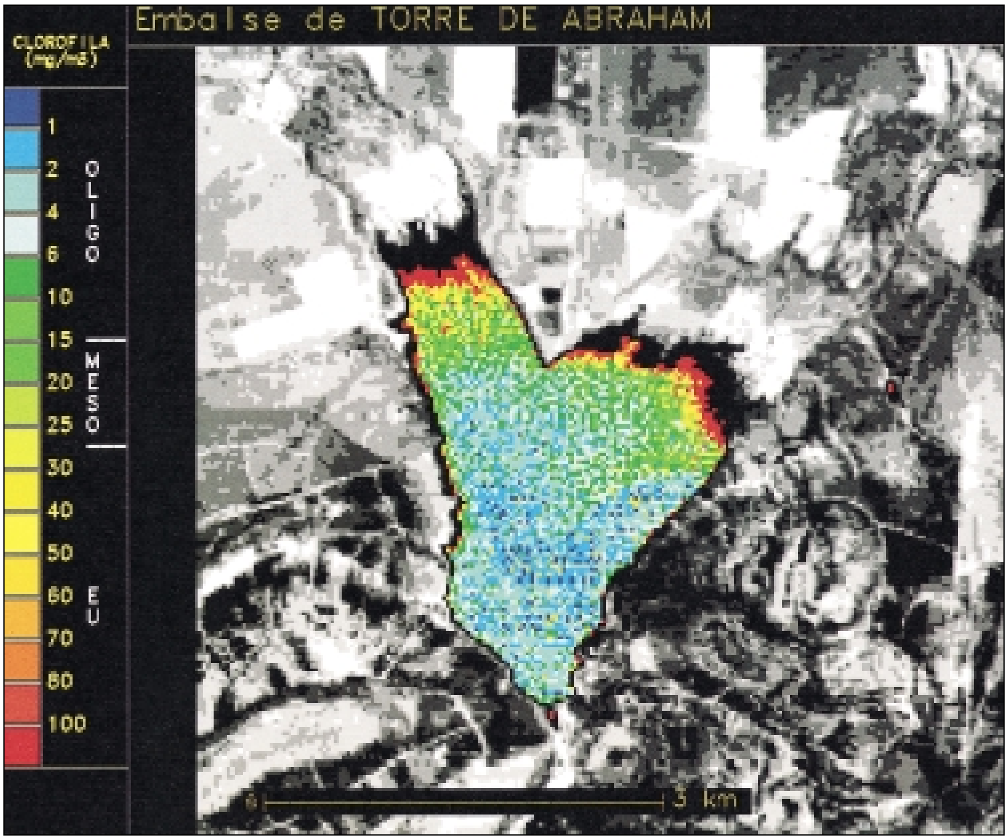


Figure 192. Image of the trophic level of the Torre de Abraham reservoir in the Guadiana basin, obtained by teledetection.

composition by introducing exotic substances liable to modify its original characteristics.

The waters with the best chemical quality come from carbonated formations. In general, they are apt for all uses, with low saline content and usually have slight or average mineralisation. This type of water is prevalent in the basins of the North, in the headwater units and northern border of the Douro basin, borders of the Sierra de Guadarrama, in the Tagus, upper basin of the Guadiana, carbonated units of the Guadalquivir and South, interior systems of the Júcar, Ebro and Catalonia Inland Basins.

The lithological variability of detritic formations gives rise to a broad diversity of types, from good-quality, little-mineralized water up to saline water, qualified as deficient for certain uses. Anthropic development on these aquifers makes pollution processes more common. The most habitu-

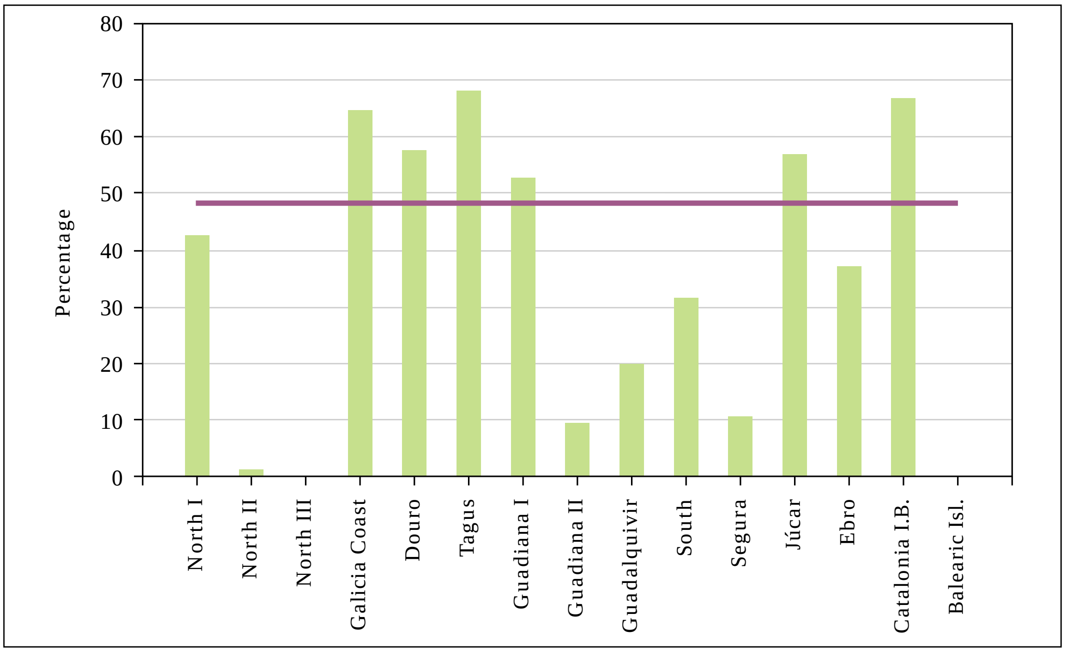


Figure 193. Degraded volume with respect to total reservoir capacity, by planning area.

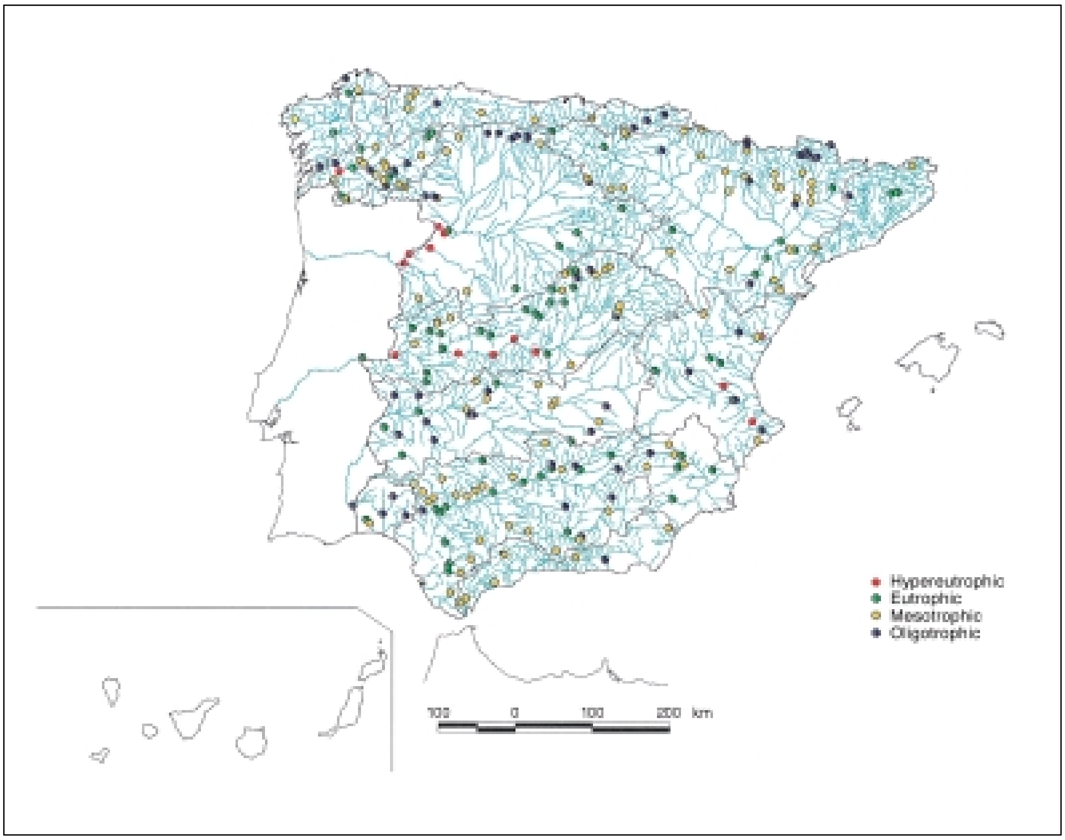


Figure 194. Map of the trophic state of reservoirs larger than 10 hm^3.

al groundwater quality problems are the presence of high concentrations of nitrogenated compounds in areas of agricultural development, and of chlorides and sodium, associated with marine intrusion in the coastal aquifers (fig. 195).

The mechanisms by which a polluting agent can reach an aquifer, and spread into it, are varied and sometimes very complex. Pollution of an aquifer from the surface of the land can be caused by solid or liquid effluent discharged into dry channels, by the existence of uncontrolled dumping or by the accumulation of pollutant substances on the surface. If the accumulated effluent contains soluble material, this will be leached by rainwater and will infiltrate into the saturated zone, joining the groundwater flow and may eventually arrive in water abstractions.

Pollution by agricultural activities takes place through the infiltration of water (rainfall or irrigation) that dissolves and entrains fertiliser and pesticides. Exploiting the aquifer carries the risk of using polluted waters, if carried out without due precaution, as happens with nitrate pollution that presently occurs in some hydrogeological units, mainly those located in east of Spain (Levante).

Domestic wastewater can pollute aquifers through the use of septic tanks, effluent recycling and, in general, of wastewater treatment systems that use the land's purifying capacity incorrectly, almost always by saturating it. Despite processes of adsorption in the soil and pollution reduction that take place in the non-saturated area, the infiltration of certain substances down to the phreatic level can represent a real threat for nearby abstractions (Candle and Varela, 1993).

Surface storage and the accumulation of liquid waste from various sources (evaporation or concentration pools, infiltration pools for industries or livestock stables, etc.) deposited in natural or artificial excavations, even discharge with little or no control, can cause groundwater pollution. A situation of special importance is when the reservoir enters into direct contact with the saturated zone (a frequent case in abandoned gravel pits), since the pollutant finds a direct access route to the aquifer. Pollution of the La Mancha aquifer by waste from distilleries exemplifies this type of process clearly. Discharge of wine waste from vineyards into the land has given rise to a double phenomenon of groundwater pollution: of the water, due to organic matter, potassium and other salts; and of the non-saturated area, due to methane emission by anaerobic degradation of the added organic load.

Direct input wells and the elimination of industrial wastewater, of brine from mining activities or of thermally-polluted water from heating or refrigeration processes, constitute a very serious threat –probably the most direct– for the groundwater quality, particularly when the wells and boreholes intended for this purpose are not appropriately designed, built, located or managed.

The advance of saline intrusion due to alterations in the flow regime, as a consequence of excessive pumping in coastal aquifers connected hydraulically with the sea, or the inadequate location of extraction pumping on this type of

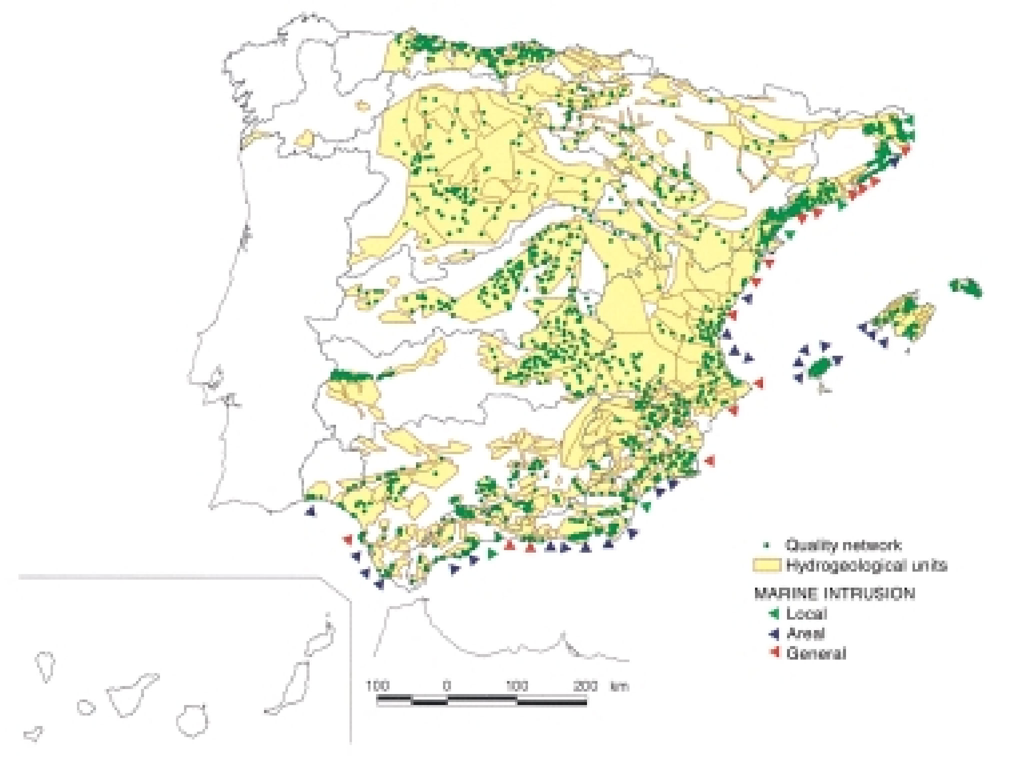


Figure 195. Map of the quality control network for groundwater and aquifer water showing marine intrusion.

aquifer, causes a wedge of salt water to move inland, since the flow of fresh water toward the sea diminishes, causing serious contamination problems in numerous hydrogeological units on the Mediterranean coast.

3.2.6.1. Detected pollution problems

Below, we describe the factors, natural or anthropic, causing alterations to the quality of groundwater, and the main problems detected in Spain (see, e.g., reports ITGE; MIMAM [1996a]; MIMAM [1997a].

3.2.6.1.1. Salinisation

The increase in saline content generally results in high concentrations of sulfates and chlorides. Its origin may be due to the influence of the materials through which the water flows (calcareous or evaporitic), to the reuse of irrigation water, with added salts in agricultural activities, in addition to salts dissolved from the soil, or to marine intrusion, caused by the invasion of sea water in coastal aquifers when excessive pumping is carried out.

The adjoining map shows, in hydrogeological units, the groundwater quality control network and the risk areas for marine intrusion identified by the ITGE.

In the eastern Mediterranean, marine intrusion is seen as widespread, and in some of its coastal aquifers (Plana de Vinaroz-Peñíscola and Plana de Oropesa-Torreblanca) the chloride content permannently exceeds 500 mg/l. The coastal aquifers of the southern Peninsula have localised problems. On the southern Atlantic coast, intense intrusion processes take place, which reached a peak between the years 1990 and 1994.

The areas at greatest risk are those where the salinisation affects the whole hydrogeological unit (general marine Intrusion). In other cases, the saline contamination is merely local and affects to very specific areas near the pumps. At an intermediate point is zonal marine intrusion, affecting greater surface areas of aquifer, where however some areas are practically unaffected by salinity from the sea.

3.2.6.1.2. Nitrate pollution

The origin of this major problem is attributed to agriculture (application of fertilisers) and to livestock farming. To a lesser extent, urban liquid effluent is also a source of nitrogenated compounds, although its consequences are usually more restricted and located in the environment around the discharge point.

Nitrate pollution significantly affects the Mediterranean coast, and it is specially intense in Maresme, where it exceeds 500 mg/l (Technical-Health Regulations stipulate that drinking water should not exceed 50 mg/l), and in large areas of the coastal plains of the Júcar (Castellón and Valencia), surpassing 100 mg/l. Among the inland units, the Mancha plain, the Ebro alluvial plain and some sectors of the Guadalquivir valley (alluvial plain of the Guadalquivir and Guadalete) are those most affected ones, with a nitrate content between 50 and 100 mg/l. The presence of nitrates locally affects several areas of the basins of the Douro (central Douro region, Esla-Valderaduey and Arenales), Tagus (La Alcarria, Tiétar and Ocaña), South (Campo de Níjar, Dalías and Fuente Piedra), and Segura (Campo de Cartagena, Guadalentín, and Vegas del Segura).

Figure 196 shows points in the control network indicating if the nitrate content is larger or smaller than 50 mg/l. As may be seen, the problem is not generalized all over the country, but the situation's seriousness in some areas, where these waters are used for supply, requires very close attention by users and by the competent public authorities.

3.2.6.1.3. Heavy metal pollution

The discharge of effluents from urban, mining and, fundamentally, industrial activities cause heavy metals to be present in groundwater, sometimes affecting its quality to the extent that it is no longer fit for human consumption.

Iron, manganese and aluminum, in particular the first two, are the metals that appear with greatest frequency and in all planning areas, in amounts that exceed the limits permitted by the Technical Health Regulation (RTS). The origin of the problem is perhaps more associated with a lithological effect than with a pollutant phenomenon. Other metals of a more toxic nature, such as cadmium, lead, copper, zinc, selenium, arsenic and chromium, have also very occasionally been detected, mainly in certain areas in the basins of the Tagus, Guadalquivir, South, Ebro and Catalonia Inland Basins.

3.2.6.1.4. Organic compound pollution

Groundwater pollution by organic compounds is a problem whose scope is still not very well-known in our country. The origin of this type of contamination is diverse, although it is frequently related with the inadequate use of phytosanitary products in agriculture. We should also mention the pollutant sources of leakage in tanks and pipelines, the elimination and discharge –both urban and industrial– of wastewater containing solvents, degreasing and cleaning agents, preservatives, etc. and the discharge of solid effluent.

In the present decade, the DGOH and the DGCA and, subsequently, the DGOHCA, established collaboration agreements with the CEDEX to study this type of groundwater pollution, aimed until 1995 at detritic hydrogeological units and, more specifically, to irrigated areas. The compounds most frequently detected in these studies, and in other spot work carried out by several organisations and researchers, belong to the group of organochlorates, particularly chlorobenzenes, chloroethanes, chloroethylenes, carbon tetrachloride and hexachlorocyclohexane.

We should note the presence, although in low amounts, of a great variety of undesirable compounds in groundwater of the basins of the Douro and the Tagus. We should also point out that in the nearly all cases –in these and in the remain-

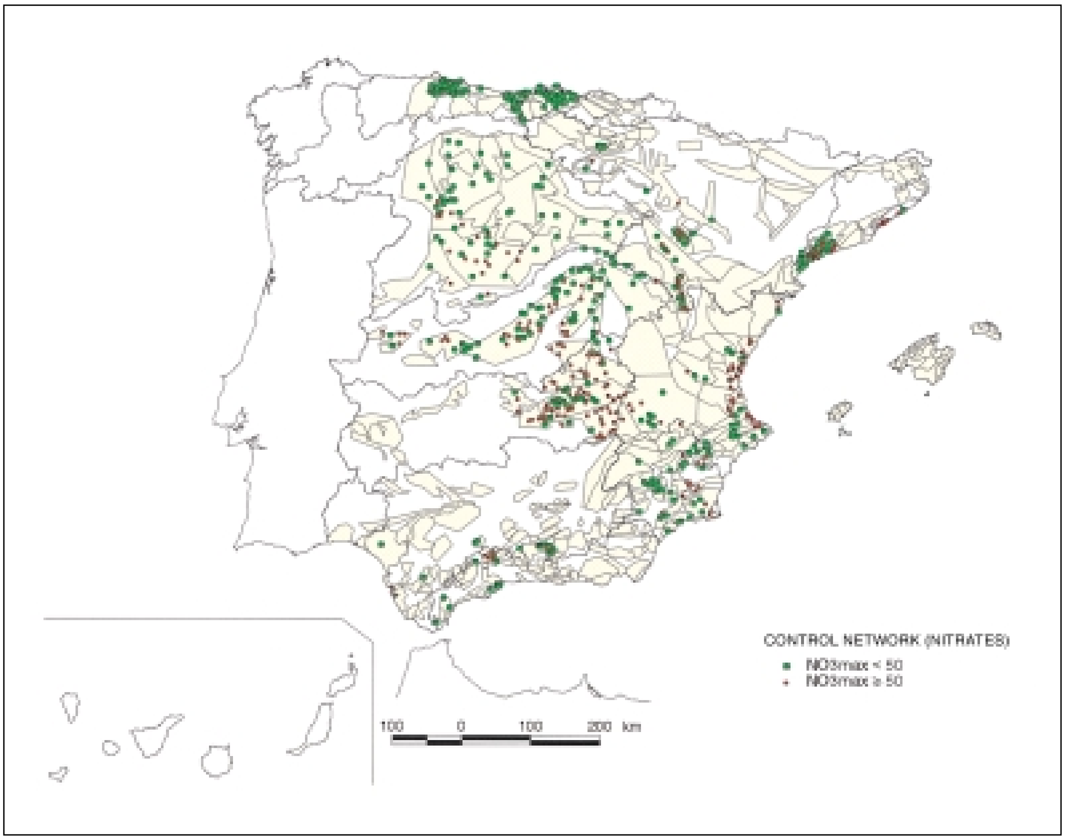


Figure 196. Map of points in the control network with presence of nitrates.

ing planning areas mentioned below– the affected wells are not intended for drinking water supply.

In the Guadiana basin, pollution due to the use of phytosanitary products has caused an accumulation of aldrin, DDT, HCH and atrazine in irrigated areas of western La Mancha, occasionally exceeding the authorised maximum limits for drinking water.

Sometimes, the appearance of volatile compounds has also been detected –tri and tetrachloroethylenes, chlorobenzenes and ethylbenzene– in the Guadalquivir basin groundwater, in the case of the Granada Depression, Almonte-Marshes and Barbate Alluvial. In these units, pollution has also been detected from petroleum derivatives. Also, the generalised apperance of pollution from oil mills, oil refining and packaging plants, such as fatty acids and their esters. In the Baza depression there are, although in low concentrations, organochlorate and organophosphorate compounds; in the Guadalquivir alluvial plain, the presence of hexachlorocyclohexane has been detected.

The presence of organic compounds also causes pollution problems in numerous detritic units of the Júcar basin, where certain substances have been detected in amounts higher than authorised. Occasionally, the problem affects population supply water. In the Sagunto and Southern Valencia plains and South Caroch, dichloroethane reaches has an occasionally very high content, of around 14,000, 13,000 and 17,000 ng/l, respectively. In the Plana de Castellón a series of compounds have been identified which only slightly and occasionally exceed the established maximum limits.

The elimination of industrial waste in the Ebro basin has contaminated groundwater in the upper Gállego basin, shown by the presence of volatile organic compounds. In the groundwater of the Vitoria alluvial aquifer, atrazine, lindane and other pesticidas have been detected, coming from agricultural activities.

In view of the toxicity of some of the compounds included in this pollutant group, and considering the insufficient knowledge of the problem's scope in Spain, it is necessary to continue with the work currently in progress, establishing sampling criteria based on the aquifers' hydrogeological characteristics and on water and soil uses in each case.

It is important to remember that information on groundwater pollution problems from certain spot sources is nonexistent or very dispersed and difficult to access. This is the case of buried deposits, gas stations, sewer system leakage, highways, etc. Although the high cost of improving knowledge on this type of problem sometimes seems discouraging, only with in-depth research will we be able to establish if the problems so far detected are more far-reaching, due to their scope and seriousness, in the deterioration of groundwater resource quality.

3.2.6.2. Decontamination of aquifers

There have not been many occasions when an attempt has been made to decontaminate an aquifer: the complexity and technical difficulty, and the economic cost involved in these operations, have usually led the affected resource to be abandoned and substituted with water from another source.

Actions in the field of aquifer decontamination in our country lie within the sanitation of areas where hydrocarbon spillage has taken place, originating from storage deposits (gas stations, etc.), though so far no information is available as regards the conclusion of any actions in progress with the aim of recovering aquifers polluted by another type of compound.

At the present moment, we should highlight the importance that the National Contaminated Land Recovery Plan will mean for aquifer decontamination, adopted by the Council of Ministers Agreement of February 17th, 1995 (Official State Journal of May 13th, 1995). In implementing the National Plan, and in coordination with the Autonomous Communities, regional amplifications of this inventory are being carried out in Andalusia, the Basque Country, Catalonia, Navarre and Castile-La Mancha. The objectives stated in the National Plan's sub-programme "Recovery Projects", have materialized with the execution of fifty polluted land projects, which not only cover the sanitation of areas affected by waste of industrial origin, but also those affected compounds of different origins.

As regards sanitation work executed, we could mention that there is work in progress aimed at decontaminating aquifers polluted with toxic compounds whose presence has made these water resources impossible to use, some of them located in the alluvial plain of the Escombreras valley (Murcia), Besós (Barcelona), and the River Jarama (Madrid).

The action being carried out in the Besós alluvial plain corresponds to the aquifer's decontamination in connection with an old factory that polluted it with solvents after an accidental fire. The sanitation technology used is catalytic oxidation of the water by means of a mobile plant. This same technology was similarly used in a gravel pit in the River Jarama alluvial plain, which contained water polluted by mineral oils.

3.2.6.3. Pollution prevention

Conservation of groundwater quality should be governed by the principle of prevention, impeding pollution from taking place, establishing the means and regulations to limit uncontrolled discharges, the execution of dangerous activities without the due safety measures, and the indiscriminate use of agro-chemical products.

Once an aquifer has been polluted, recovering its quality, although feasible, is technically extremely complex and involves a high cost. It is for this reason that the discharge authorizations laid down by the RDPH bind the owners of the discharge generating activity to pr ovide a hydrogeological study demonstrating its harmlessness.

The first actions aimed at controlling groundwater quality consist of determining the existence of pollution processes, their intensity and scope, type of compound, possible cause in the environment and the aquifers' vulnerability where potentially pollutant activities are established or are to be set up.

This plan requires improvement to the surveillance systems for temporal control and monitoring of water quality. This will allow the state of the water to be determined and trends to be assessed in terms of the anthropic activities carried out on it. For these surveillance systems to be effective, they must fulfil at least two objectives: to detect any variation in water composition and to detect pollution far enough in advance to be able to act.

The proposed community Groundwater Action Plan lays down that member states should *determine in which zones groundwater is particularly vulnerable to pollution, for geological or climatic reasons, soil type or human activities*.

In Spanish legislation, the Public Water Domain Regulations stipulate that studies assessing environmental effects, in cases of pollution that could affect groundwater, will include the assessment of the affected area's hydrogeological conditions, the possible purifying capacity of the soil and sub-soil, and the risks of pollution and alteration of groundwater quality (art. 237.3).

In both cases, the obligation seems to be aimed at evaluating the risk of pollution more than determining vulnerability, understanding this as a function of the aquifer's intrinsic characteristics.

In any event, it seems necessary to carry out territory zoning or characterization for each planning area by means of maps to differentiate different hydrogeological environments, according to the relative importance of each of the factors which, jointly, determine the aquifer's vulnerability to pollution -edaphology, characteristics of the unsaturated zone, depth of the water level, lithology, hydraulic regime of the aquifer, recharge. This zoning will be a useful tool in regulating potentially pollutant discharges, and may also be used in applying prevention measures against pollution and drawing up territorial regulation plans.

Once the different parameters regarding land use and aquifer vulnerability have been verified, specific measures can be established. This is the case of the National Urban Solid Waste Plan , and the National Industrial Waste Plan, some of whose objectives consist of characterising sites, both the facilities and the waste generated, and assessing effects on the water, particularly the effect each type of waste has on groundwater.

The protection of abstractions intended for urban supply is covered by the Water Act and the RDPH, which lay down the concept of protection perimeter. The actual implementation of these perimeters is so far very scarce, probably due to the legal and social implications on the regulation of territory and land uses. The DGOHCA has launched an initiative aimed at systematising the procedures to be used in establishing this regulatory concept, and to enable jurisdictional coordination between the basin organisations and the Autonomous Communities.

3.2.7. Quality objectives

Sections above have dealt with the state of surface water and groundwater quality, noting basic features of their current situation. To improve this current situation, and to progress to another considered possible and desirable, the instrument laid down by regulations in force is that of setting quality objectives, and implementing policies to achieve these objectives in the medium to long term.

Thus, the basin management plans should contain "the basic characteristics of water quality and the regulation of wastewater discharge" (section 235 40e WA), in addition to the "quality objectives that should be achieved in each river or river reach" as regards the uses for which the water is intended (art. 79 RAPAPH). That is, water planning should define the rivers and aquifers initial situation, and the quality they should have in a certain time horizon in relation the uses for which the water is intended. They should also establish "the procedures, lines of action and basic characteristics of discharge regulation that may be necessary to adapt water quality to its quality objectives" (art. 80 RAPAPH).

The definition of these quality objectives is carried out, in each case, by the competent relevant Administration and is included in each basin management plan. Once a potential use for a river or aquifer reach has been defined, they must at least comply with the conditions laid down by the European Union Directive on the minimum quality required of water for the uses of urban supply, fish life and bathing. They should also cover the obligations on quality and control objectives for discharge laid down by the European Directives on emission standards. This is explicitly included in the RAPAPH itself, in article 80.3, when it specifies that "action programs are foreseen to eliminate from inland waters pollution caused by those substances which due to their toxicity, persistence or bioaccumulation, appear in lists I and II of the annex to Heading III of the Public Water Domain regulations", which are in fact lists I and II of Directive 76/464, on pollution by certain toxic and dangerous substances.

The definition of quality objectives therefore takes on major relevance in the planning process, since their very existence requires certain actions in pollution treatment, prevention and management to be carried out in aquatic environments. Even Water Act, in article 105, stipulates the criteria with which these water quality protection actions will be financed in relation to quality objectives, when it establishes a charge for effluent "in accordance with the provisions of the Basin Plans regarding fresh water quality, to cover the financing of necessary structures, included in the respective basin management plans, to comply with these provisions." These quality objectives therefore become an undertaking by the water authorities with respect to the actions they will carry out in the future to fulfil them. The quality objectives proposed in the basin management plans do not contain specifications on concentrations of substances in lists I and II of Directive 76/464, on pollution by certain dangerous substances.

Specifically, quality objectives are not defined for the substances in list II, in compliance with article 7 of the above-mentioned community regulation. At present, a relevant list of substances is being studying by the Commission, mandatory for members states. As regards the quality objectives of bodies of water, most of the basin management plans aim to avoid eutrophic states, especially if the reservoir is used for supply.

With regard to quality objectives outlined for groundwater, currently existing quality will be generally ensured, although in cases of polluted aquifers, used or liable to be used in urban supply, the appropriate measures will be taken to avoid their degradation and to improve their quality.

The adjoining maps show quality objectives on the Peninsula's main river reaches. We should highlight that in some reaches of the Tagus and in almost the whole Segura basin, quality objectives have not been defined by uses, but by permitted maximum concentration of certain substances and by maximum values of some typical water quality parameters, so they are not represented in these maps. As for bathing quality objectives, almost all the basin plans specify that they will be assumed on all those reaches that have been so declared by the respective Autonomous Communities, even though the reach itself is not defined as such in the corresponding plan (fig 197, fig, 198, fig, 199).

As for the quality objective of fish life, we should specify that not all reaches have been classified taking into account the declarations made by the respective Autonomous Communities in compliance with community legislation on the issue.

Approximately 17% of the main Spanish rivers' length has been classified as A1 pre-treated objective, 30% salmonid and 41% for bathing. If we consider average flow affected by this classification, 8% of renewable resources is classified with the A1 pre-treated objective, 23% salmonid and 48% bathing.

Particularly noteworthy are the North, with 96% declared as salmonid, the Júcar and the Tagus, with 32% and 28% respectively declared as pre-treated A3, or the Guadiana and the Catalonia Inland Basins, with approximately 40% of A1.

The economic and technical feasibility that allows the Water Administration to assume certain quality objectives should be studied on the basis of the receiving channel's characteristics, of the characteristics of the discharge to be purified and of the regulation possibilities permitted by the concession regime in effect. Applying a decision model that allows quality to be assessed according to circulating flow and existing discharge, the possible economically and socially feasible alternatives can be analysed to obtain certain quality objectives whose fulfilment necessarily depends on assigning a minimum flow regime and achieving certain levels of treatment.

Figure 200 illustrates this possible decision procedure, although at present the simulation models that relate the resource's quantity and quality are not extensively used.

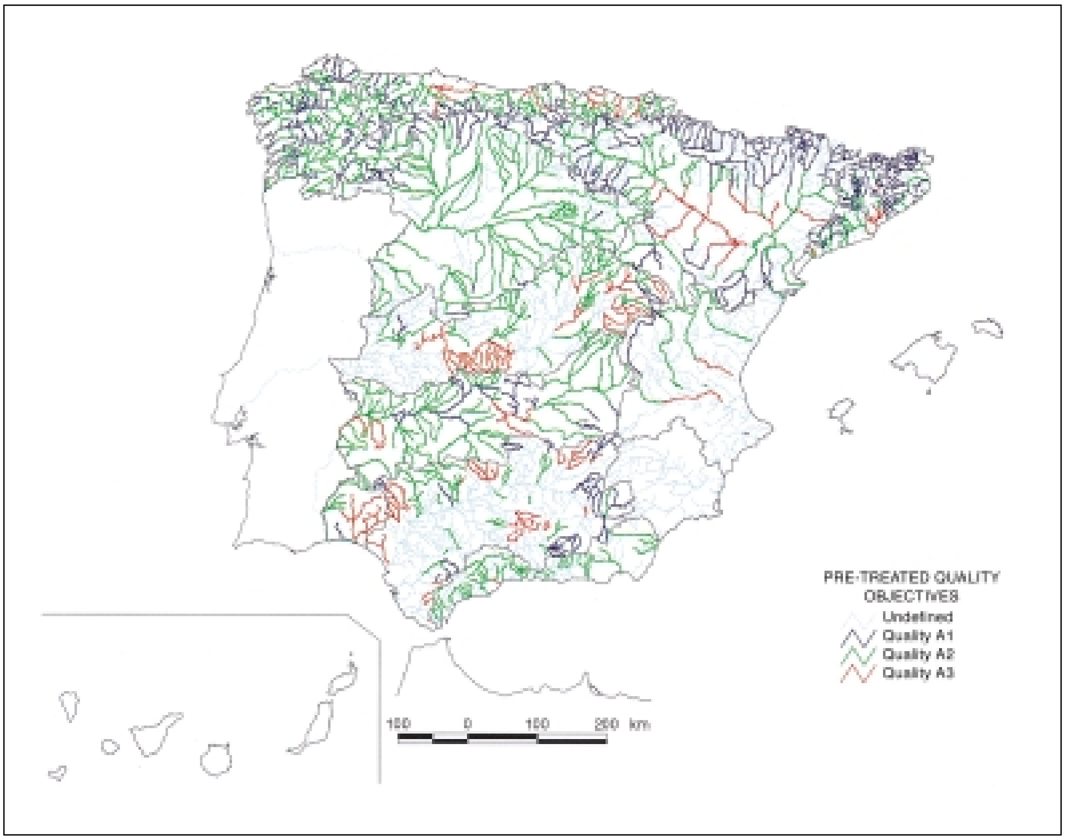


Figure 197. Map of quality objectives for pre-treated use.

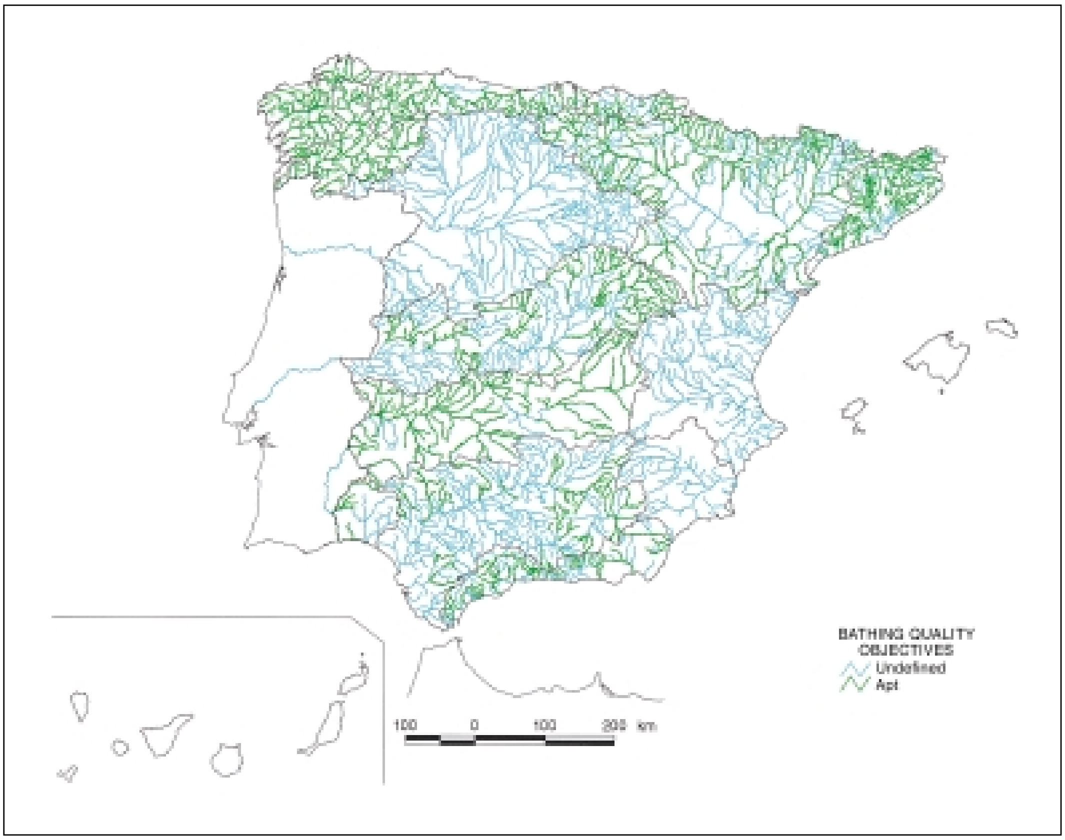


Figure 198. Map of quality objectives for bathing water.

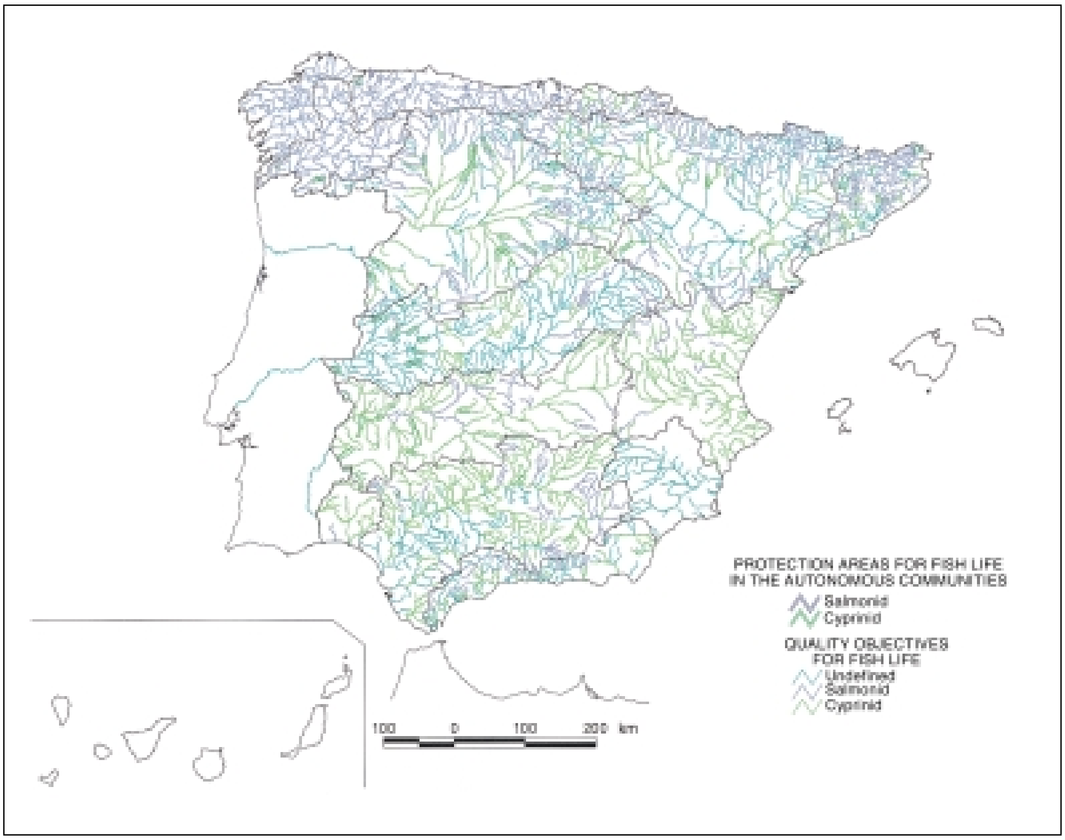


Figure 199. Map of quality objectives for fish life.

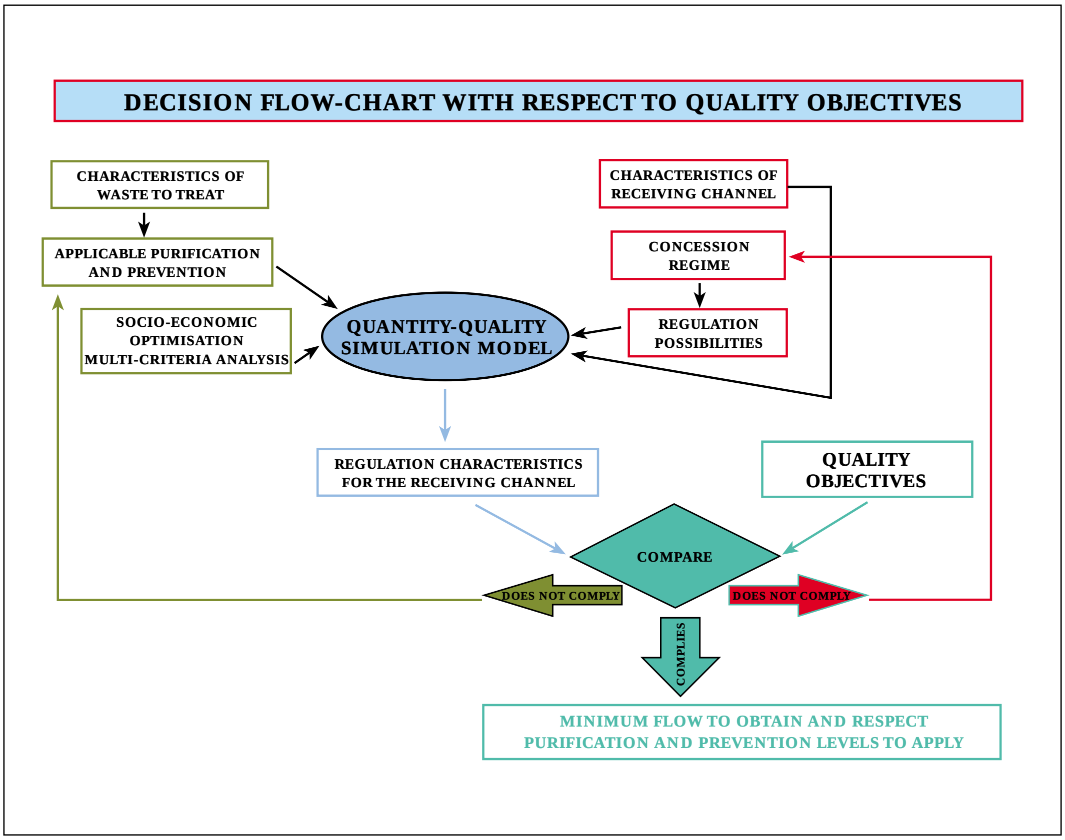


Figure 200. Decision flow chart in relation to quality objectives.

3.2.8. International Agreements on water quality

As mentioned above, there is a clear trend in establishing international agreements to allow mutual cooperation and the exchange of information on water quality in the cross-border channels. Below, we describe some of these agreements, of interest to Spain.

3.2.8.1. The OSPARCOM convention on the pollution of the Atlantic Ocean

The objectives required by OSPARCOM (Oslo and Paris Commission) from subscribing states regarding the control of marine pollution of terrestrial origin in the Atlantic Ocean are as follows:

- Control at least 90% of the following pollutant discharges: mercury, cadmium, copper, zinc, lead, lindane, ammonium, nitrates, ortophosphates, total nitrogen, total phosphorous, solids in suspension and salinity.
- Report annually on the concentrations of these substances detected in the main rivers.
- Assess discharges from diffuse sources, small sources and small rivers so as to cover 100% of discharges into the sea.

In short, the aim is to control nearly all sources of pollution into the sea, with the purpose of finding out total discharge of each substance and to foresee trends to estimate the success of pollution prevention programmes.

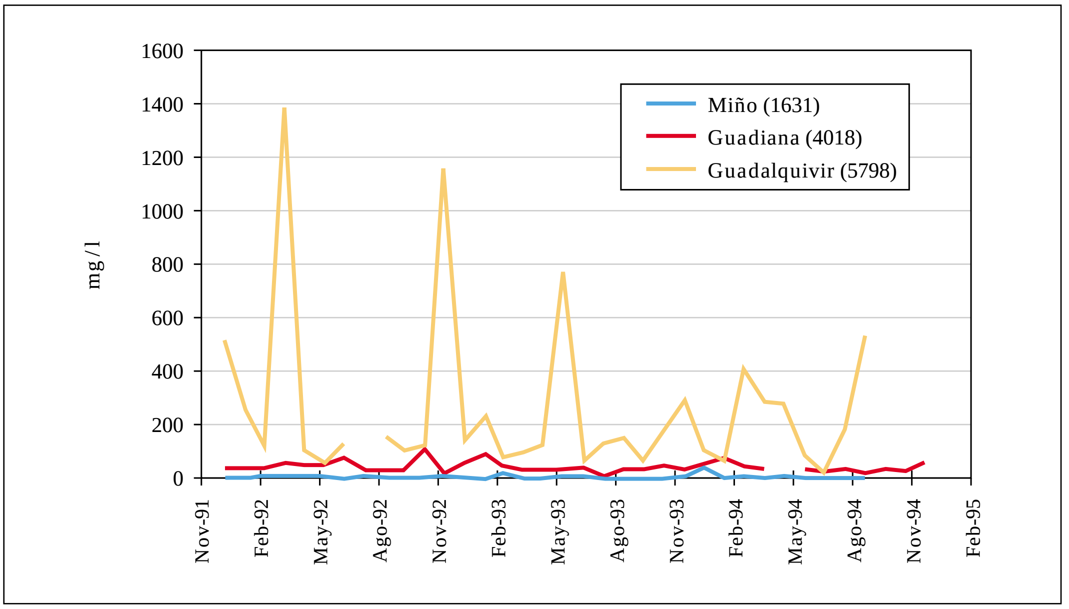
The figures below show some of these discharges from the main rivers of the Atlantic drainage area (fig. 201, fig. 202, fig. 203).

We should clarify that the information presented here only covers some aspects of the Convention, so it will be necessary in the future to intensify knowledge on the issue to meet objectives appropriately. Nevertheless, so far it has not been possible to inform satisfactorily on discharges from rivers to the sea, nor on direct discharges to the sea through submarine outlets or from purifying plants, although the procedure is under way to shortly determine the majority of pollution of terrestrial origin in the Atlantic Ocean.

3.2.8.2. The Barcelona Convention on pollution of the Mediterranean Sea

Among other things, the Barcelona Convention attempts to prevent the pollution of the Mediterranean as a consequence of land-based discharges, for which it obliges the signatories to take all “appropriate measures to prevent, abate and combat the pollution of the Mediterranean Sea area caused wastewater form rivers, coastal facilities or outlets, or from any other land-based source located within its respective territories” and to establish “a pollution surveillance system in this area.”

On the 7th of March,1995, in Siracusa (Italy), a Conference of Plenipotentiaries adopted amendments to the Protocol on land-based pollution. These amendments are so substantial that they transform the text into a new Protocol, the most



Figures 201. Concentration of materials in suspension near the mouths of the Rivers Miño (Station 1631), Guadiana (Station 4018) and Guadalquivir (Station 5798).

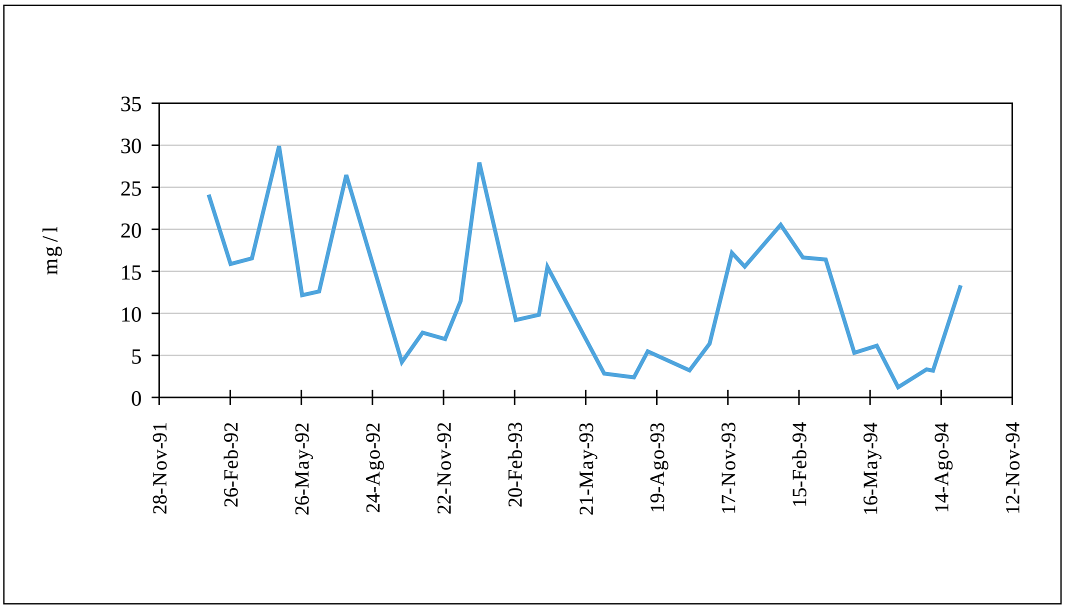


Figure 202. Concentration of nitrates in the Guadalquivir at Lebrija (Station 5798).

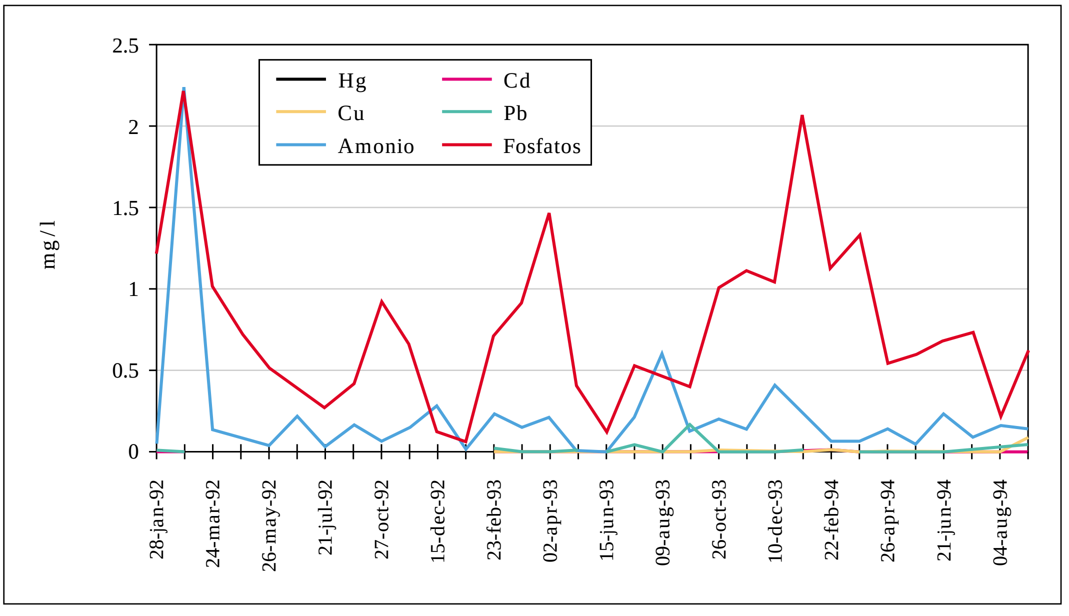


Figure 203. Concentration of mercury, cadmium, copper, lead, ammonium and phosphates in the Guadalquivir at Lebrija (Station 5798).

significant being the commitment to progressively eliminate the discharge of toxic, persistent and bioaccumulative substances in Annex I, listing the industrial sectors and different substance categories that will be taken into account in drawing up Plans and Programs. Organo-halogen compounds are listed among the substances and priority is given to the following 11 substances: aldrin, dieldrin, endrin, dioxins, furans, DDT, heptachlor, hexachlorobenzene, mirex, biphenyls polychlorates and toxaphene.

Spain supplies the Mediterranean Sea with 4% of total runoff, compared with 12% in France, 33% in Italy, 13% in Turkey, or 3% from the group of countries located to the south of the basin. It can thus be seen that most of the problem is located in the northern countries and especially in France, Italy, Yugoslavia, Greece and Turkey, although Italy and France are who add the greatest pollutant load to the largest runoffs.

3.2.9. The National Wastewater Collection and Treatment Plan

Despite the obligatory monitoring and treatment of urban discharge (all polluting activity should have a discharge authorisation), the Water Act and its subsequent regulatory development indicate that this field initially took off with the Community promulgation of Directive 91/271, on the treatment of urban wastewater.

Actions in collection and treatment began in Spain at the beginning of the seventies (notwithstanding some isolated actins prior to this) with the implementation of partial plans in coastal areas, such as the Costa Brava and Balearic Islands, which were later supplemented with some other actions in the Mediterranean arc. In the decade of the eighties, treatment systems were implemented in major coastal towns (Valencia, Alicante, Palma de Mallorca, Benidorm, partially in Barcelona, Castellón, etc.), to which we should add the significant plans of Madrid capital (Integral Collection Plan for Madrid, PSIM) and Community of Madrid (Integral Water Plan for Madrid, PIAM), Seville, Burgos, Cordova, Vitoria, Granada, Pamplona and Bilbao, the last two only with primary treatment.

Even so, deficiencies were obvious in collection infrastructures, because actions remained to be undertaken in medium and large cities and the problem was still not totally solved in areas of the coast, such as the Costa del Sol, Menor Sea, Albufera, Bay of Biscay, among other, in addition to inland cities, such as Valladolid, Murcia, Zaragoza or Logroño.

The Water Act's promulgation, Spain joining the European Union, the administrative decentralisation of the state, and greater public awareness of everything to do with the environment in general, and its hydraulic aspects in particular, have played a positive role in changing the trend in the amount of investment which, year after year, is devoted to these infrastructures. All this has enabled the promotion of collection plans like the one in the central area of Asturias which, virtually implemented, aims to meet a quality objective for salmonid fish life in the Rivers Caudal and Nalón, plus the Plans of Catalonia, Valencia and Balearic Islands which add numerous treatment facilities to those already existing.

Furthermore, the Canary Islands have progressed positively in their objective of not dumping unpurified wastewater into the ocean in those cases where such purified flow is required for reuse in the irrigation of crops, golf courses, etc. Similarly, facilities have been set up in Cáceres, Badajoz, Ciudad Real, Cuenca, Guadalajara, Soria, Ávila, Jeréz, Lérida, plus the major purifying plant in Zaragoza (La Cartuja), supplementing the already-existing one at La Almozara.

As mentioned, in the year 1991, Directive 91/271 was passed, requiring all member states implement treatment facilities in accordance with three time scenarios (1998, 2000 and 2005), demanding considerable efforts to be made, both technical and financial, by the countries of the Union, especially the most populated ones (fig. 204).

At that time, Spain had around 60% of resident population connected to some treatment system, of which 44% had secondary treatment and only 15%, primary. This percentage includes those facilities which were in construction. Nevertheless, and in accordance with the Directive, two new parameters had to be incorporated:

- The level of wastewater treatment should refer to equivalent population and not real population (an equivalent inhabitant EI. represents 60 grams of BOD5 a day. It can be said that in Spain, there exists approximately 2 equivalent inhabitants per capita).
- It was not enough to describe the population connected to some treatment system, but a level of compliance with community regulations' standards had to be established.

Therefore, it was necessary to account for the entire pollutant load in urban collection networks, including seasonal population, which is so important in Spain, and wastewater of an industrial and commercial type that is generated inside the urban area. That is to say, a mere inventory of the facilities was not enough, but it was necessary to diagnose the situation as realistically as possible.

The Community Directive stipulates three different types of areas where discharge can be treated differently:

- *Normal zones*, for which it lays down the Directive's general emission limits.
- *Sensitive zones*, for which it also requires the reduction of nutrients (nitrogen and phosphorous).
- *Less sensitive zones*, where according to population size, simple primary treatment may be allowed (these areas can only be defined in marine waters).

The Directive's annexes establish the criteria to define both sensitive zones and less sensitive zones. In accordance with these criteria, the existence of sensitive areas has been

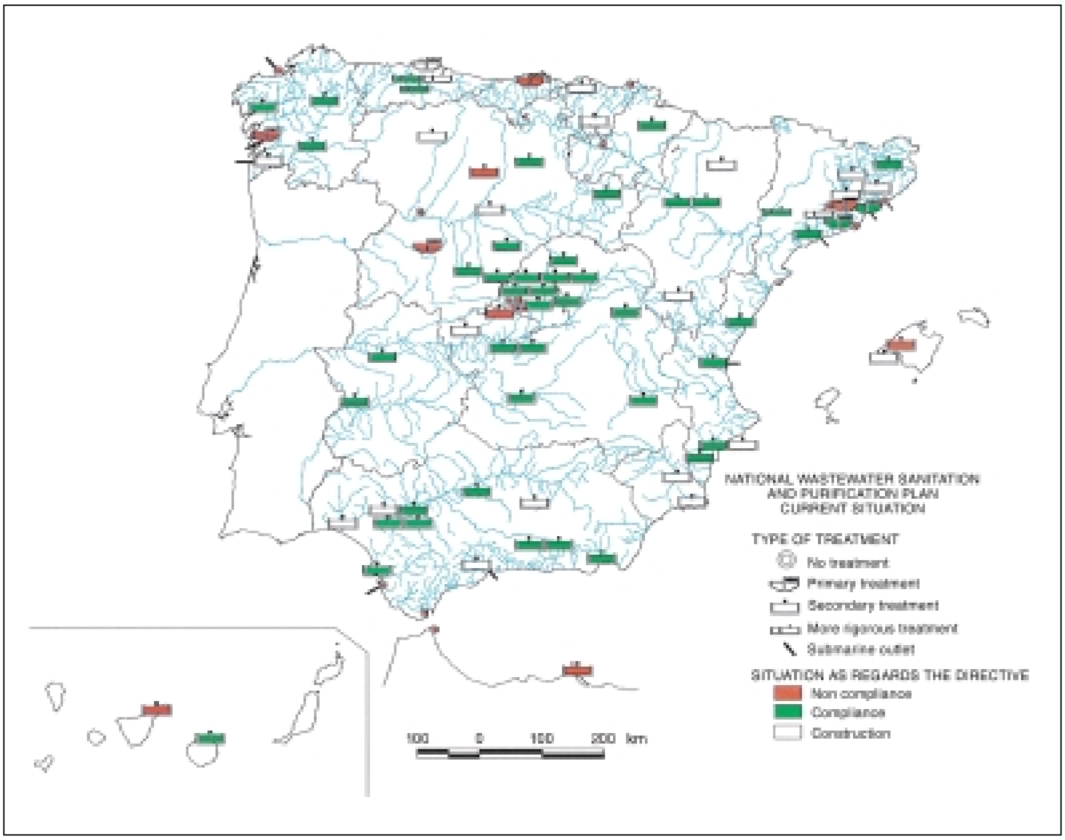


Figure 204. Map of most important purifying stations, both existing and under construction, on 31st December, 1996.

detected in reservoirs with a high eutrophy level, which are generally used for urban supply, as well as a wide range of protected areas with high environmental value, as is the case of Tablas de Daimiel, Doñana Park, Menor Sea or Albufera (see figure).

As regards less sensitive zones, the following factors have been taken into account:

- Considerable coastal length, with good conditions for water mixture and dispersion in most cases, allowing a major part of the coast to be considered as less sensitive, except for closed bays and rias and some areas where major towns are located.
- There are numerous areas on the coast considered as bathing areas, in most cases requiring treatment systems to be implemented in accordance with this quality objective.

It may therefore be the case that a conurbation is located in a less sensitive zone, in accordance with the criteria of Directive 91/271, but which requires more than primary treatment to comply with other community standards.

The Secretary of State for Waters and Coasts, by Resolution on the 25th of May,1998, declared sensitive zones in inter-community drainage basins for the purposes stipulated in Royal Decree-Act 11/1995, of the 28th of December, and in accordance with the criteria laid down in Annex II of Royal Decree 509/1996, of the 15th of March. This Resolution identifies, for each of the sensitive zones, the towns that discharge into them and which currently have over 10,000 equivalent inhabitants (fig. 205).

With this background, and with the collaboration of the Autonomous Communities, a Wastewater Collection and Treatment Plan (NWCTP) was drawn up as a planning tool for collection and treatment infrastructures, which the Spanish State should implement up to the year 2005, and as a coordinating instrument for actions by the Public Administrations with powers in this matter. The Plan was approved by the Council of Ministers on the 17th of February, 1995, and published in the Official State Journal on the12th of March of the same year. The main data is shown in table 57.

The recent evolution of the Spanish population's percentage under Directive 91/271 is shown in table 58, illustrating a positive trend.

Estimates made in the Plan raise the investments necessary to two trillion pesetas, the majority of which should be undertaken before the year 2000, with similar sums assigned to treatment infrastructures (1.0 trillion) and collection (0.8 trillion). Collection consists of the sewage system networks and the general collectors, while treatment is specifically the EDAR.

The start-up of the Plan, with the signing of Agreements between Central Administration and the respective Autonomous Communities, the declaration of general interest for several actions, the participation of European funds (Cohesion, FEDER) and the approval of specific operative programmes (Local Environmental Operative Programme, POMAL) have positively influenced in questions of compliance with the Directive.

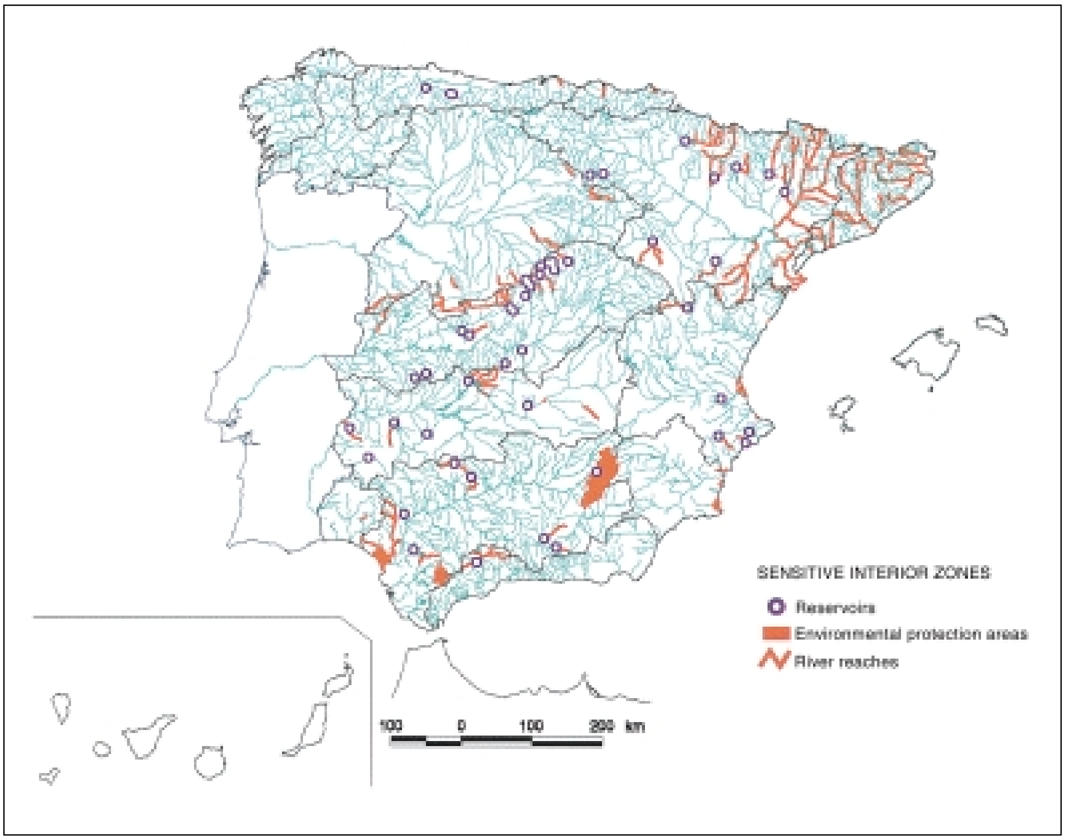


Figure 205. Map of interior sensitive zones of Directive 91/271.

In fact, in recent years the Public Administrations have begun or accelerated major projects, among which we could highlight those of Albufera in Valencia, Menor Sea in Murcia, Valladolid, Logroño, Salamanca, Palencia, Vigo, 2nd phase of Bilbao and Málaga, to mention some of the most representative.

It therefore seems clear that, although the pace is not ideal for achieving full execution of the Directive in accordance with the time scenarios mentioned, the significant effort made in recent years to reach the greatest possible level of compliance is clear.

Nevertheless, once facilities have been undertaken, another no less important problem remains to be solved: their management. In fact, this type of facility not only needs appropriate maintenance, but also good exploitation, otherwise, and even when wastewater treatment plants (EDAR) are designed to achieve the required emission standards, careless operation can mean that such fulfilment will fail and, as a consequence, so will the considerable investments made. It is well known that appropriate technical means are required to manage an EDAR and its collection networks, that exploiting the facilities requires specialised personnel, electric energy, reactive agents, transportation of by-products, etc., which all generate costs that must be charged to those who cause the pollution, through collection tariffs and fees.

Not only must the operation's financial balance be ensured, but also appropriate management through the tools that make it possible. For this reason, many Autonomous Communities have solved the problem by creating super-municipal management structures, with authority to charge a fee (through a Law on collection) ensuring facilities' exploitation *a priori*, especially in medium-sized and small districts with few possibilities of having their own means to undertake their management.

The collection of collection tariffs –which range from 0,15 to 0.18 €/m^3– allows the charge to be distributed among the various districts of one same Autonomous Community. Madrid, Catalonia, the Provincial Community of Navarre, the Balearic Islands and Valencia Community have been

Total equivalent population	85 Mhab-eq
N.º of existing facilities	3,253
– Primary treatment	2,007
– Secondary treatment	1,217
– More rigorous treatment	29
Population in compliance	34.5 Mhab-eq
Population with EDAR in construction	11.5 Mhab-eq
Population not in compliance	39 Mhab-eq

Table 57. Basic initial data on programming the Sanitation and Purification National Plan.

	Year 1995	Year 1997
COMPLY	40.6%	44.7%
DO NOT COMPLY IN CONSTRUCTION	13.4%	18.3%
DO NOT COMPLY	46.0%	37.0%

Table 58. Evolution of the percentage of population in compliance with Directive 91/271/EEC.

pioneers in defining these tools, with other communities at an advanced stage in the process.

Nevertheless, this is not the only solution possible, and other Autonomous Communities are studying and implementing other systems through joint communities, consortiums, companies associated with provincial governments, etc. All this aims to achieve a situation where facilities operate in accordance with the parameters laid down by EU Directives, and with the corresponding discharge authorisations.

3.2.10. Regulation of discharge

Discharges are regulated by the Water Act, by the Regulations on the Public Water Domain, by the Ministerial Order of the 23rd of December, 1986, and by Royal Decree 484/1995, on measures for standardisation and control of discharges (fig. 206).

The adjoining figure illustrates the flow chart for applying the said Royal decree, whose final objective is for all discharges liable to pollute the aquatic environment to have an authorisation as soon as possible.

Article 6 of this Decree deserves a special mention, dealing with Sectoral Standardisation Plans. In this respect, the DGOHCA "in collaboration with the Hydrographic Confederations, may agree and approve strategic sectoral plans in the scope of the whole country or greater than a hydrographic basin" which will be equivalent, for all industries in the sector, to the Standardisation Plans for one single discharge. "In such situations, the procedure for the Sectoral Plan shall involve effects similar to standardisation for all industries in the sector, in the scope of the corresponding hydrographic basin or sub-basin, notwithstanding the individualised effects of non-compliance".

Considering the classification of industries in the National Code of Business Activities (CNAE), they have been grouped into eleven industrial sectors with the intention of agreeing the corresponding Sectoral Plans. Approximately 270,000 companies will be subject to the corresponding Sectoral Standardisation Plans. The investment necessary to implement them will be around 3.01 M €. We should

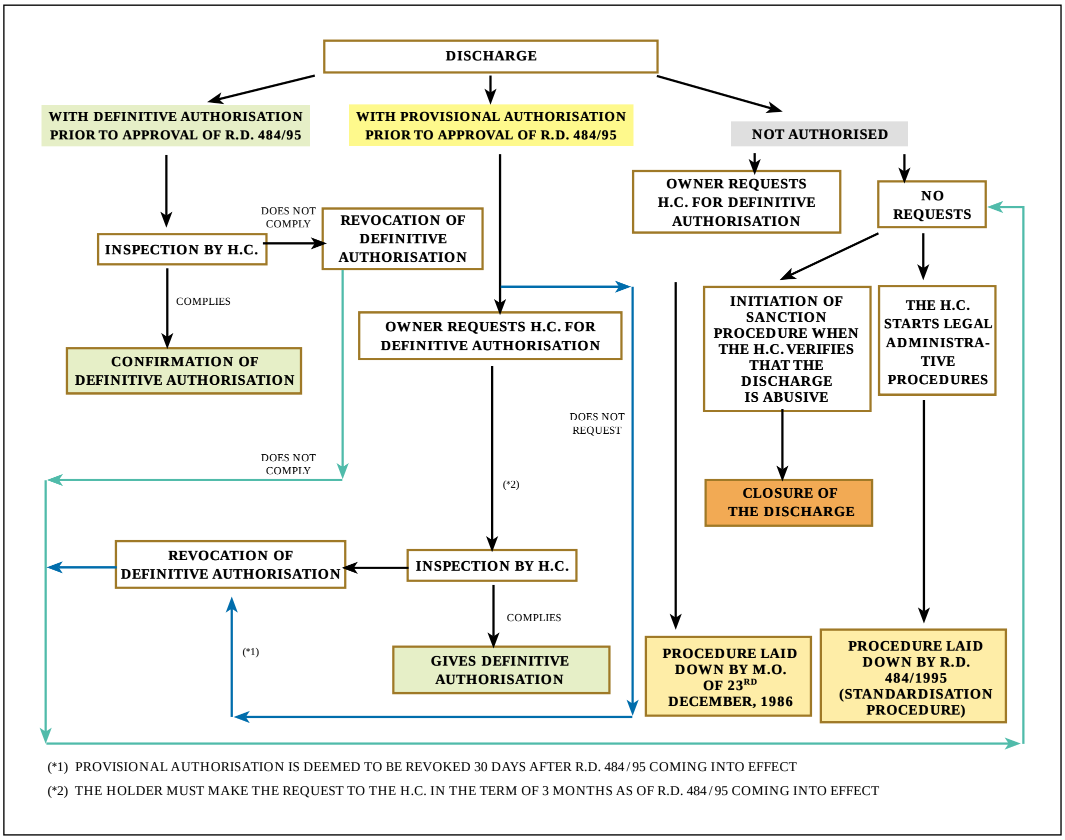


Figure 206. Layout of the discharge standardisation procedure according to Royal Decree 484/1995.

highlight that within each sector there exists considerable heterogeneity between its corresponding sub-sectors, between the different companies' sizes, and between current administrative situations with respect to discharge authorisations and the treatment of effluent. There are also significant differences between hydrographic basins. In general, the Catalonia Inland Basins, North, Tagus, Ebro and Júcar concentrate most discharge and investment.

The characterisation of discharges has been carried out in each case according to the most characteristic parameters of each sub-sectors typical effluent, although the number of samples taken has been low for a detailed characterisation of their composition, and especially for detecting the presence of dangerous substances in Lists I and II. Contrast of information with the Hydrographic Confederations' discharge data bases, and with studies carried out by the Environment Ministry will give a more detailed characterisation of discharges of each substance, and allow the opportune measures to be adopted in compliance with community legislation and quality objectives.

By way of example, and as shown by the different situations that exist, considerations are included with respect to four of the eleven sectors where the corresponding Sectoral Discharge Standardisation Plans have been studied. We should note the figures given here are approximate, and in each specific case, they would have to be accurately defined with more specific studies, in coordination with each of the affected industrial sectors, and with each of the Hydrographic Confederations' Water Commissions.

In the Surface Treatment and Galvanizing Industry, large quantities of water and chemical substances are used, which may have serious effects on the environment. The main pollutants generated by these activities are heavy metals, mainly copper, nickel, chrome, zinc and cadmium, toxic anions, such as fluorides and cyanides, various bases and acids, oils and fats and a multitude of organic dissolvents. In this industrial sector, there are very few discharge authorisations, and only the large companies have any kind of physio-chemical treatment, of which ionic exchange is a salient method. A large part of the Sectoral Plan's success will depend on processed water and sludge generated during the treatment of effluents. These are generated sporadically, with low flow, concentrating significant pollutant values and which are classified by legislation as toxic and dangerous waste, so they should be sent to the corresponding treatment plant.

In the Mining Industry sector, the low number of authorisations is significant. Just 50% of the more than 3,500 exploitations use any kind of treatment, which mostly consists of a series of settling ponds which only eliminate a part of the substantial volumes of solids in suspension generated by the sector, which more often than not is considered insufficient. We should bear in mind that closed mines, numbering about 400, often involve major sources of potential pollution.

The Leather and Footwear Industry and the Textile Industry stand out for high concentrations of BOD5 and DQO, and for the presence of substances considered dangerous in some of their processes. In the first of these sectors, it is not unusual to find chrome III, sulphurs, oils and fats in its discharge. The Textile Industry shows high toxicity in pre-weaving and gluing processes and textile finishing.

The Construction Materials, Glass and Ceramics Industry has about 30,000 companies making up a varied sector of very different-sized industries. The sub-sectors of glass, ceramic tiles and cement manufacture concentrate the greatest pollution, and necessary investment to standardise the situation.

Prioritising necessary investment and, therefore, the actions to be carried out within each sector and between the different sub-sectors, has considerable importance, since it is necessary to define, for better planning, which specific companies and which production processes require action in the first instance. Criteria for preparing this strategy may be summarised as follows:

– The pollutant character of the discharge, according to the concentration of different substances and total pollution loads.

– The characteristics of the receiving environment and, particularly, the state of quality of the channel where the discharge is made.

– Current and potential water uses and, particularly, the quality objectives that have been assigned to river reaches affected by the discharge.

– Greater social demand, with respect to awareness of enjoying the aquatic environment, or to the degradation and seriousness of negative impact caused on towns affected by discharges.

3.3. USE AND DEMAND

3.3.1. Basic concepts and terminology questions

As mentioned in the section on water resources, these should be initially considered as a natural phenomenon, which may be described in the physical-chemical-biological terms of the hydrological cycle. Furthermore, a series of factors operate upon these natural resources, which, in turn, allows them to be considered from the point of view of a *supply*, which can be used to cover a *demand* for water, subject to certain usage limitations, because, logically, not all the natural resource can –nor should– fulfil such a function.

Accordingly, the concept of *water allocation system* arises, as that in which, having covered the limitations or *restrictions* (whether environmental, socio-economic or geopolitical) that make up natural resources as a supply within the system of use, the concurrence of supply and demand takes place, and water's productive potential is developed within socio-economic systems.

Before studying this water allocation system in greater detail, presenting its basic magnitudes in our country, it is appropriate – in view of the different interpretations usually given to these concepts– to make a number of terminological definitions.

Water use

Within the prior restrictions, and therefore within the water allocation system, this *water use*, in a broad sense, may be analysed from two different points of view. From a purely *economic* point of view, using water consists of making it useful, using it to cover needs, so that it represents a means of fulfilling certain production or consumption objectives established by an economic agent. From the *natural environment* point of view, using water consists of transforming its characteristics through actions that quantitatively and qualitatively modify the natural cycle, and consequently involve impact on the environment. One of water planning's objectives is precisely to reconcile both points of view.

From the *economic* point of view, the following water use may take place:

- Human consumption (drink).
- Domestic use (toilets, air-conditioning, ornamental).
- Production.
  - agricultural.
  - animal: livestock consumption, fish farming, aquaculture.
  - industrial (specific use in products or manufacturing processes, preparation or conservation, or arising from production activities).
  - Energy.
- Transportation.
- Commercial activities and services
- Social (public services), cultural (recreational) or ritual utilisation
- Safety (fire-fighting, defence)

From the *natural environment* point of view, use may be:

- Extraction, taking water from the environment, causing a spatial and temporal separation between withdrawal and return. This is also known as *out of the current* use.
- Use in situ, which does not extract water from the environment, but uses some of its potential, in the same location. This is also known as *in the current* use.

Sectoral water uses

Having established the theoretical concept of *use*, and its typology, and turning to sectoral water use, Spanish regulations define this precisely as its different use classes according to destination (art 74.1 RAPAH). From a more conceptual point of view, sectoral water use may be considered as the material fact of applying one or several of its functions to achieve a certain effect.

As mentioned above, these *water functions* –which are the different aptitudes conferred by its physical, chemical and biological properties and characteristics, its distribution in the natural environment and its potential energy– are varied. They may be biological (water as an active component of living things), ecological (water as an aquatic biotope), technical (water as a physical agent) or symbolic (water as an element in a socio-cultural context). No other natural element can substitute water to fulfil the majority of these functions, giving it an absolutely unique utility, without an equivalent of any kind. We shall return to these issues when analysing the different bases for water policy.

Water demand

As regards *water demand*, there is also a regulatory definition in Spanish legislation. According to art. 74.2 RAPAH, it is understood to be the *need of water for one or several uses*, requiring the following data for its definition:

a) The annual volume and spatial distribution of the necessary supply, and the required quality conditions.

b) The supply guarantee level for different uses.

c) Gross consumption, that is, the part of the supply that does not return to the hydraulic system.

d) Annual volume and temporal distribution of return and forecast of quality prior to any treatment.

It should be noted that, as is well-known, this administrative concept of demand does not coincide with the original economic meaning of the term, according to which demand would be the quantity of an asset or service that an economic agent would be willing to acquire in a market at a certain price. The regulatory definition does not include this price factor, so in spite of the terms being the same, its interpretation is clearly different from the purely economic sense. Nevertheless, in view of the habitual assimilation of water resources to supply, it is common to associate water needs or requirements to the idea of demand. Although the conceptual differentiation is trivial, the swapping of these terms is very widespread, and it is traditional in literature on water resources. It is admitted in regulatory texts, and is consequently the one adopted in this White Paper. However, although in practice –and contextually– there is usually no confusion, it would be preferable to specify concepts and formally adopt more rigorous criteria.

In the real exploitation of water resource allocation systems, it is not always possible to provide each demand unit with the volume it requires. Accordingly, another widespread acceptance of the term use arises, which relates it to the *specific application* of water, or the *quantity really used*, to differentiate it from demand , which would mean the quantity required. In this respect, use would be the equivalent of supply.

Need

Furthermore, some writers also establish differences between the concepts of water *need and demand* (Erhard-Cassegrain and Margat, 1983). According to them, while water need is the *necessary and sufficient* quantity and quality of water to ensure the application of functions required for various uses, demand would be the volume considered necessary, in quantity and quality, to *meet a certain objective* in production or consumption. The concept of water need, defined this way, has an absolute, regulatory character, determined by the state of the technique, the circumstances of the case, and current and future demographic and economic levels. It is a theoretical, calculable term, while water demand, as an effective action on the natural environment, is directly observable. We may state that demand is the real expression of a need.

Gross and net demand

Other concepts it is appropriate to define are those referring to gross and net demand. *Gross demand* is basically associated with the concept of *extraction* from the environment. *Net demand*, on the other hand, is closely related with points of consumption and corresponds to the concept of necessary *supply* and replenishment, that is, to do with quantity and quality actually obtained and used. In accordance with this distinction, the basic quantitative difference between gross and net demand is loss, which is included in the former but not in the latter.

Figure 207, adapted from Erhard-Cassegrain and Margat (1983), illustrates some of the concepts defined in above paragraphs.

All the above refers to general concepts on water demand and use in a socio-economic system. The formulas and techniques by which this use is implemented under our legal system refer us to the fundamentally important legal concepts of concession, allocation and reserve, which we shall refer to in other sections.

In this document, while not ignoring the qualifications made and even referring specifically to them on occasions, the concepts of use and demand which are used correspond logically to the above-mentioned regulatory acceptations in effect.

In accordance with these concepts, sections below will present a summary of the basic characteristics and magnitudes of current water use for different purposes.

3.3.2. Knowledge of uses and demands

3.3.2.1. Introduction

Unlike natural resources which, except for the uncertainties of a possible natural or anthropogenic climatic change, are usually considered in long-term, stationary, invariable amounts, water demand and consumption is circumstantial and has an essentially temporal component, so its values must always refer to a specific date, something that should be taken into account in reconstructing historical demand and forecasting future evolution.

In general, there is a remarkable lack of reliable, regular statistics on water use and consumption, so knowledge of historical demand is sometimes as uncertain as knowledge of future demand. This uncertainty, together with the influence of numerous eternal factors that explain its composition, means that forecasts of future demand are particularly difficult, and it is not strange to find, as we shall see, major deviations between initial predictions and what finally occurs in reality.

In fact, faced with the difficulties in obtaining periodic, reliable information on volumes actually supplied and consumed according to different uses, one of the most common demand assessment procedures for population and agrarian supply uses, as we shall see, consists of applying certain theoretical supply values to populations and irrigated surface areas, according to population size, crop type, climatic characteristics, state of infrastructures, etc., and to suppose that the quantities obtained are the supplies necessary. This procedure is acceptable in establishing the future demand, for which forecasts must inevitably be made, but it its application to current demand is debatable, because the theoretical values can, in some cases, differ notably from the real ones. If reliable supply data exists, the user pays for the water consumption, and restrictions are not in force, this supply is comparable to demand, but such a situation is not always the case, not even in urban supply. This major problem's relationship with the need to substantially expand and improve current capacity and water monitoring system is clear, and different sections of this White Paper are insistent along these lines.

Below, and before dealing with a detailed description, we will review the main features and problems of each demand typology, summarising their basic characteristics, problems, and knowledge situation.

3.3.2.2. Urban demand

In the specific case of urban demand, one of its fundamental characteristics is the considerable heterogeneity as far as water use is concerned, because exploitation may be domestic (individual), municipal (watering gardens, fire service, etc.), collective (public services, such as hospitals and schools), industrial, commercial and even agricultural, all contributing to hamper, to a large extent, knowledge about it.

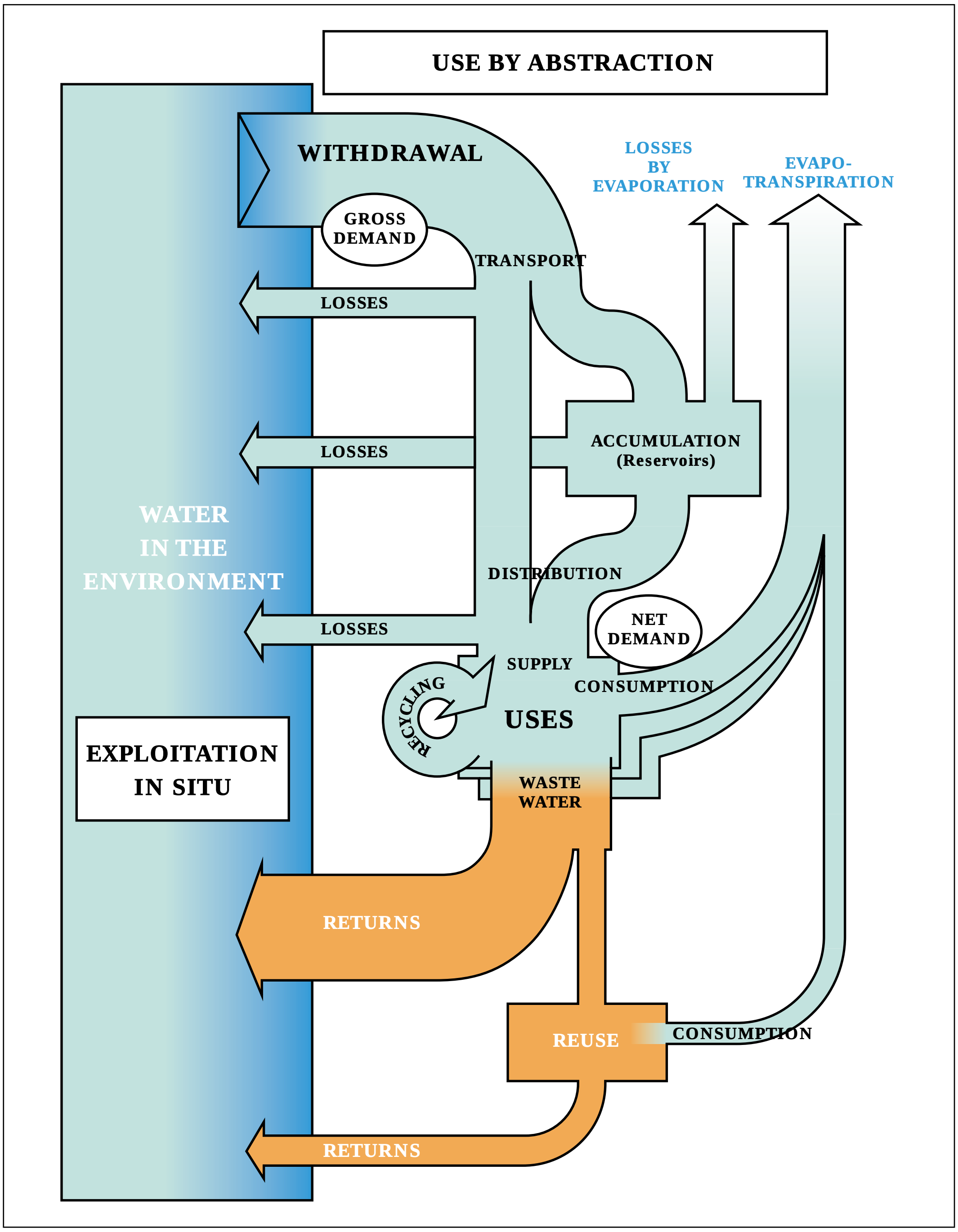


Figure 207. Simplified layout of the general water utilisation system.

In practice, it is very difficult to differentiate volumes of water consumed by the industries connected to the municipal network from those actually due to urban requirements. As we shall see further on, according to surveys by the Spanish Association of Water Supply and Collection (AEAS, 1998), and as global average indicators, together with 61% of strictly domestic consumption, around 23% of the water registered by meters is consumed by small industry, commerce and services that are supplied by the municipal network, and which for water planning purposes are calculated as urban supply demand.

Furthermore, in rural areas with major livestock farming activity, the demand due to stabled livestock located inside towns can even exceed domestic consumption.

In many parts of our territory, tourism and second homes generate a significant water demand, in some towns even exceeding that which strictly corresponds to the stable population. To give some idea, suffice to remember that, as commented in the corresponding section, in 1996 Spain registered nearly 62 million visitors, of whom almost half were concentrated in the summer season, and that, according to the INE 1991 Census on Population and Housing, there exist 2.9 million second homes in Spain, compared with 11.7 million first homes.

As mentioned, the effect of tourism on the total water demand may be important on a local scale, but it does not seem to be very relevant on a national level. In these affected areas, it causes significant distortion, and its considerable seasonal nature poses special difficulties in correctly estimating it.

Additionally, different consumption practices, a reflection of different degrees of awareness on water conservation and saving, and of different territorial resource availability, introduce major distortions in supply requirements. As regards estimating future demand for urban supply, values are determined by evolution both of the population and of network supply.

Uncertainties about the population's evolution and trends have been mentioned in above sections. As for network supply, its values are closely linked to the standard of living (generally understood as level of income), although conditioned by supply networks' rates and by their efficiency and management system. The current world trend in this respect is toward stabilisation of network water supply in the districts that have already reached a sufficient level of development. However, an analysis of the historical evolution of regulatory network supply in developed countries reveals a downward trend in the supply to small populations and, with some exceptions, an upward trend in larger populations.

To illustrate these problems, the graphs in figure 208 show different forecasts carried out in official publications over the last thirty years, with respect to urban supply demands in different hydrographic basins. Deviations are in some cases genuinely striking.

These forecasts, based on registered historical trend, were unable to predict the turning point and stagnation that was to take place in population growth, and economic crises of the seventies, giving rise to the significant deviations shown in the figures. These deviations have had some repercussions. For example, in the case of the Tagus, the Tagus-Segura transfer was affected, after having been planned by taking into consideration the hydraulic reorganisation that Madrid's rapid growth would create in the basin, with the city's supply incorporating resources from the Rivers Guadarrama, Alberche and Tiétar. In the case of Catalonia, a transfer initially planned from the Ebro was eventually, in view of the real growth in urban and industrial demand, far smaller than foreseen, limited to a transfer of resources to the Tarragona area.

Figure 209 summarises these forecasts for Spain as a whole, and shows the significant differences observed. The most moderate forecasts are, as may be seen, those of the recently approved basin management plans, with figures around half those of other, previous projections.

As for basic data, one of the most valuable sources of information on urban consumption in Spain are the 5 surveys carried out by the AEAS (years 1987, 1990, 1992, 1994 and 1996) among drinking water supply companies. In the 1996 survey (AEAS, 1998), the last one available, direct data was gathered from 66% of the population census (with 40% of the census in towns smaller than 20,000 inhabitants, and 93% in towns larger than 20,000 inhabitants). Less information exists as the size of the towns gets smaller, although these small districts are the majority in Spain. For towns of sizes smaller than 20,000 inhabitants, an major source of information is also, as we shall see, provided by the Survey of Municipal Infrastructure and Equipment promoted by the Ministry for Public Administrations in 1986, and which contains interesting information on supply systems.

3.3.2.3. Industrial demand

As regards industrial demand, data available usually refers to heavy industry, which has its own supply sources. Small and medium industry, however, is usually included within the urban supply sector, which generally leads to underestimation of industrial demand. The basin management plans offer valuable information in this respect, although they are not always comparable with each other in view of their different interpretation of the part of the industry considered within urban demand.

Furthermore, there is little knowledge on each industry's real demand, due to considerable dispersion (both territorial and sectoral), to the complexity of industrial use, and to the lack of systematic, statistical control of water consumption, beyond invoicing in the event that it is acquired from the municipal network. This lack of precise knowledge represents one of the main problems in evaluating industrial demand, giving rise to a situation where network supply is established according to occupied surface area, in the case of industrial estates, or to number of employees, in the case of specific industries, thus substituting network supply referring to unit of raw material or finished product, which –considering technological progress– could be more precise.

Accordingly, network supply is generally expressed in mean values for more or less extensive industrial sectors, which may provide reasonable average overall estimates, but lead to significant errors on smaller scales. Also, these values can differ widely according to the source consulted, fundamentally due to existing differences in consumption between industries in the same sector and even in the same type of process.

In the case of future demand, assessment difficulties are greater, because this also includes uncertainties on the evolution of industrial development, which does not usually conform to continuous, predeterminable phenomena, but to circumstantial, spot decisions, and therefore difficult to predict in the medium and long term.

3.3.2.4. Agricultural demand

As regards demand for agricultural uses, the need for appropriate knowledge is highlighted by its magnitude, which represents approximately four times the rest of consumer uses. Some of the main evaluation difficulties lie in the diversity of factors that determine it: surface areas, meteorological variables, dedication to production, soil and water characteristics, typology of plot irrigation methods and han-

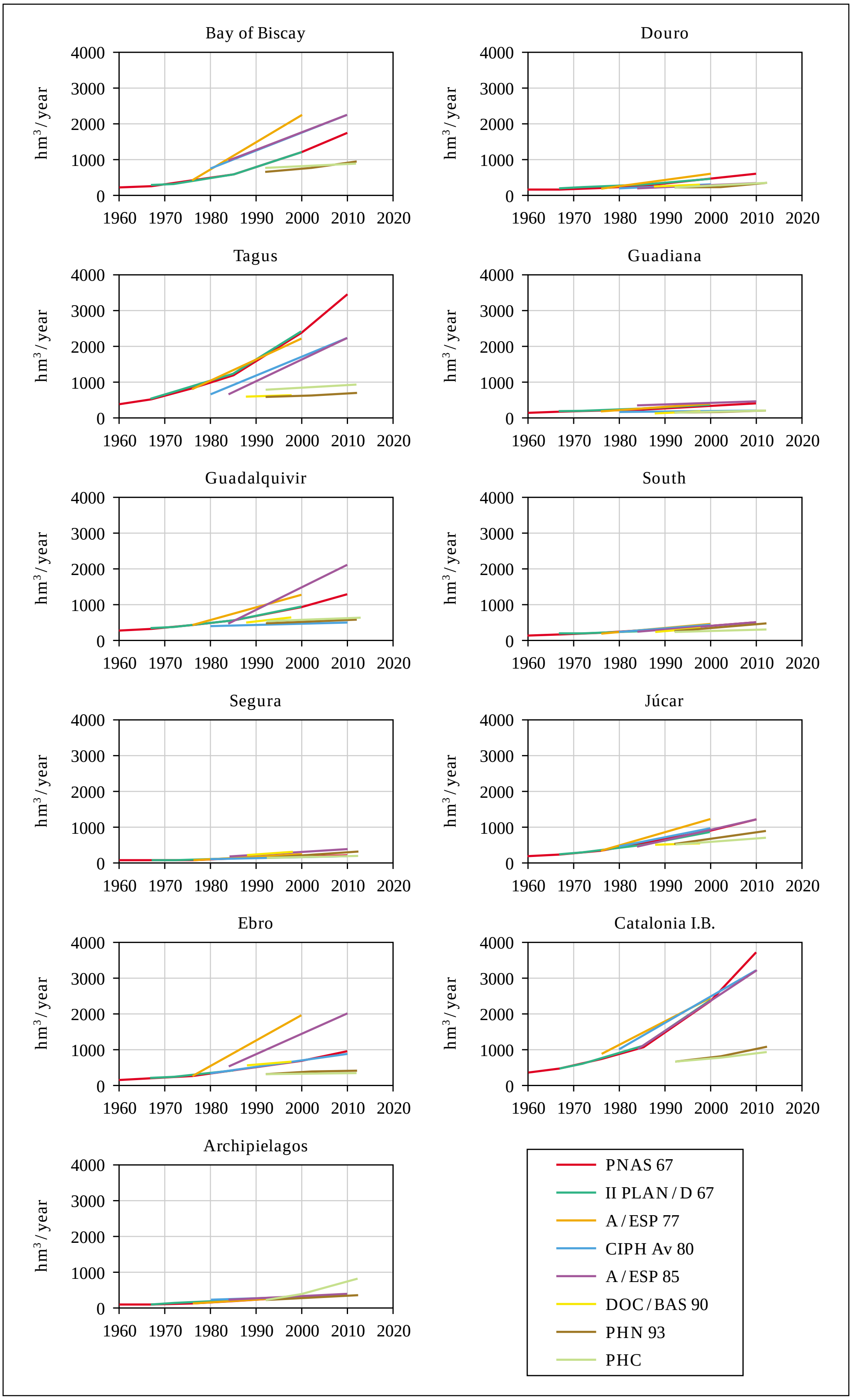


Figure 208. Different forecasts on the evolution of urban demand by hydrographic basin Bay of Biscay.

Sources: National Sanitation and Supply Plan, 1967 (PNAS 67); II Economic and Social Development Plan, PG(1967) (II Plan/D 67); Water in Spain, 1977 (A/Esp77); Inter-Ministerial Commission on Water Planning Hydrological-Advance 80, MOPU-CIPH (1980) (CIPH Av 80); Water in Spain, 1985 (A/Esp85); Basic Documentation, MOPU-DGOH (1990) (Doc/Bas 90); Draft National Hydrological Plan, MOPT (1993) (PHN 93) and basin management plans (PHC).

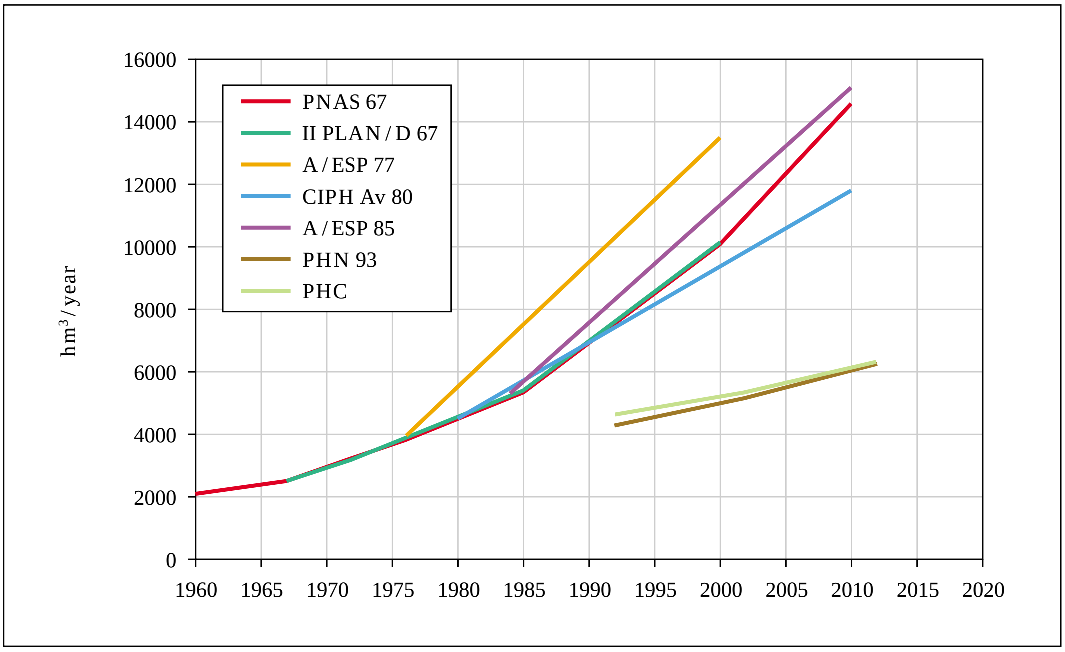


Figure 209. Different forecasts on the global evolution of urban demand.

Sources: National Sanitation and Supply Plan, 1967 (PNAS 67); II Economic and Social Development Plan, PG(1967) (II Plan/D 67); Water in Spain, 1977 (A/Esp77); Inter-Ministerial Commission on Water Planning Hydrological-Advance 80, MOPU-CIPH (1980) (CIPH Av 80); Water in Spain, 1985 (A/Esp85); Basic Documentation, MOPU-DGOH (1990) (Doc/Bas 90); Draft National Hydrological Plan, MOPT (1993) (PHN 93) and basin management plans (PHC).

dling conditions, typology of transportation and distribution networks and operating conditions, etc.

Some of these factors also have appreciable inter-annual variability. This is the case of meteorological factors (basically temperature and precipitation), which determine the water requirements of planted crops, the surface area and location of each crop, the total irrigated area and the delimitation of the mosaic of plots that are actually irrigated.

An example of demand variation due to meteorological factors can be seen in a study carried out in 30 irrigated areas in the Douro basin (CEDEX, 1992), where these areas' average net theoretical demand ranges, according to the years, between 80% and 120% of demand in an average year, with some specific areas amounting to considerably higher deviations (from 60% to 170%). As an example of significant inter-annual variation in the surface area of different crops, we could mention that national surface area of irrigated sunflower and maize, in the period 1991-1994, ranged from 169,000 to 576,000 ha. in the case of the sunflower and from 176,000 to 366,000 ha. in the case of maize (MAP data).

All this should indicate an important fact, which it is appropriate to underline, which is that it is practically impossible to know with absolute accuracy, on the scale of large hydrographic basins, the surfaces areas really irrigated in a specific year. This data is always unknown and can only be estimated, more or less approximately, according to the precision and detail of the study carried out. The truly relevant aspect, as regards water planning, is the surface area that actually describes the current situation (understanding this to mean an average of the latest representative years), and this is what is usually given in recent basin management plans.

For a specific unit of agricultural demand, gross annual demand and monthly distribution is generally evaluated, in planning, from the irrigated surface area, from the surface distribution of crops planted, of the net water requirements per surface area (allocation) of each of those crops, and of the losses that take place in the distribution and application of the water. To quantify these factors it is necessary to have a relatively complex set of basic data and empiric coefficients, and to apply certain procedures to evaluate several intermediate parameters.

Evaluating these factors, which are highly variable in time and space, involves certain difficulties arising from the variety of situations, from a lack of some basic data, from limitations as regards the availability of empiric coefficients, from some diversity in procedures to evaluate intermediate parameters and deficiencies with respect to their empiric contrast, and from the relative shortage of measurements and gauging, and as a consequence, from the lack of a contrasted, universally accepted catalogue of practical, typified irrigation duties for the whole national territory. An illustrative example, parallel to the case above for surface areas, of the considerable variation in crop duties, can be seen in the peppers of western Almería, grown in greenhouses, the area's main product under plastic (over 7,000 ha). Despite being the same crop (pepper), the same area (western Almería) and the same type of irrigation (sandy soil and drip irrigation), the water allocation for the different exploitations, in the seasons 93/94 and 94/95, ranged from 1,907 to 5,168 m^3/ha/year, due to the different cycles, the different varieties of pepper, the differences in the greenhouses, and the different irrigation practices. Between the two campaigns, the global mean values were respectively 3,711 and 3,831 m^3/ha/year (data from Pérez and Carreño, Caja Rural de Almería, Las Palmerillas Experimental Station).

As mentioned above in connection with surface areas, the important thing for the purposes of water planning is to obtain average zonal allocation, describing the current situation (understanding this to mean and average of the last representative years), and these are those usually given in recent basin management plans.

As for demand for livestock, frequently considered together with that for irrigation, both making up total agricultural demand, it represents –as we shall see in the specific section– an absolutely insignificant quantity compared with irrigation, so it is not usually broken down in detailed analyses, and is considered comprised within the first.

To forecast future demand, we also need forecasts on new irrigated surface areas, an issue of well-known difficulty, on its dedication to production, affected by the relative current agro-economic uncertainty, the potential saving from programmed modernisation actions and, to a certain extent, on possible climatic changes. All the above, which incorporates additional difficulties, leads future irrigation demand to be approached with prudently diversified scenarios.

Illustratively, and in the same way as was done for urban demand, the graphs in figure 210 show different forecasts, made in official publications over the last thirty years, regarding irrigation water demand in different basins.

Figure 211 also summarises these forecasts for Spain as a whole, and also shows how the most moderate forecasts are those of the basin management plans, and of the draft National Hydrological Plan of 1993.

The limitations and difficulties described give rise to some reservations as to the reliability of values assigned to irrigation duties and demand. It is appropriate to note, however, that its assessment, given the quantity of data and parameters that are involved, and their variability, is not an easy question. Neither is it an exclusive problem of Spanish irrigated areas, but is habitual in numerous irrigated areas all over the world. This is highlighted by the difficulties that arise when trying to obtain information on these matters –for example on water loss– in the irrigated areas of different countries. It is also necessary to take into account that the diversity of the physical environment where Spain's irrigation is established, and the variety of its social and infrastructural characteristics increases the impediments in dealing with it.

It should be noted, however, that the use of tools like teledetection, geographical information systems, the creation of databases on real allocation and demand, and the use of modern experimental and calculation procedures, they allow the problem to be confronted with new perspectives, very recently available, and that, although they have not yet solved the problem completely, are already making significant progress in improving knowledge of water demand and use for irrigation.

3.3.2.5. Environmental requirements

As for environmental requirements, it should be said that they call for special treatment, because they do not represent a water use, at least in a strict regulatory sense, but rather, to be precise, and as mentioned when describing the concept of available resources, they constitute restrictions in the exploitation of the water itself in the natural environment.

These restrictions may be designed to protect, in certain areas and periods, the natural functions of water by preserving flow, levels, volumes or its physio-chemical characteristics. Obviously, these restrictions can mean a limitation of available resources for various uses, but it is doubtful that they constitute a use in themselves. This is how it appears to be conceived by the Water Act itself, by expressly differentiating, in the chapter on assignments and reservations, those necessary for uses and current and future demand from those corresponding to the conservation and recovery of the natural environment, and this may be deduced from the constitutional relevance of environmental conservation, as a foundation upon which, harmoniously and respectfully, other activities must be based.

Besides this consideration, the first difficulty arising in the definition of environmental requirements is terminological. If the aim is to recover the original conditions of biodiversity, species and ecosystems prior to the extraction of flow from the environment, the term would be ecological flow, frequently used in Spain. If the aim, however, is to preserve current environmental conditions, the result of actions carried out throughout history, a more appropriate term could be maintenance flow.

The second difficulty arises in simply estimating the necessary volume to preserve those environmental conditions. To accurately determine this volume, it is necessary to have exhaustive knowledge of the elements that make up the physical environment of rivers and their associated ecosystems, their interrelations and mutual dependence. That is, it is necessary to know plant species and formations of riverside and aquatic vegetation and their spatial distribution, animal species and communities that depend on rivers, typologies of existing channels, etc. Once these parameters are known, it would be possible to assess water needs of each of the elements described, a task for which considerable economic and human resources are required, and which is difficult to approach technically.

Environmental requirements in Spain have been approached in the relative autonomous legislation on the protection of fishing and the preservation of aquatic ecosystems. The considerations laid down by the Autonomous Communities' legislation are very variable. Accordingly, the Principate of Asturias establishes different formulas to determine the minimum flow that should circulate in rivers where mini-stations have been set up, according to the characteristics of the fish life (trout, salmon and others). The Provincial Community of Navarre establishes ecological flow for a series of river reaches, and Castile-La Mancha and Galicia establish minimum ecological flow as 10% of the mean

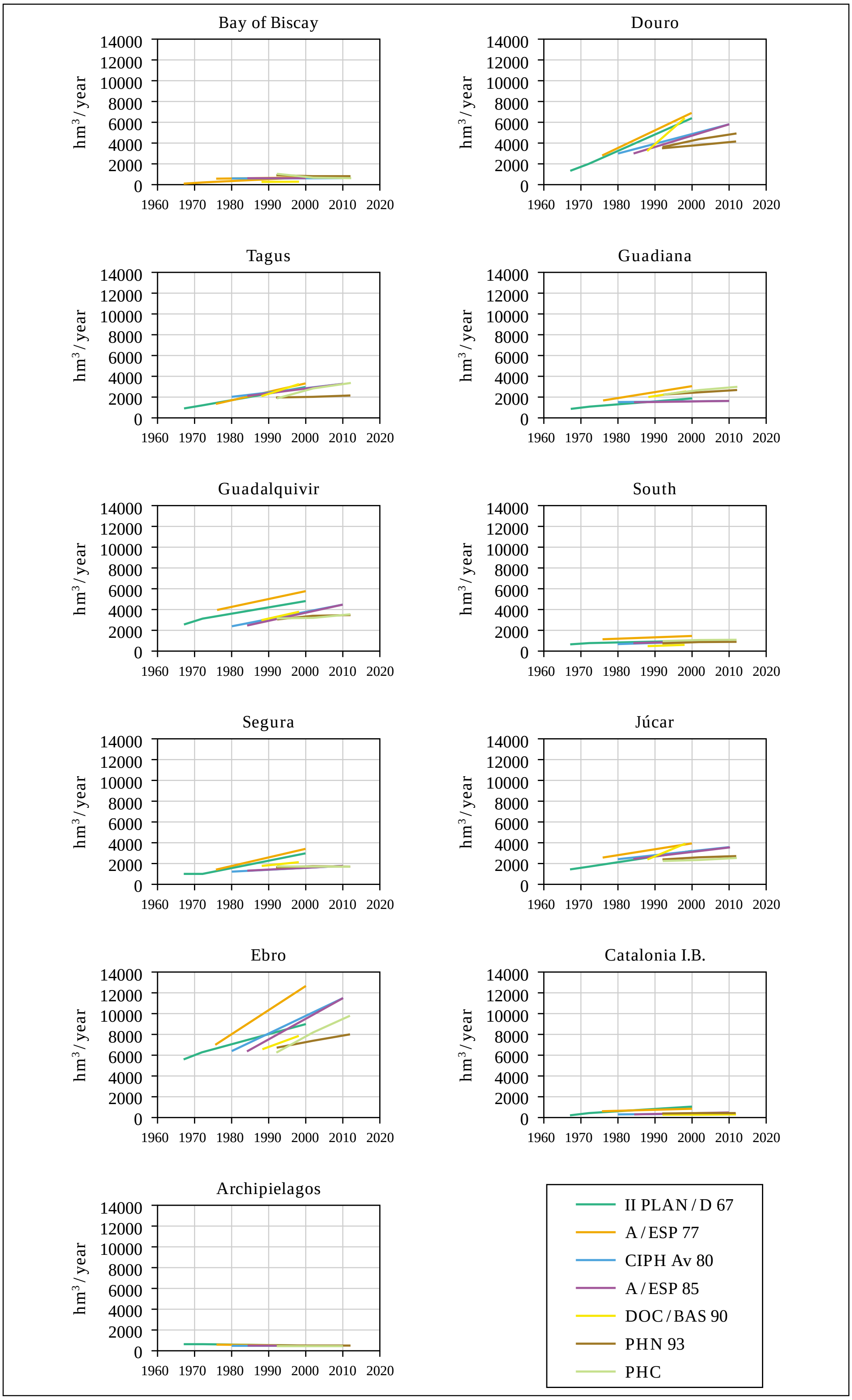


Figure 210. Different forecasts of evolution of irrigation demand by basins.

Sources: National Sanitation and Supply Plan, 1967 (PNAS 67); II Economic and Social Development Plan, PG(1967) (II Plan/D 67); Water in Spain, 1977 (A/Esp77); Inter-Ministerial Commission on Water Planning Hydrological-Advance 80, MOPU-CIPH (1980) (CIPH Av 80); Water in Spain, 1985 (A/Esp85); Basic Documentation, MOPU-DGOH (1990) (Doc/Bas 90); Draft National Hydrological Plan, MOPT (1993) (PHN 93) and basin management plans (PHC).

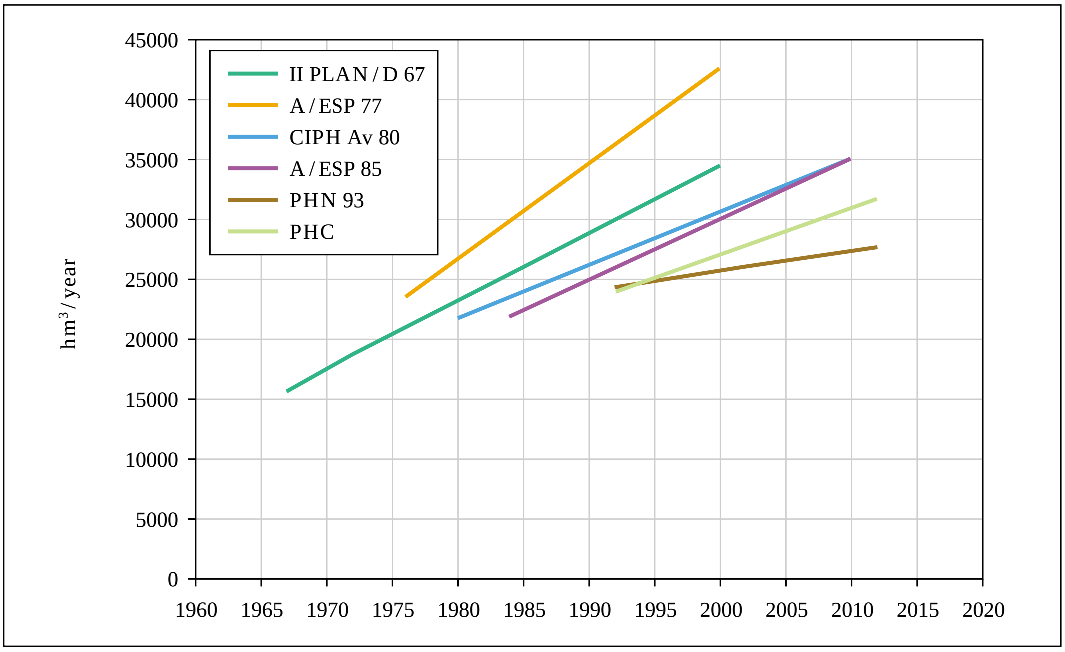


Figure 211. Different forecasts on the evolution of global irrigation demand.

Sources: II Economic and Social Development Plan, PG(1967) (II Plan/D 67); Water in Spain, 1977 (A/Esp77); Inter-Ministerial Commission on Water Planning -Advance 80, MOPU-CIPH(1980) (CIPH Av 80); Water in Spain, 1985 (A/Esp85); Preliminary design of National Hydrological Plan, MOPT(1993) (PHN 93) and basin management plans (PHC).

annual flow, Castile-León establishes that the minimum circulating spot flow shall be no lower than 20% of the mean inter-annual flow at the point in question. Extremadura does not establish any specific flow. These numerous autonomous legislative provisions for calculating maintenance flow, although seemingly incoherent, definitively show that each river is different and, therefore, requires an individualized methodology.

Furthermore, the basin plans, although not in all cases, lay down certain minimum or ecological flow. This flow may vary greatly, ranging from 1% to 10% of mean annual cumulative flow. The methodology used to calculate this cannot normally be deduced from analysis, although in some cases it does not seem to have been obtained in accordance with real environmental requirements, but according to the resources not used in covering other, already-committed demands, and whose modification could require compulsory purchase. This approach obviously lacks theoretical basis, but it may be appropriate to prevent greater deterioration of the aquatic environment.

In short, we are faced with a water requirement of considerable importance, but which still lacks, from a conceptual point of view, reflection upon its very nature, and a definition and accurate adjustment within the system of uses; from the point of view of technology, it lacks methodologies, models and generally-admitted determinations; and from a legal point of view, it lacks the necessary clarification of powers and procedures. We will to this below, when describing this question specifically, indicating the steps that have been taken to overcome this situation.

3.3.3. Urban supply

Having considered the situation and problems of knowledge about different uses, we come to a detailed consideration of each one, beginning with population supply.

3.3.3.1. General description

Water supply to populations is an unquestionable basic element of modern society, and an obligatory, non-transferable service by public authorities. The Water Act, article 58, underlines this accordingly, always considering water use for this purpose as a priority.

Despite its current consideration as a basic service, the supply of drinking water to cities is a historical problem, and one for which a solution was not found until the 19th century. To drink water in the past was always dangerous, even fatal, because the means pf supply, when they existed, were quickly polluted by their own effluent. Water supply to cities was primarily used for cleaning and sanitation, and the usual drink for people of all ages was, for the last 10,000 years, alcoholic beer and wine, both antiseptic and calorific (Vallee, 1998). An analysis of urban supply's historical evolution in our country, and of its different development stages, can be seen in Matés Barco (1999).

With the water supply's health problems basically overcome –in developed societies– current demand is characterised by the requirement of a very high guarantee level, and a basically uniform temporal distribution of necessary supply –except in areas concentrating tourism and second homes. Also, and in comparison with other uses, the quality conditions of supply are obviously more demanding, as was seen in the relevant sections. Localised spot returns take place, generally with constant characteristics, so appropriately treated is able to be subsequently re-used for purposes with lower quality requirements. The quantity of these returns usually amounts to 80% of the water supplied.

According to the survey carried out in 1996 by AEAS (1998), the source of the water used for supplies above 20,000 inhabitants is distributed as 79% surface water, 19% groundwater (including 2% of springs), and 2% from other sources (basically desalination). The adjoining graph shows the evolution of water sources (extracted + acquired) according to the five successive AEAS surveys, illustrating a significant increase in surface sources as of 1992, compared with stability in the other sources.

In populations smaller than 20,000 inhabitants, the proportions are inverted, with 22% of surface origin, 70% groundwater (39% from wells or boreholes and 31% from springs), and the rest unspecified (Sanz Pérez, 1995).

Furthermore, the uses of water delivered by urban supply networks include, as mentioned, those corresponding to demand by industries and connected services. Figure 212 also shows the relative proportion of different uses in successive surveys by AEAS, illustrating a certain stability in these proportions.

As may be seen, an appreciable difference exists between abstracted and acquired water, and the water registered in meters for different uses. This difference is due both to losses between source and delivery, and losses and/or lack of registration from the deposits, in the process of distribution to end users.

As for supply management, in accordance with Act 7/85 Regulating the Bases of Local Regime (arts. 25.2 and 26.1), the residential supply of drinking water and the collection and treatment of the delivered water are services of municipal competence that municipal councils are bound to render. This management can be carried out directly (own administration, Autonomous agencies or Public Companies) or indirectly (mixed companies, concessions, interested administration, agreement or lease).

Management can be carried out by a supramunicipal organisation, with the resulting economy of scale (in infrastructures, technical administration, general costs, etc.). Such organisations can on a local basis (joint communities, districts, metropolitan areas or grouping of municipalities) or autonomous (autonomous administrative organisations, state institutions or public companies).

The supply management regime varies considerably with population size, as may be seen in table 59, showing the results of the survey carried out by the AEAS in 1996 (AEAS, 1998) for populations of more than 20,000 inhabitants. The total results of the surveys carried out in 1992 and 1944 are also included, illustrating a consolidation of the trend in assigning management to municipal and private companies, reducing direct management by municipal corporations.

In turn, in populations with less than 20,000 inhabitants, the 60% of supply managed by the municipal councils themselves in 1994 has passed to 53% in 1996, while the 24% of management by concession in 1994 has passed to 29% in 1996.

The need to increase supply guarantee and quality –and the increment in costs that this involves– , as well as the need to complete the treatment of urban wastewater in coming years, tends to strengthen the convenience of grouping of municipalities together to diminish unitary costs of investment and exploitation. This fact, in turn, may tend to reinforce the progressive participation of companies specialised in supply water management.

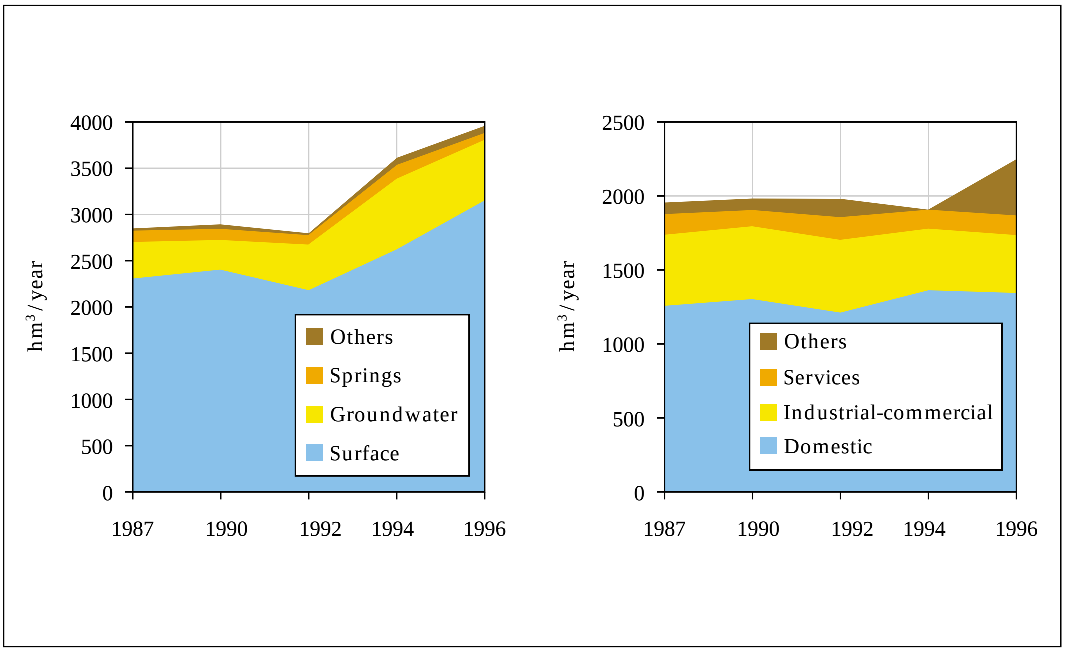


Figure 212. Evolution of urban supply water sources and uses in municipalities larger than 20,000 inhab.

Management regime	Percentage of each management regime according to population range in 1996				Total percentages		
	From 20,000 to 50,000 inhab.	From 50,000 to 100,000 inhab.	Over 100,000 inhab.	Metropol. area	1996	1994	1992
Municipal corporation	8	18	25	0	16	15	37
Priv. municipal companies	3	18	31	25	17	23	20
Joint community	0	0	6	0	2	3	6
Concession to private company	76	53	19	25	48	49	33
Mixed company	11	12	14	0	12	4	4
Others	3	0	6	50	5	6	1

Table 59. Management regime of urban supply according to population ranges.

3.3.3.2. Current use and representative consumption

According to the surveys carried out by the AEAS, it is estimated that the volume of water abstracted in Spain for population supply in 1996 was about 4,300 hm^3, having recently varied between 4,200 and 4,750 hm^3/year, depending on the different climatic situation. This figure corresponds to gross demand and includes consumption by industries supplied from the urban network, the tourist and seasonal population, public uses, non-registered consumption and losses. Since there have been neither systematic nor significant restrictions, this supply can be equated, without appreciable errors, to demand.

The demand that the basin management plans consider representative of the current situation can stand at around 4,700 hm^3/year (around 13% of total demand for urban, industrial and irrigation uses). Its distribution according to the different plans is shown in table 60 and figure 213, where estimated population figures have also been included for 1995 (INE data) and the resulting mean gross allocation. This allocation, as we shall see, fits with the AEAS estimation in its surveys. In some cases, only demand generated within the same area has been considered, even when the demand really covered by it may be different.

The populations shown in table 60 do not include tourism, and the effects de drift due to second homes in rural areas, causing higher duties in those plans that have a considerable tourist component. In the Júcar basin, for example, the equivalent population, taking the seasonal population into account (representing 2,600,000 overnight stays) would be 4,870,000 inhabitants compared with a stable population of 4,096,000 inhabitants.

The territorial distribution of this demand is, logically, similar to the population distribution, although intensified in the points of greatest urban concentration, which require larger duties.

Figure 214 shows the spatial distribution of current urban demand for the whole national territory, giving its value –in m^3/year– for every km^2 of Spanish territory. On the basis of this map, we can obtain the supply demand for any area we need (hydrographic basin, municipality, county, Autonomous Community…), just by adding the spot values

Area	Urban demand (hm^3/year)	Population 1995 (inhab)	Gross allocation (l/inhab/day)
North I	77	860,731	245
North II	214	1,611,380	364
North III	269	1,860,656	396
Douro	214	2,188,134	268
Tagus	768	6,094,487	345
Guadiana I	119	1,322,404	247
Guadiana II	38	376,806	276
Guadalquivir	532	4,753,689	307
South	248	1,996,661	340
Segura	172	1,387,446	340
Júcar	563	4,095,927	377
Ebro	313	2,752,928	311
Catalonia I.B.	682	5,562,877	336
Galicia Coast	210	1,961,496	293
Peninsula	4,419	36,825,622	329
Balearic Isl.	95	727,553	358
Canaries	153	1,556,329	269
Spain	**4,667**	**39,109,504**	**327**

Table 60. Current demand and duty of urban supply by planning area.

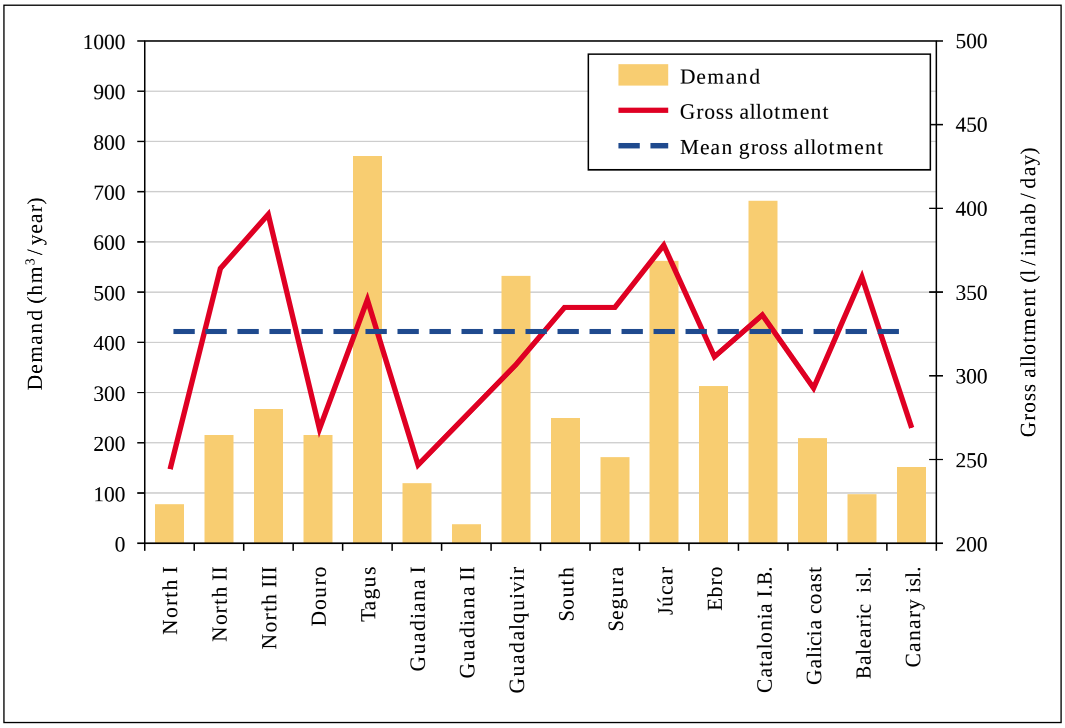


Figure 213. Current demand and allotment of urban supply by planning area.

within the area studied. As may be seen, the greatest demand is located in the big metropolitan areas (Madrid, Barcelona, Valencia, Seville and Bilbao), and on the Mediterranean coast.

This map has been obtained from the soil uses of CORINE-Land Cover, selecting the type of urban use. Each cell of the territory, with dimensions of 1x1 km, was assigned a representative value of the fraction (between 0 and 1) of occupation of urban land use. Furthermore, each cell was assigned an unitary allocation according to the M.O. recommendations of 1992, on technical coordination, depending on the number of inhabitants of the population it belonged to,

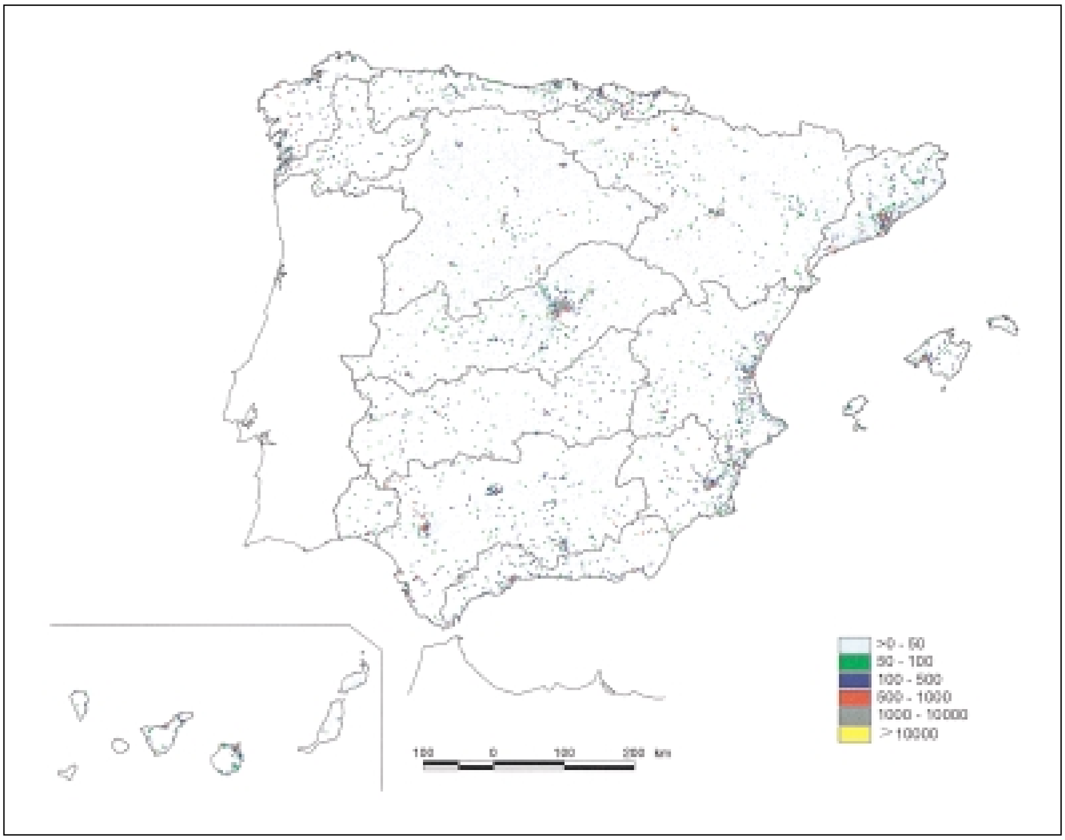


Figure 214. Map of spatial distribution of population supply demand (mm/year).

obtained by superimposing it on the map of municipal population census. The demands defined in the Basin Plans were distributed territorially according to these results, thus guaranteeing both the preservation of added volumes and their distribution on the scale of population centres.

As regards supply quantities, those obtained in the AEAS surveys in 1994 and 1996, referring to volume supplied to the network, are shown in table 61 for different-sized towns.

As may be seen, supply quantities tend to fall with the population size, which is explained the increasing effect of scale of equipment and services. For towns smaller than 20,000 inhabitants, the mean supply quantity continues falling, although major differences exist between the different towns.

Regardless of the different data sources, these supply quantities differ from the gross supply quantities in the losses that take place up to the network source, in the high-level deposits.

Furthermore, evolution of these supply quantities over recent years shows a certain drop in 1992, together with a very appreciable dip in 1994, at least in towns bigger than 20,000 inhabitants, as shown in table 62 (AEAS data).

In the drop in supply quantities in the years 1992 and 1994, we should take into account existence of a major drought, with its corresponding demand moderation, and the saving measures and of leakage reduction implemented in a large number of towns. In 1996, supply quantities recovered, but at more contained levels than those at the beginning of the decade, continuing the positive effect of moderation in consumption brought about by the drought.

As a characteristic example of this evolution, and an illustration of a trend that seems to be relatively widespread, figure 215 presents the series of annual volumes supplied at high level by the Association of Canales del Taibilla to cover consumption in its districts (76 belonging to Murcia, Alicante and Albacete, with total of around 2 million people), organisations and associations (MCT [1995]; MCT [1998]).

It shows significant continuous growth is –despite some ups and downs–, from its origins in the forties, up to the decade of the eighties. The maximum is reached around the year 1990 and, from that date on, there is a slight decrease or stabilization of the volume supplied. The series also clearly shows the effect of restrictions imposed in the droughts of ‘83 and ‘94. Later on, we shall see this behaviour pattern is not exclusive, but rather, as mentioned, seems to be widespread in other supply systems.

In this specific case, we should bear in mind that the initial evolution is not wholly due to an increase in demand, but to the fact that new districts were included and networks covered were expanded. Also, there are some districts that also have own resources, whose inclusion could slightly modify global trends shown.

Despite all this, it seems that, once the network has reached maturity, and all districts connected and covered, we should not expect very significant new continuous increases, except those arising from a slight vegetative increase or from demand of small connected industries (sensitive to economic circumstances), a few new inclusions, possible improvements to supply quantity, or growth in coastal tourism.

As regards the seasonality of urban demand, this is clearly illustrated in the following figure, showing the percentage distribution of urban supply demands in the whole Segura basin, in its industrial, agricultural and tourist districts, and of aggregate supply to San Javier, La Ribera and La Manga. It illustrates the effects of the degree of spatial aggregation on this demand.

As may be seen, the seasonal effect is logically more significant the smaller the demand unit is, and the greater its tourist specialisation. It can even be as intense as that of irrigation demand, as shown in figure 216, which also includes, for comparison purposes, average seasonal distribution of irrigation in the Segura basin.

As regards losses and uncontrolled waters, a part of the water distributed is not registered by the supply organisations. These volumes usually correspond to street-cleaning and garden irrigation, measurement errors and losses, both in treatment and in distribution. The mean value of these unregistered quantities ranges between 34% in the case of big metropolitan areas and 24% in towns smaller than 20,000 inhabitants. In towns bigger than 20,000 inhabitants, this value is relatively stable at around 30%, as shown in table 63 (AEAS data). In towns smaller than 20,000 inhab., the percentage is rather larger (around 31% in 1996).

As we have seen, domestic consumption is by far the most important part of urban use.

In order to characterize this segment better, a specific analysis has been made from the data provided by the 1990-1991 Family Budget Survey. This survey was carried out on a sample of 21,155 homes, distributed over the whole national territory. Although this survey did not measure water consumption directly, it provided information on the socioeconomic variables involved, and offered good spatial, unbiased sample of Spanish homes.

Population	Allocation (net) 1994 (l/inhab/day)	Allocation (net) 1996 (l/inhab/day)
Between 50,000 and 100,000	238	301
Between 20,000 and 50,000	264	241
More than 100,000	289	296
Metropolitan areas	295	322
Average	**265**	**289**

Table 61. Duty (supply to the network) according to population size.

Table 62. Recent evolution of mean population supply quantities in Spain.

Year	Mean network supply (l/inhab/day)
1987	309
1990	313
1992	302
1994	265
1996	289

It individually analysed expenses in water consumption registered in all Spanish provincial capitals for which complete information is available on the real tariff structure, and considered water consumption by household.

Although, obviously, water demand in residences can depend on whether they house more than one family, on the number of sanitary fittings, on domestic appliances, on consumption habits, etc., we may consider that a variable synthesizing all these elements well is family income because, in a sense, it always underlies the above, and seems stand above other factors such as tariffs. For this reason, the family water consumption calculated above has been associated with the family income, obtaining the result shown in figure 217, where both variables are represented referring to each member of the family unit.

Notwithstanding the fact that family income is not the only explanatory factor for domestic consumption, it is worth highlighting firstly that, contrary to what is occasionally stated, there seems to exist an appreciable correlation between both variables, despite the insignificant role given to the water bill in the family expenses. In this respect we should note the low participation that, according to the survey mentioned above, water expenses have in the family's total expense, with an national average of just 0,5%, in values that range from 0.3% (in Álava, Ávila, A Coruña and Lleida) to 0.9% (Canary Islands). In the Peninsula, the highest values are registered in Murcia (0.7%) and Barcelona (0.6%). These differences can be attributed more to different prices than to differences in consumption. The average annual expense on water is 3,600 pesetas (in 1991) per capita (4,300 if this only refers to provincial capitals).

Secondly, the values obtained for the elasticity of family water consumption /income are especially relevant: 0.61 on average, with 0.51 for the group of families with lower-than-average income and 0.81 for those with above-average income. Within this second group, the first half of the section, which is the most interesting in forecasting the future evolution of family income, registers a value of 0.66.

It is interesting to notice the average value resulting from consumption, which stands at 170 l/inhab/day. We should remember that this figure only refers to domestic consumption, to which the rest of non-domestic consumption would have to be added (commercial-industrial and public services) to obtain the total urban allocation.

Using a supposition of real annual GDP growth between 2.5% and 3.0% for the next few years, and allowing for this increase to be proportionally reflected in family income, and there are no changes in the current behavior patterns in consumption and the water price/family income relationship, we could forecast an average increase in water consumption per capita of between 1.7% and 2.0%, in accumulative annual terms. These figures therefore correspond to a working hypothesis, which assumes a parallel evolution of urban water demand and

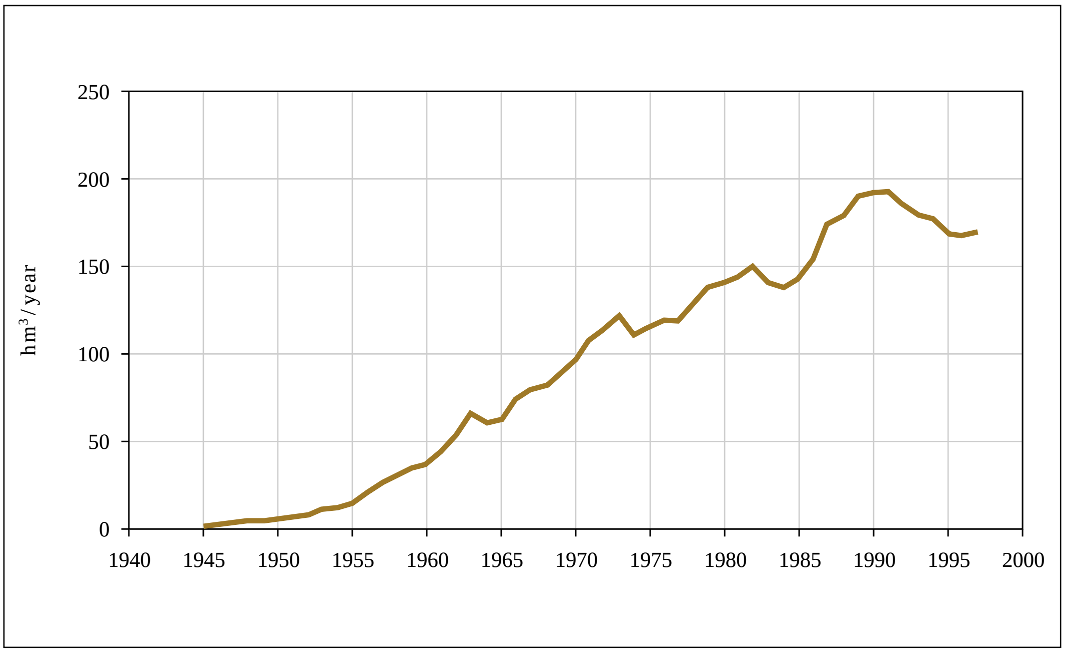


Figure 215. Evolution of annual volumes supplied by the Association of Canales del Taibilla.

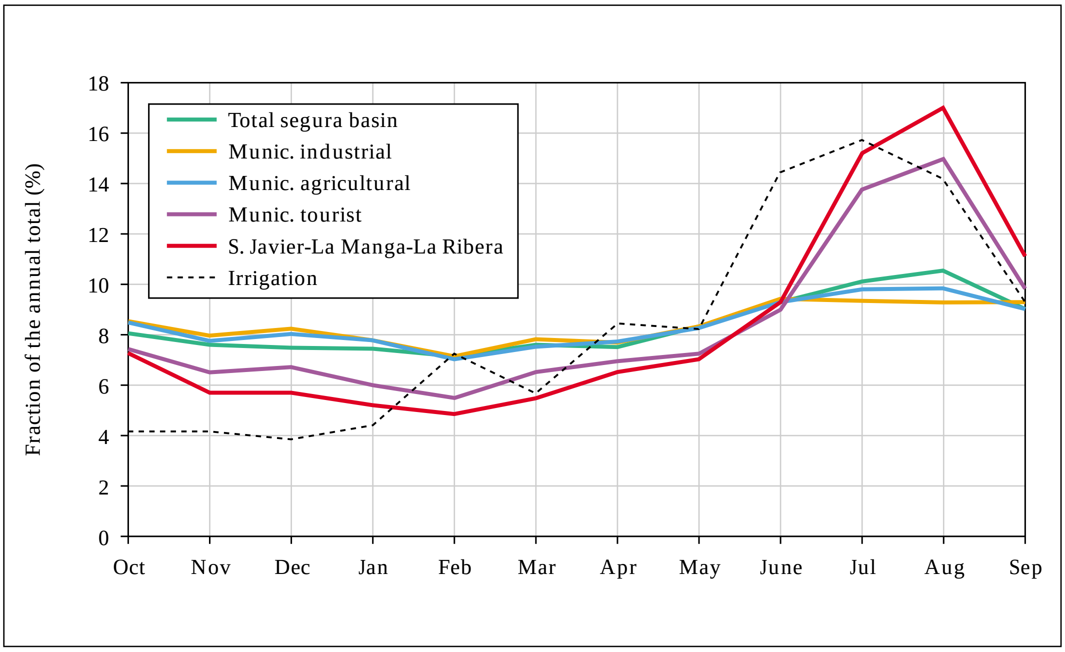


Figure 216. Examples of seasonal supply demand distribution on different spatial scales.

GDP, *ceteris paribus*, as is usually done in economic studies. In any event, it is obvious that this should not be taken as the only possible approach to this issue, with respect to making a reliable forecast of the future situation. In fact, in countries like Germany, after an initially parallel evolution of the GDP and urban water consumption, a clear divergence of both variables took place as of the eighties, with markedly different evolutions (Gundermann [1993], p. 220). We should add to this the possible effects of demand saturation, which may have already been reached in some cities, such as Madrid or Barcelona (Sánchez González, 1993). However, the above figures can be understood as a warning signal for implementing the necessary corrective measures in consumption habits, highlighting the importance of practices oriented towards saving and balancing possible growth.

Using the same source, a possible aggregated demand curve for this sector has also been established, presented in figure 218. The value of obtained elasticity: –0.57, the same as the one observed in studies carried out for cities in southern California (refs. in Jové Vintró [1993]; Baumann et al. [1998]).

The high prices of the low-consumption sections correspond, basically, to second homes a low level of temporal occupation, so the cost of the service, by referring to low consumption, takes place at high unitary prices, not strictly homogeneous with the rest of the data.

Although these results show relative dispersion, and they are not in line with the classic demand curve, they illustrate a certain response to this demand with respect to water price. The resulting rigidity, at least in accordance with the hypotheses carried out in this analysis, could be less marked than shown in some of the numerous works carried out on this matter, although it is necessary to express some doubt as to whether it is in fact an elastic response to prices (demand curve) or a structural form of behavior associated with the tariff systems and lifestyles (the reason why the abc axis is given as consumption –which is observed– and not demand).

The reason is that, as we have seen on reiterated occasions, urban consumers do not have a clear perception what price they pay for water consumed, especially when confronted with tariffs increasing in blocks, so they will hardly react to such price hikes. This may mean that a widespread increase in prices could take place, maintaining a similar upward curve, instead of observed consumption decreasing. The experience of companies in the sector indeed indicates inelastic behaviour when confronted with even significant price variations, mainly in the low-demand segments. The case of industrial use is different, where greater elasticity does exist with respect to price, and this effect, together with that of technological improvements, can give rise, as has been shown, to reductions in consumption.

There are very few studies in our country aimed at systematically characterizing the functions of urban supply

Year	Non-registered water
1987	30%
1990	32%
1992	29%
1994	28%
1996	29%

Table 63. Percentage evolution of unregistered water in urban supply.

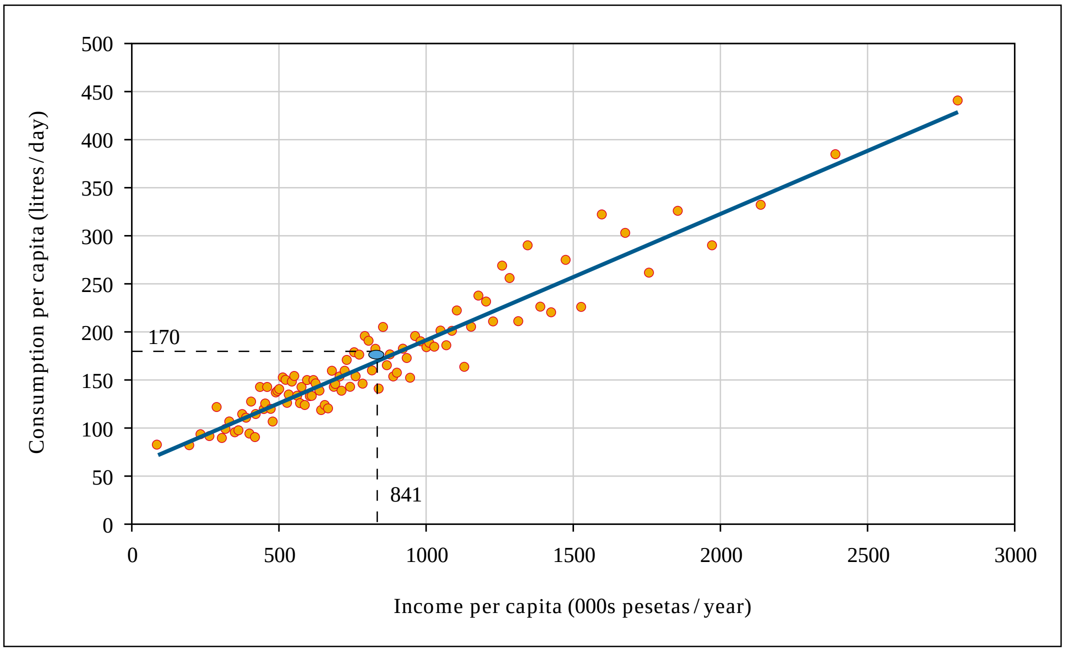


Figure 217. Relationship between water consumption and income.

demand. A basic problem is the lack of sufficient statistical information, which tends to improve with the sector's progressive incorporation of INE accounts.

It is also interesting to know the statistical distribution of water for domestic supply, as shown in figure 219 (Generalitat de Catalunya, 1999).

It illustrates the accumulated distribution of the percentage of subscribers and water supply with respect to the annual domestic volume supplied (m^3/year). This distribution has been obtained by quarterly samples of supply to almost 1 million subscribers in Barcelona and its metropolitan area, with a total supply of 26 hm^3/quarter, and can therefore be considered highly representative of urban Catalan areas and, by extrapolation, of metropolitan areas in the rest of the country.

As may be seen, 25% of supply points concentrate 50% of supply, while 1/6 of the maximum supply is provided to 50% of subscribers. The right-hand distribution line is very spread, with just 10% of supply above 250 m^3/year, and 10% of subscribers above 200 m^3/year (equivalent to 550 l/subscriber/day).

3.3.3.3. Regime of tariffs

In Spain, there exists a complex supply water tariff structure, arising both from the different concepts considered

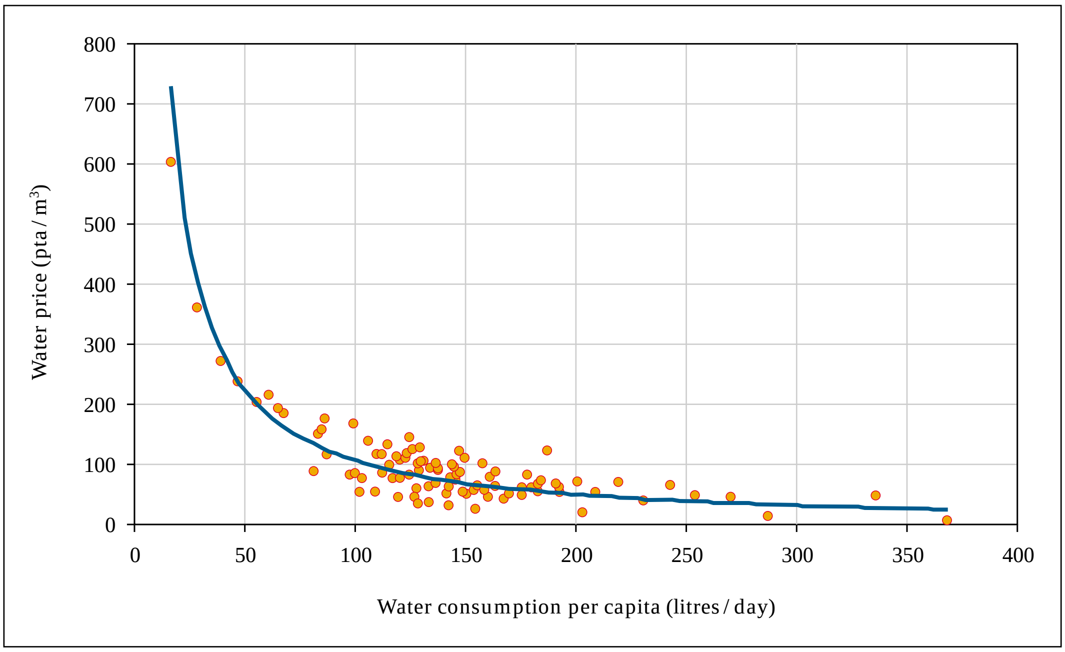


Figure 218. Water consumption curve compared with domestic supply prices.

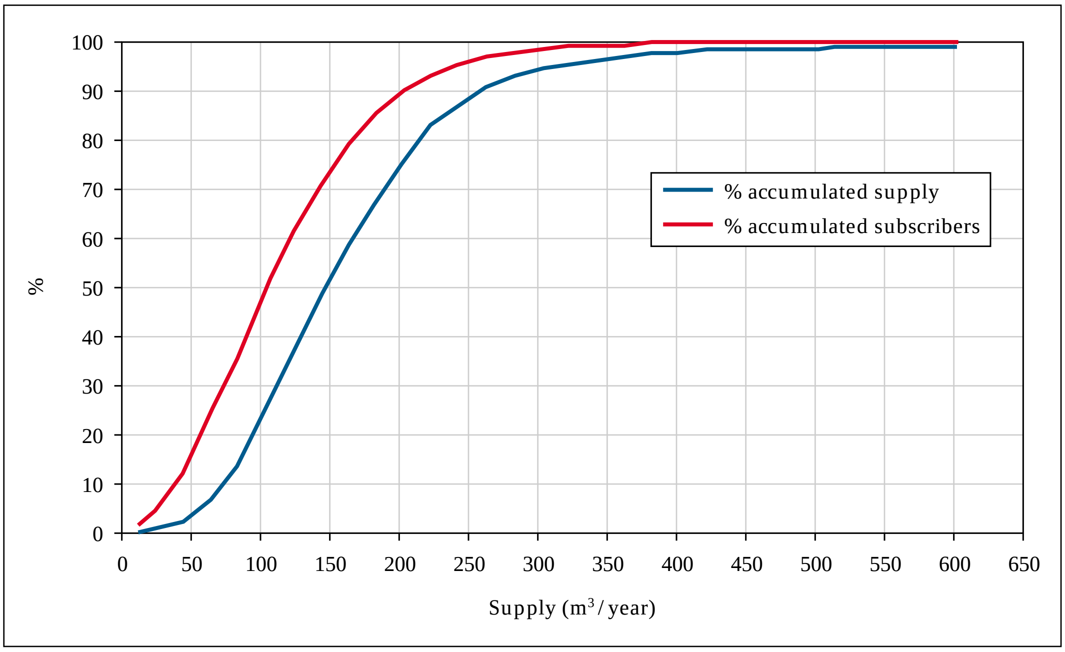


Figure 219. Distribution of subscribers and domestic supply in the area of Barcelona.

and from the different management systems, which seriously limits the conclusions that can be drawn from the few existing statistics on water prices.

The differences begin in the high-level network, managed by the Hydrographic Confederations in inter-community basins and by the equivalent organisations of the Autonomous Communities in intra-community basins. Subsequently, the low-level water supplied to users by the local organisations, that opt for one of several management regimes mentioned above. There also exist very special situations where the low-level water is supplied by the Confederation itself, as in the case of Cádiz Bay.

Invoicing users for the provision of services by the supply companies usually includes several items that, from the company's point, can be divided in two major groups:

- Own activities: drinking water service, water treatment, treatment of wastewater, network maintenance, etc.
- Activities carried out by other companies: collection and sewage network rates, charges, taxes and other fees for subscribers.

The State partially recovers investment in urban supply through the regulation charge and the use fee, whose average value amounts to about 0.5 pta/m^3. At the moment, these concepts are only applied to 25% of the volume supplied and represent, in any case, a minimum part of the final price paid by users, since investments in distribution, collection and other municipal surcharges generally have more weight.

From the users' point of view, the tariff usually includes two terms:

- Fixed term: quantity independent from consumption, which should be paid for just being connected, whether or not the service is used. This is usually named something like *fixed quota, service quota, supply quota*, etc. and is sometimes included yearly as minimum consumption. Very few large-sized towns and cities do not include this term.
- Variable term: quantity that is paid according to consumption. In some cases, the whole consumption is valued at the same price (linear tariff) and in others, different prices are applied according to the level of consumption (block tariff).

These different terms can be seen in figure 220 (adapted from Porta, in Cabrera and García-Serra [1997]), summarising and illustrating the most representative tariff systems.

The tariff system adopted is an important element in demand behaviour, and a tool for its management. Increasing block tariffs aims to encourage water saving, because when a minimum consumed quantity is exceeded, the price increases, while decreasing blocks is based on the effects of economy of scale, associated with resource production and distribution.

One of the most systematic sources of information on supply water prices in Spain is the surveys carried out by the AEAS. Based on these, some conclusions can be drawn that, although they should take with caution, are sufficiently orientative:

- The municipalities not included in metropolitan areas use service quota systems and minimum consumption systems in the same proportion, while in metropolitan areas, the use of service quota is predominant.
- The most frequent tariff structure for domestic use, in populations greater than 20,000 inhabitants, is that of block consumption with increasing prices, affecting 80% of the population, although the existence of significant amount of supply with linear rate (17%) can still be seen, and even decreasing prices (3%). The comparison of the

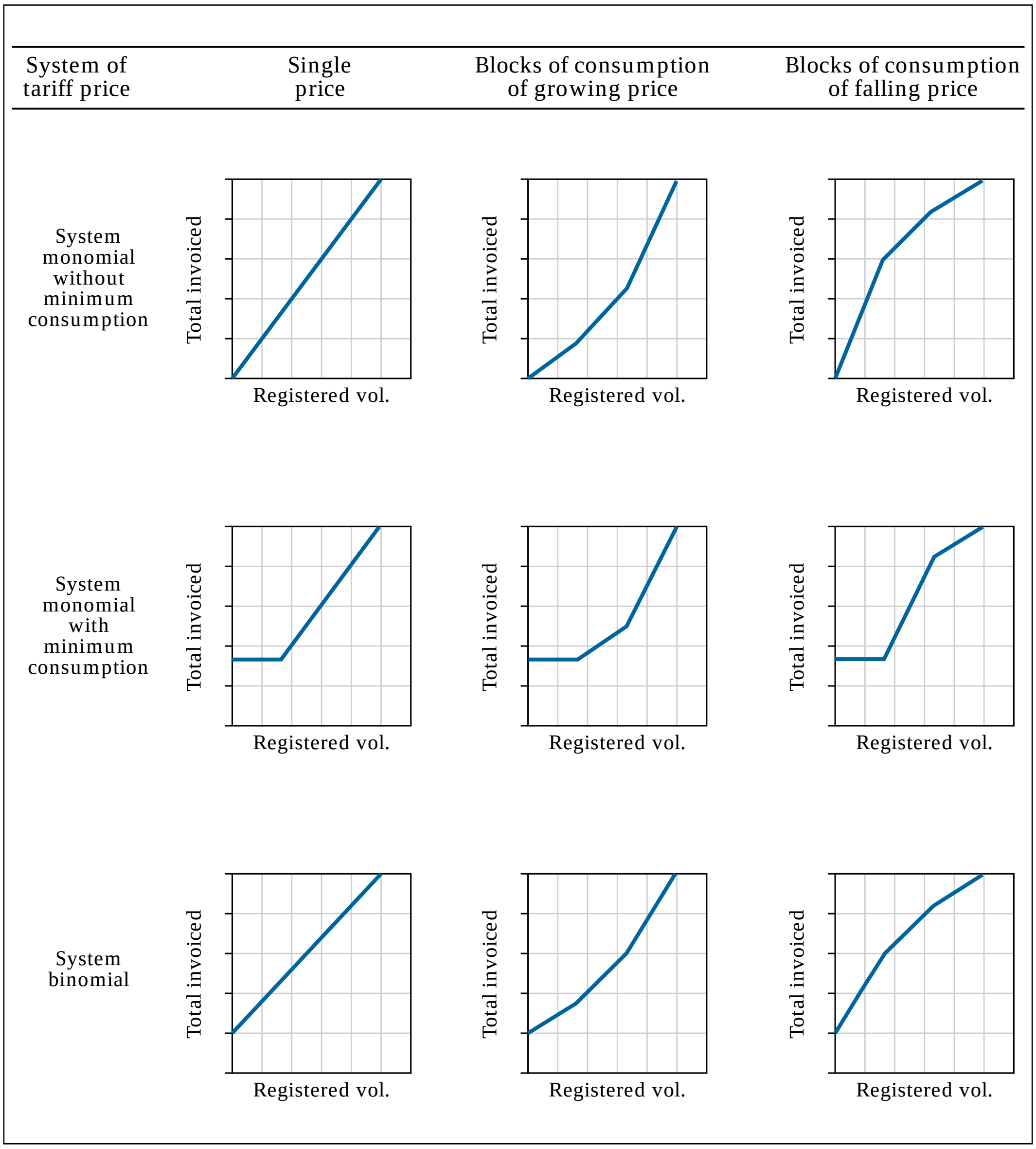


Figure 220. Tariff systems for registered urban supply.

different surveys shows a trend towards tariff progressivity, due to the implementation of systems to encourage water saving in recent years.

- In tariffs for industrial use, this trend is smaller, with increasing block rate applied to just 52% of the cases and the remaining 46% with a linear rate.
- The number of blocks in both cases can amount to four, with the use of three blocks most frequent in domestic use (61% of the population surveyed) and two blocks in industrial use.

Tables 64 and 65 (drawn up with AEAS data) show mean water prices –according to population sizes– for domestic and industrial use, detailing the items that usually make up the final invoice. It has been defined on the basis of a standard consumption of 100 m^3/year for domestic use and 180,000 m^3/year for industrial use.

According to the annual consumption level, water prices for domestic use varied yearly, as shown by table 66, with AEAS data (1994 surveys).

Also, mean water prices in 1995 (pta/m^3), in different Spanish capitals, are given in table 67. These prices must be considered as indicative and with some reservations, in view of the heterogeneity of situations considered, as not all include the same concepts.

Lastly, the National Institute of Statistics (INE) has recently begun preparing environmental statistics, and it already has an initial specific document on water prices (INE, 1998).

According to this work –based on data from 1996–, the current total mean price in Spain for the service of water dedicated to supplying urban areas is 229 pts/m^3. This price is the result of considering unitary production costs of all the activities carried out from when the water is abstracted from the natural environment to when it is returned there in optimum condition. This therefore includes population supply and collection.

Activities of water abstraction and treatment represent 17% of the total price, the distribution and supply stage represents 49%, and sewage and wastewater treatment 34%, so

Item	Water price according to municipality's inhabitant range (€/m³)				Average 1994	Average 1992
	20.000-50.000	50.000-100.000	> 100.000	Areas Metropolit.		
Provision of drinking water	0.46	0.90	0.46	0.40	94	68
Treatment wastewater	--	0.11	0.22	0.22	32	17
Conserv. sewage system network	0.16	0.21	0.11	0.10	23	16
Conserv. of pipelines and meters	0.05	0.07	0.04	0.02	8	7
Total own activities	0.53	0.99	0.64	0.74	115	81
Collection rate	0.44	0.18	0.14	0.23	47	29
Sewage network rate	0.17	0.10	0.13	0.10	23	28
Taxes charged to subscriber	0.03	0.03	0.06	0.05	7	5
Total external activities	0.58	0.24	0.26	0.52	65	37
Total own and external activities	0.97	1.18	0.88	1.26	168	113

Table 64. Structure of mean water prices for domestic use according to population size (standard consumption 100 m³/year).

Note: Total values do not come from the sum but from the average of different samples.

this mean price, in strict terms of supply, and excluding collection costs, is about 0.91 €/m³.

Regional differences with respect to this global average total are those shown in table 68.

As may be seen, in most of the Autonomous Communities, the water distribution stage is what most affects the price. However, in the case of the Balearic Islands, the sewage system and wastewater treatment is the most expensive stage, with 54% of the total price. This is also true, although to a lesser extent, in Extremadura, where this collection stage represents almost 41% of the said price. Water abstraction and distribution is more expensive in the Basque Country than in other communities –26% of the total price–. Next comes La Rioja and Castile-León, where 22% of the price can be attributed to this first stage of the water cycle.

A study of the above tables leads to the following conclusions:

- The mean price of water for domestic use is greater than for industrial use.
- The prevalence of increasing block-rate pricing is not reflected in price progressivity as regards consumption. The reason is that because most cases are fixed term rates (regardless of consumption) and variable term rates (depending on consumption), situations of very high costs can appear for very low consumption.
- The mean water price increased significantly between the years 1992 and 1994, with the highest increase relating to external activities.
- The items that have undergone the greatest increases in recent years have been wastewater treatment and collection fee, fundamentally owing to the implementation of the European Directive on discharges. It is foreseen that, in the future, these items will be the cause of the greatest increases in water prices.
- There are three cities (Barcelona, Las Palmas and Murcia) with price levels around 1.20 €/m³. The rest stand at clearly lower levels. Generally speaking, the

Item	Water price according to municipality's inhabitant range (€/m³)				Average 1994	Average 1992
	20.000-50.000	50.000-100.000	> 100.000	Areas Metropolit.		
Provision of drinking water	0.20	0.25	0.14	0.18	32	25
Treatment wastewater	--	0.15	0.07	0.13	17	9
Conserv. sewage system network	0.05	0	0.04	0.10	7	3
Conserv. of pipelines and meters	0.01	0	0	0	1	2
Total own activities	0.20	0.28	0.19	0.27	37	29
Collection rate	0.06	0.09	0.05	0.06	11	9
Sewage network rate	0.04	0.01	0.01	0.03	4	4
Taxes charged to subscriber	0.01	0.01	0.01	0.02	2	5
Total external activities	0.10	0.08	0.04	0.07	12	7
Total own and external activities	0.28	0.35	0.22	0.34	48	35

Table 65. Structure of mean water prices for industrial use according to population size (Standard consumption of 180,000 m³/year).

Note: Total values do not come from the sum but from the average of different samples.

Annual consumption (m^3)	Price charged for own activities (€/m^3)	Price charged for external activities (€/m^3)	Total price charged (€/m^3)
100	0.69	0.32	1.01
200	0.58	0.29	0.88
400	0.60	0.28	0.87

Table 66. Mean water prices for domestic use according to annual consumption.

smallest mean price corresponds to the Bay of Biscay Coast, followed by the central zone and Andalusia. The highest prices are registered in the islands and on the east coast.

- Differences in total mean prices (supply and collection) between Autonomous Communities are considerable. The highest prices correspond to the Canary Islands, with 2.44 €/m^3, followed by Murcia, with 2.18, and Ceuta and Melilla with 1.94. At the other end of the scale is Castile-León with 0.53 €/m^3, and Galicia with 0.65.

On a global level, the mean price given by dividing the total invoice by the volume of water registered (considering all uses) is 0.43 €/m^3 for the supplies surveyed. Notwithstanding the relative differences in income, this price contrasts with what is paid in countries like Germany (1.41 €/m^3), France (1.03), Holland (1.05), or Belgium (1.12), which can double or triple it, and probably points to a major difference in charging the public for the cost of drinking water.

Furthermore, it is interesting to differentiate these final prices from the part due strictly to high-level supply cost, or water availability in the headwater supply deposits.

These supply costs, like total costs, are vary greatly from some places to others. As simple indicative references, amounts may be 0.08 €/m^3 in Castellón, 0.12 in Valencia, 0.25 in the area covered by the Canales del Taibilla Asociation (basically Murcia and Alicante), 0.13 in Almería Levante (Cuevas de Almanzora, Vera and Mojácar), or 0.08 in the Sorbe Association. Exceptionally, singular quantities may appear such as Moncofer, with 0.60 €/m^3 due to partial supply with desalinated water, or Palma de Mallorca, where the transport of water by ship from Tarragona raised this cost to 2.10 €/m^3. According to INE information, mean abstraction costs in Spain, including treatment, would be about 0.24 €/m^3.

In short, and to provide a representative, global order of magnitude, we may state that, except for exceptional spot circumstances, high-level water supply costs amount to values that range between 0.06 and 0.24 €/m^3.

3.3.3.4. Experiences in saving and conservation

Water saving, often considered simply as an emergency response to a situation of drought, has gradually become an economically and environmentally attractive set of measures, over recent years, in compensating the balance between urban demand and supply. This new orientation, arising from saving experiences in the energy field, emphasises permanent water saving that could be achieved with its rational use, allowing the delay, or in some cases even the prevention, of having to create new and increasingly expensive supply infrastructures.

Accordingly, water saving would be included in the broadest concept of water conservation, a term that appeared years ago in the United States to confront an unlimited growth in demand, with the consequent requirement of ever-greater supply, degradation of water quality and environmental deterioration. The original idea of water conservation was oriented towards reducing water demand, increasing efficiency in its use and improving techniques in irrigation and ornamental uses. The concept was expanded later on to incorporate all those techniques that aim to save water or improve resource management, such as actions to

City	Price	City	Price	City	Price	City	Price
Barcelona	211	Gerona	102	Lugo	72	Ciudad Real	55
Las Palmas	204	Bilbao	99	Lérida	72	Pontevedra	55
Murcia	191	Castellón	97	Albacete	71	Palencia	54
Alicante	132	Huelva	93	San Sebastián	71	A Coruña	53
Córdoba	127	Oviedo	92	Santander	71	León	50
Madrid	122	Pamplona	91	Orense	70	Segovia	48
Palm de M.	120	Badajoz	87	Salamanca	69	Jaén	39
Almería	119	Zamora	87	Logroño	66	Toledo	36
Cáceres	116	Zaragoza	86	Vitoria	61	Huesca	35
Ceuta	116	Guadalajara	80	Valladolid	61	Melilla	15
Valencia	114	Soria	76	Burgos	60		
Seville	112	Málaga	76	Ávila	60		
Tarragona	107	Cádiz	74	Granada	58		

Table 67. Water prices in different Spanish cities.

Autonomous Community	Pr. total (€/m³)	Price distribution (%) Abstr.	Distr.	Sanit.	Mean prices (€/m³) Abstr.	Distr.	Abstr. + Distrib.	Sanit.
Andalusia	1.55	14.6	44.2	41.2	0.23	0.69	0.91	0.64
Aragón	0.81	15.0	45.6	39.4	0.12	0.37	0.49	0.32
Asturias	0.81	18.7	51.6	29.7	0.15	0.42	0.57	0.24
Balearic Isl.	1.74	17.1	28.8	54.1	0.29	0.50	0.80	0.94
Canaries	2.44	18.0	51.8	30.2	0.44	1.26	1.70	0.74
Cantabria	0.90	25.0	47.0	28.0	0.23	0.43	0.65	0.25
Castile-León	0.53	22.5	62.3	15.2	0.12	0.33	0.45	0.08
Castile-La Mancha	1.06	20.6	45.5	33.9	0.22	0.48	0.70	0.36
Catalonia	1.91	19.9	56.3	23.8	0.38	1.07	1.45	0.45
Valencia Community	1.70	18.1	52.0	29.9	0.31	0.88	1.19	0.51
Extremadura	1.17	21.3	38.1	40.6	0.25	0.44	0.70	0.47
Galicia	0.65	13.3	45.9	40.8	0.08	0.30	0.38	0.26
Madrid	1.36	10.3	48.1	41.6	0.14	0.66	0.80	0.56
Murcia	2.18	20.2	40.3	39.5	0.44	0.88	1.32	0.86
Navarre	0.78	14.3	48.3	37.4	0.11	0.37	0.49	0.29
Basque Country	1.04	26.1	32.2	41.7	0.27	0.34	0.61	0.43
Rioja	0.68	22.2	35.8	42.0	0.15	0.24	0.40	0.28
Ceuta and Melilla	1.94	13.1	55.1	31.8	0.25	1.07	1.32	0.62
Total Spain	**1.38**	**17.3**	**48.9**	**33.8**	**0.24**	**0.67**	**0.91**	**0.46**

Table 68. Mean prices for urban supply in Autonomous Communities.

modernise and refurbish networks, volume rating, low-consumption sanitary equipment, educational development and public information, re-use of wastewater, recycling, crops and gardening with less water demand, etc.

In Spain, however, the idea of water saving continues, generally speaking, to be associated with the idea of drought, and it is not frequent for this issue to be raised in situations of normality or hydrological plenty. As a result, saving experiences in Spain continue to have the character of emergency measures, and it would not always make sense to implement them in hydrologically normal situations. This would be the case of limitations to watering streets and gardens or supply cuts, which, although they are usually qualified as saving measures, are in fact exceptional restrictive measures to respond to a critical situation, and would not be possible as a genuinely rational use of water.

Nevertheless, the experience of drought situations can be useful to verify the effectiveness of this type of measure. Together with the exceptional measures mentioned, recent periods of drought have involved the implementation of other actions, such as awareness campaigns, re-use of purified wastewater, reduction of leakage, temporary price increases and others, giving rise to savings of between 5 and 15% of volume supplied in ordinary situations.

Regardless of their exceptional character, the traditional and undesirable supply cuts can be effective in distribution networks with a high percentage of losses, but their effectiveness falls in the case of well-conserved networks. Furthermore, the networks' complexity, with frequent interconnections, involves a large number of daily operations in closing and opening valves, making this measure very tiresome, if not technically unfeasible. Frequently resorting to supply cuts is, therefore, indicative of inadequate management of the urban supply service.

Restrictions in watering gardens does not represent a permanent saving measure, either. However, the practice of xerophytic landscaping, which is beginning to be implemented in some countries, provides interesting perspectives. This practice consists of using autochthonous plants, bushes and vegetation, with greater tolerance to drought than the typical grass of most residential areas. Apart from achieving a significant reduction in water consumption compared with conventional gardens, it also considerably decreases the quantity of fertilizers and herbicides necessary.

Another possible form of saving water consists of using domestic equipment (cisterns, shower heads and taps) with lower water consumption. Mexico City's experience in this type of measure seems especially promising. It is possible that, in order to implement these economic incentives or information campaigns are not enough, so the approval of this type of facility could be established within the framework of a regular saving strategy. Also interesting is the city of Zaragoza and its saving campaign (Viñuales, 1998), not so much for the modest volume objective established (1 hm^3/year), but for its effect on public opinion, participation and general awareness of the need to save.

Without a doubt, one of the most important sources of saving is reducing the losses that take place in the networks, fundamentally in the in the oldest ones.

As mentioned above, the volume of non-registered water, which includes public uses and losses in treatment and distribution, stands at a mean value of 28%, with variations of little more than 10% up to some exceptional cases where

50% is reached. These figures show the convenience of measuring water devoted to public uses, and to differentiate the real proportion of losses. There exists, however, a technical and economic limit for losses, that some specialists situate between 10 and 15%. Reaching these limits requires automated monitoring systems showing the state of the network in real time, and detecting possible incidents, so as to be able to act with the necessary speed.

Nevertheless, we should not forget that the possible saving, based fundamentally on non-essential consumptions and on losses, diminish with the level of supply. Accordingly, it is more difficult to achieve significant savings when the supplies are more limited, which worsens the situation in areas with depleted water resources, where the need is greater and supplies are smaller.

Generally speaking, once a period of drought has ended, and the hydrological situation returned to normal, demand does not usually recover to previous levels, which demonstrates possibility of making adjustments in urban consumption. Although, in the short term, the supply management organisations feel the effects of such lower consumption in their balance sheets, they end up adapting their organisation and activities to the new situation, re-establishing the balance.

This effect of containing consumption can be seen clearly in figures 221 and 222, showing evolution, on a yearly and monthly scale, of volume diverted by Canal de Isabel II. Together with a change in the seasonal regime in the middle of the eighties, there is a reduction corresponding to the drought in the same decade, and, more noticeably, in the nineties.

It is interesting to note, as suggested above, that this same effect can also be seen in the volume supplied by the Canales del Taibilla Association, and the volume supplied to the metropolitan area of Barcelona in recent years, as shown in figure 223, presenting three supply series and their relative comparison. The surprising similarity of patterns observed in systems so different from each other suggests a general behaviour pattern, and the global nature –not local– of this effect points to the fact that, as in the case of water resources, the series of demands (even those related with irrigation, as we shall see in examining the recent drought), also seem to show significant cross-correlation.

Moreover, there exist some general measures to adopt in relation to droughts, regardless of the specific system in question. Accordingly, it would be interesting to draw up a manual to define the stages and thresholds of pre-alert, to summarise something as important as the concept of anticipating adverse situations. Awareness campaigns and alternative supplies (e.g. surface/groundwater) are also fundamental in any circumstance.

Additionally, each specific system can require unique treatment, not necessarily generalizable. The actions carried out in the metropolitan area of Barcelona and in the Community of Madrid during the last droughts may be useful in illustrating the type of particular measures adopted in these cases, and their relative effectiveness.

In Barcelona, where the last drought reached its more critical point in April 1990, the following measures, among others, were adopted:

- Alert special users (hospitals, assistance centres, etc.) on the importance of adapting their interior facilities so as to have reserves and to prevent drop of pressure in the supply network.
- Almost total restriction of urban irrigation, maximum limitations on garden irrigation and obliging ornamental fountains to operate in a closed circuit.
- Preparation of a plan to limit complementary-type commercial and industrial uses and sumptuary-type domestic uses.
- Public awareness campaign in the media.

With the set of measures adopted, consumption dropped 5% between November, 1989 and June, 1990. Bearing in mind that average annual growth during previous years was 2.6%,

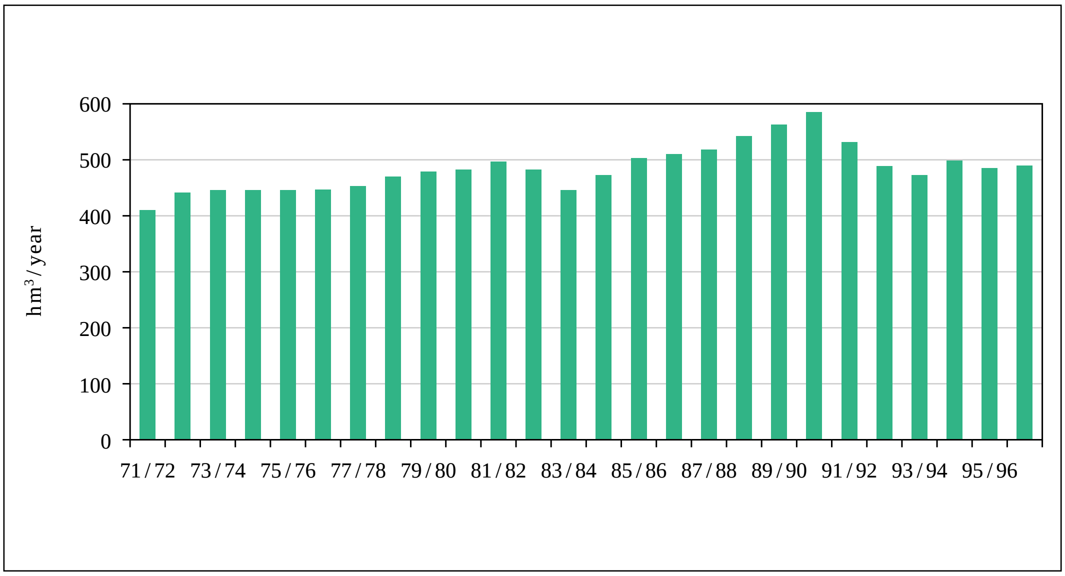


Figure 221. Annual volume diverted by Canal de Isabel II since 1971.

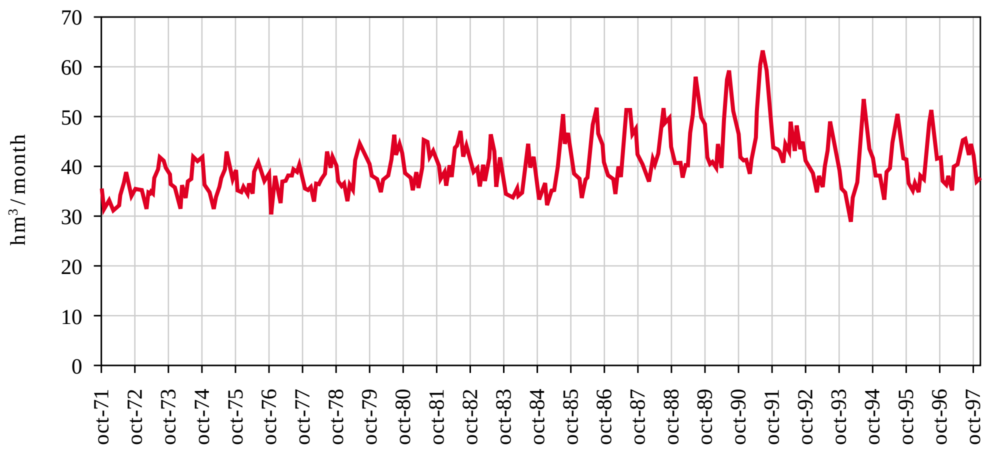


Figure 222. Monthly volume diverted by Canal de Isabel II since 1971.

the saving achieved would lie between 5% and 8%. The segment registering the greatest drop was the public use (18%), followed by industrial and commercial (7%) and domestic uses (4%).

In the Community of Madrid, the last supply crisis occurred between March, 1992 and November, 1993, with the following measures adopted:

- A Drought Office was set up.
- Parks and garden irrigation was limited (Act 3/1992 of the Community of Madrid).
- Use of purified wastewater for irrigation was provided free of charge. The volume mobilised was very small (only 37.000 m^3 transported in tanks by 300 users), which, together with the need for authorisation from the basin organisation, and the possible health problems, suggests that this measure should be implemented with caution in the future.
- Leakage control, clandestine intake and users with excessive consumption. Closing irrigation hydrants (which required specific agreements with the City councils and fire hydrants to be installed).
- Flow meters installed in the major pipelines and in the distribution network, and meters installed in parks and gardens. This must be considered the start of a campaign of monitoring improvement, which is still going on.
- Internal efficiency plan, distributing over 3,000 sets of saving devices for taps, showers and toilets. Compared with the total 1,800,000 residences covered, this quantity is very modest, but significant from the point of view of public awareness.
- Campaign in the social media.

With these measures, together with new wells opened for private users and industries, water diverted for supply by Canal de Isabel II passed from 590 hm^3 in 1991 to 522 hm^3

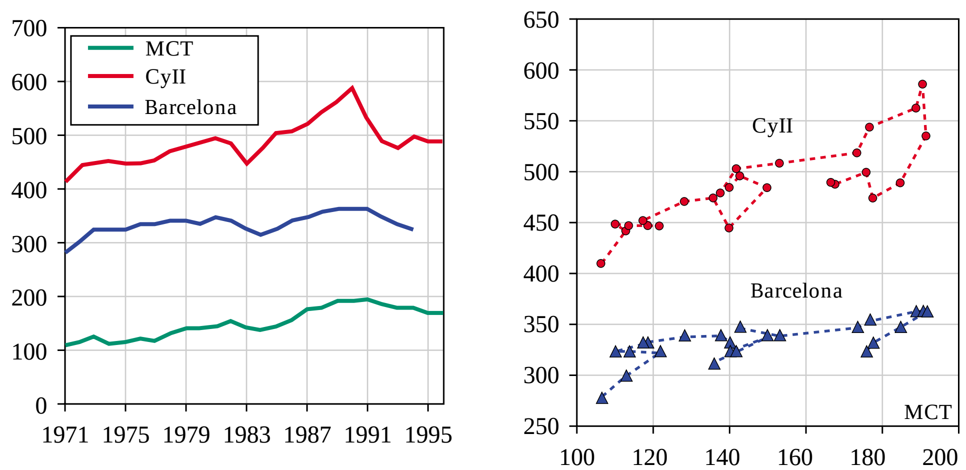


Figure 223. Evolution of annual volume (hm^3) given by Canal de Isabel II, supply to Barcelona, and the Canales del Taibilla Association, from 1971 onwards.

in 1992, and 476 hm^3 in 1993, showing a very significant drop, of about 20%. The effectiveness of the different measures varied considerably. While voluntary saving encouraged by the communication campaigns was very effective, limitations on irrigation and the re-use of purified water for irrigation had very little repercussion. Among the users that had saving devices installed, half managed to save more than 20%, and a fifth of them saved over 40%. The accumulated, progressive effect of the measures taken could also be seen: in the summer of 1993, restrictions on park and garden irrigation having ended, 24% less was consumed than in the summer of 1991.

Nevertheless, after these dry years, a certain recovery in consumptions has been observed, and in 1998 total water diverted by the Canal had already reached a figure of 506 hm^3, with an upward trend. This may be due to an increase in the number of houses –even with population stable–, to larger facilities, to price stability, etc.

As a final illustrative example, a case in point is the saving experiences are the result of a previous plan on conservation measures and efficient use applied in normal hydrological situations, and not as a response to a situation of drought. This was tried in the city of Murcia and its metropolitan area, where after a major municipal effort, they have achieved the interesting results shown in the adjoining graphs (Hervás, 1996. Data up-dated by personal notification).

As of 1984, when a municipal company was set up for the water service –and which became mixed company in 1989– the evolution of volume required by the high-level system, supplied and invoiced, has been contained and reduced despite the fact that there has been an increase in both the number of subscribers (due to natural vegetative growth and by locating and incorporating clandestine users, and increasing the number of meters) and in the areas supplied (which is reflected in the length of the networks). This has been possible mostly thanks to combined efforts in fraud detection, and maintenance, improvement and renewal of supply networks. If the trend in the period 1984-89 had continued linearly, about 50 hm^3/year would now be required, a figure that contrasts with the current 30, and which means having saved about 20 hm^3/year, that is, approximately a third of predicted consumption. This has meant passing from unitary supply of 330 l/inhab/day to 230, not only without the users feeling prejudiced, but with a generally better service. As may be seen in the graphs in figure 224, global losses in the network have gone from 45% to 25% in barely 4 years, and reduction in unitary losses has been even greater.

This is a case where the improvement of efficiency and greater resource saving and conservation has been obliged by the area's structural water shortage, which episodes of greater drought only exacerbate.

A fundamentally important aspect in developing saving and conservation measures has to do with its economy. On one hand, there are cases, basically when efficient systems or in areas with shortage, where costs involved in saving do not give appreciable economic benefits compared with the alternative of new supply infrastructures (provided these are possible), although they usually involve benefits from an

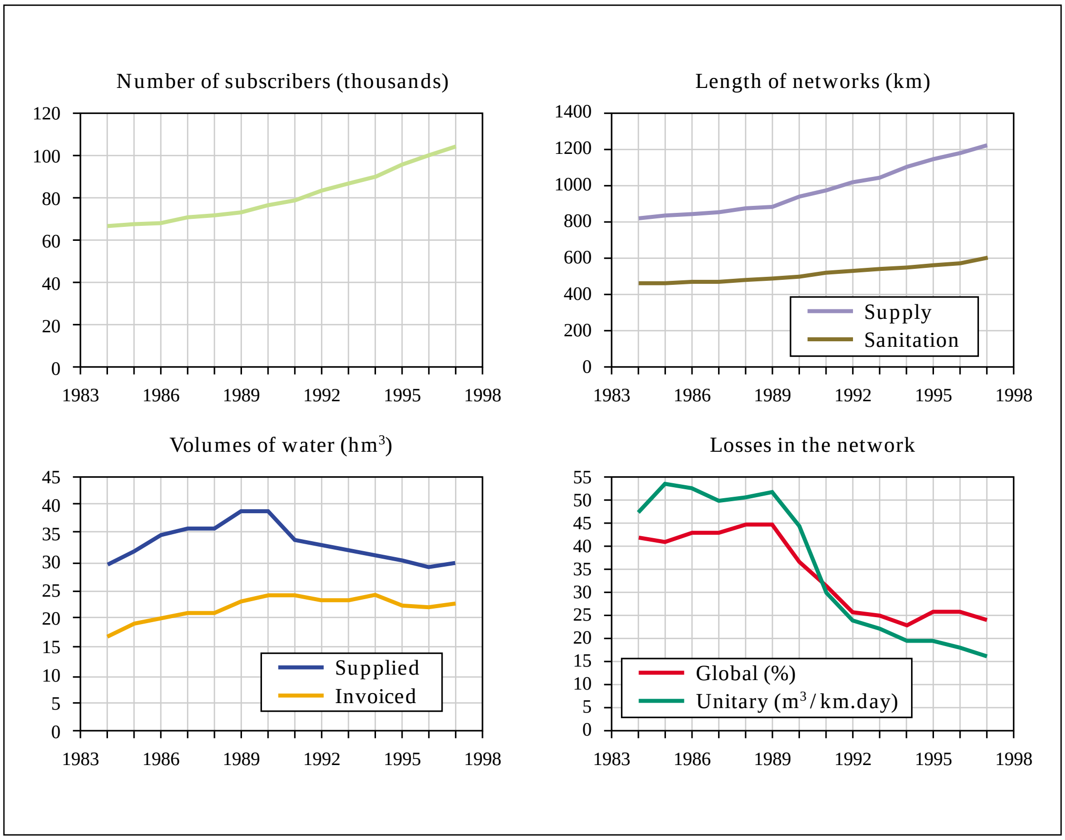


Figure 224. Indicators of supply management in the city of Murcia.

environmental point of view and in terms of social acceptance. Additionally, the variety of situations and the difficulties in assessing saving costs, less well-known than those of other resource-generating techniques, do not contribute to developing them.

From a legal point of view, there are also some difficulties in the generalised implementation of saving measures, because the concession review that these measures must involve could present problems in practical implementation, if not agreed previously by means of a joint plan whose hydro-economic or social balances are attractive for all interested parties.

On the other hand, there is the problem of return from the necessary investments involved in saving that supply service companies must carry out. Paradoxically, in situations of shortage, the companies carry out extraordinary expenses in communication campaigns to discourage users from consuming the product that represents the basis of their activity. Accordingly, the more effective these campaigns are, and the greater the success achieved, the lower the profits. This makes it recommendable to have an appropriate tariff framework so that saving and conservation programmes can be really effective.

In the electricity sector, which shares some similarities with the water sector, they have been approaching these questions for some time. In the case of the United States, specifically, the concept of shared saving has been introduced, which supposes that it more profitable for companies to invest in its clients' energy saving than in the construction of new infrastructures, by recovering –through tariffs– different proportions of investments in both concepts.

The need for such institutional or regulatory measures to encourage water conservation should be underlined, because by not expressly establishing such conservation as a primary objective, whatever progress made will be the result of critical situations, such as those of Barcelona, Madrid, Seville or Murcia, mentioned above, and will not be planned from the outset, as a possible alternative to other supply sources. Economic incentives are essential in this respect.

In any event, we should avoid the artificial, unproductive confrontation between water conservation and new infrastructures. This debate should not be presented, under any circumstances, as a dilemma, because the creation of new supply infrastructures and actions in water management and conservation should act as complementary measures, with relative necessity depending on specific circumstances. As such, a correct approach requires them to be considered jointly and in coordination.

3.3.3.5. Future demand

Forecasts by the Basin Plans on future necessities in urban supply raise demand to about 5,300 hm^3/year for the plans' first horizon (10 years) and 6,300 hm^3/year for the second (20 years), and with the territorial distribution shown in table 69 and figure 225. We should note, in all cases, that demand is being interpreted in its regulatory sense, that is, supposing projections of future consumption with zero price elasticity.

This predicted evolution of demands represents, with respect to the current situation, global increases of 15% and 36% for each of the horizons considered. These increases, which in absolute terms they could be relatively unimportant in comparison with other demands, give rise to the problem of quality demand, and significant geographical concentration, which may prevent new resources from being obtained, located at greater distances, and frequently committed.

The comparison between the demand forecasts made by the plans and the population forecasts carried out by the INE, and described in the sections on population, allows some conclusions to be made, illustrated in figure 226. This fig-

Area	First horizonte (hm^3/year)	Second horizonte (hm^3/year)
North I	81	88
North II	221	230
North III	266	270
Douro	243	337
Tagus	851	939
Guadiana I	126	137
Guadiana II	48	55
Guadalquivir	583	640
South	283	317
Segura	180	184
Júcar	613	686
Ebro	338	358
Inl. Basins of Catalonia	791	942
Galicia Coast	262	317
Peninsula	4,886	5,500
Balearic Isl.	114	123
Canaries	347	690
Spain	**5,347**	**6,313**

Table 69. Urban supply demand forecasts in the medium and long term according to the Basin Plans.

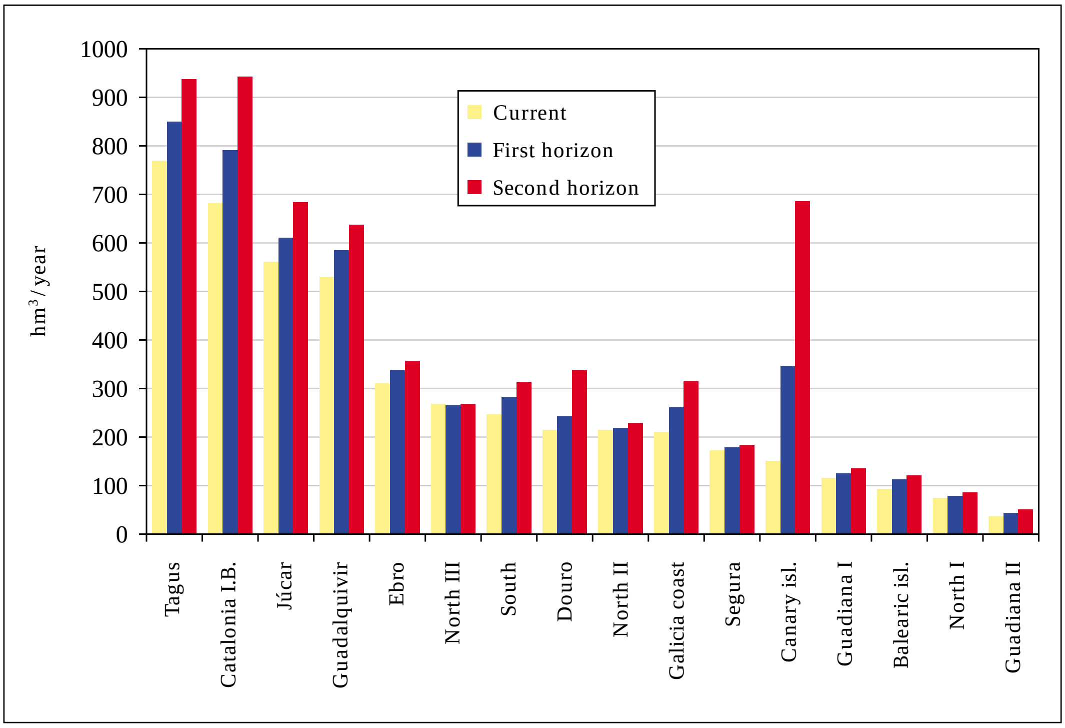


Figure 225. Population supply demand foreseen in the medium and long term in the Basin Plans.

ure supposes that the current situation corresponds to 1995 data, and that the plans' two horizons correspond to the years 2005 and 2015.

Firstly, we should point out that, compared with a generalised increase in supply demand in all the basin plan areas, population increases are only foreseen for the Guadalquivir, South, Canaries, Segura, Guadiana and Balearic Islands. In the rest of the areas, therefore, and if the INE's forecasts are correct, demand evolution foreseen by the plans would not be justified by a mere increase in the stable population, but

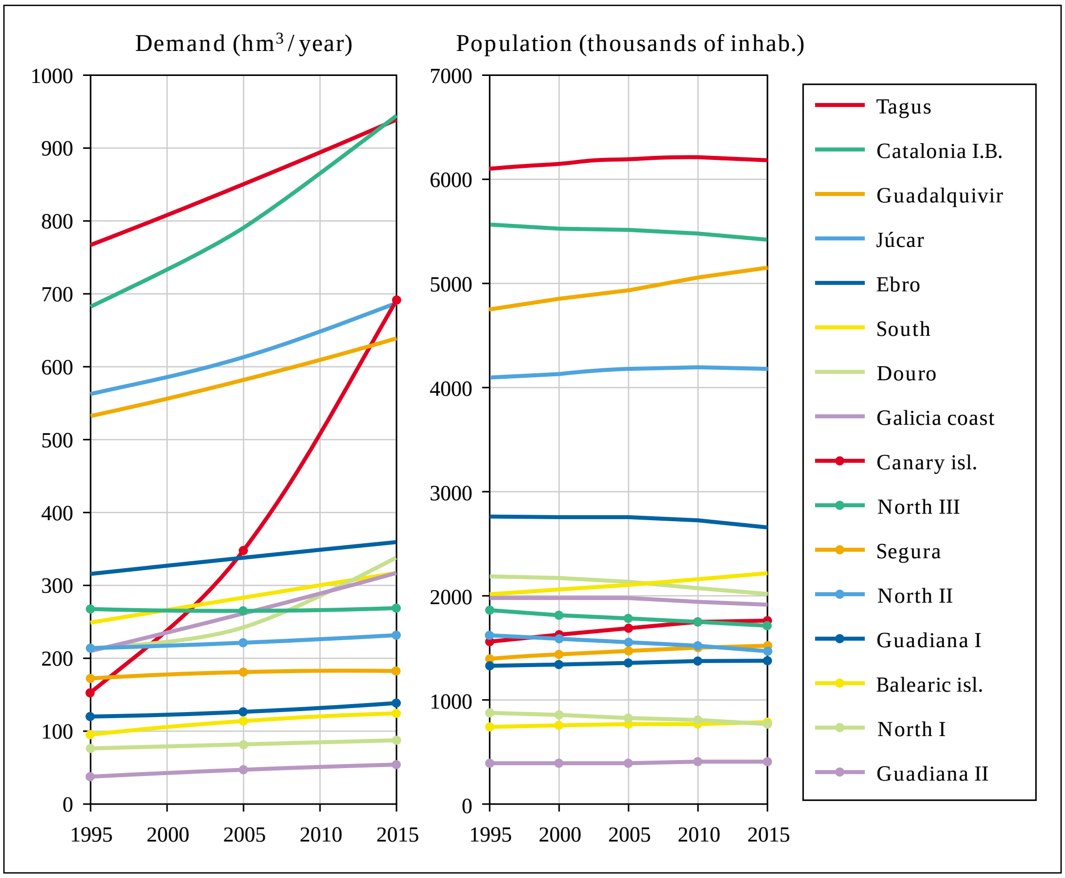


Figure 226. Forecasts for annual evolution in populaton and urban demand in the Basin Plans.

rather by an increase in unitary supply or in the seasonal population.

Analysing some of the specific cases shown in figure 226, the Canary Islands stand out, with a striking increase in demand that would exceed the second horizon for demand for all areas, except the Tagus and the Inland Basins of Catalonia. This last of these also shows considerable increase in demand, although population forecasts indicate an appreciable drop, and for the second horizon it would have the largest demand in Spain, slightly above demand in the Tagus basin. The case of the Douro basin is equally striking, where despite the clear downward trend of the population, a major demand increase is forecast.

Generally speaking, this set of forecasts does not seem to have given enough consideration to implementing the necessary saving and demand contention measures. In fact, if the evolution of supply is analyzed by dividing demand and foreseen population, its generalised increase may be seen, as shown by figure 227.

Table 70 gives this supply evolution numerically, together with the resulting annual accumulative variation rate.

This supply quantity may differ from those in the Basin Plans, because they have been obtained from different population estimates. Also, such population estimates have required a general hypothesis of distribution planning area to be adopted from INE forecasts, and some plans may have their own, more accurate estimates.

In accordance with the data in this table, a number of considerations can be expressed. Supply quantities for the first horizon seem to stand around the conventionally accepted figures, except the Canary Islands which have particularly high figures on both horizons, which we shall comment on below. Beyond this exception, supply in all the areas is lower than the one laid down by the Order of the 24th of September, 1992, stipulating, for the two horizons, a maximum supply quantity of 410 l/inhab/day for populations with high commercial-industrial activity and more than 250,000 inhabitants.

The situation is different as regards the second horizon. In this case, the areas of North II, North III, Douro, Júcar, Inland Basins of Catalonia, Galicia Coast, Balearic Islands and the Canaries exceed the maximum figure of 410 l/inhab/day laid down in this Order. Particularly noteworthy, with supply of over 450 l/inhab/day, besides the Canaries, are the Inland Basins of Catalonia, Douro and Galicia Coast, as shown in the above figure, with a sharper gradient that in the rest of the areas.

This supply evolution is reflected in the each area's annual accumulative variation rate. These rates exceed 1.5% in Canaries, Galicia Coast, Douro, Guadiana II (first period) and Inland Basins of Catalonia.

A remarkable exception to this generalised evolution is seen in the Segura basin, showing a clear commitment with the future, with saving and demand contention and negative supply quantity variation rates. This gives rise to the fact that, despite forecasts of population growth, demand only increases slightly, and may in practice be considered virtually stabilised.

Accordingly, in some cases there are significant increases in relative terms that could be partially justified by increases in seasonal demand due to the tourist sector. We should also bear in mind the foreseeable supply increase in some rural populations as a consequence of improved standard of living.

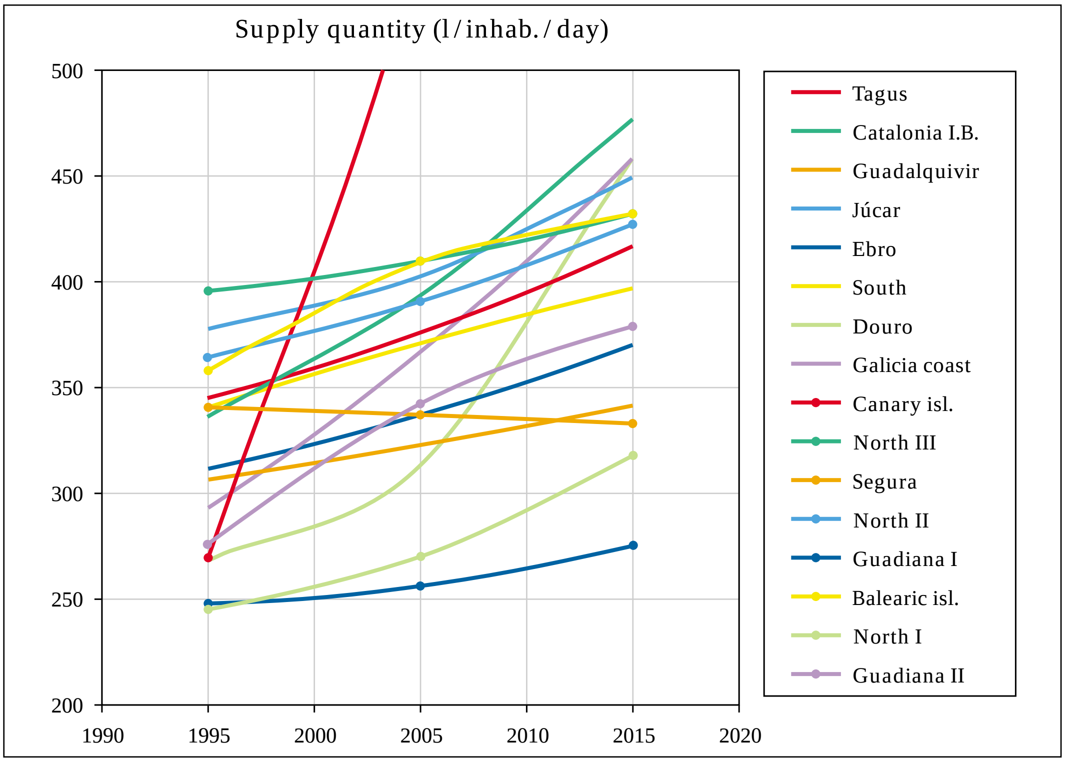


Figure 227. Foreseen evolution of supply quantities in the different Hydrological Plans.

Area	Current network supply (l/inh/day)	Network supply 1st horiz. (l/inh/day)	Network supply 2nd horiz. (l/inh/day)	Annual rate 1995-2005 (%)	Annual rate 2005-2015 (%)
North I	245	270	317	0.96	1.61
North II	364	390	427	0.69	0.92
North III	396	410	432	0.35	0.51
Douro	268	313	458	1.56	3.87
Tagus	345	376	416	0.86	1.02
Guadiana I	247	256	274	0.37	0.69
Guadiana II	276	342	378	2.17	1.00
Guadalquivir	307	323	341	0.53	0.53
South	340	370	396	0.83	0.69
Segura	340	337	332	–0.09	–0.14
Júcar	377	402	449	0.66	1.12
Ebro	311	337	369	0.78	0.93
Inland Basins of Catalonia	336	393	476	1.59	1.92
Galicia Coast	293	366	457	2.25	2.24
Balearic Isl.	358	408	432	1.33	0.56
Canaries	269	564	1,080	7.66	6.72
Spain	**327**	**370**	**438**	**1.25**	**1.70**

Table 70. Evolution of supply quantities and annual variation rate.

On the other hand, we should mention the downward trend in the number of inhabitants per residence and the growth of single-family residences, brought about by growing levels of income, both questions that clearly give rise to larger supply quantities. In this respect, some specialists are beginning to propose the use of supply quantity by residence, not by inhabitant, which would require handling data on housing classification, percentages of temporal occupation and seasonal population movements, all of which would improve current prognoses on the evolution of population supply demand.

With respect to these reasons for a possible increase in supply quantity, we should insist on the convenience of implementing saving measures that halt the growth of consumption, in view of the difficulties mentioned in taking new resources to urban areas, resources which are increasingly scarce and remote. Except in the case of the Segura, whose supply quantities drop in the long term, forecasts made by the plans do not seem to have given enough importance to this issue, when in practice improvements in the management of supply networks are already beginning to take place, with the resulting increase in efficiency, basically owing to crisis situations during the last drought. This experience will be taken very much into account in the next review of the basin plans.

The case of the Canaries, highlighted above, deserves special consideration. As we have mentioned, their forecasts indicate a frankly spectacular growth in urban demand, reaching supply quantities in excess of 1,000 l/inhab/day for the second horizon. This figure should be qualified by incorporating the significant effect that the tourist sector has in these islands. According to forecasts by the Canary Islands Government, the demand of 690 hm^3/year estimated for the second horizon would be obtained a fixed population demand of 368 hm^3/year and a tourist demand of 322 hm^3/year. The fixed population demand, bearing in mind population forecasts, would correspond to supply quantity of 576 l/inhab/day, which would still be the largest in Spain. As for tourism, demand has been obtained by estimating a supply quantity for the second horizon that varies from 500 l/inhab/day in rural accommodation to 650 l/inhab/day in hotel accommodation. These supply quantities are also high if the 1992 Order is taken as a reference, where a supply quantity of 350 l/inhab/day is laid down for chalets, considered to be the establishments with greatest consumption (in the case of hotels, a supply quantity of 240 l/inhab/day is stipulated). That is, even considering the effect of tourism in a disaggregated way, these figures do not seem to adapt to the archipelago's supply difficulties. However, in more recent work (Island Council of Gran Canaria, 1995) these quantities are significantly lowered, which seems to indicate a reconsideration of the above forecasts.

3.3.3.6. Existing and foreseeable problems

Having described the current situation and the forecasts for the future of supply demands, we shall now turn to some of the main problems this sector is facing.

Firstly, the most obvious problems in Spain's population supply system refer to its reliability and its vulnerability. Reliability, understood to be supply guarantee, should be close to 100%, which would represent total security in supply. However, the droughts of recent years have shown that in significant areas of Spain, the supply systems are not sufficiently reliable, and there are relatively frequent failures in the supply of drinking water.

These systems' vulnerability, with sizeable failures affecting extensive areas of territory, has also been illustrated. A large part of the Spanish population, estimated at about ten million people, suffered restrictions in water supply during the drought of the nineties. Cities like Granada, Jaén, Seville, Málaga, Toledo, Ciudad Real and Puertollano, and the areas of Bahía de Cádiz and the Costa del Sol had severe supply limitations, with restrictions of up to 30% in some cases, and daily water cuts of up to 9 and 10 hours' duration.

Besides these problems of inadequate resources, arising from irregularity of existence, supply problems also appear in areas with abundant resources, but low regulation capacity, as occurs in the Bay of Biscay coast, where some towns undergo supply restrictions during the summer months.

Additionally, there are problems in the exploitation of aquifers, which frequently affect some urban areas supplied by groundwater in certain zones of Spain's most tourism-oriented coastline, due to deficient management or inappropriate abstraction.

Therefore, and from the point of view of balancing resources and urban demand, there still exists serious shortages in Spain, which appear as particularly severe in periods of scarcity, when resources remain below their average value for several years. The need to raise the level of supply guarantee, bringing it up to 100%, as far as technically reasonable and feasible, requires the adoption of measures to restore balance, helping to reduce current demand levels through actions oriented towards water saving and conservation, or to increase resources where these actions are seen to be insufficient (Cabrera et al., 1998).

Apart from problems regarding resource availability described above, there also exist problems in Spain regarding the supply infrastructure. In some cases, facilities do not have enough capacity to handle demand, especially in summer in areas with a significant seasonal population. In these areas, facilities must overdimension to handle consumption peaks in the months of maximum occupation. Due to the rapid development of tourism in some of these areas in recent years, the pace of expanding facilities has not always managed to adjust to the growth rate in requirements, with increasing supply problems.

Additionally, the deficient state of some infrastructures occasionally causes significant loss of water, fundamentally due to leakage from pipelines. This problem does not always affect populations with abundant resources, so it is advisable to stress the need to correct this urgently.

Quality problems arising in urban supply are usually the consequence of resource pollution at source, in some cases, and the lack of appropriate treatment, in others. At present, abstraction for a large number of towns is located on river reaches with a qualification lower than A3. In some areas, quality problems come from deficient treatment of urban wastewater. This problem is increased in periods of low water by the smaller natural flow in rivers, which, in some cases, gives rise to use restrictions being imposed.

Towns supplied with groundwater are affected, in some situations, by the deterioration of the resource, both from pollution of the aquifer and from saline intrusion in coastal areas, and as a consequence, sometimes, of inadequate management.

In small towns, where management is carried out independently by each local council, appropriate treatment is not always available. Larger towns, conversely, do not have this problem, and the quality of water supplied is generally acceptable.

In this respect, in some cases there are significant differences in the quality of services provided in large and small towns. In the former, by having specialized organisations or companies, more efficient service and better quality levels are usually achieved, while in the latter, mainly in the case of small local councils, there may be problems even to achieve the appropriate treatment of drinking water. This has given rise to the increasingly frequent integration of small and medium-sized municipalities into supramunicipal organisations that provide service to local councils integrated within this organisation. With this system, as mentioned above, apart from greater technical expertise in management and supply guarantee, it is possible to lower costs. There are many small towns, however, supplied from wells and springs in good condition, which means a simple, economic solution at municipal level.

The traditional separation of drinking water and collection services (including evacuation and treatment of wastewater) currently tends to be corrected with the unification of services, providing a more rational management of the integral water cycle.

However, at the same time, this management is characterized by the overlapping and concurrence of different organisations and performance levels, with participation by central, autonomous and local administrations. We shall return to this issue later, when making new proposals for water policies, but this fact can be stated here since it clearly affects tariffs, which instead of being integrated as a result of harmonious coordination, represent a genuine aggregation, resulting from the concurrence –which sometimes becomes conflict– of different levels of action.

Accordingly, revenues from tariffs go to a variety of destinations: Municipalities, Unions, Consortia, Autonomous Communities, basin organisations, etc. They all have responsibilities in some part of the service, and all aim to cover the cost of their actions with these revenues. This way, the result is an aggregate tariff whose components have differing legal characteristics, bearing little relationship with the economic nature of the service provided.

Additionally, in certain cases, the water invoice includes external concepts, making the supply service a mere fund-raising instrument, and debasing the perception of the price paid for the water.

3.3.4. Industrial supply

3.3.4.1. Introduction

This section describes the characteristics of industrial supply for non-energy uses. It therefore focuses on water use for industrial production, comprising specific use in products and in manufacturing processes, fitting-out and conservation. It also includes covering needs arising from the corresponding production activities, such as feeding and personnel hygiene, maintenance, security of the facilities, etc. Industrial energy uses (hydroelectric production and refrigeration of power stations) are described further below.

A part of the supply to industries comes from their own abstractions, directly or through self-supplied industrial estates. Another part, mostly low-consumption industries located in town areas, it usually supplied from the corresponding municipal network. Finally, a relatively small proportion of industries uses water from both sources. As mentioned above, water for industrial use provided by municipal networks is calculated as population supply use, so industrial supply usually only refers to industries not connected to municipal networks.

This section in fact refers specifically to these industries without supply network connection, but it should be noted that total industrial demand consists of demand from these industries plus the fraction of industrial use comprised within population supply.

Among the characteristics of industrial demand, we could mention that, as with urban supply, it requires high levels of supply guarantee. Resource quality requirements, however, vary according to industry type and to how the water is used in the process.

Water needs are determined by the different forms of use within the industry (refrigeration, steam production, incorporation into the product, etc.) and they are the result of a series of specific variables, such as quantity and type of final product, number of employees, production system used, the existence and characteristics of recycling (re-use inside the factory itself), etc. Again, as with urban supply, the seasonal distribution of this demand is virtually uniform throughout the year.

Volume and composition of returns vary greatly according to industry type, and in some cases there may be highly pollutant discharge, difficult to treat. The possibility of re-using returns depends on their specific characteristics.

3.3.4.2. Current use and standard supply quantities

According to the basin management plans, total current demand by industries not connected to municipal networks is 1,647 hm^3/year, with distribution by areas as shown in table 71 and figure 228.

The map in figure 229 shows the spatial distribution of this demand, logically associated with major concentrations of industrial activity.

This map has been obtained from the land uses of CORINE-Land Cover, selecting the classes of industrial-type use. For each cell in the territory, with dimensions of 1x1 km, a coefficient was assigned, representing the fraction (between 0 and 1) of occupation by industrial land use. Industrial demand defined in the Basin Plans was distributed territorially according to these coefficients, thus guaranteeing both the preservation of aggregate volumes and their distribution on a scale of industrial centres.

Accordingly, standing out due to high demand volume are the industrial areas of Torrelavega and Avilés (North II), Ría de Bilbao (North III), industries of the Canal Imperial de Aragon (Ebro) and Bajo Llobregat (Inland Basins of Catalonia). These four areas concentrate 73% of Spain’s industrial demand not connected to municipal networks.

The supply quantity used depends on a variety of factors, with the shortage or abundance of water bearing considerable influence. In fact, demand frequently adjusts according to supply, significantly reducing volume of water necessary by means of appropriate production procedures. It is not surprising, therefore, that industries in the same sector and

Area	Demand (hm^3/year)
North I	32
North II	280
North III	215
Douro	10
Tagus	25
Guadiana I	31
Guadiana II	53
Guadalquivir	88
South	32
Segura	23
Júcar	80
Ebro	415
Inland Basins of Catalonia	296
Galicia Coast	53
Peninsula	1,633
Balearic Isl.	4
Canaries	10
Spain	**1,647**

Table 71. Current industrial demand by planning area.

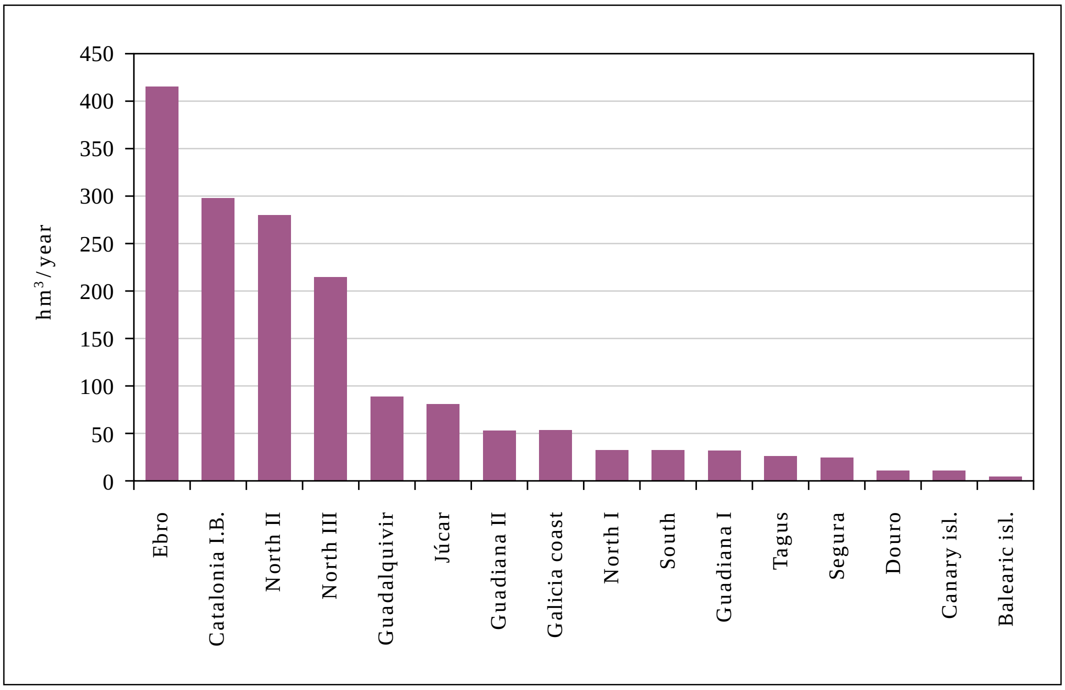


Figure 228. Volume of current industrial demand by planning area.

with similar production, demand very different quantities of water.

A habitual practice in assessing this demand consists of using supply quantity according to the number of employees in the corresponding industry. An example of this can be found in MOPT Ministerial Order, of September 24th, 1992, establishing the orientative supply quantity shown in the following chart.

In the same M.O., a supply of 4,000 m^3/ha/year is laid down for new industrial estates.

Some writers question using this type of indicator, and suggest the use of other variables that give better correlation with water consumption and they can therefore lead to better estimates. This would be the case of the contracted power or electric power consumption, which could give rise to more accurate demand values.

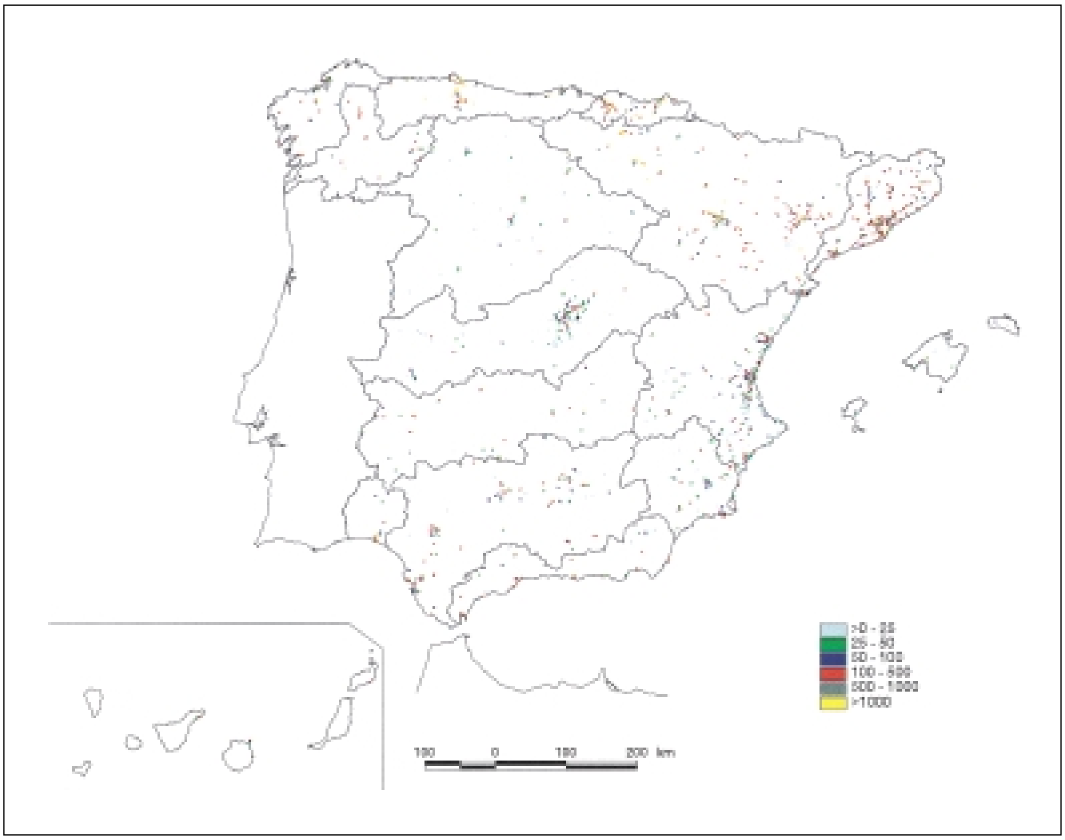


Figure 229. Map of spatial distribution of industrial demand (mm/year).

Sector	Supply quantities (m³/used/day)
Petroleum refinery	14.8
Chemicals:	
Manufacture of basic products, excluding pharmaceuticals	16.0
Rest	5.9
Foostuffs:	
Industries, alcohols, wines and flour products	0.5
Rest	7.5
Paper:	
Paper pulp manufacture, paper and cardboard transformation	20.3
Graphic arts and edition	0.6
Leather treatment	3.3
Construction materials	2.7
Rubber products	1.8
Textile:	
Dry textiles	0.6
Water-sector textiles	9.2
Metal products	0.6
Rest	0.6

Table 72. Industrial supply quantities.

In any case, given the above-mentioned differences that occur between similar industries, together with distortions in consumption arising from a relatively widespread lack of data on supply, the use of standard supply quantity to assess industrial demand does not offer much reliability.

It is therefore necessary to make an effort to improve available statistics on real water consumption by industries.

3.3.4.3. Future demand

As regards estimates of future demand, in addition to the lack of current knowledge, there is great uncertainty as to its possible evolution, because it does not usually follow continuous, and predictable patterns, but circumstantial, spot decisions, difficult or impossible to predict in the medium and long term.

The estimates carried out by the basin management plans are shown in table 73 and figure 230, which also shows, for comparative purposes, current demand.

These forecasts expect an overall growth of nearly 18% for the first horizon, and up to 26% for the second, which means an annual growth of 1.65% in the first period and 0.73% in the second.

This growth, however, varies greatly from one plan to another. While in five of them (North III, Douro, Tagus, Balearic Islands and Canaries) growth is zero, in Galicia Coast an increase of 72% is foreseen up to the end of the first horizon and 143% to the end of the second.

There is no reason to expect an increase in supply quantity for industrial use. On the contrary, international experience points towards an increase in water recycling and reuse in industry, with greater reductions in supply quantities, so

Area	Current (hm³/year)	First horizon (hm³/year)	Second horizon (hm³/year)
North I	32	34	35
North II	280	291	299
North III	215	215	215
Douro	10	10	10
Tagus	25	24	24
Guadiana I	31	34	38
Guadiana II	53	58	64
Guadalquivir	88	99	99
South	32	37	42
Segura	23	38	38
Júcar	80	92	116
Ebro	415	534	534
Inland Basins of Catalonia	296	346	406
Galicia Coast	53	91	129
Peninsula	1,633	1,903	2,049
Balearic Islands	4	4	4
Canaries	4	10	10
Spain	**10**	**1,917**	**2,063**

Table 73. Forecasts of industrial demand in the medium and long term according to the basin plans.

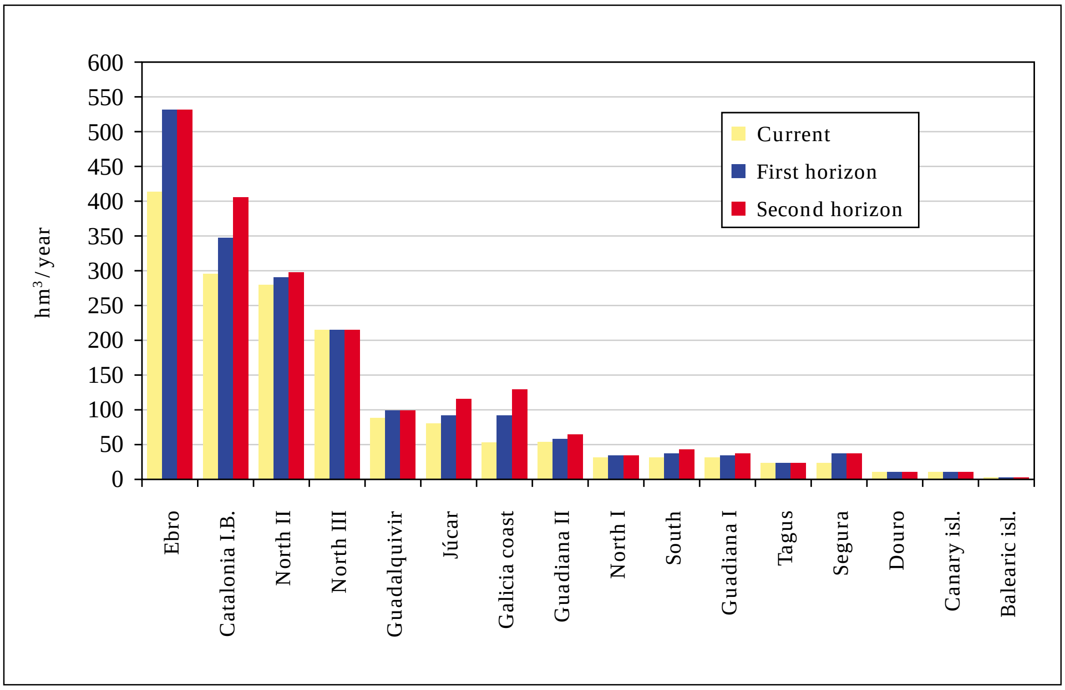


Figure 230. Industrial demand foreseen in the medium and long term in the Basin Plans.

foreseen increases in demand must be associated with an increase in industrial activity.

Finally, it should be noted that industry is one of the areas where technical saving possibilities are greatest and where, additionally, reduction in consumption has an obvious added effect, by reducing returns that can be highly pollutant.

3.3.5. Agricultural uses

Agricultural water uses comprise specifically agricultural activities, to do with the crop production, and livestock-related activities, to do with animal production.

From a quantitative point of view, however, water demand for livestock farming, as we shall see, is not very significant in comparison with agricultural demand.

The most important agricultural use is irrigation, which includes the volumes of water required for the evapotranspiration of crops and, where relevant, other additional volumes of smaller quantity, such as those used for washing soil, anti-frost irrigation or other local climatic modifications.

As we know, water is necessary for plants to develop, and its application increases productivity, and contributes to crop diversification. In Spain, the considerable temporal irregularity of precipitation does not allow for this application to occur naturally, and obliges water to be added artificially through irrigation.

Unlike previous uses, the water demand for irrigation is characterized by its enormous volume and its concentration in the driest months in the year, which requires the regulation and mobilisation of significant annual quantities of water. It is, by far, the use with greatest water demand in Spain.

Guarantee levels for irrigation supply are, however, less demanding than for urban use, and quality conditions are also less strict. Consumption, on the other hand, is higher, with a generally much smaller part that in other uses returning to the hydraulic system. The conventionally-accepted return figure stands at around 20% of supply, although this figure logically varies significantly with the supply quantities applied, with much higher returns, in some cases. Unlike urban and industrial uses, these returns do not usually take place locally, often giving rise to diffuse pollution that is complicated to correct.

As regards agricultural uses, the National Irrigation Plan (NIP) deserves a special mention, approved by the Government in 1996, and which is being currently redrafted by the Ministry of Agriculture, Fisheries and Food. This Plan can be an extremely useful instrument in estimating the evolution of future irrigation requirements, representing a key element in assessing such future demand. For this reason, a specific section –within this section on irrigation– has been given to commenting this Plan's main approaches and available results, and another section –in a later chapter– will be devoted to studying its legal characteristics and its relationship with water planning instruments.

3.3.5.1. Historical background to irrigation

The use of water in Spanish agriculture is very old, with isolated accounts from the Peninsula's first prehistoric inhabitants, and it developed in such a way that from the first millennium B.C., we could already see autochthonous irrigation in the Mediterranean watershed, consolidated and extended with the influence of the Phoenicians, Greeks, Carthaginians and Romans, continuing in the Visigoth period (Al-Mudayna [1991]; Gil Olcina and Morales Gil [1992]; Sáenz [1992]).

The Arabs, with clear Syrian and Egyptian influences, left a structure and a very refined technology of irrigation which, in some cases, has lasted up to the present time. In the 13th century, very meticulous legislation began to develop on the possession, domain and use of waters, not only in Aragon, with Jaime I, but also in Castile, with Alfonso X and his “Partidas” (Laws), where the outlines of Irrigators’ Communities were established. The first two centuries of the Modern Age saw the transformation of medieval irrigation, both in terms of infrastructures (with the construction of major hydraulic structures, such as the Canal Imperial de Aragon), and in terms of artificial regulation (as we shall see when studying the historical basis for the water concession regime).

As of the 17th century, the state began to promote irrigation policies, with the abolition of the property regime of water, intended to boost the country’s wealth by means of agricultural production (this was the period of Jovellanos’ renowned Report on the Agrarian Law). During the 19th century companies were set up with private capital that, having recourse to the regime on concessions, set about building irrigation structures, and there were numerous legal provisions in this respect, up to when the Water Act of 1866 came into effect, the first specific Spanish –and European– law on this matter. Water policies became agricultural policy’s basic instrument during the Restoration, backed by the regenerationist school of thought, represented mainly by Joaquín Costa, for whom real agricultural development was based on irrigation and on its social component. The implementation of hydraulic structures by the State, the Water Act of 1879, and the system of subsidies to private companies to build channels and reservoirs of public interest (Act of 7th of July, 1911), formed the basis of hydraulic development during almost the whole 20th century, and one of the basic elements of water policy’s traditional model, dominant until very recently, and which will be analysed in later sections.

At the beginning of this century, there existed in Spain rather more than a million hectares of irrigated land. Its expansion was a basic objective of successive governments’ water policy, supported by a great deal of relevant legislation on such policy, and which developed by means of various instruments such as the creation of the first Hydrographic Confederación (the Ebro) in 1926, the draft of the National Hydraulic Structures Plan in 1933, and the creation of the National Colonisation Institute in 1939. This organisation, later to become the Institute of Agrarian Reform and Development (IRYDA), was decisive in overcoming the crisis of the post-war period, and in contributing top the process of socio-economic recovery, greatly supported by the strength of the agriculture sector (see, e.g., MAPA-MAP-MOPU [1988]; Barciela [1990]).

This expansionary policy for irrigation was maintained, as mentioned above, until well into the second half of the 20th century, taking advantage of the virtual non-existence of competitive markets. The fundamental objective was to produce, and accordingly, the widespread conviction prevailed that regional development could be based or irrigation, even when, in some areas, the lack of appropriate commercialisation structures prevented products from leaving.

A result of this water policy was the extraordinary increase in irrigated surface area: the 1.5 Mha existing in 1950 rose to the current 3.4 Mha of permanent irrigation, that is, the surface area doubled in less than 40 years. Its expansion so far this century (almost 2.4 Mha) is due both to private and public initiative, in almost equal proportions.

Figure 231, drawn up here from MAPA data (1997) p. 34; Sáenz Lorite (1990) pp. 87-92; and Barceló et al. (1995)

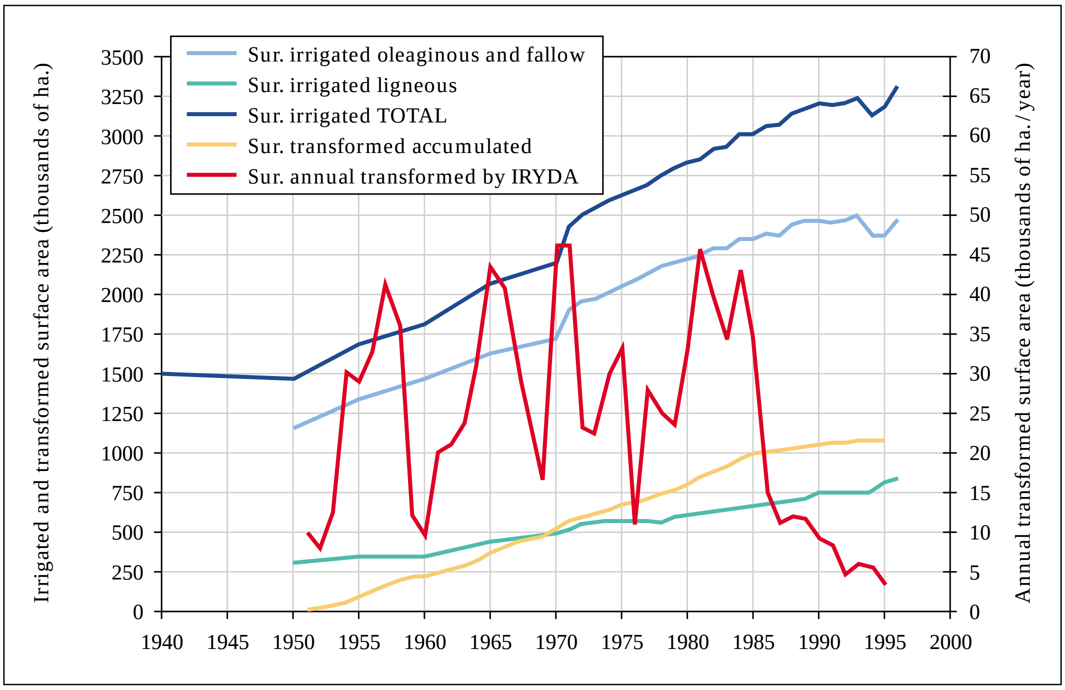


Figure 231. Evolution of irrigated surface areas and areas transformed by the IRYDA.

pp. 186, 249, illustrates this process, showing the evolution of the surface area of irrigated crop land in Spain, and the transformations promoted by the Agriculture Ministry (INC-IRYDA), both in its zones of action (around 15% of the total), and in zones of action coordinated with the Directorate General of Hydraulic Works (around 85% of the total). Transformations carried out solely by the DGOH are very small in size in comparison with these others (about 10% in its period of maximum activity).

As may be seen, from the year 1950 onwards, continuous growth is registered in the total irrigated surface area (with greater dynamism in arable than ligneous), that only toward the end of the 80s began to fall off. In the 40 years between 1950 and 1990, the INC-IRYDA has transformed, in its zones of action coordinated with the DGOH, more than a million new hectares of irrigated land –representing about 25,000 ha/year–, and the total surface area of Spanish irrigated land has more than doubled. From the mid-80s –when the Autonomous Communities assumed competence in this matter– the MAPA's public transformations began to remit, and dropped progressively to the current levels, of about 3,000-4,000 ha/year. As we shall see, these figures are much lower than the almost 25,000 ha/year foreseen for next ten years by the draft National Irrigation Plan Horizon 2008 (MAPA, 1998), which would mean returning to the transformation rate of the sixties.

In addition to the increase in irrigated surface area, and associated with this, the transition from traditional agriculture to modern agriculture was also characterized by an exceptional increase in the use of agricultural production methods.

Accordingly, figure 232 (prepared with MAPA data [1997] pp. 604-606, 615) illustratively shows the historical evolution of total annual agricultural consumption (in millions of current pesetas) in phytosanitary products (including insecticides and acaricides, fumigants, fungicides, herbicides and several others), and of the total annual agricultural consumption of fertilizers nitrogenated, potassic and phosphate, in tons of N, K2O, and P2O5 respectively.

So as to offer a relative idea of these magnitudes, total fertiliser consumption has been divided by the fertilisable surface area (crop lands minus fallow plus natural meadows) existing every year. Figure 233 shows this evolution.

These figures are logically simple indicators, because the average given may hide very significant spatial irregularities. In any case, it may clearly be seen that from the year 1950 onward, an enormous growth is registered in the use of these methods, quintupling the unitary quantities applied in nearly 40 years.

Similarly, another clear illustration of the transformation that took place is given by examining the evolution in auxiliary mechanical methods in agricultural production. Accordingly, the graphs in figure 234 (prepared here from MAPA data [1997] pp. 609-610) show the historical evolution, in recent decades, of inventories at December 31st, of tractors, balers and cereal harvesters registered with the Provincial Agriculture Governments, and of these vehicles' annual power, in millions of horsepower.

As may be seen, growth in number and power as of the fifties is permanent, and continues at the present time particularly with tractors, compared with some stagnation in balers and cereal harvesters.

To give a relative idea of how this increase in production methods is related with the increase in crop surface areas, figure 235 offers (MAPA data [1997] p. 610) the series of power existing for each 100 cultivated hectares (known as the *mechanization rate*).

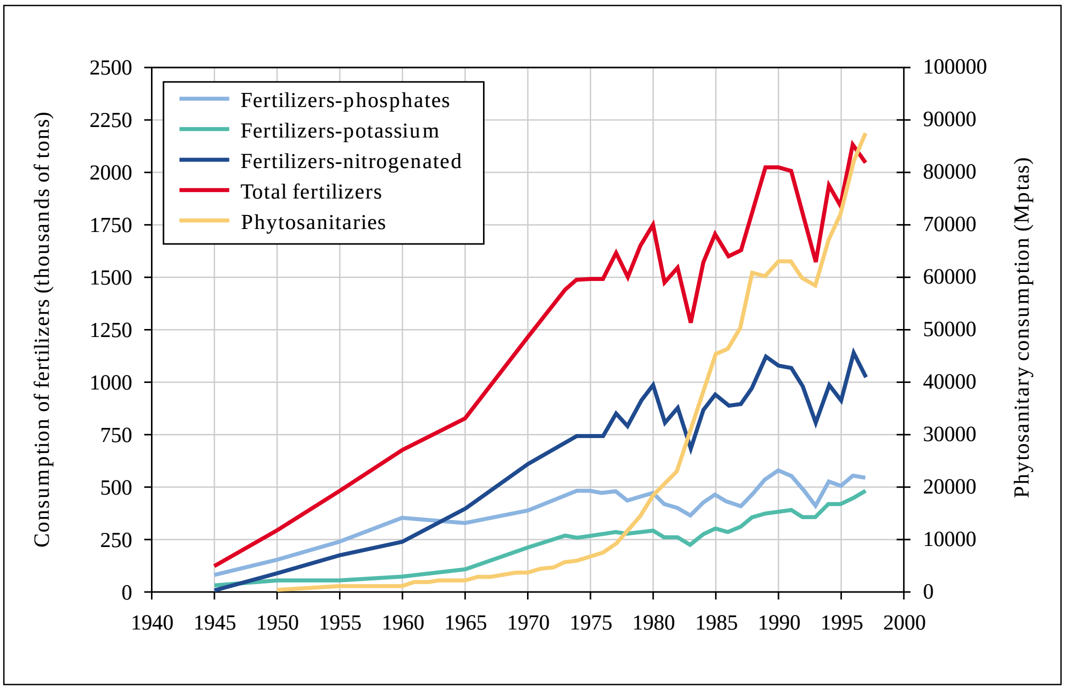


Figure 232. Evolution of consumption of fertiliser and phytosanitary products used in agriculture.

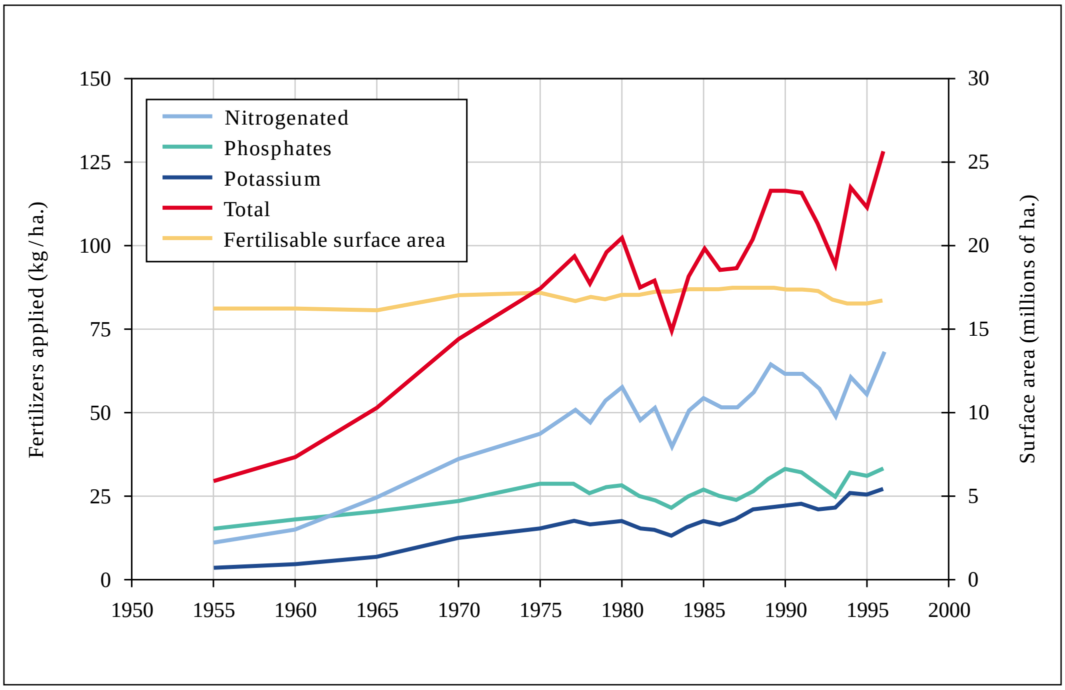


Figure 233. Evolution of consumption of fertilizers products per hectare of fertilisable land.

In short, the considerable development in these production methods has meant an extraordinary increase, in recent decades, of input contributing to agricultural activity.

As we shall describe further ahead, when Spain joined the European Union in the middle of the eighties, transformation of our agricultural environment accelerated, forcing even further the transition from a traditional autarchical model (or of agriculture conceived as a way of life), to another based on the modernization of infrastructures, productivity, commercial competitiveness, prices and quality (or of the agriculture as an economic activity and a business), which adapted it to the demands of world trade –especially of Community Agricultural Policy (CAP)–, in a framework of advantages and relatively rigid limitations, and complex international regulations.

The final result of this process is still to be seen, but along with certain benefits, some distortions and inconveniences are already being felt. In later sections, such problems and future perspectives will be dealt with.

3.3.5.2. Current use of water for irrigation

Irrigation's interest as a national production activity lies in the fact that it forms the basis for the agricultural system, and that, covering only 15% of useful agricultural surface

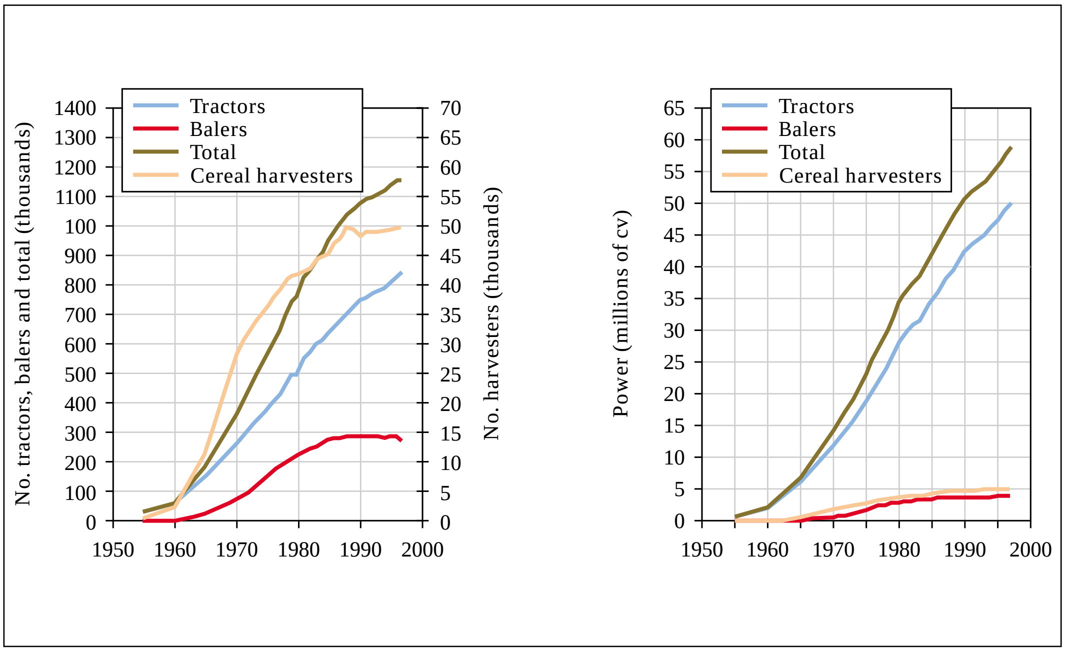


Figure 234. Evolution of number and power of the tractors, balers and cereal harvesters.

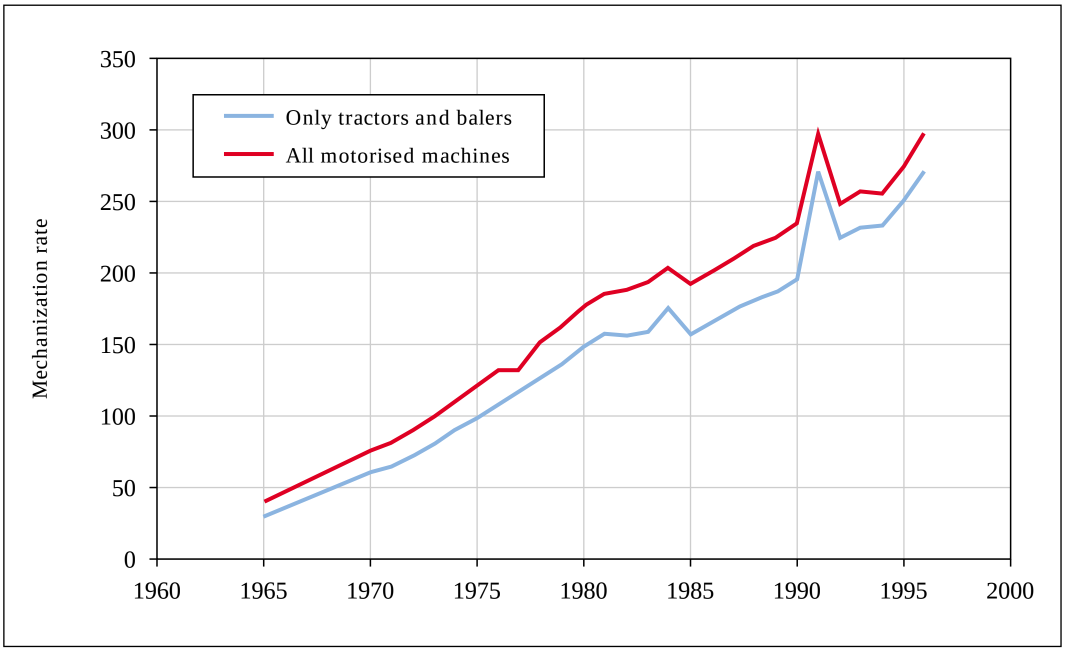


Figure 235. Evolution of the mechanization rate.

area, obtains 55% of the final agricultural productivity. Additionally, it generates 30% of salaries necessary for the agricultural sector. In some regions, such as Andalusia, this percentage almost doubles, and in others, such as Aragon, the agro-food sector generates 15% of the region's entire industrial employment. Both examples give an idea of irrigation's considerable socio-economic importance, beyond its contribution to the GDP.

The graph in figure 236 (drawn up here from MAPA data) shows the recent evolution of this agricultural production (in trillion ptas. of 1996), as well as the productivity relationship (ptas/ha) between irrigated and dry crop land. The considerable relative magnitude of irrigation compared with dry crop land can be appreciated, and how this relationship has tended to increase with the passing of time. These magnitudes also show significant territorial differentiation, as we shall see in sections below.

Focusing our attention on irrigated surface areas, which are the relevant ones from the point of view of water resources, table 74 shows the irrigated surface data existing at present, according to the recently approved basin management plans.

In the table, the surface area corresponding to Levante Left Bank irrigation has been considered, including the whole Segura area, despite the fact that an important part is in the Júcar area. The ATS irrigation in Almería is not included in the Segura, but in the South.

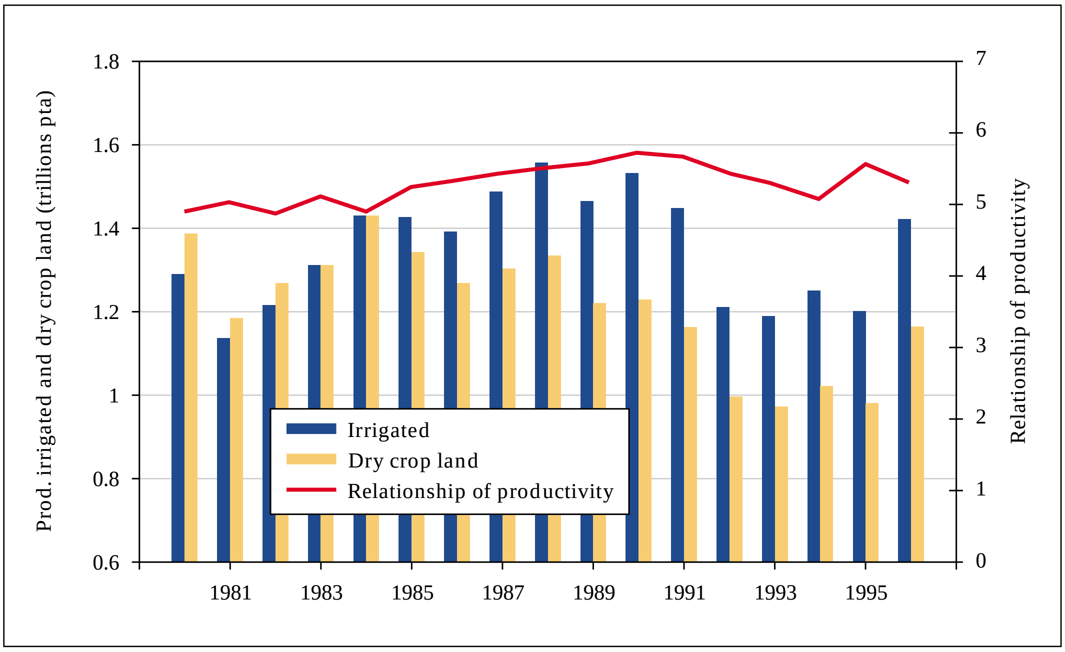


Figure 236. Evolution from 1980 onwards of total agricultural production of irrigation and dry crop land, and the productivity relationship between both.

Table 74. Currently existing irrigated surface areas according to the basin management plans.

Area	Surface area (ha)
North (I, II and III)	69,972
Douro	550,326
Tagus	230,720
Guadiana (I and II)	340,974
Guadalquivir	483,170
South	159,607
Segura	265,969
Júcar	370,000
Ebro	783,948
Catalonia I.B.	64,502
Galicia Coast	63,811
Peninsula	3,382,999
Balearic Isl.	24,039
Canaries	30,000
Spain	**3,437,038**

The map in figure 237, drawn up with information from the basin management plans, shows existing spatial location of this irrigation, in terms of gross surface areas or irrigation perimeter enclosures.

Additionally, figure 238 shows the distribution of irrigated surface areas, identified by means of teledetection analysis, by combined data from the years 1984, 1987, 1991 and 1995.

As may be seen, both maps have an identical appearance, but with different density. This may easily be accounted for, considering they represent two different concepts: the first one outlines the irrigation perimeter enclosures (known as agricultural demand units, with gross surface areas), mapped and considered in basin management plans, while second represents the result of a multitemporal teledetection study, identifying really irrigated (net) surface areas in the summers of the years 1984, 1987, 1991 and 1995.

The change from gross surface area to net requires of the corresponding reduction coefficients to be applied for the purposes of rotation effects and fallow land, with potentially significant differences between both concepts. Accordingly, and by way of example, starting from the Segura basin, and based on the inventories of hydraulic uses carried out over an aerial picture with great detail and spatial resolution, a total of 457,950 gross irrigated ha. have been mapped, (cultivated and, at some time, occasionally,

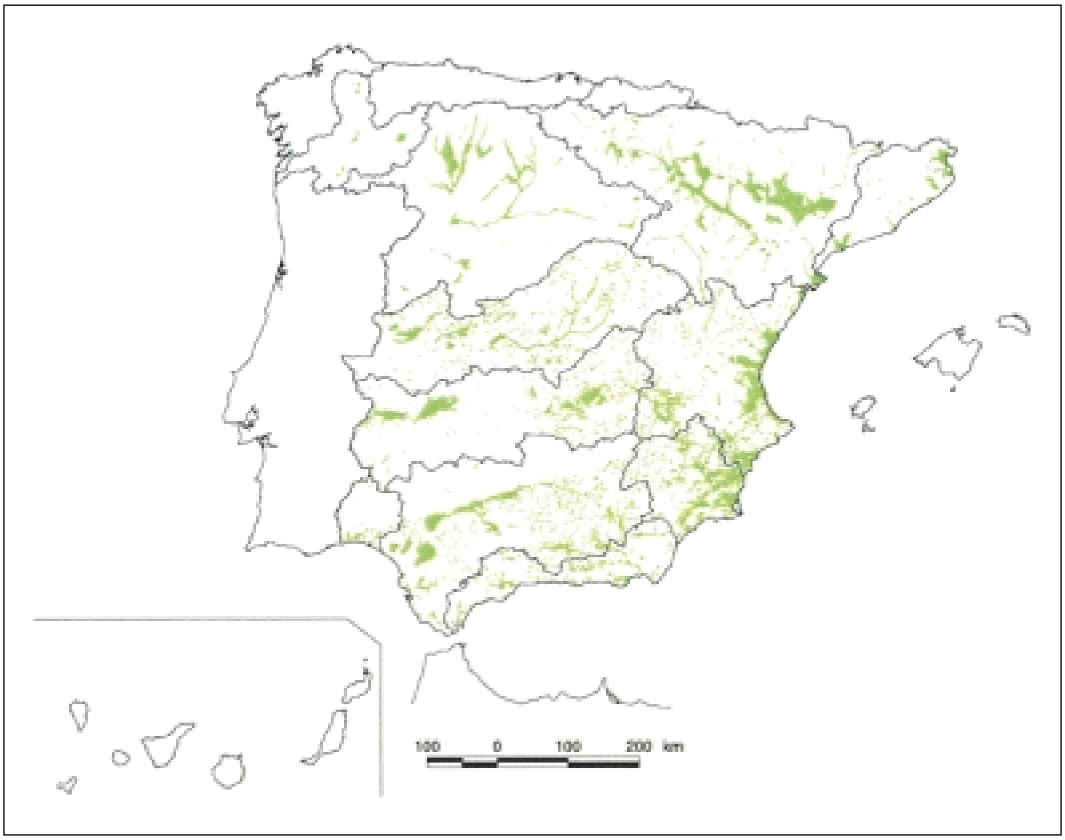


Figure 237. Map of gross irrigated surface areas identified in the basin management plans.

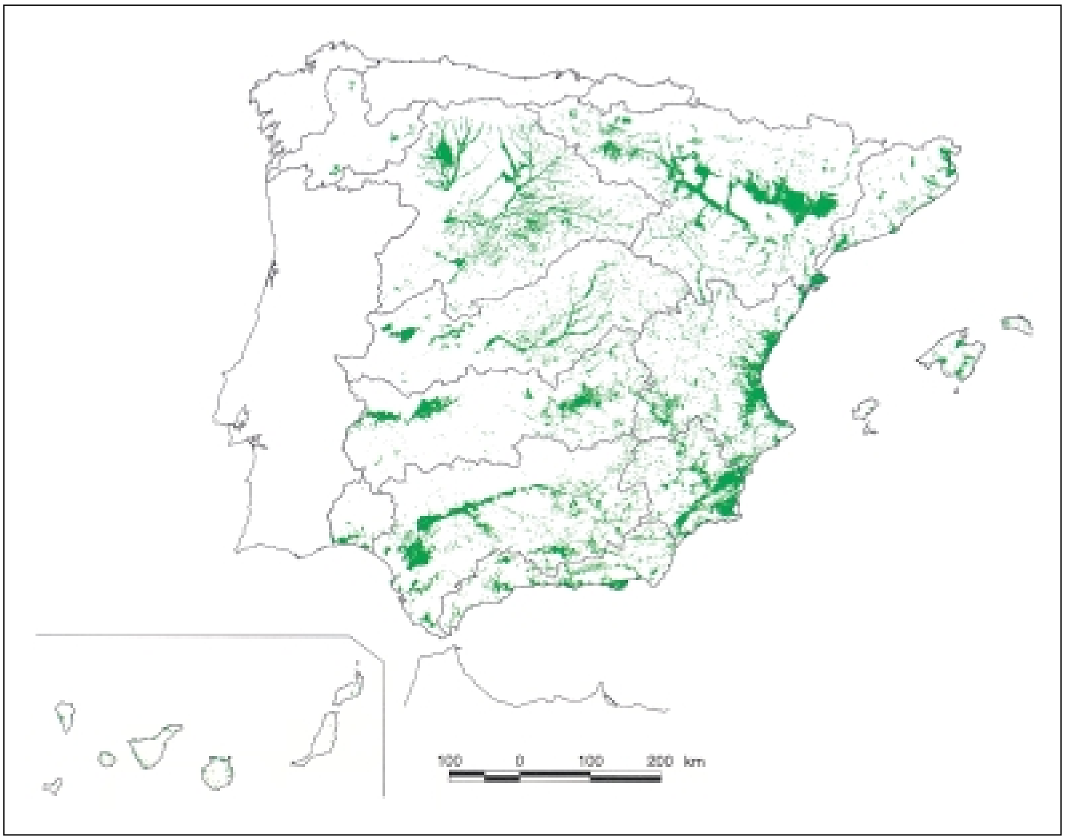


Figure 238. Map of irrigated surface areas identified by teledetection (years 1984, 1987, 1991, 1995).

irrigated), while those really watered (net) whose demand is consolidated, and it should be satisfied in an average representative year, have been estimated, including the ATS irrigation in Almería, at 269,029, that is, barely 60% of the gross values.

These irrigated surface areas generate a significant water demand. Table 75 shows this current demand according to the basin management plans, expressing its values in absolute terms, and in percentage over total irrigation demand in Spain, and also presenting resulting overall average supply quantity.

As may be seen, total demand is about 24,000 hm^3/year, of which more than half corresponds to the large basins of the Ebro, Douro and Guadalquivir. Average supply quantities range between 5,750 (I.B. Catalonia) and 8,800 m^3/ha/year (Canaries), with a mean global value of 7,000. Figure 239 visually presents these results.

As for the irrigation methods used, 59% of surface area occupied irrigates by gravity, 24% by center-pivot, and 17% by drop.

The data referring to the source of water used in Spanish irrigation is not sufficiently contrasted with direct invento-

Area	Irrigation demand (hm^3/year)	Irrigation demand (m^3/ha/year)	Average supply quantity (hm^3/year)
North (I, II and III)	532	2	7,589
Douro	3,603	15	6,547
Tagus	1,875	8	8,127
Guadiana (I and II)	2,285	9	6,701
Guadalquivir	3,140	13	6,499
South	1,070	4	6,704
Segura	1,639	7	6,162
Júcar	2,284	9	6,173
Ebro	6,310	26	8,049
I.B. Catalonia	371	2	5,752
Galicia Coast	532	2	8,337
Peninsula	23,641	98	6,988
Balearic Isl.	189	1	7,862
Canaries	264	1	8,800
Spain	**24,094**	**100**	**7,010**

Table 75. Irrigation demand and current average supply quantities by planning area.

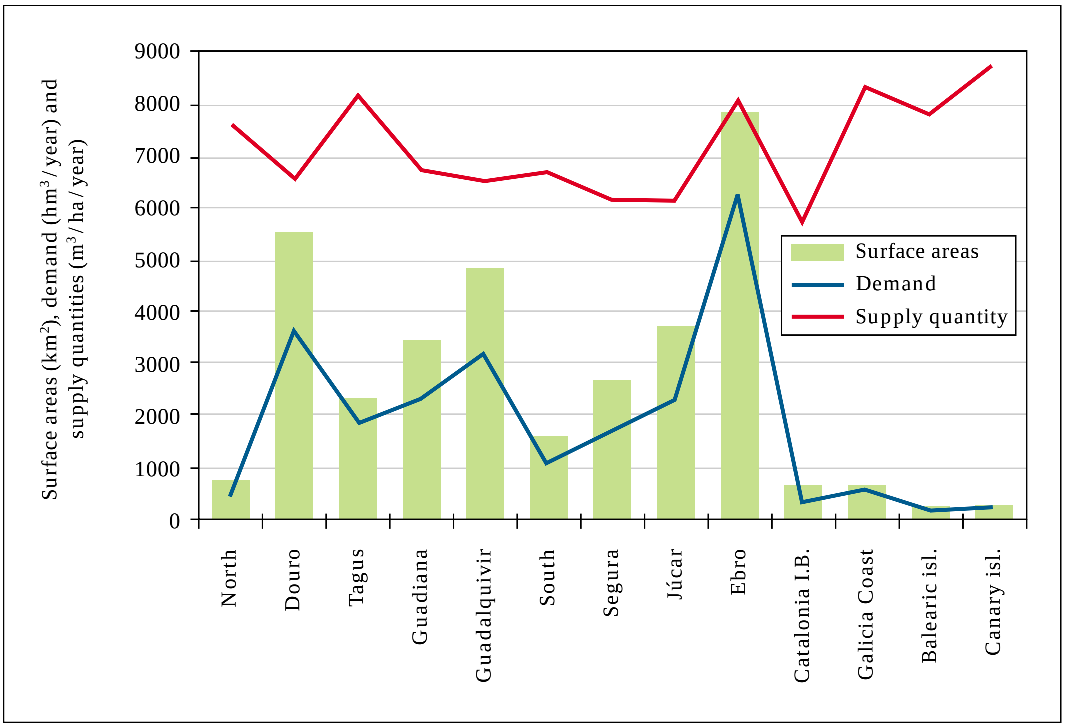


Figure 239. Surface areas, demand and current supply quantities by planning area.

ries. In those covered by groundwater, one of the main causes of lack of knowledge about them is the fact that these transformations, in general, have been carried out by private initiative, and only from 1986 onward did they need the corresponding obligatory administrative concession. If we also consider the fact –relatively frequent in some areas– that one same area of land has resources from different sources, we can understood that identifying the origin of resources for all irrigated land is an arduous and very complex task.

Despite these difficulties, both the MAPA and the MOPTMA have drawn up different estimates, obtaining percentage distributions that amount to the same order of magnitude, as shown in table 76.

Figure 240 shows source of water in irrigated areas according to the MOPTMA assessment (1987).

On the other hand, and as mentioned above, the seasonality of irrigation demand can be very marked, which increases the need for regulation, when demand peaks coincide with periods of lower natural availability of water resources.

Figure 241 illustratively shows the mean values of seasonal distribution for this demand according to data from some basin management plans. It can be seen that in those areas where the climatology allows winter crops, such as the Sefura, Júcar and South, this distribution shows less seasonality, while others such as the Guadiana, Tagus or Douro, practically cancel demand from November to March.

3.3.5.3. Water prices in irrigation

Below, as in the case of water use for population supply, we shall present some pricing figures paid for irrigation water in different areas of Spain.

Statistical concern with this data is relatively recent, and although there is plenty information in this respect, it is usually spot data on samples, and not always very representative. In recent years, some interesting systematic studies are being done on this issue, although limited to specific territories (see, e.g., Carles et al., 1998).

Here, the methodological difficulties in estimating supply prices are, if anything, exacerbated, because the diversity of situations in Spain's irrigated areas or agricultural regions is extraordinary. Accordingly, there are spot typology differences in crops, irrigation technologies and practices, distribution and pumping costs, different costs for one same area depending on the circumstantial supply source used from among the different possibilities, different costs according to the hydrological situation of each year, depending on

Source of the water	Irrigated surface area (%)	
	MAPA	MOPTMA
Surface	68	67
Groundwater	28	23
Mixed and Others	4	10

Table 76. Distribution of irrigated surface areas according to source of the water.

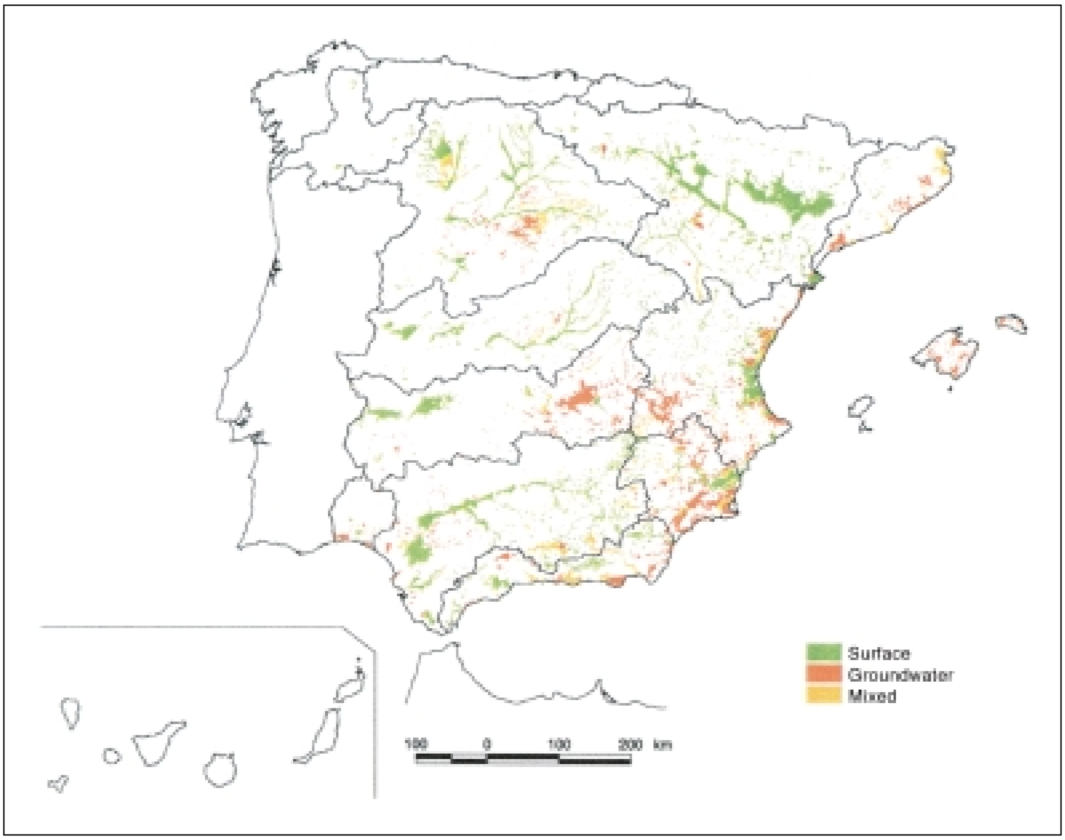


Figure 240. Map of irrigated areas with their water sources.

whether data comes from official tariffs or from surveys, on whether it is an extreme circumstantial value or a sustained average value, on whether it is a sales cost or production cost, and so on.

In short, all this leads to the existence of a great variation in prices, even between areas in close proximity, and even for the same area according to the year and data source, so the available figures from different studies and surveys must be considered as merely indicative, and subject to considerable dispersion.

To obtain a global idea of irrigation water price in Spain, we may consider the following simplified typologies: traditional irrigation or major public initiative transformations, with surface water, are usually those with the lowest water cost (around 0.01-0.02 €/m^3); other, more technified surface irrigation or with greater scarcity has higher prices (0.03-

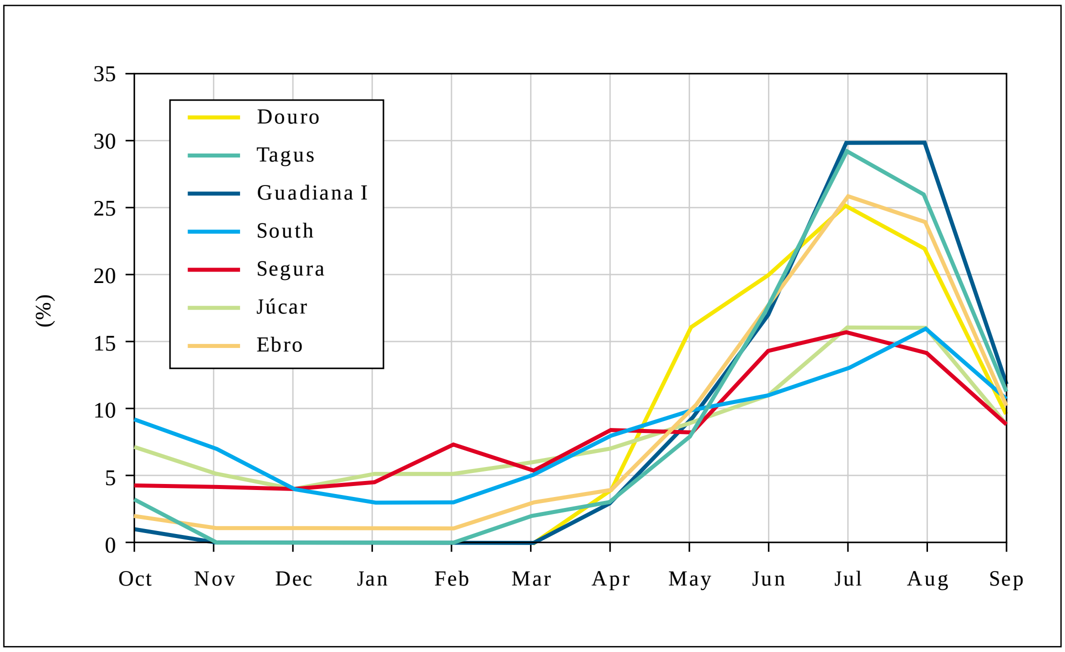


Figure 241. Average seasonal distribution of irrigation demand in some Basin Plans.

0.06 €/m^3); irrigation with groundwater also usually has higher prices (0.03-0.09 €/m^3); irrigation with transferred water has prices even higher than these (0.12-0.15 €/m^3); lastly, highly productive irrigation with greater supply shortage has the highest water prices (0.15-0.39 €/m^3).

As for water demand elasticity against these prices paid, this is a little-studied field in our country, although in recent years different studies of interest are being carried out allowing them to be demarcated and characterised (Sumpsi et al. [1998]; National Federation of Irrigators' Communities [1999]). A review of other economic aspects related with irrigation can be seen in Garrido Colmenero (1995), and some reflections on irrigation economy in Albacete y Peña (1995).

3.3.5.4. Future demand

Forecasting future demand for irrigation is particularly complex, and subject to some uncertainties (future development of irrigation, PAC restrictions, financial availability, agricultural markets, water resource guarantee, environmental impact, water prices, etc.).

Despite such difficulties, and in order to delimit their magnitude, the basin management plans have made an estimate of this demand, considering the different social requirements (basically of the agricultural administrations and the users), and considering its feasibility from the point of view of water availability. The figures obtained are those summarized in the adjoining chart, and they should be interpreted as a future potentiality (which, as we shall see, the National Irrigation Plan calls potential irrigation), which may materialise, where relevant, to the extent that the mandatory administrative procedures are implemented and the necessary financial means are put forward for the transformations. In any event, it should be indicated that –as was the case with population supply forecasts– demand is being interpreted in a regulatory sense, that is, supposing theoretical estimates of maximum future consumption with zero price elasticity.

Tables 77 and 78, and figures 242 and 243, show surface areas and irrigation demand considered in the basin management plans.

In addition to possible initiatives by the Autonomous Communities and private parties, implemented within the scope of their respective powers and interests, the MAPA has programmed, within the context of the National Irrigation Plan, a series of actions to be carried out in the medium term, by co-financing mechanisms with the rest of the agricultural administrations and, where relevant, with private individuals. These actions would involve the transformation of about 240,000 ha in the next 10 years, corresponding to irrigation in execution, social and private, detailed below, in the section describing the Irrigation Plan. As mentioned, this is a very fast pace, similar to the sixties.

Additionally, a basic issue relating to irrigation's future is price level that agriculture can bear from the point of view of water requirements. Greater or lesser future demand will depend largely on the resulting price of water for irrigation and its greater or lesser elasticity, a question we referred to above.

Furthermore, in the context of the preparatory work for National Irrigation Plan Horizon 2005, currently in force, a multi-criteria selection was made of the potential future irrigated lands, considering the technical-economic and social feasibility of the transformation, the agricultural structures and agro-industrial environment, and the environmental impact and possible corrective measures.

A group of 1,153,203 potential future irrigations were thus defined (MAPA [1996] pag. 23), of which 209,818 were by public initiative with legal regulation (already declared), 828,632 were by public initiative without regulation, and 114,753 were by private initiative. Their implementation will obviously be conditioned by their social interest, economic profitability, the availability of water and financial resources, market demand and environmental repercussions.

The potential surface areas identified by the PNR-2005 in force, together with those of the draft PNR-2008 (MAP [1998]), and those included for the long term (year 2018) by the basin water planning, are shown in table 79.

As may be seen, the three sources give very similar global figures.

3.3.5.5. Existing and Foreseeable Circumstances and Problems

Having presented the basic data and estimates for irrigation, we now turn to outlining some questions related with their future situation and prospects. In assessing these perspectives of Spanish irrigation, not only economic problems must be taken into account, but also environmental, social, etc.

Table 77. Forecasts of possible maximum irrigated surface areas in the medium and long term according to the Hydrological Plans.

Area	Current surface area	First horizon	Second horizon
Galicia Coast	63,811	63,811	63,811
Peninsula	3,382,999	3,931,600	4,547,284
Balearic Isl.	24,039	64,039	24,039
Canaries	30,000	34,000 (1)	38,000
Total	**3,437,038**	**3,989,639**	**4,609,323**

Area	Current demand (hm³/year)	First horizon (hm³/year)	Second horizon (hm³/year)
North I	475	339	357
North II	55	55	55
North III	2	3	3
Douro	3,603	4,349	5,022
Tagus	1,875	1,785	2,048
Guadiana I	2,157	2,454	2,645
Guadiana II	128	300	421
Guadalquivir	3,140	3,299	3,659
South	1,070	1,127	1,172
Segura	1,639	1,639	1,639
Júcar	2,284	2,420	2,580
Ebro	6,310	8,213	9,879
Catalonia I.B.	371	410	494
Galicia Coast	532	277	277
Peninsula	23,641	26,670	30,251
Balearic Isl.	189	189	189
Canaries	264	264	264
Total	**24,094**	**27,123**	**30,704**

Table 78. Forecasts of maximum irrigation demand in the medium and long term according to the Basin Plans.

Considering that Spain, a genuinely Mediterranean country, is one of the members of the UE where, due to its climatic characteristics, its agricultural activity depends to a large extent on irrigation, we cannot leave aside the problems arising from changes in the world agrarian markets, which will have an impact on Community Agricultural Policy, affecting the competitiveness of Spanish products. As a consequence, it is foreseeable that agricultural prices will drop, brought about by markets opening up and competition being created among them.

Water supply problems in irrigated areas deserve special attention, in some cases preventing crops' water requirements to be covered, in quantity and in quality, either due to a lack of adaptation in supply service or because the water allocation calculated for the project, and destination, where relevant, of the concession, have been surpassed by the introduction of new crops with greater water needs.

There must also be assessment of the environmental risks arising from intensive agriculture, and which, to achieve competitive products, tend towards the use of greater quantities of pollutant chemical products, and to the over-exploitation of aquifers and other natural resources.

The section below briefly describes some of these basic problems.

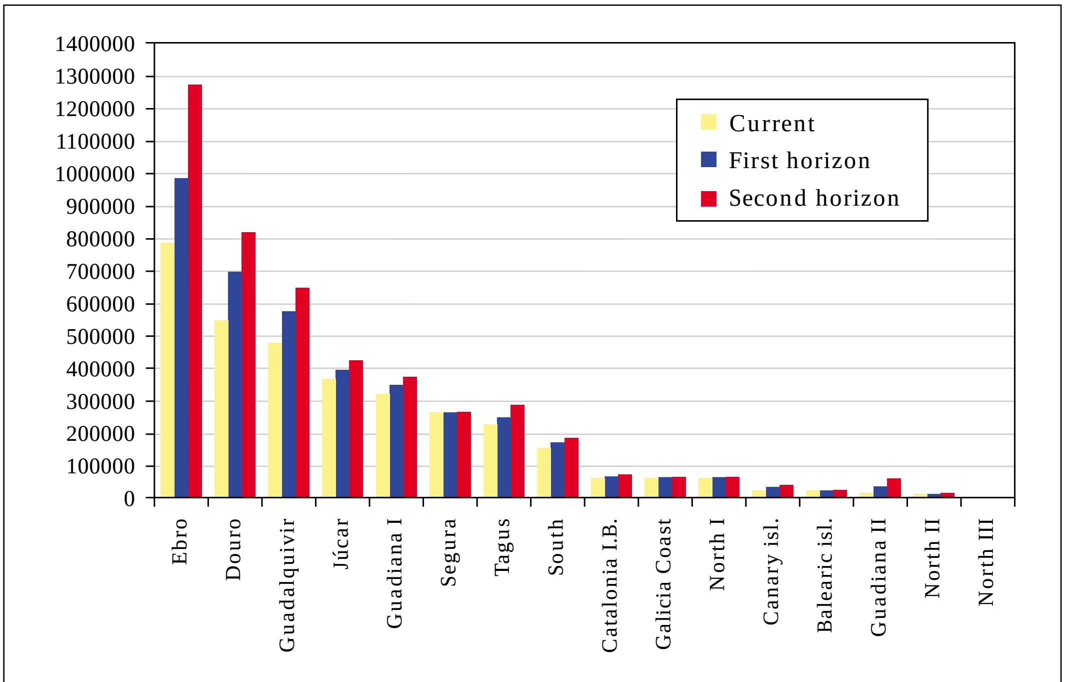


Figure 242. Irrigated surface areas (ha) in the basin management plans.

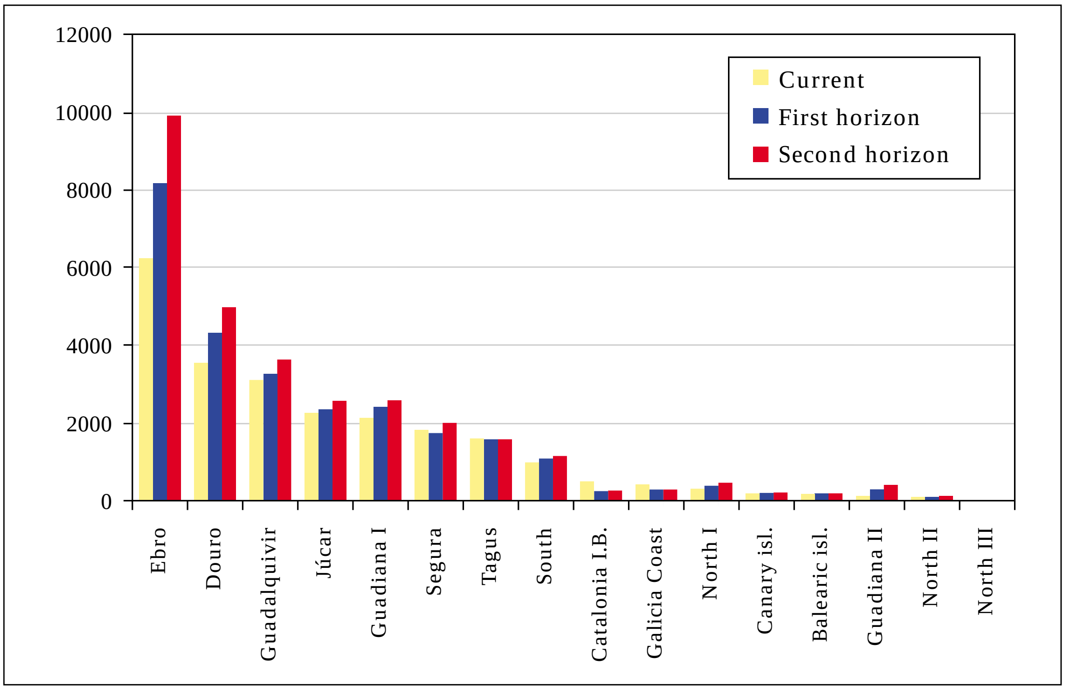


Figure 243. Maximum irrigation demand foreseen in the medium and long term in the Basin Plans.

3.3.5.5.1. Market conditions and competitiveness of production. Common Agricultural Policy. Future trends

Water has always been a basic element in the agriculture of Mediterranean countries, among them Spain, because their agricultural potential depends heavily on irrigation activities, and which, as is well-known, water is an essential factor in its production process. For this reason, Spanish water policy has been permanently influenced by objectives set by irrigation policies, as an instrument of agricultural policies, lthough it is foreseeable that, as we shall see when analysing the traditional model's crisis and the new bases for water policy, this relationship will gradually tend to diminish in the future.

In this respect, it is necessary to devote preferential attention to the exterior context where the sector will develop in coming years. Without ignoring the perspectives of the world agricultural markets, it especially relevant to describe the institutional and regulatory framework that defines the rules of action. The literature existing on this major issue is very extensive, e.g., Tió (1997). Furthermore, an interesting analysis of the current circumstances of the agricultural economy and of its future perspectives is the one provided by Velarde (1996).

In summary, we may state that the process of world-wide market liberation, including agricultural, starting in the fifties, was one of the reasons that gave rise, in 1957, to the creation, by the Treaty of Rome, of the European Economic Community and to the establishment of a Common Agricultural Policy (CAP) as mechanism to defend European interests.

Since its origins, the CAP has basically consisted of a policy to regulate markets of agricultural products inside the UE

Basin	Potential PNR-2005	Potential Draft H-2008	Long term PHC
Galicia Coast	707	0	0
North	8,604	0	4,528
Douro	349,567	249,503	268,097
Tagus	51,232	35,777	59,190
Guadiana	74,043	93,983	89,849
Guadalquivir	84,847	92,963	165,872
South	14,550	6,708	22,865
Segura	30,823	2,145	0
Júcar	48,000	75,758	55,000
Ebro	485,216	465,981	487,358
Catalonia I.B.	0	0	11,526
Balearic Islands	4,000	750	0
Canaries	1,614	3,400	8,000
Total	**1,153,203**	**1,026,968**	**1,172,285**

Table 79. Determinations on potential irrigated surface areas by planning area.

and, although it has not marked a specific strategy on irrigation development, since this is a structural strategy that corresponds to member states, there is no doubt that it conditions actions on national levels as regards irrigation.

Initially, the philosophy of the CAP was based on setting, by means of certain Common Market Organizations (CMOs), a minimum guarantee price for products, which assured farmers the value of their crops, beyond price fluctuations, provided that frontier protection limited imports to situations where internal prices of the agricultural common market exceeded a preset threshold. The principle of financial solidarity led to the community budget supporting the growing costs that necessarily accompanied the system's maintenance.

The failures of this policy, among which we should highlight considerable surpluses generated in continental European agricultural products, led to strong criticism from the middle of the eighties, faced with such a situation. This consolidated the idea that it was neither economically reasonable nor financially possible to achieve an integral guarantee of unlimited quantities of agricultural products (Green Paper 1985), and at the end of the eighties, the EU was forced to consider the need for far-reaching reform of the CAP.

This process culminated in 1992 with the approval, by the Agriculture Council of the EC, of the CAP reform, effective for the period 1994-1999.

In 1986, coinciding chronologically with criticism of the CAP then in force, the 8th Round of GATT began in Uruguay, concluding with the Marrakesh agreements of 1994. These were the first steps towards total world-wide trade liberalisation, referring basically to exterior agricultural trade.

These agreements clearly prejudiced European agriculture due to the difficulty of adapting their high production costs to low international prices. The European Union, thanks to the CAP reformation in1992, managed to obtain a delay in applying these agreements until the next meeting of the World Trade Organization (WTO), substituting the GATT, foreseen for 1999.

With the CAP reform, apart from preparing European agriculture for future GATT agreements, the new scenario incorporated restrictive measures that substantially modified the expectations with which Spain had negotiated its agriculture's entry into the community market.

Accordingly, and as we saw when analysing the evolution of surface areas, our agricultural production has passed, in a short period of time, from a model derived from the strategy defined in the sixties with the basic aim of reaching the highest possible degree of self-supply, and which was heavily protected from the exterior, while maintaining traditional exports encouraged by comparative advantages (wine, olive oil, fruit and vegetables), to another, radically different one.

At present, and as we shall see later on, exploitation subsidies, coming mainly from the EU, amount to 24% of national income from crop and livestock farming, with some Autonomous Communities exceeding 40%. These figures show our agriculture's considerable dependence on such help. Without it, it is probable that an large part of cultivated surface area in Spain would have been abandoned, with the resulting deterioration of the rural environment. Figure 244 and table 80 show agricultural subsidies for Autonomous Communities in 1995, both absolute (direct aid, FEOGA-guarantee, FEOGA-Orientation and Structural Funds), and relative, with respect top regional agricultural GAV (MAPA data [1998]; García Sanz [1996] pp. 230-234).

Some writers interpret subsidies not strictly as such, but as compensatory payments to encourage agricultural income to approach the rest of the European economy, while others consider subsidies are only assistance give directly to the farmer, without considering the aid devoted to improving production structures. It may be interpreted this way, but, whether directly or indirectly, it is a fact that the Spanish agricultural sector has received an important contribution from European funds in recent years, aimed specifically at financing agricultural income.

Generally speaking, the new CAP aims to annually regulate markets, seeking formulas compatible with the GATT agreements to maintain the level of agricultural income by means of a complicated compensatory aid programme, and preventing surplus production from being generated in the European Union. The new philosophy is summed up in the following measures:

- Reduction of the institutional prices
- Establishment of compensatory aid by hectare for arable crops (based on historical yield of cereals) or else by means of premiums per head of livestock. This compensatory aid is limited by the reference surface area laid down by Community Regulations (dry crop land: 8.1 million hectares distributed by Autonomous Communities; irrigated land: 0.4 million hectares for maize and 0.7 for other arable crops), and conditioned, except in the case of small farms, to the rotating withdrawal of production (set-aside) of a part of the land. Pre-existing production limitations are maintained for the rest of crops (sugar production quotas, etc.).
- Accompaniment measures of environmental protection (extensification, reduction of pollution, etc.), afforestation of agricultural lands and early retirement.

As regards the horticultural sector and other Mediterranean products, vital for the interests of Spanish agriculture, they generally have a much lower protection level than continental products: limited intervention systems and incomplete exterior protection in some cases. Several of the Common Market Organizations' reforms are still pending specification, and there are serious doubts about maintaining the principle of community preference in these cases.

The new CAP is characterized by abandoning protection of the product, via prices, and substituting this with a system

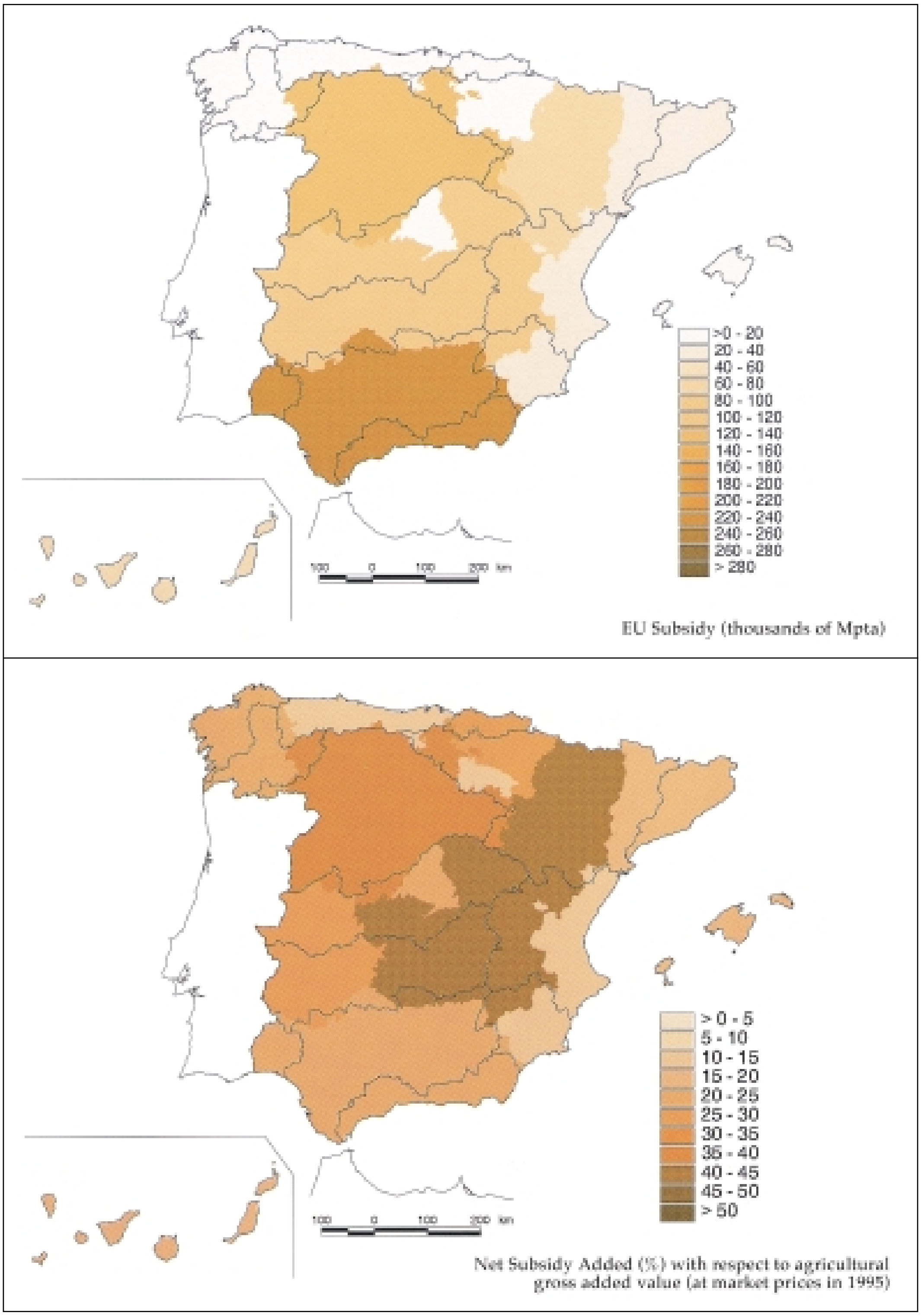


Figure 244. Maps of agricultural subsidies by Autonomous Community.

of aid for the producer. The relevance of this fact is that production-associated activity that cannot compete in a free market, and which need the payment of subsidies to survive, depends on annual approval by the community budget. The margin of uncertainty that this adds to the expectations of agricultural exploitation is unquestionable, despite the will to persist that some writers maintain with respect to the aid system.

This feeling is strengthened by the lines defined in this new phase regarding the dilution of classical agricultural policy into a much more global policy, oriented towards integrated rural development, where environmental and conservation considerations play an increasingly important role. In this context, neither traditional agricultural activity nor irrigation should represent the most important element in the rural environment.

In short, for Spain, this situation means increased freedom and competition within European markets of agricultural products. The new CAP promotes, from the point of view of such exploitation's micro-economic behaviour, technical

	Autonomous Community	Agricultural Subsidy	
		Absolute (thousands of M€)	Relative (% agricultural VABpm)
1	Andalusia	1.43	20.9
2	Aragon	0.42	41.6
3	Asturias	0.04	12.6
4	Balearic Islands	0.03	15.8
5	Canaries	0.25	18.3
6	Cantabria	0.02	13.6
7	Castile-La Mancha	0.70	43.9
8	Castile-León	0.82	37.3
9	Catalonia	0.23	16.4
10	Extremadura	0.52	28.5
11	Galicia	0.12	20.8
12	Madrid	0.05	23.5
13	Murcia	0.14	10.6
14	Navarre	0.11	29.2
15	La Rioja	0.03	11.3
16	Valencia Community	0.15	11.7
17	Basque Country	0.07	27.6
	Global	**5.11**	**24.3**

Table 80. Agricultural subsidies by Autonomous Community.

solutions allowing unitary costs ro be reduced while maintaining, and even improving, net margins per hectare, but without increasing yield.

Furthermore, the agreements by the Uruguay Round of GATT meant a significant reduction in tariffs, as well as of numerous non-tariff obstacles. The liberation of exchanges thus received a boost, in the expectation that the results of world income would not take long in showing a significant increase. Among other issues they mean a major change in the treatment given to agriculture, since from now on, actions by Governments on question of agricultural policy must respect a series of commitments governed by international laws. In short, the Agreements of Uruguay Round of GATT basically affected Spain in three aspects:

- Access to the community market. A double commitment exists: the tarification of frontier protection and the subsequent reduction in tariffs and tariff equivalents (36% in the period 1995-2000, gradually). The minimum access clause commits Spain to maintaining opportunities to import up to 2 millions tons of maize and 0.3 million tons of sorghum.
- Reduction of internal support. The European Union must reduce the global average of aid by 20%. This excludes aid like that established for reforming the CAP (aid by hectare and by head of livestock).
- Reduction of exports eligible for subsidy. The European Union must reduce the quantities exported with subsidies to third-party countries by 21% and the community budget devoted to export refund by 36%, between the year 1995 and 2000.

The consequences that these commitments may involve are not uniform for all Spanish production orientations, but in view of the framework established by them, of more open and competitive markets, we may foresee a drop in real agricultural prices.

As regards the bench marks of competitiveness that Spanish products will reach in a future framework of liberalized markets, we should highlight the added difficulty for our agriculture in the current plot structure of irrigated exploitation, with properties of dimensions that are difficult to mechanise and, consequently, subject to exploitation costs that are not easy to reduce.

As regards the framework of the current CAP, table 81 compares maximum surface areas, deduced from the different OCM, with those normally cultivated. As equivalent surface areas, it considers those established as maximum eligible surface areas, or those able to produce the block quantity applicable to Spain, according to historical yield. In the case of olive oil, fruit, fresh vegetables, flowers, dried fruit and other crops, no surface area is given since they are block crops or productions for all the countries that make up the EU. As normally-cultivated surface area, it shows some average figures that may vary from one year to another according to climatology, markets, etc., or else officially-accepted figures for irrigation.

Additionally, there also exist the livestock farming limitations sown in table 82, with significant repercussions on irrigated fodder production.

An analysis of these tables indicates that maximum surface area has been reached in a large majority of crops, so their indiscriminate expansion would provide a progressive decrease in aid currently received by farmers, and even the imposition of penalties.

However, the fact that for various sectors covered by community aid maximum surface areas stipulated by communi-

Product	Equivalent surface (ha)	Surface usually cultivated (*) (there is)
Cereals, oleaginous and proteaginous	1,371,089	1,380,000
Rice	104,973	90,000
Leguminous	20,000	20,000
Hops	1,200	1,200
Hemp and textile linen	Without limitation	48,500
Fodder (**)	360,000	360,000
Cotton	83,000	83,000
Tobacco	16,000	18,000
Bananas	10,000	8,000
Fruit and transformed vegetables	30,000	30,000
Sugar	135,000	135,000
Olive oil (total dry crop and irrigated 2,2 Mha)	--	150,000
Fresh fruit and vegetables	--	870,000
Flowers	--	2,000
Dried fruit	--	50,000
Vineyards	Surface monitoring	40,000
Various crops		57,000

Table 81. Maximum usually cultivated surface areas of main agricultural products.

(*) These surface areas may correspond to areas with more than one annual crop.
(**) Spain has a guaranteed production of 1,224,000 t of dehydrated fodder and 101 t of sun-dried fodder. Expected production in a normal year.

ty regulations have been reached, or are about to be reached, should not be understood as a stringent factor in preventing irrigated surface areas in Spain.

Without taking other factors into account, and exclusively from the point of view of regulating agricultural markets, irrigated cultivation is an asset in itself thanks to the stability that production provides compared with other alternatives, its greater flexibility and capacity of adaptation against changing scenarios.

In short, and in accordance with the framework described above, a series of basic conclusions can be made.

Firstly, the exterior context allows an uncertain future to be foreseen for Spanish agriculture, and for irrigation in particular, considering the momentous changes registered in recent years in how markets operate. Other factors of internal origin still pending decision by agricultural policy simply contribute to reinforcing this diagnosis. Faced with these circumstances, it seems recommendable, from the point of view of water resource management, to adopt short-term solutions that do not commit substantial financial resources and which allow the necessary margin of flexibility to adapt to the new situation.

Secondly, and for the medium and long-term horizon, there seem to be only positive prospects for exploitation areas that reach an appropriate level of profitability in an environment that will be characterized by increasing competitiveness and open markets. The question to be solved at this time is to what extent irrigation can contribute to achieving this objective and in which territories.

Exploitation areas' private profitability is generally associated with the extent to which water costs are transferred to such exploitation. Their partial transfer favours business results, but tends to reduce efficiency in the use of water resources. Only a combined assessment of these circumstances, where the environmental effects of the alternatives must necessarily be included to be integrated , may lead to an appropriate solution.

Thirdly, an expansion of continental crops is improbable, both arable and industrial, due to the limitations of surface areas or productions eligible for aid, and to the foreseeable downward trend in agricultural prices, worsened by the liberalization of markets arising from the GATT agreements. It is even possible that surpluses of European countries with greater productivity substitutes a part of the national production. As a result, it is likely, within the margin of error that always accompanies any prognosis, that the regressive tendency already detected will continue in a large part of irrigated inland Spain, due to its low profitability, despite the protection mechanisms put forward by the new CAP for continental production, and the relative abundance of available water resources in these areas.

Product	Limitation	Affected crops
Milk	5,566,950 tons	Fodder and cereals
Cows	1,460,167 breeding cows	Fodder
Goats and sheep	19,650,311 heads	Pasture and fodder
Calves	603,674 heads	Feed
Pigs, fowl and eggs	--	Feed

Table 82. Limitations on livestock farming.

Also, horticultural production, concentred basically on the Mediterranean coast, south Atlantic coast and some inland areas, such as the Ebro valley, are those that seem to have a better prognosis, given their high productivity and profitability reached in these production orientations at present. This fact is a reflection of Spain's comparative advantages over European agriculture. And this is true in spite of their low protection level, of the threat originating from agreements with third-party countries, and of the considerable restriction their development suffers due to the depletion of water availability in these areas.

This statement is backed by these production areas' positive behaviour in the composition of agricultural exports. In this export, which has passed from 23% to 43% of final agricultural production (FAP) in the period 1983-93, we could highlight the existing level of concentration, since the chapters of fruit and vegetables and their derivatives amounted to 50% in 1993, a result similar to the one obtained in 1986, the first year of EEC membership.

Since we joined the EEC, horticultural exports as a whole have grown constantly, but at a falling rate up to the year 1991. In 1992 (first devaluation of the peseta) it increased sharply again, and in 1993 (second devaluation and full integration in the CAP), there was a major increase, which consolidated the following year.

We should underline the considerable spatial concentration of horticultural exports in the Mediterranean area. The provinces of Castellón, Valencia, Alicante, Murcia and Almería amount to 78% in quantity and 72% in value of this export. Valencia and Castellón represent over 50% of fruit export, both in value and in quantity, mainly to citrus fruits, while Almería and Murcia accumulate approximately the same figure in vegetable exports.

It is foreseeable that Spanish horticultural exports will continue to grow in the future, but to drop in rate as the expansive effects arising from full integration in the CAP and from the last monetary devaluations are diluted over time. In addition, there will be greater international competition arising from the agreements of the Uruguay Round of GATT and from possible free exchange agreements by the EU with third-party countries.

This data, together with the maintenance, during this period, of the foreign agriculture sector's relative participation in total foreign trade (around 17% for exports) and of its cover rate (around 100%), although with variations in recent years, offer the conclusion that clear production specialization is taking place in Spanish agriculture, associated with its comparative advantages, in favour of horticultural crops and in detriment to continental- type products.

In any event, it should be recognized that the positive forecast for horticultural products does not imply major expansion possibilities for irrigated surface areas in the Mediterranean, due to the reasons described, and their high yield per hectare. Conversely, we could defend the appropiacy of consolidating and guaranteeing water resources in territories that, even with water deficit, offer the best production results, especially in the foreign markets.

Finally, this will constitute the future framework where Spanish agriculture will have to develop, in the scope of a Community Agricultural Policy on which the World Trade Organization will pressure to achieve the liberalisation of agricultural production. Consequently, our irrigation agriculture will be oriented basically towards competitiveness in future markets, both in price and in quality. This recommends assigning the country's financial and water resources, mainly and preferentially, to guaranteeing supply, consolidating and improving existing irrigation and, where relevant, creating others whose social, economic and environmental purpose is clearly recognised.

3.3.5.5.2. Water supply

In some existing irrigated land, problems arise with water supply, so they do not always have the necessary quantity and to satisfy demand for the crops growing in the area.

These situations may be due to low guarantee in supply, to its lack of adaptation to the real needs of irrigation, to problems of fairness in its distribution, or to low efficiency in irrigation.

Guarantee problems, arising from the repeatedly-mentioned irregularity in cumulative flow, have appeared particularly overwhelmingly in recent years. Despite the existing regulation infrastructure, the long duration of some sequences of dry years causes, with some frequency, shortages in water supply for irrigation. In the first years of this decade, these shortages had an significant effect on Spanish irrigation, with an appreciable reduction in supply quantities, and it was even impossible to irrigate in large areas.

Apart from guarantee problems, there is occasionally a lack of adaptation in delivering of the required quantities. This may be due to incorrect estimate of the irrigation needs, with the consequent inadequacy of the supply at moments of maximum necessity for plants. On other occasions, for commercial reasons, new crops are introduced with greater water requirements than the alternatives foreseen in the project, so in these situations supply may also be insufficient. In other cases, the reduction of labour schedules in the field, with the subsequent reduction in operation time, makes the networks, if they have been designed for a continuous 24-hour supply, unable to transport the flow necessary to supply the required quantities.

Problems of fairness can also arise in the allocation of water throughout the network. The natural trend of headwater irrigators to take advantage of their situation by taking more water than corresponds to them, breaching the programmed delivery shifts, or by means of unlawful handling in the irrigation channels, can lead to the system's lower reaches not having enough water .

Another supply-related problem refers to irrigation efficiency, closely associated with the conservation of water resources. In the case of irrigation, efficiency not only refers to process of transporting and distributing water, where significant losses can take place due to filtration and discharge, but to the process of actually applying it to crops, where an excess of water, apart from increasing losses, can give rise to salinisation problems (Krinner et al., 1994).

Losses in transportation and distribution depend largely of the state and characteristics of the infrastructures. Of the more than 100,000 km of irrigation channels that make up the distribution network at present, a large part is earthen channels (unlined). Approximately 30% of the network is over 100 years old, and a large part of the rest is more than 20 years old. An considerable part of the network was built at a time when good construction materials were expensive and scarce, creating the current situation of deterioration, despite the effort put into its conservation and maintenance. This deterioration, together with the networks' ageing, is one of the causes of water losses in the channels and ditches, which in turn leads to smaller available volumes for the crops, although these resources may be, generally speaking, used downstream. This all highlights the need to refurbish and modernise the networks in certain areas of Spain's irrigated lands, and which should be considered a basic, priority objective of irrigation policy in our country.

As regards the application of water, only 41% of existing irrigation, basically those using groundwater, use modern pressure application methods, such as irrigation by centre-pivot and localised micro-irrigation.

The traditionally most-widespread irrigation method (59% of occupied surface area) is by gravity, known as drop irrigation, with distribution by shifts. This irrigation is usually fed by a network of open-air channels and ditches designed to attend crop demand at moments of maximum need, involving continuous, 24-hour operation. As mentioned above, the reduction of labour schedules in the field has led to such distribution networks being insufficient to transport necessary flow during the day. If there is a lack of structures for appropriate sectioning or intermediate regulation pools, significant losses can take place in the backwaters of the channels during the night, with the consequent loss in the network's efficiency.

Drop irrigation can generate excessive percolation, leading to the leaching of pollutants and the washing of salts and nutrients. In some areas and crops without supply problems, or with appropriate drainage systems and downstream re-use, it may be an appropriate method but, in general, inappropriate management and insufficient land systematisation give rise to excess consumption.

The need to achieve pressure at the nozzle in sprinkler irrigation and the fact that it is a method associated with groundwater irrigation or at elevations from canals or natural channels that require pressure, makes the global efficiency of the system high, except in cases of network deterioration.

Drop irrigation is a recently-implemented method, associated with resource shortage. Its excellent adaptation to the development and framework of crops, allows for very precise water dosage. Problems with drop irrigation are related to soil salinisation.

In addition to the problems mentioned, we could mention those arising from the excessive exploitation of some aquifers, which has given rise to some irrigable areas being unsustainable with their own resources. With respect to this question, we should highlight significant role played by users' associations in one same hydrogeological unit or one same aquifer, and the expediency of setting up Exploitation Plans in this type of situation.

3.3.5.5.3. Environmental effects

The need to achieve agricultural production at affordable prices for direct consumers has guided agriculture towards an intensive exploitation regime that tends to use, in increasingly greater quantities, fertilizers and phytosanitary products, as seen above, when analysing the historic evolution of irrigation.

The inappropriate use of chemical products, together with inadequate agricultural practices and the occasionally excessive supply of water for irrigation, represents a pollution hazard, not only for the surface channels that collect runoff, but for the aquifers where, dissolved in the percolation water, harmful compounds, such as nitrates, can arrive diffusely, and are difficult to eliminate.

As we saw when studying the situation of water resources, a considerable fraction of total pumped water comes from over-exploited aquifers, and consequently cannot be maintained indefinitely. The total surface area served with this water is a significant fraction of total irrigation with groundwater, and is located in areas with over-exploitation, noted there.

The practice of irrigation, as we have seen, is not harmless from an environmental point of view, although not all its effects are negative, and they are also environmentally positive potential effects, such as:

- The intensive production in irrigated areas will allow areas currently devoted to agriculture to be liberated, and these may be dedicated to desirable environmental objectives: reforestation, extensive meadows.
- Favorable energy balance per unit generated in the irrigated area, which is of considerable interest considering the current situation as regards CO2 accumulation.
- Improvement of the natural environment in certain plateau areas with significant seasonal drought. Irrigation in those areas is a source of life for hunted species.
- The possibility to recreate, thanks to water availability, wetlands, pools, woods and, in short, elements of biological and landscape interest associated with irrigation. Examples of this could be the Canal de Castilla or the San José Reservoir, genuine biological treasures of the plateau steppe.

The balance between negative and positive effects cannot be globally formulated, and requires specific consideration for each concrete case.

3.3.5.5.4. Other problems

Apart from the problems described, there exist others, of various types, of less global importance or more localised, such as deficiencies in the drainage and highway networks, problems of salinisation in some lands, or those related with the production or commercialisation systems.

An interesting issue is posed by the country's unfavourable demographic evolution, and its possible impact on irrigated agriculture.

Some recent studies (Martín Mendiluce [1996a], pp. 5-16) have shown a significant influence of this population factor, which could come to represent one of the greatest limiting conditions for the development of new irrigation, and they have therefore suggested total maximum growth figures of around 250-300,000 ha. for the next 20 years.

The only action to offset these effects would be to adopt immigration policies that enable both the possible growth of surface area, and even the conservation and improvement of the surface areas already transformed.

3.3.5.6. Livestock uses

As mentioned above, water demand for livestock is of very little quantitative importance compared with the agricultural total. According to the last livestock census, and in accordance with the calculations based on commonly-accepted figures of gross consumption by head and by livestock type (bovine, ovine, caprine, porcine, equine and avain), this demand can be calculated, for all Spain, at about 350 hm^3/year. Table 83 shows their estimated distribution by Autonomous Community.

The use, in most cases, of springs and of other dispersed supply sources, is the main cause of problems in dry seasons, although, in recent years a network of livestock water supply points has begun to be set up, and which should be developed and completed.

As regards the environmental effects of livestock uses, the uncontrolled implementation of intensive livestock exploitation indoors, in fodder areas or in strategic sites within our geography, may be another important source of surface and groundwater pollution, due to the high content of slurry and silage at specific points.

3.3.5.7. The National Irrigation Plan

3.3.5.7.1. Background

In an attempt to rationalize irrigation's development in Spain, and to have a global reference framework for this fundamental issue, the Plenary Session of Parliament, in their session of March 22nd, 1994, agreed to urge the Government *to forward to the Parliament, together with the National Hydrological Plan, an Agricultural Irrigation Plan which accurately considers the surface area of new irrigated land, the surface area of current irrigated land to be improved, water consumption and saving, the crops to be established in accordance with the reform of the CAP and the GATT agreement, the corresponding profitability studies and their possible alternatives, as well as the areas to be transformed into irrigated land for social reasons.*

After a period of study and analysis, and in compliance with this instruction, the Government approved, on February 6th, 1996, a National Irrigation Plan Horizon 2005, currently in effect, and which is being reviewed by the MAPA.

It is evident that, as indicated above, any modern irrigation policy requires, very significantly, consideration of community agricultural policy, binding for all countries of the European Union. This policy, together with liberalising pressure from the World Trade Organization, forced the

Autonomous Community	Livestock demand (hm^3/year)
Andalusia	39
Aragon	28
Asturias	16
Balearic Islands	2
Canarias	1
Cantabria	12
Castile-León	64
Castile-La Mancha	19
Catalonia	50
Extremadura	27
Galicia	38
Madrid	2
Murcia	8
Navarre	7
La Rioja	3
Valencia Community	8
Basque Country	8
Various others, 3%	10
Total	**342**

Table 83. Livestock demand by Autonomous Community.

action programmes of the National Irrigation Plan (NIP) to take into account the new frameworks defined by these policies, without this meaning, in any way, neglecting the strategic value of our agriculture to be able to ensure, at any time, a minimum level of self-supply, to guarantee the associated agro-transforming industry, and to maintain a rural environment that is the basis of it all.

The Plan should basically consider our irrigation's competitiveness, bearing in mind the possibilities offered by the decrease (abandonment) of equivalent surface areas of dry crop land or marginal irrigated land, so that national production (or surface areas) are in line with the quotas laid down by the EU, or can be placed on international markets, in turn taking into account the opportunity to create irrigable areas due to social interest, territorial regulation, rural development, etc.

3.3.5.7.2. Objectives of the NIP

Obviously, the basic objective of the NIP is to comply with the points laid down in the above-mentioned parliamentary agreement urging its implementation. Also, the NIP aims to improve the farmers' standard of living, to maintain the population in the rural environment, to consolidate the agricultural system, to improve the environment, to prevent desertification, to rationalise and optimize water consumption for irrigation and provide water planning with the requisite information and criteria from the specific and sectoral point of view of agriculture.

3.3.5.7.3. Characterization of existing irrigation

Of the existing characterisation and typification studies of irrigation prepared by the MAPA for the NIP, it may be deduced that the perimeter surface area mapped (basically equivalent to the gross enclosures of the Basin Plans) is 4.7 Mha; the total irrigable surface area in Spain, understanding this to mean that which, equipped with some irrigation infrastructure, has been irrigated at some time, is about 3.76 Mha, and the surface area really irrigated in a normal campaign (which would be the net or significant area for water planning purposes) is, on average, about 3.34 Mha.

Contrasting these figures with those obtained in the basin management plans approved, it may be seen that the overall difference is very small (3,340 Mha compared with 3,437 Mha, that is, around 3% discrepancy), confirming the validity and good general agreement of the estimates made. Some basins, however, show significant differences, which may be due to methodological disparities, different assessment periods, or different criteria as to whether or not to consider some areas as irrigated.

From the point of view of demand, the results obtained also basically coincide (24,094 hm^3/year according to the basin plans, compared with 23,552 hm^3/year according to the studies of the NIP).

Similar agreement is obtained with unitary supply quantities (7,010 m^3/ha/year in the basin plans compared with 7,042 in the NIP). Figures 245 and 246 summarise the comparative results on the scale of planning areas.

Examining these figures illustrates, notwithstanding some singularities, good general agreement of both evaluations, with figures lying well within the margin of errors and uncertainties inherent to this type of study.

Even in many cases of greater divergence, such differences could be irrelevant from the point of view of water planning analyses and study. Nevertheless, if it is estimated that this is

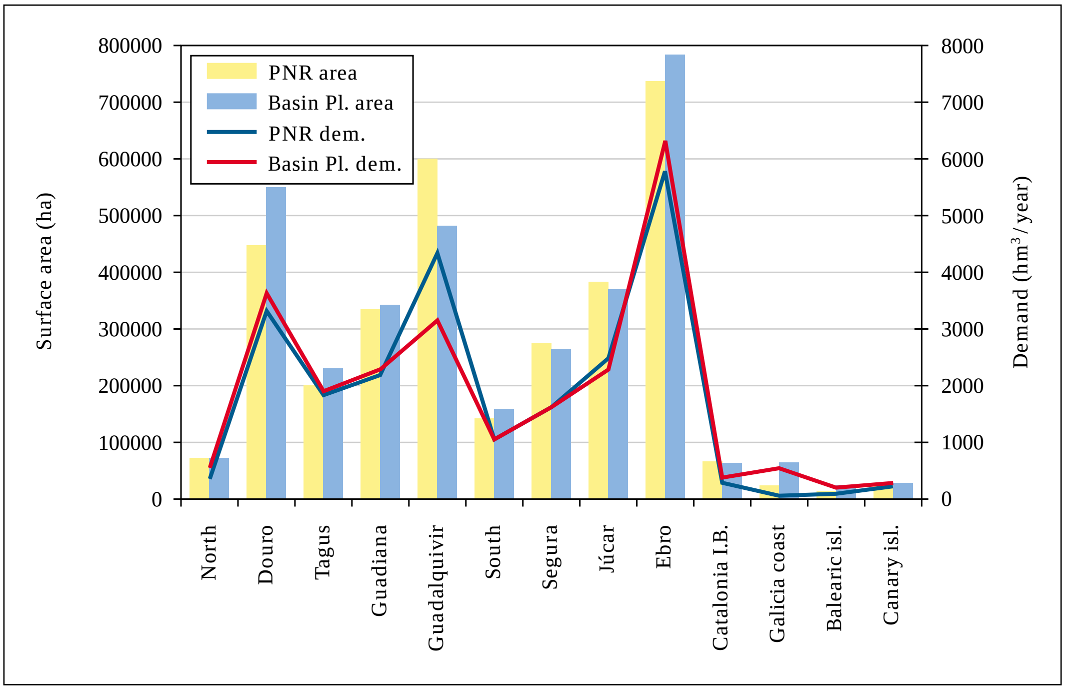


Figure 245. Irrigation surface areas and demand according to the basin plans, and typification studies by the NIP, by planning area.

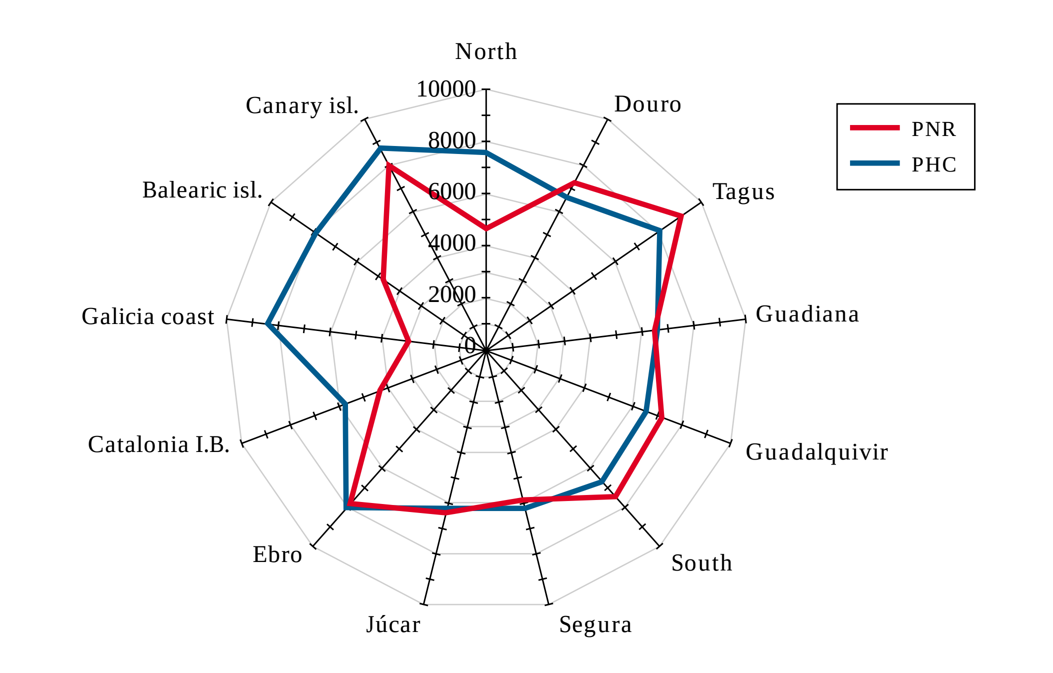


Figure 246. Average water duty (m^3/ha/year).

not so in some specific case, the regulatory procedures in force provide for such a situation and allow for its resolution.

In fact, once the basin management plans have been approved, and their monitoring and review process consequently implemented , this regulated process is the appropriate, competent, technical-administrative mechanism for, as is the case with all other concurrent sectoral aspects in water management, monitoring and analysing data that becomes successively available, and subsequently, where relevant, reviewing and up-dating the information within the organisations responsible for water planning.

In the cases of Galicia Coast and Balearic Islands, both intra-community areas and showing the greatest differences in relative terms, it would be required, where relevant, to analyse and unify the information with the competent autonomous administration, since their corresponding management plans have not yet been approved and, consequently, no recourse is had to the review mechanism.

3.3.5.7.4. Action programmes

The National Irrigation Plan considers a series of action programs that mainly aim to comply with the above-mentioned agreement by the Plenary Meeting Parliament on March 22nd, 1994. As a consequence, this is being carried out as described below.

3.3.5.7.4.1. New irrigated surface areas

This section considers irrigated areas in execution, that is, those with investment of some size, already made and pending conclusion, and new surface irrigated areas, which comprise areas to be transformed for the purposes of social interest and by private initiative.

- **Irrigation in execution (termination)**

This comprises those areas in transformation where public investment of some size has already been made in works (not in studies), regardless of their administrative situation and whether the initiative is by the Autonomous Communities or by the General State Administration.

- **Areas to be transformed into irrigated land for social reasons**

An important aspect of the Plan is to determine those areas whose transformation into irrigated land has a clear social interest, by maintaining, or raising, the income of certain rural sectors so as to ensure the permanency of populations in their traditional environment.

Provisions have been made to transform a total of 106,835 ha for this concept, on the horizon 2008.

- **Private initiative irrigation**

The NIP stipulates that private initiative irrigation that conforms to their forecasts may be eligible for the subsidy established for actions to consolidate and improve irrigation.

It has been considered that the transformation rate of these areas may be about 4,000 ha/year (which means a total of 40,000 ha for the horizon 2008), of which it is estimated that 3,000 will be eligible for benefit and aid.

- **Other areas studied**

The NIP has made an exhaustive summary of all areas irrigated by public or private initiative which in the course of recent years have been considered as potentially irrigable, both by the Autonomous Communities and by the MAPA, whether included or not in the basin management plans. The total surface of these areas amounts to approximately 1 million hectares.

In each of these areas, technical and socioeconomic feasibility studies have been carried out for their transformation into irrigated land.

The inclusion of an irrigated area as potential irrigated land does not presuppose its transformation into such. The development of this irrigation will be mainly

conditioned by its economic profitability, water availability and financial resources, market demand, environmental repercussions and, particularly, by social interest.

3.3.5.7.4.2. Current irrigated surface area to be improved

Apart from the mentioned new transformations, the NIP provides for action on existing irrigated areas but which require improvement action. Within this chapter we should consider both existing under-supplied irrigated land, and other areas which require modernisation and improvement work because their infrastructures, whether due to facilities' ageing, or their out-dated design, are incompatible with the implementation of modern techniques capable of improving their competitive conditions, and prevent the rational management of water resources.

- **Under-supplied irrigation and its consolidation**

According to the studies carried out by the MAPA in characterising and typifying the existing irrigated areas in Spain, there are around 1,129,320 ha with insufficient water supply water.

The causes of this problem have already been described: losses in the transportation network, out-dated irrigation systems, depletion of resources, over-exploitation of aquifers, abusive use by headwater irrigators, etc.

The re-supply of these irrigated areas or, in other words, their consolidation re-establish their potential productivity, should be one of the NIP programs treated with priority in its actions.

- **Modernisation and improvement of existing irrigation**

As mentioned above, a large part of existing irrigated areas are equipped with completely obsolete infrastructures for irrigation, drainage, communication and commercialisation, which, since they were created many years ago and, even despite the effort to maintain them in an acceptable state of conservation and use, respond to a very antiquated technology, impossible to adapt to the development requirements of modern, competitive agriculture.

The poor state, also due to ageing, of the irrigation network in many areas, is the cause of losses of major volumes of water, which, by reducing the flow that reaches the plots, make them more awkward and expensive to apply and reduce profitability in those exploitations.

Water availability in the different hydrographic basins is very variable, and the profitability of the irrigated area, in each of them, depends on the agricultural products obtained, according to different climates and soils. This suggests that the profitability of investments oriented towards water saving will vary notably between basins and areas within them.

The NIP's characterisation and typification studies estimate that the area affected by these problems amounts to approximately 1,500,000 ha. Two important aspects must be taken into account as regards the modernisation of Spanish irrigation, for what involve with respect to added for our agriculture, in comparative terms with other countries around us.

Firstly, the restructuring of property by means of the corresponding reparcelling actions , whenever these are necessary, with the aim of achieving areas where, despite their new dimension –which in general will continue to be insufficient–, it will be possible to apply modern irrigation techniques, a certain mechanization of equipment, etc.

Secondly, the peculiar Spanish orography, characterized by the few plains and a predominance of abrupt, even mountainous, terrain, which physically prevents the creation of smallholdings of sizes appropriate for mechanisation, whether in irrigation or in tilling or in any another farming work.

This section, therefore, should distinguish two types of action which, although different, they are not independent of each other, and which would be oriented to improving the competitiveness of agrarian exploitation, to increase profitability and, with it, farmers' standard of living, achieving a more rational application of water, thus saving on consumption and releasing volumes for use in increasing guarantee for new transformations, or for other uses.

The activities to be carried out in this irrigation improvement and modernisation programme would affect, mainly, hydraulic-type infrastructures (rationalization of transportation and distribution networks, modification or improvement of irrigation systems and the drainage network), communications infrastructures (highway network), agrarian structures (parcelling), production and commercialisation systems (alternative crops, product consolidation, development of cooperativism, encouragement for the development of product commercialisation and conditioning systems for products, agricultural industries).

This type of action, basically oriented towards improving the current competitiveness of irrigated areas, is a high-priority objective of the NIP, given the growing trend in markets toward liberalisation and freedom in the scope of world trade.

3.3.5.7.4.3. Consumption and saving of water

As may be deduced fro the above, the study of water consumption and the measures to contribute to its saving –modernization of infrastructures and better use of the resource– are implicit in the studies carried out with respect to the improvement and modernisation of existing irrigated areas.

As regards new irrigated areas, this type of action is contemplated from the very moment they are planned, by adopting modern, appropriate technology, and measures for correct use of water in the bylaws of the new Irrigators' Associations.

The above is true notwithstanding other measures to encourage the saving, or to discourage waste, laid down by the Water Act in force and in its draft amendment.

3.3.5.7.4.4. Crops to be established in accordance with the CAP reform and the GATT agreement

Spain, as member of the European Union, is fully associated with the Community Agricultural Policy, whose basic principles have been described above. This CAP, with its advantages and limitations, probably includes the greatest conditioning factor for the development of agricultural production in EU member states, which are also subject to liberalising pressure from the World Trade Organisation.

The NIP, as a document that must consider evolution and trends, not only of the CAP, but also of the WTO, devotes a large part to analysing the situation of markets, both national and European and international, in order to be able to profile the most appropriate actions for Spanish agriculture.

As mentioned above, once the limits of subsidised production have been reached, there may be a risk of incurring penalties –that they would be passed on to the farmers themselves– for surpassing those limits. For example, areas devoted to arable crops (cereals, oleaginous and proteaginous) that reach the highest percentage, 40%, of the total irrigated area, are laid down in the CAP reform of 1992 taking as a reference the area cultivated in 1989, 1990 and 1991, and now, having reached it, there exists considerable pressure to enlarge it, with the risk mentioned.

3.3.5.7.4.5. Profitability studies and possible alternatives

The NIP would have no practical value if it omitted a chapter as important as this. The orientation of Spanish irrigated agriculture should be towards factors that are capable of achieving more competitive production (in prices or in quality), so that they can reach stable market benchmarks compared with other countries, in an increasingly internationalised commercial context.

In this respect, the NIP's profitability studies are a basic tool for comparing the different alternatives considered, offering a selection of the most interesting actions, as well as distinguishing competitive, stable irrigated areas from others foreseen as difficult to continue.

3.3.5.7.4.6. Areas to transform into irrigated land for social reasons

As mentioned above, an important aspect of the Plan is establishing areas whose transformation into irrigated land has a clear social interest by maintaining, or raising, the income of certain rural sectors to ensure the permanency of populations in their traditional environment.

It is a question of analysing, among other things, situations where, generally due to a drop in the profitability dry crop land, populations associated with a certain environment are forced to emigrate to the cities in search of some way of life that allows them to make a decent living. In such cases, implementing small transformations, no greater than 2,500 ha, could be enough to impede the exodus and maintain such families in the countryside. This consequently prevents the possible environmental deterioration that their abandonment would cause, as well as the massive demographic affluence towards urban zones, frequently unable to offer appropriate solutions –always costly– to these emigrations.

3.3.5.7.5. Training for irrigators and awareness of irrigation techniques

Considering the major economic effort that the NIP's actions mean for the country, it is essential to attempt to gain maximum yield from the investments made, by means of the best use and operation of the facilities, cultivation equipment and techniques and water application, which, in turn, will have a favourable effect on the farmers' standard of living.

This involves the need to appropriately train irrigators by establishing, on one hand, professional training courses and, on the other, agencies or consultancy services and periodical information on irrigation parameters, as an indispensable complement if the aim is to achieve the technical level, in the field, required for competitiveness - which, in the final analysis, will be what determines the success or failure of our irrigated agriculture. Such professional training courses for irrigators(many of them, already at a very high level) should be supplemented with the collaboration of existent organisations, both from the Central Administration Central and from the autonomous authorities, with permanent actions among farmers to create awareness of more appropriate technologies as regards irrigation, to obtain the desirable effectiveness of the actions included in the NIP.

As regards consultancy services for irrigators, there exist in Spain very interesting antecedents in the old agronomic services of the Hydrographic Confederations, and, in more recent times, of those set up by some Autonomous Communities. These services' operation may act as a model for implementing a network, on a national scale, of centres providing users with information, in real time, oriented towards improving water application, and optimising its use.

3.3.6. Energy uses

3.3.6.1. Introduction. Historical evolution

The importance of hydroelectricity within the energy sector and, particularly, within the electricity sector, as well as its contribution to the national economy, and some of the most relevant territorial aspects in hydroelectric production, were already dealt with in the section on the socio-economic and territorial framework. For this reason, this section is oriented to complementing the characterization of the most significant aspects relating to this water use.

The first characteristic of water use for hydroelectric purposes that we should highlight is its non-consumptive nature, although this consideration should be qualified by two reasons. In the first place, we should note that, although hydroelectric use does not consume in a strict sense, since it involves no evaporation at all, returning to the hydrographic network all the water it uses, nor does it degrade the quality, what is true is that it exclusively occupies a reach of the river channel, and in some cases relocates the natural resource in order to better take advantage of topographical differences. In any case, it involves an environmental effect of varying intensity and, in the sense described, a certain consumption of the assets that make up the public water domain's environmental value.

Secondly, it is expedient to note that, although in general this use type is compatible with the rest of water demand, it occasionally imposes restrictions on the exploitation of water resources available for other uses (it can totally prevent them when uses refer to the same level) and bears an impacts on the operation of exploitation systems, affecting balances, losses, guarantees, etc. As a result, it involves a substantial opportunity cost.

The water demand for electric energy production is also characterized as being a function derived from demand for an asset (electricity) whose production is simultaneously implemented in generation units that make use of different energy sources and, finally, is offered to consumer as a unique product, after being carried through the same transport and distribution networks, regardless of its origin.

At this point, it is worth considering the functions that hydroelectricity has within the energy production system, since, given that electric power cannot be stored, certain characteristics of hydroelectricity lead to its being maintained a basic component in this production system, despite its progressive loss of participation in the total. We should also note the great sensitivity of production to rainfall conditions, giving rise to significant variability from some years to others, and making it unable to guarantee, by itself, major demand, but to act as a component in guarantee and service stability. In short, the functions that hydroelectric energy carries out could be summed up as follows:

- To provide great flexibility to energy generation, giving a high response capacity to the system, to cover a demand characterized by considerable variations in short time intervals. Hydroelectric energy allows this adaptation to take place with the required quality conditions (voltage stability and frequency) and at low operation costs.
- To as a warning and back-up system, in the case of failure in a thermal generating set, to be connected to the grid at maximum power, from a very low value which is permanently activated. This function, and the above one, are essential in a service whose guarantee of continuity is fundamental in contemporary society.
- To enable surplus energy from thermal generating sets to be used at off-peak hours, by pumping water from lower to upper reservoirs, so that this energy, instead of being lost, can be used at peak hours.
- To provide a certain defence capacity against floods, through deposits and hydroelectric dam management.
- To constitute a source of clean energy, since its generation does not create waste. In the future, this characteristic will be an increasingly important advantage if, as is foreseeable, the emission of greenhouse gases continues to be a growing problem. It is also renewable, which certainly represents another advantage in comparison with sources that involve the depletion of non-renewable resources.

The use of water as an energy resource played an essential role in the industrialization of the 19th century, although long before, hydraulic energy had been traditionally used in waterwheels and mills, a use that was carried out on the very bank of the river, for very limited functions.

The appearance of electricity at an industrial level brought the construction of the first hydroelectric power stations at the end of last century. The location of the hydroelectric power stations built at that time was conditioned by the existence of a waterfall near a centre of consumption, due to the technical limitations for transporting electricity over much distance. In other cases, it was the small industry that was established next to the hydroelectric station. In some places, such as Catalonia, these circumstances were decisive factors in its territorial and socio-economic organisation (Maluquer de Motes [1990]; Vilar [1990]).

The appearance of alternating current, at the beginning of century, opened up the possibility to transport electricity over great distances, and centres producing greater power started to be built.

In 1901, the hydroelectric power installed in Spain was already 37,000 kW and thermoelectric power was 57,000 kW.

Electric power production passed from 240 GWh in 1905 to 2,609 GWh in 1930, and 3,617 GWh in 1940. From the beginning of the century until the year 1922, annual consumption grew to at a rate of 8%. In the period 1922-29 this growth became 10% and dropped to 5% in the period 1930-36.

In the forties, there was a rapid growth in consumption, starting from an initial situation where a large number of generating sets were damaged by the effects of the Civil War, and the rest of the industrialized countries were at war. This situation was worsened due to drought in the years 1944 and 1945.

Hydroelectric development began its real boom in the fifties, reaching its maximum growth rate in the decade of the sixties, subsequently, and progressively, falling. This was more due to the economic regime applied to hydroelectric production than to difficulties in developing these energy resources. Between the years 1950 and 1970, a large part of the current Spanish hydroelectric equipment was implemented, since about 9,000 MW was installed, that is, almost 55% of current hydroelectric generation.

From 1971 to the present time, the construction of pure pumped storage stations has been carried out, together with large combined pumped-storage stations, in coordination with the development of thermal generating equipment, and various extensions of existing stations.

The function of hydroelectricity in covering the electric demand has varied substantially over time. Initially, when hydroelectric power stations worked in a non-interconnected network, they supplied isolated towns, having to supply power as it was demanded, and it was common to stop the machines outside the hours when lighting was used. Then, power capacity was enough to cover expected demand and flow was sufficient for the machines to provide maximum power.

When demand grew, it was necessary to increase the power capacity in hydroelectric power stations that supplied local markets, having to store the water in small reservoirs formed by waterwheels to divert the water. This way, the water was concentrated for use during the hours of greatest consumption.

Due to the seasonal irregularity of flow in most of our rivers, with the flow guaranteed at low water, only a small part of the hydroelectric energy resources could be exploited, so to use greater flow and guarantee supply, it was necessary to install thermal generating sets that operated at times of low water, supplementing the lack of hydroelectric energy, and to build regulating reservoirs that supplied enough flow to guarantee power capacity at times of greatest demand. This frequently involved an economic, technical and human effort (Capa [1999]; Martín Gaite [1983]).

The lack of local hydroelectric stations capable of covering the growing electric power demand, the need to increase supply security and the economy of scale, led to local markets successively connecting to the national grid, preferentially supplied until 20 years ago by hydroelectric energy, and later supplemented by production from thermal power stations at hydrologically unfavourable times.

When hydroelectric production was predominant, its power stations had to follow the load curve according to demand with regulation power stations reaching uses of around 5,000 hours/year. In the permanent flow hydroelectric power stations and, at times of high water, also in those regulated by reservoirs, there were considerable energy surpluses outside the hours of greatest demand, so electric power use in industries that could work intermittently was encouraged.

As consequence of the technological advances in thermal power stations, of the economy of scale obtained by installing large generating sets, of the application of nuclear energy to electric power supply and because the most favourable hydroelectric locations had already been occupied, the participation of thermal energy in the electric power supply increased, and surpassed, hydroelectric production.

At this stage, hydroelectric power stations associated with reservoirs whose exploitation was not conditioned by other uses, were over-supplied with power, so as to concentrate their production in the hours of greatest demand, allowing the thermal power stations to operate with the greatest continuity and use possible. Reversible power stations were also installed, which could accumulate water by means of pumping using surplus energy that cannot be placed directly on the market in off-peak hours, concentrating energy production with the water accumulated at peak hours.

The evolution described is shown in the graphs in figures 247 and 248, where UNESA data is presented (1998a) on the evolution of power capacities in Spain, on 31st December of every year, and of annual electric power production, according to origin: conventional thermal, hydraulic or nuclear.

Additionally, figure 249 shows UNESA data (1998a) on the evolution of net total electric power consumption in Spain –logically similar to the evolution of production–, and on international exchanges (with France, Portugal and Andorra) that have taken place. As may be seen, these exchanges began to occur with some regularity by the middle of the 60s, and with a negative balance (more was supplied than was received). At the moment, the balance is alternating, with results of about 3000 GWh a year.

Actions should also be mentioned in the field of hydroelectric power stations smaller than 5 MW, commonly known as "minicentrales". These power stations, which in many cases had been abandoned on account of low or zero profitability in the years previous to the energy crisis, were modernized, automated and provided with remote control, so that in many cases they can compete with other alternative forms of energy.

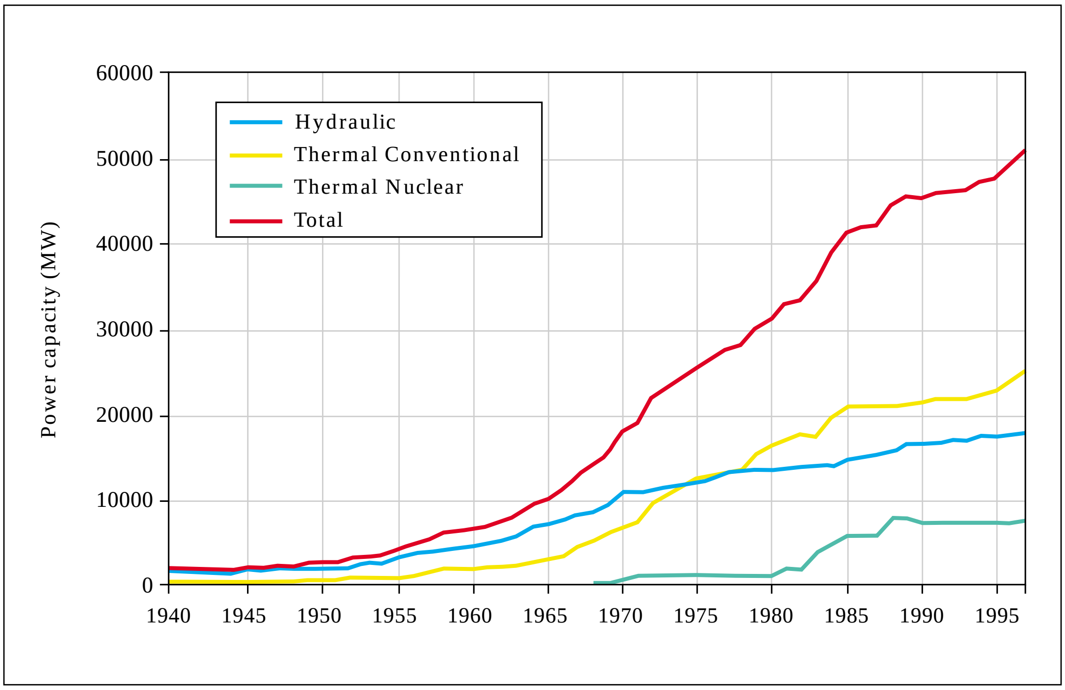


Figure 247. Evolution of power capacity since 1940.

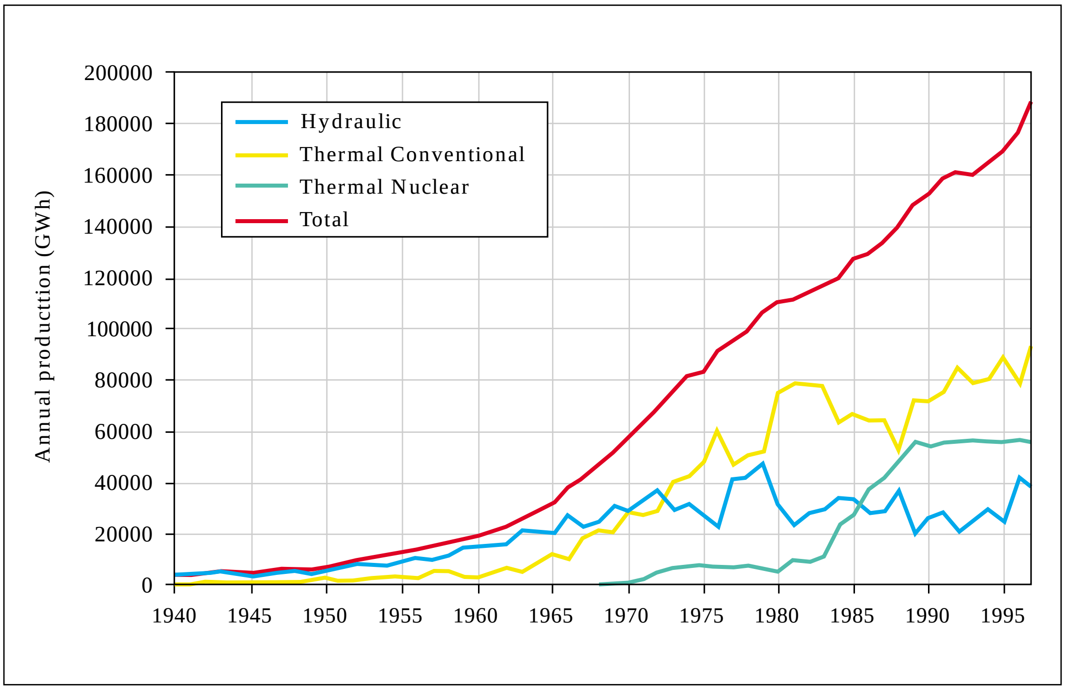


Figure 248. Evolution of electric energy production since 1040.

Under the Energy Conservation Act of 1981, a Small Hydroelectric Power Station Plan was drawn up, the result of which has been the incorporation into hydroelectric power generation of numerous small facilities. These "mini-centrales'" power capacity in 1994 almost amounted to 900 MW. In some cases, they are new power stations, although most of this power comes, as mentioned above, from the restoration of old stations that were out of service.

Furthermore, this Act and its later development, in addition to the various renewable energy plans, the actions by various public organisations, and the prices received by self-producers for the energy supplied to the National Electricity grid, made investment in small power stations attractive for industrial and private companies, causing a significant increase in electricity generation by means of small hydroelectric power stations.

3.3.6.2. Hydroelectric uses

Water demand for hydroelectric use is determined by a variety of factors. On one hand, physical reasons to do with the shortage of as yet unexploited rivers, of sufficient flow or of suitable sites to take advantage of new waterfalls. All this represents a limitation on the long-term growth of this demand

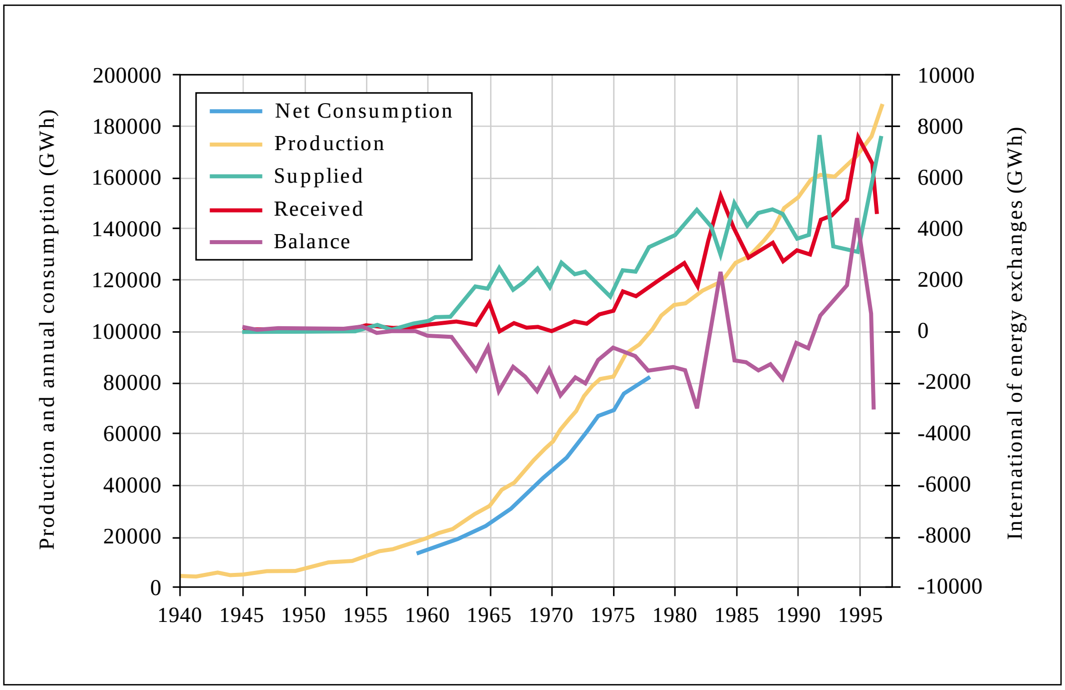


Figure 249. Evolution of production, consumption and international electric power exchanges.

type. On the other hand, reasons of a managerial type. In fact, companies own generation stations of various types (hydraulic and others), a circumstance that makes water demand for hydroelectric use is also conditioned by relative production costs within these companies (the cost structure is characterized by having practically zero variable costs, so unitary costs sharply drop when production increases. At the moment, generation costs fluctuate between 90% of average cost for all energy sources in dry years and 60% in wet years). Finally, we should not neglect central administration policy, in a sector that traditionally has been highly regulated, although currently undergoing a process of liberalisation.

In any case, it is a quantitatively very important use, since it is estimated that the volume diverted in an average year is around 16,000 hm^3. As regards the reservoir capacity required for this use, it can be said to be about 20,000 hm^3. Both figures, compared with the total water used for consumption or with total reservoir volume, show this demand's importance. At the moment, power capacity stands at around 17,000 MW, currently showing rather sluggish growth, after the rapid expansion that the hydroelectric sector underwent in the third quarter of the century. Production, on the other hand, has undergone a slight reduction in average values owing to, on one hand, the long drought during recent years and, on the other, growing water consumption for other uses, particularly irrigation, which has reduced usable hydraulic cumulative flow for electric power production. In the year 1996, which was a wet year, production exceeded 40,000 GWh, with average annual energy produced at around 30,000 GWh, while in a dry year like 1995, it did not reach 25,000 GWh.

As can be seen in the graphs in figure 250, Spanish hydroelectric production is characterised by significant territorial concentration, a consequence of our country's hydrography, orography and topography. Accordingly, the basins of the North, Douro and Ebro amounts to almost 80% of total production by themselves, and with the Tagus come to 90%.

On the other hand, the sector is also quite concentrated in the business field: hydroelectric production of the five biggest Spanish companies covers between 80% and 90% of total production. The case of electricity generation is an example of how the beneficial effects arising from the construction of certain infrastructures can occur in regions a long way from those where the these infrastructures are located, regions which suffer the inconveniences of their installation. From this point of view, it may be said that territorial restrictions generally in force for various water uses are not effective in the case of hydroelectric uses, where the energy product's transfer is normal, although the water remains in the same basin.

The physical limitations referred to above, and the growing costs of possible new infrastructures, are objective reasons to suppose that in coming years there will be a modest growth, in relative terms, of power capacity. The National Energy Plan (NEP) of 1991 estimated, up to the year 2000, an increase of 900 MW in medium-sized and large hydroelectric power stations, and 800 MW in small hydroelectric stations (this represented 20% of estimated total growth). Other, more optimistic estimates consider that the power capacity could even increase up to 7,000 MW in 20 years, if the State encourages this energy type with legal and economic measures.

Estimates of this type were also made in the above-mentioned NEP of 1991 for electric energy production in stations fuelled by petroleum, coal, gas, combined cycle, and nuclear power stations. This responds to the concrete policies proposed by this Plan as criteria to follow as regards managing these fuels. It is expedient to specify, in this respect, that the NEP only aimed to offer guidelines, to highlight the State's forecasts to electric power production companies.

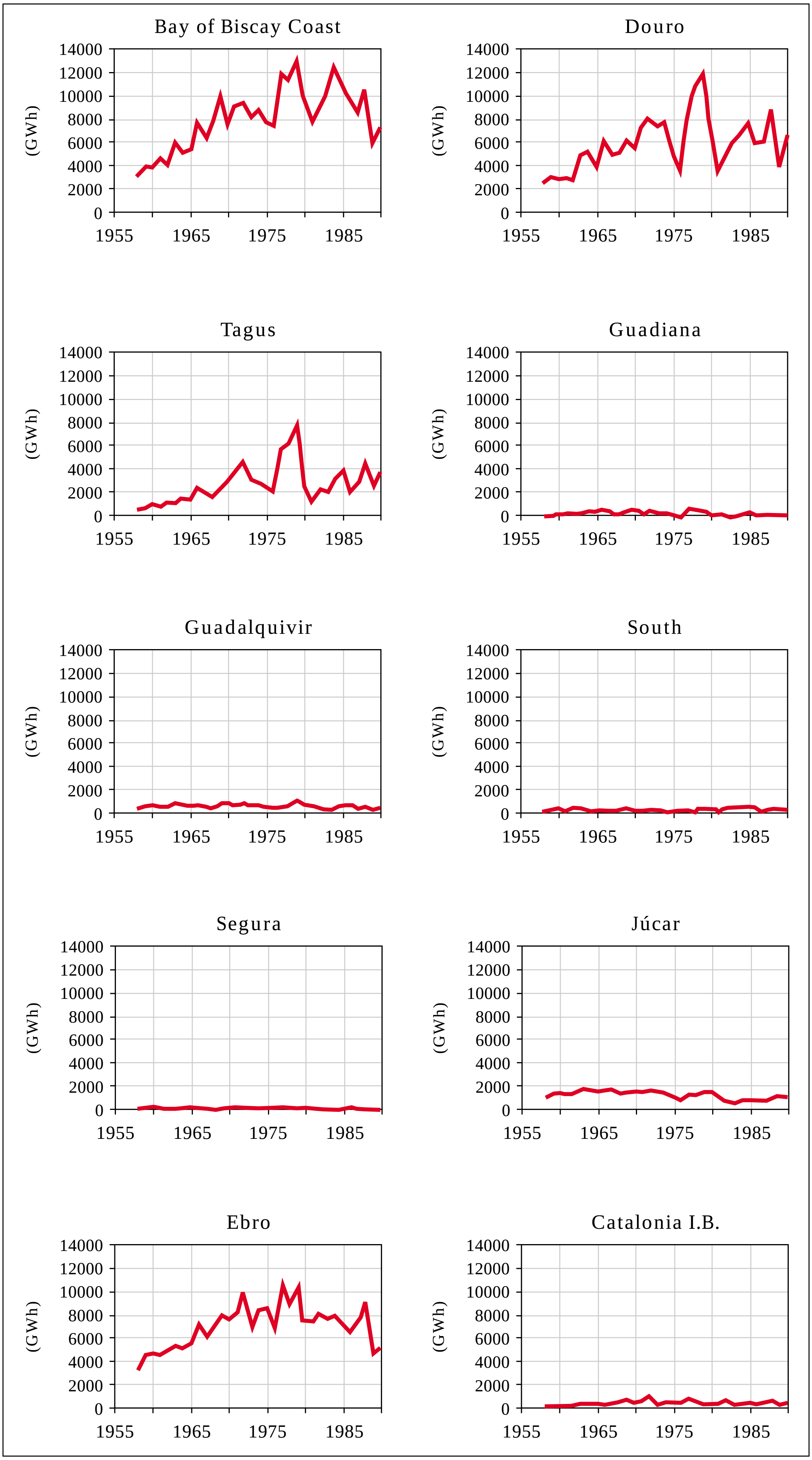


Figure 250. Evolution of the production of electric power of hydraulic origin in different basins.

We should bear in mind, however, that current electric policy is oriented towards reducing state intervention in the sector, considering that electric power generation should be organised under the principle of free competition, so the State recognises private individual's entitlement to freely install power stations to generate energy, and merely acts, through legislation, to achieve the objectives of guaranteeing supply with the requisite quality and at the lowest possible cost, and to protect the environment.

In this situation, the hydroelectric sector's evolution and, therefore, its water demand, will basically depend on its comparative advantages against other energy sources, although evidently stability guarantees in water concessions are necessary so that the companies take an interest in the construction of new facilities. Finally, the defence of the environment subsists as the main argument for the State to encourage certain hydroelectric actions.

3.3.6.3. Thermal production

Apart from hydroelectric uses, water is used for energy purposes in the refrigeration of thermal power stations, whose demand, especially when open circuit, consumes very little, because it returns around 95% of the water it uses at short distance from the point of abstraction. This use type, however, may significantly condition the exploitation of systems, because it demands the availability of large volumes regulated, guaranteed water.

Distribution, by territorial planning area, of the refrigeration demands included in the basin management plans is shown in table 84.

The main demands for open-circuit refrigeration are the nuclear power stations of Ascó (2,270 hm^3/year) and Santa María de Garoña (766 hm^3/year) on the River Ebro, and Almaraz (583 hm^3/year) on the Tagus, as well as the Aceca thermal power station (544 hm^3/year) also on the Tagus.

The refrigeration of electric power stations in an open circuit involves high temperatures that are often incompatible with other uses downstream, or with the requirements of river fauna. As mentioned when commenting on thermal pollution, the average temperature increase on the river reach is limited to 3 °C by the Regulation of the Public Water Domain (more demanding limits exist for fish life), so considering the power that is usually installed in new power stations, the open circuit is limited to rivers with a large basin area and substantial low-water flow, unless seasonal stoppage of the power station is feasible. Water cooling in a closed circuit, although it allows the power station to stand next to rivers with less flow, involves, for power capacities in the current stations, significant water consumption which may significantly alter the overall balance of the system in question.

On the other hand, and from a strictly economic point of view, this is probably one of the uses with greatest profitability per m^3 consumed.

Finally, and in the context of thermal uses of water, we should mention geothermal energy resources, currently used very little, but with interesting possibilities for development in some areas of the country. The upwelling of groundwater at high temperature may allow for tourist uses through the installation of spas, greenhouse heating, and the final use of the water itself in production processes.

3.3.7. Aquaculture

Aquaculture refers to the various, more or less intensive, methods for breeding or fattening fish, crustaceans or molluscs in fresh, brackish or sea water. Several categories can be distinguished, depending on the approach used for clas-

Area	Demand for refrigeration (hm^3/year)
North I	33
North II	40
North III	0
Douro	33
Tagus	1,397
Guadiana I	5
Guadiana II	0
Guadalquivir	0
South	0
Segura	0
Júcar	35
Ebro	3,340
Inland Basins of Catalonia	8
Galicia Coast	24
Total peninsula	4,915
Balearic Islands	0
Canaries	0
Total Spain	**4,915**

Table 84. Demand for refrigeration of electric power stations by planning area.

sification. According to the type of water used, sea farming differs from continental aquaculture in fresh or brackish water.

Spain is a country with major fish-farming resources due to its 5,000 kms of coastline, and to the variety and size of its hydrographic network and its reservoirs. In Spanish rivers, trout have been bred for re-stocking purposes since the end of last century, although the first fattening factories did not appear until 1960. Some years before, in 1940, the first experiences had begun in fattening mussels in the Rías Bajas in Galicia.

In Spain, continental aquaculture constitutes a firmly established activity, with stable production and results in recent years. The main breeding and fattening species are the salmonids (trout), cyprinids (carp) and crustaceans (river crab). Rainbow trout *(psalm gairdneri)* is the majority species, due to its rapid growth and level of domestication, with an annual production for human consumption of 20,000 tons. The rest of the production is divided between crab and other species, such as the common trout, tench, etc. Figure 251 shows the evolution of rainbow trout production since 1980.

Production for human consumption represents approximately 80% of total trout production; the rest is devoted to re-stocking.

Fish factory models are usually concrete ponds with a fishbone or race-way type arrangement, more recently introduced. The second of these, with staggered deposits, has allowed improvements in mechanisation, in turn giving rise to more efficient use of circulating water flow. In both models, the existence of a settling pond is essential, where excrement and harmful substances produced by the aquatic animals are collected.

The water demand for aquaculture is not very significant as far as volume is concerned. In the whole Segura basin, for example, aquaculture represents an annual volume that does not amount to 20 hm^3. The most important fish factory for trout production is in the Ebro basin, on the river Segre, downstream from the Oliana reservoir. In this basin, some 80 inventoried facilities exist, of which 51 continental fish farms are operative and 11 sea farms.

However, the quality and temperature conditions required by continental fish farms are quite demanding, which may represent a conditioning factor for upstream uses.

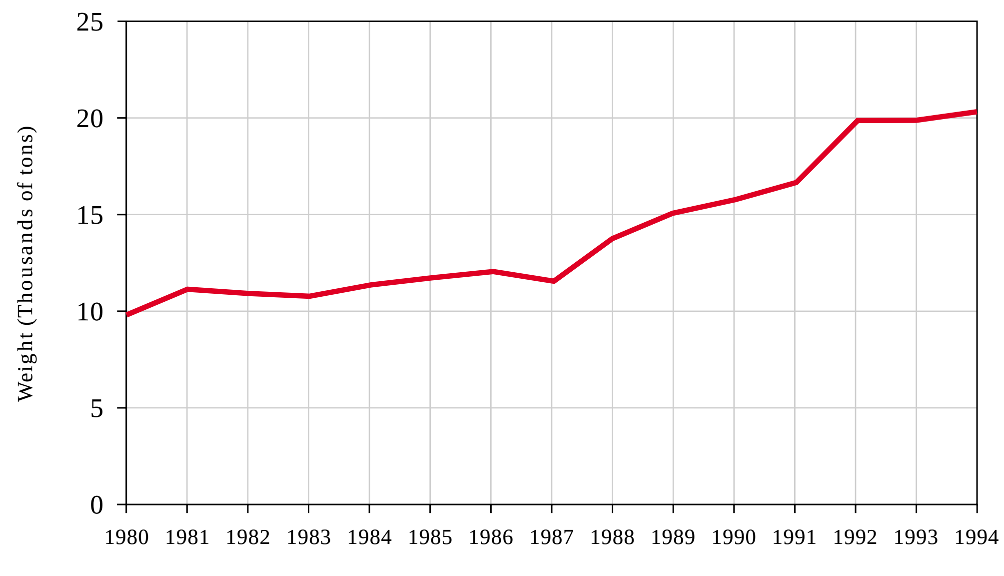
Returns are very high, because it is a very low-consumption use, returning practically the entire diverted volume to the river. Nevertheless, the accumulation of organic waste and the cleaning of the ponds and settling pools may transfer a significant trophic load to the river, requiring discharge to be corrected.

3.3.8. Recreational uses

The concept of recreational water use comprises very varied uses of the water domain, which have the common objective of satisfying the society's leisure and relaxation requirements. Interest in these uses has increased significantly in recent decades, its development presents new problems and opportunities, and its study is the subject of growing attention (see, e.g., Bru Ronda and Santafé Martínez, 1995).

From the point of view of water resource use, we could distinguish three major categories.

In the first place, recreational uses that involve diverting water from the natural environment. These include, for example, irrigating sports fields (golf, soccer, etc.), swim-



Figures 251. Evolution of rainbow trout production intended for human consumption.

ming pools and aquatic parks, sports complexes, artificial snow in ski resorts, watering places for hunting, aquatic sports facilities or recreational areas with artificial bodies of water. They generally represent moderate water consumption, the highest rate of consumption being registered in the irrigation of sport facilities. Sometimes, these recreational uses are difficult to separate from urban use, because the supply often takes place through the urban network. On the other hand, the irrigation of the golf fields is usually considered as included in demand for irrigation.

Secondly, there are all the leisure activities that use the water of reservoirs, rivers and natural places in a non-consumptive way. These include a large variety of aquatic sports on calm water (sailing, windsurfing, rowing, motor boats, water-skiing, etc.) or rough water (canoeing, rafting, etc.), bathing and fishing. They usually require certain levels of water to be maintained in the reservoirs, and flow in the rivers, which may represent a condition for managing the exploitation systems, with the rising repercussion on available resources for other uses. In some cases, certain water consumption can take place as consequence of increased evaporation due to maintaining certain water levels in the reservoirs.

Thirdly, all those leisure activities that are indirectly water-related, using it as a centre of attraction or reference point for associated activities, usually known as scenic use. This group includes, for example, camping, excursions, ornithology, hunting, trekking and all kinds of tourist or recreational activities that are carried out near bodies and courses of water. Frequently, they are related with non-consumptive recreational uses, such as, for example, water sports or bathing. They can condition management of exploitation systems in a similar way to non-consumptive uses by requiring certain reservoir levels or minimum river flow, besides what is necessary, where relevant, for the recovery and protection of the natural environment. They can represent some water consumption at supply points for campsites and excursions.

Recreational river uses can condition the management of exploitation systems in a similar way to environmental flow, because in both cases they aim to maintain a minimum flow in the channel. They mainly differ in their purpose, which is conservation of the environment in one case and in the other public amusement, which can give rise to a system of different priorities. Nevertheless, the two concepts come together if the basis of the recreation is to keep rivers and natural areas ecologically intact.

The correct assessment of demand associated with recreational uses is complicated, due to the diversity of activities involved and to the rising difficulty in obtaining data on public participation in these activities, without appreciable membership of associations of recreational character. Therefore, in many cases, activities related with the enjoyment of nature and outdoor sports are usually not reflected in official statistics.

Also, there is no easily quantifiable relationship between the activities carried out and the quantity of water they require. It seems evident that the growing number of citizens who want to take advantage of the reservoirs and rivers for bathing and recreation will end up demanding greater consideration of their interests. However, the quantitative repercussions of such pressure on water resources requires specific assessment in each particular case.

At the moment, there exist in Spain very few cases where the management of exploitation systems is being conditioned by recreational uses. One of them is on the River Noguera-Pallaresa, where withdrawals for hydroelectric production are carried out in coordination with demand for aquatic sports (rafting). At the moment, about 70,000 descents per person are made annually on this river, with the rising economic effect of tourism on this area.

Other cases of withdrawals for recreational purposes we should mention in this context are, for example, canoeing competitions that take place in the area of Miranda de Ebro, which require from 10 to 20 m^3/s for one day; the descent of the River Aragon from Yesa toSangüesa, coinciding with the fiestas of the town of Sangüesa (15 m^3/s for 4 hours); the descent of the Jalón during the Ateca fiestas, as well as a series of competitions and “water fiestas” on the Rivers Piqueras and Albercos (5 m^3/s for 6 hours), both tributaries of the River Iregua; or the “descent of the Alguazas.”

It is expedient to stress that the quantities of water devoted to these activities are usually relatively moderate, and withdrawals requested by the respective canoeing associations and federations are generally compatible with demand for other uses, and surplus volumes are used for recreational purposes.

The same thing should be stated for the large number of recreational uses on reservoirs and riverbanks, frequently equipped with camping areas, piers and other sporting facilities that usually offer only a leisure opportunity according to water availability.

It may therefore be considered that the recreational use of water in Spain has a relatively marginal character at present, and its demand is covered when the needs of other uses are satisfied. The consideration of recreational needs in the management of exploitation systems is made under the premise that other uses are not prejudiced, although extreme cases can arise where the pressure of the recreational use in fact imposes easement on the other, previously established uses.

Nevertheless, there are relatively common examples oriented towards the social development and environmental adaptation of reservoirs and rivers, although they do not generally involve an allocation of water resources. Frequently, a classification exists for the secondary, recreational use of reservoirs, which regulates its aptitude and the authorization to carry out leisure activities and aquatic sports.

In some countries, the consideration of recreational uses in the planning and administration of the water domain is more common situation, probably due to an older tradition of nature-related leisure activities. In California, for example, it is estimated that nearly 3% of total water demand is due to recreation. The sport of rafting reaches a magnitude in excess of a million people/day per year on the most popular rivers in the State (CDWR, 1998). In natural parks, which often have surface waters (natural or artificial), more than 60 million visitors are registered every year, with growth rates of around 15% a year for most of the eighties. Although this growth seems to have diminished in recent years, the figures indicated give an idea of the magnitude and dynamics of leisure sector in California.

In Spain, nature-related leisure activities, although they are still smaller in volume than in other countries, show spectacular growth in some sectors. For example, according to data from the National Parks Autonomous Organisation, the number of visitors to National Parks, which is currently calculated at about 8.1 million people a year, has been increasing with an average annual growth rate of 11% during the period 1984-96. In recent years the growth has been even bigger, with an average annual rate of 13% during the period 1989-96. It is expedient to bear in mind that most of the visits correspond to National Parks located in the Canary Islands (5.3 million) and that the growth rate has been greater on the islands than on the Peninsula (15% compared with 9%). Even so, It seems clear that the trend of visits to National Parks is upward. Table 85 shows the number of visitors and average annual growth during the period 1989-96.

Similar growth rates are seen in campsites, which have registered –according to INE data (1995a)– an increase both in the number of travellers and in the number of overnight stays, with average annual growth rates of 15% and 12%, respectively, during the period 1975-94. Although most campsites continue to be located in coastal provinces (780 from a total of 1080), the biggest growth rates, both in capacity and in number of establishments, are registered in the inland Peninsula (7% compared with 3% in the coastal provinces in the period 1984-94).

For the purposes of comparison, we should highlight that the hotel sector, being much bigger in volume, has seen a much smaller growth than campsites, of an average annual 2% in the period 1975-94 (INE, 1995a).

Another variable that may help to interpret the evolution of activities related with the recreational use of the water is the number of fishing licenses issued. Figure 252 shows how, during the period comprised between 1965 and 1996, the number of licenses underwent a significant increase, jumping from 190,000 to 862,000 (MAP, 1997), meaning an annual average growth rate of 6%. Despite the drop at the end of the seventies and the beginning of the nineties, it is clear that freshwater fishing has registered an decidedly upward overall evolution over recent decades.

Although all the evolutions described coincide with a general growth of the economy, and of economic welfare in Spain during these years, it may be seen that some of the variables mentioned, such as those on campsites and National Parks, have grown far in excess of the general economy, expressed in terms of Gross Domestic Product (GDP), as may be seen in figure 253.

The data presented indicates that, apart from a general expansion, there seems to have been a certain orientation towards nature-related activities and open spaces. In a society where a growing number of people live in big cities, this trend seems logical, especially bearing in mind improvements in the means of transport and greater mobility of the public, the change in family structures, the increase of free time and a higher budget devoted to leisure. Although, at the present time, it is not possible to quantify the impact that these trends will have on the use of water resources, it is expedient to bear in mind that, in the future, society may demand more consideration for the recreational uses of water.

3.3.9. Environmental requirements

3.3.9.1. Introduction. Prior concepts. Environmental flow and volume

The background in our country, and generally in all countries, on the question of minimum flow that should circulate in rivers, are historically not linked to the preservation of aquatic ecosystems (more general concept associated with

National parks	Number of visitors 1989 (thousands)	Number of visitors 1996 (thousands)	Annual rate 1989-1996 (%)
Picos de Europa/Covadonga	700	1,676	13.3
Ordesa and Monte Perdido	450	625	4.8
Doñana	250	366	5.6
Tablas de Daimiel	102	131	3.6
Cabañeros		11	
Peninsula	1,502	2,809	9.4
Teide (Tenerife)	1,000	3,000	17.0
Timanfaya (Lanzarote)	800	1,575	10.2
Garajonay (Gomera)	125	450	20.1
Caldera de Taburiente (Las Palmas)	100	250	14.0
Cabrera (Balearic Islands)		39	
Islands	2,025	5,314	14.8
Spain	**3,527**	**8,123**	**12.7**

Table 85. Visitors to National parks.

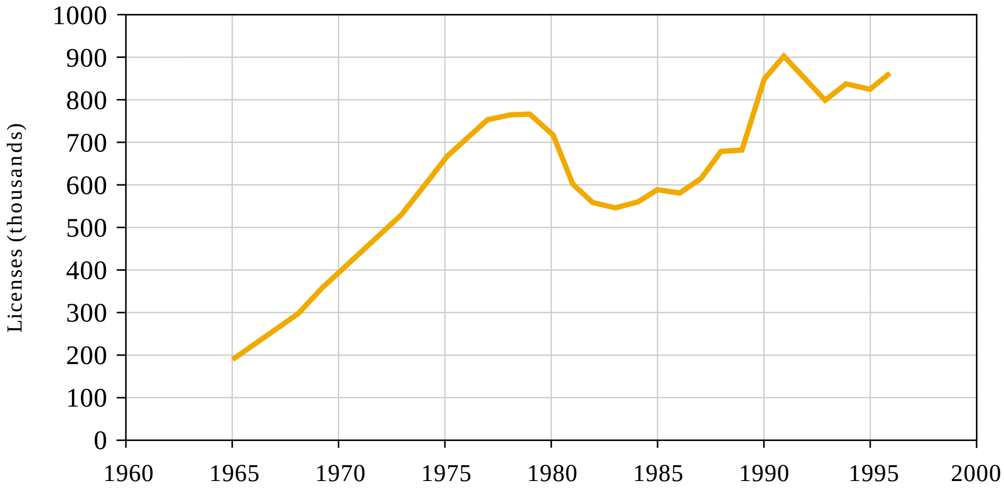


Figure 252. Evolution of the number of fishing licenses.

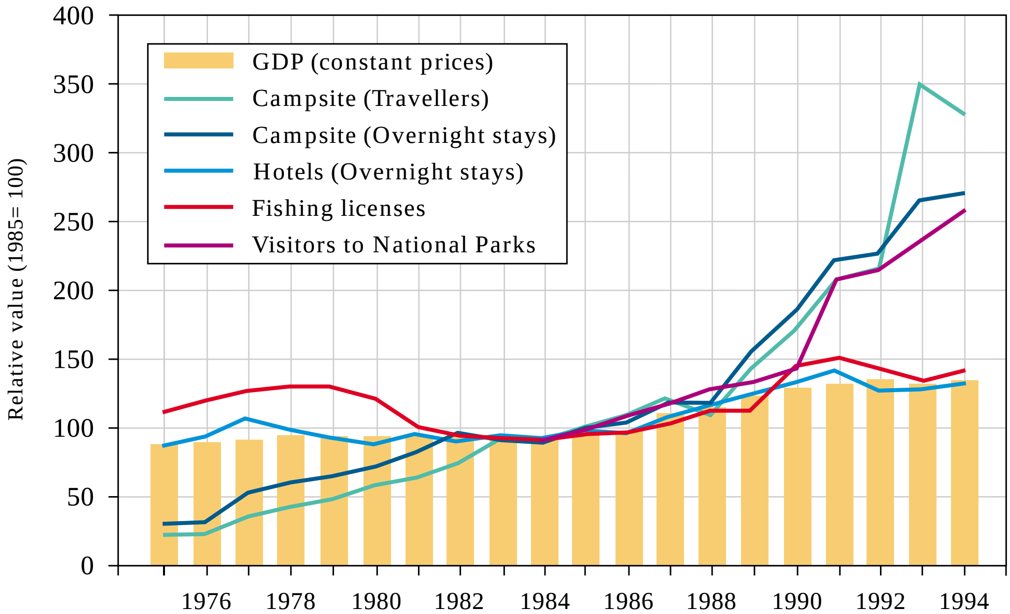


Figure 253. Evolution of some variables related with the recreational use of water.

what is currently known as ecological state of the water), but to the need to preserve fishing.

Although the Spanish Fishing Act of 1942 limited the minimum values of circulating flow through fish ladders, we may consider that the Administration did not adopt criteria to establish limitations on circulating flow in regulated reaches until September, 1990, the date when the first Declaration of Environmental Impact was published. On the basis of that first impact declaration, the approach habitually used has been to condition the construction of a large dam to the fact that, in its management, it maintains a discharged flow calculated for the survival of the ecosystems that exist downstream from the dam. Nevertheless, in spite of the time that has passed, clearly defined criteria are not available.

In this respect we should state that, at present, a varied group of terms has been used to define the flow necessary to maintain a fluvial habitat with enough capacity to preserve the life of the aquatic environment and of the riverside, such as *environmental flow, ecological flow, minimum flow, reserve flow*, etc. A brief review of the literature shows the use of other terms such as *reserved* flow, that is, a fraction of the natural flow necessary to be preserved for a specific purpose, recommended or regulated flow, referring to flow established as a consequence of some regularisation of the flow's natural conditions; etc. Some writers (Palau, 1994) propose substituting these terms with *maintenance flow*, which implies maintaining an acceptable level of development for aquatic life downstream from each regulation use or diversion (modification of the natural regime). Although this term is also debatable, we should consider that maintenance flow is not a simple single value, but rather it comprises a number of concepts, consisting of several elements that form a strategy, a protocol or, if we prefer, a regime of rational management for fluvial systems.

It is obvious that the best maintenance flow will be that which imitates a natural regime, since aquatic biocoenosis evolves in accordance with historical patterns of floods and low water. However, the need to make use of water for the functions required by society obliges us to consider such flow as non-optimal, but other minimum requirements that maintain the river's natural populations and its ecological values, in such a way that they do not decrease in quantity without.

However, once these minimums are identified, with the consequent difficulties in estimating them, they must be considered as prior, superior restrictions or external limitations on the system of water use itself. This was the idea put forward by the National Water Council in its Report on the proposals by the basin management plans, in April, 1998, and is the position proposed in this White Paper.

The main difficulty in estimating these requirements is in defining the limit up to which it is acceptable to modify the regime of natural flow without endangering the survival and normal (natural) levels of aquatic populations. Although in the last two decades a lot of research has been done into the effects of flow regulation, a great deal of scientific data is still unknown, especially on the requirements of many Iberian species, of which even quantitative data (distribution, densities, etc.) is lacking. Probably a good indicative parameter of the different types of rivers are their associated fish. Certainly, the ichthyology practiced so far in Spain should open up to more applied fields in the practical management of rivers, since there will be no fish without them. As a first step towards knowledge of Iberian rivers, their characterisation and systematisation is proposed through indicators of different typologies (hydrological, hydraulic, ecological, etc.). Once the different types of rivers have been recognised, and their requirements ascertained, the conditions will exist to incorporate environmental conditions into water planning and the river basin management.

The different calculation methodologies developed so far have the objective of quantification and temporal distribution of different flow values, allowing environmental requirements to be covered in the channel. Of all the methodologies developed, the most-used is the Instream Flow Incremental Methodology (IFIM), one of whose tools is the PHABSIM model (Physical Habitat Simulation). This model obtains the flows required by a concrete species, in an area, and for a specific period. That is, it is a model that allows an estimate of the flow necessary for the survival of a species in certain state of biological development. This methodology arose in the United States to approach the need to protect commercial or sporting fish species in rivers with high, permanent-regime flow. This all gave rise to a limitation, the result of considering the solution to a single problem, without proposing a water flow or volume for the maintenance of other elements that make up aquatic and riverside ecosystems (aquatic and riverside vegetation, macroinvertebrates, etc.).

In Spain, this methodology has been applied on some river reaches, but modifying it, to adapt it to their particular characteristics, and appreciating the significant limitation mentioned. There have recently been developed other methodologies and application tools that move away from this concept, trying to integrate the water-related ecosystems' different environmental variables. Among these methodologies, we could highlight the so-called Basque method (Docampo Pérez and García de Bikuña [1995]; García de Bikuña [1997]).

Mostly, the broad range of proposals has, as the only common factor, the use of hydrological-type criteria, with a greater or lesser degree of sophistication (Palau [1994]; Mora Alonso-Muñoyerro [1995]; CEDEX [1998c]), although numerous applications of the IFIM or PHABSIM methodology have also been carried out (see, e.g., Cubillo et al. [1990]; García de Jalón [1997]; Muñoz y Robert [1997]; Mariño [1997]; CEDEX [1998d]; Sanz y Martínez [1999]). An example of the growing interest aroused by environmental requirements in our country is the number of thematic meetings held, dealing with, apart from purely technical aspects, the legal, economic, social or landscape issues. This is the case of the Jornadas de Valladolid (CHD, 1997), or the I^st^ Congress on Ecological Flow of Tarrassa (APROMA, 1999).

In short, the current state of establishing and implementing maintenance flow in Spain is emerging, with numerous experiences and practical examples of interest, but as yet without consolidated, standardised methodologies for their generalized use in the whole country.

In this situation, it does not seem possible to establish, in the immediate future, the requirements of maintenance flow in the regulated tracts and non-regulated reaches of all our rivers, so, in the absence of such determinations, it is reasonable to propose, as has been generally done in the Basin Plans, a preventive reserve of part of the natural resources, in accordance with the options given in sections further ahead.

Figure 254 shows the location of aquatic ecosystyems identified, according to some available inventories .eg., MOPT [1991]; MOPT-MA [1995d].

3.3.9.2. Legal concepts

From a legal point of view, establishing environmental requirements (such as, for example, so-called ecological flow) for the public water domain, is a function that should

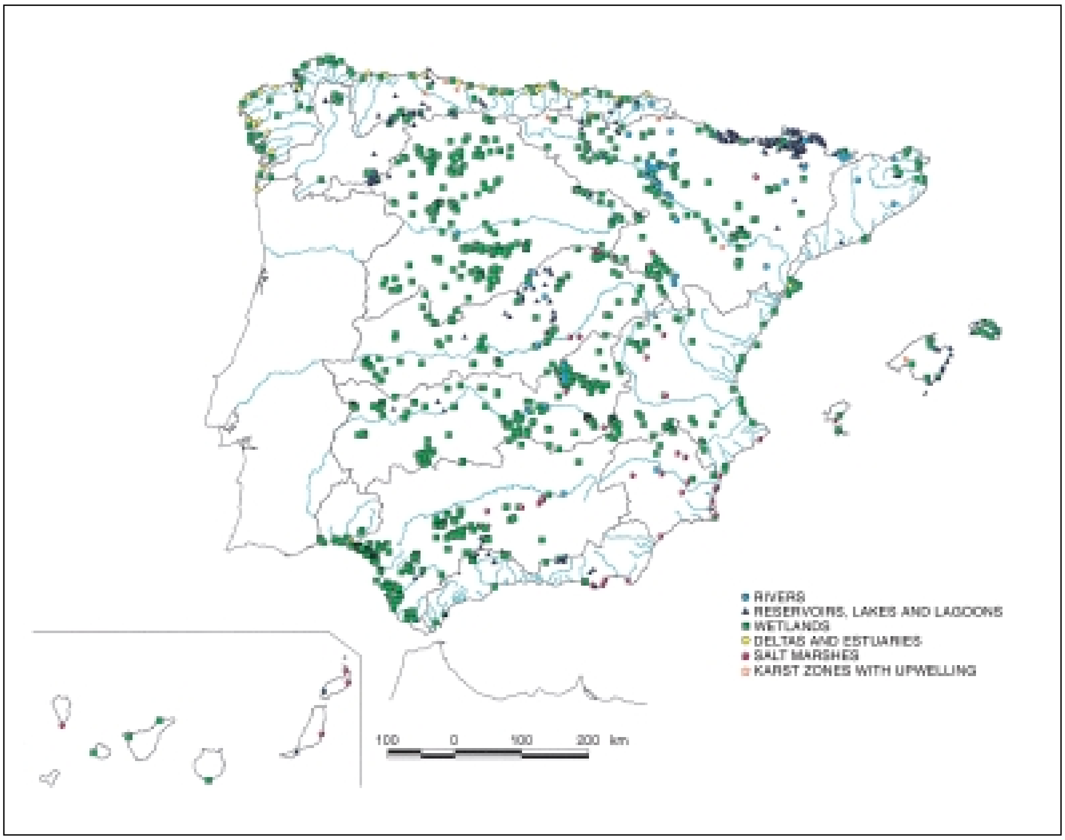


Figure 254. Inventoried aquatic ecosystems.

be understood as attributed to basin water planning. Firstly, the Basin Management Plan is the legal instrument for regulating the subject, without prejudice to whom the initiative or technical analysis may correspond for its particular determination. After the Plans' approval, their determinations are effective, and if errors, omissions, or inadequacies in evaluation are detected, the required procedure is to review and improve the corresponding Basin Plan, which should be ongoing work by the basin organisation.

In this sense, certain legal principles of the Autonomous Communities that affect the flow regime of rivers, and which were subject of actions brought before Constitutional Court, have given rise to various sentences to clarify any doubt and lack of determination.

Accordingly, Constitutional Court sentence of May 21st, 1998, declared several sections of Act 6/1992 of 18th December, on the protection of aquatic ecosystems and regulation of fishing in Castile-León, unconstitutional with respect to the distribution of powers, laying down the legal basis that determining flow regime is an authority that must be legally considered as the regulation and concession of water resources and uses and, therefore, in inter-community basins, exclusive competence of the State, and so in accordance with the provisions of the Water Act, minimum and maximum circulating flow can only be established through basin organisations. The Court insisted on the mutual collaboration that should exist between the basin organisations and the Autonomous Communities whose territory wholly or partially forms part of their hydrographic basin, with the autonomous legislator entitled to stipulate formulas enabling such collaboration to be established.

This recent sentence ratifies the position of the Constitutional Court expressed through the sentence of January 22nd, 1998, which declared several sections of Act 292, of May 7, on river fishing in Castile-La Mancha, also unconstitutional with respect to the distribution of powers. The Court insisted on the need to put forward procedural and intervention formulas allowing the exercise of respective powers to be harmonised, avoiding the displacement or prejudice of third party powers, and the importance of these collaboration formulas, which develop the essential principle of the constitutional framework on collaboration between the State and the Autonomous Communities.

Finally, we should mention another very recent sentence by the Constitutional Court, of 4th June, 1998, declaring that article 90.3, on the Regulation of the Public Water and Water Planning Administration, in the subsection "declare certain areas, basins or reaches of basins, aquifers or bodies of water under special protection", and section 4 of the same article 90, "the files declaring protected areas that are initiated subsequently to the approval of the Basin Plan are bound to be informed by the corresponding basin organisation", invade powers of the Autonomous Community of Cantabria, so it is not directly applicable there.

The same sentence declares that articles 2.2, 71.2, second parenthesis, 73 to 87 and 89.2 of the above-mentioned Regulation is not basic, so not directly applicable in the

Autonomous Communities of the Basque Country and Cantabria, although notwithstanding the direct application of the basic provisions of the Water Act that some of them reflect.

This formal consideration has been recently included in the amendment to the Water Act, establishing (single section, paragraph twenty) that Ecological flow will be laid down by the basin management plans, and that to establish them, the basin organisations shall carry out specific studies for each river reach.

Also, in recent years an interesting doctrinal argument has taken place with respect to the artificial nature of environmental flow and, specifically, its consideration as a water use (see, e.g., Delgado Piqueras [1992] pp. 30-32, 187-209; Embid Irujo [1994] pp. 149-169).

This question has also been resolved by the amendment to the Water Act, following the criteria established in this White Paper, and included in Royal Decree 1664/1998 on the approval of Plans, and regards not recognizing their nature as a use for the purposes of granting concessions, but as a prior restriction that is imposed on use systems (single section, paragraph twenty). The importance of this approach, from the point of view of environmental conservation, is decisive, although it has not yet been clearly perceived.

3.3.9.3. Rivers

The general conditions of circulating flow laid down in the basin plans with indications in this respect, are shown in table 86.

Apart from these general conditions, table 87 shows the particular conditions for circulating of flow laid down by some plans for some rivers or river reaches, set for the first horizon of their development. Next to the current that the circulating flow conditions are applied, a brief description of them is given.

We should distinguish between among regulated and non-regulated reaches and, logically, between fixed flow and the net resource requirements to cover them, since circulating flow can be wholly or partially used for uses downstream.

Accordingly, the definition of non-regulated reach - upstream from which no work or action has been carried out, altering the natural regime of the water in its basin - is only included in this chapter so as to highlight that the treatment given to certain environmental flow in them is different to that on regulated reaches, because in the non-regulated reaches a maintenance flow can be determined, potentially reserved for the purposes of use concessions granted upon it.

In regulated reaches, that is, those where there is some action that alters the natural regime of the river course, some type of maintenance flow can be determined from the regulation works and in the quality conditions most similar to what the water would be like in a natural regime.

Some problems in interpreting ecological flow in the basin management plans are commented in Heras Moreno (1994).

3.3.9.4. Reservoirs and water bodies

The Water Act seems to grant lakes and reservoirs the category of wetland while marshland areas, although it is the Basin Plans that should include them, where relevant , classification as protected areas.

The environmental water requirements of a lake or reservoir are determined by their volume, capacity and water quality. That is, for their environmental preservation, it is necessary to consider factors such as maintenance of the water quality, regulation of uses in drainage basins and some minimum levels that they should never go below. This last point could compromise guarantees for the uses of the reservoir, so an interesting solution, commented later, is the construction of containment dikes allowing this level to be maintained in an area of the reservoir, and volume freed for the uses to which they may be allocated.

3.3.9.5. Wetlands

Wetlands not only include bodies of water without thermal stratification, but also areas of territory with a positive gradient of water content that provides the soil with some

Area	General Conditions
North	Minimum flow: 10% of the inter-annual average, with a minimum of 50 l/s.
Douro	No general minimum flow is specified.
Tagus	Environmental demand: Monthly volume equivalent to 50% of monthly average cumulative flow in the months of summer, measured in the series of natural cumulative flow.
Guadiana	Minimum volume discharged from reservoirs: 1% of natural cumulative flow to them.
Guadalquivir	The greatest value of 35% of mean daily flow occupying the 19th place in the series classified in ascending order of natural mean daily flow or 50 l/s.
South	Ecological flow: 10% of annual mean cumulative flow.
Segura	minimum Flow: 10% of annual mean cumulative flow.
Júcar	Maximum reserve: 1% of total resources of the basin.
Ebro	Minimum flow:10% of the mean inter-annual cumulative flow.
Catalonia I.B.	Minimum flow: 5% of the average in 10 serial years, in excess of 50 l/s.
Galicia-Coast	Minimum flow: 10% of mean annual cumulative flow.

Table 86. General conditions of circulating flow in basin management plans.

Basin Plan	Current/description	Flow (m^3/s)
Douro	Esla/Discharge from Riaño reservoir	4
Douro	Porma/Discharge from Porma-Juan Benet reservoir	3
Douro	Tuerto/Discharge from Villameca reservoir	0.1
Douro	Orbigo-Luna/Discharge from Barrios de Luna reservoir	2.5
Douro	Carrion/Discharge from Camporredondo-Comp. reservoir	0.5
Douro	Pisuerga/Discharge from Requejada reservoir	0.6
Douro	Ribera/Discharge from Cervera-Ruesga reservoir	0.5
Douro	Pisuerga/Discharge from Aguilar de Campoo reservoir	2
Douro	Arlanzón/Discharge from Arlanzón reservoir	0.1
Douro	Arlanzón/Discharge from Uzquiza reservoir	0.3
Douro	Douro/Discharge from Cuerda del Pozo reservoir	0.6
Douro	Riaza/Discharge from Linares del Arroyo reservoir	0.1
Douro	Tormes/Discharge from Santa Teresa reservoir	6
Douro	Agueda/Discharge from Agueda reservoir	2
Tagus	Tagus at Aranjuez	6
Tagus	Tagus at Toledo	10
Guadalquivir	Guadalquivir down-stream from Pedro Marín dam/ Control river	1.6
Guadalquivir	Guadalquivir down stream from Mengíbar dam/ Control river	4.4
Guadalquivir	Guadalquivir down-stream from Carpio dam/ Control river	7.2
Guadalquivir	Guadalquivir down-stream from Alcalá del Río dam/ Control river	12.1
Guadalquivir	Genil at Puente Genil/Control river	1.5
Segura	Segura: Ojós-Contraparada/Flow in river	3
Segura	Segura: Contraparada-Guardamar/Flow in river	4
Júcar	Cenia down-stream from Ulldecona to La Cenia/Flow in river	0.3
Júcar	Guadalaviar down-stream from Benagéber reserv. to	**0.2**
Júcar	Sichar d.s. from Sichar res. to Onda central return/Flow in river	0.7
Júcar	Guadalaviar down-stream from Loriguilla res./Flow in river	0.5
Júcar	Cabriel down-stream from reservoirs of Contreras/Flow in river	0.4
Júcar	Júcar down-stream from reservoirs of Alarcón/Flow in river	0.4
Júcar	Júcar down-stream from central diver. from Picazo res./Flow in river	0.4
Júcar	Júcar down-stream from Tous dam/Flow in river	0.6
Júcar	Júcar down-stream from Forata reservoir/Flow in river	0.2
Júcar	Serpis/Flow in river	0.08
Júcar	Guadalest down-stream from Guadalest reservoir/Flow in river	0.1
Galicia-Coast	Verdugo/Flow in river	0.5
Galicia-Coast	Otaivén/Flow in river	0.5
Galicia-Coast	Lérez/Flow in river	1
Galicia-Coast	Umia/Flow in river	1
Galicia-Coast	Ulla/Flow in river	1.5
Galicia-Coast	Forcadas down-stream from Forcadas reservoir/Flow in river	0.5

Table 87. Flow conditions in Basin Plans.

moisture, enabling the establishment of plant communities clearly differentiated from their environment, known as "*criptohumedales*" (González Bernáldez, 1981). As for wetland water requirements, notwithstanding the possible proposal of a minimum volume to be reserved from total national total resources, it would be necessary to determine, for each wetland, the expedient management for its preservation, referring to entry of water and phreatic level of the aquifer where they are located, for which the conclusion of the national wetland inventory, whose implementation was laid down by Act 4/1989, on Nature Conservation, was of considerable interest.

With the exception of the plans for the Guadiana, the Júcar and the Segura, no other basin plan indicates any specific water requirements for wetlands or natural areas and, as a consequence, neither do they allocate specific quantities to cover these requirements. The Ebro plan only mentions maintaining a minimum flow in the natural area around the mouth of the Ebro. Finally, no minimum volume has been specified to be maintain in reservoirs either, except in the Guadiana plan, where all the basin's reservoirs will maintain certain volumes. Table 88 shows the annual volumes devoted to maintaining wetlands, preventing saline intrusion in coastal aquifers or maintaining natural areas, as they have been established for the first horizon of the plans for the Guadiana, Júcar, Segura and Ebro. From a legal point of view, the complex problems arising from the management and conservation of wetlands has been analysed by Delgado Piqueras (1992), among others, who considers their protection as a paradigm of the environmental focus of new water legislation in Spain, or by Calvo Charro (1995), who reviews the historical background of wetland regulation, and the current state and legal problems arising from their conservation.

Plan	System / Unit of demand	Current/description	Volume (hm^3/año)
Guadiana I	Tablas de Daimiel	Guadiana	20
Guadiana I	U. H. Eastern La Mancha	Záncara/Reserve of natural water contributions	60
Guadiana I	Lagoons of Ruidera	Guadiana/Reserve of natural water contributions	30
Júcar	Cenia-Maestrazgo	System Rivers/Prev. marine intr.	48
Júcar	Cenia-Maestrazgo	System Rivers/Maint. of coastal wetlands	23
Júcar	Mijares-Plana Castellón	System Rivers/Prev. marine intr. and maint. coastal wetlands	74
Júcar	Palancia-Los Valles	System Rivers/Prev. intr. Sea. and maint. coastal wetlands	18
Júcar	Turia	System Rivers/Prev. marine int.	15
Júcar	Júcar	System Rivers/Prev. marine intr.	55
Júcar	Júcar	La Albufera/Maint. of wetland	100
Júcar	Serpis	System Rivers/Prev. marine intr. in Plana de Gandia-Denia	21
Júcar	Marina Alta	System Rivers/Prev. marine intr. in Peñon-Mongo-Bernia - Bernisa H.U.	4
Júcar	Marina Alta	Marjal de Oliva-Pego/Maint. of wetland	26
Segura		Dispersed wetlands	50
Ebro	Outlet of the river Ebro	Ebro/Maint. of the protected areas of the Delta	3,150

Table 88. Volumes of maintenance of some wetlands.

3.3.9.6. Deltas and estuaries

Deltas are formations associated with the mouth of a river, in shallow seas with gentle tides, where the river bears a large-enough load of material so as, upon reaching the sea, the wave movement is not sufficient to wholly carry it along the coast, giving rise to deposits of sedimentary material. When the solid load carried by the river is very large, it may form deltas in seas with appreciable tides. The type and development of different deltas depends on the grading composition of the sedimentary material, as well as the physical conditions of the water in the river and the predominant marine climate at the mouth. The main deltas on the Spanish coast are the Ebro (325 km^2) and in the Llobregat (90 km^2). Others of lesser importance are the Almería Delta and those of the Rivers Odiel and Tinto.

As regards these deltas' water requirements, the fluvial contribution is largely responsible for these formations' evolution, both from the point of view of sedimentary contributions and the maintenance of wetlands associated with these systems through the feeding of aquifers. This can be seen in the Ebro delta (see figure 255) and the Llobregat, both shrinking due to decrease in solid contributions to the delta, basically caused by retention of regulating reservoirs built in the drainage basins upstream.

As for *estuaries*, these are characterized as being river mouth areas whose banks open out in a funnel shape, and where continental fresh water is mixed with salt sea water, giving rise to specific hydrobiological processes. In estuaries, the flow of fresh water, the tide range and the distribution of silts are varying continually and, therefore, it is hard for them to reach situations of balance. On the Spanish coast, there are 27 estuaries or rias, with the rias of Pasajes and Pontevedra and the Guadiana estuary particularly standing out, shown in figure 256.

The specific fresh water requirements of estuaries are very difficult to assess due to the very high natural variability of the agents acting upon them. The establishment of a reference situation with respect to which these requirements can be evaluated, requires detailed studies into the evolution of the most interesting variables in each particular case. Examples of this type of study are those described by Dolz et al. (1997) or Ibáñez et al. (1999) in the Ebro delta.

3.3.10. Summary of current uses and demands

Table 89 and figures 257 and 258 summarise uses and current demands according to data in the Basin Plans.

Table 89 has assumed the conventionally-accepted figures on consumption and return (80% and 20% in irrigation, 20% and 80% in urban and industrial supply and 5% and 95% in refrigeration) to obtain the values of the last columns.

3.3.11. Impact of climatic change on water demands

In an above section, dealing with water resources, the possible impact of climate change on these resources was analysed. Here, we briefly consider this impact from the point of view of demands, and propose, where relevant, some criteria oriented in this respect from the point of view of water policies to adopt in the future.

Initially, and in general, it would be appropriate to say that an eventual climate change such as the one can predicted may represent an upward trend in demand. This increase would take place in the agrarian sector, among others, as a consequence of greater water deficit in the soil, in ecosys-

Figure 255. Ortho image of the Ebro delta.

Figure 256. Ortho image of the Guadiana estuary.

Area	Urban	Industrial	Irrigation	Refriger.	Total	Consumption	Return
North I	77	32	475	33	617	403	214
North II	214	280	55	40	589	145	444
North III	269	215	2	0	486	98	388
Douro	214	10	3,603	33	3,860	2,929	931
Tagus	768	25	1,875	1,397	4,065	1,728	2,337
Guadiana I	119	31	2,157	5	2,312	1,756	556
Guadiana II	38	53	128	0	219	121	98
Guadalquivir	532	88	3,140	0	3,760	2,636	1,124
South	248	32	1,070	0	1,350	912	438
Segura	172	23	1,639	0	1,834	1,350	484
Júcar	563	80	2,284	35	2,962	1,958	1,004
Ebro	313	415	6,310	3,340	10,378	5,361	5,017
I.B. Catalonia	682	296	371	8	1,357	493	864
Galicia Coast	210	53	532	24	819	479	340
Peninsula	4,419	1,633	23,641	4,915	34,608	20,369	14,239
Balearic Isl.	95	4	189	0	288	171	117
Canaries	153	10	264	0	427	244	183
Spain	**4,667**	**1,647**	**24,094**	**4,915**	**35,323**	**20,783**	**14,539**

Table 89. Summary of current uses and demands (hm^3/year) according to data from the basin management plans.

tems, due to a reduction of dissolved oxygen through rising water temperature, and in public supply, also due to the temperature increase (MOPTMA, 1995c).

Nevertheless, this simple approach allows for such qualification that the final result is, at the very least, highly uncertain.

Accordingly, as regards urban supply, in practice the foreseeable increase may be insignificant. Urban demand for commercial and industrial uses would not plausibly be affected by climate change, except absolutely marginally (e.g. via increases in drinking water or air conditioning due to higher temperatures), and the component that might be affected is domestic and municipal demand, basically due to greater requirements for park and garden irrigation. Although in other countries this effect may be eventually significant, in Spain its quantity is likely to be trivial.

Additionally, if the effect of greater winter rainfall in contrast to less in summer is confirmed, the final result of urban demand could be positive, and therefore, initially, the problems of water availability would not arise. Nevertheless, the greater seasonal imbalance in demand could represent greater difficulty due to an increase in supply points, for which infrastructures are possibly not equipped.

As for irrigation, there exist different contrasting effects whose final balance is not even well-known. Accordingly, in contrast with greater water needs due to higher temperatures (more evaporation), there is greater efficiency in water use by the plant, due to the increase of atmospheric concentrations of CO_2 (less transpiration per unit leaf area), although a greater leaf growth (due to higher photosynthesis rates) could partially compensate the reduction in perspiration. This greater net efficiency of use could compensate for higher evaporation or smaller water supplies, making the final demand increase, should it occur, insignificant. If these physiological processes are also considered together with the complex biophysical interactions of the climate and CO2 on soil fertility and pests, the final result becomes uncertain and very dependent on local conditions (Rosenzweig and Hillel [1998] pp. 5, 70-100; Postel [1993] pp. 74-75). Also, the different possibilities for irrigators to adapt practices and crops to the new climatic circumstances may play a decisive role in future water requirements from the point of view of climatic change.

Recent studies carried out in some irrigated areas of Spain (CEDEX, 1998b) indicate that, generally speaking, by increasing temperatures, the risk of frost is reduced, the crop cycle shortens, yield drops significantly and net irrigation requirements eventually fall, due basically to the reduction of crop duration. The results obtained as regards variation in water requirements for irrigation should be considered, however, in conjunction with variations in yield, because with a drop in yield, the cultivation of some crops may be economically unfeasible in certain areas. On the other hand, we should bear in mind that in coming years technological advances will produce varieties that minimise the negative effects of possible climatic change, not forgetting the physiological adaptation of crops themselves to new climatic conditions. Additionally, and as happened with supply, the seasonal modification of precipitation may give rise to changes in seasonal irrigation requirements, with a final balance that is not known.

Although impact is generally anticipated as negative, other water demands such as hydroelectric generation, power station refrigeration, or, mainly, the requirements for environmental conservation, are also uncertainty and indeterminate at present, from the point of view of climatic change, and to quantifying their effects globally is impossible without an itemized analysis of each specific case.

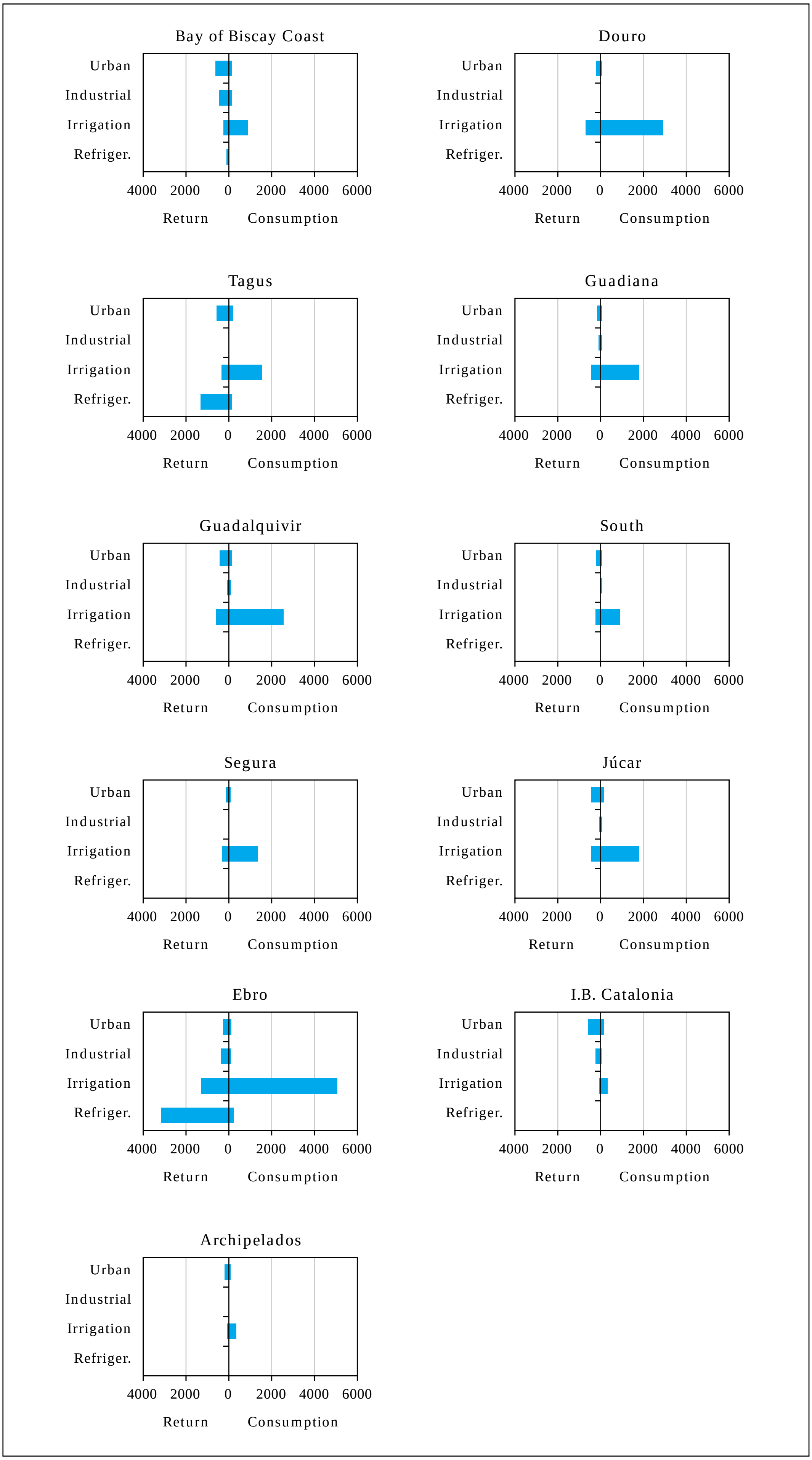


Figure 257. Main current uses (hm³/year) in the different planning areas.

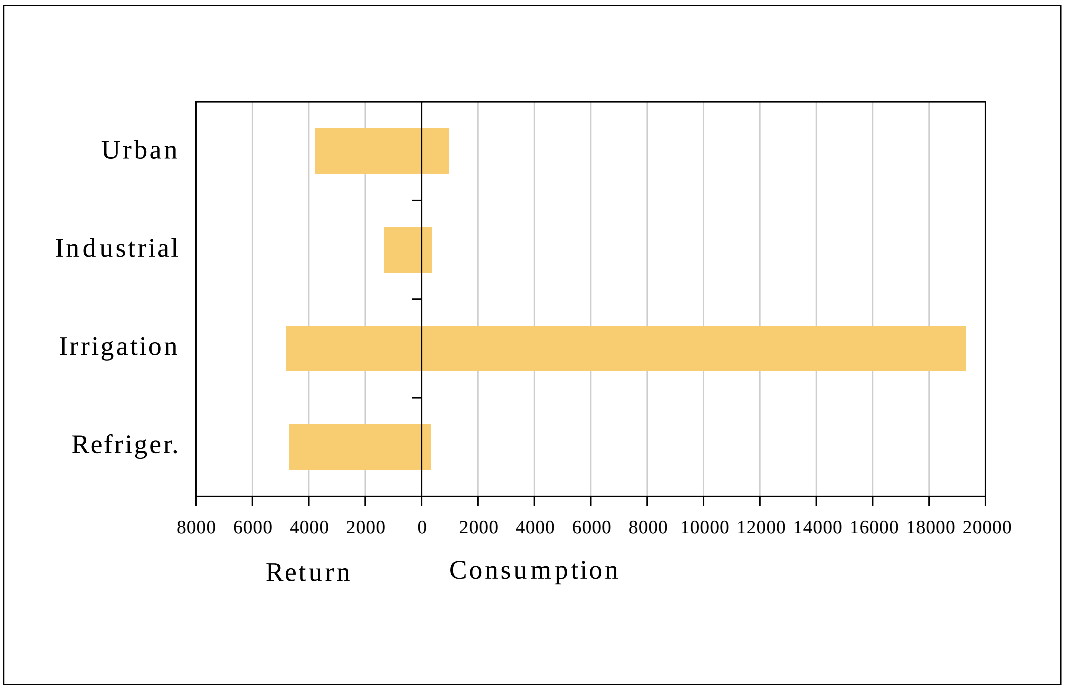


Figure 258. Main current uses (hm³/year) in Spain.

In short, the different sources of uncertainty with respect to the effects of possible climatic change on water demands do not suggest any quantitative result for the future, from the point of view of water planning.

The simple uncertainty of the level of industrial activity, population and future cumulative flow is much greater than the possible superimposed effects of climatic change on urban requirements. Similarly, the predicted contrasting effects on irrigation demand do not give rise to firm conclusions, because the simple uncertainty associated with future crop alternatives and to their irrigation efficiencies, is significantly greater than possible effects of climatic change on water demands in irrigated areas.

In short, and contrary to the case of resources, it does not seem necessary to adopt any specific criteria on future water demands as regards climatic change, from the point of view of water planning.

3.3.12. Comparison with other countries

To conclude this chapter on the study of water uses and demands, it is expedient to provide a comparative view of the situation with other countries, allowing us to see our relative position better in an international context.

Total water demand in the European Union (EU) is estimated at about 246 km^3, which means approximately 21% of total renewable resources.

As may be seen in figure 259, this demand tends to remain relatively constant, similar to what happens in the United States and Canada and in contrast with the increases that are so anticipated both in the Asian region in considering the planet as a whole.

Water demand in the different European countries is logically distributed according to the natural and socio-economic characteristics of each one. Considering total demand per capita, Spain, with a volume of 900 m^3 per inhabitant and year, would only be surpassed by Italy within a European context, where this value is 662 m^3/inhabitant/year (see table 90, drawn up with EEA data [1998] and figure 260).

As regards available resources, total demand in Spain is also above the European average, estimating the quotient between total demand and resources at 32% (see table 90 and figure 261).

Although the relationship shown (Total demand/ total renewable resources) gives an idea of water's supply-demand relationship in a certain country, in reality, by not taking into account returns that take place for each demand type, it is not sufficiently representative of the real level of water resource use.

If we consider, in an initial approach, that returns taking place in agricultural, urban and industrial, and energy demand involve percentages of 20%, 80% and 95%, respectively, of the water applied in each use, table 91 is obtained (drawn up here with EEA data, 1998).

Considering, therefore, consumption, Spain and Italy are clearly the two countries where the highest values are reached, so that, between them, they consume two thirds of the total consumed in the EU. According to these figures, Spain has the highest consumption demand per inhabitant and year, more than doubling the average of the countries considered, and showing the most unfavourable relationship in consumption demand with respect to total renewable resources, which is about three times greater than the European average.

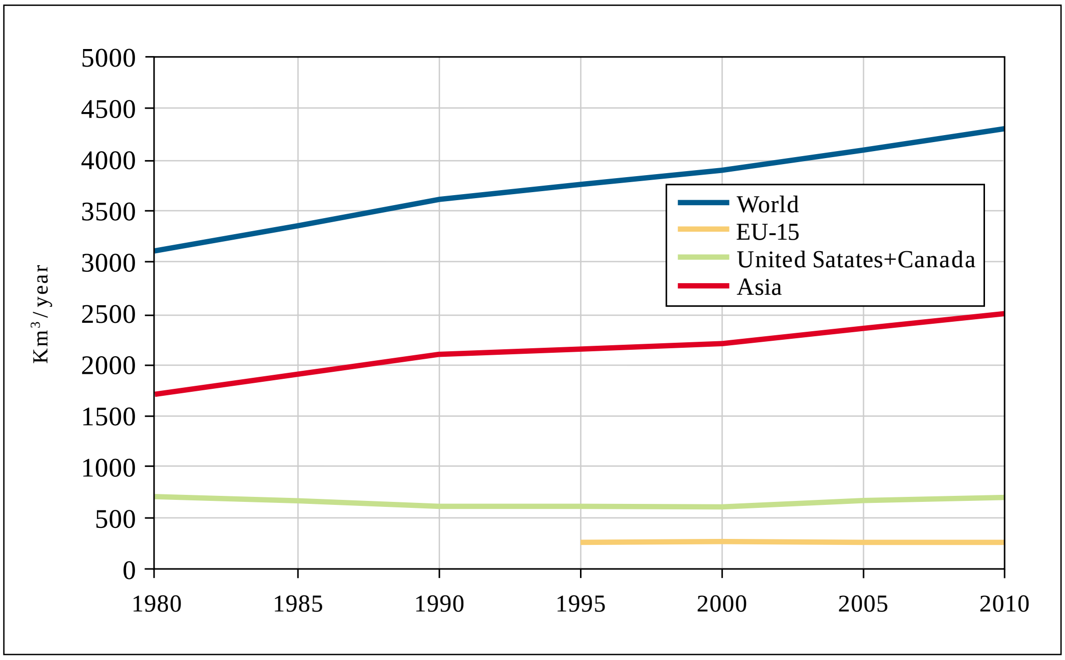


Figure 259. Predicted evolution of water demand in different continents.

Country	Population 1995 (1,000 inhab)	Renewable resources total (km³/year)	Total demand (hm³/year)	Demand per capita (m³/inhab/year)	Ratio Demand / Resources
Germany	82,400	164	58,862	71	0.36
Austria	7,968	84	2,361	296	0.03
Belgium	10,141	16	7,015	692	0.44
Denmark	5,225	6	916	175	0.15
Spain	39,238	111	35,323	900	0.32
Finland	5,115	110	3,345	654	0.03
France	58,251	188	40,641	698	0.22
Greece	10,480	60	5,040	481	0.08
Ireland	3,575	52	1,212	339	0.02
Italy	56,126	175	56,200	1,001	0.32
Low countries	15,534	91	12,676	816	0.14
Portugal	9,915	66	7,288	735	0.11
United Kingdom	58,204	145	12,177	208	0.08
Sweden	8,852	174	2,708	306	0.02
Total EU	**371,024**	**1,187**	**245,704**	**662**	**0.21**
United States	260,651	2,520	453,651	1,740	0.18

Table 90. Total resources and demand in the European Union.

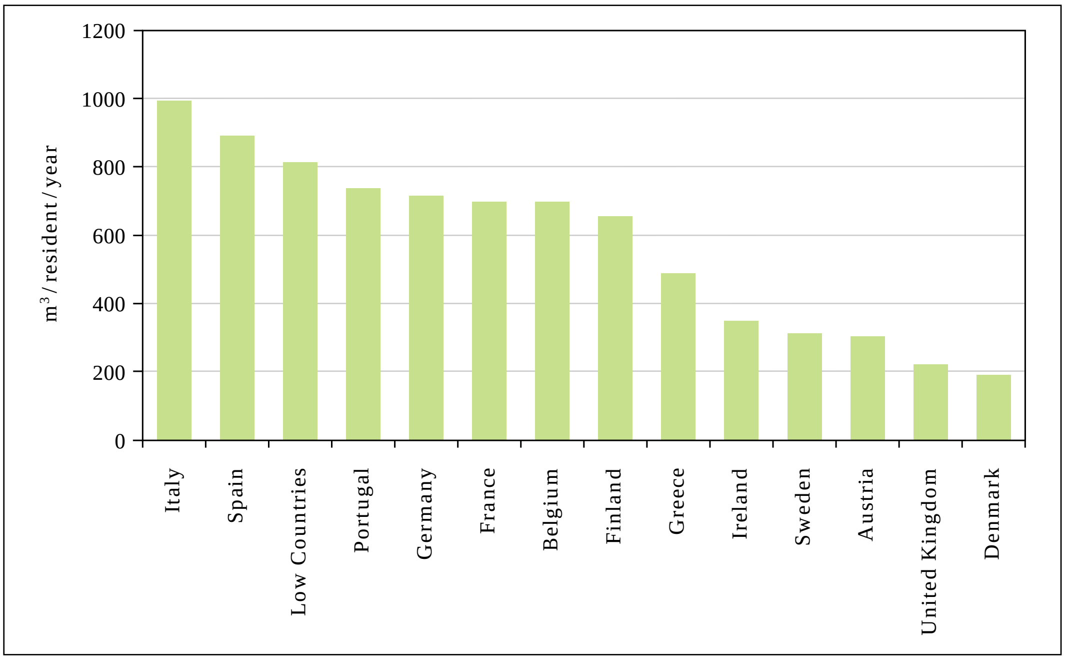


Figure 260. Demand per capita in countries of the European Union.

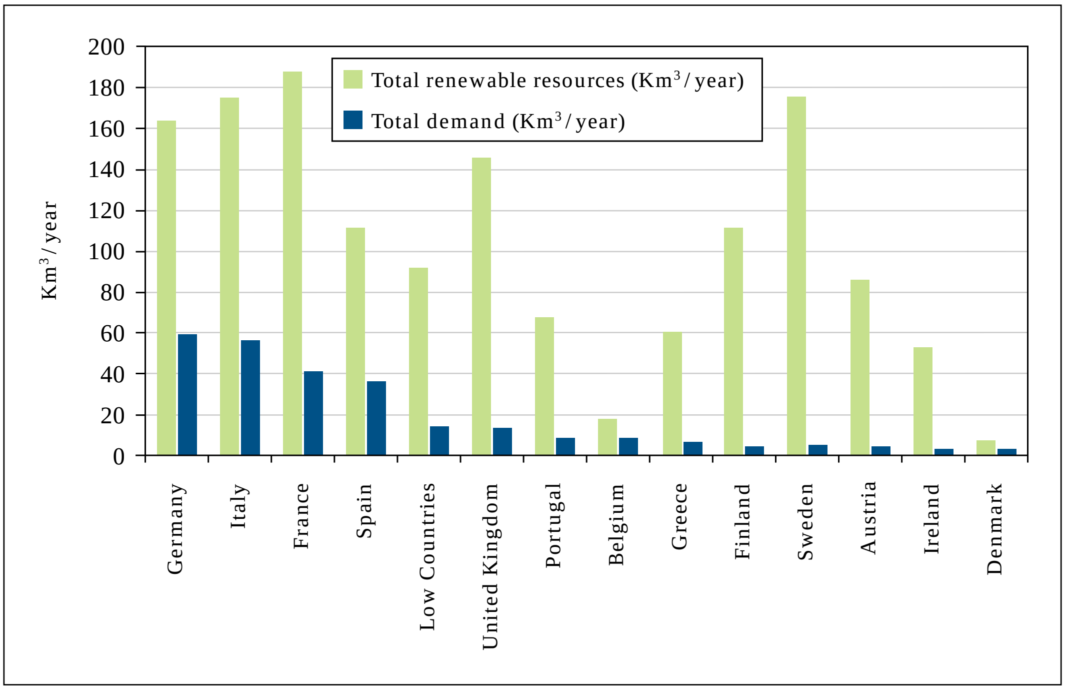


Figure 261. Total renewable resources and demand in countries of the European Union.

Table 91. Resources and consumption demand in the European Union.

Country	Population 1995 (1,000 inhab)	Renewable resources total (km^3/year)	Consumption demand (hm^3/year)	Consumption demand per capita (m^3/inhab/year)	Ratio Consumption demand/ Resources
Germany	82,400	164	5,857	71	0.04
Austria	7,968	84	460	58	0.01
Belgium	10,141	16	504	50	0.03
Denmark	5,225	6	414	79	0.07
Spain	39,238	111	20,784	530	0.19
Finland	5,115	110	457	89	<0.01
France	58,251	188	7,204	124	0.04
Greece	10,480	60	3,502	334	0.06
Ireland	3,575	52	303	85	0.01
Italy	56,126	175	29,356	523	0.17
Low countries	15,534	91	957	62	0.01
Portugal	9,915	66	3,362	339	0.05
United Kingdom	58,204	145	2,974	51	0.02
Sweden	8,852	174	628	71	<0.01
Total UE	**371,024**	**1,187**	**76,762**	**207**	**0.06**

The high level of water consumption demand in Spain, with respect to the European average, does not mean anything –as has sometimes been erroneously suggested– in terms of greater or lesser efficiency of use in our country, but rather it is mainly due to the tremendous relative importance of irrigation in Spain. As may be seen in table 92 and the graph in figure 262 (drawn up here with EEA data, 1998), total agricultural demand, which is mostly consumed in irrigation, represents 68% of total water demand, meaning 79% of consumption uses in Spain (agricultural demand/total demand not including refrigeration). This phenomenon is also seen in the other Mediterranean countries of the European Union; Greece, Italy and Portugal, where irrigation represents 83%, 57% and 53% respectively, of total water demand. However, in Europe as a whole, the predominant use of water is the refrigeration of power stations for electric energy production (46%), followed by agriculture (30%) and urban and industrial uses (14 and 10%).

Although up to 1990 the demand for agricultural water use in the EU was increasing due to growth in the area devoted to irrigation, in this last decade, a certain stabilisation of these values has been observed.

An analysis of figure 263 (drawn up with EEA data [1998]), showing the foreseeable evolution of the total cultivated area for EU countries as a whole (dry crop + irrigation), total irrigated area, and total agricultural demand, indicates that the total cultivated area will tend to diminish, with an increase in total agricultural production due to an increase of the area devoted to irrigation, at the expense of unirrigated land.

Country	% urban uses	% industr. uses	% agricultural uses	% refrigeration
Germany	6	11	3	80
Austria	33	21	9	37
Belgium	11	3	0	86
Denmark	49	9	42	0
Spain	13	5	68	14
Finland	13	33	2	52
France	15	10	12	63
Greece	12	3	83	2
Ireland	39	21	15	25
Italy	14	14	57	15
Low countries	8	4	1	87
Portugal	8	3	53	36
United Kingdom	52	7	14	27
Sweden	35	55	6	4
Total EU	**14**	**10**	**30**	**46**
United States	12	7	42	40

Table 92. Sectoral use of water in the European Union.

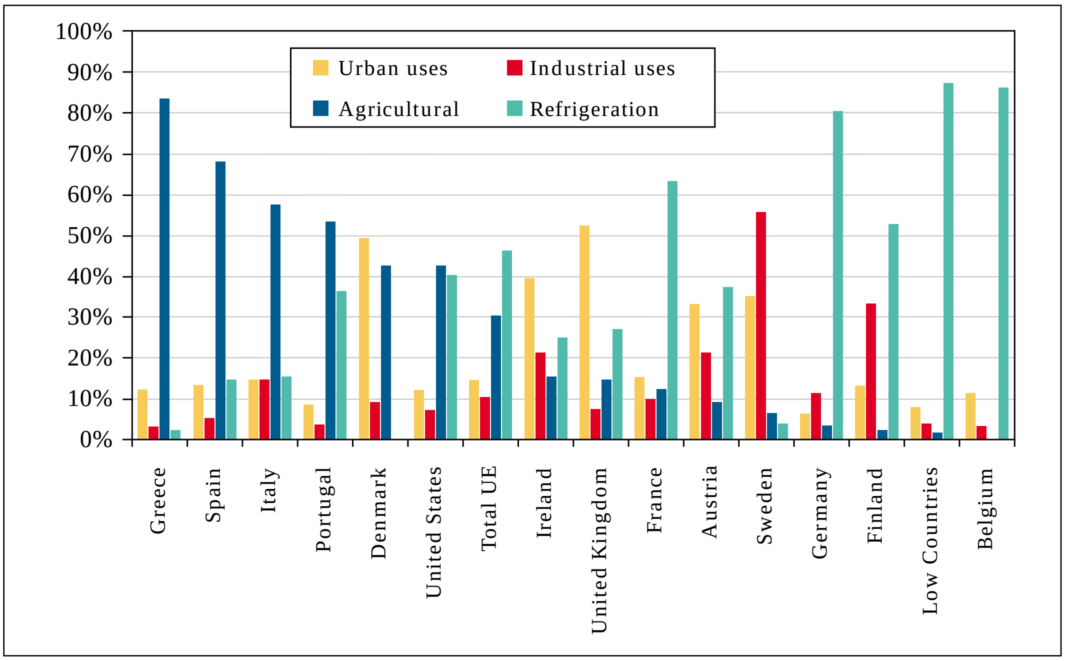


Figure 262. Relative sectoral uses of water in different countries of the European Union and United States.

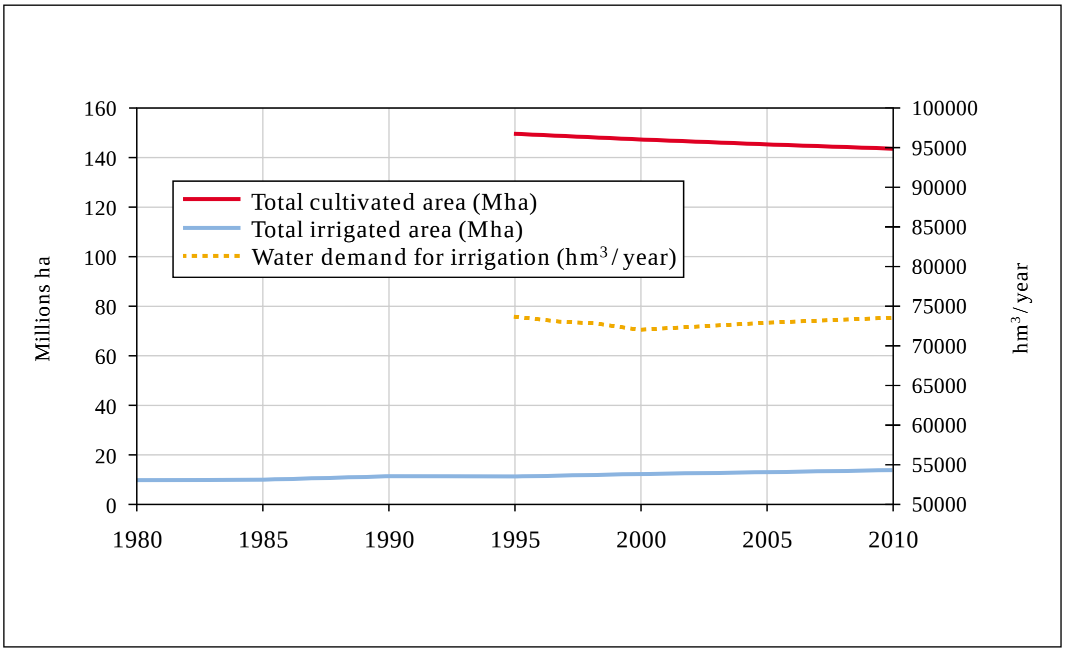


Figure 263. Recent evolution and forecast of agricultural surface areas and irrigation demand in the European Union.

The water abstraction applied in each country to each cultivation type, obviously depend on this, on climate and on irrigation type. In fact, the relative importance of irrigation is totally different in Mediterranean countries, where it represents an essential element of total agrarian production, compared with the countries of Central Europe, where irrigation merely represents a way of improving agrarian production in the summer months. This fact can be seen in table 93, which defines a value of the average water abstraction for irrigation by total irrigated surface area, without differentiating between different crop types. The values corresponding to Austria, Belgium, Finland, the United Kingdom and Sweden are not very reliable, due to the small amount of irrigated surface area.

Country	Irrigated area (1,000 ha)	Average supply quantity (m^3/ha/year)
Germany	475	3,842
Austria	4	15,000
Belgium	1	14,029
Denmark	481	800
Spain	3,437	7,010
Finland	64	1,245
France	1,630	3,017
Greece	1,328	3,150
Italy	2,710	11,883
Low countries	565	224
Portugal	632	6,066
United Kingdom	108	15,932
Sweden	115	1,508
Total UE	**11,641**	**6,351**

Table 93. Areas and water abstraction of irrigation in some European countries.

3.4. WATER EXPLOITATION. ALLOCATION AND RESERVES

3.4.1. Introduction. Basic concepts

So far, natural and available water resources have been examined, in addition to the different types of existing demand, from a perspective that we could describe as physical, or of technical concepts, that is, without any reference to how these water uses materialise on a legal and institutional level.

To understand this basic question correctly, it is necessary to comprehend some fundamental concepts, which we describe below.

On the basis of any existing exploitation system, made up of its different components ((demand, origin of resources, regulation and transportation infrastructures, abstraction from an aquifer...), the mechanism by which it is imputed to a certain demand unit (e.g. a large irrigated area, an association of towns jointly supplied by common treatment, a group of small-holdings distributed along the same river...) a certain annual volume and monthly distribution of water, of a certain quality, and coming from a certain origin (e.g. a diversion from a river, or a well field, or an outlet on a channel, or a combination of these origins), this is what is called an allocation of resources.

The allocation mechanism must therefore be based on the correct identification of water requirements in the corresponding demand unit and, once this real requirement has been ascertained, determine where the water must come from to adequately cover this need, understanding adequate cover to be appropriate compliance with established guarantee criteria.

The allocation to this demand therefore becomes a withdrawal from the natural environment, and a return, partial or total, instantaneous or delayed, with identical or different quality, to this natural environment.

Furthermore, to implement the resource allocation it is obviously necessary to ensure such resources exist. This is carried out by means of the corresponding reserve, a legal figure of great importance, and which will be studied in later sections.

Notice, despite their evident interrelation, the fundamental differences existing between the concept of allocation and that of concession: the latter grants the right to the use of the water, is completely individualized in character, and has detailed conditions and procedures in order to to be granted. Allocations, however, do not by themselves confer the right to use water; they have a more general character (in a manner of speaking, they would comprise a number of concessions), and they do not have a formally regulated procedure beyond their mandatory establishment in Basin Plans.

Consequently, allocations and reserves represent a type of intermediate concept between the absolute generality of aggregate calculation of total resources and demands, and the full detail of the concession list. By operating on this intermediate level, they act as a complete representation of the exploitation system, establishing these technical systems' association with the legal reality of water uses, thus representing an essential legal-technical element in water planning.

On the other hand, this conceptual model operates on a pre-existing reality where legal allocations are already consolidated, whose volume may or may not coincide with the true requirement, and respond to present reality or not. Also co-existing in this reality are public ownership waters and private waters, in quantities that under no circumstances should be underestimated, and which should be considered in any regulatory action. There also exist a large number of peculiar and complex situations (historic rights, concessions of surpluses, portfolio concessions, irrigated areas without concession, etc.) whose consideration and analysis is essential in any attempt to deal with the varied field of water exploitation with rigor.

In short, an institutional world and a complicated –and exciting– administrative level, which the following sections of this chapter will deal with, and which constitute one of the basic foundation stones that any future regulation must be structured upon.

3.4.2. The right to use water. Concessions

The essential element in legislation regarding the use and exploitation of water in Spain is the concept of administrative concession. Its importance is such that it requires, at least briefly, specific consideration.

Since the 1985 Act, which eliminated prescription (peaceful, uninterrupted use for years) as a method of acquiring the right to exclusive use of public waters, these rights can only be acquired by two procedures: administrative concession or legislative provision. By means of concession, the Administration grants an individual a real entitlement to use the waters, under certain conditions, for a certain term, usually by payment of a fee, and always for the purposes of some kind of utility or public interest.

Recently, numerous, intense debates have been raised on the current relevance of this concept, and its possible modification to improve the legal system of access to water resources. Privatizations, purchase and sale of rights, exchanges, markets, water banks... these are pressing questions that can only be correctly approached from knowledge of the concept and regulation of water concessions, and reflection on their historical background, their embodiments and their possible deficiencies.

3.4.2.1. Basis and historical background

The concept and basis of administrative water concession cannot be understood, as it has traditionally been conceived in our country, and the complex current organizational and institutional structure of water uses, without knowledge of the historical events that produced and predetermined it. This is also true at nearly all levels of human activity, but in the case of water, and given the special significance that, as we have said, are comprised within organisational and institutional aspects, it is certainly true.

Consequently, we shall give a brief description of some historical aspects of water use which, highlighting their more significant features, help us to understand the circumstances of the present. This review also helps to enlarge and relativise our current point of view, and to see how many of what we find great innovations of our time are in fact old problems that have simply returned in a different disguise.

3.4.2.1.1. Ownership of water in the Middle Ages

In feudal Europe, water was always considered as personal or capital property. Following the description by Maluquer de Mottos (1985), we may say that from the first centuries of the Middle Ages, they appear as belongings subject to the sovereign's eminent domain, and therefore, subject to his right to own them. As royal property, water could be allocated, donated or change domain, under private law, in favour of lords, monasteries, abbeys, cities, or other individuals, who thus obtained full capacity of decision over them. Accordingly, and by means of this mechanism of partial transfer of sovereignty, the feudal lords assumed hereditary property rights over the waters.

An important feature of this regime is that a reserve of water use always existed by means of which the lord's right of ownership was compatible and complementary with third parties' right of use. This way, the lords' eminent ownership co-existed with others' useful ownership, who could enjoy the water openly, freely and perpetually, although limited to its use, and without powers of decision upon it.

Frequently, the useful owners of the water, full beneficiaries of its exploitation, were not individuals but villages, communities or towns, in such a way that, as indicated for the land, also for the water, the communal element was comprised in the lordship, together with forests, meadows and lands where the population settled. Additionally, and due to the nature of some uses, the communal useful domain was assigned to individuals, although the community conserved ownership of this domain. Free communal use of the water was generalized, so possible individual, exclusive use by neighbours, at the expense of communal waters, was not made against payment, but by means of staking out the ownership and effective occupation.

Notice that this system was hierarchically organised into four types of associated property: the sovereign's rights, those of the lords, those of the towns, and those of individuals. Apart from the eminent domain that corresponded to them under lordship, the lords sometimes retained the useful domain of the waters, while other times they gave it to third parties by means of various formulas (transfer of domain, long-term lease, donation, etc.).

From the lower Middles Ages, and under Roman influence, the evolution of law tended to modify water's socio-economic regime due to the sovereign's increasingly bigger attributions. Royalist doctrine, which understands royalty as a right reserved for the king without being subject to any purpose, meant the gradual withdrawal of eminent domain over waters in the sovereign's favour, but this did not represent a substantial change in the regime, which continued to be in ownership, belonging to the king.

In summary, the feudal regime of water in the pre-industrial society was very complex and varied. The eminent domain corresponded to the sovereign, but also to the feudal lords and even to municipal communities. The useful domain could be retained by the eminent owners themselves or be granted to the towns, so the waters were transformed into communal goods (belonging to everyone), in which case they could remain as pure common property –of all the community members– or become municipal property or personal property of the neighbours. They could also be given directly to individuals (transfer, long-term lease or donation). In turn, any holder of eminent or useful property could donate, lease or grant his rights to third parties, so the numerous combinatory possibilities consequently gave rise to a very complex, inter-related network of overlapping rights, some of which were perpetuated for centuries and resulted in the old consuetudinary rules of water management. Heirs of an ancestral tradition, our country has some excellent examples of these rules (see e.g. Ruiz-Funes García, 1916), some of which have basically subsisted up to the present, appearing under the current form of the bylaws of historical and traditional irrigators' associations.

From the point of view of economic development, the feudal regime of water ownership represented a major difficulty, because to carry out virtually any production activity, and since water was frequently a production factor, it involved an considerable specific cost if not a total impediment due to impossibility of access. Rigidity in ownership therefore represented a major obstacle to economic growth, although with territorial differences, since in Catalonia, Valencia and the Balearic Islands accessibility was greater and production exploitation was higher than elsewhere.

Notice how the legal rigidity, which nowadays is mentioned in proposing legislative reform to encourage a better use of the resource, was already considered in similar terms, although certainly in a very different context, five hundred years ago. The collapse of that model took place as consequence of the liberal revolution, when the modern regime of water use really started in Spain, and when the basic foundations of this regulation were consolidated.

3.4.2.1.2. Water and the liberal revolution

In western Europe as a whole, and especially in the Mediterranean area, water demand increased rapidly throughout the 18th century.

Factors contributing towards this were the genesis of the industrial revolution, growing urbanisation, the displacement of large segments of active population from the primary to the secondary sector and from the country to the city, and the need to supply more food to this population. In short, there was an authentic water fever, of which there exist excellent historical testimonies in our country (see, as examples, Pierre Vilar's work (1990) for the Catalonia of the 18th century, or Pérez Picazo y Lemeunier [1984, 1985] for Murcia).

To respond to this new situation, it was necessary to bring about changes in the water regime which, overcoming its status as property, could enable this development, and these changes came with the liberal revolution.

Accordingly, the abolition of water ownership in Spain –we could say of the traditional regime– began by means of two important decrees by the of the Cortes of Cádiz, of August 6th, 1811, and of July 19th, 1813, respectively. The first one eliminated eminent domain of lords over the waters whose useful domain was individual, making them an absolute interest in their benefit, although respecting common exploitation by virtue of vicinity. The second extended this to the waters subject to Royal Ownership (fundamentally those of Catalonia, Valencia and the Balearic Islands). Thus, the holders of the useful water domain automatically received the direct domain and, consequently, were freed of payments or charges for their use.

3.4.2.1.3. The Modern era

With the Water Act of 1879, administrative water concession for the implementation and exploitation of hydraulic uses by private initiative, heir of the disestablishments and liberalisation of the 19th century, was perfected and substantially developed. This Act laid down:

1.- Concessions for population supply, granted to private companies, for 99 years, after which time all would revert to common property, and prior establishment of a rate of prices.

2.- Concessions for irrigation, differentiating between those made to societies or companies to irrigate third parties' lands, which limited the concession term to 99 years, after which the works would return to the irrigators' association; and concessions to the landowners which were perpetual. The payment of the fee was obligatory, those that refused to pay were forced to sell their lands to the concessionary channel company. The law also ordered the Government to survey existing irrigated lands, so that no irrigator wasted the water supplied, and to prevent torrential waters from flowing into the sea, when other users required them, notwithstanding acquired rights.

3.- Other concessions: for navigation channels, for ferries or floating bridges for public use, etc.

This law was developed by several varied legislative regulations, particularly the Order of June 14th, 1883, Royal Decree-Act of January 7th, 1927, and the Regulation approved by the Decree of November 14th, 1958, which regulated the granting of concessions, as well as the Water Policing regime, water channels and authorizations with respect to wastewater, bridges, etc. Other, different procedures were added to these legislative regulations, among which we could highlight the Royal Decree of June 14th, 1921, which, by generally laying down a 75-year maximum term for hydroelectric concessions, increased it to 99 years when it implied the construction of large regulating reservoirs. The Decree of January 10th, 1947, also encouraged the construction of dams to take better advantage of the subsequent regulation of the rivers where they were built.

3.4.2.2. The current situation

The Act of 1879 was revoked by the Act of 1985, which substantially respected the law, introducing some modifications.

Accordingly, and as examples of significant features in the current situation, we might note that the maximum term for which a concession is granted is 75 years, that the Administration does not answer for the possible drop in flow granted, that the granting of concessions is discretionary and its priority is as laid down in the basin plans, that the resource must be dedicated to the granted use and may not be applied to other, different ones, nor different land in the case of irrigation, that the licensing Administration may impose the substitution of all or part of the assigned flow for others of a different origin for the purposes of rationalising the use of the resource, etc.

It is important to remember these last two issues, because they indicate the possible flexibility of water uses mentioned above: firstly, the impossibility of applying the waters to other uses apart from those granted, and secondly, that the Administration can unilaterally modify the concession by imposing a different water source than the original one.

Additionally, an important question refers to terms of concession. In the Water Act of 1879, the concessions for irrigation were perpetual, and it was the Public Lands and Funds Act of 1964 that laid down the maximum concessionary term of 99 years, reduced to 75 by the Act of 1985. The question of whether this reduction of terms could suppose a privation of rights was considered in Constitutional Court Sentence 227/1988 (Basis 11), resolving that the temporal limitation of perpetual uses is not a privation of rights but *a new regulation of the same rights that does not affect its essential content.* The problem is associated with the provisions of section 43.1.d. of the Water Act, which we will refer to in connection with the contents of the National Hydrological Plan.

Furthermore, we should refer to the systems of concession modification, transfer and review.

Modification involves altering the concession's content, that is, the rights and obligations that are constituted by the concession, with the law requiring previous administrative authorization by the same authority that granted it, with its corresponding dossier.

In the case of transfer, the law makes a substantial distinction, depending on whether the it is a case of transfer of water exploitation involving a public service or the establishment of charges upon it, or it is another type of concession. In the first supposition prior administrative authorization is required, while in the second it will only be necessary to authorise the transfer.

Finally, the review system for concessions foresees three cases where it must be carried out:

1. When the conditions determining the concession have been modified. Such a circumstance will be considered to have taken place when the objective circumstances that acted as a basis for granting the concession have varied so that it is impossible to materially fulfil the purpose of the concession.
2. In cases of *force majeure* at the request of the grantee.
3. When its adaptation is required by the Basin Plans.

These stipulations provide, at least in theory, a sufficient formal legal basis to approach the major transformations (review of historical situations, adaptation of consumption to requirements, flexibilisation of use rigidities, adaptability to changing circumstances, etc.) demanded by present circumstances. Nevertheless, it is necessary to note a fundamentally important fact, which is that, in practice, all these formal legal changes do not seem to have had appreciable impact on the administration of water rights, and we may state that the possibilities they offer have so far not been practically applied, nor have they had any real effect.

Collective consideration is necessary on the reasons for this practical inefficiency, to draw the necessary conclusions. Is it a deficiency or difficulty of the legislative regulations, of lack of interest by the grantees, of management difficulties by the Water Authorities? Only after identifying and diagnosing the problem may we successfully proceed in designing a path to its solution.

It is certain that one of the contributing factors has been the absence of water planning. This lack has meant that there exists no formal reference for allocations of resources to current existing uses, and, in consequence, there exists no firm technical, legal basis for the review procedure. Nevertheless, there are doubts about the fact that, after approving the plans, the water administration has sufficient means to approach this very complex and laborious process.

Apart from these circumstances, there exist situations of unregistered exploitation (many of them the result of initiatives by the administration itself, which was limited to the execution of the works, and was incapable of concluding the administrative dossier), incomplete definition of exploitation sites (even of those already inscribed), inaccuracy of rights in possession (especially in historical exploitation), indifference or neglect by users in filling out dossiers, faulty application of the transitory legal provisions, etc... all questions of great importance that we will consider further in later sections of this document, and with recommend a radical, far-reaching study of this model, its current virtuality, and, where relevant, possible guidelines in reforming it.

3.4.2.3. Water concessions and water planning. Concession review

As we have noted, the connection between Basin Plans and water concessions is very close, and not only because it is extensively supported by certain sections of the Water Act of 1985, but because it could be claimed that the plans' very essence is the realisation of the possibilities of using the resource in a certain period, as well as the consecration of the pre-existing right or else their modification, defining the approaches or conditions under which the system of concessions should be governed, and always for the purposes of general interest. Specifically, section 40.c of the Water Act stipulates, among the contents of basin management plans, the criteria of priority and of compatibility of uses, as well as the order of preference between the different uses and exploitations.

This relationship can also be seen in section 57.3, according to which *All concessions will be granted according to the provisions of the Basin Plans, with temporary character and for a term no greater than seventy five years*. Additionally, however, the order of preference for concessions should be regulated by the basin management plans, also laying down that this preference defined by the Plan can give rise to compulsory purchase, since section 58.2, states that *all concessions are subject to compulsory purchase. in favour of another use that precedes it according to the order of preference laid down by the basin management plans*.

The Act expresses a similar concept by considering that concessions may be modified to adapt them to the Hydrological Plan (section 63), which can be reviewed at any time in accordance Art. 110 of the Regulations on Public Water Administration and Water Planning, and necessarily every 8 years according to this article. However, in this case, they will be reimbursed, but these compensations will be regulated by the Law on Compulsory Purchase, whose application by the Administration has generally been carried out through the exceptional procedure of urgency (section 52 of the LEF).

As laid down by section 63, the Plan will be the instrument to apply the legal regime of concessions, making the order of preference for exploitation no longer as rigid as in the Acts of 1866-1879, but rather it will depend on what is stipulated in the Plan, with the logical limitation that population supply will always occupy the first place. Nevertheless, the Law lays down a supplementary order of preference (section 58), which, compared with that of previous legislation, promotes industrial uses – especially electric power production and aquaculture– and includes recreational uses, maintaining –with dubious basis– the predominance above them of irrigation.

An important problem that can arise is if the legal situation of individuals against the Administration is not essentially altered by the existence of Basin Plans or water exploitations. Above all, it is expedient to consider the basic principle in the regime of public domain that individuals are not entitled to a subjective right in the exclusive exploitation of these assets.

Therefore, the Basin Plans, due to their partial character as internal instructions of the Administration regarding individuals, have a function in informing on the Administration's policy, which legally takes the shape of limiting administrative discretion in granting concessions. This certainly does not imply a recognition of subjective rights by the Plans, as expressly stipulated in section 38.3 of the Act: The Basin Plans... shall not in themselves create rights in favour of individuals or organisations.

However, we should also note what doctrine terms negative binding of the plan, that is, that the Administration is not obliged to grant exploitations because individuals do not have an enforcable right, but, at the same time, the Administration cannot grant concessions that contradict the provisions of the plan.

3.4.3. The registration of rights. Administrative water registers

Administrative registers are essentially one of the basic ways –and without a doubt one of the most important– to protect the public domain. This is true insofar as the Administration is provided with information on the state of public domain assets, and their exploitation by individuals. Their purpose is therefore to favour legal security, to constitute a method of testing, and provide protection for the exploitations registered in them. With this concept of registers, it is obvious that their relevance, in the water-related issues, is maximum: all other considerations of water administration and the protection of the domain are invalid if this essential function (to know who is entitled to the use of the water, in what quantity, and in what way) is not carried out –as regrettably is the case– in a fully satisfactory fashion. The paragraphs below deal with commenting on this basic problem, its background, and the current situation and existing problems.

3.4.3.1. Background

The only significant antecedent of the current Water Register is the Register of Public Water Exploitation created by the Royal Decree of April 12th, 1901. The purpose of this old register, obligatory and declarative in character, was to register all exclusive uses of public waters, both of a concessionary and mandatory origin, so that the Administration could have effective knowledge of the rights of different users of water, and manage the information relative to the initiation, modification and termination of exploitation, so as to, in the words of the provision's preamble, *avoid abuses and loss of the wealth that water represents*.

It is clear that the need for registration and control arises from the perception of a new problem: water exploitation is expanding together with conflicts over such exploitation, and water is starting to be perceived as a limited resource, whose access must be authorised by verifying the existence of available flow, even when not committed to another pre-existing user. Such authorisation could hardly be carried out without some statistics on uses and resources (that is, *registration* and *capacity*) whose systematic necessity was already perceived at the beginning of century. Regrettably, and as mentioned in other sections, these two old problems continue to exist, and we have come to the end of the century without having fully satisfactorily solved these two issues which arose when the century started.

3.4.3.2. Evolution. Registered, clandestine and abusive exploitation

As mentioned above, as of the creation of the old Register, registration was mandatory, since non-registration involved the declaration of abusive exploitation. However, up to 1941 (forty years later) the Administration was not empowered to impose penalties, and these powers were not entirely effective because penalties imposed were condoned by subsequent provisions.

The result of this process was that existing, non-registered exploitations of public waters, came to be so numerous that legislator's initial purpose of declaring them illegal became unfeasible. After a long, contradictory series of legal sentences on these problems, the unregistered exploitation was qualified, in a fundamental statement by the Council of State, as clandestine, understanding that they were legitimate uses since the absence of registration could be corrected by simply presenting the administrative document in the case of concessions.

It is interesting to note the difference between both concepts, because while abusive exploitation involves a basic irregularity (no entitlement, not legitimised by concession nor mandate nor law), a clandestine exploitation only involves formal irregularity (non-registration, despite having entitlement) that does not affect the content of the right that the user holds, but only affects the good order and administrative control.

The old Register consisted of a central Register, under the Directorate General of Public Works, and some provincial Registers under the corresponding Departments of Public Works. The first of these was not set up until the reform carried out in 1963 (provisions of July 24th and November 23rd), by which the Central Register of public water exploitation was created, under the Directorate General of Hydraulic Works, and where the existing registrations were filed in different books –about 45,000, from Civil Governments, Departments of Public Works, Hydraulic Services, Waters Authorities, Hydrographic Confederations and Water Commissions– (Pérez Pérez y Reverte [1991] p. 366; Maestre Rosa [1969] p. 106). This Central Register was the only one with the character of public notary.

When all the mentioned exploitations, which were known about, were transferred to the Central Register, it was necessary to modernize the registrations to adapt them to the reality beyond the register, so the Order of April 29th, 1967, was promulgated, enabling the necessary revision procedures. The present article 148 RDPH is the heir of those determinations (del Saz [1990] p. 295).

The final results of this whole process cannot be qualified, despite the intense effort made, as positive. Users' indifference in declaring their exploitations, foreseeing possible penalties or fines, the procedure's economic costs, for which the legislator eventually granted fiscal exemptions to generate interest in registration, (Maestre Rosa [1969] p. 48), irrigators' apathy with respect to these administrative requirements, and the material problems arising from the considerable parcelling and complexity of the affected properties, meant that, as mentioned above, the final result was not entirely satisfactory.

Apart from the low number of dossiers, it was common for registrations of old irrigated properties to include large, estimated flow quantities, or even registering *the whole river flow* , which can be understood considering the gauging and concessionary procedures of the past, oriented towards perpetuating old appropriations and privileges of rivers with significant periods of low water, where it was necessary for many proprietors to irrigate simultaneously in periods when the river had enough flow.

On the other hand, in the dossiers on water exploitation, capacity was an indispensable requirement when other prior concessions existed, but low-water flow capacity was never necessary to grant winter, spring or torrential waters that were not used in lower territories, which in time gave rise to a situation of seasonal imbalance between the accounts of available resources and the accounts of water granted.

Also, it is important to understand that, beyond the current, circumstantial difficulties in applying the transitory provisions of the Water Act, the concession rights granted and registered under the old Act of 1879, that is, the immense majority, cannot be considered, with the current perspective, as well-defined rights, because since the Act ordered the use of permanent flow waters, not regulated, only maximum flow granted at the outlet was generally registered, and not its annual volume nor its monthly modulation.

Despite all these deficiencies, it is fair to recognise that, with major difficulties, a Central Register was established with frequently indicative values as regards historical situations, and, without any doubt, of great quality as regards new concessions that were granted from those years onwards.

In addition to the Register of Public Water Exploitation, by Decree of 23rd August, 1934, a Register of Springs was set up for private waters from springs and wells, which gave rise to interesting jurisprudence in the Supreme Court, whose analysis gives a better understanding of the extraordinary expansion of groundwater in Spain in recent decades (see Moreu Ballonga [1996] pp. 260-273).

3.4.3.3. The new regulation of 1985. Associations with other public Registers

Knowing all these old problems, and in an attempt to overcome them, the legislator of 1985 conceived a new Water Register considering registration as obligatory and, to avoid the problems that in practice arose with the old Register of Exploitation, stipulating that registration is automatically carried out by the Administration itself, which may impose fines on whoever, as holders of public or private water exploitations, does not register (that is, allowing clandestine exploitation to be sanctioned, even though it is not abusive).

Registration in the Water Register is declarative, and omission does not represent illegality or absence of exploitation right (which is obviously conferred by the title document and not registration), but privation of registry protection due to clandestinity.

Compared with the merely administrative character of the old register, which only had statistical purposes, the current register could be considered, in some way, a legal register, because it acts as a method of testing and grants specific protection to those who register, in spite of the intense doctrinal controversy on the true scope, meaning and effectiveness of such protection (see e.g., Moreu Ballonga [1996] pp. 639-721; Martín Retortillo [1997] pp. 155-157; del Saz [1990] pp. 296; Alcaín Martínez [1994] pp. 235-265; Pérez Pérez [1998] pp. 173-203;, Caro-Patón [1997] p. 347). Its importance has been confirmed by Constitutional Court Sentence 227/1988, by declaring that Water Register must be considered as *basic*, to be an *essential element of the system of administrative water concessions, as an indispensable instrument in their guarantee.*

Also, the new regulation has eliminated the Central Register by entrusting each inter-community basin organisation with setting up a Water Register of exploitation facilities with an outlet within its territorial area. All that it maintains, for precautionary reasons, is the requirement of a copy of all Water Registers in the Environment Ministry, a copy that at present does not exist.

Furthermore, although it has been termed Water Register, the registration laid down by the new law is really a register of uses of waters (González Pérez et al. [1987] pp. 526; Quintana Petrus [1992] p. 131). The rights that are reflected do not refer exclusively to the use of water, but rather define in turn the use and destination of the resources. It is not expedient to conceive water exploitation as something abstract, because it is always associated with another asset: earth in irrigation, industries in these uses, generation facilities in hydroelectricity, etc. This means that water registration cannot be independent, but rather it is related with other registers that include assets that water is associated with. The close conceptual and legal relationship between Water Register and Property Register is accordingly highlighted with absolute clarity, although, in practice, no material relationship exists, nor any exchange of information between them.

Faced with this fact, and since in reality all the legal situations of public and private waters that may be included in water registers (except reserves laid down by Basin Plans) are subject to registration in the Property Register (Pérez Pérez Reverte Navarro [1991]; Pérez Pérez [1998]), the possibility has occasionally been porposed that water registers be incorporated into property registers, being absorbed by them. Notwithstanding the fact that this possibility could be studied, the reality is that the substantive basic element of property registration is property, and water has always resisted its legal consideration as property, since it has certain peculiarities (randomness, mobility, interrelation, degradation, etc) that require specific treatment, and notwithstanding the fact that the material implementation of water registration could be undertaken, where relevant, by property registration.

It seems clear, therefore, that the correct focus of the question is based on considering the complementary character of both registers (Pérez Pérez, 1995), analysing the possibilities of their inter-relation, and undertaking the necessary legal-administrative actions and reforms, in the certainty that this is a question of strategic importance.

Also, the exceptional progress made in the field of information technology, communication networks, and computational systems of geographic and cadastral information, allow the problem to be approached from an entirely new perspective, and with extraordinarily powerful technological resources. It is necessary (and it will be unavoidable) for the world of regulation and of administrative practice to gradually incorporate these technical advances in the short term, if the aim is to substantially improve effectiveness of activity.

3.4.3.4. The current situation

13 years after the promulgation of the THE, the registry situation of uses is as summarised in table 94.

As may be seen, the situation is very discouraging. Of a total of over half a million exploitation sites estimated in inter-community basins, just a little more than half are declared, and of these, only a little less than half are registered.

Notwithstanding the fact that some estimates give much higher figures for the number of existing exploitations sites (specifically in groundwaters), and that a serious registration deficit exists in the catalogue of private waters (just 8% of the estimated number), surface waters, usually considered to be better characterized from a legal point of view, only show 60% registered compared with the estimated total, and of this registered total two thirds come from the old Register of Exploitation and still do not have the mandatory characteristic review (7th t.d. Water Act) prior to being transferred to the new Water Register.

Table 95 and figure 264 detail the registry situation of surface water exploitation, shown per different basin. Table 96 and figure 265 detail the registry situation of groundwater exploitation.

Surface waters	Estimate	Declared	Registered	
			Reviewed	7,902
			Without review	35,898
			After 1/1/86	9,132
Total	88,900	80,700		52,932
Groundwaters				
Public waters (post 1/1/86)	27,150	15,650		4,206
Smaller than 7,000 m^3	129,592	56,642		18,005
Temporary uses	98,922	98,922		70,300
Catalogue of private waters	203,302	73,489		16,510
Total	458,966	244,703		109,021
Total	**547,866**	**323,403**		**161,953**

Table 94. Summary of the registry situation of water exploitation.

This problem with respect to knowledge of exploitation sites granted, and their possible review and modernisation, raises major difficulties, as mentioned. The ARYCA programme, developed by the Directorate General of Hydraulic Works and Water Quality, aims to improve this situation, correcting the deficiencies indicated.

Below, some representative sectoral situations are commented, contributing to understand and outline the problem.

3.4.3.4.1. Population supply

After the civil war, the Hydrographic Confederations intensified their collaboration with local councils in drafting and implementing projects and structures for population supply and collection, logically considered actions of great public interest. The reasons behind this specific help lay in the widespread technical and financial deficiencies of

Basin	Date	Estimated	Declared	Registered
North	April 1997	17,000	14,000	13,000
Douro	March 1995	10,500	10,100	9,250
Tagus	April 1997	10,400	8,700	8,272
Guadiana	March 1995	3,000	3,000	2,000
Guadalquivir	April 1997	11,500	10,500	4,260
South	March 1995	300	300	200
Segura	April 1997	2,200	1,200	1,100
Júcar	March 1995	4,000	4,000	3,550
Ebro	March 1995	30,000	28,900	11,300
Total		**88,900**	**80,700**	**52,932**

Table 95. Registry situation of surface water exploitation in inter-community basins.

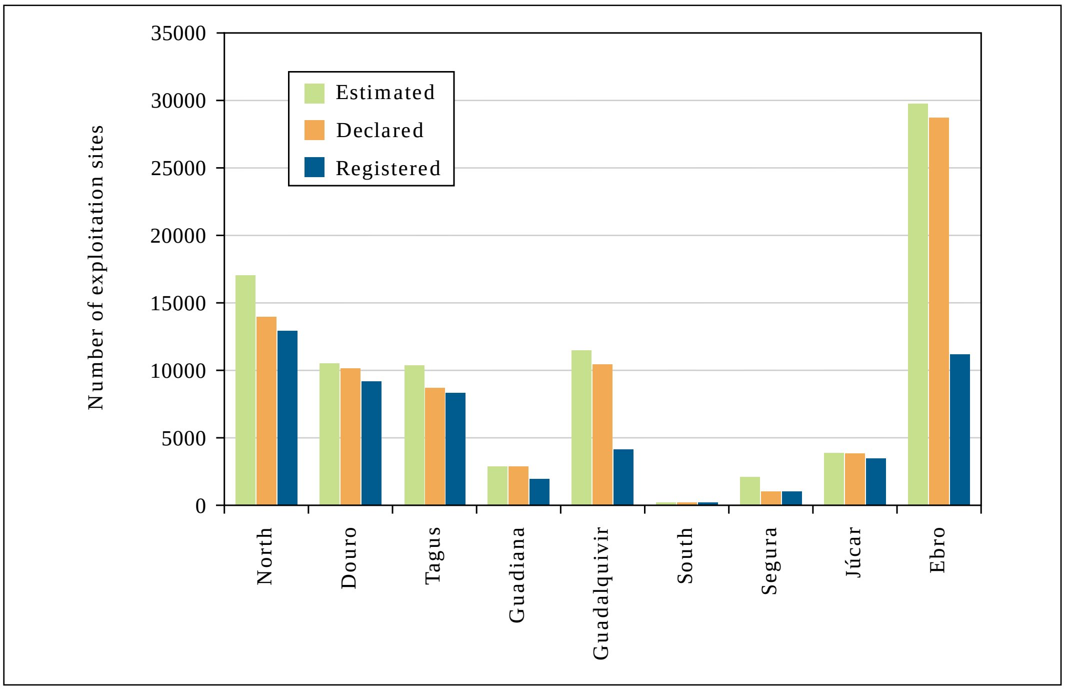


Figure 264. Registry situation of surface water exploitation in inter-community basins.

Table 96.
Registry situation of groundwater exploitation sites in inter-community basins.

Basin	Date	Estimated	Declared	Registered
North	April 1997	27,350	21,850	21,050
Douro	March 1995	88,050	59,150	42,800
Tagus	April 1997	97,322	12,422	9,579
Guadiana	March 1995	64,000	31,500	15,600
Guadalquivir	April 1997	65,444	61,831	3,668
South	March 1995	24,000	18,600	4,800
Segura	April 1997	20,350	4,500	2,574
Júcar	March 1995	20,100	20,000	350
Ebro	March 1995	52,350	14,850	8,600
Total		**458,966**	**244,703**	**109,021**

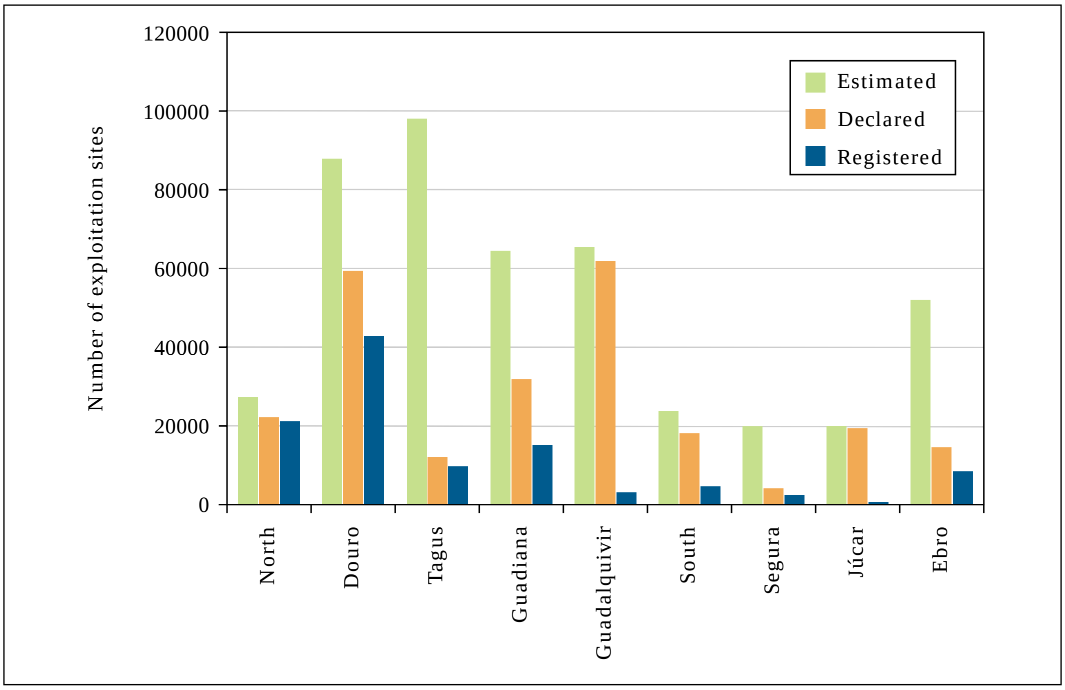


Figure 265.
Registry situation of groundwater exploitation in inter-community basins.

Corporations at the time (with the exception of big cities) in approaching such projects. In any case, it may be understood that, in such a context, drafting projects and implementing structures (the transport of water) was much more important than regulating the administrative situation of these actions.

Accordingly, the ordinary process that should have been followed (application to the Water Authorities by the interested local council, drafting of a project that had to be approved by this Authority, obtaining the mandatory administrative concession, and implementation of the work) usually began at the end, and finally, as a last step, legalising the administrative situation of something that had already been built. As a result, nowadays there are few water supplies to major centres of population that have the appropriate administrative concession.

Since supply use is high-priority, it should be relatively simple to regularise this situation. We should point out, however, problems that may arise when starting the administrative process: it is possible that such flow for supply must be reserved (they already were in their day) from concessions granted prior to them. In accordance with the legislation in force, it was and is possible to do so, but the affected grantees may claim compensation. This might be one of the reasons why local councils have not been encouraged to start legal procedures. The possible solution to these difficulties is noted further ahead, when analysing the complex and interesting question of historical rights.

3.4.3.4.2. Irrigation

In this respect, it would be expedient to differentiate three types of different situations:

State, or public initiative, irrigation

As mentioned above, the process by which state initiative irrigation has been developed in Spain has consisted of planning and building the necessary regulation structures to guarantee irrigation flow, and then organising the irrigated areas, these actions being implemented by means of plans coordinated between the IRYDA and the DGOH. Most users of these facilities do not possess an administrative concession, considering the difficulty involved in granting these before having finished the mentioned regulation structures, and the little interest shown by the Confederations, concerned with implementing the structures, in processing the corresponding documents before the Water Authorities. The simple fact that the work was carried out by the state led many to think –erroneously– that it therefore complied with the legislation in force.

Private irrigation with surface waters

Within this group, we may include what is known as traditional irrigation, and irrigation by recent private initiative. The administrative panorama of traditional irrigation varies from having no authorization nor concession granted at all, simply governed by custom, to having their facilities legalised by extinguishment (by usucaption, or appropriation by use), or having old registrations, clearly divergent from current reality.

Extinguishment, eliminated by the Act in force, did not require the necessary documents to be filled out (project approved), so in these exploitation sites it is usual to speak only of instantaneous flow rate or, at most, annual flow, without further determinations, neither knowing nor having been approved by the Water Authorities any document that specifies (sections 110 and following of the RDPH) how such flow is actually used (justification of granted flow). We will return to this crucial question later on, when referring to the question of historical rights.

Private irrigation with groundwater

The fundamental feature that characterizes these situations is the enormous quantity of exploitations sites and the difficulty involved with respect to their knowledge and control, especially in terms of their territorially dispersion and economic dynamism.

The assumption of this new competence by the Water Administration, and the mechanism laid down by the transitory provisions of Water Act, have given rise to a complex, serious situation where, as was seen, the mechanisms laid down have not been very effective, either due to an evident lack of means, or –as has sometimes been suggested– due to their own difficulty or intrinsic unfeasibility (Moreu Ballonga [1990]; Alcaín Martínez [1994]).

3.4.3.4.3. Hydroelectric exploitation

Hydroelectric exploitation and electric energy production facilities in Spain have generally been developed by initiative of the private sector. Logically, the objective was to achieve the greatest economy and integral exploitation of the resource, an exploitation whose feasibility was analysed and programmed by the corresponding services of the old Public Works Ministry.

The process followed, in general, was to propose to the Water Administration, from a hydroelectric point of view, the exploitation of land level differences and flow –or of flow for consumptive use in the case of conventional thermal and nuclear power stations–, an exploitation whose compatibility and feasibility was, as we have said, studied by this Administration and, where expedient, granted the corresponding concession, either as specific concessions for each installation, or by the procedure of granting an integral concession to exploit a reach, or several reaches, of a hydrographic basin that was then divided into several facilities.

It is also worth mentioning the close relationship that usually existed between flow regulated by hydroelectric facilities and refrigeration uses in central and nuclear power stations. Given the commercial problems involved with the use of electric power in Spain, it has been possible to coordinate these uses, when either they belong to the same owner (the same electric company), or electric companies created by large companies to exploit specific facilities.

On the other hand, there exist hydroelectric power stations installed in facilities built by the State (usually next to dams). In these cases, the expedient concessions have also been granted under tender in accordance with provision both of the legislation in force (section 132 of the RDPH) and in laws now repealed. In summary, it may be said that large hydroelectric facilities all possess expedient administrative concession.

The case of many small power stations –and other uses– is different, with abstraction from secondary channels, which do not have authorization of any type from the point of view of exploiting the water, although the Water Administration is occasionally aware of its exploitation data, and they have prior administrative authorization, from the point of view of Industry, for construction and exploitation, approval of the execution project, and start-up authorisation.

The fact that procedures have been started for the regularisation of such facilities does not authorize their exploitation, and to allege their peaceful, continuous operation over more than of twenty years (basis for extinguishment) does not legitimate this operation, among other reasons because when terms have been given for legalising these situations, the interested parties themselves have not made use (records of renown) of the possibility to regularise they were being offered. Additionally, and conversely, there is a need to start expiry procedures for abandoned exploitation sites –very numerous– that have relinquished the use of the water for over three years, or review due to modification of some of their characteristics.

Despite these deficiencies, it is not imprudent to state that hydroelectric exploitation sites are among those with the best overall conditions from the point of view of authorizations and concessions of the public water domain.

It is important to consider, with respect to hydroelectric exploitation, that these facilities were conceived, in their day, only for electric power production and that, on the other hand, the public water domain (the water) itself was used for producing something marketable, but subject to significant administrative regulation, so we could say that there really existed no business liberty in putting on the market the kWh produced by each installation. The most recent example we have today is in the now-disappeared Stable Legal Framework. However, at the present moment we are in a new situation where the product obtained from use of the public water domain itself is to be marketed freely, and which is to be placed on the market according to the offer that each grantee can make.

It is therefore expedient to wonder if the economic-financial balance of the concessions, granted in their given moment, may be altered by this circumstance, and accordingly, from the point of view of the resource's integral administration, whether the flow regulated in what was initially conceived as solely hydroelectric reservoirs should not now also be considered as resources for other uses.

3.4.3.4.4. Conclusions

As may be deduced from the brief sectoral analysis presented, the current moment is characterized by a large number of complex, varied situations, inherited from the past, and which, in short, express the weight of the long, eventful history of hydraulic development in Spain –a living, unfinished history, and whose effects can still be felt at the present time. The following section will deal with the consideration and analysis of these historical situations.

As we have seen, the current registry situation arising from this historical process is a long way from satisfactory, and registrations have not really been a means of statistical testing and control for existing legal situations to do with water exploitation. To a large extent, it is commonly-accepted practices that are in fact determining current use of the resource, and the perfect association of such practice with their registration is not fully guaranteed, nor has it represented a significant concern for users, nor for the Water Administration.

The declarative, non-substantive, character of the Water Register; the lack of diligence in resolving conflicts by legal action; the complexity of uses and exploitation systems; the imperfect definition of rights even for registered exploitations; the complete absence of registration in numerous important exploitations sites; the possible economic consequences of the registrations; and, very importantly, the overwhelming effect of customs, have unquestionably contributed to this undesirable situation, socially accepted, of relative legal insecurity.

As a simple example of these difficulties, and in relation to the problems of current regulation, the complexity of the regulatory procedure in processing concessions could be mentioned, where the sum of the different partial terms laid down, in the case of normal procedure, without special incidents, easily surpasses a year and half. If we add to this doubts as to effectiveness, work load and a certain feeling of discouragement given the magnitude of the problem and lack of means on the part of the Confederations, it is easy to understand the need to establish reforms to the current regulation, and find new, more effective, modern and simplified mechanisms.

Nevertheless, apart from such necessary simplification in the regulation in force, it is possible that in the future, and in view of the seriousness of the problem described, drastic measures may be required to confront the situation, introducing new mechanisms for the definition and registration of exploitation rights, and associating these rights with ordinary practice. This will obviously require profound prior legal and social reflection which, approaching the current reality without prejudices, involving all interested parties, identifies possible new concepts and lines of action in this crucial issue.

3.4.3.5. The content of historical rights. "Paper" rights and effective rights

As has already been noted, and notwithstanding the above-mentioned lack of registration that often occurs, the analysis of a river basin's files, inventories and Water Registers shows the existence of a large number of entitlements to exploit public waters that are derived from extensive legislation, both general and specific, that regulates them, and of the age and complexity of a large part of the exploitation sites –and very particularly irrigation facilities– in Spain.

However, this situation of relative abundance of old registrations has not been efficient, either from the point of view better exploiting water resources, nor of the economic management associated with it, nor even, from a strictly legal point of view or regarding the content and real scope of rights and their administrative protection. Furthermore, the reality is that, frequently, a complex series of rights has developed which, apart from its little practical utility, has been seen to cause conflictive situations by contrast with corseted, purely nominal situations, in most cases with little or no real content. The necessary reflection on possible reforms to the definition and register of rights, mentioned above in connection with Water Registers, has here, as an example, an important issue for consideration and study.

Accordingly, in the historical areas of intense exploitation, a detailed analysis of the titles effective shows references to those that are denominated within them –as objects and categories of water law– Winter and Spring waters, flood waters, spring waters, excess waters, surplus waters, white waters, regulated and permanent-flow waters. ...or traditional and extension irrigation, exclusive and complementary, low and high-level, of day or night rates, irrigation of grace, irrigation of cloudy water, etc.

This long list of water typologies, irrigation, privileges and historical rights today has practically no virtuality at all –they are to a large extent "paper" rights–, and does not respond to a real legal requirement as a result of its presumably peculiar nature. It can even be stated that these vestiges of the past –full of expedience and sense when they were conceived– today represent an impediment as regards the inevitable concept of integrated basin water exploitation systems, a concept that stands as a decisive factor in a modern, integrating vision of water administration.

Historical rights cannot therefore be assimilated under the literal content of the old titles or registrations –largely non-existent in many cases anyway–, and not just because such an assimilation would be in many cases irrational (and, as the law stipulates, no title may protect the wastage or squander of water), but because the new legal, hydraulic and socio-economic circumstances have mostly relegated them to the status of archaic, as residue of the past, noted down in water's history and culture, but in no way forming part of this resource's modern management and use.

To demonstrate this irrational situation leads to the rigid maintenance of historic titles must not, in any way, lead to negating such titles any real content in the present day. Nevertheless, recent, detailed studies (Moreu Ballonga [1996] pp. 159-209) have shown that the approach followed by the Supreme Court on these questions has been, almost always, to respect historical rights, maintaining their validity. The basic problem arises when the current lack of precision on the specific right included in the title (e.g. a concession from 1910 of excess water from an upstream use), the difficulty in enforcing them literally against the changes of all kinds that have taken place (e.g. the right to certain flow in fixed sections and night shifts), the apparent inequity or social rejection arising from their content (e.g. the assignment of a complete river to a beneficiary), or complex mixed situations (e.g. the above three and others, co-existing in the same sub-basin), make their literal practical application extremely difficult, if not impossible, and some kind of interpretive approach is required.

Accordingly, the problem that arises is one of how to determinate, in the current context, the value and scope that these historical titles may have. In our opinion, solving this problem must involve determining their current real exercise, according to the present needs and circumstances of those exploitation sites. It is this value or current real utility that is the genuine basic content of historical rights, and their demarcation and consolidation cannot give rise to any compensatory claim, since, as jurisprudence has insisted, only privations of certain, effective and current, but not eventual or future rights, are entitled to indemnification, and basis of a possible claim, which would be the user's loss of property, is non-existent due to the very nature of the concept proposed, because it is simply the current real value (the true current property) which is being determined and recognised.

Therefore, having identified the current situation (obviously not at a specific moment, but representative of the current moment), and the true needs of these historical exploitation sites, the consolidation of their current needs and temporal preference in situations of shortage must be –and nothing else– the true material content, liable to inclusion in registers, of the historical rights, and these are the determinations that correspond to the Water Administration at the present moment.

In a time of transformations, changes in use, new technologies, and integration and optimisation of exploitation in the increasingly complex systems of exploitation, titles of the past can be reinterpreted in terms of outlining real need and temporal preference with respect to later uses, transforming this preference into the true material expression of their historical character. The regulation of water exploitation and reallocation of resources carried out by the Júcar and Segura Basin Plans are excellent examples of such an interpretive approach, and of how this complex technical-legal review can be carried out, with the exemplary participation and agreement of the interested parties, in a rigorous and satisfactory way.

In short, and as Martin-Retortillo (1997) maintains in relation to the non-retroactivity of those standards and the reforms of the laws, compared with the usual arguments that refer, ultimately, to the value of the parchments and the prestige of history to perpetuate past situations of water access, we should invoke, without reservations, the powers of the Administration so that, according to the common property that its decisions must cover, it promotes a review to prevent the continuation of obsolete legal situations, anchored in the past, contrary to the good order of uses, or even to the new allocation or new legal classification promulgated, obviously, because it is taken to be better than the old one that is being modified.

The invocation of history cannot be presented as a defence of an unacceptable petrification of rights or of legal classification, because these rights do not operate in abstract, atemporal or immaterial territories, but in concrete, changeable, hydrological, economic and social realities which, due to their very nature, resist being frozen in a specific historical moment. Quite the contrary, the true legitimacy of these rights requires their continuous adaptation to the reality of each moment, as what they really ought to be: an instrument of common utility for progress and collective well-being. The Water Administration is not only empowered for this work, but rather it is called upon, committed, and urged to deal with it.

3.4.3.6. Water register and Water Planning

We have already pointed out the fundamental importance of the registry concept as an essential instrument in protecting the public water domain. Also, we should highlight the close relationship existing between those water registers and water planning.

It is not appropriate to conceive of a unitary, rational administration of water resources, as they are constitutionally regulated, without complete knowledge of water exploitation, public and private, so this question has become a radically basic question. It has been recognised as such for a long time by the Water Administration, for which registry problems have been a constant concern, giving rise to numerous general and specific regulatory provisions, in those territories with the greatest conflicts and difficulties, such as the Segura and Júcar basins (Maestre Rosa [1969] p. 106).

In the current regulation, it is on the basis those registrations that the water organisations must draw up the necessary statistics for water planning (section 197 RDPH). Similarly, and in the opposite sense, concessions cannot be granted and registered the existence of flow has not been verified, according to what is laid down by the basin plans. The relationship between planning and registration is, therefore, very close and in both senses we may state, without any exaggeration, that the correct implementation of one activity cannot be conceived without the correct implementation of the other.

3.4.4. Public domain reserves

Public domain reserves represent a singular precedent in water planning. The Water Act of 1879 did not provide for them, but did consider other standards included within its series of group of complementary provisions.

Accordingly, the Law On Irrigation in Upper Aragon, 1915, authorizes the government to execute works and to irrigate certain areas, showing the basic characteristics of a reserve, although the origin of this concept can be located clearly in the Royal Decree of 1918, on water concessions. This Decree laid down that *by provision of the development minister and prior to the necessary studies, certain reaches of public channels may be reserved for services of the state* . The same approach remained in the Decree-Act of 1927, with two additions: the reserve could be carried out at all times and refer to all channels.

There are plenty examples of this technique's application: the Decree of 1953, on the regulation of irrigation on the river Segura which is fundamentally no more than the establishment of a reserve of the new regulated resources for these irrigated areas' re-supply and extension; the Decree of 1954, which reserved flows from certain reaches of the rivers Lozoya, Jarama, and Sorbe for the supply of drinking water to Madrid and neighbouring towns; the Decree of 1946, granting the INI the reserve of integral hydroelectric use of the Noguera Ribagorzana river basin; the concession to the INI in 1984 of the reserve of the integral hydroelectric exploitation of the upper basin of the River Sil; or the reserve for the Ebro transfer to the eastern Pyrenees in 1974.

Notice that in all the commented examples, the reserves have been established by means of decrees or laws, but since the promulgation of the Water Act, the established procedure is that of inclusion in the Basin Plans (Barcelona Llop [1996]; Ortiz de Tena [1994]). In the absence of approved plans, reserves of water resources continue to be established by means of laws and decree-laws (such as Royal Decree-Act 3/86 which reserves, in favor of the State, all possible existing resources in the Segura; or the Act of 1987 that reserves a flow of 1 m^3/s from the Contreras reservoir for the consumption of Sagunto; or the Royal Decree-Act of 1995 that reserves up to 50 hm^3 from the headwater of the Tagus for supply in La Mancha).

After the Water Act of 1985, the only instrument empowered to establish reserves is the Hydrological Plan, and only the Law can substitute it. This empowering hydrological plan can be within the scope of a basin or on a national level, the former responsible for establishing the volumes that must be reserved for future uses and demands, and the latter for establishing volumes for inter-basin transfers.

The legal obligation to establish reserves in the Basin Plans must take place in relationship with its purpose, since it makes little sense to establish such reserves when there exist no objective reasons that make them necessary. Motivation, purpose and temporality are therefore basic requirements for the correct formulation of reserves which, as foreseen by the regulations in force, must be registered in the corresponding Water Register of the basin organisation, and be progressively cancelled as the reserved flows are granted in concession.

3.5. THE CURRENT ALLOCATION SYSTEM

Having analysed water resources, existing and foreseeable uses and demand, and the mechanisms for the allocation and reserve of resources for these uses, we shall now turn to examining all this from a global, integrating point of view, allowing us determine the territorial balance between resources and needs, and to identify possible imbalance.

This analysis is approached in two different ways. Firstly, a cartographic approach is carried out, based on the realisation of balances based on maps of the variables involved, that is, natural resources and demand for main uses. This balance is carried out by means of the cartographic operations habitually available in the Geographical Information Systems and provides, in a homogeneous, rigorous and conceptually simple way, a general, simplified view of the current system of water use in national territory as a whole.

The second method to approach the problem is based on the analysis of systems and has consisted of preparing a unified system of water resource exploitation, which we have already referred to in sections above. This system has been designed on the basis of a mathematical model for optimising water resource management, providing greater depth of analysis and a better approach than the cartographic model above by incorporating storage and transport infrastructures, minimum flow, use priorities, supply guarantees, etc. Also, and this is very important, this model incorporates the variability of resources and the possibilities provided by appropriate systems management.

Below, we describe these two analysis instruments briefly, their functionalities, the main conclusions obtained, and the possibilities offered by their immediate application in the framework of national water planning.

3.5.1. Cartographic Modelling of the use system

3.5.1.1. Introduction. Basic processes

Cartographic modelling (Tomlin, 1990) constitutes a relatively recent technique, which in recent years has developed with growing enthusiasm. It allows large amounts of spatial information to be handled very efficiently, which has made it a particularly useful instrument to carry out analyses that, like the one in question here, have a basically territorial component.

The model implemented here uses part of the cartographic information created in preparing this White Paper and presented in chapters above. Specifically, the basic information used in the model consists of the map of natural resources and maps of urban, industrial and agricultural demand. The working resolution chosen for the model is 1 km^2, which means discretizing the national territory into more than 500,000 cells, in each of which the various algebraic operations described below are carried out.

Starting from natural resources, that is to say, renewable resources that are generated in Spain, both of a surface water and groundwater origin, the model determines potential resources, in other words, the fraction of natural resources that truly represents a potential offer. The reason for differentiating these potential resources lies in the need to consider environmental requirements as a higher-value restriction, external to the water use system itself, as was commented when describing the conceptual basis of the water allocation system. It is therefore a question of differentiating and reserving some resources that the system cannot count on to achieve the production objectives of water use. Only the remaining resources, those which really represent a potential, are those that can be mobilized in the water allocation system and are, therefore, those that should be included in the balance between resources and demand.

The sum of the maps of urban, industrial and agricultural demand gives rise to the map of total demand, understood as abstracted from the environment. Nevertheless, to take into account the returns that are incorporated back into the environment and are liable to be subsequently used downstream, the consumption and non-consumption fractions of each use have been differentiated, giving the corresponding maps of consumption and non-consumption demand, whose sum is total demand.

Based on the maps of potential resources and total consumption demand, the cell-by-cell balance is made, giving two maps with the territorial distribution of deficit and surplus. These maps logically are merely illustrative, because water use is not carried out in an isolated way in each cell, but in wider territorial enclosures. For this reason, the model makes a territorial aggregation based on the delimitation of various administrative units. Firstly, an aggregation is made according to the exploitation systems defined in the basin management plans, allowing existing imbalances in the area of each plan to be identified. Next, new aggregation is made for territorial planning areas, which can give an idea of overall behaviour in the area of each plan.

To summarise and to be able to make a clearer interpretation of the results obtained, the model calculates several indices relating to the levels of exploitation and consumption reached in each territory.

The first of these, termed index of exploitation, is the quotient between total demand or abstraction and potential resource. An index of exploitation that approaches or even surpass the value 1 does not necessarily indicate a water shortage, because if the abstractions are not too spatially concentrated, a major part of the return is used again.

The second index used is the consumption index, obtained as quotient between the consumption demand (abstractions minus return) and the potential resource. This relationship can be interpreted as indicator of the risk of shortage. If its value is higher than 0.5, it would show a more or less localised spot shortage, while if it approaches 1 it would be a shortage of a structural nature. Conversely, a low consumption index would reveal a little-used potential (Erhard-Cassegrain and Margat, 1983).

With these criteria, the model finally draws up a map of shortage risk shortage according to the different spatial aggregations made.

The process followed in the cartographic model described is summarized graphically in the diagram in figure 266.

Below, the information used in the model is presented, together with the results obtained in the different stages of the modelling process.

3.5.1.2. Natural resources

Natural resources considered in the cartographic model are represented by the total runoff in a natural regime assessed in chapters above, and corresponding to the period 1940/41-1995/96. Their value, for the whole national territory, has been estimated at about 111,000 hm^3/year and their territorial distribution is as shown in figure 267.

3.5.1.3. Environmental requirements and potential resources

To determine the potential resources that can be used in the process of productive water utilisation, a precautionary reserve of 20% of natural resources is supposed, to fulfil those prior requirements of an environmental type and to cover the possible uncertainties in the estimate of resources. This means a reserve, for future generations, of more than 60% of the whole water demand currently existing in Spain, according to the basin management plans.

With this initial limitation, potential resources would decrease to about 89,000 hm^3/year, and their territorial dis-

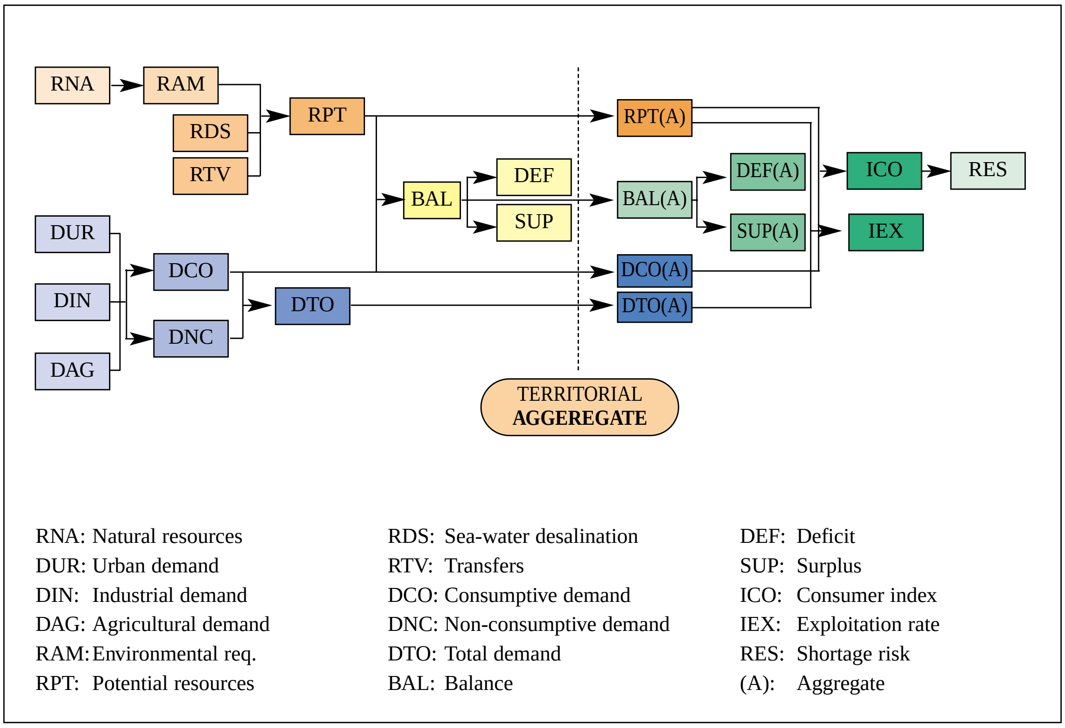


Figure 266. Cartographic model of the exploitation system.

tribution would logically be similar to that of natural resources, because the supposition is that the reserve is made equally at all points in the territory.

A second limitation which, in accordance with the conceptual design proposed, must be introduced, corresponds to geopolitical restrictions. In our case, this affects the Hispano-Portuguese basins, and a commitment to contribute certain minimum volumes at the frontier. We shall refer to this in later sections.

In addition to the resulting potential resources, we should add those originating from sea-water desalination, which is carried out by distributing currently desalinated volumes in the territory of the exploitation systems with the possibility of using them. On a national scale, the actual magnitude of these volumes is very small, though they may contribute to remedying localised problems in some exploitation systems, basically on the islands. The location of these volumes from desalination is shown in figure 268.

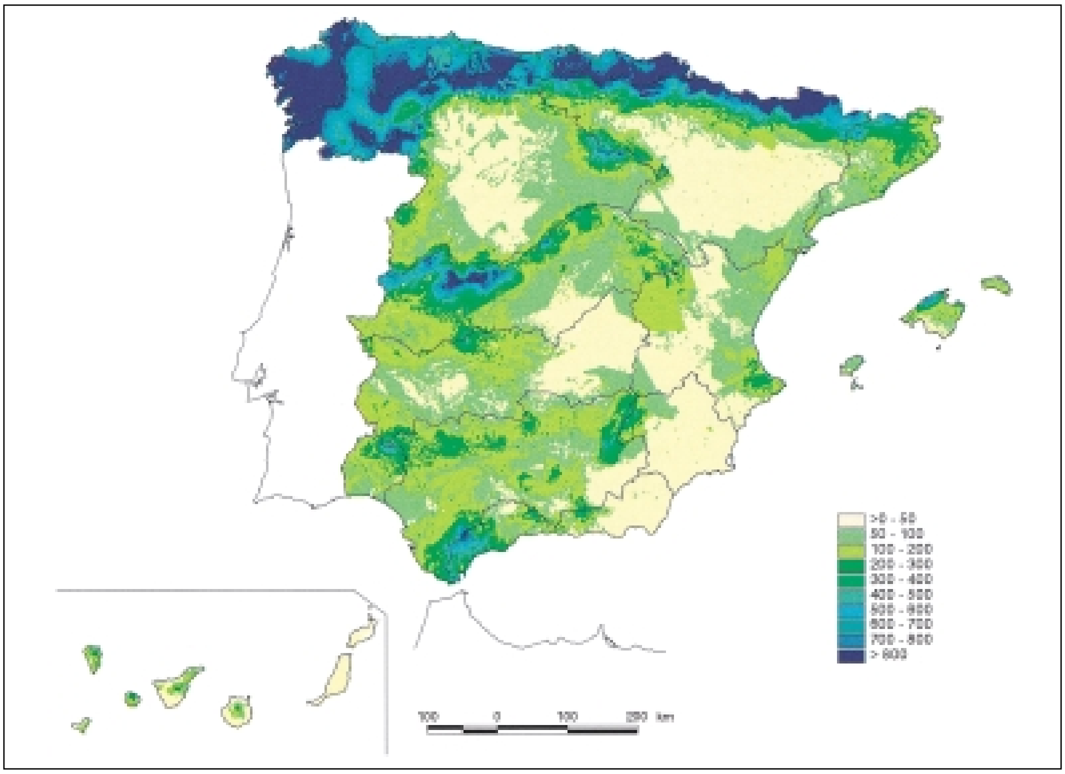


Figure 267. Map of total annual natural resources in mm (period 1940/41 – 1995/96).

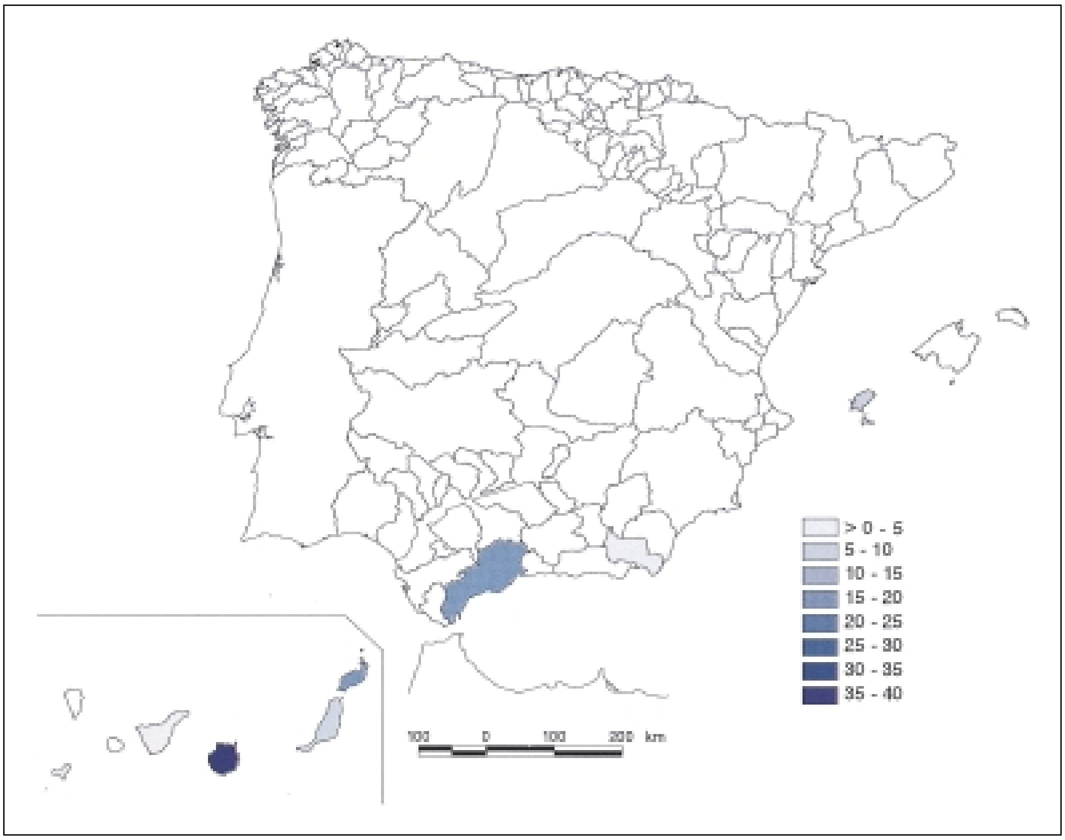


Figure 268. Map of resources from sea-water desalination in exploitation systems (hm^3/year).

We should also consider current transfers which, although they obviously do not increase potential national resources, do modify their distribution, increasing them or reducing them, respectively, in those systems that are the destination or origin of the corresponding transfer. This distribution is carried out by exploitation systems, abstracting the corresponding resources from donor systems and increasing the resources of the receiving system. Nominal transfers have been used, that is, those that may be carried out considering exclusively legal or technical limitations, which represents the maximum utilisation limit of existing transfers, which, although in some cases may be greater than the transfers actually implemented, represents the intended potential value of resource mobilisation by means of transfers.

The transfers considered are shown in figure 269, representing receiving systems in blue, with positive values, and donor systems in red, with negative values. Some transfers have been included that have not yet begun exploitation, such as the Esla-Carrión or the Guadiaro-Guadalete.

3.5.1.4. Demand

This model adopts, as demand representing the current situation, the demand specified in the different basin management plans.

To determine consumptive and non-consumptive demand, and in view of this model's global character, conventional figures for consumption and return in the different uses were initially adopted, which in the case of urban and industrial means a consumption of 20% and a return of 80%, while agricultural use means a consumption of 80% and a return of 20%.

However, on the basis of these habitually-accepted figures, it is necessary to consider the singularity of urban and industrial exploitation next to the coast. In these areas, the possibility of using returns from these is smaller, and is usually carried out by planned or direct reuse, which means a far lower exploitation than in cases with standard return figures. To take this fact into account in the balances subsequently drawn up, urban and industrial demand located less than 10 k from the coast has been identified, which represents about 2,115 hm^3/year on the Peninsula, and about 240 hm^3/year on the islands.

The two archipelagos as a whole currently reuse about 45 hm^3/year, which represents about 20% of urban and industrial demand located less than 10 km from the insular coast. On the Peninsula, current reuse stands at about 190 hm^3/year, meaning about 9% of coastal urban and industrial demand.

Therefore, and to reproduce these re-use possibilities more in accordance with reality, the non-consumptive fraction of demand, that is, that which could be used again, is obtained by applying 20% to irrigation demand in the whole territory, 10% to peninsular urban and industrial demand located less than 10 km from the coast, 20% to urban and industrial demand on the insular coast and 80% to the remaining urban and industrial demand.

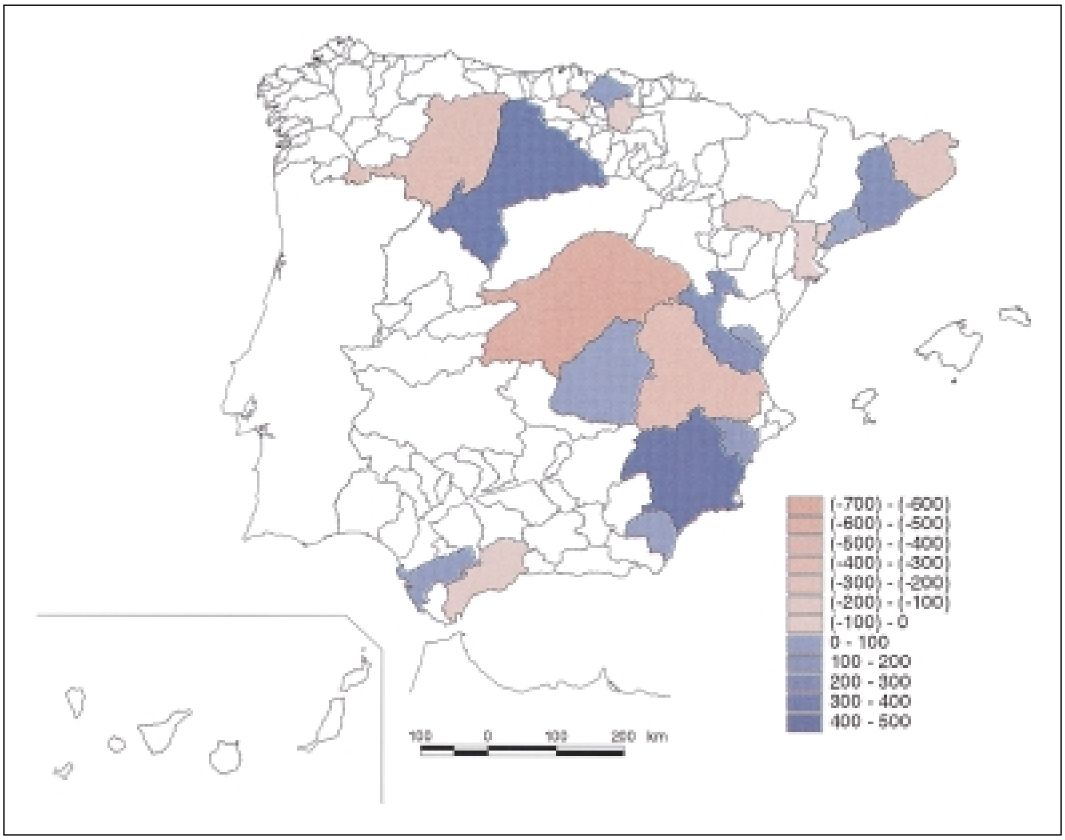


Figure 269. Map of nominal, current or transfers in execution, between exploitation systems (hm^3/year).

As regards consumptive demand that is subsequently included in the balance, this is obtained by applying, in the corresponding areas, the percentages that complement the above, that is, 80% for irrigation demand and 90% for urban and industrial demand on the peninsular coast, 80% on the insular coast and 20% for the rest of the territory.

This procedure, which may seem excessively prolix and laborious, aims to reproduce, with some degree of reliability, the possibilities of re-mobilising resources on the coast, where major urban concentrations are located giving rise, fictitiously, to significant possibilities of using returns if conventional figures are accepted. This could considerably distort the results, especially affecting demand for these large concentrations.

By applying the above-mentioned percentages to the demand maps for each use, we obtain the maps corresponding to consumptive and non.-consumptive fractions of each of them, and from there, maps of total demand and extraction, together with their consumptive and non.-consumptive fractions.

The resulting map of current total demand, always according to the data provided in the basin management plans, is shown in figure 270.

So as to more clearly appreciate the resolution of the work used, figure 271 shows two details of this map, corresponding to the areas of Madrid and Valencia. They illustrate the high demand of conurbations and the concentration of irrigated areas on the Valencia coast.

3.5.1.5. Balance

Once the maps of potential resources and demand have been drawn up, they are compared to identify existing imbalance and its territorial location.

The balance is made between the maps of potential resources and consumptive demand. The first of these, as mentioned, consist of the non-reserved fraction of natural resources plus the resources from sea-water desalination, and taking into account the redistribution derived from current transfers.

As regards the map of consumptive demand, it has been obtained, in accordance with the procedure described, by applying 80% for irrigation demand and 90% for urban and industrial demand on the 10 km coastal strip, 80% on the same insular coastal strip and 20% for the rest of the territory, thus reflecting the different direct or indirect possibilities of re-using the resource-

The resulting balance produces two maps which represent the cells of the territory showing deficit, that is, those where the potential resource is lower than consumptive demand, and the cells with surplus, that is, those where the potential resource exceeds consumptive requirements. Both maps are shown in figures 272 and 273.

As may be seen, the territorial distribution of deficit practically coincides with the distribution of demand, intensifying in the major areas of irrigation and conurbations. The map of surplus, complementing the one above, identifies the

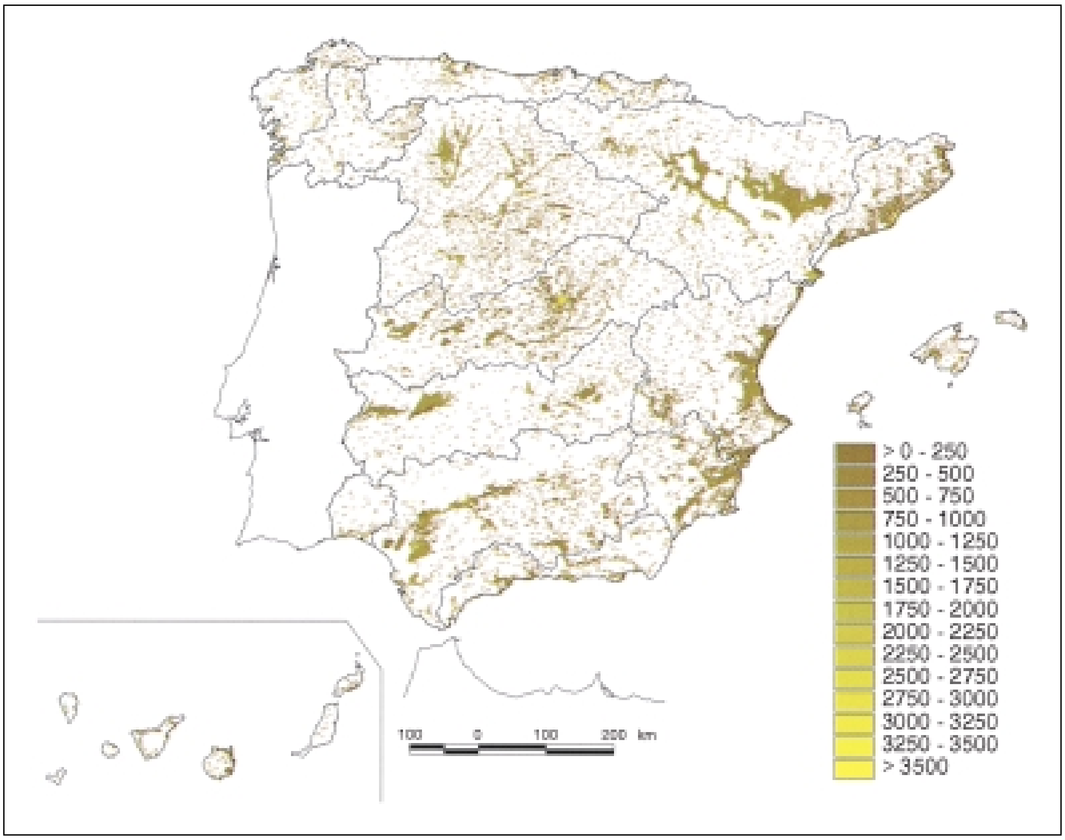


Figure 270. Map of total current demand in mm (urban,industrial and agricultural).

location of territories with abundant water in the peninsular north, except for isolated zones.

As mentioned above, these maps only have illustrative value, since water exploitation is not carried out in an isolated way in each cell, but takes place on an upper aggregated level, in a framework of broader territorial management units, with relatively autonomous exploitation. Nevertheless, on the basis of the two maps, it is possible to make this aggregation, and compare potential resources and consumptive demand with various levels or territorial integration. The first of these levels refers to the exploitation systems defined in the basin management plans, continuing with aggregation in the scope of each plan.

3.5.1.6. Territorial aggregation by exploitation system

In view of the hypotheses assumed in this cartographic model, the aggregate balance by exploitation system assumes the complete utilization of potential resources gen-

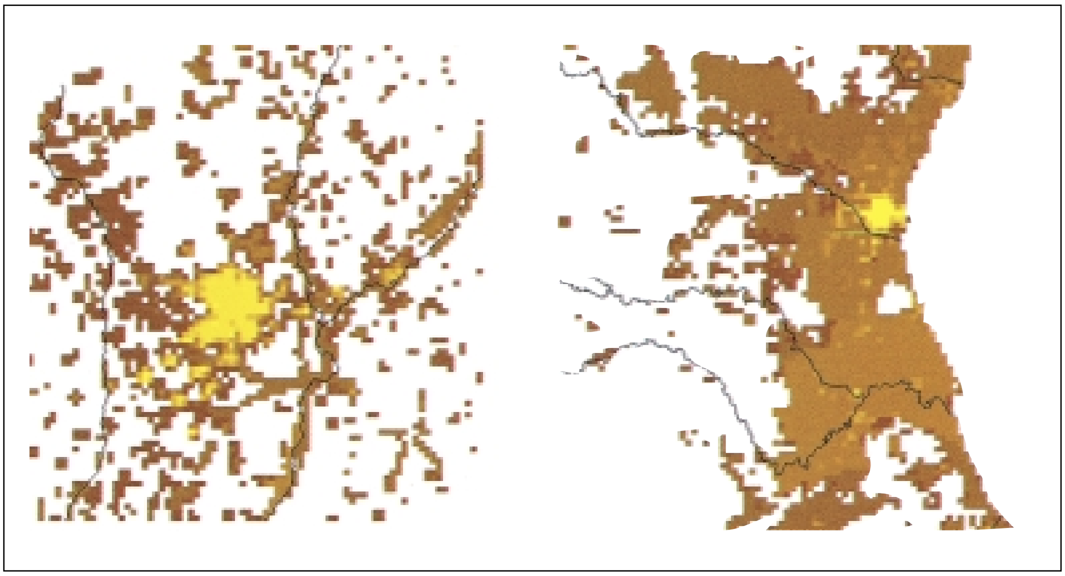


Figure 271. Detail of the total demand map in the areas of Madrid and Valencia.

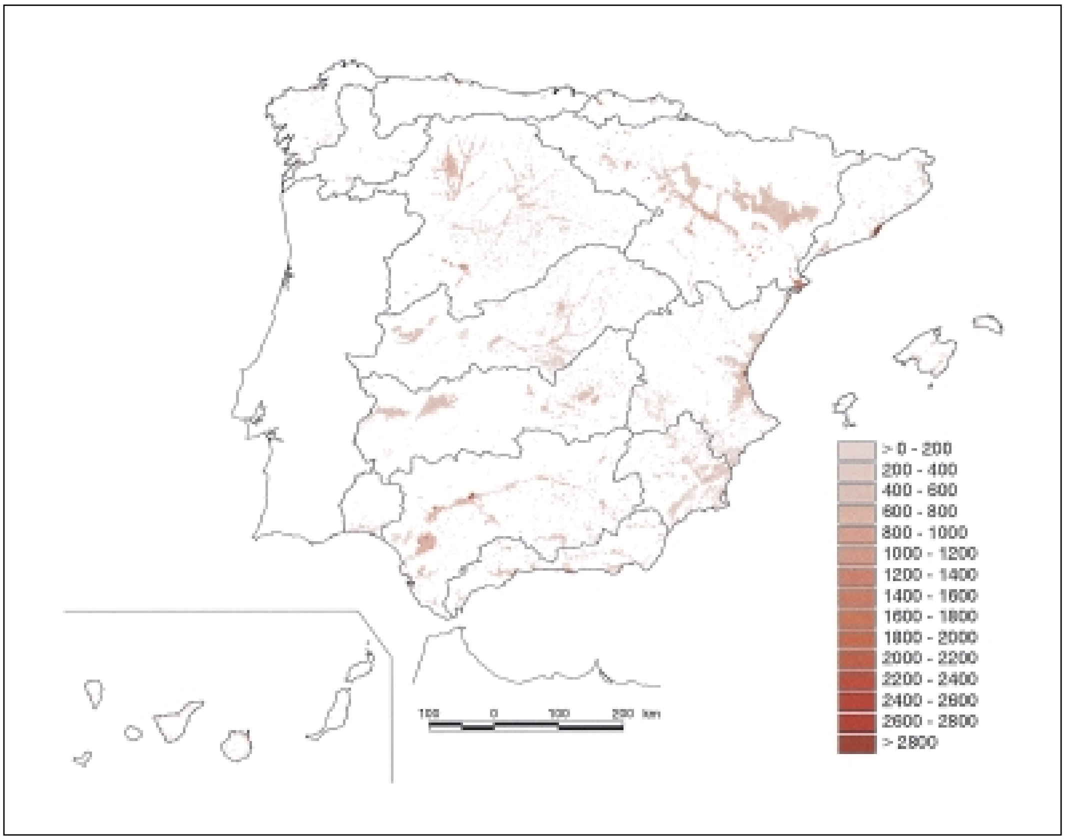


Figure 272. Map of territorial distribution of deficit (mm/year).

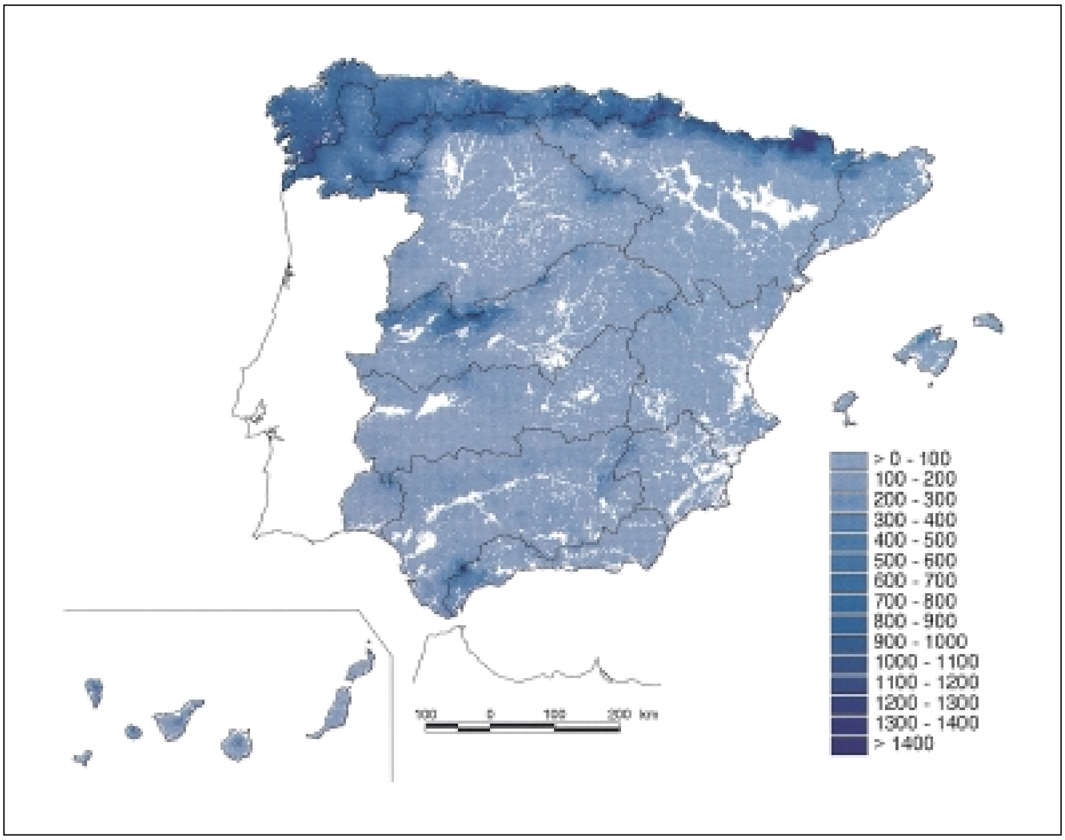


Figure 273. Map of territorial distribution of surplus (mm/year).

erated in the system's whole territory, in addition, where relevant, to resources originating from sea-water desalination and transfers from other systems. This represents a maximum exploitation limit which would require all the necessary infrastructures and to comply with the requisite quality standars. The model assumes, therefore, that such infrastructures exist and that there are no limitations due to water quality, so that supply limitations arise, exclusively, from the lack of water resources.

All this means that a deficit system (defined as that where the sum of the balances in all its cells is negative) will be unable to cover the consumptive fraction of its demand even in the extreme event that it was equipped with all necessary infrastructures for full exploitation of its potential resources, and that these complied with the necessary quality requirements.

Conversely, in cases where the system shows a surplus (defined as those where the sum of the balances in all its cells is positive) we should not deduce that supply problems never arise. These problems may exist, even serious ones, but not as a result of lack of resources, since globally they are greater than consumptive needs in the system's territory. They may arise from a lack of storage or transport infrastructures, or limitations due to water quality, or to the existence of environmental conditioners greater than the standards suppositions.

On the other hand, the fact of making the balance with values corresponding to the consumptive fraction of demand implicitly means that the maximum possible level of re-use of resources is reached. In the same sense, considering nominal transfers supposes that the maximum legal and technically feasible transfers are in fact made.

In short, the model's results, since they assume full equipment with infrastructures, maximum possible level of re-use, sea-water desalination and the maximum currently permitted transfers, strictly identify those exploitation systems that are unable, even in a scenario of exhaustive exploitation, to reach reasonable coverage for current demand.

With these premises and definitions, the results obtained are shown in figures 274 and 275.

The deficit map shows that these sites are located mostly on the Segura, Guadiana headwater, Vinalopó-Alacantí and marina Baja on the Júcar, eastern zone of the South basin (systems of Sierra Filabres-estancias, Sierra Gador-Filabres and Sierra Nevada), together with other, smaller systems on the right bank of the Ebro (Huerva, Aguas Vivas, Huecha ansd Queiles). However, despite the fact that all these systems show a deficit, the magnitude of the problems is, obviously, very different, and the situation of the systems on the right bank of the Ebro, of great local importance, is not comparable with that in the Guadiana headwater or the group made up of the southern systems of the Júcar, the Segura and the eastern systems of the South, with considerably greater territorial impact and dimension.

The surplus map, on the other hand, gives an idea of the overwhelming majority of systems with a positive balance, that is, systems with excess natural resources to cover cur-

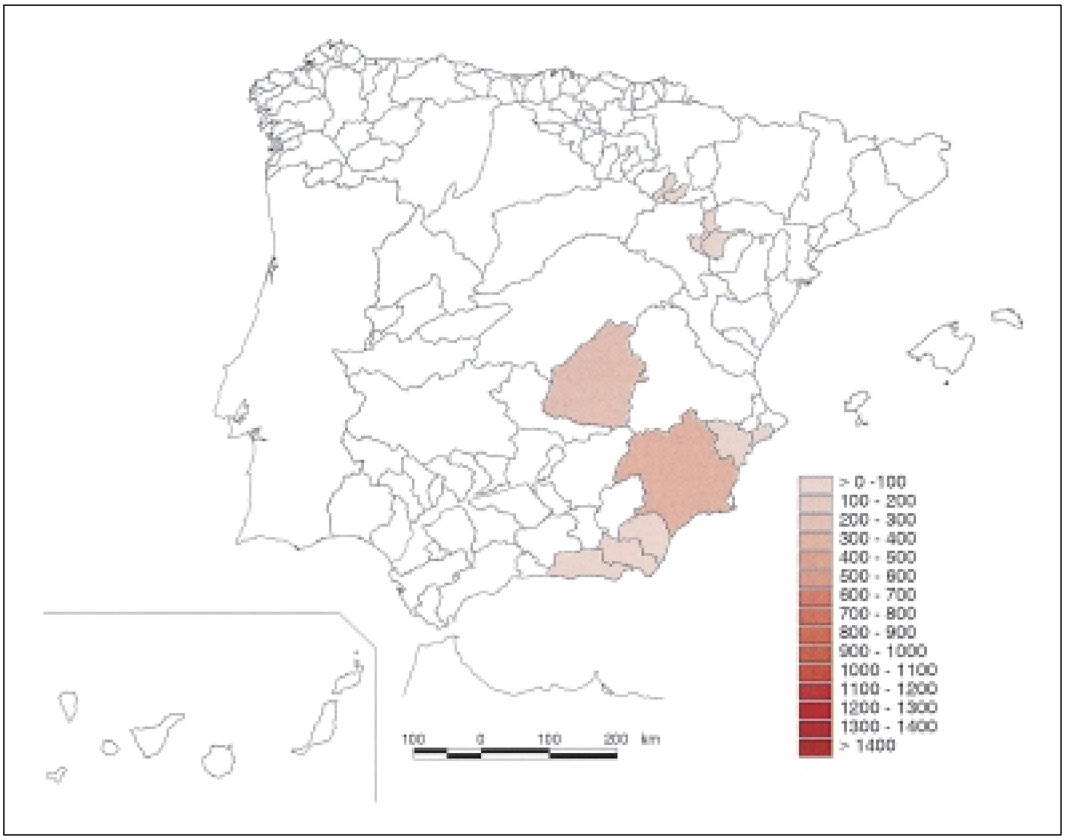


Figure 274. Map of deficit (hm³/year) in exploitation systems.

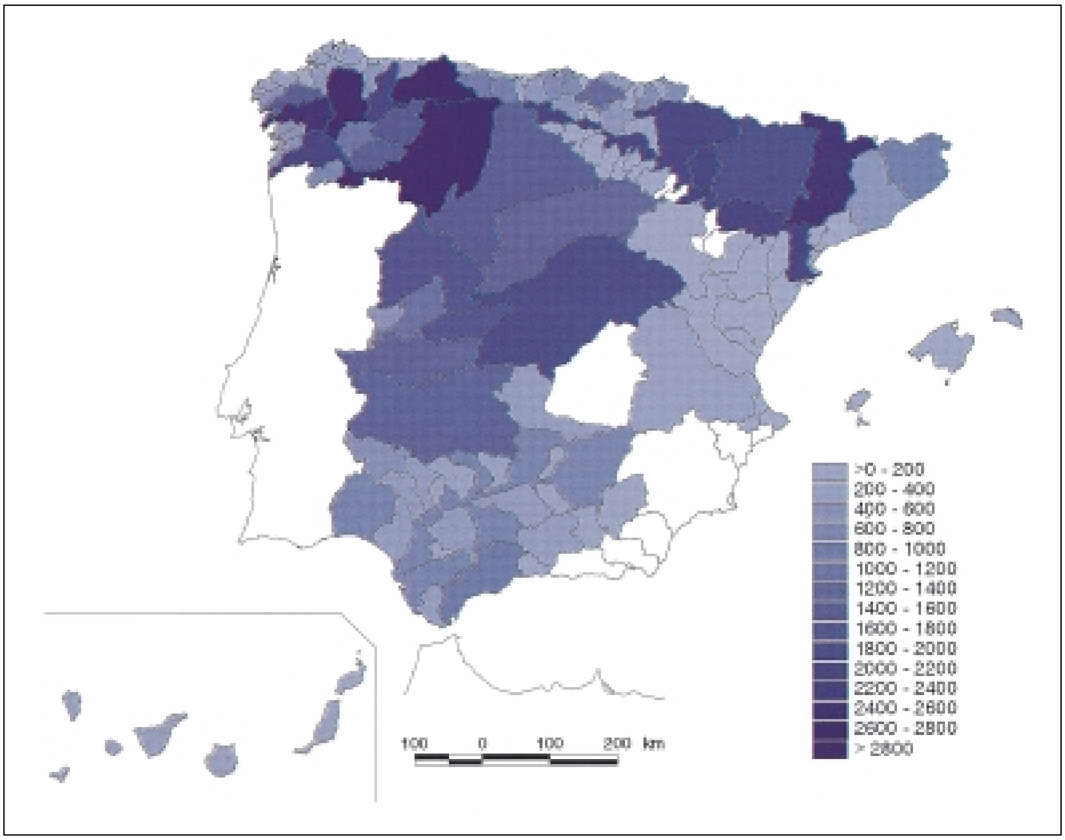


Figure 275. Map of surplus (hm^3/year) in exploitation systems.

rent demand, including transfers to other systems. As mentioned above, this theoretical aggregate surplus does not imply that such demand cover is in fact being correctly carried out. The map also shows the clear asymmetry between the left and right bank of the Ebro and the basically surplus character of most of the systems of North I (Navia and Nalón), together with the Esla-Valderaduey system on the Douro and the macrosystem at the headwater of the Tagus.

However, these maps may give rise to erroneous interpretations, since they use absolute figures, which vary greatly from one case to another. To avoid this, exploitation and consumption indices have been drawn up, relating total demand and consumption, respectively, with potential resources. The second of these gives rise to the map of shortage risk shown below (fig. 276).

The figure illustrates that deficit systems have a structural-type shortage, that is, the potential resource, including re-use, desalination and transfers, is systematically lower than the consumption level it is intended to reach. There also exists, however, a series of systems which, even with surplus, run the risk of suffering circumstantial shortage, due to consumption levels that are very close to potential resources. In such conditions, adverse hydrological sequences may cause supply problems due to lack of resources. These situations of circumstantial shortage occur in Hoya de Guadix, Jaén and the Guadalquivir general regulation system, Sierra Tejeda-Almijara in the South, almost all the Júcar, except Marina Alta and the systems with structural shortage (Vinalopó-Alicantí and Marina Baja), Alhama, Jalón, Martín, Guadalope and Matarraña on the right bank of the Ebro, central and southern systems of Catalonia and the islands of Ibiza, Tenerife and Gran canaria.

As may be seen, a significant part of the exploitation systems in the south-eastern half of the Peninsula, together with some systems on the right bank of the Ebro, part of Catalonia and some islands, even in the hypothetical case of maximum potential resource exploitation, including desalination and transfers, and maximum re-use levels, would be subject to structural or circumstantial resource shortage.

It should be noted, however, that the situations of circumstantial and structural shortage have different levels of seriousness. In the first, problems with lack of resources are temporary, and are generally associated with adverse hydrological spells, in such a way that under conditions of hydrological normality they do not have problems. In fact, it should be remembered that these systems, even circumstantially subject to risk of shortage, show average surplus in greater or lesser amounts. In situations of structural shortage, however, the systems are permanently unable to cover consumption, and the lack of resources, even in the event of exhaustive exploitation, represent a chronic problem.

In these circumstances, and considering that the balance is made with the consumptive fraction of total demand, if the intention is to reasonably cover current demand, the solution to remedy such decompensation can only stem from an increase in the supply of external resources, from sea-water desalination, or from other systems not liable to such risk and with a low level of use of potential resources.

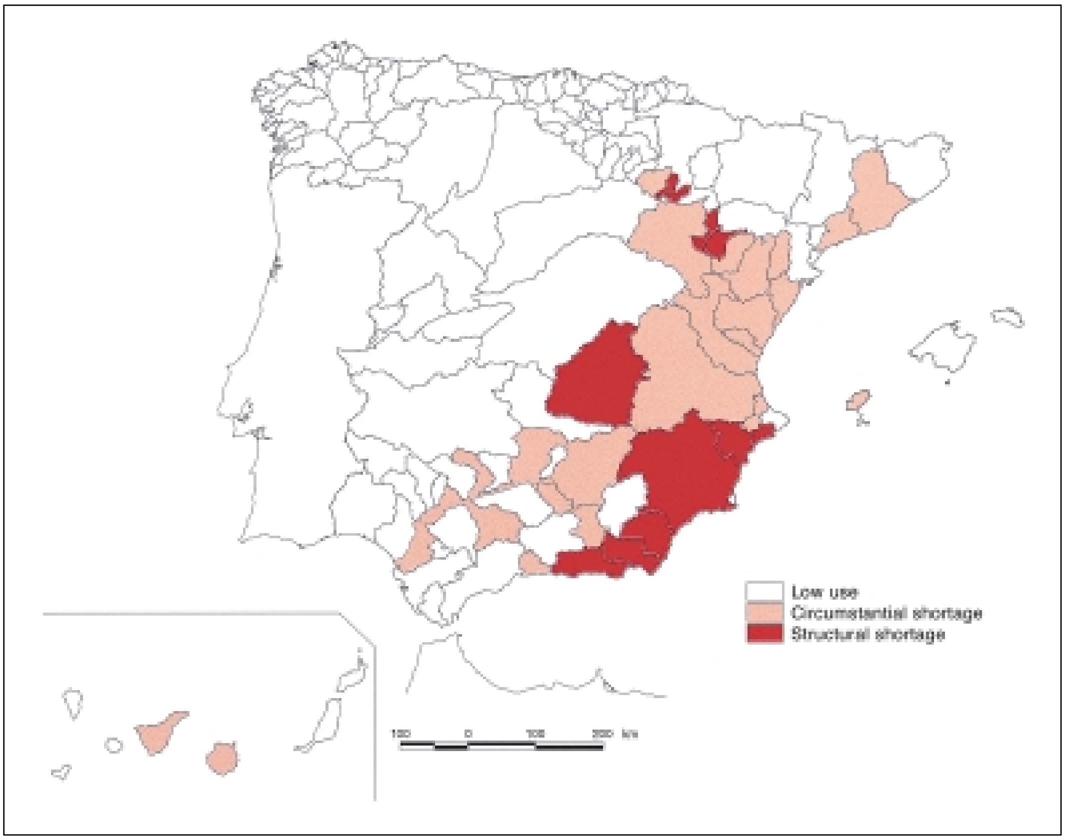


Figure 276. Map of shortage risk in exploitation systems.

3.5.1.7. Territorial aggregation by planning area

With the same consideration as above, a second level of integration has been carried out in the territorial area of each Water Plan. The result is the location of plans with deficit or surplus and the identification of those subject to some kind of shortage risk.

The maps obtained are shown in figures 277 and 278.

The maps clearly reveal that the only plan unable to cover its own consumption levels, in the supposition of maximum exploitation of the potential resource (including transfers and desalination) and maximum re-use levels, is the Segura. The rest of the plans, although they may show shortage problems in some of their systems, could, in such an event, remedy these problems with own resources generated in their territorial area. This does not mean that the solution to existing decompensation should always be sought within the scope of each plan, since there may be more appropriate solutions based on the use of resources from systems in other areas, which are closer or whose level of potential resource use is lower.

At this level of aggregation, analysis by exploitation and consumption indices gives rise to the map of shortage risk shown in figure 279. It illustrates the structural shortage in the area of the Segura and a risk of circumstantial shortage in the Júcar and South areas, whose aggregate levels of consumption are relatively close to potential resource values. In the rest of the plans, there are no global shortage problems, although, as commented above, localized problems arise in certain exploitation systems.

3.5.2. Analytical modelling of the water allocation system

3.5.2.1. Introduction

The preceding cartographic model is useful for finding out, in a preliminary analysis, the classic discordance in the field of water resource planning and management between the location of the resource and the location of the use, in addition to the discordance in mean values between the natural offer of the resource and demand. This is the strict meaning when the analysis is made on the scale of the elementary cell considered.

When the analysis is carried out in the environment of an exploitation system according to the hypotheses made in the above section, the result is a maximum bench mark of the resource exploitation, and its utility consists of identifying, homogeneously, rapidly and transparently those units that unequivocally are in a situation of shortage, and those units that could have a very favorable relationship between supply and demand. The result has the same meaning when the analysis is carried out on a scale of territorial planning areas.

It is, therefore, an initial calibration of the large figures resulting from the comparison between resources and demand, which is a necessary prior step to outline later analyses in greater detail. In short, the cartographic model described allows a procedure to be carried out, in a clear and simple, but homogeneous and rigorous way, a simplified territorial accounting of the balance between resources

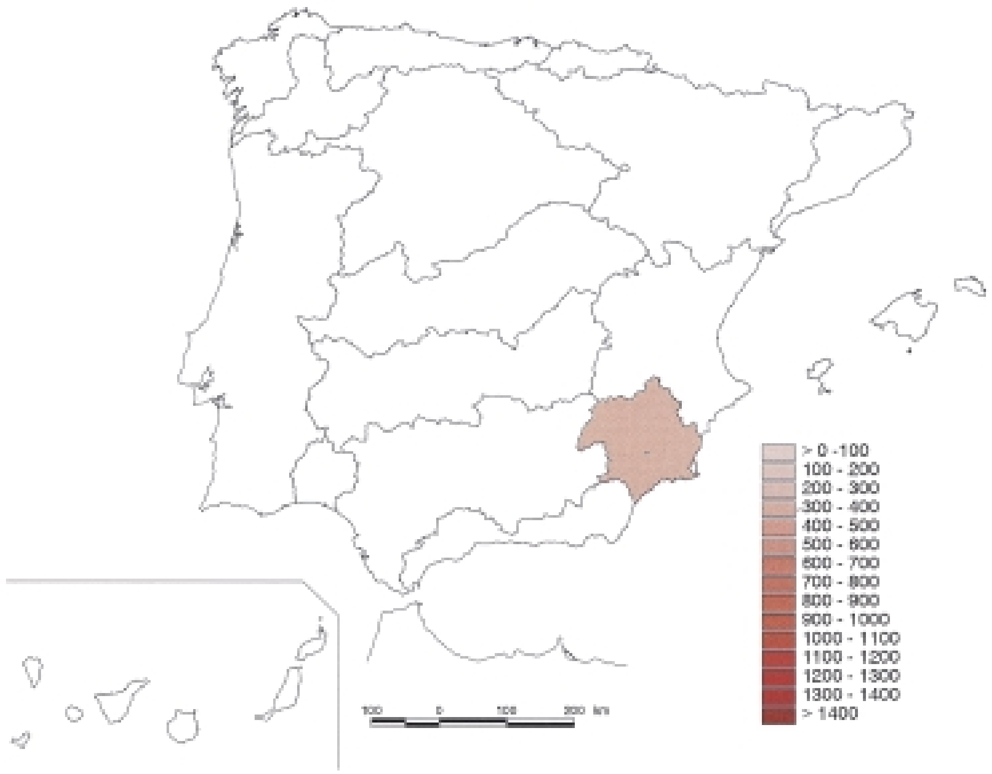


Figure 277. Map of deficit (hm³/year) in basin plan territorial areas.

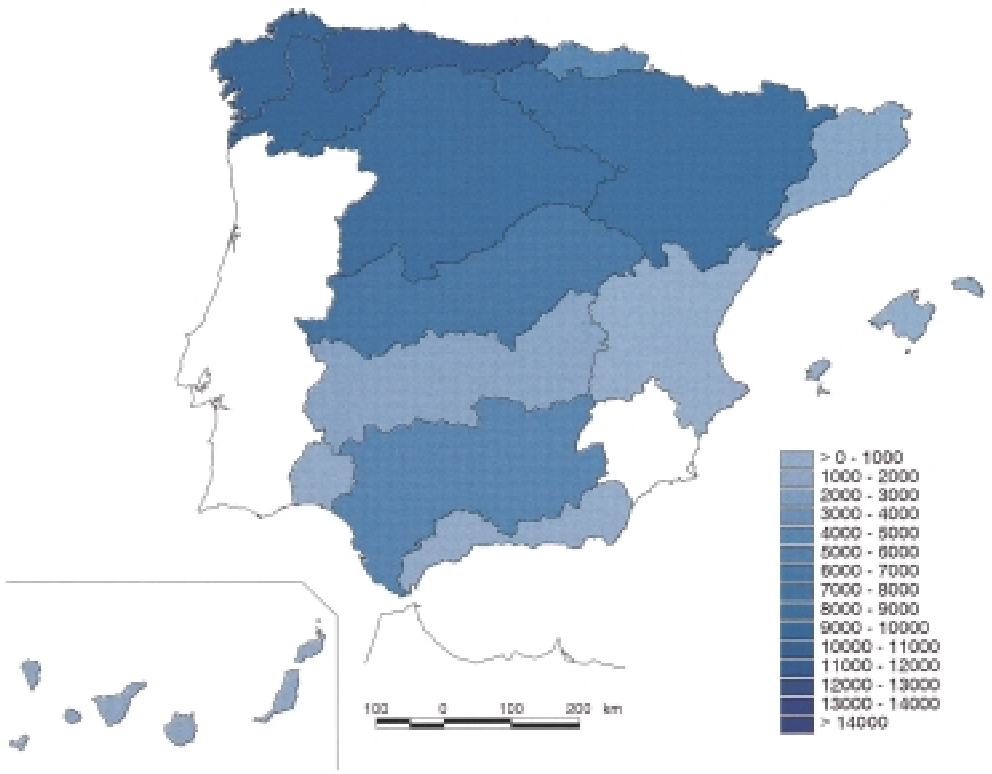


Figure 278. Map of surplus (hm³/year) in basin plan territorial areas.

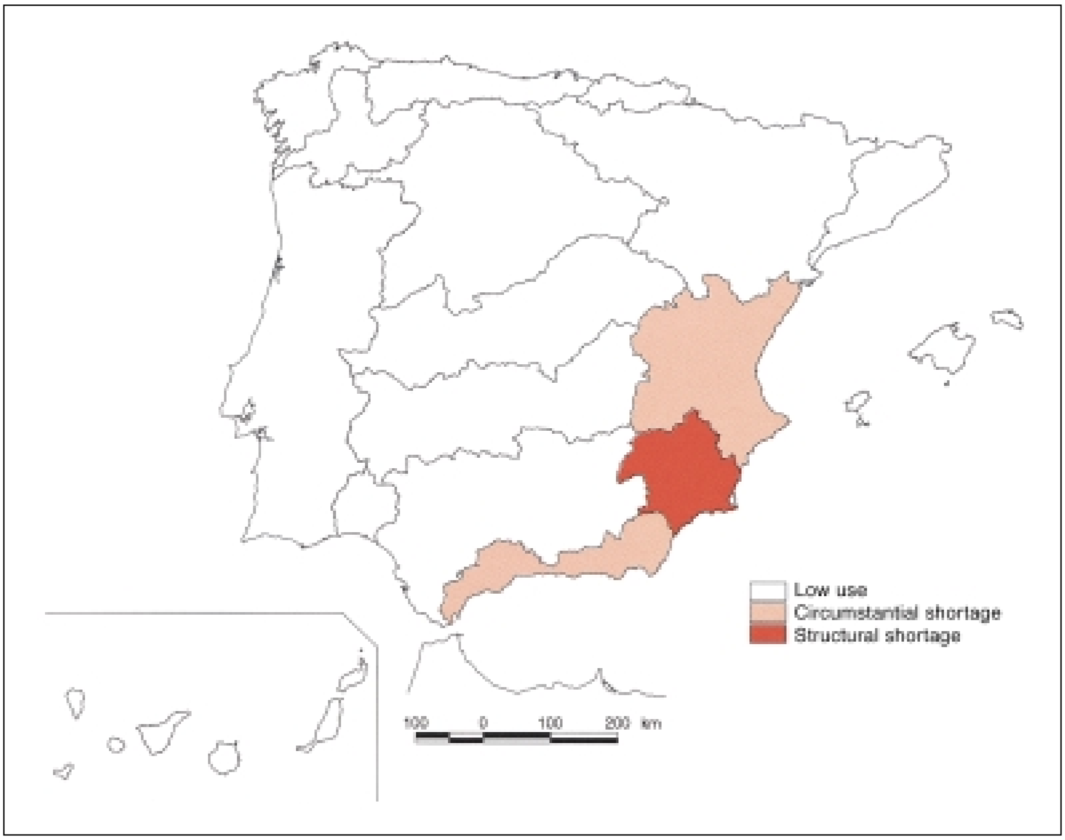


Figure 279. Map of shortage risk in basin plan territorial areas.

and demand, and to initially identify the areas where attention should be centred.

However, if we aim to have a more realistic assessment of the situation in these areas, and of the possibilities of action in the national area, it is necessary to carry out the analysis bearing in mind the temporal variability of resources, and introducing two fundamental aspects for their exploitation: the elements of regulation and transport (both artificial –pipelines and reservoirs–, and natural –rivers and aquifers–), and the management of systems.

It is absolutely necessary to take into account the temporal variability of resources, because, as we have been mentioned above, the use of mean annual values only provides upper bench marks of resource exploitation in the hypothesis that it were possible to completely eliminate this variability, which is not feasible in most cases. To introduce this variability, it is necessary to extend the analysis to longer time periods, similar to the useful life of the systems (or at least to an order of comparable magnitude), and to consider, as an elementary time unit, a fraction of the annual cycle that represents a balance between the appropriate representation of variability and the complexity of the calculation (a month is usually adopted as the time unit).

The elements of artificial and natural regulation (reservoirs and aquifers) are necessary in the analysis, because the system's capacity to compensate the temporal imbalance between supply and demand will depend precisely upon them.

Finally, the management of the systems is an essential aspect, increasing in importance the higher the level of the resource's development and the closer the relationship between mean values of supply and demand. Management's transcendence is such that efficient administration can mean major saving of investment in infrastructure, both for regulation and for transport, while inefficient management can even end up eliminating the expected profits from these infrastructures. In this sense, it is vital to carry out efficient management, not just at an elementary scale (for example, a reservoir, or an aquifer), but also on a global scale within the exploitation systems and the territorial planning areas, and in an integrated way with resources of different origin. In this last aspect, it is essential to consider, where possible and relevant, the combined use of surface water and groundwater resources, because this provides a more advantageous exploitation of the resource with fewer infrastructures and greater guarantees.

To carry out the analysis appropriately with the introduction of these fundamental aspects mentioned above, and given the complexity and level of development of exploitation designs in most Spanish basins, it is essential to resort to the analysis of systems and to use tools that offer simulation and optimization of resource management with respect to different infrastructure and management alternatives, and with respect to different future scenarios.

The use of these technologies should be made on different scales. On one hand, they should be used in each planning area to analyse their various exploitation systems, as well as for a global analysis of the complete area, as recommended by the Ministerial Order of 1992. On the other hand, they should be used in the national area if interaction possibilities are considered between Plans. As is obvious, in each of these mentioned scales, a different level detail should be used and, therefore, a different conceptual design.

The first scales correspond, in accordance with section 41 of the Water Act, to the structures laid down in the mandatory contents of the basin management plans, while the last scale corresponds, in accordance with section 43, to the work necessary to comply with the mandatory contents of the National Hydrological Plan. These last works should be based on the first, whenever these responded to criteria that allowed them to be considered as sufficiently homogeneous.

To evaluate water allocation systems, the different basin management plans have defined a set exploitation systems, referred to in above chapters, on the basis of which the corresponding balances between resources and demands have been made. The result of these balances shows a deficit in the current situation of about 3,500 hm^3 p.a., concentrated fundamentally and in terms of volume in the planning areas of the Guadalquivir, Guadiana I, Segura, South and Júcar, as may be seen in figure 280.

However, it is necessary to specify that this figure is an aggregate of very different estimates and, therefore, may be qualified. Analysis of the basin plans reveals that they have used different procedures and analysis methodologies, with different interpretations of some concepts and heterogeneous levels of accuracy. Demand has not been treated with enough homogeneity and the guarantee criteria used according to the various uses, when specified, differ considerably. We should add that, in general, the recommendations of the Ministerial Order of 1992 have not been followed as regards the creation of single system for the entirety of each basin, to carry out the global analysis of their exploitation.

To get round all these difficulties that may distort, at least to some extent, comparative analyses, and to be able to make the balances with the homogeneity required by a National Plan, in the preparation work for the White Paper, the construction of an unified system of water resource exploitation was undertaken, comprising the territorial area peninsular Basin Plans, and which allowed a global analysis to be made. The system has been designed on the basis of a set of decision-helping tools for the management of water resources, allowing its behaviour to be analysed in different scenarios, and providing an estimate of resource availability, level of demand satisfaction and the resulting water balances (Andreu et al., 1995).

As an initial instrument it has been decided to create, among the tools available, an optimisation model that can carry out an initial assessment of the major alternatives for action and an initial selection of scenarios according to the previously established framework, by means of the above cartographic model. If the study of the alternatives outlined in the preparation of the National Hydrological Plan showed it necessary, this unified optimisation model can provide subsystems for separate analysis, or else simplified hierarchical diagrams can be designed aimed at highlighting an important aspect of the Plan.

The model has been used in evaluating currently available resources, as described in the corresponding chapter. It has

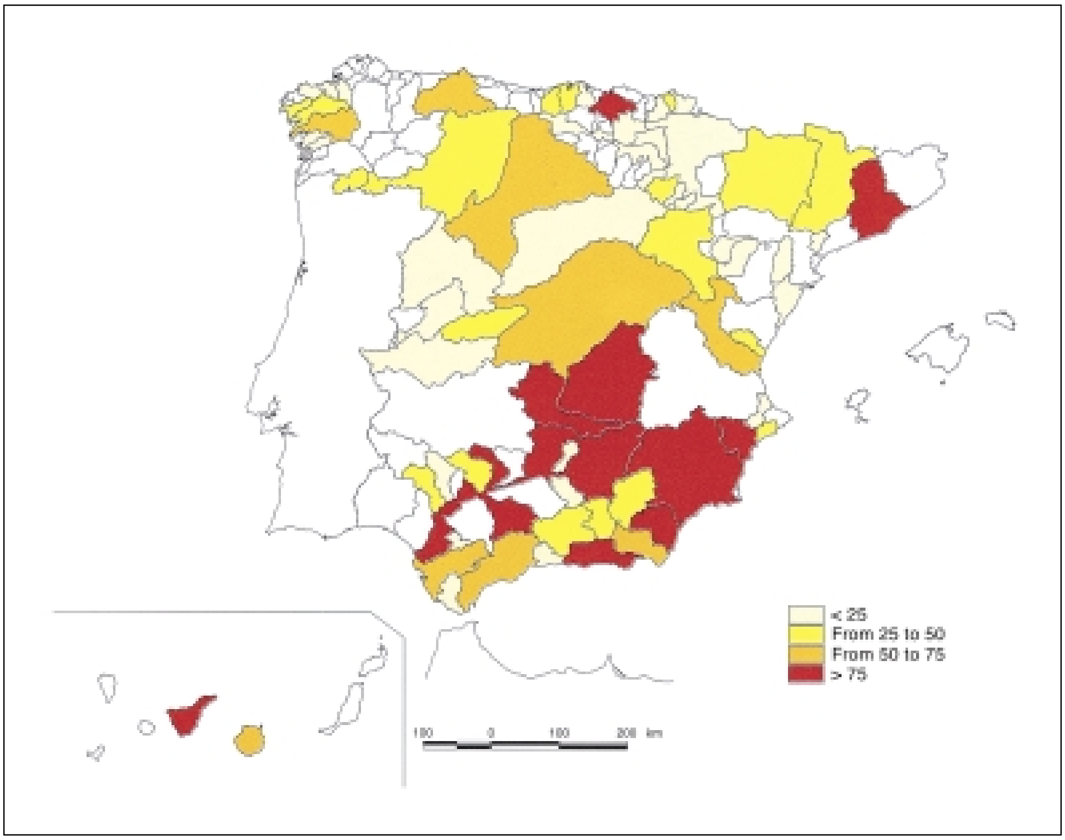


Figure 280. Deficit map (hm^3/year) in the exploitation systems defined in the basin plans.

further provided a unified, organised and intelligible basis of the most relevant information in the current water allocation system in the Peninsula, thus fulfilling one of the objectives foreseen when preparing this White Paper.

The model also allows for analysis, with homogeneous criteria, of the current situation in the different river basins with the latest hydrological information available, verifying the level of coverage of existing and future demand, in accordance with the forecasts on its evolution, and to assess the effect of environmental protection policies and of the different scenarios of socio-economic growth or of development in the agricultural, energy and industrial sectors. Furthermore, it can assess the expediency of the different possibilities for action as regards management of demand or supply increase for water resources.

On the basis of this optimisation model, and if considered necessary in the development of structures by the National Hydrological Plan, it is possible to prepare a simulation model to validate and to refine the alternatives studied previously with the current optimisation model, further allowing more detailed aspects to be included, which may be relevant. This simulation model would allow, for example, a more complete analysis of the aspects related with uncertainty and risk.

3.5.2.2. General scheme

The optimisation scheme designed, referred to the current situation, consists of the main infrastructures (dams, waterwheels and pipelines), existing demands with their return points, river reaches, cumulative water flow and the junctions where rivers or flow come together.

Groundwaters and their exploitation are implicitly taken into account in this model by means of their influence on the cumulative flow considered, whether loss due to the effect of abstraction, as would be the case of the River Júcar with respect to the eastern La Mancha aquifer, or increases due to the effect of recharge (for example, from irrigation returns); by including the deficit of over-exploitation as fictitious demand, as in some units of the Segura basin; or by modifying the acceptable guarantee criteria. In the simulation model which, where appropriate, is developed on the basis of this optimisation model, and according to the alternatives considered in drawing up the National Plan, they could be explicitly included, by means of the corresponding aquifer model, those considered relevant in this respect.

The general appearance of the scheme, in great detail and complexity, can be seen in figure 281.

The following figures show, as an example, the extensions corresponding to the schemes of the Júcar and Segura basins, as they are taken from this unified system. (fig. 282 and fig. 283).

The scheme includes different demand types (supply, irrigation, industrial, recreational and mixed), characterized by annual volume and the temporal distribution of the supply necessary, the required guarantee level and the return.

The reservoirs, or groups of reservoirs, selected in the scheme represent about 95% of Spain's total reservoir

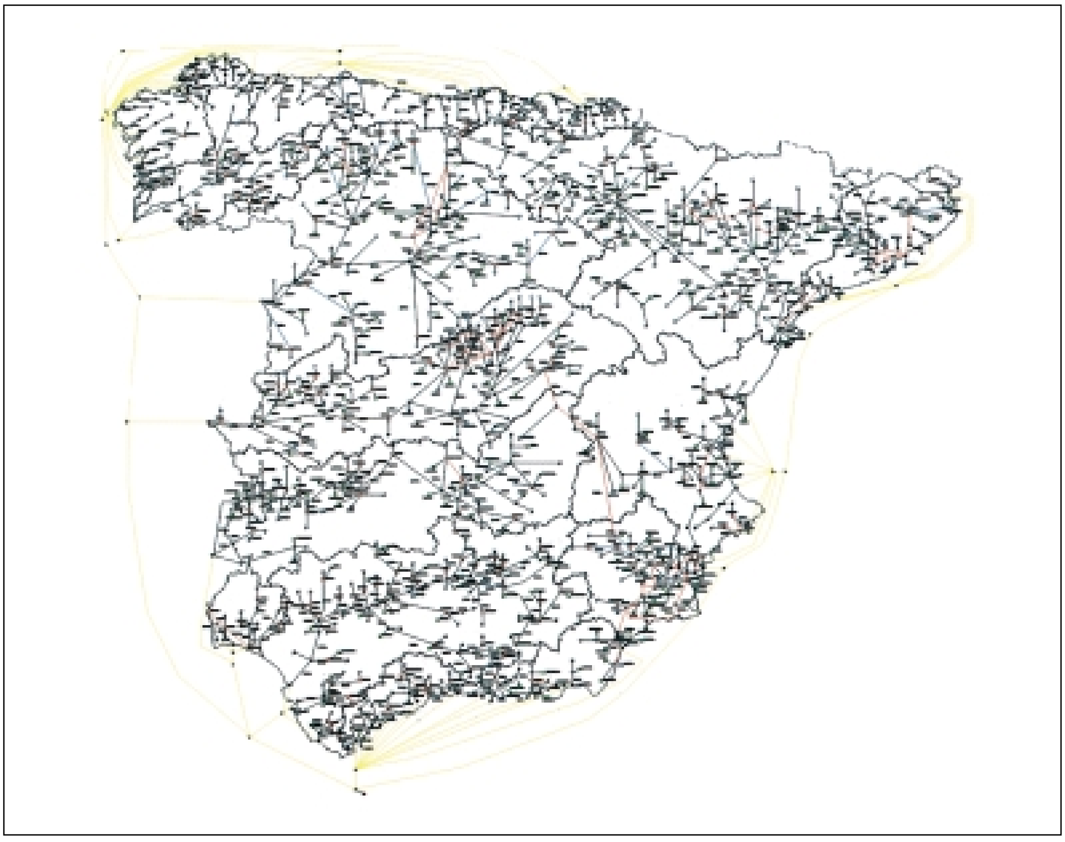


Figure 281. Outline of the unified water resource exploitation system.

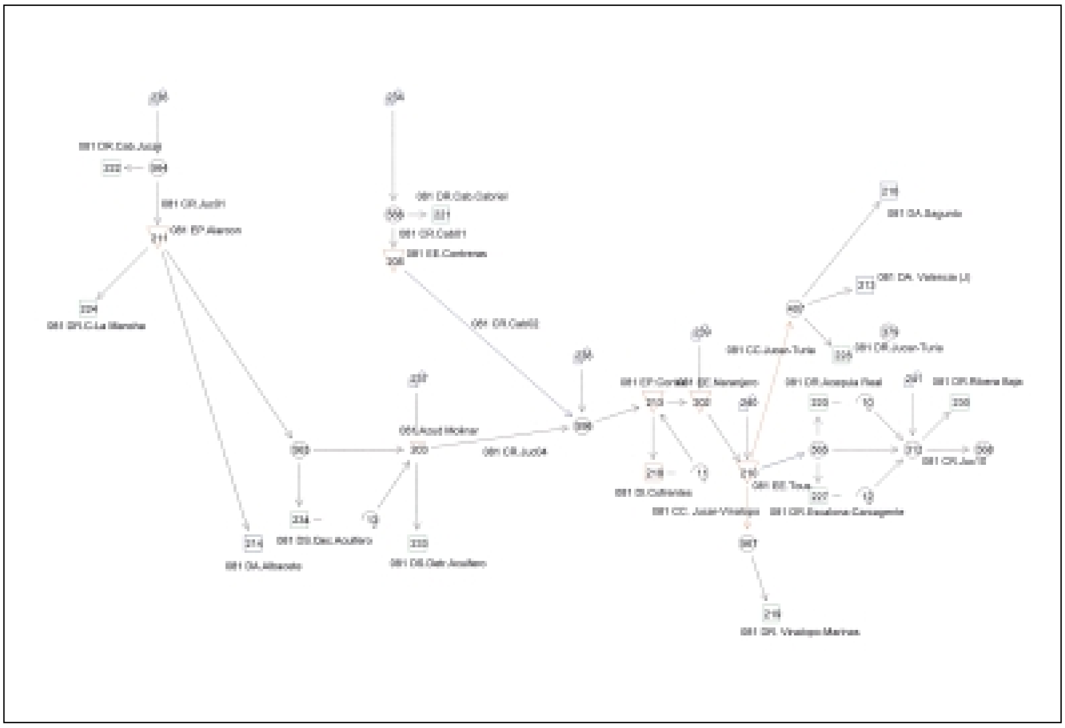


Figure 282. Detail of the optimisation scheme of the River Júcar basin.

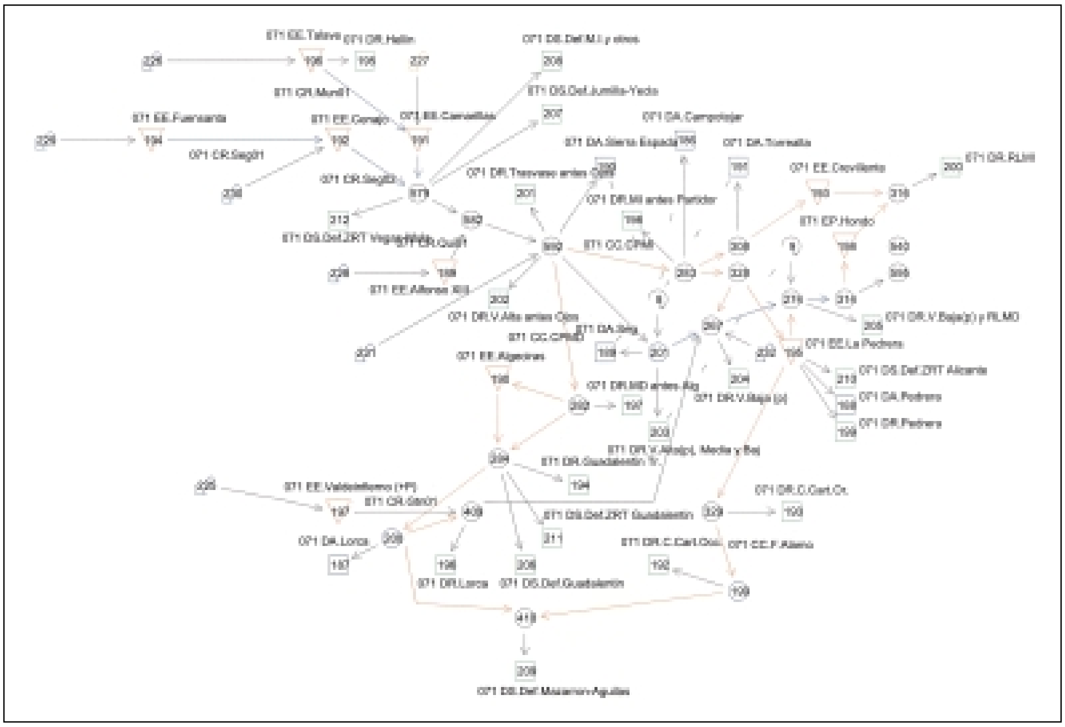


Figure 283. Detail of the optimisation scheme of the River Segura basin.

capacity. They are characterized by their maximum volumes, varying monthly to take into account the possibilities of flood storage, their storage capacities and flooded surface area for different bench marks of dammed water, and the evaporations in the area of each reservoir, obtained with the natural resource assessment model described above. For the purposes of possible later analysis, state reservoirs have been distinguished from those belonging to private individuals, local councils or communities.

The fluvial network is made up of the most important rivers (those whose mean annual cumulative flow in a natural regime it grater then 50 hm^3/year). Natural cumulative flow is included as a monthly series that joins the scheme at about 350 points, corresponding to reservoirs or junctions in the fluvial network.

Environmental requirements are introduced in two ways: as specific units that represent the water needs of wetlands, or as minimum flow that should circulate in the different river reaches and which may vary monthly.

3.5.2.3. Demand units

The scheme includes demand for urban supply, irrigation, industry, refrigeration, recreation (fundamentally golf courses) and mixed, corresponding to the case in which several uses, generally urban supply and irrigation, share one transport infrastructure. The demands are characterized, in accordance with the Regulation on Public Water Administration and Water Planning, by annual volume, temporal distribution of necessary supplies, required guarantee level, order of priority and quantity and restitution point of return.

3.5.2.3.1. Urban demand

For these demands to be included in the scheme, the first step is the localisation of towns larger than 50,000 inhabitants, aggregating those with the same origin of supply. A map with the representation of these towns was given above, when presenting, in the socio-economic framework, the Spanish population and its spatial distribution.

To incorporate demand corresponding to the rest of towns, information has been obtained from the basin management plans, and they have been aggregated considering, as units of urban demand, those where an annual consumption of 4 hm^3 or greater can be calculated and allocated to a certain consumption point. The following cases were considered:

- A town with a single abstraction point that exceeds or equals this quantity.
- A town with a demand around this quantity with several different abstraction points.
- A concrete abstraction point which is used for supplying the established quantity. This would be the case of channels that extract from a river, or pipelines that extract from a reservoir, and supply, for example, several different towns at some distance from each other.
- Several different points of abstraction and several different consumers, but managed jointly. The most typical case would be that of the associations or towns that are supplied by supra-municipal management companies, when the different towns participate in the different abstractions.

Additionally, demand units assimilate urban areas with a sufficient density of towns, although they are not associated and have independent supply, for their geographical proximity and origin of the resources to make them adaptable for the purposes of demand computation to a single town.

It should not be forgotten that we are speaking of annual consumption, so we should also consider tourist towns or resorts where, due to the seasonal population increase, the annual 4 hm^3 is exceeded.

When demand is lower than 4 hm^3/year, the demands have been grouped by river reaches.

For the purposes of modelling them in the global system, urban demands are characterized by annual volume, monthly distribution, level of priority with respect to other demands, return coefficient, supply guarantee and the levels of demand coverage, aiming for equitable distribution of resources in situations of shortage.

For the return coefficient, a general value 80% of the supply is adopted, following the recommendations in the Ministerial Order of September 24th, 1992, by which the complementary technical instructions and recommendations are approved for the preparation of inter-community basins management plans.

As for guarantee criteria, according to these recommendations, supply is considered satisfactory when the deficit in one year does not exceed 10% of the demand, in two consecutive years 16% of annual demand and in 10 consecutive years 30% of this demand. Despite these being the most demanding levels in the range recommended by the M.O., the expediency of such recommended thresholds has been seriously questioned by Sánchez López (1995), suggesting the convenience of reducing them to lower quantities, less tolerant with supply deficiencies.

In fact, such proposed thresholds originate from the criteria used by major supply systems to characterize situations of drought. Accordingly, Canal de Isabel II considers as an objective guarantee that it is not necessary to act in reducing consumption in more than 4% of the years, and that this decrease is lower than 9% of total annual demand (CYII, 1996). The reality is that these reductions of water availability can be assumed, with internal adjustments in some of these big supply systems' services (such as irrigation conditions in parks and public gardens, etc.), without such reductions significantly affecting the public service. In smaller systems, such as those over most of the country, such readjustement possibilities are much smaller, so, as Sánchez López demonstrates, the application of these thresholds would involve a theoretical compliance with the guarantee criteria while, in practice, providing unacceptable service.

For this reason, it has been considered preferable to adopt, as a standard approach for guaranteeing urban demand, the concept of practical absence of supply failure, which we will express operatively by means of accumulated maximum annual deficit thresholds of the 2%, 3% and 10% for one, two and ten years respectively.

3.5.2.3.2. Agricultural demand

The identification of agricultural demand units has been carried out with the main objective of establishing distinguishable management units in irrigated areas, where the origin and the quantity of required resources, the irrigated areas served and the magnitude and destination of returns are defined. Water demand for livestock farming has not been considered due to its low quantitative significance.

The work implemented has used, as fundamental information, that included in the Basic Documentation and in each basin management plan and, as complementary information, that contained in various documents drawn up by central and autonomous administration organisations, and by other related institutions.

In each case, the basis has been the list of irrigated areas included in the basin management plan, indicating, for each area, the irrigated surface area, the annual volume allocated and, generally, the exploitation system or subsystem where it is located. Next, using the basic information and the complementary data mentioned in the paragraph above, the corresponding demand units have been defined. This task has been carried out considering the origin of the resource used and the geographical proximity of the supplied areas, and based, generally speaking, on a variety of basin divisions and, in some cases, administrative borders (municipal districts).

In the delimitation carried out, three basic types of unit have been differentiated:

- Those corresponding to areas of traditional or public initiative irrigation, generally large-sized, whose boundaries coincide with the corresponding irrigation perimeters.
- Those located in river valleys of some importance and their tributaries, that have been delimited on the basis of the basin divisions.
- Those corresponding to frequently scattered irrigated lands where groundwater supply is predominant, which have been delimited considering, according to each case, areas of influence of hydrogeological units, basin divisions and, sometimes, purely administrative boundaries.

The number of demand units identified in the inter-community basins is about 700.

Using the digitized cartographic information provided by various organisations of the Administration and other institutions, and from the CEDEX, a map of agricultural demand units has been drawn up for each of the mentioned basins, which includes irrigated surface area, allocated supply quantity and annual demand in each.

Figure 284 shows the territorial distribution of agricultural demand units identified. Different colours have been assigned for each unit code.

With the purpose of being able to rapidly assign each demand unit with any additional geographical information (for example, identification studies of irrigated areas by teledetection) a semi-automatic procedure has been set up based on crossing information on irrigation with a layer of geographical information which includes the maximum perimeters of the agricultural demand units obtained by applying geographical, hydrological, hydrogeological and administrative criteria, and others relating to the particularities of each unit.

For its modelling within the system, agricultural demand, the same as for population supply, is characterized by annu-

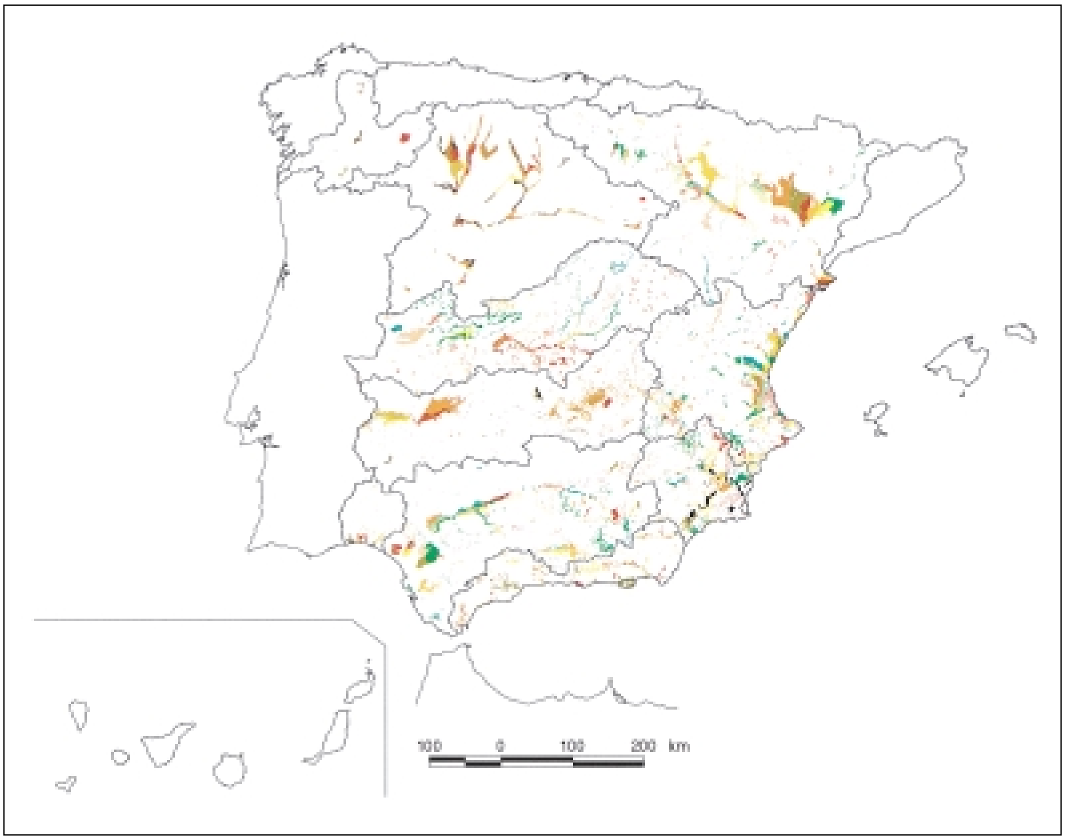


Figure 284. Map of Agricultural Demand Units in intercommunity basin plans.

al volume, monthly distribution, level of priority regarding other demand, return coefficient, supply guarantee and the levels of demand coverage, aiming for equitable distribution of resources in situations of shortage.

For the return coefficient, following the recommendations of the Order of 1992, a value is adopted that depends on annual gross supply quantity and which varies between 0, for quantities lower than 6,000 m^3/ha, and 20% for quantities higher than 8,000 m^3/ha.

As for service guarantee, it is generally proposed to consider supply as satisfactory when deficit in one year does not exceed 50% of demand, in two consecutive years 75% of annual demand and in 10 consecutive years 100% of this demand.

These thresholds are outside (they are slightly bigger) the range recommended by the above-mentioned Order of September 24th, 1992, but they are in accordance with existing international experience, they comprise and give averages for very different crop situations, empirically approaching optimum economic production, and they are those proposed as standard for developers of this type of guarantee criteria (see Estrada, 1994).

3.5.2.3.3. Industrial and refrigeration demand

Although basically the concept of industrial demand unit –not refrigeration– is the same as for urban demand, here demand in excess of 4 hm^3/year is more common, so this limit has been made more flexible. We also have to take into account the possible seasonality of some industries, so the limit has been pegged to the monthly consumption in the months when it is operative (0.33 hm^3/month).

In the cases where it was acceptable, urban demand units were incorporated.

As for refrigeration demand, the model has included the water-cooling requirements of the main thermal and nuclear power stations whose singularity is their very high value of return coefficient.

3.5.2.3.4. Other demand

This category comprises demands of a recreational type, such as golf courses, and mixed demand, represented by those cases where several uses, generally supply and irrigation, share one transport infrastructure.

3.5.2.4. Environmental requirements

So as the model includes the environmental requirements laid down in the Basin Plans, the different possible situations laid down in these Plans have been conceptually identified, typifying such situations, for the purposes of modelling them mathematically, in specific demand nits or conditions of flow circulation.

The map in figure 285 shows –not exhaustively– some points, of different typologies, where environmental requirements have been established as minimum circulation

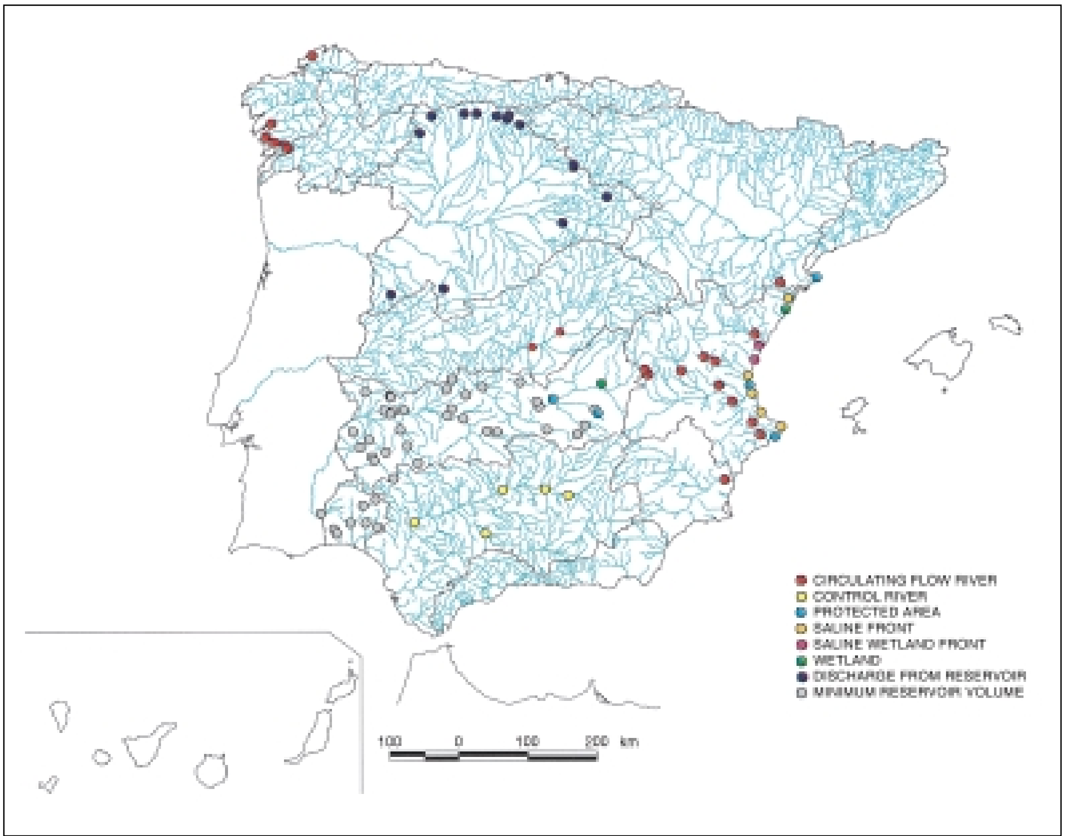


Figure 285. Map showing some selected points and typologies of environmental requirements.

in river reaches, or as minimum volume to be maintained in reservoirs, volume to cover the demands of wetlands or protected natural areas, and volume for defence against saline intrusion in some aquifers.

3.5.2.5. Surface water resources

To build the scheme of the river network, rivers have been selected whose mean annual cumulative flow is greater than 50 hm^3/year. To identify the rivers that fulfil this condition the natural resource assessment model, described in above sections, has been used.

This criteria resulted in a selection of 246 rivers. The mean annual cumulative flow of the these rivers as a whole is about 99,000 hm^3/year, which represents 90% of total mean annual cumulative flow in the Peninsula (110,000 hm^3/year), so the selection made is considered to represent peninsular basic fluvial outline in a sufficiently representative way.

Accordingly, the resulting fluvial network is subdivided into reaches separated by reservoirs or junctions, according to the real configuration of the exploitation system.

Cumulative flow is introduced as a series of monthly values that joins reservoirs or junctions in the fluvial network. These values represent the monthly volumes that would have circulated if the flow regime had remained natural. To obtain these values it is necessary to restore this natural regime from the values registered in gauging stations or to reproduce the process of runoff generation, by means of mathematical models, on the basis of precipitation data.

The data used corresponds to the historical series registered. This stage of the work has not used synthetic series obtained by means of technical of stochastic hydrology. These artificial series allow a sensitivity analysis to be carried out on the system's behaviour with respect to variations in natural resources, so its use is considered more appropriate in later works.

However, two different sets of data series have been used. On one hand, the data used in analysing the exploitation systems of the basin management plans and, on the other, the new series generated by the mathematical model simulating the natural regime described in above chapters. This second group of series, as commented, has the advantages of homogeneity in the calculation process and of the updated analysis period that has been extended to the year 1995/96, so the possible effects of the last drought have been included.

The points where cumulative flow series are incorporated into the scheme have been selected bearing in mind the configuration of the fluvial network, the situation of reservoirs and the location of the main consumption junctions.About 350 points have been chosen, reproducing, with sufficient accuracy, the territorial distribution of natural resources in the peninsular territory. The location of these points is represented in figure 286.

Given the procedure used by the system optimisation model, the cumulative flow series should be introduced gradually,

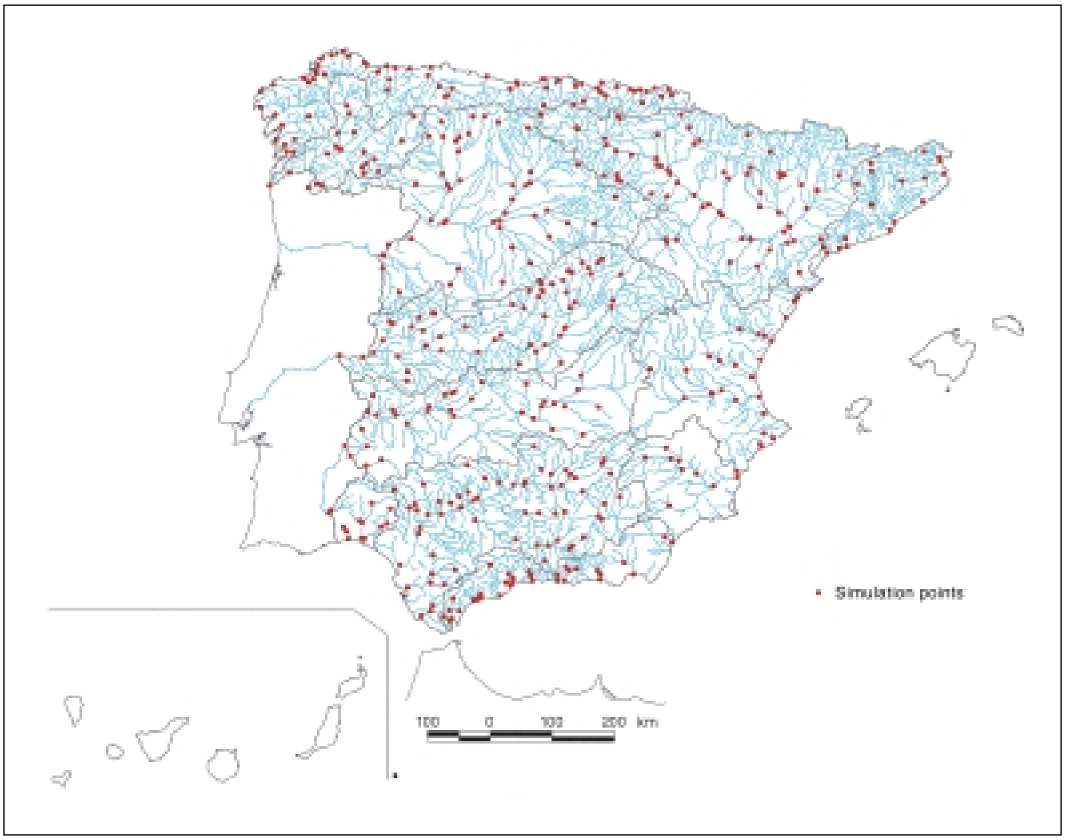


Figure 286. Map of points of incorporation for cumulative flow series.

that is, each series should represent the monthly value for runoff that takes place between the point in question and the incorporation point located immediately upstream.

Because in most cases the cumulative flow series were accumulated, it has been necessary to design a procedure that, taking the network's topology into account, gives the incremental series on the basis of the accumulated series.

In the case of natural cumulative flow series used in the exploitation systems of the basin management plans, it has also been necessary to adapt the data to obtain values for the selected points and to unify presentation formats in the different plans. To generalize this adaptation process, a programme has been designed that allows this data's management and modification.

3.5.2.6. Groundwater resources

Groundwater and its exploitation is implicitly taken into account in the optimisation model by means of the following procedures:

- Its influence on the cumulative flow considered, whether by abstraction , or increases due to the effect of recharges (for example, irrigation returns). This is the case, for example, of the eastern La Mancha aquifer in the Júcar basin, where abstraction due to pumpings from irrigation in the area of Albacete, is deducted from cumulative flow to the River Júcar in the reach comprised between the Alarcón and Piers reservoirs.
- The inclusion of the fraction of over-exploitation that the intention is to eliminate as demand for the surface water system. This would be the case, for example, of the Guadalentín aquifer, in the Segura basin.
- The modification, for computational purposes, of acceptable guarantee criteria. This is the case, for example, of demand in the Ribera del Júcar, where the Plana Sur aquifer allows guarantee criteria for this demand to be relzed, by representing available reserve in dry seasons. Another similar case is that of urban demand in Madrid, where the Madrid aquifer would also allow guarantee criteria for this demand to be relaxed.
- Including the acceptable range of volume variation as just another reservoir in the system. This is the case of some coastal aquifers, such as the Plana de Castellón aquifer, where the range of volume variation comes from the range used in the alternative joint exploitation. The phenomenon of the saline intrusion can be offset using this possibility of alternative joint exploitation.

As general criteria, those aquifers without the possibility of relevant joint utilisation in national water planning have not been considered, because it is with the basin plans' characteristic level of detail that these aquifers' potential joint use may be assessed.

In the simulation model that can be built on the basis of the optimisation model, and according to the alternatives considered in preparing the National Plan, by means of the corresponding aquifer models, those considered relevant after the optimisation analysis may be explicitly included. The possibilities of including aquifers from the simulation model range from simplified analytical procedures to distributed numerical procedures with discretization into finite elements or finite differences.

3.5.2.7. Non-conventional resources

The resources derived from the sea-water desalination are introduced as monthly cumulative flow series, with a modulation adapted to the production rate for desalinated water.

On the other hand, the possibilities of direct re-use are incorporated as elements of return elements in those junctions where demand extracts these resources from.

3.5.2.8. Infrastructures

The exploitation system has included the reservoirs that are fundamental from the point of view of the general regulation of each basin. Taking into account the scale of the work, an effort has been made to simplify schemes trying not to lose significant information in order to appropriately reproduce the system's behaviour. Two parameters have therefore been considered: the reservoirs' capacity and their mean annual withdrawal. The first has been obtained from the Inventory of Dams in preparation, while the second has been obtained from the HYDRO database. In cases where this last information was unavailable or the reservoir was recently built, and therefore had unrepresentative data, the procedure has been to estimate inflow to this reservoir on the basis of hydrological information from neighbouring stations.

Using the two parameters mentioned, the following criteria has been used to make an initial pre-selection of reservoirs to consider:

- All reservoirs with a capacity greater than 200 hm^3 are considered.
- No reservoir with a capacity lower than 10 hm^3 is considered.
- No reservoir whose mean annual withdrawal is lower than 10 hm^3/year is considered.
- Of the remaining reservoirs (comprised between 10 and 200 hm^3) only those whose capacity-withdrawal ration is greater than 0.3 are considered.

This preselection was later refined in accordance with the experience of the technical personnel of the Hydrographic Confederations' Planning Offices, eliminating or adding some reservoirs and identifying possible unions of reservoirs that do not involve significant effects on the system's performance.

The useful available volume for regulation has been considered, by default, as 95% of each reservoir's total capacity, reserving the remaining 5% for freeboard and dead volume. In the case of real data being available for a specific reservoir, it has been included.

In order to model them within the system, reservoirs are characterized, besides by live storage which can vary monthly, by bathymetry, or the relation between stored volume and flooded surface, and by the monthly evaporation rate. To obtain some homogeneous, comparable evaporation values, the results of the natural regime resource model have been used, described in above sections, specifically the mean monthly values of evaporation in the analysis period. Territorial distribution of annual mean values is shown in figure 287.

The bathymetry values have been obtained, in most cases, from studies carried out for the basin management plans.

Finally, each reservoir can be assigned a priority number that reflects preferences as regards origin of supply from some reservoirs or others.

The system has only considered conduits that involve resource transfers between rivers. The conduits that cover demands located in the same basin of the intake point has not been considered, but rather demands have been directly located at this intake point.

As regards modelling them, conduits are characterised by zero minimum flow and maximum flow similar to their transport capacity, which may vary monthly.

Finally, the model also incorporates some fictitious conduits that take into account the series of outlets to the sea from each planning area, and from the whole Peninsula.

3.5.3. Conclusions

The cartographic analysis carried out has allowed us to identify, homogeneously and with technical transparency, the territorial units (exploitation systems or planning areas) that are unequivocally in a situation of shortage, even supposing exhaustive use of all their resources. Also, it has enabled the identification others with a significantly favourable balance between resources supply and demand.

After this initial calibration of the cartographic model, purely territorial, it is necessary to proceed with more specific and more meticulous analysis, but now focusing on the previously-identified large areas. To do this, the above-mentioned analytical model has been designed, incorporating the characteristic detail of the elements that make up exploitation systems, and which provide, in the framework of national water planning, to find out the technical feasibility of the different alternatives proposed in the debate subsequent to this White Paper.

As mentioned above, basic aspects such temporal variability, regulation problems, supply guarantees, trends in consumption and its future projection, etc., must be specifically analysed in that context.

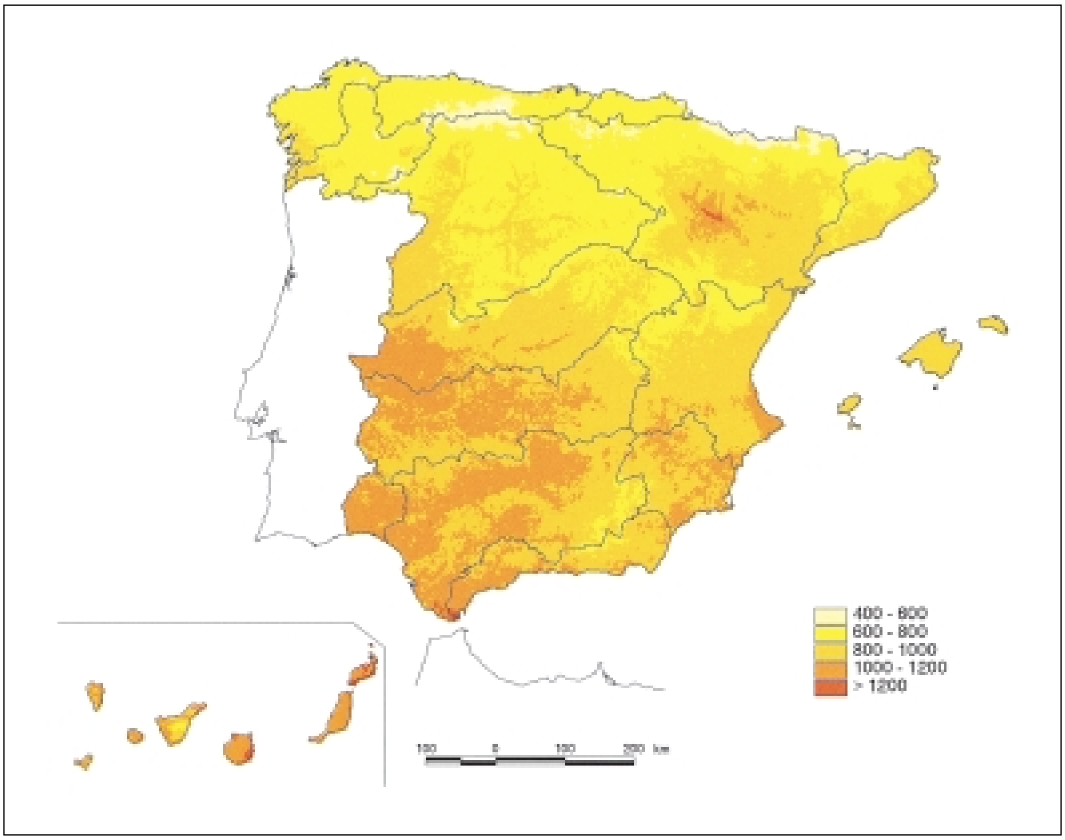


Figure 287. Map of mean annual evaporation in mm (period 1940/41-1995/96).

3.6. EXPERIENCES OF INTER-BASIN TRANSFERS

Having described the resources, demands and situation of exploitation systems, it is expedient to analyse the main structural actions that have been carried out to interconnect these systems, and to overcome the territorial water imbalance, which are the inter-basin transfers.

Firstly, we should point out that no water diversion or use of any size takes place that does not already involve, in a strict sense, an inter-basin transfer. Accordingly, for example, urban supply to Madrid, Barcelona, Valencia or Bilbao is covered by inter-basin transfers, and there are numerous irrigated areas that receive water not strictly originating from the sub-basin where they are located.

Discussion on inter-basin transfers must always bear this in mind, and not forget that it is, more than of a conceptual acceptance or rejection of transfers, which is unfounded in view of their absolute theoretical necessity, a discussion on the scope of scales on which these transfers can be made, and their conditions of acceptability and feasibility on these different scales.

Another fact that is appropriate to remember is that, contrary to what might be imagined, the history of inter-basin transfers in Spain is very old, and numerous antecedents exist at least since the 16th century (see, e.g., Moral Gil [1988]; Gil Olcina [1995]; González Tascón [1998]; Franco Fernández [1999]).

This section summarises the basic aspects of the most significant transfers carried out in our country, leaving for later –in the section devoted to water economy and the Act's general economic-financial regime– analysis of their economic regulation.

3.6.1. Tagus-Segura

The Tagus-Segura transfer was originally planned in the National Plan of Hydraulic Structures (PNOH) of 1933, drawn up under Lorenzo Pardo by commission of the Minister of Public Works Indalecio Prieto. The initial plan was not carried out, regardless of politically-oriented reasons, for two fundamental technical reasons. Firstly, due to lack of demonstration of the existence of surpluses in the Tagus headwater, so significant effects on this basin could not be ruled out. Secondly, because during the process of public information, alternative solutions were put forward, originating from the Rivers Ebro and Júcar, and which raised some doubts as to the suitability of the proposed solution.

In the General Plan of Public Works drawn up by Peña Boeuf and approved by means of the laws of April 11th, 1939, and 18th April, 1941, the Plan of 1933 was analyzed and the studies to implement were suggested before deciding on the different transfer alternatives. Also, three basic guidelines were established for developing water resources on a national level:

- Integral regulation of own resources in deficit basins prior to proposing transfers.
- Improvement of management in deficit basins to reduce external supply from other basins as far as possible.
- Use in the deficit basins of only excess flow from abundant basins.

With these premises, which as may be seen are now being repeated in proposing these issues, the DGOH, in the decades of fifties and sixties, gave preferential attention to remedying the deficiencies of the 1933 Plan, and in 1967 the General Draft of the Tagus -Segura Aqueduct (MOP-CEH, 1967) was published. This Draft was based on the criteria of using surpluses and was framed inside a global preliminary plan for water resource exploitation in the Tagus and Ebro basins in the east of Spain.

The Draft included a new balance criteria based on the possibilities of expansion for the basins affected by the transfers, from which the following conclusions were drawn:

The Ebro basin is not an inexhaustible source of water resources that by itself can cover the whole deficit of the Mediterranean coast, even were it technically and economically feasible, except if it were to end up in worse conditions with respect to the remaining basins. It is not possible to think of depleting its surpluses. The expansion possibilities in which the Ebro basin remains with the combined uses proposed are similar, in percentage of current resource use, to those derived for the Segura basin, which shows the lowest percentage. At the moment, and due to considerations of water balance, it does not seem prudent to allocate more flow from the Ebro to deficit areas.

The Tagus basin must be taken into account when planning a remedy for peninsular water imbalance. Its expansion possibilities, after donating the flow foreseen by the Tagus - Segura joint exploitation, are still very large, because they exceed those of the basin that benefits most from the remedy proposed, in relative terms, which is the Eastern Pyrenees. The non-use of the Tagus' resources in joint exploitation would constitute a waste of our natural resources.

This cleared up the uncertainty that had arisen in 1933, and resolved the old controversy of opting to transfer from the Tagus or the Ebro, coming to the conclusion that both schemes were necessary, concurrent and non-exclusive.

The Draft was drawn up in the Centre for Hydrographic Studies, conforming to the recommendation made in the 1940 Plan with respect to aiming to minimize the so-called *local influence*, considered counterproductive for such works: *The idea of water transfer from one basin to another involves a series of opposing interests, which make it extremely complicated, and since it is very difficult for the Water Service engineers not to be influenced by the local area, it would be prudent for these studies to be carried out by the Directorate General of Hydraulic Works, with the necessary collaboration provided by the Provincial Services.*

Figure 288 shows the scheme for this significant action.

Figure 288. General plan of the Tagus-Segura Aqueduct.

The proposal for the Tagus-Segura aqueduct (ATS) was based, among other things, on the hydraulic reorganisation that supply to Madrid would involve in the Tagus basin, by establishing future water supply sources for the capital from the abundant resources of the Rivers Guadarrama, Alberche and Tiétar. They would enable a diversion of up to 900 hm^3/year, and their returns to the Jarama represented additional resources for the middle reach of the Tagus, so the resources transferable to the Southeast from the Tagus headwater could be considered as coming from the abundant surpluses of the Tagus basin mouth, and which were first utilised supply to Madrid, following the guidelines of maximum resource re-use.

In the Tagus basin, accepting this proposal, two prerequisites were required:

- That the transfer flow be immediately established comparing the regulated, available resources at that moment with the potential demands of the basin.
- That the State takes on, by legislation, a commitment to develop the possibilities of water resource utilisation in the basin.

As consequence of these requests, the transfer was divided into two phases. In the first, the diverted volume would not exceed 600 hm^3/year, a figure representing the spot surpluses calculated for potential demands. To undertake the second, of 400 hm^3/year, it would be necessary to verify, prior new public information, that the available regulated surpluses had grown by such an amount. Act 21/1971 of June 19, apart from laying down the above-mentioned separation into phases, and sanctioning the concept of surpluses for transferred waters, specified the structures and studies that would have to be undertaken in the Tagus basin.

The experience obtained in the procedures for public information of the ATS, first, and then the Ebro-Eastern Pyrenees transfer (see corresponding section), recommended implementing the measures that the Administration stipulated for the new Water Act on the economic-financial regime of hydraulic structures, prior to the ATS.

For this purpose, Act 52/1980 of October 16th was promulgated, regulating the economic regime of the Tagus-Segura aqueduct exploitation, which laid down new principles for setting water tariffs.

This Law has represented one of the most positive steps in recent years in making the policy of hydraulic structures feasible, because on one hand it abandons paternalistic state policies as regards irrigation subsidies, which seems logical if the structures are planned for the economic benefit of the country and, on the other, it encourages the diversion of water surpluses in the Tagus towards the Southeast, because every cubic metre transferred contributes to the economic improvement of that basin's inhabitants by means of the compensation mechanism.

Also, and following the trends of the time, the 1980 Act introduced a new restriction: the maintenance of a flow in the Tagus, before it joins up with the Jarama (in Aranjuez), no lower than 6 m^3/s, although without any specific study to endorse neither the figure established nor its necessity, which shows the possibility of establishing precautionary mechanisms of minimum flow, even when there exist no detailed studies to determine it. This flow in turn underwent singular transitory modification by Royal Decree-Act 6/1995, adopting extraordinary, exceptional and urgent measures as regards water supplies as consequence of persisting drought. These included the possibility of reducing this flow to 3 m^3/s.

Other aspects of the transfer regulation, such as those on the transfer's legal-administrative regulation from the point of view of rights of water use, perimeters of application, coordinated plans of the irrigated areas and the granting of concessions, were the subject of varied, complex proceedings, described in the water planning documents of the Segura basin, and producing a final balance that, from this point of view, cannot be qualified as positive. They lesson of this process may be summed up, once again, as the need to insist on the legal aspects of regulation and administrative control of exploitation, compared with simple water-construction regulation for flow circulation, instrumental and accessory with respect to the former.

The ATS began implementation in 1979, with its first flow arriving in the Segura basin on the 18th of June. For the first 21 years of operation (1978/79-1998/99) an average of 284 hm^3/year has been supplied to the Segura, which increases to 308 if the first two years are not counted. On the whole, about half the foreseen maximum has been transferred, the largest values being reached in recent years (544 hm^3, over 90% of the possible maximum, in 1998/99). Figure 289 shows the annual capacity series of the ATS in Fontanar, the point where the aqueduct ends and the waters are discharged into the Talave reservoir, in the Segura basin from then on. This volume is similar to the one diverted from the Tagus in Bolarque (shown by the fine line), but it does not exactly coincide with it by including losses, spot loans, intermediate intake, channel drainage, etc.

The deficient result that the ATS exploitation has had, with respect to its initial forecasts, has been ascribed by some to calculation errors, such as the consideration of mean values not counting the statistical distribution of series, ignoring regressive trend in flow, considering unreal series, etc. Suffice to examine the hydrological analyses of the Draft (MOP-CEH, 1967) to see how erroneous and unfair this judgement is. Accordingly, and as a simple technical curiosity, we should note that –far beyond the trivial distribution of cumulative flow– it was in fact precisely here that, for first time in Spain and probably in Europe, that the use of synthetic series was proposed for the analysis of flow regulation, in an official, non-academic project, barely a few years after the technique, now widely extended, was formulated by Thomas and Fiering in the classic Harvard book on water planning (Maass et al. [1962], cap. 12).

The reality is that the unfavourable results in the ATS' operation were basically the result of three fundamental overlapping causes where, given the importance of this hydraulic action, we will stop to briefly describe.

Firstly, one basic reason was the intense, prolonged drought that occurred during the period 1980/81-1994/95 (as was clearly highlighted when analysing the water resources), which led to a mean cumulative flow in the Tagus headwater, in that period, of 715 hm^3/year, compared with the interannual average of about 1,270, that is, about 56% of this average. Figure 290 shows the series of net cumulative flow in the Tagus headwater from the year 1912/13 to 1996/97, and the global averages and average from the mentioned

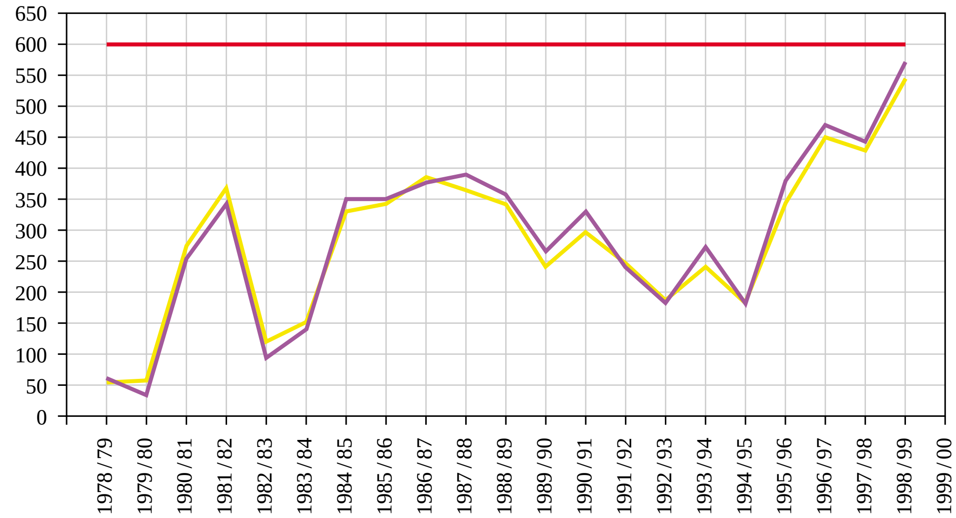


Figure 289. Series of flow from the Tagus-Segura Aqueduct to the Segura basin (hm^3/year).

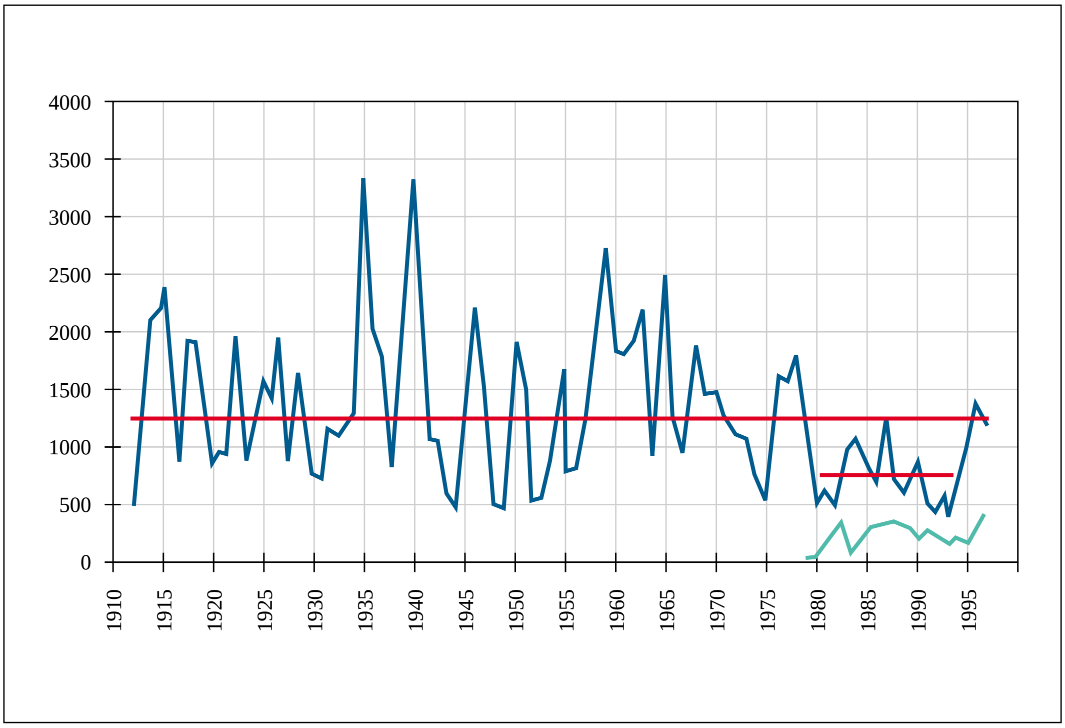


Figure 290. Series of annual cumulative flow in the Tagus headwater (hm³/year).

period of drought, showing this reduction effect with full clarity. The previous series has also been repeated, on volume flowing to the Segura by means of the ATS in that period, illustrating its considerably reduced relative quantity compared with total headwater cumulative flow, and how simplistic and erroneous the statement is –heard on occasions– that at the head of the Tagus enough water does not exist to cover the transfer.

Secondly, this reason purely hydrological reason was overlapped by a poorly-planned exploitation of the Tagus headwater reservoirs during the initial years of implementing the ATS, that gave rise in the two years 1979/80-1980/81 to withdrawals of about 2,000 hm^3, about three times more than necessary to cover the basin's own needs. Such an exploitation regime and its very negative consequences have even led some analysts to suggest the possible existence of liability relating to property (Pérez Crespo [1996]). Also, the two years previous to these (1977-78 and 1978-79) total quantities in excess of 3,000 hm^3 were withdrawn (more than 1,500 hm^3 /year), so, certainly, no use was made of the hyperannual storage required at the headwater.

Figure 291 shows the series of annual outflow from Bolarque over the last 20 years, and of annual inflow to the Almoguera waterwheel. With some slight differences, both series are similar and very indicative of head withdrawals, and show the large outflow volumes of the late 70s, and the effect of moderation, regularity and control of the exploitation carried out in recent years.

Figure 292 shows the monthly quantities stored in Entrepeñas-Buendía since the hydrological year 1960-61, and also shows the spectacular ongoing emptying that took place between the year 1979 and 1983, when reserves were depleted and, as seen, with a long drought ahead that made their recovery impossible. These were the years of tension and the water war.

Finally, a third explanatory circumstance for this operation is the lack of formal definition, in all the years, of what should be understood by surplus resources, the only ones that could legally be transferred. This lack of specification generated countless conflicts and discussions on possible transferrable quantities at each moment, given the discretionality with which the concept could be interpreted.

As regards the first hydrological circumstance, we have nothing to add, except that it will have to be taken into account for the future management of the Tagus headwater system, as is already being done by means of the recently drafted exploitation rules (MIMAM, 1997b).

Regarding the second cause, it certainly stands as a lesson for the future, and it has contributed, as we have seen, to the Tagus Hydrographic Confederation adjusting headwater discharge to their real requirements, and carrying out, in recent years, optimum exploitation of the system.

With respect to the third, it has been fully overcome by the Tagus Basin Plan fully and precisely defining what should by understood by surplus resources.

3.6.2. The mini-transfer to Tarragona

What is known as the mini-transfer Ebro-Tarragona is another of the major inter-basin resource transfer actions in Spain. As a significant forerunner to this action, it is expedient to consider the failed transfer project of the Ebro - Eastern Pyrenees, with which we shall begin by briefly describing.

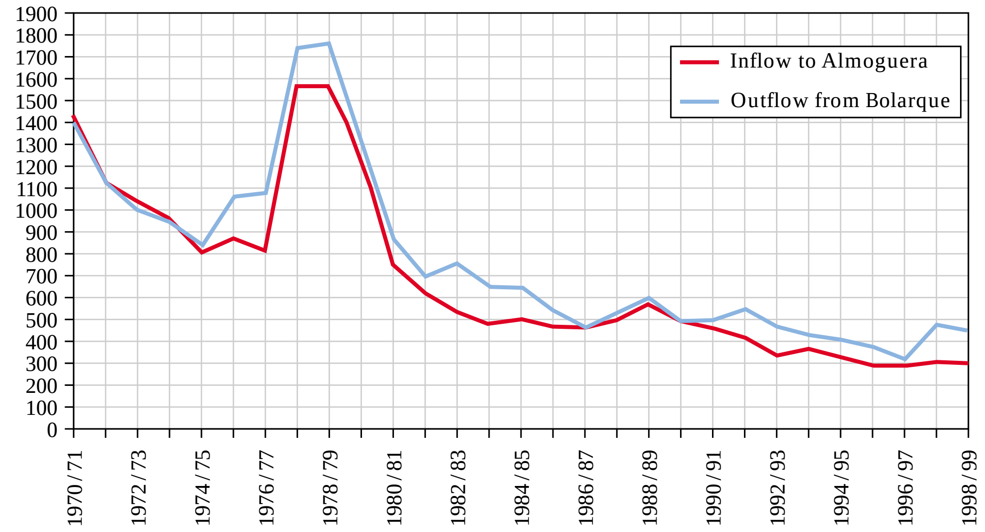


Figure 291. Series of annual withdrawals from the Tagus headwater (hm³/year).

3.6.2.1. Antecedents. The Ebro-Eastern Pyrenees transfer project

In accordance with the guidelines laid down in the mentioned General Preliminary design of combined use of hydraulic resources in the Centre and Southeast of Spain, the DGOH, implementing the instructions of the Executive Committee on Economic Affairs, drafted and submitted to public consultation, in 1974 (Official Bulletin of Tarragona Province, February 12th), the Preliminary Design of the Ebro-Eastern Pyreness Aqueduct, to locate 1,400 hm^3/year from the Ebro in the Catalan coastal region, devoted to urban supply, irrigation and industrial uses.

Numerous letters of opposition were presented against this Preliminary Design, whose criticisms focused on three main questions:

1. Doubts as to the existence of surpluses.
2. Priority in executing of the development works in the Ebro basin with respect to those of the transfer.

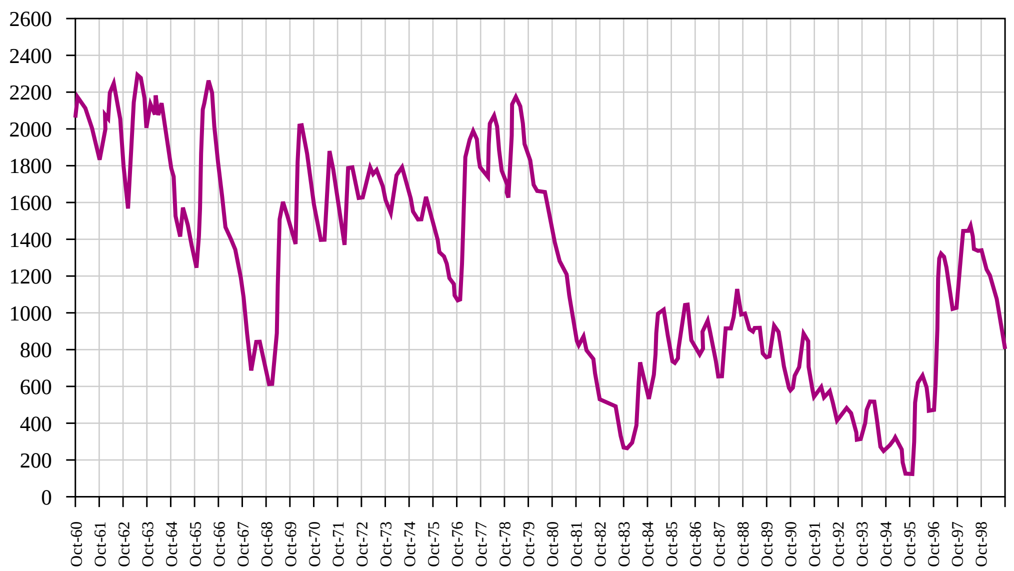


Figure 292. Monthly stored quantity in Entrepeñas-Buendía (hm³).

3. Legal feasibility of undertaking a transfer without prior legal guarantee.

Regarding the **existence of surpluses**, from the Ebro basin, and prior to the Administration submitting the specific diversion plans for flow on the lower reach of the river to public opinion, a potential exploitation was proposed, apparently so exhaustive that it could lead people to believe that surpluses would not exist in the future.

The studies carried out in the Preliminary Design, and subsequently, meticulously analyzing the detailed balances of the Ebro basin in the hypothesis of maximum development, showed the existence of such surpluses, and the compatibility of this foreseen maximum development for the Ebro basin with the uses proposed to remedy the national hydrographic imbalance (MOP [1974]).

Demonstrating the existence of surpluses, although difficult, did not meet with an appropriate response with respect to the consistency of the Administration's technical arguments, and it was understood that such surpluses did indeed exist, even in the maximum development supposed for the Ebro basin.

However, the question of **priority of economic state action** remained unsolved, and is a matter that continues to be controversial, because the Ebro basin was a depressed region by comparison with the basins of Catalonia, already well-developed in that time, and which, thanks to the proposed transfer, led some to think that the territorial differences could be even further accentuated. In short, all this contributed to presenting regional imbalance as an argument against the proposed transfer, so that this position was basically debating, more than the territorial distribution of state investment, water planning of resources allocated to water demands.

Accordingly, some opinions in Aragon maintained that it was not enough to guarantee resource availability for all potential development in the Ebro basin, and the possible transfers to be carried out with part of the remaining surpluses, but rather that no hydraulic infrastructure enabling the economic growth of Catalonia should be implemented with public funds, at least until all that could possibly done with the water had been done in Aragón.

This posture does not stand up very well from the point of view of the economic rationality, and even of territorial balance, because, as mentioned, it simplisitically confuses general economic policy of the State, and its instruments of territorial organisation and development, with a possible diversion of flow located, additionally, downstream, but there is no doubt that it contributed to exacerbating animosity towards this transfer.

A more reasonable approach was maintained by the General Council of Aragon with respect to the announcement of the new water legislation and the transfers: to require the prior development of own exploitation and potential, and that the possible transfer of surpluses were only carried out in precarious situations so as not limit the donor basin's development (see, e.g., Bolea Foradada [1986] pp. 506-511; Gaviria y Grilló [1974] pp. 265-279).

Finally, the economic recession that the country underwent with the petroleum crisis, and the drastic reduction in migratory flow from other regions to Catalonia, led to the rate of increase in demand for urban and industrial water (growing at that time at accumulated rates of 7% p.a.), main driving force for the Ebro-Eastern Pyrenees transfer, was far lower than predicted, and the projections of future demands were shown to be erroneous in very few years. For this reason, no definitive resolution was finally taken with respect to this Aqueduct, and the idea of its immediate implementation was discarded.

The fact that Aragon was one of the regions of emigration to Catalonia, in those years of rapid Catalan economic development when the transfer was proposed, helps to better comprehend the social conditions leading to the considerable –and logical– adverse popular reaction to this infrastructure.

Lastly, and with respect to the proposed transfer's **legal feasibility**, apart from the serious criticism generated by the fact that such an important action were proposed by means of simple publication in a provincial official journal, for the first time, significant doctrinal reflection took place on the problem of inter-basin resource transfers (Martin-Retortillo et to the., 1975), resolving against the planned aqueduct.

This negative conclusion was not due to the fact that it was based on a radical aprioristic supposition against transfers, but because it understood that the necessary prior legal requirements and conditions, involved in an action of this scope, were not complied with (Martín Rebollo [1993] pp. 147-151). Other considerations of these major problems, in the light of the past experiences and of the new legal classification, are provided by Moreu Ballonga (1993).

The final result of all the above was, in short, this project's abandonment such as it had been initially conceived. Nevertheless, the idea of transferring water from the Ebro to the Pyrenees re-emerged some years later, during the serious situation that was developing in the district of Tarragona.

3.6.2.2. Proposal and development of the transfer

Although, as mentioned, the area of Barcelona did not grow at the predicted rate, and the starting date for the planned Ebro-Pyrenees Aqueduct's exploitation –foreseen for the start of the decade of the eighties– was postponed indefinitely, until demand growth required it, an urgent solution had to be found to remedy the serious problems of water supply for domestic and industrial use in the region of Tarragona, with progressive depletion and degradation of own resources, with poor-quality waters, salinated by marine intrusion in the over-exploited coastal aquifers, and without possibility of alternative resources.

Accordingly, in order to remedy this situation, Act 18/1981 was proposed and passed, on water-related actions in Tarragona, enabling the implementation of the so-called-minitransfer from the Ebro to Tarragona. This Act (not just simple public information) established the following basic principles:

- The quantity of water destined to improving urban and industrial supply in districts of the Tarragona province was the same arising from the reduction in losses that took place in the hydraulic infrastructure of the Ebro delta, with a maximum of 4 m^3/s, equivalent to 126 hm^3/year. These losses were assessed by the centre for Hydrographic Studies, in 1972, as 12 m^3/s.
- The recovery of losses involved executing a works plan to refurbish and improves the delta's irrigation channels and ditches, with more than 250 km to be lined, from a total of 450 km, and at a cost, in 1986, of over 15,000 million pesetas. This Plan was financed at no cost for the Irrigators' Associations of the Ebro Delta, and with a payment of 0.03 €/m^3, to be reviewed as of 1981, by the concession's beneficiaries.
- Exploitation of the water thus recovered would be carried out by administrative concession, attributed by the law to a Consortium, with individual legal status, consisting of the Generalitat of Catalonia, local councils and industries.
- The work would be carried out without any contribution from the State.

Therefore, surplus flow from the Ebro was not used to remedy the deficit, but part of the loss recovered from the delta's irrigation channels which, due to their earthen construction and nearly a hundred years of age, gave rise to losses of about 12 m^3/s, equivalent to over 30% of the flow granted at the headwater (25 m^3/s for the right bank channel and 19 m^3/s for the left bank one). This achieved, without negative secondary effects, and by means of a simple reallocation of resources (Erruz, 1997), a way of financing the works plan to refurbish the delta's channels, as well as remedying the water deficit in Tarragon, a deficit that later turned out to be less than initially foreseen (fig. 293).

To enforce Act 18/1981, on April 2nd, 1985, the Tarragona Water Consortium was set up, an organisation with individual legal status made up of the Generalitat of Catalonia, local councils and industries from the district, and representatives from the two irrigators' associations in the Ebro delta, where the water was to be taken from.

By decision of the MOPU on August 20th, 1987, the Consortium obtained the concession of 1,982 l/s, later increased by decision of June 24th, 1992, to 2,850 l/s (90 hm^3/year). The Consortium may request new concessions up to the maximum 4 m^3/s by law (López Bosch, 1995).

The high-level supply of water (distribution to housing is carried out by local councils or companies) began on July 30th, 1989, and has evolved from 36 hm^3/year in1990 to almost 50 at present, as may be seen in figure 294. This figure, drawn up with data provided by the Tarragona Water

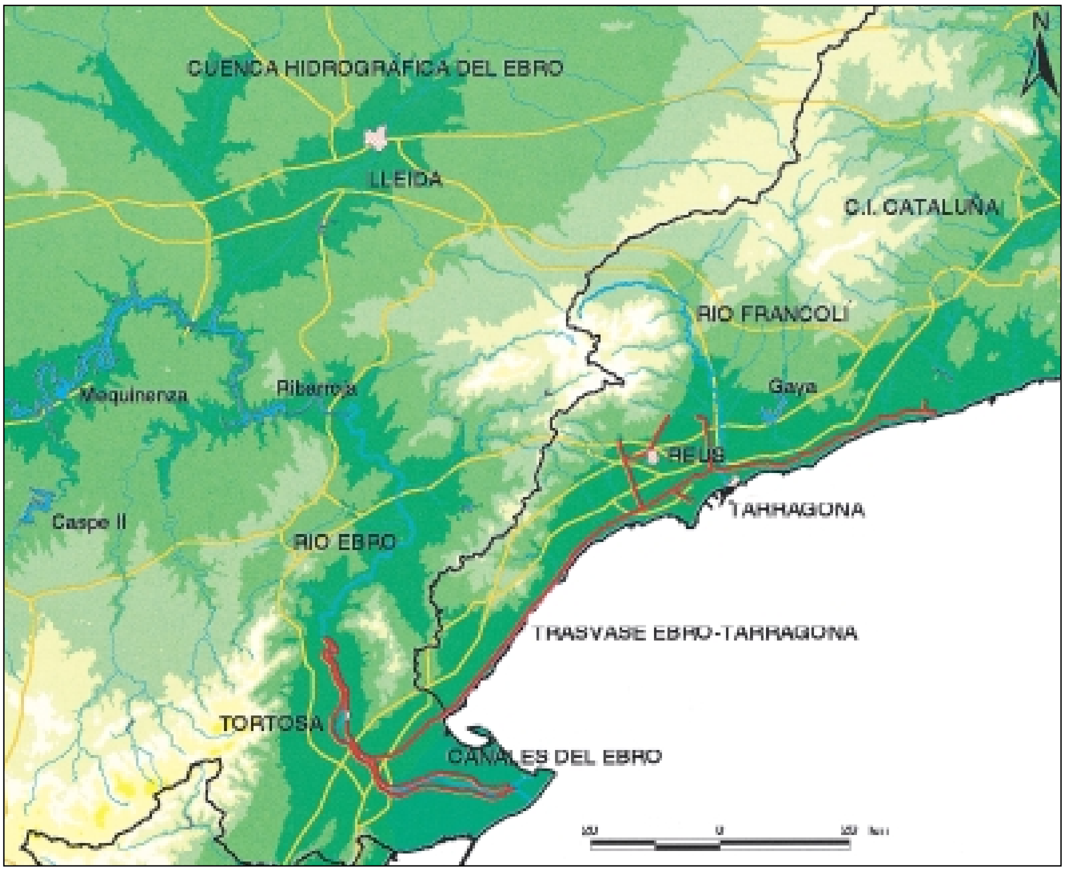


Figure 293. General plan of the Ebro-Tarragona transfer.

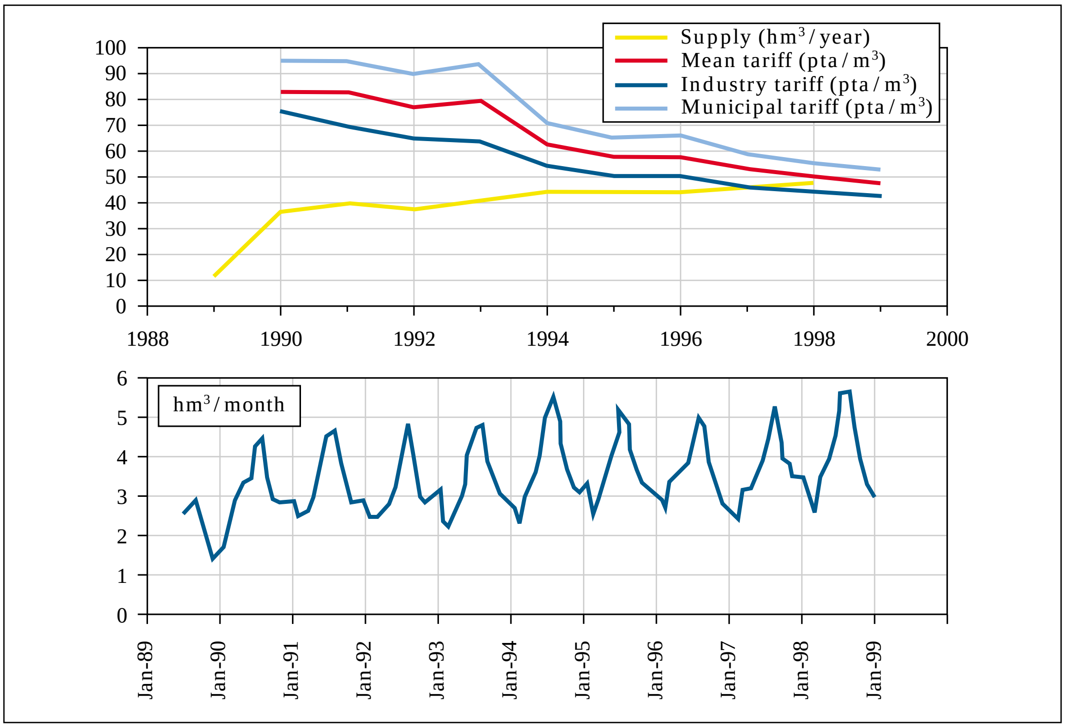


Figure 294. Annual and monthly series of volumes provided by the Tarragona Consortium and tariffs applied.

Consortium, shows the evolution of annual and monthly volumes provided by the Consortium from the start-up of operation. If we add total losses (between 5% and 10%) to these supplies, we obtain the flow diverted through the Ebro delta's channels. Additionally, the annual evolution of water tariff for local councils, industries and average, has been included in current pesetas.

It may be seen that resources supplied have grown slightly from 1990 to the present, at a mean rate of 3.6% annually. It may also be seen that the seasonality of demand is very noticeable, with tourist-related summer maximums around 6 hm^3/month, compared with winter minimums of less than 3 hm^3/month.

It is also seen that tariffs applied have fallen over time to a mean annual rate of 5.7% in current pesetas (11% in constant pesetas), which is basically due to the drop in interest rates, and to the progressive increase volume supplied.

Since the transfer's start-up, the aquifers have shown an appreciable recovery, and the salinity of wells near the coast has also fallen.

The minitransfer is a clear example of the need to recognise water's economic value to achieve appropriate exploitation. In this case, a controlled exchange of flow was granted to the Ebro Delta Irrigators' Association, based on an improvement of the irrigation system and of resource manmagement. However, in order to do so, it was necessary to pass a specific law.

3.6.3. Other transfers

Among the inter-basin transfers currently in exploitation, we could highlight those from the Ebro to the Nervión and the Besaya which, paradoxically, transfer water from the Ebro basin to that of the North, the region with the greatest abundance of water in the Peninsula. This is due to the fact that in this region, although it has abundant precipitation, it is not easy to install regulation reservoirs due to topographical difficulties, and for the significant natural area they would affect.

The first of these, Ebro-Nervión, has permitted the transfer of about 180 hm^3/year, over recent years, from the Zadorra reservoirs, in the Ebro basin, to the River Arratia, in the Nervión basin (North III water planning area). Initially conceived and built for spot electric power production, it has efficiently remedied the supply problems of Greater Bilbao.

Furthermore, the lack of regulated hydraulic resources in the industrial area of Torrelavega was the reason for implementing the second of the mentioned transfers, to divert 22 hm^3/year from the Ebro reservoir to the Besaya basin, in the North II water planning area. The project was drafted and built with a view to the scheme's reversibility, so as to regulate waters of the Cantabrian drainage basin in the Ebro reservoir, taking advantage of the request for concession of a reversible hydroelectric power station of 100 MW in the area.

As recent actions, we could mention the Guadiaro-Guadalete transfer, currently under construction, approved by Act 17/1995, of June 1st, planning an inter-basin transfer from the territorial area of the South to the Guadalquivir, with an annual maximum transferible volume of 110 hm^3/year.

Additionally, and though cannot be legally classified as transfers under national planning, there exist many other connections in Spain, within the scope of the different basin plans, of great importance both for the quantities they mobilise, and especially for the major problems they remedy. This is the case of the Ter-Llobregat, in the Inland Basins of Catalonia, conceived in the 16th century and implemented in the sixties, or the Júcar-Turia, developed in the seventies in the territorial area of the Júcar, both with excellent practical results.

3.6.4. The environmental consequences of transfers

Despite the lack of studies and publications on the environmental effects thast the transfers carried out in Spain may have caused, some of their consequences are obvious, and they can be presented without the need for specific detailed research.

Accordingly, impact mainly arises in the donor basin from the loss of circulating flow. This decreased availability of water in the environment can cause alterations to the hydrological regime, geomorphological changes in the channels located downstream, modification of the ecosystems that occupy them and, as a result, a possible transformation of the landscape.

In the territory crossed by the transfer channel, environmental effects characteristic of transport infrastructures occur. However, the most important of all are the barrier and corridor effects caused on people and fauna by territorial sealing, caused by the channel.

In the receiving basin, effects include the alteration of the hydrological regime which, in turn, transforms the composition of the riverside vegetation, so that with greater flow during summer, they increase in abundance and diversity. Another significant effect may be modification of the circulating water’s physio-chemical parameters.

Accordingly, in the Segura basin, with a high sulphate content in some reaches of the channel carrying transferred water, the inflow of water from the Tagus, with a low load of these salts, gives rise to an increase in their concentration due to the re-dissolution of the sulphate precipitates existing in the channel. This modification also causes an alteration in the composition and structure of communities of live organisms present in the waters, and dependent upon them. Lastly, one of the most striking environmental consequences in water transfers is the incorporation of species of fish, macroinvertebrates and aquatic vegetation from the donor basin, and which were not found in the receiving basin prior to the transfer. For example, in the River Segura, species detected include the gudgeon *(Gobio gobio)* and goldfish *(Carasius auratus)*, copepods like *Cyclops furcifer* and *Tropocyclops prasinus*, ephemeroptera like *Prosopistoma sp*. and other species from the Tagus, nonexistent in the Segura before the transfer. These effects have also been seen in the transfer to the National Park of Tablas del Daimiel, with waters from the Tagus (Mas Hernández, 1986; Suárez, 1997, personal notification).

If the transfer infrastructure includes regulation reservoirs there is also environmental impact on the pre-operational environment occupied by the transport line, its immediate environment and the affected channel.

It is therefore desirable, in view of the scanty available information on the environmental consequences of transfers, that their rigorous identification and analysis be undertaken, together with corrective or compensatory measures that may reduce them. Additionally, it is necessary to minimize the impact already caused by the transfers constructed, and when appropriate, submit possible new constructions to a procedure of environmental impact assessment, studying their feasibility from this point of view.

3.7. WATER ECONOMY

The technical aspects of water availability and use described in sections above, we shall now turn to their consideration as an economic asset.

A lot has been said and written in recent years on this crucial question, and some have even maintained, not without reason, that there can be no rigorous action on water-related issues if their management does not initially include some economic considerations, explicitly and from the first moment.

In the sections below, we shall review the current Spanish situation as regards these issues, firstly showing what is the real role played by water in the different sectoral production processes, in terms of its real contribution to the national economy. The interest of these assessments is obvious, because frequently, to claim advantages or quotas for resource use, biased or simply false arguments are put forward, and it is expedient to know, at least approximately, the underlying macroeconomic reality and its territorial peculiarities. Secondly, we shall review the economic-financial regime in effect, showing the problems and deficiencies detected in its practical application.

The possible improvements or criteria in economic policy to improve the current situation and to overcome its difficulties may respond to different initial criteria and positions, and consequently be submitted to discussion and debate. Therefore, following the criteria adopted in organising the White Paper, they will be presented in a later chapter.

3.7.1. Water as an economic production factor

3.7.1.1. The agricultural sector. The contribution of irrigation to the Spanish economy

Due to its considerable relevance as a consumer of resources, and for the general reasons already pointed, it is interesting to know the features and basic characteristics of irrigation’s economic contribution to the Spanish economy, so we analyse this major question in some detail below.

The graphs in figures 295 and 296 reflect the National Accounting results, for the three classic major production sectors, during the period 1980-94, through the relationship between Gross Added Values at sectoral market price (GAVmp), and total GAVmp, in current pesetas. This indicative GAVmp is the economic end result of production activity, and is obtained by subtracting Intermediate Consumption from Final Production (expenses outside the sector or intermediate elements incorporated into the production process). This macromagnitude has been chosen by considering, for the purposes in question, that it constitutes the best indicator because it has neither subsidies nor direct taxes. Although most of the data is presented in relative terms and terms of structure, these have been determined in current pesetas, in order to include the effect relating to different price behaviour in the different sectors during the period analysed.

In the magnitudes of the different sectors, Agriculture includes the activity branch of agriculture and fishing,

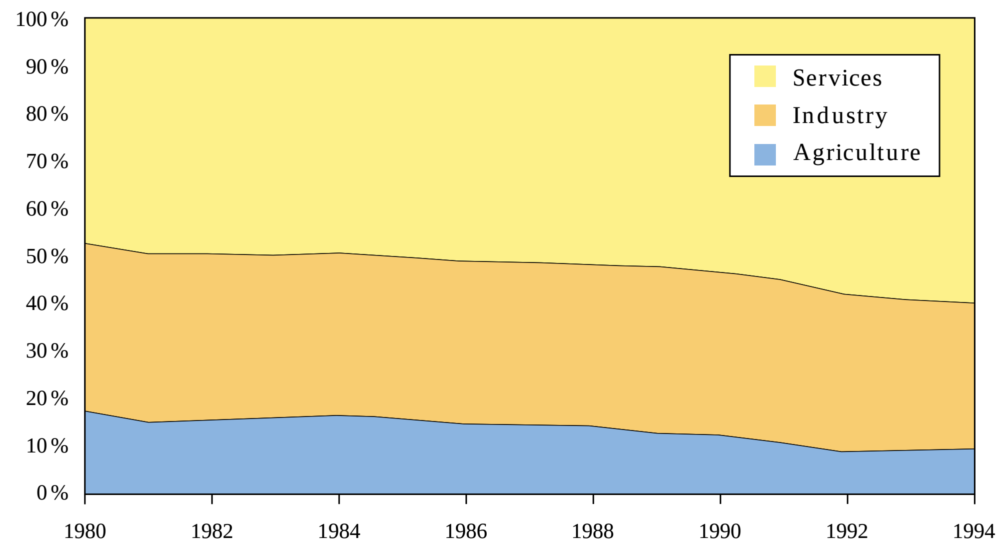


Figure 295. Evolution of the sectoral structure of Total Gross Added Value (%).

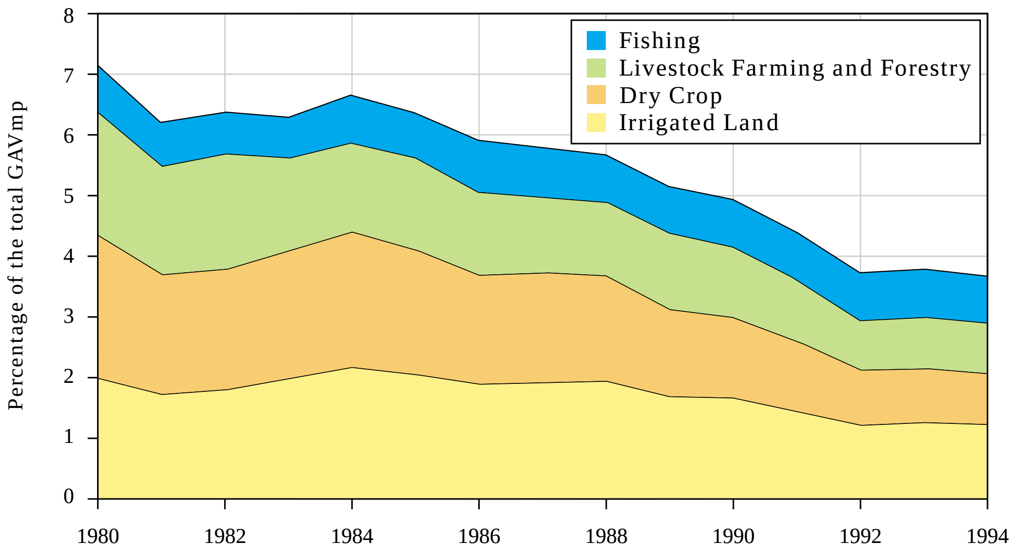


Figure 296. Evolution of Gross Added Value in the Agriculture and Fishing sector.

Industry includes energy, industrial products and construction, and Services include both sales and non-sales.

It should firstly be pointed out that the branch of Agriculture and Fishing, where the contribution from irrigation is included, began the period with a proportion of 7.19% (when in the early sixties it was higher than 20%) and finished with 3.67%, showing a clearly downward trend throughout the period.

If we bear in mind, in order to disaggregate Agriculture or Agrarian Production, that the last available data on Fishing (period 1980-89) shows a relative stability and proportion of around 0.75%, not dropping in any event, it is correct to estimate with some certainty that Agriculture currently contributes no more than 3% to the total GAVmp.

Nevertheless, in connection with water resources, it is still interesting to distinguish, within Agrarian Production, the part that can be attributed to plant production, specifically dry crops and irrigation (Agricultural Production), from the rest that makes up the agrarian total (Livestock Farming and Forestry). The available data, again for the years 1980-89, shows that participation of agricultural GAVmp to agrarian GAVmp is around 72% and which is seen to be stable with a slight upward trend; we may therefore state that crops (dry crops and irrigation) contribute approximately 2.10% of the total GAVmp.

Finally, and although precise information does not exist for irrigation in this respect, an sufficiently-adjusted estimate allows us to conclude that irrigation already represents 60% of the agricultural GAVmp, leading to a result of around 1.25% that irrigation's contribution to the GAVmp is limited to in the national total. Regarding this figure, we could highlight, firstly, its insignificance and, second, its downward trend (it remained almost until the end of the eighties around 2%), although it should be recognised that it is the activity showing the most positive behaviour within the agricultural sector.

It is not easy to specify what part of the national irrigation production should be linked directly with the maintenance of activity in the rest of the agricultural sector (whose contribution to the national total seems to stand at around 15%), but it is expedient to point out that only in certain territories can it be described as intense. In any event, it is likely that the globalization of markets will lead this dependence to diminish in the future.

This global overview, based on mean national data, should not hide the major differences registered among the different Spanish territories.

Accordingly, the map in figure 297 showing the mean values, in the period 1986-92, of the contribution of the agriculture and fishing sector to the total provincial GAV.

Furthermore, the maps in figures 298 and 299 show, on the basis of available data on a provincial and autonomous community level, the trend of Agriculture and Fishing's contribution to the territorial VAB, compared with the national one, observed in the period 1980-1992.

In connection with this evolution, we should mention some significant facts. In the first place that, leaving aside region-

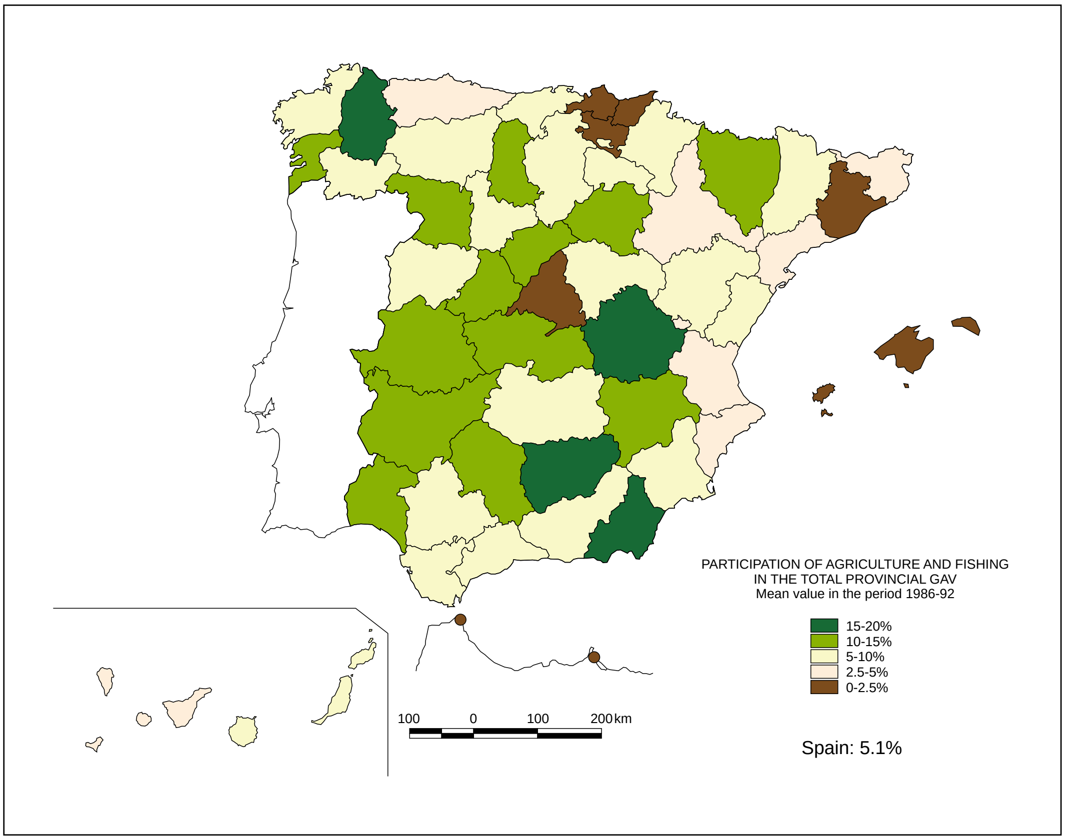


Figure 297. Map of agriculture and fishing's contribution to total provincial GAV.

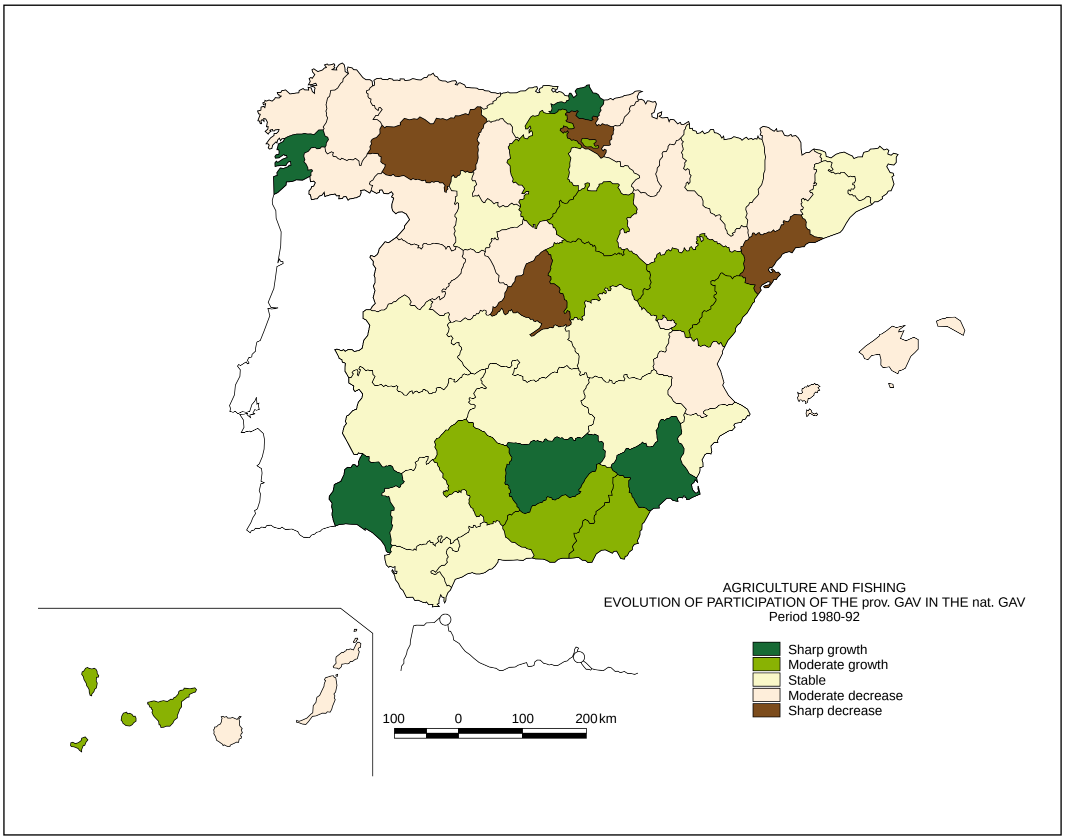


Figure 298. Map of trends of contribution to provincial GAV compared with national GAV in Agriculture and Fishing.

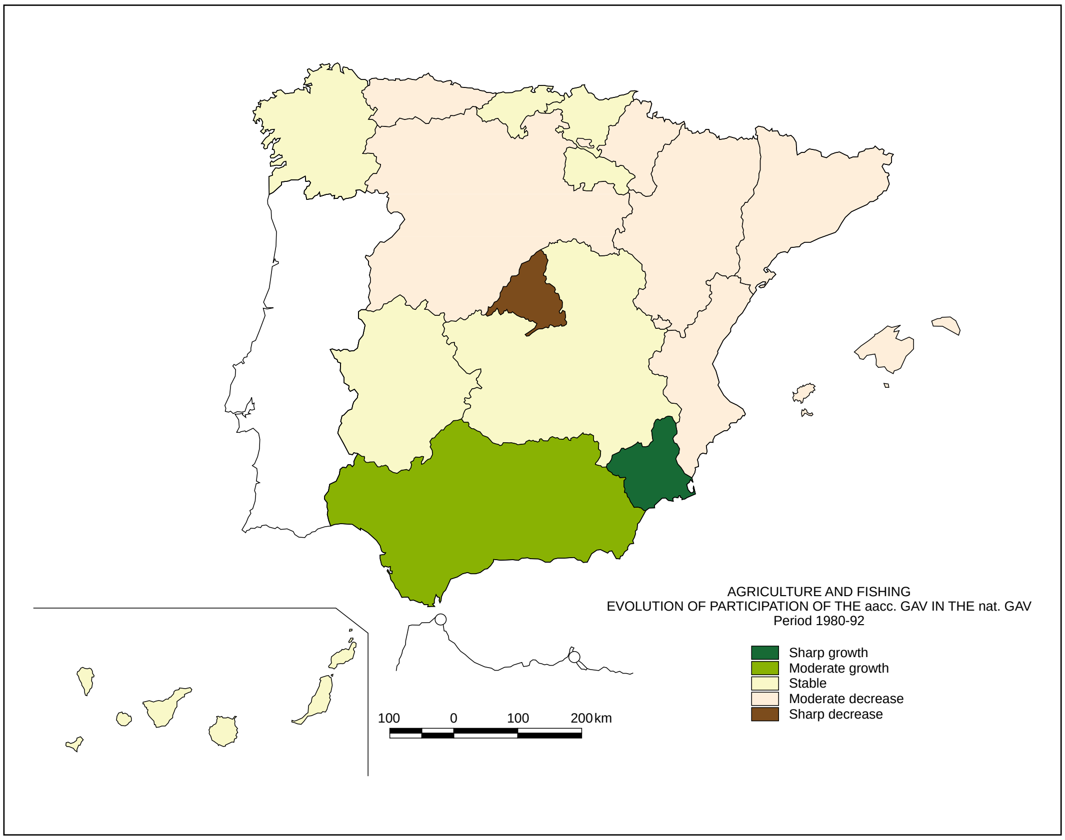


Figure 299. Map of trends in agriculture and fishing's contribution to autonomous GAV compared with national GAV.

al heterogeneity within provincial units, which could influence these results, the increase in the quota of participation in the national total arises basically in the southern and eastern provinces. Secondly, that this increase does not bear a relationship with greater abundance of available water resources, but rather the contrary, the areas with highest deficits and highest temperatures (such as Murcia) are those that show a greater increase. Thirdly, a clear correlation is seen between loss in economic quota and territories with more irrigated surface are on high ground, as may be deduced from comparing these maps with the hypsometric characterization previously offered in the sections on natural conditions. This process coincides with the results obtained by other studies made on the basis of the Agrarian Census of 1982 and 1989, demonstrating a regression of irrigated surface are in higher-altitude territories.

It seems, therefore, that an unequivocal trend can be seen towards greater specialisation and economic productivity of agriculture in the Mediterranean and southern regions, looking for lower-altitude territories, and without the greater lack of water in these areas being a decisive factor nor a deterrent.

This fact that the regression of irrigated surface areas bears a direct relationship with altitude (the relationship altitude-surface area was examined above in studying the physical framework), can be reasonably explained in economic terms. In most of Spain, in fact, altitude has a significant correlation with the temperature regime, so, considering that the vegetative development of plants is influenced by the average frost-free period and by the heat integral, altitude orients the production that can be carried out in the different irrigated areas and its unitary yield. This takes place regardless of appropriate water supply, that is supposed to be satisfactorily covered in all cases.

Generally speaking, the climate at altitudes higher than 500-600 m above sea level prevents irrigation from materialising the comparative advantages that, for reasons of latitude (and of the climate to be expected of it), correspond to Spain's territories, and limits it to production orientations that enter into in full competition with European continental agriculture.

Conversely, irrigated land located below 300 m, apart from having generally higher yield, allows production orientations to be adopted that, either due to the exclusivity of the crops, or to the early dates when the crops can be harvested (and therefore placed on the market), do not suffer such competition, thus representing a unique, genuinely strategic economic resource for our country, a comparative advantage without possible competition from Europe.

Following on with this analysis of altimetric dependence, the apparent net productivity of water, calculated through the relationship between agrarian added value and gross water consumption, provides an economic characterization of irrigation transformation projects according to the factor that interests us here, which is that of water resources (data and results by DGPT [1995b] p. 549). By representing the results obtained graphically in comparison with the altitude where these projects are located, a significant dispersion of values is seen, although clearly showing that the irrigated areas with most productivity are at lower altitudes. Notwithstanding this dispersion, that makes it a relevant point, figure 300 shows the trend given from the calibration of a potential function.

We should mention that, leaving aside other possible social advantages, some opportunity costs could be incurred if resources are mortgaged in alternative, low productivity agriculture, in detriment to other uses in competition, also

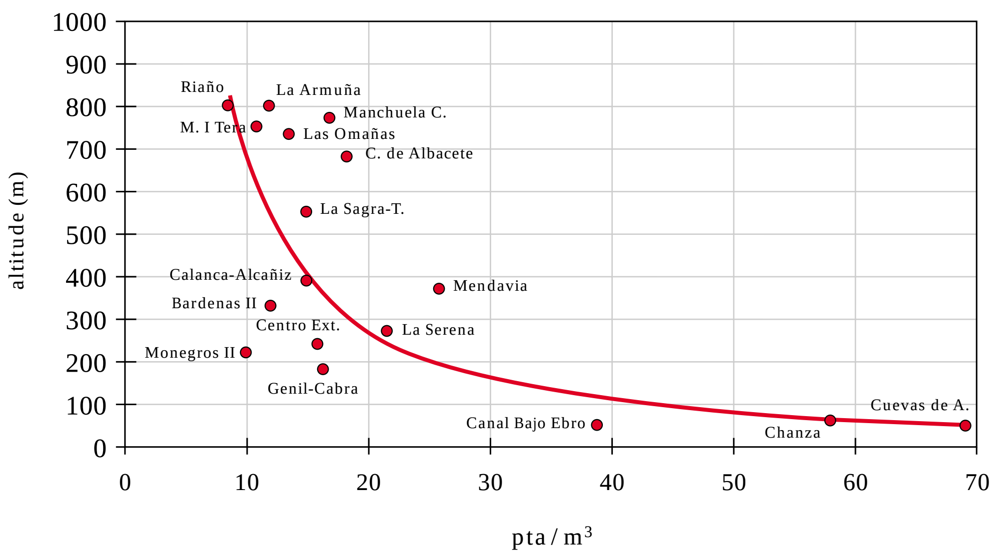


Figure 300. Productivity of water in irrigation in different areas.

agricultural, more advantageous in the use of the resource. Responding to such questions is, in any case, a complex issue because, as has been pointed out, not only strict economical reasons are involved. An approach that is often explicative is that of users' vocation and initiative, such as the case of Monegros II, where to a large extent irrigation has been developed with enthusiasm and economic effort of the irrigators. Other areas may in principle have greater theoretical productivity but lack such vocation to irrigate and, therefore, give rise to delays in transformations and inefficient management, making them clearly less preferable to the former.

Finally, and in relation to the issue of irrigation's economic productivity, some interesting results from the exploitation of basic statistical sources are offered. The maps in figures 301 and 302 show, firstly, productivity of irrigation on a municipal level (in pesetas per hectare), according to the last Agrarian Census in 1989, the last one carried out, and secondly, the dry crop/irrigation relationship of this productivity, on a provincial level, according to the MAP Yearbooks of Agricultural Statistics for the period 1990-94. This last ratio can be considered a good indicator of the profitability to be expected in possible transformations of dry crop into irrigation in the different territories of Spain.

A study of both maps leads to the unequivocal conclusion that the most productive areas are concentrated in the Mediterranean, south Atlantic and Ebro valley, and the greatest pressure for transformation in the same areas (especially, in Murcia, Almería and Huelva). It is clear that this pressure toward transformation can only be controlled by the historical limitation of their water resources, and this limitation has led to situations of over-exploitation and degradation that must be remedied, and cannot continue in the future.

We cannot end this brief characterization of irrigation, from an economic point of view, without dedicating some paragraphs to Spain's considerable horticultural production. This horticultural production, concentrated basically on the Mediterranean coast, is that which seems to have a a bright future in view of the high productivity and profitability presently achieved in these production orientations. This fact is the reflection of Spain's comparative advantages over European agriculture, despite the low level of protection it enjoys, from the threat involved in agreements with third-party countries and from the considerable restriction its development is subjected to by supply difficulties and the depletion of internal-origin water availability.

3.7.1.2. Industrial sector

Industrial activity contributes, in mean data from the last decade, approximately 25% of total Spanish production in terms of GAVmp (33% if construction is included), a figure that represents a slight drop with respect to the previous decade.

To be highlighted, as we saw, is its high degree of concentration in a few spatial environments, although it cannot be said that this phenomenon has increased in recent years. The Autonomous Communities of the peninsular

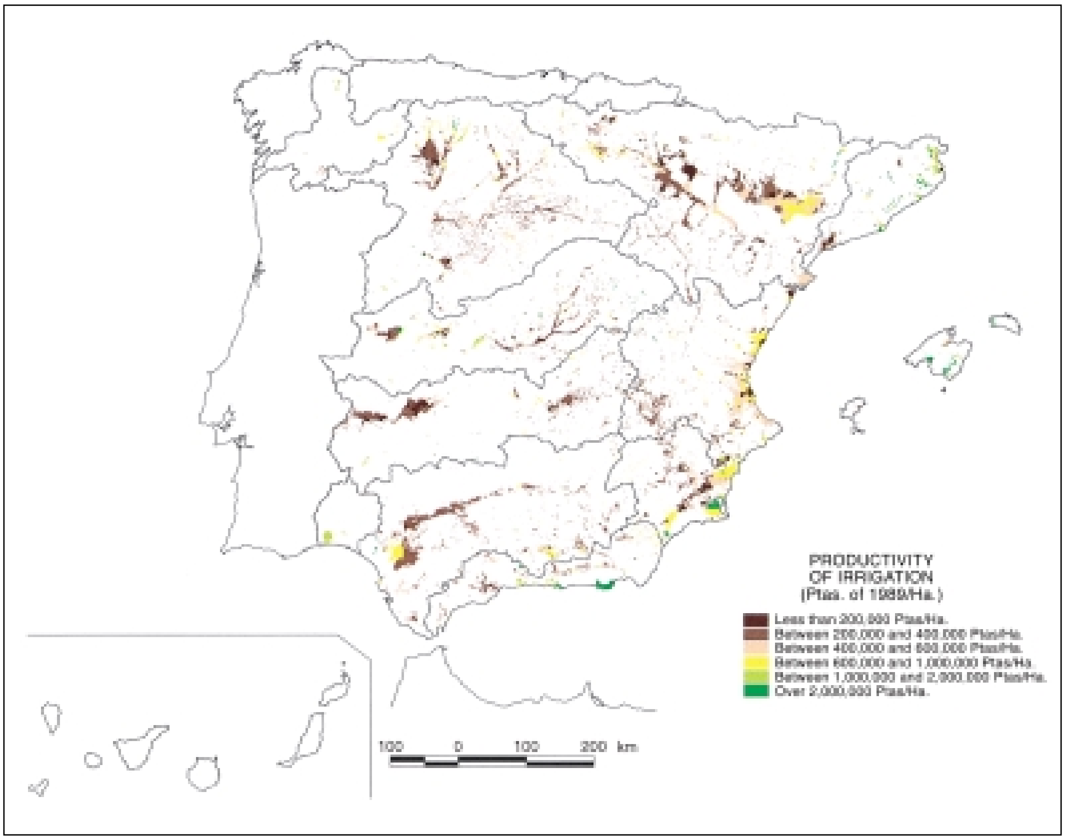


Figure 301. Map of irrigation productivity.

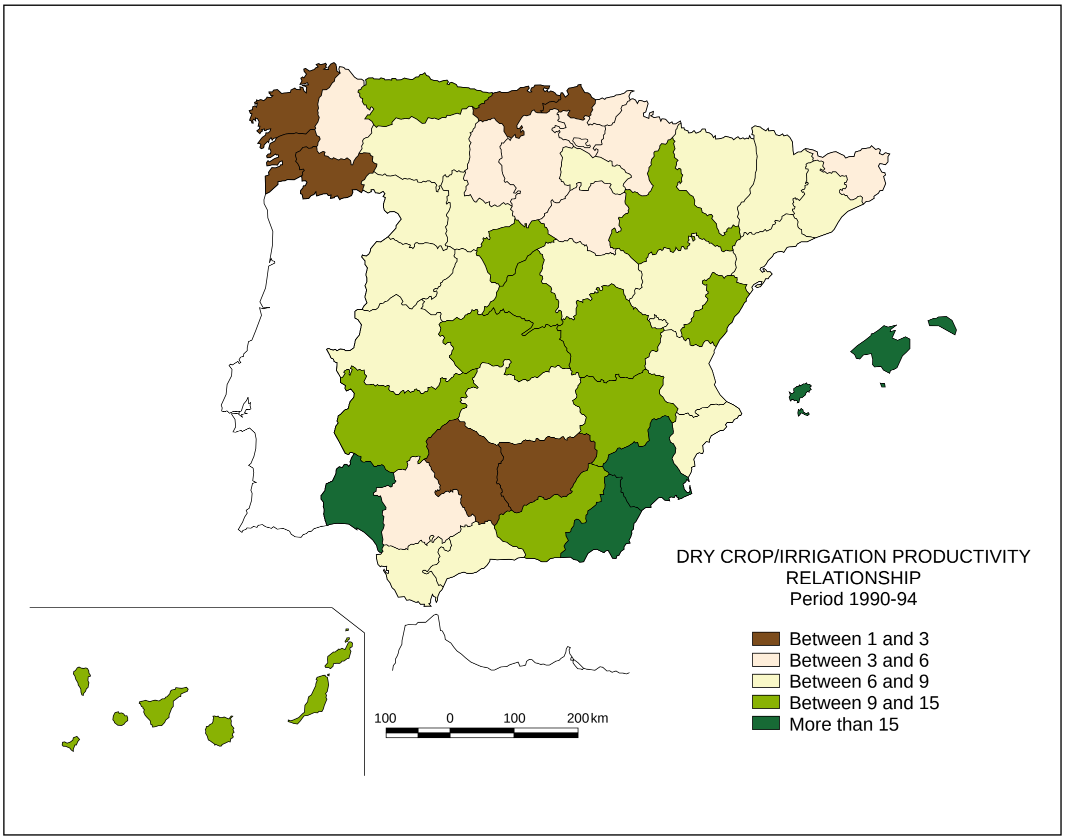


Figure 302. Map of dry crop/irrigation productivity relationship.

Mediterranean coast contribute around 47% of Spanish industrial GAV (Catalonia more than 25%, Valencia Community 11.2%, Murcia almost 2% and Andalusia 8.5%). Madrid concentrates almost 2.3% and the Bay of Biscay Coast 15% (Basque Country 9.5%, Cantabria 1.4% and Asturias 3.8%).

Consequently, these three spatial environments represent in total 74% of Spanish industrial production, although two should be pointed out: the good performance shown during this period by regions with traditionally agricultural vocation (Castile-La Mancha, Extremadura, Navarre, La Rioja, Castile-León and to a lesser extent Galicia), with growth rates of industrial GAV significantly higher than the national total in all cases, and the spectacular decline of the sector in the Bay of Biscay Coast, especially in the Asturian area, which lost almost 3 percentage points of participation in the national total, with respect to the previous decade.

As regards water demand, the sector contributes 5% to total demand. This figure refers specifically to an identified demand; to this, we would have to add consumption carried out through the municipal urban supply networks which, although the available data is not disaggregated, could be estimated as lying between 2% and 3% (industry would thus come to a total figure between 7 and 8%, insofar as population supply, without industrial uses, would lie between 10% and 11% of total demand). According to a specific study of 423 observations aimed at parametrizing water consumption in the sector, and carried out by the Autonomous Communities of Valencia and Murcia (territories subjected to a situation of lack of abundance in water resource availability), there are some patterns in how this demand appears, which are worth pointing out:

– There is considerable heterogeneity in water consumption in industry, and a large number of factors influence it, but the most relevant aspect is that water is an input that industrial activity does not make reference to, in general, when organising its production processes. The reason for this behaviour probably lies in the low participation that this factor has its products' cost structure.

– It is common practice to base the projection of this demand on the different planning horizons, in water consumption per employee; however the available data suggests that there are variables showing a better correlation with water consumption and can therefore lead to better estimators. This is the case of the contracted power (and also electric power consumption), for which a value of 75 m^3/kW is obtained. Therefore, the best forecasts on the growth of water consumption in the industrial sector should be associated with those of growth in energy consumption in this sector.

– The relationship between water consumption and the origin of the resource is especially significant. In fact, average industry tends to consume far more water when it is supplied from wells than when it uses another supply type. For these purposes, average industry is understood to be that whose performance or relationship is established statistically from data provided by all the interviewed industries. The results provided by this model indicate that given two industries with an average character or performance, which have the same value for the variable considered (final production, etc.), greater water consumption may be expected in that which is supplied by own abstraction (well).

It may also be said that approximately half the consumption takes place in own abstraction, either directly, or through self-supplied industrial estates, and comprises the big business consumers; the rest comes from the municipal network, including the industrial estates connected to it. A small percentage of industries are supplied from two or more types of supply sources.

Without a doubt, this behaviour can be attributed to the significant cost differences arising for companies as a consequence of the different supply sources. These costs are always lower –about half– in the case of own abstraction, although we should note that in this case they do not include costs arising from treatment and purification of wastewater.

In short, the great majority of industries carries out a low level of control over water consumption in the different production processes, despite the considerable volumes consumed, which without doubt is due to the low consideration that input water has in establishing the final price of the product.

3.7.1.3. Energy sector

With the objective of carrying out an economic analysis of water resources from the point of view of their hydroelectric potential, a study has been made to determine the relationship between water's energy-economic value and its altitude. To do this, all the Spanish rivers with a major hydroelectric exploitation have been reviewed, considering, as a general criteria, all hydroelectric power stations with a capacity of more than 5 MW. This study has allowed an assessment of both mean energy coefficients (kWh/m^3) in each power station, and the accumulation in each river reach, so that it is possible to make an approximate estimate, as indicated, of the value in terms of energy –and economy– of each cubic metre of water at different points (altitudes) of the Spanish hydrographic network.

The results obtained are summarised in the graph in figure 303, representing unitary production or energy coefficients (kWh/m^3) compared with altitude (m. above sea level) of the sample analyzed (110 power stations), and the potential curve adjusted to this data.

If an economic value is assigned to the kWh produced (which, coinciding with other data given in the text, is in terms of gross added value at market prices, estimated at 0.05 €/kWh), this energy productivity curve becomes another, of apparent economic productivity, in terms of net added value, just by making the necessary change of scale.

3.7.1.4. Irrigation and hydroelectricity. Opportunity costs of alternative use and territorial differences

The combination of the graphs shown above, on water profitability in agricultural and hydroelectric uses, gives the unified graph in figure 304, reflecting the economic potential or apparent productivity for possible alternative energy or agricultural uses of a unit of water, according to its altitude point (the Bay of Biscay Coast has not been included –despite its considerable use of hydroelectricity– by not entering into competition with other alternative uses).

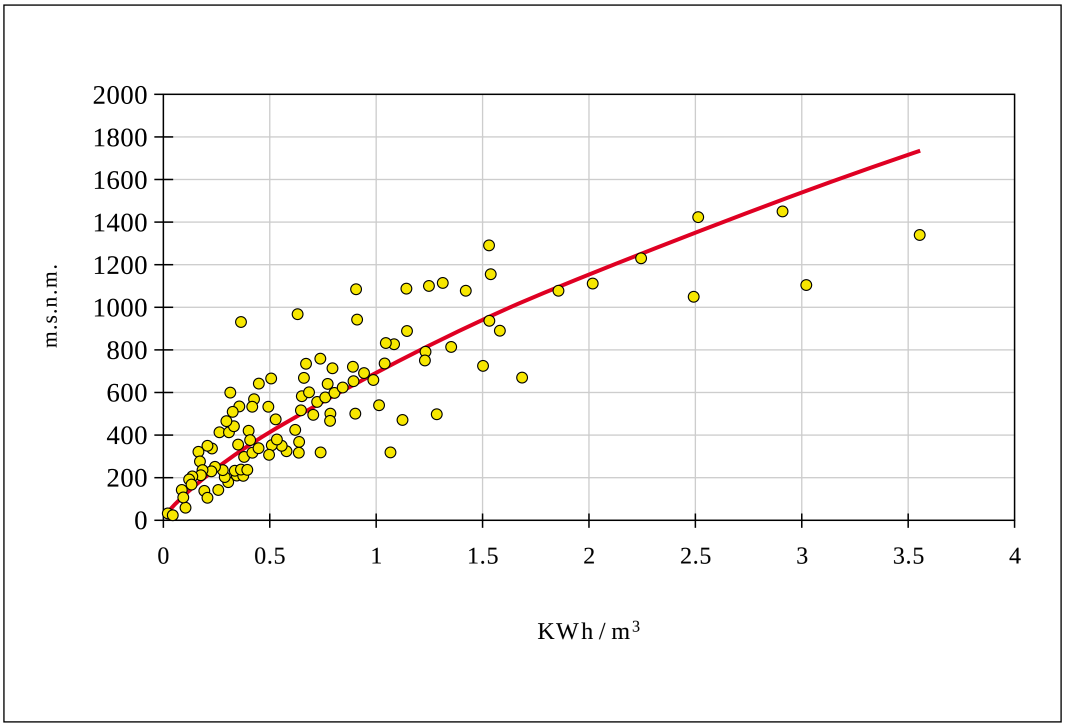


Figure 303. Water energy productivity.

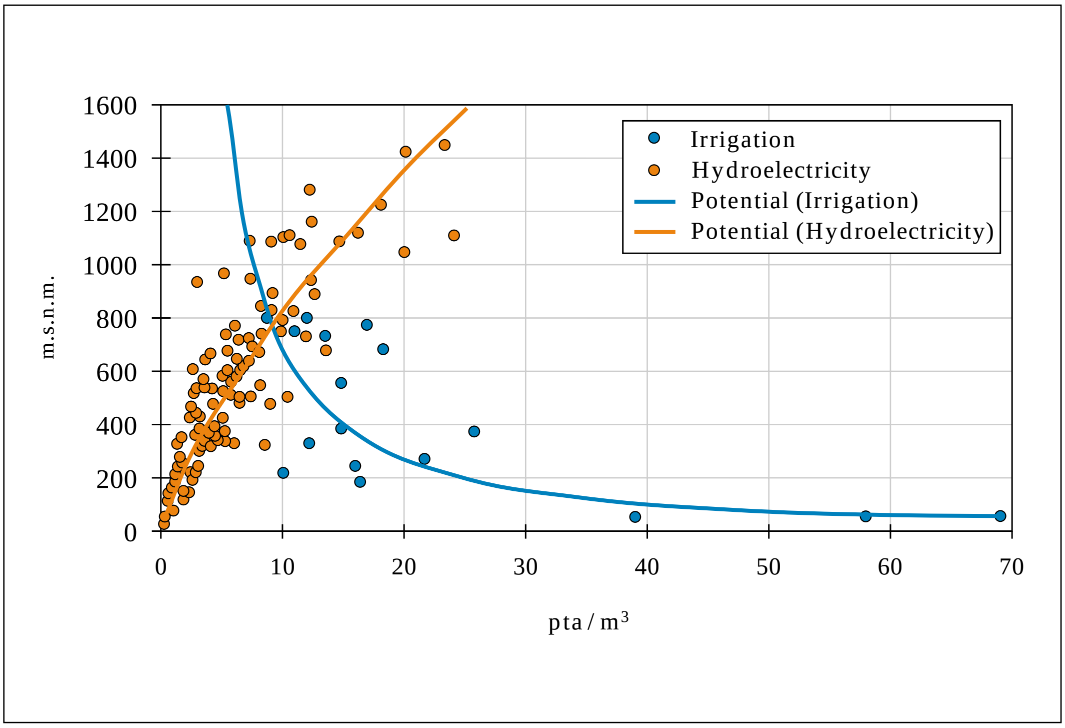


Figure 304. Compared energy-irrigation productivity.

It is obvious that each particular case would require detailed analysis, including its specific characteristics, and which, considering the obvious simplifications of the analysis carried out (which includes highly varied situations), these results give no more than merely indicative value, but it is illustrative to the extent that, by approximately quantifying a qualitatively well-known fact, it informs on the order of magnitude of these economic activities' relative average profitability.

Thus, it seems to demonstrate the economy of irrigation at altitudes around 700-800 m above sea level, compared with the option of energy production, and it also shows the turning-point around 400 m, above which productivity stagnates or drops, and below which it increases significantly, mainly from the 200 m level down. Naturally, the selection of alternative options can –and should– include other factors, different to those of immediate economic productivity, but it is a good idea not to lose sight of these results so as not to unconsciously incur in unfeasible long-term solutions, negative for the national economy.

The location of water use for irrigation in the lowest parts of the basins does not show the opportunity, environmental and hydroelectric potential costs that are assumed by using it for irrigation located in the basin's upper territories, oriented mostly to winter and summer cereal production, oleaginous and fodder. These projects are subjected to high negative externalities arising from loss of hydroelectric energy production, increasing the higher up the irrigated land lies, and the greater the basin's energy use. Conversely, the highest profitability rates correspond to the Mediterranean and south Atlantic coast, whose basic production is oriented toward horticultural crops.

Therefore, from the point of view of efficiency of water use, as a scarce resource, and also of the budget, it would be necessary to require public managers of both resources to have some consideration for these options, not only as regards new irrigation transformations but also with those already existing. This type of analysis shows the opportunity costs that may be incurred, in a scenario of limited water resources, such as the Spain is experiencing.

In any event, future water demand for irrigation concerning new transformations by state initiative is conditioned to the criteria and commitments laid down in the National Irrigation Plan in this respect. It is to be expected that this Plan defines the general guidelines of agricultural policy in the near future, and specifies the objectives to reach in the short term, defining to what extent priority should be given to irrigation located in Mediterranean territories with water deficit (generally the most competitive), and to what extent actions aimed at covering social objectives should be continued.

3.7.1.5. Services sector

The economic impact of water economy on the services sector is difficult to separate, since, in a general, diffuse way, all services require water resources, to a greater or lesser extent. From the indirect relationship through urban supply required for any activity inside urban areas, to the most direct in specifically water-related services, the relationship is, in any event, very widespread.

Considering tourism as a part of the services sector, we should reiterate comments made particularly with respect to this activity.

3.7.1.6. Conclusions

Before turning to conclusions more strictly to do with water resources, it is interesting to see the map in figure 305, on Gross Added Value at market prices by Autonomous Comunidades which globally sums up the sectoral and territorial structure of the Spanish economy.

It is interesting to observe that this indicator does not seem to bear any relationship with the greater or lesser availability of water. Indeed, as water shortage increases in a northwest-southeast direction, GAV per capita does so in a northeast-southwest direction.

Another helpful conclusion from the above is the extent to which water contributes to creating wealth in the Spanish economy, through its main users/consumers, in terms of GAVmp, and according to the results of Spain's National Accounting. In order to do so, it is necessary to include the data regarding Supply, which involves a substantial a margin of uncertainty.

In fact, the contribution of water consumed for supply (residential and tourist population) is indirectly assessed: drinking water is a basic need and an essential resource for life, so from this point of view, its value would be infinite; however, demands registered for supply are far greater than these strict necessities. On the other hand, society is willing to devote around 0.30% of total GAVmp to cover these demands, as the official statistics show –Spanish National Accounts. Years 1986-1992. Subrama of water (abstraction, treatment, distribution)–. This figure should be considered as a minimum, since there are services associated with population supply that are not reflected in it, among other reasons because they are diffusely supplied by different public administrations. The consideration of these questions, subject to a high margin of doubt, provides an assessment, avoiding error of underestimation, as a likely figure of about 0.5% the national total.

In short, and to sum up, the following chart is presented, giving the percentages of each sector's contribution to total GAVmp, and their corresponding percentages with respect to total water consumption. A zero hydroelectric consumption is supposed because all the water used returns to the network, although we must check the existence of a modulation effect for the exploitation, which may prevent its exploitation in other uses (table 97).

Leaving aside the above-mentioned uncertainty of these results, it seems clear that the order of magnitude of contribution to GAVmp is certainly low, a conclusion that contrasts strongly with the frequently-used argument of productive water use that relates it with major general economic interests affected.

In fact, in the light of these figures, it could be thought that such economic interests are not only unimportant, but rather they seem quite modest since, despite the significant degree of exploitation to which Spanish resources are subjected –with the environmental effects that this involves–, only 2.45% of national GAVmp can be attributed to economic activity directly associated with intensive water use.

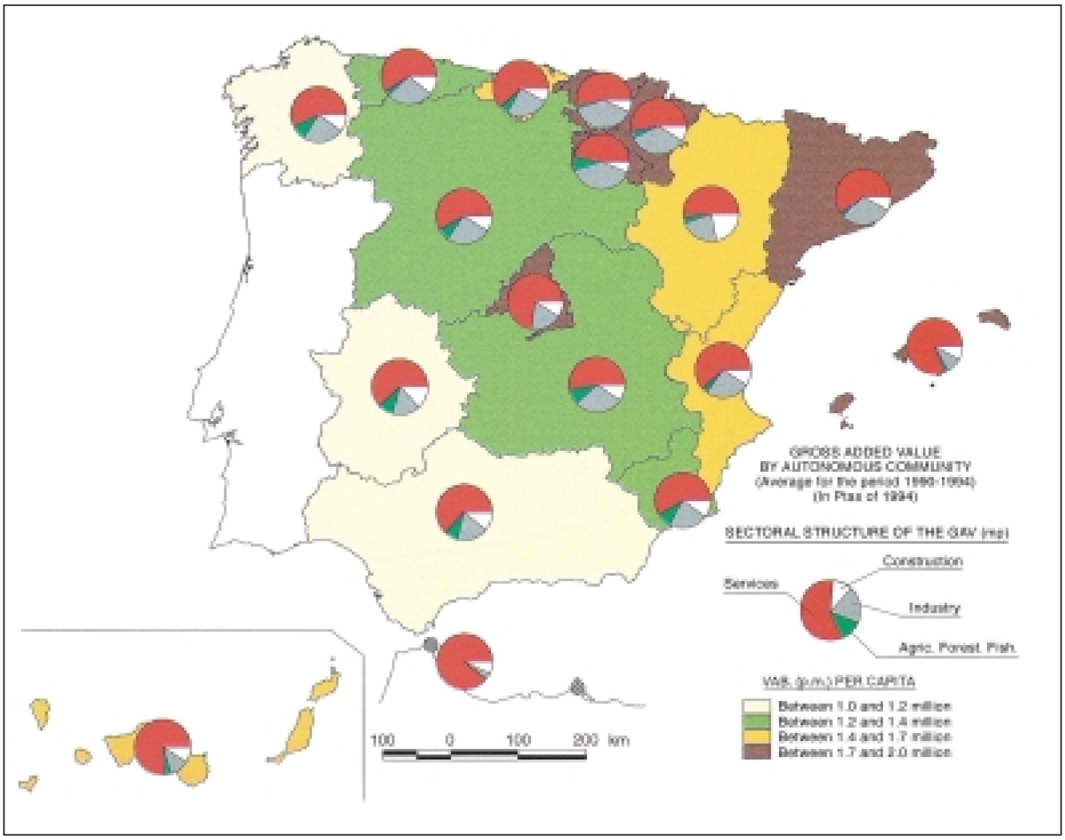


Figure 305. Map of sectoral structure of GAVmp by Autonomous Community.

Sector	Participation in the VABpm (%)	Participation in the consumption of water (%)
Supply	0.50	15
Irrigable	1.25	79
Production hydroelectric	0.70	--
Total	**2.45**	**94**

Table 97. Percentage participation of sectors in GAVmp and in water consumption.

However, such an significant general conclusion requires some qualification.

Firstly, it is fact that, beyond their strict economic repercussions, there are very significant –and legitimate– interests involved, in a debate that often becomes visceral, and where social and community values – studied in other sections of this White Paper– can matter more than directly economic-productive ones. In the case of irrigation, its strategic significance and the multiplying effect that it can play in the rural world make these macroeconomic determinations an issue to be handled with caution, especially considering its economic impact on other associated activities (for example, in the transport sector associated with fruit and vegetable production, or agriculture).

The spatial heterogeneity of economic activity associated with irrigation also leads to these figures evening out significant territorial differences in the Spain's various agricultural areas.

From a hydroelectric point of view, it should be considered that this use does not represent any cost for the public budget, since it is mostly carried out by private initiative. This means that profitability criteria in actions were those that they required, so contribution to GAVmp does not fully reflect its economic efficiency.

On the other hand, these figures do not consider a circumstance that, in the case of irrigation, can be very significant, which is the hidden or black economy.

With respect to this, we should begin by saying that there is a difference between what is simply hidden economy and what would be criminal economy, so the situation of the rural economy is quite illustrative, with producers for self-consumption, work below the legislation that cannot be pursued because small landowners cover real income from work with busines surplus, or maintenance of the rural life through barter, or emigration to urban-industrial areas or other countries (Velarde, 1998). These activities cannot clearly be included in the concept of criminal economy, and they can influence the figures provided, so it is appropriate to outline them briefly.

In order to define the importance of this phenomenon, the adjoining graph shows the estimated evolution between 1964 and 1995 of the percentage of the Spanish submerged economy in Gross Domestic Product. A downward trend can be seen from 1964 to 1974, probably due to the black market, started at a very high level. From 1974 to 1992 the curve climbs sharply, turning down slightly from then on up to 1995, and has continued descending up to the present. As may be seen, 14% of the GDP is a reasonable estimate of this economy's current global magnitude.

Additionally, the map in figure 306 shows the territorial distribution of indicators of the hidden economy, with regions (1) where submerged income and labour irregularities are lower than the Spanish average, regions (2) where submerged income is greater than the average but labour irreg-

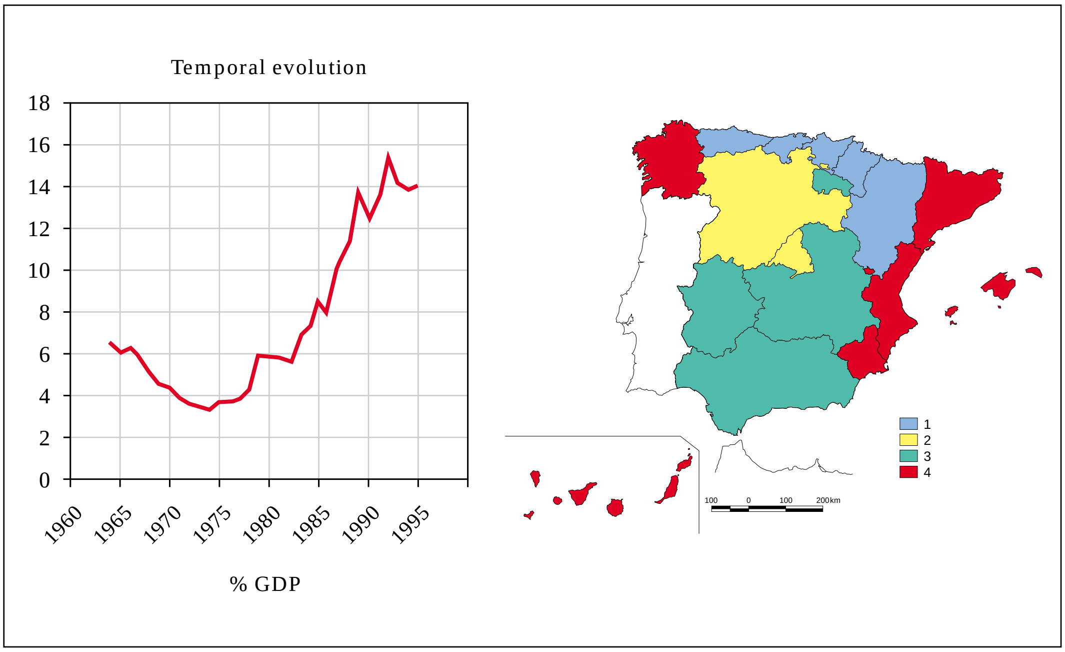


Figure 306. Temporal evolution of Spain's submerged economy in percentage of GDP, and indicators of its territorial structure.

ularity is lower, regions (3) where submerged income is smaller than the average but labour irregularity is greater, and regions (4) where both submerged income and labour irregularity are greater than the national average (Serrano Sanz et al., 1998).

As may be seen, it is in the Mediterranean regions, Galicia and the archipelagos where the phenomenon is most apparent, probably owing to the special characteristics of their production structures. The effect of this situation on the macromagnitudes given above for the directly water-related economic sectors, cannot logically be ignored, and would represent an upward modification of the quantities shown.

3.7.2. The economic-financial regime in effect

Having considered the basic concepts and magnitudes of water as an economic factor, it is expedient to consider what treatment this question has received in Spain from the point of view of legislation, and experiences observed in applying this regime.

There is little need to stress the importance of this question: there is no modern, rigorous water management if the economic-financial regime that regulates it is not sufficient and satisfactory.

3.7.2.1. Introduction

References to water use in terms of rationality and economy are numerous in the Water Act (Heading II: On the public administration of water. General principles; Heading III: On Water Planning, for example). The Constitution (article 45) also gives specific attention to this matter, as a natural resource. As a result of these provisions, we should briefly examine organisation, from the point of view of the economy, that has been defined in Spain with respect to water resources, and to consider whether it is the most appropriate to confront current problems and challenges.

In the case of water, and as mentioned above, we may refer to it on two basic levels: firstly, as a natural resource and, secondly, as an available resource with a certain guarantee thanks to the necessary hydraulic regulation infrastructures. In this last case, it would be necessary to think of it more as a product in an economic sense, resulting from production process that uses the natural resource itself as a production factor. In other cases, water resources are used directly, without requiring human intervention (permanent flow, enjoyment of the environment, etc.).

All societies should solve three basic questions of economic organization when dealing with limited assets or, rather, scarce with respect to existing demand. As regards water resources, although there exist a considerable range of services associated with them, it is expedient here to refer to those that are most directly competence of the State, more specifically, what constitutes the basic water supply. These questions would be as follows:

- Which water-related services should be produced, and in what quantity, in particular, how much water to regulate to convert into available?
- Who or what agents should be the suppliers of these services and how or what methods should be used?
- For whom is this to be carried out, that is, how to allocate the available resource among demand, users or consumers?

Societies adopt different economic systems in an attempt to respond to the three problems outlined, and to allocate their scarce resources in the best possible way. As is well-known, the countries around us, including Spain, have adopted mixed systems of general economic organisation whose elements are mostly a market economy where prices, profits and market play a fundamental role. Alongside these, there are also cultural elements and some arising from customs, and others more characteristic of a centralized economy, to correct the possible shortcomings of the market. The resulting scenario familiar to everyone.

In the case of water, there is little need to point out that cultural and traditional elements have most influenced the establishment of the basic regulation in effect as regards water resources. However, we should consider: Is water, except for some peculiarities, an asset like other goods and services, and therefore, should there not be distinctions when analysing the efficiency with which its economic organisation solves the questions outlined? or, conversely, does it have enough particular characteristics that suggest not using the same methodology and criteria that the economy applies as scientific discipline to the study of other goods and services?

Answering these questions is neither easy nor immediate, in view of the multiple levels that the study of water resources must involve. But whatever the answer, what is appropriate to consider is whether the current regulation of water resources in Spain has led to satisfactory economic organisation from the point of view of providing an efficient response to the basic questions of the economy.

With respect to the first of the questions, the answer has already been given, in this document, in the chapters on water demand and availability, respectively. We therefore do not reiterate the significant amounts reached by water supply, only indicate that a significant part of this has been driven by the public sector itself, with the consequent effect on maintaining the demand.

In connection with second, responsibility has generally fallen to the State, under the implementation of the economic-financial regime described in some detail in this section. This has possibly been because the considerable investment required for executing infrastructures (the example of surface water regulation is illustrative) exceeded, with the exception of the electric sector, the financing capacity of private agents. Alongside these actions, the numerous uses of groundwater should be mentioned, which have mostly been carried out by private individuals. Finally, the level of technological development in each period has responded to the need to resolve issues.

The answer to the third question is basically given by the concessional regime laid down in the Water Act and the Regulation of the Public Water Domain, since they regulate the exclusive use of water which, together with legal provisions, complete the rights to the use of the public water domain. In short, this question has also been considerably influenced by the State.

As a result, the most prominent characteristic in the allocation system descibed is that, unlike what happens with many other economic assets where it is the market that plays this role, this has been significantly conditioned by state initiative.

More specifically with respect to the economic-financial regime that presently regulates the basic aspects of utilisation of the public water domain, we should mention that it is basically laid down in the Water Act of 1985 and in the regulations that develop it, approved by Royal Decree 849/1986, of April 11th. However, it is important to point out the existence of numerous specific funding regimes that resond to a wide variety of reasons, as we shall try to summarise.

Firstly, there are singular cases within the general legislation itself. An example would be hydroelectric uses, whose economic obligations centre on the production standard by which state-associated power stations are bound, and which lie not within the scope of water legislation, but in the scope of Public Administration contracts.

Secondly, there are powers which, when exercised by the different administrations concerned, may define additional or alternative economic-financial frameworks (the case of the regulations promoted by the agricultural administration for the transformations into irrigation, as will be explained later on; of supply and collection services, where considerable responsibility lies within autonomous and local scope; or of the wide margin that the Autonomous Communities in inter-community basins clearly enjoy).

Thirdly, we should mention the provisions that regulate, in a dispersed way, the transfers of water resources currently existing between different hydrographic basins. As we shall see, some of them lie within the traditional principles of water legislation (Tagus-Segura, Guadiaro-Guadalete and Tagus-Guadiana), but others define special economic-financial regimes (supply to the Tarragona countryside and Mallorca).

Finally, apart from the above-mentioned regulations, which directly affect the economic-financial conditions in which water services are supplied, we should not forget others, such as those in the agricultural sectors and, to a lesser extent, electric, since they condition the demand for products from these sectors and therefore, indirectly, the utilisation of the public water domain. Although it is not expedient in this document to cover this issue in greater depth, their economy-related effects on the regulation of Spanish water resources cannot be denied.

The following section describes, due to their major significance in the development of hydraulic infrastructures, Act 7 of July of 1911, still in force, and Decree 118/1973, of January 12th, which approved the redrafted text of the Agricultural Development and Reform Act. As regards the Water Act, consideration wil be given not only to the basic provisions of Heading VI, specifically dealing with these issues, but also some of those in the Heading IV, especially those on authorisations and concessions.

3.7.2.2. Historical background. The Hydraulic Works Act of 1911

Regenerationst ideas on hydraulic and irrigation affairs were definitively consolidated in the legisaltion with the Act of 7th July, 1911, on hydraulic constructions for irrigation, defence channelling, although we should mention its forerunner, Act 7th of July, 1905, which remained in force for irrigated areas of less than 200 hectares. Known as the Gasset Act (modified by the Act of 16th May, 1925 and that of August 24th, 1933), applicable only when the irrigable surface area exceeded the above-mentioned size, it laid down a system of public assistance in financing the type of works included within it.

Chapter I of this Act, dealing with hydraulic constructions for irrigation, stipulates that the State, besides taking responsibility for drafting projects and other complementary studies, has three procedures in channelling aid:

Execution by the State with the assistance of interested towns

In unirrigated land transformations into irrigable, landowners should undertake to contribute 50% of the expenses for construction work (including compulsory purchases), although they should only satisfy 10% (which may be be replaced with the contribution of the lands it may be necessary to occupy), because the other 40% can be advanced by the State at an annual interest of 1.5%, to return in 25 years as of the fifth year from the date of termination of the works.

In improvements or extensions to existing irrigated land, the irrigators undertake to contribute 60%, although of this percentage only 20% should be contributed during the execution stage of the work (with the same observation as in the case above), because the other 40% can be advanced by the State at an annual interest of 2%, to be paid back in 20 years. Two Decrees of December 15th, 1939, and of July 27th, 1944, include, respectively, within this type of works, those of canal lining and those of rise in dams and other complementary work, with some slight modifications to quantities and aid conditions.

The aid is declared compatible with other possible subsidies provided, where relevant, by the provincial governments or the local administration. Once the requirements laid down by law are complied with, the works will become the exclusive property of the landowners or irrigators' associations, with a perpetual concession issued in this respect.

Additionally, the possibility is foreseen that the Government may execute regulation works whose objective, complementary to that of irrigation, is the best exploitation of hydraulic energy, with the help of the beneficiary groups and organisations and under the conditions that are agreed.

In the event that the interested parties in the execution of irrigation works regulated by it have the cooperation of industrial organisations willing to exploit the hydroelectric energy that can be obtained from such works, the assistance required by the State will be increased in percentage, variable according to the technical characteristics of the dam, which will be covered by said industrial users. This same obligation is also stipulated for all concessions for new dams (to be satisfied in 20 annuities) and is generalised, with some qualifications, for the exploitation of existing dams that benefit from works already carried out by the State.

Execution by Companies or Societies with assistance from the State

Referring to transformation of unirrigated land into irrigable, with applicants required to authenticate representation of the landowners of at least half of the irrigable area. In this case, the subsidy amounts to 50% of the works budget (included compulsory purchases), plus another 25% on loan, at an annual interest of 2% and repayable in 25 years. For these cases, the possibility is also considered of having recourse to the Assistance Act of 27th July, 1883. This modality had little application and therefore very little practical transcendency. We should indicate this formula's conceptual similarity with modern construction mechanisms and exploitation of hydraulic works implemented by State Companies.

Sole execution by the State

This procedure is reserved, provided certain requirements are fulfilled, for works comprised in the plans approved by the Hydrographic Associations, and as long as a general hydraulic works plan has not been approved. The lands affected by the irrigation works are subject to the payment of certain tariffs which progressively amount to the value stipulated by law. Similarly, industrial uses that benefit from extension or improvement works executed by the State are obliged to pay a tarriff. This third procedure was, by far, the most used of all, and the only one that gave significant results in practice.

As regards defense and channelling works (Chapter II), the beneficiaries of the works of such a nature will guarantee, at least, 25% of their total budget, being able to become effective in 20 years. The provisions of Order April 4th, 1923, are relevant to the actions described here, because they require an economic study to be carried out to demonstrate that the wealth created with them or whose loss could be avoided, is greater than the costs involved in the works.

The system defined in the Law, and which is summarised above, was perfected by several decrees on the ratification of rates (133/1960, 134/1960 and 144/1960), enacted under the Rates and Parafiscal Levies Act, of December 26th, 1958. Each one defines, under a similar scheme, the rate structure it ratifies: in the first of them, irrigation rates; in the second, the tarriff for occupation or exploitation of public domain assets; and in the third, the regulation tarriff. From this moment onward, a terminology was coined that ended up decisively influencing the Water Act of 1985 (Álvarez Rico et al., 1981).

Finally, we should mention, as regards irrigated areas declared of national interest, the Act on Colonisation and Distribution of the Property of Irrigated Areas of April 21st, 1949. This law promoted, in the following decades, the transformation of unirrigated land into irrigable over large areas, through combined actions of the Ministry of Agriculture and the Ministry of Public Works, with the Agricultural Development and Reform Act enacted in 1973, and whose text revises the legislation on colonization of large areas and land parcelling.

This Law stipulates aid of 100% for works of general interest (rural service roads, channelling and protection of the banks of public channels, connection ditches and various other works); of 40% for works of common interest (secondary distribution and drainage networks), plus an interest-free loan of the other 60%, repayable over 5 years as of the official declaration of irrigation start-up; and, lastly, for works of private agricultural interest (parcelled network), a grant of 30%, plus an interest-free advance of the other 70% to pay back in 20 years. By modernizing the repayments, the practical result was an almost zero return to the State.

3.7.2.3. Basic principles of the regime in force

This section examines the basic inspiring principles of the regime currently in force on water-related economic-financial affairs. As we shall see, this regime is made up of four basic concepts, and a varied set of related precepts.

3.7.2.3.1. The four basic concepts of current regulation

The economic-financial regime in force, defined in Heading VI of the Water Act, is structured around four basic concepts, whose administration and collection is entrusted to the basin organisations. Below, we describe the basic features of these four different levies, which must be paid for the exclusive utilisation of the public water domain, and we shall then examine the results of their application since the enactment of the Water Act, the problems arising from this practical application, and some reflections on these experiences.

Tariff for utilisation of public domain assets

This tariff, introduced in section 104.1 Water Act under the denomination of tariff for utilisation of public water domain assets, and also known as occupation tariff, charges for the occupation or use of terrain of the channels and beds of lakes, lagoons and reservoirs over public channels, which require authorization or administrative concession.

- It is applied to all the assets of the public water domain except water.
- It is aimed at protecting and improving the affected public water domain.
- The amount is set at 4% of the taxable base, this being the value of the asset used.
- Water grantees are exempt.

Discharge tariff

This levy, introduced by section 105 Water Act with the denomination discharge tariff, charges for authorized discharge in accordance with the provisions of the relevant sections of the Act.

- It is aimed at protecting and improving the receiving environment affected by the discharge. It refers to actions on water quality, in accordance with the quality objectives laid down the basin management plans.
- The amount calculated by multiplying the pollutant load, expressed in units of pollution, for the value allocated to each unit. Unit of pollution is understood to mean that caused by the domestic-type discharge corresponding to 1000 inhabitants, in one year. Details about these units and the equivalents for discharge of other types, are established by legislation. The value may be different according to river reaches and will be set according to the forecasts of the basin water plans.

Regulation tariff

This tariff, introduced by section 106.1 Water Act, charges the direct or indirect beneficiaries of surface or groundwater regulation structures carried out wholly or partially by the State.

- It is aimed at compensating the State for its financial contributions.
- Their annual quantity is calculated by adding the following concepts:
  1. Operating and maintenance costs for the work carried out.
  2. Management costs that can be attributed to such works.
  3. 4% of the investments made by the State, duly updated and taking into account the technical amortisation of the structures. The type of amortisation (decreasing line) was determined by legislation, by means of a formula, and a period of 50 years was established in this respect. Although an up-date of the taxable base is laid down, a discount was established (not provided for in the Act) of 6 percentage points over the legal interest for the money. This has, as we shall see, major consequences.
- The distribution of this amount among the beneficiaries shall be carried out with critera of water use rationalisation, fairness and self-financing. Legislation stipulates that it will be in proportion to the participation in profits generated by the structures. The unitary value of individual application, once the opportune equivalents have been established among the different uses, are given in units of arable surface (the usual criteria in irrigation), flow, water consumption, energy or other that may be considered appropriate.

As mentioned, the regulatory modification has major consequences, illustrated in figure 307. It shows the result of applying the previous concepts, the evolution of amortisation and the regulation tariff with and without the discount of 6 points introduced by regulation, in a supposition of investment 100 and legal interest of 9%.

Figure 308 shows users' participation in the payment of the investment according to the legal interest of the money.

Water use tariff

Introduced by section 106.2 Water Act, this levy charges beneficiaries of other specific hydraulic structures (not regulation) carried out entirely by the State, and for the concept of water availability or use.

- It is aimed at compensating the State for its financial contributions.
- Its annual quantity is calculated by adding up the following concepts:
  1. Operating and maintenance costs of the structures implemented.
  2. Costs that may be attributed to the State for these structures.
  3. 4% of the investments made by the State, duly updated and taking into account the technical amirtisation of the structures.

     In this case, its characteristics are also laid down by law, being similar to those described for the regulation tariff, except with respect to the term of amortisation, which decreases to 25 years.

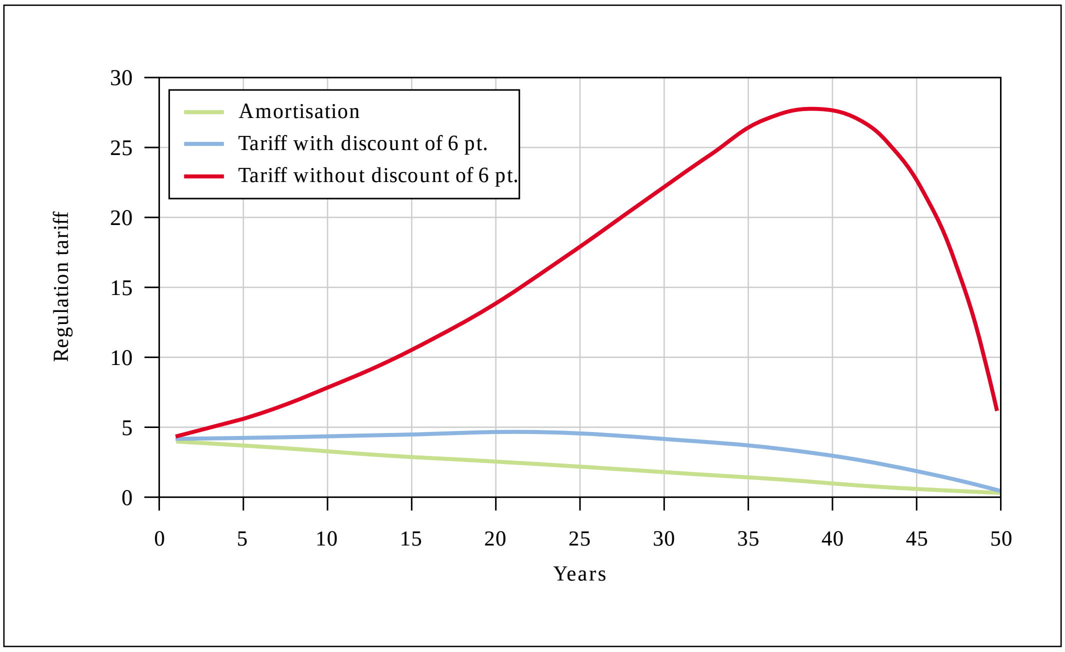


Figure 307. Evolution of the regulation tariff (Investment = 100; legal interest = 9%).

- From the above, it may be inferred that, unlike the case of the occupation tariff, the economic value of the asset utilised (the water) is not recognised or considered, and it therefore continues to be considered as free.
- The distribution of the amount of the said tariff among beneficiaries shall be carried out with criteria of water use rationalization, fairness and self-financing. The legal specifications made for the regulation tariff are also valid here.

As in the above case, legal modification has major consequences, illustrated in figure 309. It shows the result of applying the concepts above, illustrating the evolution of the amortisation and the use tariff with and without the discount of 6 points included in the regulations, in a supposition of investment 100 and a legal interest rate of 9%.

Similarly, figure 310 shows users' participation in the payment of the investment for the work according to the legal interest rate.

3.7.2.3.2. Recent incorporations

Act 13/1996, of December 30th, on Fiscal, Administrative and Social Measures, section 173, lays down the possibility of a contract to grant construction and exploitation of hydraulic structures, for works and infrastructures associated with the regulation of hydraulic resources, their trans-

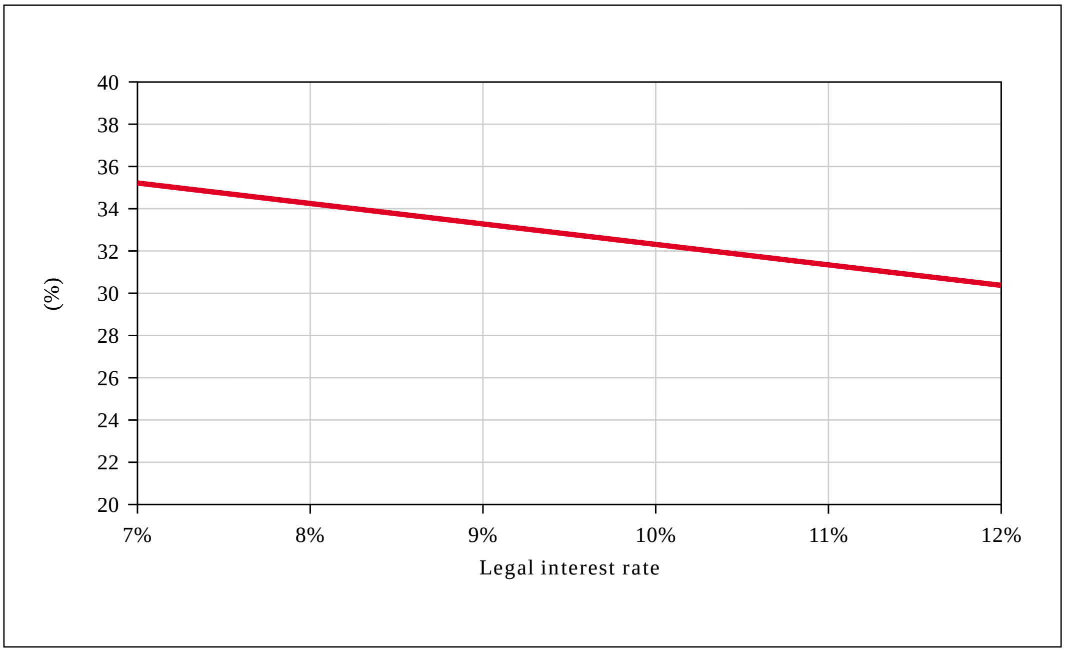


Figure 308. Users' participation in the payment of regulation investment according to the legal interest rate.

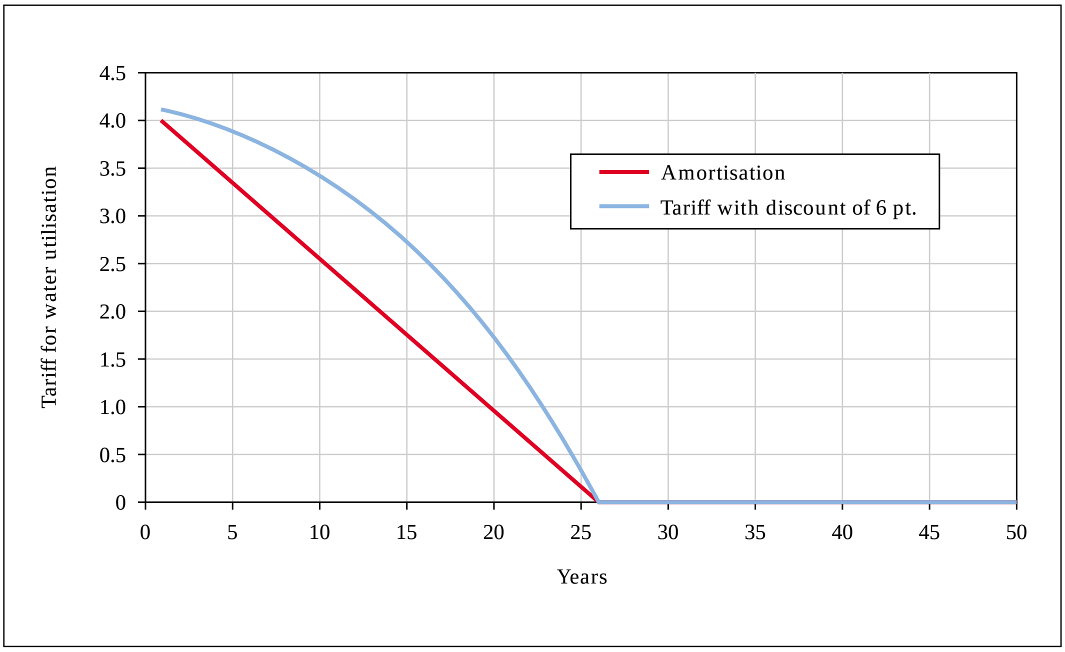


Figure 309. Evolution of utlisation tariff (Investment = 100; Legal interest rate = 9%).

port, treatment and desalination, and with the collection and treatment of wastewater, the grantee being entitled to charge a tariff as compensation.

The economic-financial regime laid down for the contract, still pending legal development, grants the competent administration the following rights:

- To set the tariffs. These will include costs for operation, maintenance and management, investment recovery and capital cost.
- To safeguard the financial balance of the concession.

The prominent aspect of this new figure is that, without affecting the regime in force for utilising water resources, it opens new opportunities for the participation of private initiative in the supply of hydraulic infrastructures. This is important to the extent that it enables private capital to be included in the investment made, and the execution of those actions whose demand cannot be covered by the public sector can proceed. Furthermore, and maybe even more importantly, co-financing by private individuals leads to greater economic rationality in the initiatives undertaken.

3.7.2.3.3. Other relevant aspects

Apart from the basic regulation laid down in the economic-financial regime of the Water Act, there are other precepts

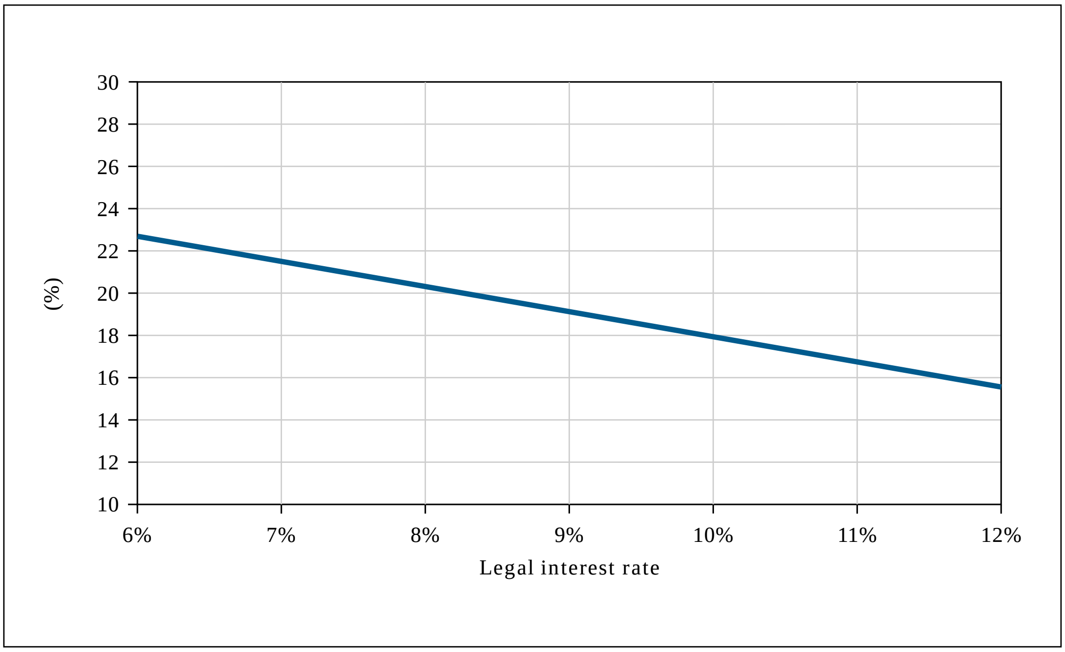


Figure 310. Users' participation in payment for utilisation investment according to the legal interest rate.

of this Law with significant economic effects on the organisation of water resources. We should highlight some of those relating to the concession regime insofar as, together with the legally defined hypotheses, they define the rights to exclusive use of these resources and they directly affect their allocation. We could mention, among other, the following:

- There exist tariffs based on concessions, which are none of those foreseen above in the four concepts of the general regime described. This is the case of hydroelectric production tariffs, charged in the concession itself.
- Concessions are granted according to public interest, in compliance with the forecasts of the basin plans, and must observe the order of preference define by them or, otherwise, the one established by law. In any event, priority should be respected for population supply. However, in cases of incompatibility of uses, for decision-taking purposes, the only possibility considered is to assess the greater or lesser public or general utility of those of the same type. Any concession is subject to comupulsory purchase in favour of another use that precedes it.
- This is understood to be without prejudice to third parties, which in a strict theoretical sense is impossible since there is always some environmental effect, to a greater or lesser extent.
- The characteristics of the concession are established: purpose, location, granted annual volume, generally in terms of flow (in irrigation, also surface area and allocation; in hydroelectricity the technical characteristics of the generating sets and the dam) and term, which shall be no greater than 75 years (in the case of hydroelectric production, this depends on the useful life of the generating equipment). Such long terms mortgage the management of water resources for a long period.
- In water concessions for irrigation, in a regime of public service, the administration shall approve the maximum and minimum values of the irrigation tariffs to apply.
- The water granted is ancillary to the uses stated in the concession title, and may not be applied to other, different ones, nor to different land in the case of irrigation. Except by administrative authorization, modifications are not allowed to adapt to possible changes in the conditions that led to requesting the concession.
- Concessions can be reviewed by the administration when the conditions that determined their granting have modified and when the basin plans so require; in this last case, compensation is obligatory. Despite the force and importance of this possibility on an economic level, at present it has not yet been used.

There is another aspect of the ordinary procedure of granting concessions that exceeds merely procedural scope, and which, due to its economic implications, should be highlighted. This is with respect to the procedure in competition: in equal conditions, preference is given to those uses that involve a more rational use of water and a better protection of the environment. This precept trusts, although in a very restricted way, in the benefits of competition for resource allocation.

Lastly, we should mention the philosophy that seems to underlie the Chapter on state aid, which stipulates assistance for those who implement instruments aimed at achieving lower water consumption or a smaller pollutant load. In fact, although the law does not protect the abuse of rights or the wrong use of water, and it seems obvious that rational use of the resource should be a permanent objective of any user, such an idea may not be explicitly deduced from this precept. Possibly, the need for such a provision arises from the lack, with respect to this, that exists uncovered in the economic-financial regime in force.

3.7.2.4. Results of applying the regime in force

Having described, in the above section, the basic features of the current economic-financial regime, we now turn to a study of the results obtained from practical application of this regime, since the Water Act came into force.

Accordingly, we will review the data on invoicing for the different levies, and contrast this with the amounts actually collected. We should note that the organisation of collection management is different in the different basins, because it is common for these levies to be invoiced as broken down for different individual users, and not to Irrigators' Asscoiations, as would be appropriate and desirable. We should also point out that some delay in applying the new regime, together with distortion caused by delay arising from droughts, particular court action, etc. mean that the figures provided should be considered with some reserve as to how representative they are in an ordinary situation. Additionally, the mean values may hide significant interannual differences. Nevertheless, this hypothetical representative situation would not differ greatly from the amounts given.

3.7.2.4.1. Tariff for utilisation of public domain assets (section 104)

Figure 311 shows the distribution, by hydrographic Confederation, of the mean amounts invoiced (Mpta) and the collection/invoice relationship (%) for this economic concept, in mean values for the period 1986-1997.

Figure 312 also shows the temporal evolution of these aggregate amounts for the Confederations as a whole.

It may be seen that, although there is a generally upward trend over time, the total amount for this tariff is extremely low (about 250 Mpts/year), contrasting significantly with the intensive occupation and utilisation of channels, beds, etc. that should be charged for.

Percentage of collection is high in general, standing between 80% and 90% in recent years.

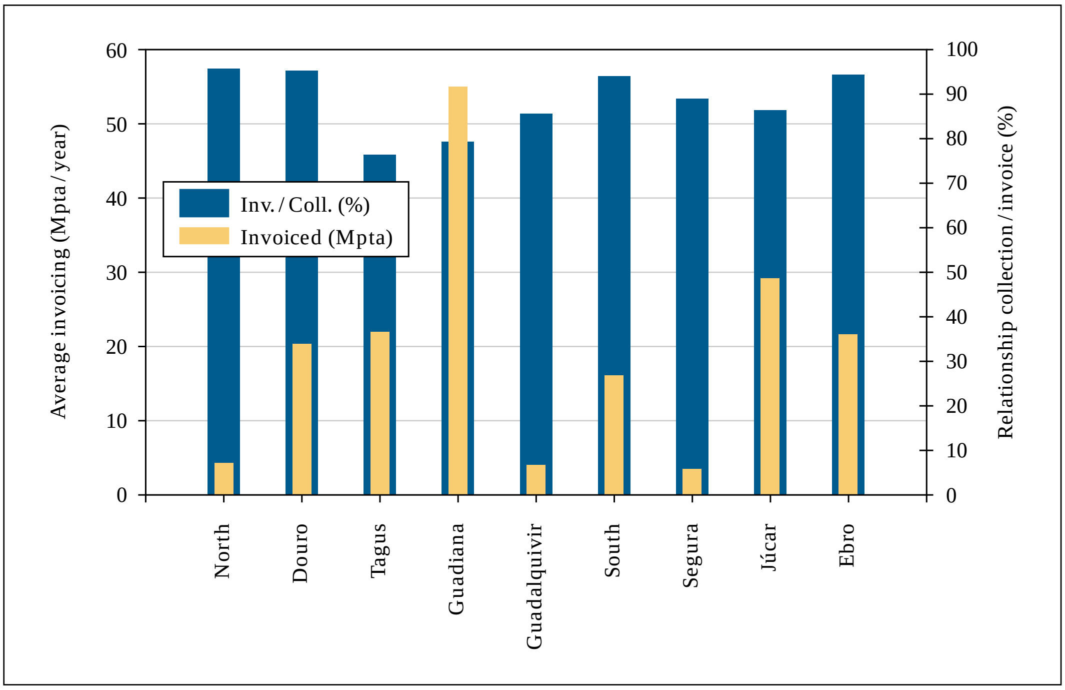


Figure 311. Mean values for invoicing by Confederations and the collection/invoice relationship for the public domain utilisation tariff.

The very low value of 4% for basic taxable amount (value of the asset), together with the exclusion of grantees, means that this tariff is in practice inoperative in achieving its objective, which is to protect and improve the affected public domain.

3.7.2.4.2. Discharge tariff (section 105)

As in the above case, figure 313 shows the distribution, by Hydrographic Confedration, of the mean invoiced amounts (Mpta) and the collection/invoice relationship (%) for this economic concept, in mean values for the period 1986-1997.

Figure 314 also shows the temporal evolution of these aggregate amounts for the Confederations as a whole.

As may be seen, this levy was not applied until the year 1988, when the specific development regulation came into full effect.

It may be seen that, except for a period of growth from 1988-1991, since that date until today both invoicing and collection seem to have stabilised at total figures of around

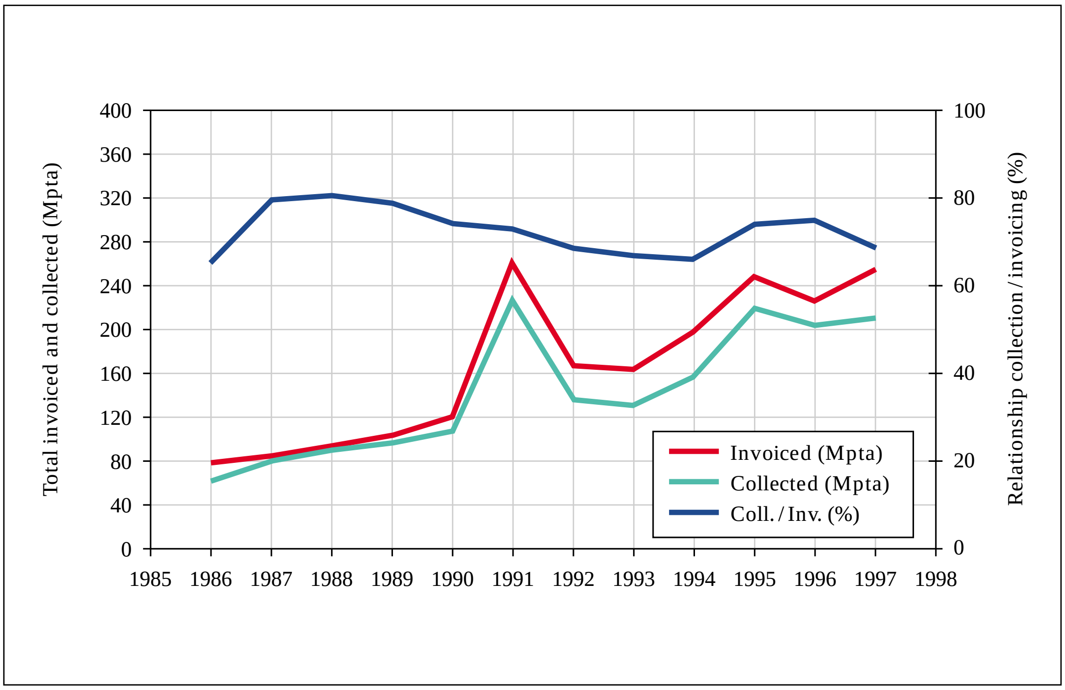


Figure 312. Global evolution of invoicing, collection, and collection/invoice relationship of the public domain utilisation tariff.

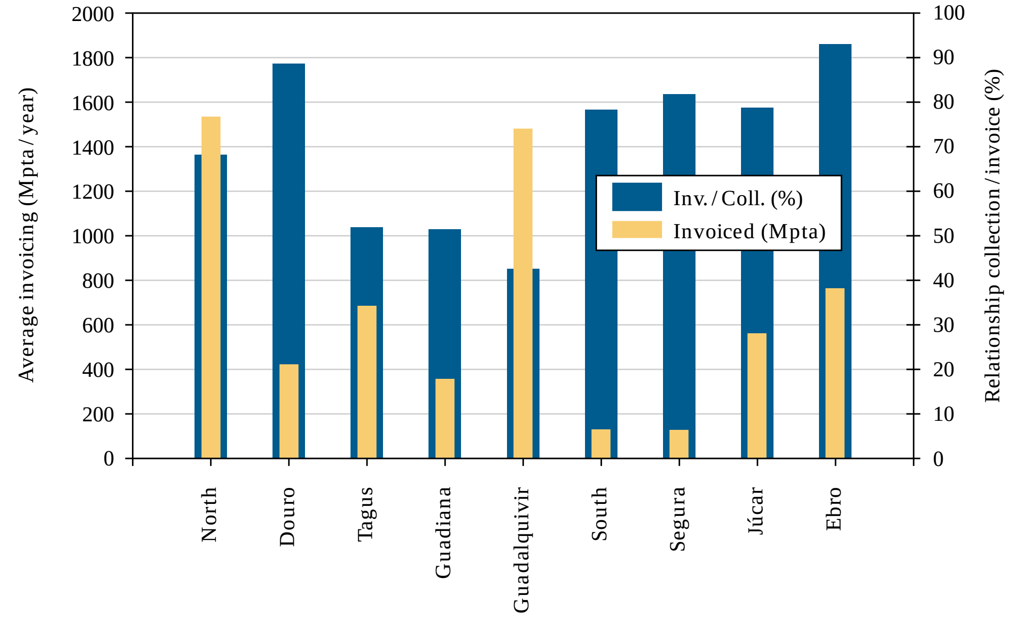


Figure 313. Mean values of invoicing by Confederation and the collection/invoice relationship of the discharge tariff.

6,000-7,000 Mpta and 4,000-5,000 Mpta respectively. Slow payment is, therefore, very widespread (about 30-40%).

The person chargeable for this tariff is frequently the local administration, which means that a large part of it is paid by the –very slow– method of compensation through the Ministry of Economy and Treasury

3.7.2.4.3. Regulation tariff (section 106.1)

As in the above cases, figure 315 shows the distribution, by Hydrographic Confederation, of the mean amounts invoiced (Mpta) and the collection/invoice relationship (%) for this economic concept, in mean values for the period 1986-1997.

Figure 316 also shows the temporal evolution of these aggregate amounts for the Confederations as a whole.

As may be seen, and excluding delays and court action, there was some initial growth in the period 1986-1991, followed by a certain stabilisation up to 1996, and a very sharp increase in both invoicing and collection in the year 1997, probably due to recovery after the heavy drought of previous years. Collection has remained at levels of 60-90%, possibly with an overall downward trend as of ‘91, probably due to the same reason of supply shortage.

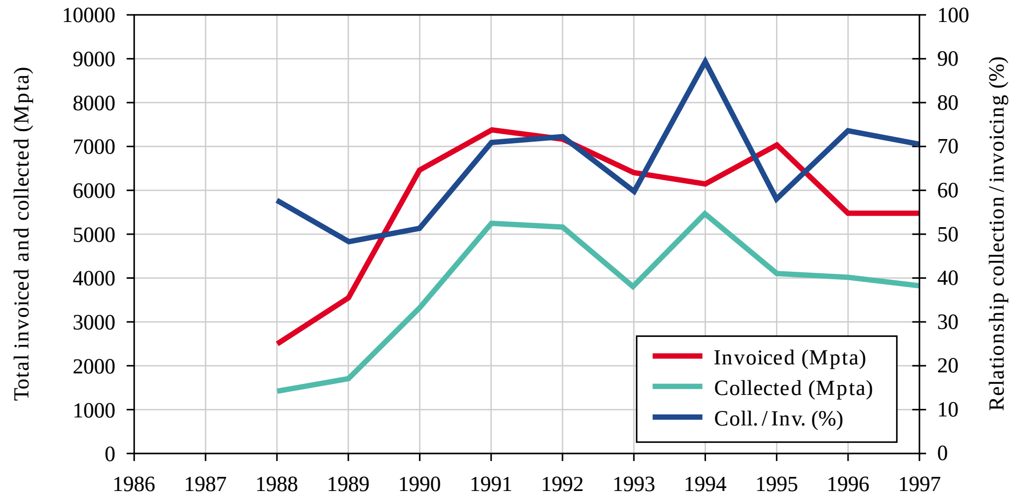


Figure 314. Global evolution of invoicing, collection, and collection/invoice relationship of the discharge tariff.

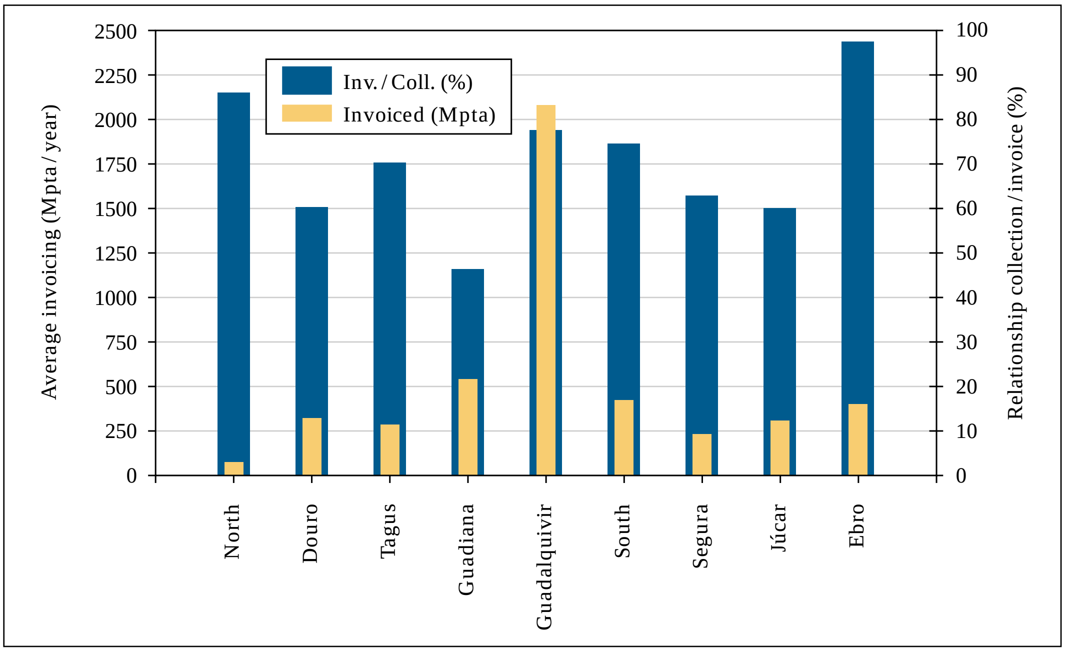


Figure 315. Mean values by Confederations of invoicing and the collection/invoicing relationship of the regulation tariff.

3.7.2.4.4. Water utilisation tariff (section 106.2)

As in above cases, figure 317 shows the distribution, by Hydrographic Confederation, of the mean amounts invoiced (Mpta) and the collection/invoice relationship (%) for this economic concept, in mean values for the period 1986-1997.

The next figure also shows the temporal evolution of these aggregate amounts for the Confederations as a whole (fig. 318).

As may be seen, the Segura is the basin with the highest collection levels, of comparable amounts to the sum of all the others (40% of the total). The reason for this is the tariff for the Tagus-Segura transfer, which although governed by its own regime, not corresponding to provisions of section 106.2, Water Act, could be assimilated to that concept. Collection of this tariff represents 100% of invoicing, and in view of its considerable relative importance, it has also been shown in the graph for illustrative purposes.

Notwithstanding this particular situation, there seems to be a similar overall pattern to the above, with growth up to the year 1991, stagnation from then on, and sharp growth in 96-97, certainly arising from the post-drought situation. It may also be seen that the global collection percentage is very high, over 90% in general. If the transfer tariff is deducted, this percentage falls to 80%.

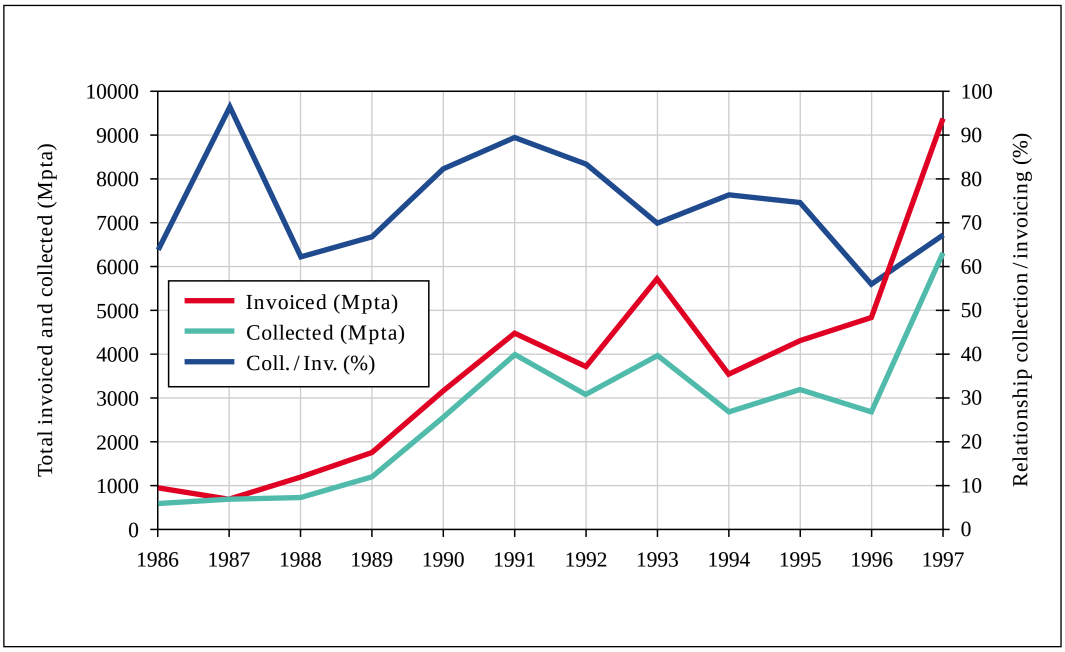


Figure 316. Global evolution of invoicing, collection, and collection/invoice relationship of the regulation tariff.

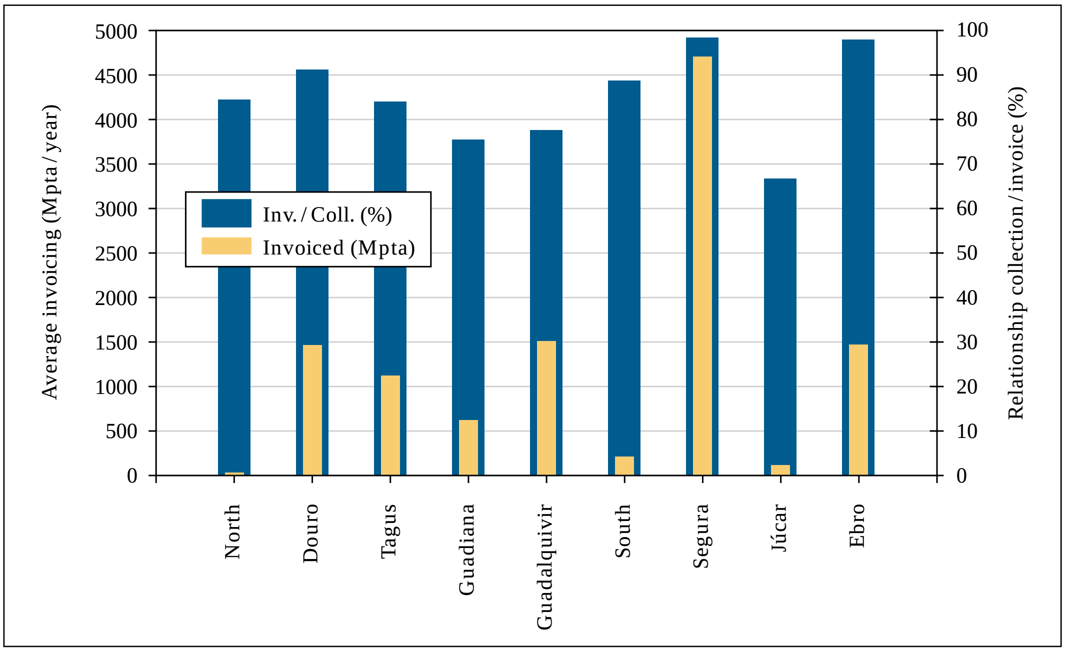


Figure 317. Mean values of invoicing by Confederation and the collection/invoice relationship of the water utilisation tariff.

3.7.2.4.5. Summary of results

Aggregating the above results to give a global view, figure 319 shows evolution from 1986 –when the Water Act came into effect– of invoicing and collection by all the Confederations and all the concepts of the economic-financial regime in force.

As may be seen, we should identify three differentiated periods. The first, up to the year 1991, when the new regime was being progressively developed and applied, with moderate increases from year to year. The second, from '91 to '95 (coinciding with an intense drought), showing stagnation or a slight drop in the situation. Finally the third, from '95 to '97 (characterized by a significant hydrological recovery after the drought), with a sharp increase in invoicing and collection (mainly, and as to be expected, due to the regulation tariff and the water use tariff). Furthermore, the mean overall level of collection remained around 80-90% at all times, although with differences arising by territories and fiscal concepts.

Not considering the years of transition and initial start-up, and adopting the seven last years of the series as an indicative period of reference (1991-97), the average annual situation by basin is shown in the graph in figure 320.

The sum of all the amounts invoiced annually by the Confederations totals –in the reference period– to about 24,000 Mpta, of which about 20,000 is collected (30,000 and

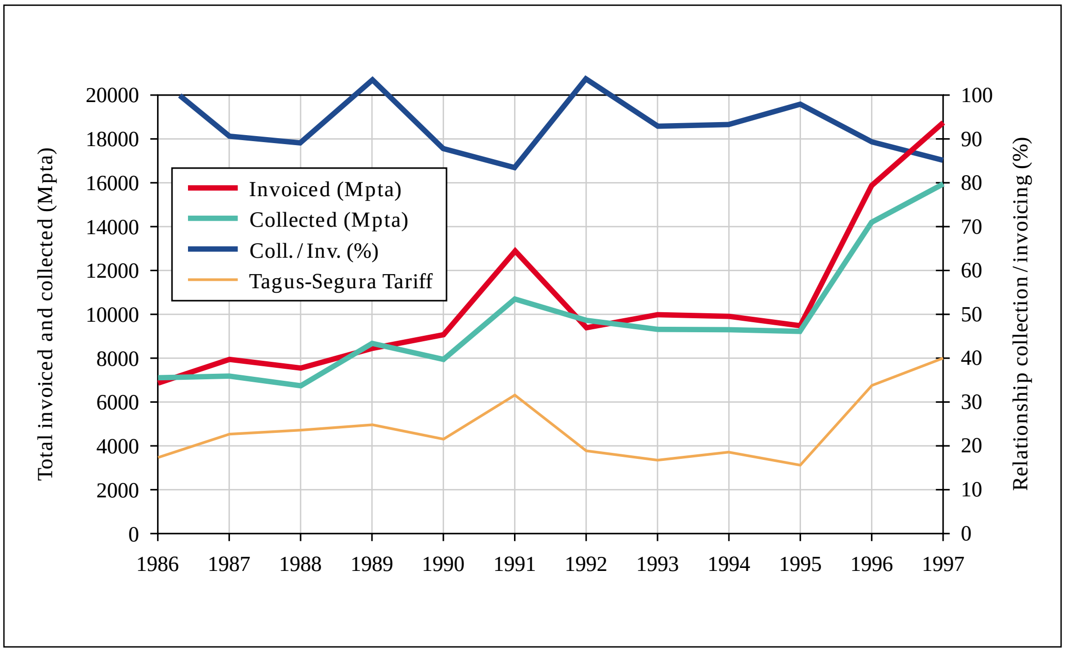


Figure 318. Global evolution of invoicing, collection, and collection/invoice relationship of the water utilisation tariff.

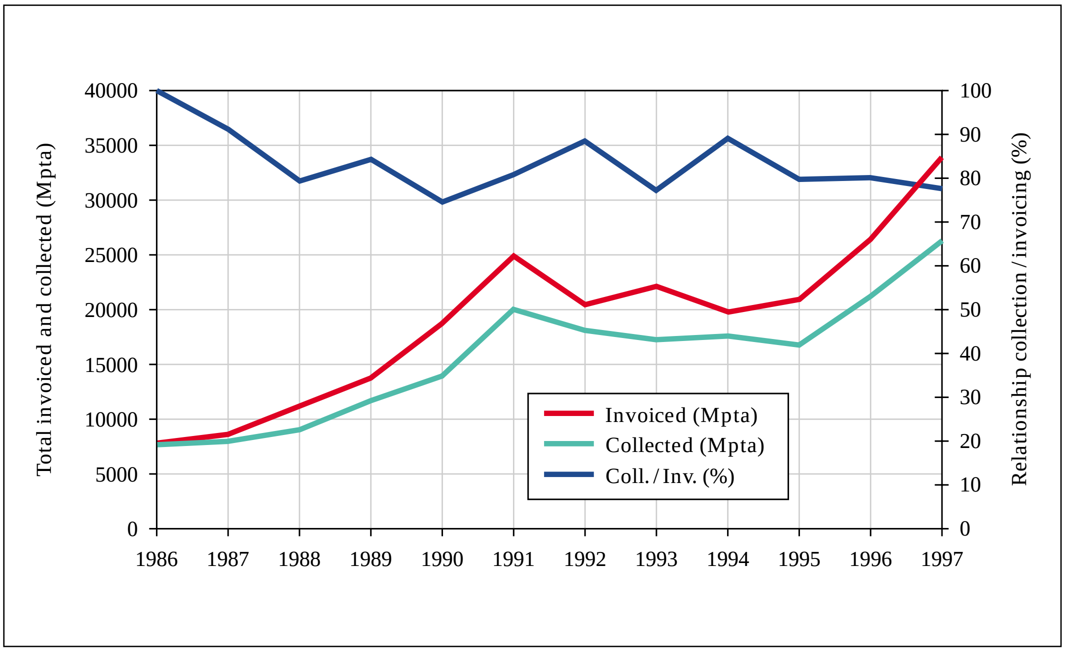


Figure 319. Global evolution of invoicing, collection, and collection/invoice relationship for all the Confederations and all the concepts of the economic-financial regime in effect.

25,000 respectively if we take the last two years). This figure is a very small fraction of the annual State Budget dedicated to water, and would barely even cover the personnel costs of the State Water Administration. If we suppose total recovery from the drought, with ordinary supplies, and improved collection, this all indicates future overall collection would not go beyond 35 or 40,000 Mpta/year, unless there were significant modifications as regards the number of persons chargeable for tariffs, or in the amounts involved.

Figure 321 shows these reference period figures broken down by charge figures, illustrating the relative importance of the different concepts.

As may be seen, the tariff for utilisation of public water domain assets is absolutely insignificant (about 220 Mpta/invoiced p.a., which does not even amount to 1% of the total) compared with the others. The discharge tariff (which invoices about 6,500 Mpta/year and collects 4,500) shows the highest level of default (30%), which, together with other serious deficiencies described in the section below, recommends its complete reconsideration.

It is also surprising that the enormous effort made by the State as regards hydraulic regulation only generates invoicing of 5,000 Mpta/year and collection of 3,700, absolutely trivial amounts (of about 0.2% replacement value, as we shall see when evaluating hydraulic property) compared with the real costs of these infrastructures and the enormous profits generated by their use.

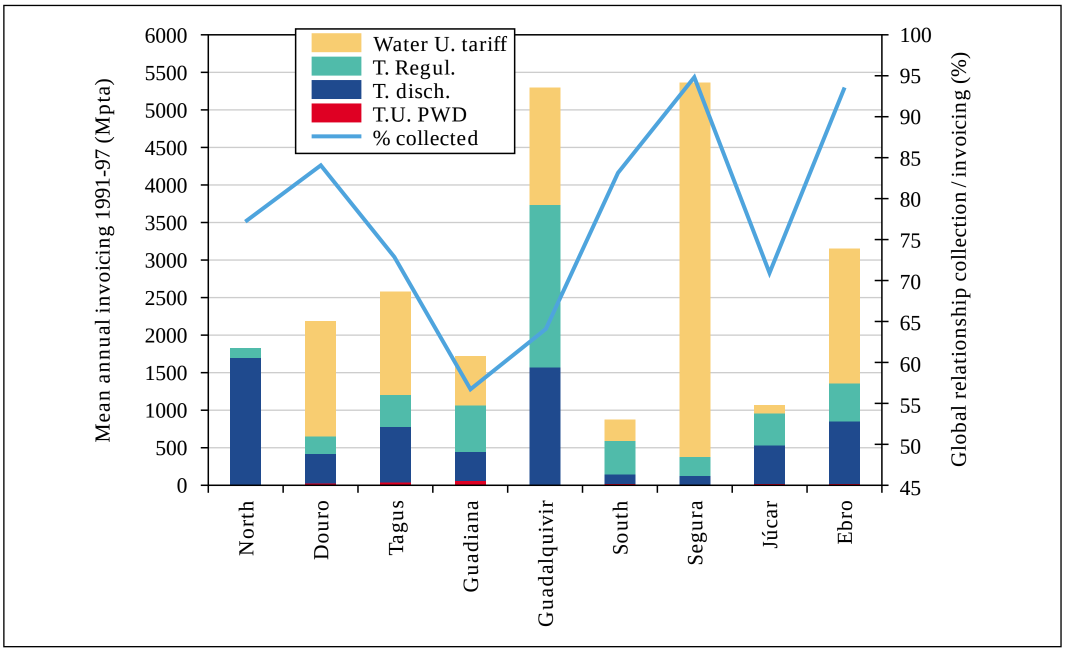


Figure 320. Mean values of invoicing for the different concepts by Confederation and the overall collection/invoice relationship.

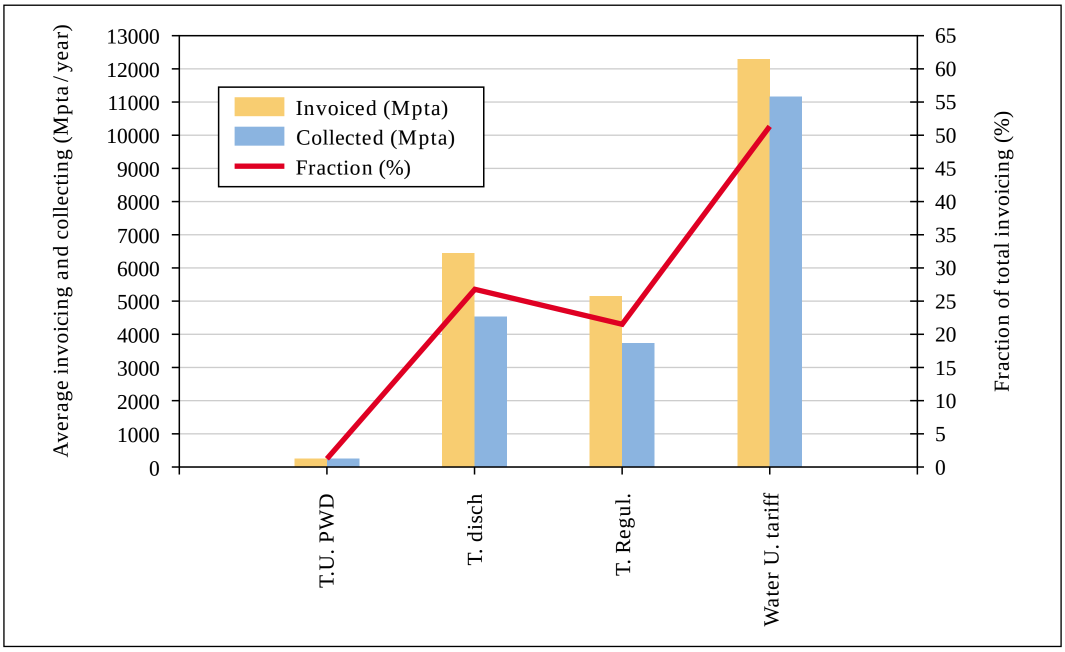


Figure 321. Mean overall value of invoicing and collection according to the different concepts.

The importance of the water utilisation tariff is clear, because its invoiced amount exceeds the sum of the other three tariffs (about 12,300 Mpta/year which means, as we shall see, about 0.5% of the channels' replacement value). If we remember that, as mentioned, approximately 40% of this tariff corresponds to the Tagus-Segura transfer, it may be concluded that this system –which mobilises less than 3% of the water consumed in Spain– generates approximately a fifth of the sum of all economic revenue made in all the Confederations for all concepts in effect. Such imbalance is in no way reasonable, and requires, as we shall see, a radical, in-depth reconsideration of the problem.

3.7.2.5. Experiences and problems

The problems that affect the situation described above, and which arise from it, are highly varied, some from not strictly water-related areas.

Firstly, and going back to the historical, conceptual origin of the problem, it should be noted that a complete forecast was not made of the implications which, with respect to water resources, were to be expected from the different policies implemented in the sectors demanding most water, especially from the agriculture aid policy. In fact, the numerous subsidies and aid which, historically (and even at the present time) have been channeled toward irrigation by the public administrations, creating demand for water that, on a national level, has reached decidedly high levels, and prices in general a long way from real costs. It must be said that this situation is not exclusive to Spain, but rather responds to an internationally widespread historical conception of water resources' role as incentivation for development, and whose availability should be provided at minimum costs by the public authorities. This assumed combination of protectionism and subsidising is largely the origin, at least psychologically, of the current situation.

Although such aid and subsidies were often fully justified in the past, on the basis of requirements for self-supply and to overcome situations of famine, the current situation is very different, and requires a repositioning of such inspiring hypotheses, in the light of the new economic and environmental conditions which, in principle and notwithstanding the obvious exceptions, do not justify a generalised system of subsidies like that of the past. We shall refer broadly to these questions in the next chapter, in studying the basis for water policy.

Secondly, and here in connection with the regulation of the economic-financial regime laid down by the Water Act and its statutory development, we should note the following aspects:

- It is not a regime of general application to all water users, but only those who benefit from certain structures or are grantees of authorised discharges.
- As we have seen, effectiveness in collecting levies is irregular, which may not only be attributed to the conceptual design of the economic-financial regime itself, and non-compliance with regulations, but also to the low effectiveness of the levy collection system and the considerable delays that frequently take place.

  This circumstance firstly prevents the recovery of the necessary financial resources for appropriate monitoring, control, administration, maintenance of the hydraulic infrastructures and protection of the public water domain and the associated environment. Secondly, it shows the low internalisation of costs generated in the process by users.
- The relevance of this fact lies not only in the matter of revenue generation, but, especially, in its economic effects on demand. In fact, none of the levies in question allows for effective demand management, that is, they do not encourage users towards rational behaviour from the point of view of economising scarce water resources.

- The complexity (and often almost technical impossibility) of accurately calculating the levied amounts, as they are proposed, considerably hampers their application and is a source of numerous legal disputes.

- In particular, in the occupation tariff, which is the only one to take into account the real value of the asset used, exploitation grantees are excluded, leading it to have insignificant effect in practice, as we saw above, because it affects none of the majority uses (irrigation and hydroelectricity).

  Its application, taking the value of the asset occupied (land) as a basis gives rise to totally insignificant amounts. A possible modification could be oriented not towards the asset's value, but to benefit from its utlilisation.

- The discharge tariff, despite being based on the basic principle of who contaminates pays, is turning out to be totally ineffective in practice to assure appropriate water quality in rivers. Conceived as a foundation-stone of the economic and financial system to protect water quality, it has been subject to authentic denaturisation as a consequence of the agreements subscribed with the Autonomous Communities.

  As an example, and using the North Hydrographic Confederation as a reference, where this is of essential importance, as we have seen, the value initially collected was around 0.03 €/m^3 of wastewater. Considering that total real costs for investment and exploitation of the treatment plants are about 0.60 €/m^3 (70 for investment and 30 for exploitation), it may be calculated that collection hardly covered 1/6 of the exploitation costs, or 1/20 of total costs. If we add that 85% of collection goes to the Autonomous Communities, and what finally goes to the Confederation for protection and improvement of water quality is about 0.0045 €/m^3, not only is no kind of treatment feasible, but rather it does not even cover the basic cost of an ambitious program of analysis and control of water quality.

  Furthermore, the collection tariffs set up by different Autonomous Communities are based on a philosophy and criteria similar to those of the discharge tariff (polynomial formulas with the BOD, solids in suspension...), which has perverted the system and generated a legally untenable situation (overlapping of collections, dependence on subscribed agreements, etc.). The lack of determinations in the Hydrological Plans in relation to the discharge tariff also gives an idea of problem's complexity.

  The fact that a large part of discharge lacks authorisation makes this undesirable, if possible, even worse.

  A possible remedy for this state of things would be to reconsider concepts in effect, so that the discharge tariff became a tariff for monitoring and controlling the public water domain, and not for financing structures. This financing may be carried out by the Autonomous Communities, which are already being paid for this concept in practice, notwithstanding the necessary promotion and development of water planning in matters concerning discharge and water quality, as an instrument to rationalise the different territorial actions in the basins.

  If the fundamental public service of water quality monitoring and control is understood to be necessairly provided by the State, this tariff would not be required, but, in any case, and whatever the eventual solution, this tariff's urgent, radical re-orientation is necessary.

- The regulation tariff and utilisation tariff, as mentioned above, aim to compensate the State for the financial resources contributed in executing hydraulic works; but they do not take into account water's economic value, even without these works. Therefore, it does not affect the majority of groundwater exploitation, nor those that use their own infrastructures (most of hydroelectricity and a great deal of population supply), nor traditional irrigation or irrigation prior to existeing regulation works. Approximately, just 50% of irrigation, 25% of urban and industrial use, and 5% of hydroelectric use is subject to regulation tariff and utilisation tariff (MOPT, 1993b).

  In these levies, the distinction between operating and exploitation costs and investment is often not clear, which would be extremely important considering the very different repercussions that each one has on the computation of the annual quota. Neither is the desegregation or breakdown of the administration costs arising from specific infrastructures.

  It may be deduced that the legislator, at a time of high nominal interest rates, had the intention of not charging real interest (amounting to 6%) and to only reflect inflation. The paradox arises when the nominal rates approach that figure, or are lower, like is happening at the moment.

  Additionally, this discount of 6 percentage points that the Regulation lays down for the legal interest rate for up-dating the quota supposes that the reflected cost, in the regulation tariff, only stands at around 30%-35%, and in the utilisation tariff far less, for the usual inflation rates registered in the recent past.

  Finally, the individual distribution of these costs to the different users, in accordance with the legal rulings on the matter, are accompanied by significant crossed subsidies. To carry ourt this distribution among the different beneficiaries according to the theoretical benefit that each one obtains is an approach that can cause inefficiency, by favouring the maintenance of less productive uses. Also, there is no clear, common approach for allocating costs in multi-purpose actions, and considerable disparity in the manner of approaching this issue can be seen in the tariffs and levies drawn up by the Confederations. Classic concepts such as separable costs-retained earnings have not been duly considered in regulations nor in administrative practice, and the habitual rules of proportionality –mostly arbitrary, and reinterpreted in each case– can give rise to inequality among users according to the territorial area the exploitation is in.

Another very important aspect, in the case of irrigation, is that the collection unit for the water use tariff is the arable surface area, instead of the water volume actually consumed. This means that, for the irrigator, the water's cost is an almost fixed cost that cannot be reduced even though consumption is restricted, which is no incentive for economising water.

- Finally, and in a general sense, a major problem for the economic and financial system's correct operation and the effectiveness of the economic administration, is the clear, correct identification of the beneficiaries of rights to use water. Any reform of the economic regime proposed in the future will require significant improvements in this respect, which takes us back to the fundamental problem of the administrative water registers, extensively dealt with in other sections of this White Paper.

In short, we are faced with an economic and financial system conceived by the legislator in 1985, largely the heir of previous concepts and rulings whose practical application has pros and contras, but which, as its outstanding feature (different sectoral and territorial quantities, transfer anomaly, etc.), has turned out to be unequal application. Notwithstanding the fact that the regulatory framework of action is the same for the whole territory, different local conditions, different habits in managing the Hydraulic Administration, different profitabilities from agricultural uses, greater or smaller level of users' association and self-government, different rulings by the Autonomous Communities, political pressure and local interests from the town councils… have given rise to a situation where, in practice, the unitary, globalising character of state legislation has been diluted in its specific application, and where, we may state without any reserve, there are obvious deficiencies, and which has diverged significantly from what the legislator foresaw.

Nevertheless, the justified criticism –often expressed and from different fields– of the deficiencies and weaknesses of our administrative system in the economic consideration of water resources, must necessarily lead, as if it were an inevitable consequence, to far-reaching legislative reform.

In fact, notwithstanding the fact that such structural reforms may be approached in the future, more effective application of the regulation in force, with possible improvements to those aspects considered appropriate (such as the one mentioned for the discharge tariff, or some system of cost allocation), would significantly contribute to improving this situation, and would certainly give rise to greater rationality in the resource's use and management.

Accordingly, and as an example, economic concepts such as full cost recovery, proposed in the Water Framework Directive, could be naturally and easily incorporated in regulations in force, with no more than an explicit consideration in the formula of contribution to the cost of works foreseen in section c) of the tariffs and levies for hydraulic works, and its requisite statutory development.

It is clear that such an economic policy –basically desirable in the long term– must be applied, where relevant, gradually and progressively, avoiding socioeconomic impact that could be very negative for agricultural economies.

3.7.3. The economic regulation of transfers

Having studied the Water Act's general economic and financial system in effect, it is interesting to briefly examine the different specific rulings in our country with respect to the economic-financial regime of inter-basin transfers. To do so, and following Embid Irujo's systematic description (1996), we will refer to the Tagus-Segura transfer, the Tarragona countryside supply or minitransfer from the Ebro, the Mallorca transfer, the Guadiaro-Guadalete transfer, and the Tagus-Guadiana. Other transfers (from the Ebro to Bilbao or Torrelavega, or from the Tagus to the Tablas de Daimiel, on the Guadiana) do not have their own specific regime.

As we shall see, these economic regimes are currently very varied, with the practical consequence of potential legal uncertainties, different treatment –and, therefore, unequal consideration of the transfers' beneficiaries, and lack of a necessary single approach when economically assessing possible future actions. This is thus a very important –and unresolved– legal question, whose consideration (according to section 43 WA) corresponds to the National Hydrological Plan. The Plan Act could, as we shall see, include all the existing figures and, revoking their specific regulation, enact a general, single regime for all currently-existing transfers and those which, where relevant, may be implemented in the near future.

3.7.3.1. Inspiring principles and modalities

Since the question of inter-basin transfers was resumed in 1967, after its initial conception by Lorenzo Pardo in 1933, the philosophy governing the policy for these actions was that the major infrastructure works they involved should be economically justified, eliminating or doing without the –extensively commented– protectionist, subsidising spirit that state policies had implemented as regards irrigation from the enactment of Assistance Act of July 7th, 1911. This ensured that hydrographic transfer structures were genuinely of national interest, not just for social reasons, but also economic ones.

This change of direction was basically due to the fact that, as has already been mentioned, the protectionist policy of the state, applied from beginning of the century and dating back to the 19th, had led to irrigation tariffs applied up to then not even representing, in the best cases, 10% of the structures' real cost, a untenable situation in an economy that tends to be governed by market prices, as was the case in Spain as of the sixties, with the end of autarchy. The transfers, as new hydraulic structures intended to remedy major national development problems, could not continue to be governed by interventionist, protectionist guidelines , and the aim was to establish and assume this idea clearly, from the outset.

Therefore, and as we shall see in sections below, the Tagus-Segura transfer and its economic regulation represented an extraordinarily significant advance in the process of reflection and modernization of the economic regime of hydraulic structures, and of passing costs on to users, which we shall devote particular attention to in this White Paper. Other, subsequent transfers adhered to the regime of the Water Act or established their own regimes, up to the latest action, which is the Negratín-Almanzora, with a peculiar regime arising from its implementation procedure through the new formulas of association, set up very recently.

3.7.3.2. Transfers with an economic-financial regime inspired by the traditional principles of water legislation

Among the cases of transfers whose economic-financial regime is regulated by the traditional principles of water law are the Tagus Segura, Guadiaro-Guadalete, and Tagus-Guadiana. All of them, although with some particularities, basically assume the traditional principle of beneficiaries being responsible for the cost of the structures and of their maintenance and exploitation costs.

3.7.3.2.1. The Tagus-Segura transfer

Act 52/1980, which regulates this transfer's economic regime, calls what the user must pay water transport tariff, and breaks it down into three addends: the first one corresponding to the distribution of the cost of the structures from the allocated water (subtracted from concessions or commitments), with corrections according to use; a second one for fixed costs of exploitation (regardless of the annual transferred volume); and a third for variable costs (depending on the annual transferred volume).

For the first addend, it is foreseen to periodically up-date the investment values, but without the Act specifying how such up-date takes place, and having recourse to the decision of the Council of Ministers. Additionally, and since the aqueduct's current operation is limited to 60% of its total capacity (600 hm^3/year of the so-called first phase, compared with 1,000 hm^3/year in full operation), it is foreseen to consider this 60% of the total investment for the purposes of amortising the structures by beneficiaries. Both characteristics diverge from the provisions of the Water Act, because the system of up-dating tariffs and levies is regulated by law (section 300 and 307 RDPH), without the non-specification of recourse to the Council of Ministers, and additionally, the Law does not provide for any subsidy or partial payment of the hydraulic structures amortised. However, a recent sentence has ratified the obligatory amortisation of structures - following the general principle of the Water Act - in view of the lack of regulation in a specific Law.

This system, conceived in the seventies following the orientation of national economic policy towards the need to pass the cost of structures on to beneficiaries, and to gradually end with the protectionism of the past, was an major landmark in state economic policy as regards the economy of hydraulic structures, as mentioned above, by establishing these main guidelines for establishing water tariffs:

- The structures of main transport, regulation and distribution lines, both in the Tagus-Segura Aqueduct proper (transfer) and in the Segura basin (post-transfer), were not eligible for any subsidy, as had been a habitual practice in all the country's irrigation structures, by means of applying the Assistance Act of 7th July, 1911 (this consideration excluded distribution, drainage and road networks and complementary facilities characteristic of the irrigated area and population supply sectors). This materialised as a significant increase in tariffs that was to rationalise, in economic terms, the use of resources, providing greater economic efficiency in their allocation. However, regional, secondary distribution networks, independent of the transfer, continued using the habitual criteria. Subsequently, the Water Act of 1985 provided the possibility of generally applying non-subsidy policies, although the Act of 7th July, 1911 remained in force so that the State, when it suited the interests of the country, could continue applying subsidising policies, but now extraordinarily.
- Earnings obtained from the tariff on water transport, corresponding to the concept of contribution to the cost of the structures is applied, regardless of the credits consigned in the General State Budget, to investments that allow more rapid development of the Tagus basin in water-related issues (what were called compensation hydraulic works). This compensation measure, obviously absent from any previous law or ruling, aimed to facilitate the potential transfer by generating a monetary flow in the opposite direction to the water, which would contribute to developing hydraulic works in the Tagus basin, and to raise its inhabitants' level of income. It seemed logical to suppose that the Tagus basin territories would show an interest in sending surplus flow to obtain such benefits, but in practice this incentive has not been very effective, so this question deserves reconsideration and reflection within the scope of national planning.
- Review of the tariff every two years according to the up-date of investments, a measure that involves re-assessing assets to guarantee the purchasing power of the monetary flow from the Segura to the Tagus, by which the Tagus basin's economic interest in the transfer would be maintained, and could help in implementing its second phase.

These specific economic conditions for the Tagus_Segura transfer aimed to join the two basins in a spirit of mutual cooperation. On one hand, they demonstrated the transfer's economic value to public opinion by establishing the first hydraulic structure in the country built entirely without subsidies. Also, they established a permanent up-date, because water tariffs were not frozen.

Accordingly, the Tagus-Segura transfer did not only begin to remedy the country's hydrographic imbalance, but also, with its special economic measures, in a sense gave rise to possible and desirable correction of the economic imbalance that until then had prevailed in the tariff system for hydraulic structures, due to the excessively protectionist attitude of the State. In this sense, it represented an important conceptual antecedent for applying the economic criteria that would later be introduced by the Water Act of 1985, without considering the practical results, rather scarce, which this legal regime has brought about in practice.

Despite the innovations that it introduced, we should recognise that the transfer law did not wholly bring about the expected results from its application as of 1980, so certain aspects should be reconsidered for possible future transfers.

Accordingly, and among other aspects, we should mention that the monetary flow from the Segura to the Tagus which, as mentioned above, was expected to be a major stimulus to facilitate the transfer of water, has not been enough, in view of the significant limitations caused by diverting flow year after year. One of the reasons is possibly that the economic resources' specific allocation to hydraulic structures that the Law stipulates for the donor basin, in accordance with its section 6, and with the Agreement of the Council of Ministers of April 18th, 1986, section 4 -, is too restrictive, especially if the donor basin does not have any special interest or need for new hydraulic structures, generally less and less associated with the wealth and prosperity of regions, as has been explained in detail in this White Paper.

Furthermore, there is some doubt about the principle of charging users with structures aimed at promoting the economic development of territories affected by a transfer, in what could give rise to a certain overlapping with respect to public administrations' obligatory responsibilities in these territories (such as, for example, rendering services of water supply to the population). A more appropriate conceptual theoretical framework could be to compensate for the existence value of water resources, and allocated to fundamentally environmentally-related actions.

3.7.3.2.2. The Guadiaro-Guadalete transfer

Enacted by Law 17/1995, of June 1st, this resource transfer from the River Guadiaro, in the territorial area of the South, to the River Majaceite, a tributary of the Guadalete, in the territorial area of the Guadalquivir, planned a maximum transfer of 110 hm^3/year, with the condition that no flow could be diverted while the Guadiaro did not have a circulating flow for the river, at the diversion point, of a minimum 5 m^3/s, and only the circulating flow for the river in excess of the said 5 m^3/s could be transferred, with a maximum spot limit of 30 m^3/s.

Its economic regime faithfully follows the terms of the Water Act as regards the regulation tariff and utilisation tariff.

It is interesting to highlight in this regulation that:

- The name given to the levy applied is *transfer tariff*, and its purpose is *to complete the State's economic contribution and to cover the corresponding exploitation and maintenance costs.*
- The components of the transfer tariff are the three laid down in section 106 WA, there being no distinction between fixed and variable exploitation costs, and a specific provision that the contribution referring to compensating for investments –and only that– may be increased or reduced according to the transfer's actual use every year.
- A possible penalty is introduced for excess consumption.

3.7.3.2.3. The Tagus-Guadiana transfer

Royal Decree-Act 8/1995, of August 4th, provided for the diversion of resources from the River Tagus to the upper basin of the River Guadiana, by means of intake on the Tagus-Segura aqueduct.

In this case, there are only two prominent questions:

- The principle of completely passing on costs to beneficiaries, because it is stipulated that these are to *finance costs corresponding to their amortisation, exploitation and maintenance.*
- Legal regulation with respect to everything else (taxable base, taxable individual, etc.), broad and totally non-specific, what has led to, in practice, a situation where the planned passing-on of costs is not being fulfilled.

3.7.3.3. Transfers with special financial and economic regime

3.7.3.3.1. Supply to the Tarragona countryside

Act 1/1981, of July 1st, on water-related actions in Tarragona, establishes an economic regime for the transfer of water from the Ebro, consisting of in laying down a tariff of 0.03 €/m^3, to be reflected in the supply tariff (since it refers to urban and industrial uses exclusively), and which will be up-dated every two years by the MOPU. This tariff is collected by the Ebro Confederation (with the Generalitat of Catalonia's jurisdiction for collection subrogated by virtue of Royal Decree 2646/1985 on the transfer of functions), with a Consortium obtaining the concession and carrying out certain functions with respect to the administration of the tariff.

The tariff's purpose is to provide payment for the works plans to improve hydraulic infrastructure in the Ebro delta, and when amortisation is concluded, to be applied to *other works of hydraulic infrastructure in the basin that lead to better use of its resources*, which clearly consists of a compensation by means of hydraulic works in the donor basin.

It is curious to notice that this tariff will be permanent (it certainly seems to be a water price), and that it is not really intended for payment of the transfer structures, but to structures in the Ebro delta intended to achieve *greater effectiveness in water distribution… recovering the losses that at present take place in this area.*

The evolution of the this transfer's tariffs is as shown above, in the section describing existing transfers.

3.7.3.3.2. Supply to Mallorca

Act 34/1994, of December 19th, by which urgent measures are adopted for water supply to the towns of Palma de Mallorca bay, provided for the possibility of a water transfer from the Tarragona countryside to Mallorca. This transfer is artificial and technically related with the previous one, since it operates on the flow transferred in turn to the Tarragona countryside.

Its high-level supply tariff is the same as the one set by the Tarragona Water Consortium, including the tariff of the 1981 Act, and other additional expenses (such as transportation by ship) paid by the beneficiary.

3.7.3.4. Conclusions

It may be deduced from the above that there is no common denomination for payment of water transfers (water transport tariff, transfer tariff, tariff), which causes nominal and legal lack of determination that can be remedied by means of national planning.

As for state subsidies for transfer infrastructures, they are only specifically in the Tagus-Segura Law, and there for the purposes of contrasting between the dimensioning of the transfer with respect to its possible current use. The transfer to Tarragona says that state subsidies are forbidden for the exploitation of the water granted, although subsidies from the General State Budget are provided for the infrastructure plan in the Delta which, in some way, may affect the revaluation of the tariff.

As regards compensation for donor basins, all the transfers described –in one way or another– associate their economic system with such compensation, which may be interpreted as an application of inter-territorial balance (Menéndez Rexach and Díaz Lema [1986] p. 638), or, in economic terms, as an expression of the existence value of the water diverted.

Accepting their universality, the difference lies in the different formulas used, and there may be the cases of:

1. Allocation, from the first moment, of the total concept of the tariff intended to compensate for state investment in implementing hydraulic structures. This is the case of the Tagus-Segura and its tariff component contributing to the cost of the work.
2. Allocation of the whole tariff to hydraulic structures, but at a different future time. This is the case of Tarragona, once the structures in the Delta have been amortised.
3. Allocation, from the first moment, of a percentage of a component of the tariff, to compensation hydraulic structures. This is the case of the Guadiaro-Guadalete, where this percentage of the component intended to compensate for state investment, and intended for compensation structures, shall be established by the MOPTMA.

These systems unquestionably contribute positive advantages to the economic regulation of the works, but they also present some serious drawbacks. Firstly, the concept of recovery of state investment is perverted if a fraction of this amount is diverted to compensation structures, because if this is the case, there is no true, full recovery of the investment made, but only the part that remains after diversion to compensation.

Furthermore, and as mentioned already in connection with the Tagus-Segura, certain sanitary or supply structures foreseen as compensation are really legal requirements and social needs, so they should not be considered donations from the beneficiaries for the transfers.

Finally, and as was also deduced from the experience of the Tagus-Segura, it is not desirable for compensations to be necessarily associated with hydraulic infrastructures in donor basins. In view of the fact that what is really interesting for the different territories is to conserve the wealth created and to promote socio-economic development, a formula of broader compensation could be to allow the income generated to be used in any other investment project, not just in the hydraulic sector, of an environmental type, or even in exploitation costs of hydraulic systems in operation. The mechanism of redressing territorial balance by hydraulic transfers could then, in a sense, be comparable to the Inter-territorial Compensation Fund, to which it certainly has a number of similarities.

3.8. THE PUBLIC ADMINISTRATION OF WATER

3.8.1. Introduction

After examining some of the characteristics of Spain´s water economy, it would be relevant to review the main problems related to its administrative organisation.

It is undeniable that all the problems of the public water administration, related to its adaptation to current objectives and changes, and to the efficiency and quality of its management, represent essential challenges (beyond the stereotypical time-space irregularity or the reduction in quality) which our country will have to face in the long and medium term as far as water is concerned.

The crisis of the traditional water policy, descending from a brilliant tradition as a public service, an efficient instrument for major improvements throughout last century, and a constant promoter of recent relevant social and economic changes, has been thoroughly analysed under different chapters of this Paper, together with the difficulties and scarcity of resources to adapt to current needs, have placed the water administration in a difficult situation requiring urgent attention and action.

It is obvious that this statement must be reasonably defined, and should not lead to a groundless state of alarm. Unfortunately, such crisis is not a strange or special abnormality within the context of Spanish Public Administration, and it is possible to state categorically that the efficiency of the water administration´s management is definitely comparable to –if not considerably better than– the management of many other similar sectoral units or public institutions. But this is not sufficient. Neither the urgency or seriousness of the current problems, nor the legal obligations to fulfil, nor the social demands, nor the fidelity to memory and the constant, arduous efforts made in the past, should allow us to face this situation in a resigned or indifferent way.

Having said that, it is obvious that the politic powers with jurisdiction over this water administration failed to promote firmly, after the passing of the Water Act, its adaptation to the new obligations, or to encourage the reconversion of its structures, objectives and capacity at the pace imposed by this new legislation, and by social demands in particular. This imbalance has led to a serious problem which will have to be faced in the future, given that the development and the execution of the new water policies require a flexible tool, with a capacity and aptitudes which our current water administration does not have yet.

The legislative changes which took place in the 80s therefore required from this Administration a capacity to act in sectors such as quality, subterranean water, environment, planning and water economy, as well as the strict management of the resources in legal and administrative terms. All these factors separate it, to a certain extent, from its traditional scope of action, and the Administration, as indicated above, has not been provided with the necessary financial and human resources required by the new situation. In addition, it has not been sufficiently analysed whether or not its current organic and functional structure is the most adequate.

3.8.2. Main problems of the current Water Administration

Even if, in the next chapters of the Paper, when dealing with the crisis of the traditional model and the legal basis of the new water policy, we will analyse in greater detail the problems and changes to be implemented in our Water Administration, it would be relevant to list some of the major deficiencies related to the type of management which will be required from it in the future:

a) A scarcity of human resources and technological means to prepare and execute directly the growing number of projects which are being allocated to it. This leads to a high number of technical assistance requests and to the progressive drop in technical level and discouragement of professionals, finally retrained as contract managers. This circumstance is not necessarily negative, but if this model is eventually chosen, it will have to be explicitly taken into account when designing the administrative organisations and their different functions.

b) Regulations on contracts which are not adapted to the reality of public water works or to the capacity of civil servants to assume direct responsibility over the projects.

c) An excessive number of rigid regulations on contracts, which are inadequate to meet the need of flexibility and efficiency required by the changing problems and social demands.

d) An economic-financial system established by the Water Act which is insufficient to support the high responsibilities allocated to the Administration as regards the protection of water public water domain and the quality of water.

e) A scarcity of human resources with specific qualifications to develop different specialities from those traditionally executed in this administration, and therefore to assume efficiently the new functions legally allocated by the water administration (economy, law, chemistry, biology, etc.).

f) A lack of internal procedures clearly establishing the operational mechanisms and the personal and corporate responsibilities concerning projects and works for protecting the environment.

g) An excessive, disproportionate attention to State-run irrigation, in accordance with a traditional vocation whose current validity is arguable, to say the least.

h) The maintenance of an administrative management system based on concessions and registrations, which has proved to be hardly efficient to reflect the reality of the uses of water, and has not been adapted to the new legislative and jurisdictional framework with the necessary diligence.

i) The maintenance of structures in the Ministry´s central agencies which partially overlap those from Hydrographic Confederations, thus limiting global efficiency, the necessary autonomy of the basin organisations, and the clear definition of the mechanisms for cooperation and mutual responsibilities.

j) Non-existence of an actual integration of the previous administrative bodies with powers over water (Water

Commissions and Confederations) into the new Hydrographic Confederations, and the existence, in practice, of a simple juxtaposition of both bodies, whose operation has not changed significantly, but with fewer resources because of increasing responsibilities, and the President as the only major innovation with regard to the previous situation.

3.8.3. The environmental challenge

An issue which deserves to be analysed, with a view to the future re-organisation of the Water administration, is the fact that, given the environmental consideration of water resulting from EU policies, the allocation of the management of inland water to the Environment Ministry and the social demand itself, the civil servants in the Water administration are facing different responsibilities –which can even be criminal on the grounds of ecological crimes– which do not correspond to the resources or the structures which have been implemented to deal with such responsibilities.

The Water administration is therefore coping, to a large extent thanks to the sense of responsibility of its civil servants, with a stress that they should not be suffering and which should be eliminated. This means that the resources available and the obligations imposed should be proportional.

3.8.4. Users' associations

A classic doctrinal controversy concerning water law in Spain is the legal nature of users´ associations. There are two opposing criteria: for part of the doctrine, these associations are actually and mainly part of the Administration, or public-law legal entities, whereas a different group of specialists considers them as private legal entities. The Water Act has followed the first of these interpretations, and has expressly declared that they are public-law entities. They may therefore be included in this chapter on the water administration.

Descending from a long, successful tradition, initially defined as irrigators´ associations and later extended to general users by the new act, these organisations are bound to play a major role in the management of water, and all efforts made to improve, support or collaborate with them will undoubtedly be efficient and useful.

These organisations have multiple problems and difficulties, which are not easy to solve given the extensive number of specific cases and circumstances. Among the difficulties and issues detected, as an indication, the following aspects should be highlighted:

These associations and their representative bodies (the National Federation of Irrigators´ Associations) have always been deeply concerned about the economic regime of water.

The possibility of imposing a price exceeding its cost, thus modifying the regime included in the Water Act, has been rejected by these organisations, which argue, among other reasons, that such price had never been imposed in the past; that it would not have a deterring effect or become an instrument for saving water, given the rigidity of the demand, which covers the needs and remains unchanged even if prices go up; that imposing such price would imply a loss of competitiveness for Spanish agriculture, which is already at a disadvantage in comparison with the rest of Europe as regards the natural regulation of water-related resources and the global cost of these resources; and, finally, that it would imply a unilateral change on the part of the State of the current concessions granted to Irrigators´Associations (thus infringing the legal security principle), which would lead to the contradiction that the compensation received by beneficiaries of concessions would be equivalent to the price they would have to pay for the water, etc. (See, for instance, Valero de Palma's report, 1996).

As a general reflection, without analysing these arguments, we should state that it is doubtful that they may be held in the near future, for a variety of reasons. The current differences between Associations as regard their fees and their financial management clearly explain the existence of considerably different situations (we might even say different worlds), in respect of which it will be difficult to establish common criteria which all of them will accept. In addition, it will be necessary to take into account new types of irrigation which, for historical and legal reasons, imply other kinds of organisations (usually different from Irrigators´ Associations), and whose financial operation and management capacity certainly differ from those applied in such Associations.

Another important issue, repeatedly highlighted as well, is the legal procedure of reviewing the concessions.

As regards this possible review, it has been said that it should take into account the historical condition of irrigation, the changing needs of water for the crops, the state of the irrigation structure and the topographical and edaphological conditions of the irrigated plots, and that the review of a concession resulting from the execution of works should be subsequent to their completion, after the objective of increasing efficiency has been achieved. In addition, it has been said that the review should result in the relevant indemnity and the adequate compensations in proportion to the damage caused, and that it would be necessary, before taking any further action, to give legal security to Irrigators´s Associations with effective concessions.

This is undoubtedly a complex issue, but a highly important one as well, since the review process could result in the release of resources nominally allocated which, in such event, would increase the currently available resources.

Without analysing the efficiency and the practical possibilities of this question, we refer to other chapters of this Paper which deal with the matter of concessions, water registrations and historical rights, and which establish the fundamental criteria related to this issue.

In addition, at regulatory and organisational level, several authors (such as Jiliberto and Merino, 1997) consider that, even though they are Associations are an indispensable element to promote an efficient management of water, Irrigators' Associations are governed by an excessively generic legal framework vaguely defining their duties as regards the management of the public domain they use, which results in the absence of the operational regulations which would be necessary in connection with the social function they carry out. This means that there are no strict economic management rules imposing the application of transparent accountancy procedures leading to their financial analysis, which results in Irrigators; Associations having difficulties to carry out a modern financial management.

According to these authors, several surveys carried out show that simple cash-accounting is the most common method used (probably by 50% of the Associations) among Associations having fewer than 200 associates, which leads to absolute financial opacity as regards its assets, because it fails to reflect their rights and duties as creditors and debtors. Therefore, it is impossible to deduct the global economic result of their administration.

In addition, budgetary accountancy, implemented in 13% of the Associations, makes it possible to estimate their income and expenses account and to know their financial administration in great detail, but is insufficient to know their assets and liabilities and their real level of indebtedness.

This situation seems to result from the legal loophole concerning the technical and financial regime of Irrigators´ Associations, which is inconsistent with their importance as managers of a large number of water resources. On the contrary, given the existing analogy, it has been observed that the economic regime of Consumers and Users´ Cooperatives is perfectly defined by the General Cooperatives Act (3/1987 Act, of the 2nd of April).

One obvious conclusion is therefore the need to define in greater detail the regulations governing Irrigators´ Associations, so that they may lead a major role as modern managers in the future, in accordance with the social function conferred to them as Public-Law Corporations, without prejudice to the old doctrinal controversy regarding their legal nature.

In this respect, and as mentioned above, all technical, financial, informative and training support received from the Administration would be justified, since the improvements which could be achieved in the management of water by Irrigations' Associations would have positive effects in society as a whole.

3.9. PROTECTION AND RECOVERY OF THE PUBLIC WATER DOMAIN

In the chapters on allocations and reserves, the issue of administrative water registers and their specific problems was analysed. As we indicated there, it is obvious that the main condition for adequately protecting water public domain is knowing it, and this necessarily implies having complete, updated administrative water registers. This question, we must repeat, is highly important.

However, in addition to inland water, public water domain comprises the beds of natural streams, the beds of lakes, lagoons and dams on public channels, and aquifers for the purposes of assigning or allocating water resources.

All these elements of public water domain, and often their associated environments, require special protecting measures, leading to their preservation, maintenance and improvement, which will be briefly referred to in the following chapters.

3.9.1. Segregation

Although the nature of this measure might seem more administrative than environmental, the first measure which should be mentioned is public domain segregation. It is obviously difficult to protect something which is not known. In many cases, it will therefore be necessary to segregate public domain as a first, essential measure for its protection. Given the extraordinary length of Spain's rivers, it is impossible to apply this practice completely. The actions must therefore be prioritised in areas where the risk of unlawful usurpation, degradation or occupation of the public water domain is particularly high, and where the problems resulting from the development of the territory and the avenues are specially serious.

Particular attention must be paid to river reaches located downstream from the dams which, as a result of their regulating and laminating effects, frequently suffer invasion processes. It is therefore recommendable to segregate them before starting to operate new dams which might trigger this phenomenon.

The LINDE project, developed by the Directory General for Hydraulic Works and Water Quality, aims at reaching these objectives (Nieto Llobet [1995]; Villarroya Aldea [1997]).

3.9.2. River return. Conservation and restoration

3.9.2.1. Introduction

A river is complex fluvial ecosystem where several thousands of living beings may be found, therefore supporting a complex network of ecological relations. Ignoring such reality and considering rivers as mere canals transporting a water stream would lead to a partial, narrow view of a reality which is much more complex and richer than the simple water element.

The extensive variety of rivers and their channels: fast and still waters, sand, rock and gravel; waterfalls and large puddles; light and shade; hot and cold waters, etc., gives shape to a large diversity of micro-biotopes resulting in the existence of hundreds of different ecological niches, which are necessary for the survival of all their complex, sensitive biocenosis (flora and fauna).

The balance of this complex fluvial ecosystem depends on a series of basic factors, such as physical parameters (temperature, density, surface tension, viscosity, etc.), the dynamic conditions resulting from the dissipation of energy due to its downward movement, and the chemical and biological quality of the water. On the basis of these factors, a series of metabolic processes takes place, starting with the photosynthesis of algae, which establish a wide variety of biotic conditions which regulate and influence the biomass of all their ecological networks.

The life of every single species present in the rivers is related to all the others, in all the river's micro-biotopes. The first step (phytoplankton) directly depends on the existence of certain amounts of gases and salts dissolved in the water. The existence of algae makes it possible for zooplankton to exist and, in turn, the complex world of invertebrates and of the whole ecosystem depends on zooplankton. At the root of this chain, the main components are the sunlight and simple elements such as nutrients. Finally, the ecosystem itself is also capable of recycling organic matter as bacteria and excrements or zooplankton bodies.

The conditions of life of a natural channel may be highly demanding and changing, which is reflected by the fact that only a small part of the total number of living beings has been able to colonise fresh water. There are in the world scarcely 14,000 species of algae, 1,100 of higher plants, and nearly 14,500 Metazoa species, adapted to the waters of our rivers and lakes, extremely low figures if compared with the almost one and a half million living beings known. The species which have adapted themselves to the harsh conditions mentioned now depend on the river to survive and, in this sense, it is essential that the characteristics of the river are as close as possible to its natural ones.

The traditional management of water and the intense use of the extremely fertile lands surrounding the rivers have had undeniable positive effects throughout History from the social and economic point of view, but have also resulted in the obvious deterioration of the elements in the natural environment formed by the river and its surroundings, which often leads to the impoverishment of its ecosystems' biodiversity. Unfortunately, when their accessibility so permitted, riverside forests have often been eliminated or deeply modified, thus altering their natural ecosystems or leading to the presence of foreign species or, at best, to their reduction to a narrow band near the river. To a large extent, they have been replaced with agricultural and forest crops (poplar groves) which, particularly in Mediterranean environments, have found exceptional conditions for development in those fertile valleys. In addition, the plains flooded by rivers have often suffered the damaging effect of shepherding and extractions of sediment. However, some riverside forests are preserved without any apparent alteration, given the inaccessibility of the valleys where they are located, thus guaranteeing their natural conditions.

Prat (1995) gives a summary of the role of water in ecosystems; in addition, a description of the ecological condition of the different types of water ecosystems may be found, for instance, in (1998). In the next chapters, this basic issues will be analysed.

3.9.2.2. Channels, riverbanks and riversides

Within the framework of the protection and recuperation of rivers, the concepts of channels, riverbanks and riversides, without forgetting their legal definitions, must be treated from a functional point of view. In that sense, the channel is the physical base on which the water needed by the river's ecosystems flow; riverbanks are the surfaces covered with submerged plants, or with the plants living near the water; and riversides are the surfaces covered with plants which depend on wet land (in geomorphologic terms, flood plains). In other words, these realities must be perceived with an eco-systemic, integrating approach (González del Tánago [1998]).

Figure 322 sketches the concepts and the relations between channels, riverbanks and riversides, according the regulations in force. In Spain, the vegetation found in the channels and on riverside land includes riverside forests (20%), reed beds and marshland (30%) and (on the remaining 50%) willow groves, thickets, etc. (Sánchez-Mata y de la Fuente, MOPU, 1986).

In the upper reaches of rivers, different trees be found, such as birches, poplars, lindens, mountain willows, etc. together with these reaches' natural species, such as firs, beech trees, oaks, heather, etc. In middle reaches, typical riverside formations appear, such as alder, elm or poplar groves, together with bush-shaped willows. Finally, in rivers' lower reaches, white poplar groves and willows are more common. Bushes and herbaceous plants complete a landscape of extraordinary beauty and environmental quality, a paradise for contemplation.

Apart from having a strong effect on the lamination of spates resulting from the overflowing of rivers into their flood-prone banks, these groves and riversides teem with an wide variety of fauna species, mainly birds. Amphibians (newts, tritons, toads, and frogs) are represented by a variety of endangered species and endemisms. There are also water snakes, both in rivers and their banks, as well as numerous mammals (otters, water rats, shrews, moles, etc.). There is an outstanding number of birds, and the fact that

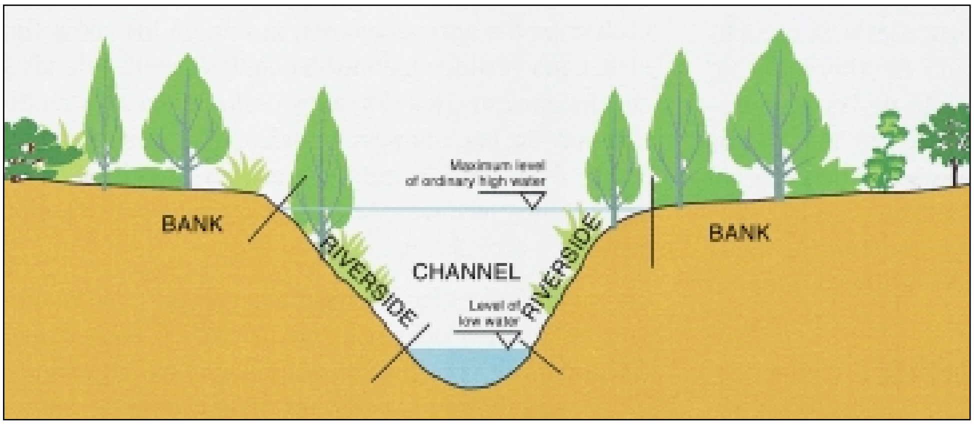


Figure 322. Riversides, channels and riverbanks of a fluvial stream.

some river reaches are isolated turn them into excellent shelters for endangered species.

Riverbanks are therefore potentially rich biotopes and privileged spots where different species can settle. However, the truth is that most of these rivers have been deeply altered by all kinds of human activities, and therefore it is extremely difficult to identify and to preserve the reaches which are kept in good condition (SEO/BirdLife [1996]).

Consequently, it is necessary, first of all, to have a sound knowledge of the biological communities found in rivers and fluvial environments. Unfortunately, there are no systematic, comprehensive inventories on existing species at national level , which means that the first thing to do is to know in great detail the actual level of conservation of rivers. As an interesting antecedent for this inventory, as regards water planning, it would be relevant to mention the characterisation work on river fish communities in the different basins, carried out by the Commission for Water Resources within the framework of the II Development Plan (PG [1967] Annex 3).

In accordance with the results obtained, the most urgent action to implement would be, in principle, the strict protection of the best-preserved reaches and of the most interesting ones from the ecological, scientific or pedagogic point of view. They will have to be protected both from direct aggressions in their surroundings and from the degradation of their tributaries. After guaranteeing the survival of these reaches, the second step should be the recuperation of the rivers with a low level of alteration, trough the development of the above-mentioned proposals. Eventually, the actions would be focused on highly-altered reaches. Through these actions, it will be possible to regain the benefits of rivers and their surroundings, which are directly linked with the regeneration of these ecosystems, without forgetting their possible use as recreational areas.

Every specific problem related to the restoration of rivers will require special solutions which may only be proposed if every situation is analysed individually; however, some general guidelines to be followed should be the rivers' structural stability, the preservation of their conditions in accordance with the diversity of biotopes within the ecological unit formed by the channel, the banks and the flood plains, a deep knowledge of all the ecological, hydraulic and morphological processes, etc.

3.9.2.3. Lake, lagoon and reservoir beds

As regards lake, lagoon and reservoir beds, two groups must be differentiated: those of natural origin, which must be governed by an individual management plan, and those of artificial origin, basically reservoirs. Reservoirs, with a total lake surface of about 3,000 km^2, have different environmental effects. Some of them are negative, such as the elimination of habitats when they are filled up, together with the destruction of the ecosystems present on their beds, or the marks resulting from the reservoir's water level, which leads to loss of ground and absence of vegetation. Consequently, the transit of vertebrates from the forests to the reservoirs becomes dangerous, since they are exposed to the action of predators. Other effects are positive, given that they make it possible to recreate riverbank vegetation, and they replace the natural wetlands lost throughout the last centuries, etc.

In addition, the construction of new dams and their reservoirs in enclosed areas, which can only be accessed with difficulty –and which are therefore well preserved– may result in the disappearance of rich riverside formations if the relevant compensatory measures are not implemented.

3.9.2.4. The effects of human activities on rivers

There are human activities which can have negative effects on the ecological characteristics of rivers and their surroundings. Among them, we should mention agricultural or stockbreeding activities, the cutting of riverside groves, non-controlled dumping, canalisation and channelling works, the dredging of channels, the modification of river courses, constructions in the channels, dams and waterwheels, the refrigeration of thermal power plants, fish hatcheries, the extraction of sediment, etc.

As regards the negative effects of said activities on rivers and their surrounding ecosystems, the following should be highlighted: the invasion of natural biotopes, the destruction of highly varied micro-biotopes, the occupation of riverside land, the modification of natural landscapes, the displacement of animal and vegetal species, the pollution of water and land, the accumulation of rubbish and waste, the general artificial appearance of rivers, etc.

Among the man-made activities which may have negative effective on river environments, we must highlight the channelling works aimed at giving protection against floods, which lead to the pronounced impoverishment of biological diversity and a strong artificial appearance affecting landscapes. In some Western countries, such as Germany, the Netherlands or the United States, the principles which led to these activities have been questioned recently, so that some of the channelling constructions made throughout the 20th century are currently being destroyed, in order to recreate the sinuosity of the river lost when it was corrected, and *soft* works are being carried out instead, which are correctly integrated in the landscapes. The reasons for this change of position, which has led to strong conflicts in recent years, essentially lie in the higher social pressure to recuperate the natural appearance of rivers, and in the fact that the universal suitability of this kind of activities as a protective instrument is generally questioned, even if it is true that, in consolidated urban areas, there is often no other method applicable to protect riverside populations.

One clear example of the negative alterations resulting from some channelling constructions is the evolution suffered by alluvial riverside or gallery forests, of high ecological value, and whose correct preservation results in important advantages: stabilisation of riverbanks, reduction in erosion, lamination of avenues, green filters, a high biological diversity, shelters for endangered or sensitive fauna or flora species, the high value of their landscapes, and of their exceptional ecological corridors in particular, which link together remote natural areas.

In accordance with these principles, any river's channelling works should be essentially executed in reaches of rivers running through consolidated centres of population, in order to avoid, through planning and development instruments, the settlement of urban or industrial communities in flood-prone areas, after carrying out thorough studies concerning their alternatives and their final effects.

It is obvious that not all works have negative effects, and it is also obvious that their importance depends on a variety of factors which result from their specific ecological an social characteristics, as well as from their landscapes.

3.9.2.5. The problem of sediment yield to beaches

The sediment carried down to the beaches by rivers and ravines represent an essential factor for their existence, maintenance and conservation, and are an element which has not always been taken into account when designing and executing works for the regulation and channelling of rivers. This circumstance, together with other factors, has led, in many points of Spanish coasts, to a loss of the balance between the presence of sediment carried down by their natural sources and the losses resulting from the action of the sea, which has brought about an erosion and recession process affecting Spanish seashores, with considerable reductions in the surface of beaches.

The conservation of our beaches is an essential value, not only from the environmental, cultural or sociological point of view, which is important per se, but also from the territorial point of view, as a protection of the territory itself against the erosion caused by the sea, and also from the purely economic point of view, specially in Spain, given that beaches, as indicated in other chapters, represent a basic support for tourism activities, an extremely important sector (nearly 11%) in terms of Gross Domestic Product.

It is therefore indispensable to analyse and consider the potential risks of any works or constructions in the channels of rivers or ravines for the physiographic unit of the seashores and, in addition, to implement efficient measures against the negative effects which could result from such works or constructions, in order to maintain the sediment-carrying sources and the necessary sedimentary balance.

The goal mentioned may be achieved through the relevant studies on fluvial and seashore dynamics, which will affect not only the new hydraulic works to be executed, but also those already completed.

As regards the second objective, it is essential to select the correcting measures which will be most appropriate considering the interests at stake and each channel's characteristics. Such measures, as an indication only, could range from the preservation of a minimum solid channel in places where this is possible, to the transportation of sediment by mechanical means from the different points of the river where an accumulation is detected.

In any case, it seems advisable and relevant, given the increasing scarcity of sediment, to study the supply of sediment, on a priority basis, to beaches in the physiographic unit affected, with preference over any other use or allocation which might be given to the sediment. For this purpose, before granting any concession or authorisation to extract sediment from a river, the relevant administrative body in charge of monitoring and managing the shoreline public domain, should certify whether or not this sediment has to be supplied to the beaches included in the physiographic unit affected by such river.

3.9.3. Special protection areas

3.9.3.1. Introduction. Regulations

Within the framework of water public domain and its related aspects, there is a number of areas which, given their specific characteristics, require a special type of protection. Among these areas, we should highlight wetlands, natural sites, strategic-interest aquifers and certain reaches of rivers.

The areas are governed by relatively complex legal framework, which establishes different levels of protection. The main landmarks concerning this framework are indicated below:

On a national level, these areas are governed by the Act of 4/1989, of the 27th of March, on Conservation of Wild Flora and Fauna Natural Areas, which effectively protects natural areas and endangered fauna and flora species. According to this Act, the relevant water planning for every river must take into account its needs and conditions for the conservation and restoration of the natural areas it comprises, and of wetlands in particular. The Royal Legislative Decree of 1302/1986, of the 28th of June, on Assessment of the Environmental Impact, and the subsequent Royal Decree of 1131/88, of the 30th of September, approving the Regulations for implementation purposes, also contain important provisions, given that the techniques for assessing environmental impact are among the most important tools for protecting the environment. Finally, as we will see later, the Water Act regulates all issues related to wetlands.

At regional level, Autonomous Communities have jurisdiction over environmental issues. In accordance with such jurisdiction, many of them have regulated their protection and conservation activities through regulations on protected natural areas.

At European level, we must highlight the 79/409/EEC Directive on Birds, whose main goal is the protection of wild birds and their habitats through a system based on Special Protection Areas for Wild Birds (SPAs for Wild Birds) and the 92/43/EEC Directive on Habitats, regulating the conservation of natural habits, whose main objective is to maintain biodiversity.

At international level, it would be relevant to mention different instruments which, subsequently, have been essential to understand the principles of the different national policies concerning specially-protected areas: the 1971 Ramsar Convention, on Wetlands of International Importance, specially as the habitat of water birds; the 1979 Bonn Convention, on Conservation of Wild Fauna Migratory Birds, to which Spain adhered in 1985; the 1977 Bern Convention, on Conservation of the Wild Life and Natural Environments in Europe, to which Spain adhered in 1986; the Biodiversity Convention, open to signature after the United Nations Conference on Environment and Development, held in Rio de Janeiro in June, 1992; and the Barcelona Convention (IV Protocol) on Specially Protected Mediterranean Areas, signed by Spain in 1982 and ratified in 1987 (reviewed and updated in June, 1995), whose main objectives are the protection, preservation and management of areas having a special natural or cultural value in seashore areas in the Mediterranean basin. Finally, the Council of Europe presented in 1995 a Pan-European Strategy for Biological Diversity and Landscapes, which expressly refers to wetlands and proposes a series of specific actions to be implemented.

3.9.3.2. Wetlands

3.9.3.2.1. Introduction. Inventory

So far, no technical definition of wetland (like the one established by the US Fish and Wildlife Service) has been unanimously accepted in Spain by scientists and professionals in the different fields related to ecology and the management of these ecosystems.

However, unlike other EU countries, Spain has established a legal definition of this term, given that both the Water Act and the RDPH offer a definition of wetland or *wet area*, according to which this term applies to *marshy or easily flooded areas, even those which were artificially created*. In particular, this concept includes salt marshes, peat bogs or still-water areas, as well as their banks and their surrounding land. The concept of salt marsh, which was first defined by the abrogated Regulations (1912) of the 1880 Harbours Act, has been transferred, without taking into account the connotations related to their salubrity, to the new 1988 Coasts Act, which includes salt marshes in the shoreline public domain, together with upwellings and coastal marshes. In a subsequent chapter dealing with the Strategic Plan for conservation of wet land, this terminological issue will be analysed in greater detail.

From a scientific point of view, a wetland, according to the definition established by González Bernáldez (1992), is a functional unit which, without being a lake, a lagoon or a marine environment, amounts, in space and in time, to a hydrological phenomenon with regard to its dry environment. Given the merging of topographic, climatic, geologic and hydrological factors, the presence of humidity is relevant enough to affect that unit's edaphic, physical, chemical and biological processes.

An interesting starting point to identify and study these areas, and to define protection criteria and establish a specific regulations on this issue is the classification made by the MOPTMA (1996a).

The Spanish wetland domain is extremely varied and special in terms of the ecological types it presents, with remarkable examples of different wetlands, which can be temporary or permanent, with fresh or brackish water, etc. In fact, Spain is the only European country where most of these types are present (for example, ravines or endorheic hyper-saline lagoons). In addition, there are large coastal wetlands, even if interior, small wetlands are more frequent (lagoons, ponds). These extensive variety is poorly represented in the current network of wetlands declared as Protected Natural Areas. Even if the number of protected wetlands has gone up from 7 to 150 during the last 17 years, they represent a small fraction of the actual number of wetlands existing in Spain, estimated at over 1,500. It is calculated that their current total surface is about 114,100 ha, which, according to different estimations, amounts to about 30 to 40% of the surface existing 50 years ago.

This reduction in surface results from different factors. Until recently, several wetlands were drained for sanitary reasons –essentially to fight malaria and water-related diseases– and to gain new grazing land and crops. This fact was favoured throughout the 20th century by the Act of the 24th of July, 1918, on drainage of lagoons, salt marshes and marshy land –abrogated by the 1985 Water Act–, which encouraged this type of activities. The drainage of the Janda lagoon, in Cadiz, with a natural surface of about 40 km^2, and that of the Nava lagoon in Palencia, with a surface of 22 km^2, are probably the most significant actions resulting from the 1918 Act (MOPTMA-MINER, 1995).Other lagoons have been drained, such as the Antela (Orense), Ruiz Sánchez and Calderón (Seville) lagoons, or the Tenerife Lagoon, after which the city was named (Tello and López Bermúdez, 1988).

Other important reductions in the surface of Spanish wetlands result from groundwater abstractions; in fact, in recent decades, the most evident alterations have taken place in wetlands related to aquifers. The most representative examples may be found in the Guadiana basin –Tablas de Daimiel, Ojos del Guadiana, etc.–, where an excessive groundwater abstraction, carried out without an adequate plan, has led to the disappearance of numerous wetlands. However, this is not the only basin where these problems have occurred.

It is difficult to individualise a sectoral policy for conserving wetlands in Spain, given that, especially in recent years, a global conservation policy has been adopted, concerning all natural resources as a whole, whose essential principle has been to guarantee the protection, conservation, restoration and improvement of natural resources and their surrounding areas, without prejudice to their optimal use and their sustainable development. To reach this individualisation, it is indispensable to incorporate the basic principles of conservation into the different sectoral policies (agriculture, industry, etc.).

Within the wide, varied jurisdictional framework affecting specially-protected areas, it is possible to highlight the aspects related to the conservation of wetlands, laying stress on those which could define a national policy for their conservation.

Among these aspects, the following deserve to be mentioned:

- The Water Act and its Regulations establish the obligation to conserve wetlands, together with its direct surroundings having and hydraulic influence. In addition, they provide and regulate the making of National Wetland Inventory.
- The Coasts Act (of 22/1988, of the 28th of July) and the Regulations which develop it (approved by Royal Decree of 1471/1989, of the 1st of December) specifically establish that the different types of seashore wetlands are shoreline public domain assets.
- The Act for Conservation of Wild Flora and Fauna Natural Areas highlights the conditions for the conservation of wetlands and their relation with water planning, and indicates the need to make the relevant inventory. In addition, some other regulations stemming from this Act are also essential, because they have favoured its development and implementation. Among them, it is necessary to mention Royal Decree of 1997/1995, of the 7th of December, establishing measures which contribute to guaranteeing biodiversity through the conservation of natural habitats and of wild fauna and flora of natural habitats and of wild fauna and flora (incorporation of the Habitats Directive into national legislation) and Royal Decree of 2488/1994, of the 23rd of December, determining the functions and the operation rules of the National Commission for the Protection of Nature, and creating, among others, the Wetland Committee, whose main function is "to co-ordination the actions concerning the conservation of these ecosystems, particularly those resulting from the performance of the Ramsar Convention, as well as to monitor the National Wetland Inventory". At the recent meeting of the Conference of the Parties to the Wetland Convention (Ramsar Convention), the lineaments for integrating the conservation and the rational use of wetlands in connection with basin management were approved (COP7 Ramsar, 1999).
- The (Consolidated) Act on Land Regime and Urban Development (Royal Legislative Decree of 1/1992, of the 26th of June), updated by the Act of 6/1998, of the 13th of April, on Land Regime and Assessments, even if it contains no special reference to wetlands, establishes a regime for the protection of land having exceptional value for defending the fauna, the flora or ecological balance, through the official declaration of the area as Specially-protected Land not Available for Development (Land not available for development, in accordance with section 9.1. of the Act of 6/1998).
- Royal Decree of 1131/88, of the 30th of September, approving the Regulations for the implementation of Royal Legislative Decree of 1302/86, of the 28th of June, on Assessment of Environmental Impact, represent an important step forward, given that the techniques for assessing environmental impacts are among the most important tools for effectively protecting natural environment, and wetlands in particular.
- Different Royal Decrees, such as those of 51/1995, of the 20th of January, of 632/1995, of the 21st of April, and of 928/1995, of the 9th of June, are an integral part of a broader set of regulations which adapted the EEC Regulation no. 2078/92 of the Council, of the 30th of June 1992 to Spanish law (Agro-environmental Regulation for reforming the Common Agricultural Policy), whose importance lies in the fact that they will lead to the elimination of a number of agricultural practices which are harmful for wetlands.

Consequently, in order to guarantee the future conservation of wetlands, the main priority is the development of a National Strategic Plan for the Conservation of Wetlands, within the framework of the National Strategy for Biological Diversity, as an instrument for combining all the all the sectoral policies related with the conservation of wetlands.

In addition, it is necessary to complete the National Wetland Inventory, tackling the problem of its delimitation, including the entire diversity existing in Spain, and establishing indicators for monitoring and assessing their level of conservation.

3.9.3.2.2. Water requirements or maintenance volume

In order to guarantee the future conservation of wetlands, it is necessary to determine the water conditions required for their operation, given that one of the most serious problems affecting the conservation of these areas is the intensive exploitation of aquifers, which results in the drainage of springs and upwellings, with which these natural areas are frequently associated.

Since the current information concerning wetlands' water requirements is not sufficiently developed, it will be necessary to establish a strict research and monitoring system leading to an accurate quantification and to the seasonal distribution of the necessary volumes, even if some previous experiments have already made a first assessment, in a highly simplified way, of these requirements by carrying out a simple hydrological appraisal of the areas affected.

3.9.3.2.3. Wetlands and groundwater

As indicated above, wetlands and aquifers are often linked (Tóth,1966), as reflected in Spain by numerous examples.

Some of the best known, significant cases are indicated in Table 98.

In figure 323, there is an ortho image of the Albufera de Valencia, a wetland of extraordinary environmental value, whose uniqueness lies in the fact that the cumulative flow carried down into its water balance is comes from both ground (aquifer from the Plana de Valencia) and surface water, from tributary ravines and irrigation surpluses.

3.9.3.2.4. The Strategic Plan for the conservation and rational use of wetlands

The Strategic Plan for the conservation and rational use of wetlands, within the framework of the water systems they depend on, is conceived as a Sectoral Action Plan within the National Bio-diversity Strategy, in accordance with the Resolutions of the Contracting Parties to the Ramsar Convention, based on the fact that, under section 9.3 of the Act of 4/1989, of the 27th of March, on Conservation of Natural Areas of Wild Flora and Fauna, water planning is conditioned by the conservation and rational use of wet lands.

One of the main problems arising from its preparation was the scope it should have, given that, as indicated above, there are different definitions of wetland.

On the one hand, the Ramsar Convention, in its article 1, establishes a definition of wetland which, in fact, goes beyond the traditional concept, and includes all fluvial ecosystems and most of the coastal ones, and even totally marine ecosystems (for instance, coral reefs or islands being less than 6 meters deep).

However, from the point of view of internal Law, wetlands consist of groups of ecosystems excluding rivers and reservoirs, and probably lakes as well (section 103 of the Water Act, and 275.2 RDPH, Coasts Act, certain Autonomic Acts on Mountains and all the Autonomic Acts having specific legislation on wetlands). The situation of the Madrid Community deserves to be highlighted, since its Act expressly oppose wetlands and reservoirs.

The contradiction has been solved by the National Commission's Wetland Committee for the Protection of

	Hydro-geological unit	
Wetland	Code	Denomination
Villafáfila lagoons	02.06	Esla-Valderaduey Region
Tablas de Daimiel	04.04	Western Mancha
Ruidera lagoons	04.06	Campo de Montiel
Moguer and Palos lagoons	04.14	Almonte- Salt marshes
Doñana	05.51	Almonte-Salt Marshes
Adra upswells	06.15	Adra's delta
Fuentepiedra lagoon	06.34	Fuente Piedra
Peñíscola marsh	08.10	Vinaroz-Peñíscola plain
Albufera de Valencia	08.25 y 08.26	Valencia plain
Pego-Oliva marsh	08.38	Gandía-Denia plain
Gallocanta lagoon	09.44	Piedra-Gallocanta
Ojos de Monreal	09.46	Jiloca hill
Aiguamolis de L'Emporda	10.01	Baix Muga-Fluviá
Banyoles lagoon	10.05	Banyoles
Albufera de Muro	11.11	Inca-Sa Pobla plain
Son Bou	11.32	Migjorn

Table 98. Some wetlands and their associated aquifers.

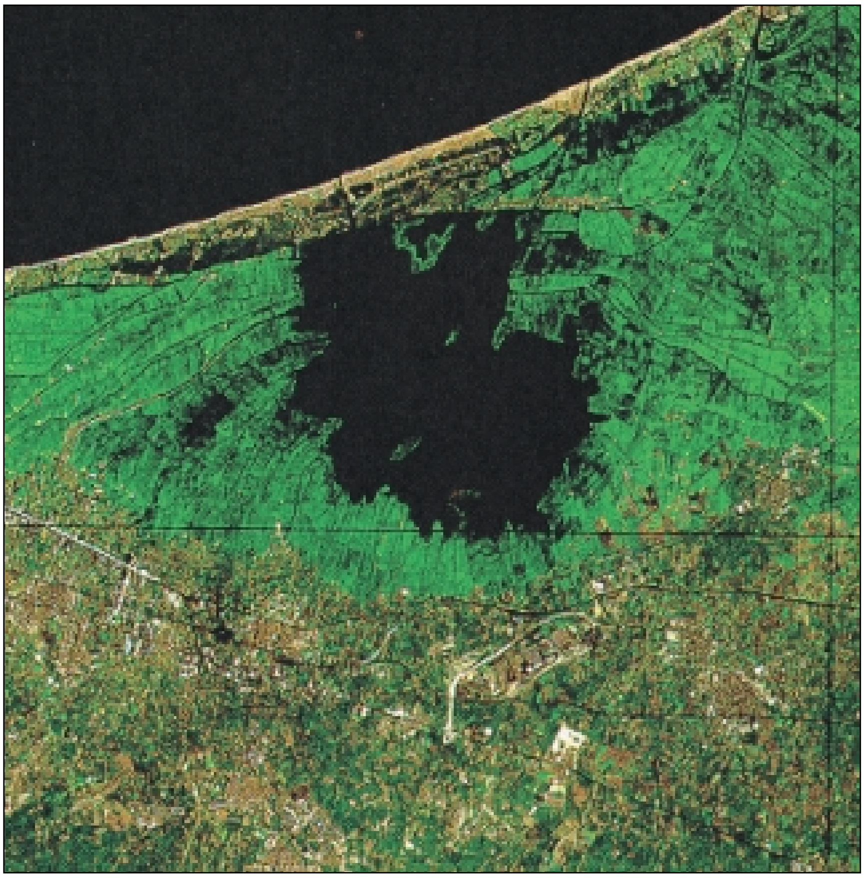


Figure 323.
An Ortho-image of the Albufera de Valencia.

Nature, the body coordinating the State's General Administration with Autonomous Communities, which also includes the Directory General for Hydraulic Works and Water Quality. According to this body, even if the Plan's main objective must be to determine the strategy for conserving and rationally using wetlands, considered either with their traditional or limited meaning, the scope of the Plan should also take into account the strategic wetland planning in the wide sense, as defined by the Ramsar Convention. However, in this event, the functions of the rivers and reservoirs included within this framework must be clearly defined, to differentiate them from those which should be included within the framework of water planning.

As regards this circumstance, that is, determining the planning and management elements of all water ecosystems governed by the Wetland Action Plan, such Plan should simply include the aspects having a special influence on the ecological functions of rivers, reservoirs, seashore areas and large lakes or lagoons: the protection of water birds, Special Protection Areas (SPAs) for Wild Birds and Sites of Community Importance (SCIs) within the future Natura 2000 Network, the streams brought down into wet lands from surface and groundwater (especially from water having special ecological value), the quality of the water carried down, the use of wetlands when planning flood prevention systems, the permanence of reservoirs, even if they are full up, to use them as wetlands, the maintenance of rivers in their natural condition (scenic rivers), the use of rivers and wet lands as non-polluting green filters...

This list is given as an indication only, since the exact decision concerning which aspects of water or river ecosystems (wet land areas in the broad sense) must be included in the strategic plan is yet to be finally determined. It is clear that, after the water plans are approved, such decision will have to be made in accordance with said water planning, in a coordinated, integrated way.

As regards wetlands in the strict sense (not in their broad sense, as river ecosystems), the Wet Land Action Plan is based on achieving nine objectives:

1. To obtain additional information, at all levels, on wetlands. The drafting of a wetland inventory must be the main priority, on the basis of the variables used by the Directory General for Hydraulic Works and Water Quality, but also of the variables on wetlands included in the National Biodiversity Strategy and Act of 4/1989, on Conservation of Natural Areas and Wild Flora and Fauna. Thanks to this inventory, all planners (either from the State, Autonomous Communities or City Councils) will become aware of the exact location of the wetlands and of the factors having an influence on these areas. In addition, wetland managers, given that these areas are protected, will have specific information on the wetland itself, including data on its properties, fauna, flora, hydrological cycles and physio-chemical variables concerning the mass of water and the soil.
2. To heighten public awareness in society as a whole on the values and functions of wetlands. In this respect, the

Strategic Plan will insist both on reformulating high school and university curricula being most related to these areas, and on making the general public aware of these sites, so that any person whose behaviour may have an impact on a wetland understands the socio-economic and environmental costs which would result from its degradation or disappearance.

3. To grant legal protection to all wetlands, by reviewing both the legislation which is specifically aimed to protect them and the legislation which will be used as a conduct code for the agents who could affect them most (for instance, modifications in the Land Act to declare wetlands, in theory, as areas not available for urban development, modifications in the acts governing the quality and the conditions for the execution of public works and constructions in general, modifications in the legislation regulating the land consolidation process, etc.).

4. To guarantee that all wetlands are managed in an efficient, integrated way, in particular those which must be legally protected given their special ecological interest. This objective could be reached by applying interdepartmental management systems, so that such this management is not simply focused on an isolated area with no external connections, and that it may include functions which are not only related to maintaining biodiversity.

5. To strengthen the capacity of institutions, organisations and entities, to achieve the goal of conserving and rationally using wetlands. The actions should influence the training received by technicians and experts at all levels, guaranteeing that the indispensable basic "technology" is known by and at the disposal of any wetland manager (including geographic information systems, models for monitoring water cycles, management of flora and fauna species which are traditionally found in wetlands, analysis of the main water quality parameters which may have an influence on its degradation, capacity of the number of visitors, maximum amount of nutrients the wetland can "clean", etc.). Given that NGOs often tend to create, and to manage by themselves, micro-reserves in some relatively small wetlands, their technicians should also receive the relevant training.

6. To strengthen cooperation between governmental or non-governmental institutions, bodies and entities, including local and private-sector entities. Thanks to the Plan, it would be guaranteed that all wetland values are fully known by authorities in charge of planning other infrastructures or carrying out projects which could affect the wetland, so that these authorities may get in contact, during the first stages of the projects, with the bodies responsible for protecting and managing wetlands. The Plan will also aims to protect the smallest private wetlands, together with those related to aquifers/ river systems, in order to analyse and preserve their interactions as a network throughout Spain (in accordance with the technique applied in Valencia to its micro-reserve network).

7. To raise funds which would be allocated to the conservation and rational use of wetlands, provided that the objectives of the relevant actions are in line with those set out by the Strategic Plan. These funds would not be raised from the public sector exclusively, and it would be based on identifying the elements creating added value for local economies and resulting from the proper design of wetland management (for example, in terms of tourism or for possible biotechnological uses).

8. To guarantee the effective performance of international agreements entered into by the State with regard to Conventions, Directives and international and European policies related to wetlands, and to foster international cooperation. Spain has recently joined the MedCom process, which is the Ramsar's regional system for the Mediterranean world. Under the Biodiversity Strategy, a private Centre will be created in Valencia to develop, as an excellence centre and together with the one in Camargue (Tour de Valat, in France) and the Biotope Centre (in Greece), policies and techniques for managing Mediterranean wetlands. The activities covered by Spain through this Centre are related with the design of wetlands for visitors (tourism and activities highlighting the value of wetlands in public or private urban development operations), the development of biotechnology in highly saline wetlands, the technology for operations related to restoration engineering and artificial creation of wetlands, and the creation of legal and administrative frameworks for the management of wetlands.

   Within a wider geographical scope, Spain has actively participated in the Ramsar Convention International Conference, held in Costa Rica in May, 1999. This is the first time that the Contracting Parties have met in South America, a continent which has just started to apply public policies for managing wetlands. Spain will host the next Convention Conference on wetlands, which will be held in 2002.

9. To support the Strategic Plan and use all possible endeavours so that the maximum number of Entities and Institutions in the environment, whether public or private, join such Plan.

3.9.3.3. Protected Natural Areas

According to data issued by the Directory General for the Conservation of Nature (DGCN), the total surface declared as a Protected Natural Area in Spain covers about 32,000 km^2. The surface of Special Protection Areas for Birds comprises about 27,000 km^2, and the surface declared as wetlands of international importance by the Ramsar Convention covers about 2,000 km^2. It is relevant to point out that part of the areas declared as SPAs may be included under the Ramsar Convention and, at the same time, be a Protected Natural Area.

With this information (from the DGCN and the DGOHCA), it has been possible to draw the map on figure 324, which

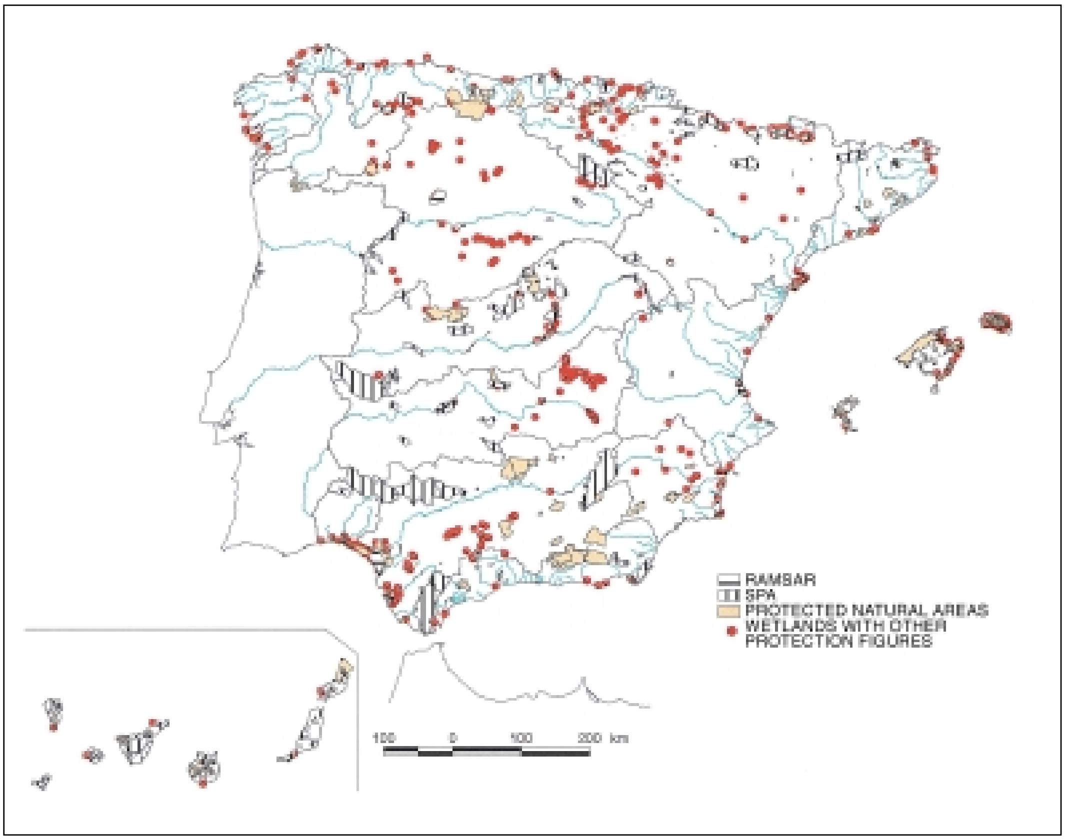


Figure 324. Map of Special Protection Areas.

incorporates the legally-protected natural areas (whether regional or national), the wetlands included in the Ramsar Convention, the Special Protection Areas for Birds under the 79/409/EEC Directive, and finally the wetlands having a different kind of legal protection, included those registered in different reservoir and wetland catalogues and inventories, such as the Madrid Community inventory, the wetland catalogue of Castile-Leon and other similar ones.

Given their diversity, it is not possible to establish any general formulas for protecting these areas, beyond the need to make a physical environmental and socio-economic diagnosis of the area, and the formulation of sectoral guidelines and regulations with an integrated approach to the area to be protected.

As an example of these activities, in the natural area of the Ebro delta, different works have been carried out, such as the multidisciplinary characterisation of the delta area (sediments, erosion, groundwater, water environments, infrastructure, agriculture, water quality, etc.) executed in ROP (1997), the Generalitat de Catalunya Guiding Plan (1996), the sustainability plan prepared by SEO/BirdLife (1997), or the description of guidelines by Ibáñez et al. (1999). The results and proposals concerning this kind of plans, which are often very different, reflect the complexity of the problem, and the difficulty –given the variety of common interests and perceptions– to find common, socially-shared objectives, and to identify the means to achieve them.

Another highly interesting case is Doñana, where a Sustainable Development Plan has been applied, with the participation and funds from the European Union.

3.9.3.4. Special interest aquifers

As an introduction, aquifers may be declared as especially interesting in different circumstances:

- When they are an important present or future source supplying potable water to populations.
- When they constitute the water support for wetlands, watercourses and other special interest natural areas.
- When they are part of the prevision plan for managing droughts.

The Water Act and its Regulations include administrative and prescriptive instruments which may be used to preserve the quantity and quality of the resources in aquifers of strategic interest.

In general terms, their application will require making the relevant provisions in the Basin Management Plans as regards the assessment of hydrogeological units or aquifers of strategic interest, together with the measures to be adopted in each case.

Some of the instruments applicable for this purpose are:

- Reserves of resources, aquifers or sectors thereof (sections 40.d and 41.1 LA and section 92.1 of the RDPH), applicable in aquifers which may be either allocated to supplying populations, or integrated in the system for regulating the resources of a basin.
- Declaration of special protection aquifers (section 41.2 of the Water Act and section 90 of the RAPAPH), for aquifers related to special interest natural areas.

- Delimitation of protection perimeters (section 54.3 of the Water Act and sections 173, 278 and 279.3 of the RDPH), for harnessing constructions or aquifers used for supplying water to populations, wetlands or other areas of ecological interest or with interesting landscapes.
- Groundwater policy (section 86 of the Water Act), which is particularly applied in the above-mentioned protected areas.
- Prioritisation of uses (section 58 of the Water Act and section 76 of the RAPAPH). The basin management plan may favour some general-interest or public-utility uses in certain areas within its territorial scope.
- Regulations on the granting of authorisations or concessions for exploiting aquifers (section 84.4 of the RAPAPH). The basin management plan may establish rules for the exploitation of hydrogeologic units or special-interest aquifers, related to the maximum abstraction flow, the distance between exploitation sites, the depth of wells, and installation of pumps, sealing of aquifers, etc.
- Regional planning (section 4.1.3. of the Water Act). The above-mentioned measures for protecting certain areas will have to be respected by the different regional planning instruments.
- Assessment of environmental effects (section 90 of the Water Act and section 236 to 239 of the RDPH). This assessment will be specially applied when processing concessions or authorisations affecting public water domain in the above-mentioned protected areas.

3.9.3.5. Protected reaches of rivers

The 78/659/EEC Directive, pursuant to its section 1.3, aims at *protecting or improving the quality of inland water where it is possible to find, or it would be possible to find if pollution decreased, fish belonging to indigenous species presenting natural biodiversity or species whose presence is considered as desirable, for the purposes of water management on the part of Member States'competent authorities.*

Pursuant to this Directive, the Spanish Government, in agreement with the Autonomous Communities, has declared certain reaches of rivers as protected: 27 salmonid reaches (573 km) and 113 cyprinid reaches (2,764 km), which are deemed to deserve protection because of the presence of indigenous species. The list of these reaches was submitted to the Commission in April, 1990. At the same time, some basin management plans, such as the Ebro or Douro plans, include these reaches in the chapter on quality objectives, and other plans, such as the one applied in the Guadiana, in the chapter on special protection areas given their environmental or natural interest.

This information has been reflected on the map in Figure 325. The data it shows were taken from the *Inventory on important "salmonid" and "cyprinid" water,* prepared by the old ICONA, and the publication of *Spanish Freshwater Fish. Inventory and classification of river areas. (Doadrio et al., 1991).*

As regards species whose presence is deemed desirable for the purpose of managing water, the Spanish State has not granted special protection to any section.

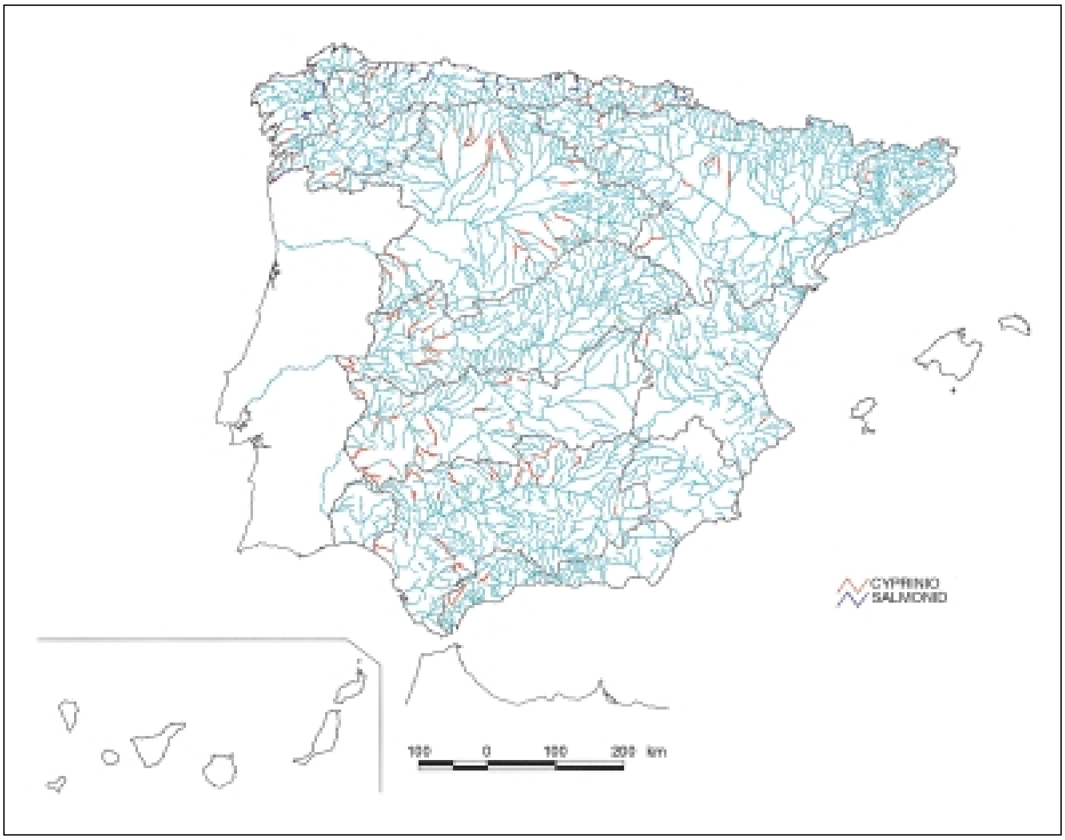


Figure 325. Map of sections of salmonid and cyprinid rivers protected by the 78/659/EEC Directive.

In addition, after making these inventories, some Autonomous Communities, such as Asturias, have given protection to some river stretches by means of specific Recuperation and Protection Plans.

It must be indicated finally that, in practice, it would be convenient to broaden the concept of protected river reaches, not only for the sake of conserving fish, but also to maintain their high structural conservation level and the relations between their elements.

3.9.4. Economic exploitation sites

In addition to the environmental functions of water public domain and its related areas, which have to be legally protected, this public domain includes other possible economic exploitation units, which are or can be highly interesting.

Two significant examples are the extractions of sediment and riverside forest exploitation. Both activities must be studied and programmed, considering their possible impacts both on rivers themselves and on beaches and on river outlets.

3.9.5. Promotion of social use

The social and recreational use of water public domain and its environment must become one the main functions in the immediate future.

We will only point out here that this use is currently being applied to our rivers and masses of water in different situations and areas (river bathing, recreational activities, sports, trips, navigation, etc.), and will be increasingly applied in the future, as pointed out when describing reference frameworks.

In addition, these uses are highly important from the economic point of view, and in some countries and areas they have become as important as the traditional productive uses.

3.9.6. Hydrological-forestry restoration

Spanish legislation, mainly the Water Act and the Act for the Conservation of Natural Areas and Wild Flora and Fauna, pays special attention to the conservation of soil-water vegetation, within the framework of the preservation of the water cycle, the essential ecological processes and basic life systems. In addition, Spain ratified on the 15th of January, 1997, the United Nations Convention to Combat Desertification. One of its main objectives is to combat desertification by means of integrated strategies simultaneously focused on increasing land productivity and on the rehabilitation, conservation and sustainable use of land and water.

The need to preserve the ecosystems of basin drainage areas is not only a social demand, reflected in the current regulations, but the verification of a scientific reality which, if not taken into account, will increase the already intense negative impacts suffered by a large part of Spanish basins, leading, as regards water resources, to imbalances which will not be easy to solve in the future.

The degradation of the vegetal cover, the erosion and desertification are currently among the most widespread, persistent and increasing problems affecting the water cycle, the oxygen-carbon biospheric cycle and, in general, the regenerative mechanisms of the life systems which have settled in and live on the soils. The over-exploitation of aquifers and agricultural practices play a central part in these environmental degradation processes (Puigdefábregas, 1995).

The United Nations Convention on Desertification Prevention sets out that “the desertification results from complex interactions of physical, biological, political, social, cultural and economic factors”, and points out that the combat against desertification must aim to “prevent or reduce the degradation of land, the rehabilitation of partially-degraded soil and the recuperation of desertified soil”. In Spain, the whole or part of the provinces of Castellon, Valencia, Murcia, Almería, Granada and Malaga are classified as areas with an extremely high risk of desertification, whereas a large part of the Ebro valley, of the plateau of Castilla, Extremadura and the province of Huelva present a moderate risk of desertification. The map in figure 326 shows the potential erosion risks in Spain, as determined by the ICONA (MAPA, 1994) for the different basins.

One of the main consequences of the soil deterioration process is the loss of its biological potential. This is one of the issues which were most insisted on by the World Strategy for the Conservation of Nature, defined in Madrid in 1980. This Strategy highlighted the special importance of soils as integral parts of a life system on which most of the non-water food production depends. Forests are essential for these purposes, given their advantageous effects on the climate, the water cycle, the erosion and physical and biological degradation processes suffered by soil, and the control of high waters and water quality.

The graph in table 99 summarises the effects of erosion and sedimentation on the storage capacity of some reservoirs, in accordance with the bathymetrical campaigns available.

The legal framework applicable to the actions for controlling erosion and fighting desertification is considerably broad, both at European Community and national level, and includes rules such as the Forestry Act of the 8th of June, 1957, Act of the 20th of July, 1955, on conservation and improvement of agricultural soil, ECC Regulation no. 2157/92 of the Council, of the 23rd of July, 1993, modifying EEC Regulation no. 3528/86, on the protection of the Community’s forests against atmospheric pollution, etc.

Hydrological-forestry planning should be included in the framework of a strategy for controlling erosion and fighting desertification, which would cover the whole of Spain’s territory and would make it possible to prioritise action areas in accordance with the urgency of the actions to be carried out. It should be coordinated with other plans or national

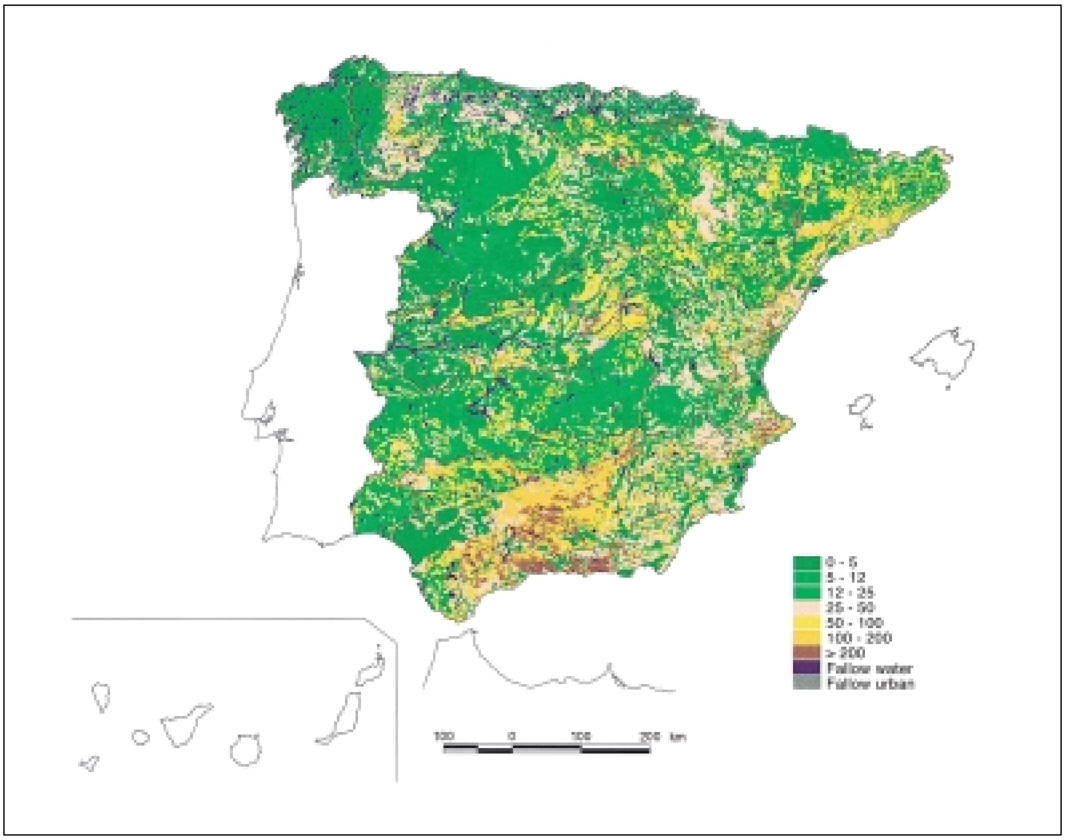


Figure 326. Map of the potential loss of soil (t/ha/year).

strategies for developing or conserving natural resources and, as regards water resources in particular, both with the essential issue of controlling runoff and high waters, and with the actions for the conservation of wetlands and the restoration of riversides.

The actions may be included in four different blocks: reforestation, to create a protective plant cover, forest treatments to maintain and improve the pre-existing plant cover, hydrological techniques to correct channels and gullies, and development and correction works on specially deteriorated or threatened basins.

Given that the actions system is based on bilateral Conventions expressly negotiated with every Autonomous Community, after the distribution of powers made under the Royal Decrees of 1984 and 1985, and given the legal rank of such Royal Decrees among the regulations which make up the constitutional framework, the Basic Forestry Act should either consolidate and legitimate the system, or restructure the

Basin	Number of reservoirs studied	Total initial capacity (hm^3)	Total capacity according to last bathymetry (hm^3)	Loss of capacity (hm^3)	Loss of capacity (% of the initial volume)	Average period of time (years)	Loss of yearly average capacity (% of the initial volume)
North I	6	517	499	18	3	31	0.11
North II	3	314	256	58	18	33	0.56
North III	2	64	62	2	3	36	0.10
Douro	5	899	875	24	3	34	0.08
Tagus	12	3,970	3,892	77	2	28	0.07
Guadiana I	5	2,082	1,932	150	7	29	0.25
Guadiana II	0	--	--	--	--	--	--
Guadalquivir	22	3,706	3,581	124	3	28	0.12
South	6	558	544	15	3	24	0.11
Segura	12	951	855	95	10	49	0.20
Júcar	16	1,474	1,420	55	4	30	0.12
Ebro	17	3,075	2,805	271	9	35	0.25
Catalonia I.B.	4	211	199	12	6	36	0.16
Coast of Galicia	0	--	--	--	--	--	--
Total	**110**	**17,321**	**16,921**	**901**	**5**	**31**	**0.16**

Table 99. Reservoir bed aggradation.

actions so that the funds for ordinary actions are allocated on a territorial basis through the mechanism set forth by section 153 of the General Budget Act; in that case, the State would be responsible for managing a special fund aimed to finance actions which, given their scope, are beyond the territorial or funding capacity of an Autonomous Community. This would be a solidarity fund, which would prevent and avoid endemic problems or more serious natural catastrophes.

Accordingly, the Central Forest Administration could be the body in charge of carrying out actions on such basin headwaters as are considered absolutely indispensable by the basin management plans. For these purposes, a Mixed Commission could be constituted, which would analyse the actions to be carried out under the basin management plans, so that the Hydrological-Forestry Restoration Plan may be reformulated.

As regards desertification prevention and its integration in the forest strategy, the main actions to implement in areas which are either desertified or threatened by desertification, would be:

- Hydrological-Forestry Restoration in arid or semiarid areas. The core actions to combat desertification include works for restoring the soil and the vegetal cover in arid and semiarid areas affected by forest fires, abandonment of crops which results in the soil losing its properties and its production capacity, and improper shepherding, among other factors. These restoration actions also include the promotion of biodiversity and of the complexity of vegetal groups in arid and semiarid areas impoverished by the over-exploitation of resources. The prioritisation of actions will be determined by the original value of the degraded ecosystem and the effects arising from the degradation. The degradation of valuable vegetal groups, or the absence of water regulations leading to a considerable increase in the risk of catastrophic high waters, are therefore factors determining a high restoration priority. Just like the Hydrological-Forestry Restoration Plan, the National Action Plan to Combat Desertification must identify areas where the actions are clearly too costly to be covered by an Autonomous Community's budgets, so that the General State Administration may directly manage the relevant actions (with the collaboration of Hydrographic Confederations and of the Autonomous Communities within which such area is located). The actions to be carried out in the remaining areas and in the other programmes of the Plan will be distributed on a territorial basis by allocating every year, before the 15th of March, the relevant State investments.
- Monitoring and assessment. The starting point for controlling desertification is knowing its actual and potential development within the territory. For such purpose, the RESEL (Stations Network for Monitoring and Assessing Erosion and Desertification) was created under the Lucdeme Project.

  This network comprises 41 experimental fields with Spain's desertification landscapes. The network will be extended with new stations and complemented with information from other domains, such as tele-detection and inventories or databases (Forest Inventory, Forest Fire Database, Monitoring of the Phytosanitary Condition of Spanish Forest Masses) and the thematic cartography on natural resources made by different institutions (Forest Map, Land Map and Lucdeme Project). The information obtained is processed and placed at the disposal of entities related to the planning and execution of actions against desertification. As regards monitoring and assessing these processes, there are additional aspects to consider, such as the development and the dynamics of systems.
- Biotechnology in arid areas. Its aim is to test new crops and uses for arid areas, and to promote traditional uses having lost relevance recently. The objective is to contribute to the development and conservation of arid areas by making their genetic resources profitable. Within this context, tests and feasibility studies are carried out on tests and esparto byproducts, aromatic and medicinal plants, and, in particular, algae in extremely saline aquatic ecosystems.

Other actions to be implemented under the Plan will include, for instance, the development of sustainable extensive shepherding systems in arid areas and the international cooperation with the north of Africa.

3.9.7. Monitoring and control of public domain

Among the multiple aspects which deserve to be highlighted under this concept, stress will be laid on three basic questions, which we will simply mention: water police, cooperation and urban development.

It should be pointed out that the task of monitoring and controlling public domain is mainly and especially assigned to the river security guards. In broad terms, this institution's problems may be the same as those of the water administration, but with certain functional particularities which must be taken into account during future reforms. It should be simply considered that the real uses applied cannot be possibly known without a close contact with the rural environments where such uses are located, and without a thorough knowledge of the landscapes, customs and habits, water infrastructures and users themselves, and such comprehensive knowledge can only arise, in the first place, from a well-staffed, well-equipped service and motivated guards. It will be necessary to promote these services decidedly, given that they currently poorly funded, and they are essential for a proper water management.

In addition, the actions to be implemented within the policing area, to be efficient, require the collaboration of local administrations. Cooperation formulas under conventions, which may be promoted by the Autonomous Communities to maintain and clean these areas, are highly useful instruments, which have already led to positive results in the past.

Finally, the close coordination with urban development programmes is not only a legal obligation, but also a real need. The relations between these programmes and public water domain are not simply based on reserving and excluding the land included in such domain; they must be applied to the factors conditioning the activities or facilities within the scope of protection of groundwater.

Even if regulations on this issue have been approved, there is little experience as regards the practical operation of these mechanisms, but it is clear that these activities are becoming increasingly important, and they will have to be developed in the immediate future.

3.10. WATER INFRASTRUCTURES

3.10.1. Systems and typologies

3.10.1.1. Basic infrastructure systems

The main basic water infrastructure systems (abstraction, storage, transport, treatment, etc.) are logically associated to the fulfilment of the main water demands. The extensive number of cases related to these varied demands results in different infrastructure systems, with highly different typologies, functions and level of conservation, which are briefly described, as regards typologies representing basic systems, description, in the following chapters.

3.10.1.1.1. Supply systems

In Spain, urban supply systems are highly and increasingly concentrated, which has led in recent years to important initiatives aimed to establish integrated systems under unified management. In table 100, the main existing systems are included, together with their relevant sphere of influence.

As it can be observed, eight large distribution systems cover nearly half of the Spanish population, which reflects the importance of these systems. Figure 327 briefly shows the system of the *Canal de Isabel II* –the largest channel in Spain– which supplies water to nearly 5 million people.

Despite this integrating trend, the water management dispersion at municipal level is still a major problem, which will only be solved if effective, supranational integration and management formulas are found.

3.10.1.1.2. Traditional irrigation

As regards irrigated land, which is the main consumer of water, the concept of traditional or historical irrigation applies to those executed before the year 1900, i.e., before the 20th century. There are specials situations where this concept also has a legal meaning, such as the case of the Segura basin, where *traditional* irrigated land, to which special regulations apply, is that which existed in 1933.

In broad terms, the surface of historical irrigation in Spain amounts to about 1,075,000 ha. This land obviously covers the most fertile valleys around rivers, as well as oasis located in small vegetable gardens irrigated with springs, using surface water and gravity-based irrigation systems. In general, this land is managed by the irrigators' associations, even if some important historical channels (350,000 ha of irrigated land) are still managed by Hydrographic Confederations.

From a more modern point of view, the structure of the exploitation units is not the most adequate, given that most of them have a surface of less than 2 ha, and the average surface of the plots is less than 0,5 ha, which clearly highlights one of the most serious problems affecting this irrigated land, i.e., its extreme dispersion in small plots.

The water supply network is made up of main channels, most of which are already lined, and a series of earthen ditches, with inadequate layouts and poor service conditions. In traditional irrigation, the distribution of water is carried out by turns or shifts, through networks which were originally designed to be operational 24 hours a day. Now that the working day is considerably shorter, its reaches are currently insufficient.

Examples of traditional irrigation are the Castilla Channel, the Aranjuez Channels, the irrigated plains in Murcia and Valencia, the Aragon Imperial Channel, etc.

3.10.1.1.3. The risks of public initiative

In this category, which comprises the irrigated land developed throughout the 20th century on the initiative or with the assistance of the Public Administration, several types of irrigation may be highlighted:

- Irrigation carried out under the Public Works Ministry's initiative, under the Assistance Act of 1911 and the Decree of 1964 (316,000 ha)
- Irrigation carried out by National Colonisation Institution (INC) and its successor, the Institution for Agricultural Reform and Development (IRYDA) (Acts of 1953 and 1973), both on an exclusive basis and under Plans Coordinated with the Public Works Ministry (992,000 ha).

Supply systems	Population supplied
Canal de Isabel II (Madrid)	4,820,000
Aigües Ter-Llobregat (Barcelona)	4,240,000
Taiblilla Channels' Association (Murcia and Alicante)	1,800,000
Consortium of the Cadiz area	1,600,000
Seville Municipal Water Company	1,158,000
L'Horta Association (Valencia)	976,000
Gran Bilbao Water Consortium	921,000
Western Costa del Sol Association	900,000
Total	**16,415,000**

Table 100. List of the main water supply systems.

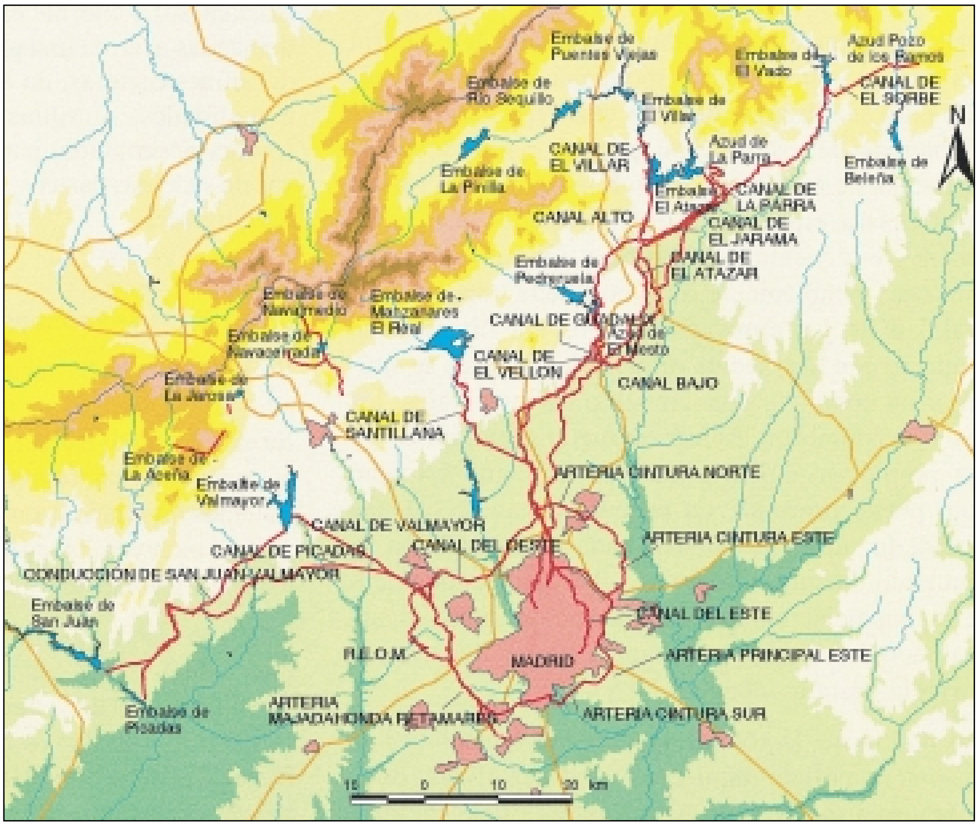


Figure 327. Supply system of the Canal de Isabel II.

- Actions in Autonomous Communities (95,000 ha).
- Private collective irrigation, but partly carried out with State subsidies (115,000 ha).

This type of irrigation, with a total surface of 1,518,00 ha, is usually applied to the most fertile areas of large valleys and in the interfluvial plains which are most suitable for irrigation.

The infrastructures, generally old and deteriorated after many years in service, have few mechanisms for controlling and regulating flow, which results in low global efficiencies.

The plots are slightly larger than in traditional irrigation, but they are still too small to be adequately modernised through technical means in accordance with new agricultural requirements. A typical example of this type of irrigation is the area of the Guadiana's fertile plains, whose corresponding Badajoz Plan is schematised in the graph in Figure 328.

3.10.1.1.4. Individual private irrigation

This type of irrigation has been developed on private initiative through administrative public water concessions or through public water exploitation units. It covers a total surface area of about 1,168,000 ha and, whether they use ground or surface resources, irrigation water is generally obtained through pumping from its abstraction or feeding source.

In general, it is directly financed by the farmer, even though, in some cases, it has been implemented by means of public economic subsidies or soft credits. The hydraulic works for extracting water are usually exclusive for each exploitation site, even if in some regions, such as Spain's south-east (especially in the Murcia region) and in the Canary Islands, the owners form associations to exploit jointly abstractions, conducts and regulation ponds.

Due to the high costs and the expensive facilities needed (only partly subsidised), the most common irrigation systems are those requiring lower water volumes, such as the aspersion system, in all its modalities, and the localised micro-irrigation system, both implying high-level technical means and, in broad terms, high global efficiency values.

The sum of all the above-mentioned irrigation systems results in a total surface area of about 3.7 Mha, which is the surface considered to be equipped with irrigation structures, or which has been actually irrigated in the past. It is obvious that this number is not, and cannot be, equivalent to the surface which is actually irrigated in a normal year, which is about 3.4 Mha.

3.10.1.2. Water infrastructure typologies

3.10.1.2.1. Dams

Dams are undoubtedly the most special, complex water infrastructures. Spain has an extensive, long tradition in the construction of this type of infrastructures, and, still today, a few dams built by the Romans are in use, such as the Cornalbo and Proserpina dams, constructed in the 1st century, and which may be considered as engineering masterpieces, even in the light of modern technique standards (Díaz-Marta, 1997).

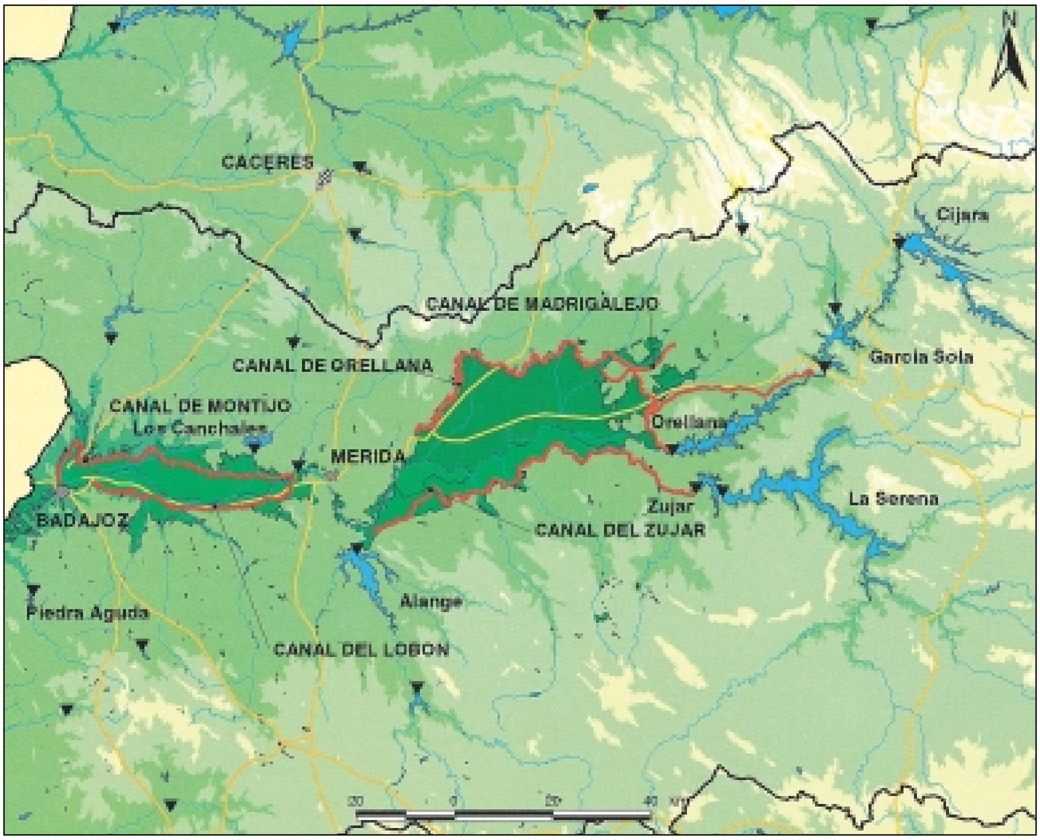


Figure 328. Badajoz Plan.

The number of currently operational dams exceeds one thousand (1,133 including side dams), with a total storage capacity of about 54,000 hm^3, which can be increased to 56,000 hm3 if the dams currently being constructed are included (September, 1996).

As it can bee seen in figures 329 and 330, the rate of execution of these infrastructures was specially high in the 50s and the 60s, and the storage capacity rose from 6,000 to about 37,000 hm^3, with nearly 2,000 new h^3 every year between 1955 and 1970.

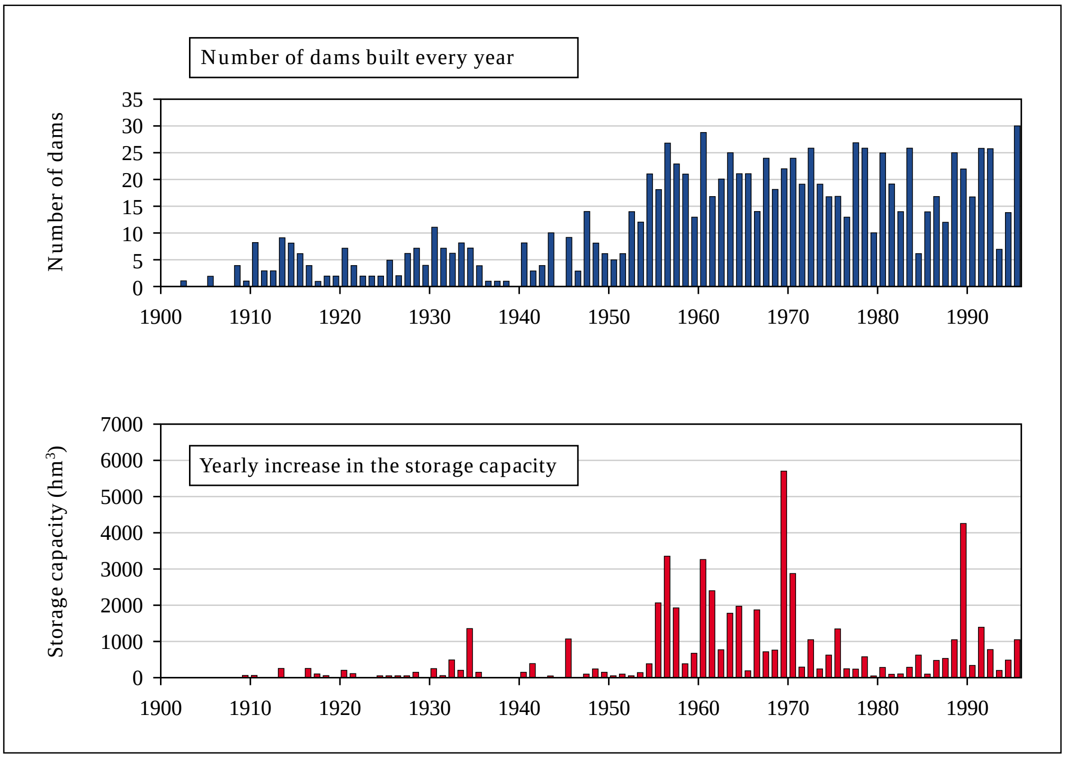


Figure 329. Increase from 1900 in the number of dams built every year and in the storage capacity generated.

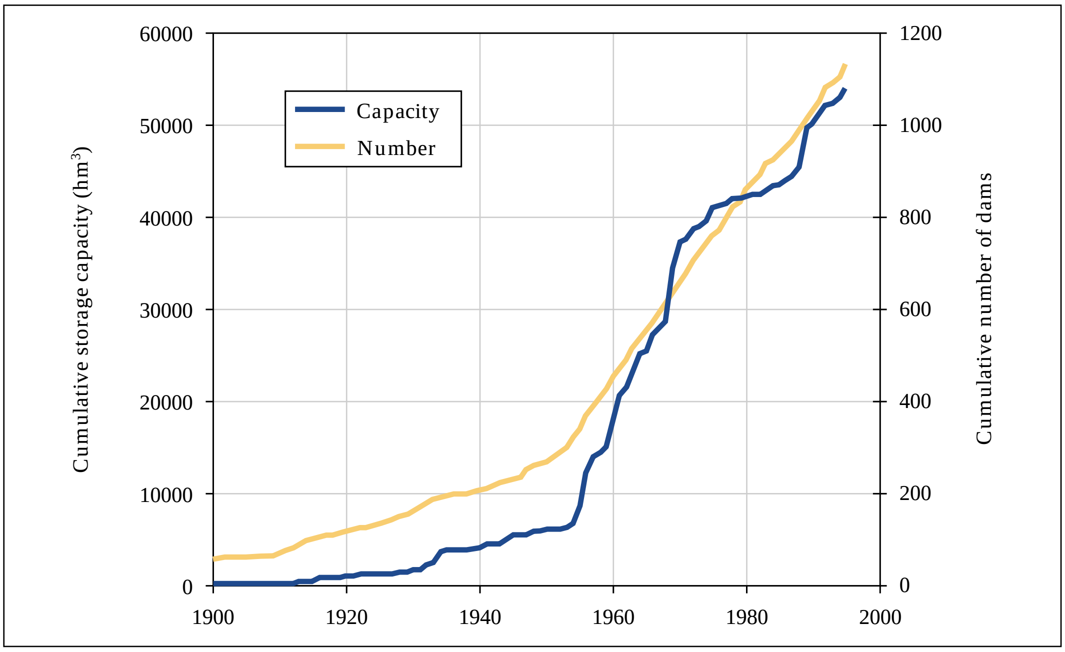


Figure 330. Accumulated increase from 1900 in the number of dams constructed and the storage capacity generated.

Two clearly different stages may be observed with regard to the evolution of the number of dams. Up to 1955, about 4 new dams were built every year, and the number of dams went from about 60 in the early 20th century to about 270 in 1950. After that year and up to the present, the rate became considerably higher, resulting in the construction of about 20 dams/year before reaching the current number.

The storage capacity has evolved in a similar way, but with a few differences. Up to 1950, the storage capacity and the number of dams evolved similarly, but after that year the capacity grew more intensively than the number of dams, given that large-capacity dams were built during that period. From 1970, the growth of such capacity slowed down until the late 80s, when the Serena dam started to be operational.

Table 101 shows the main data concerning the dams being exploited and executed (in September, 1996) within the scope of the different Plans.

Despite this considerable number of dams, it is important to highlight that most of the storage capacity (about 98%) is concentrated on 300 reservoirs with a capacity of over 10 hm^3. Low-capacity reservoirs, however numerous, account

Plan	Number of dams being exploited	Capacity of the reservoirs being exploited (hm^3)	Surface flooded (ha)	Capacity of the reservoirs being exploited (hm^3)	Total capacity (exploitation and exeTagusion) (hm^3)
North I	53	3,040	11,771	0	3,040
North II	27	559	2,913	0	559
North III	32	122	712	0	122
Douro	67	7,654	35,417	13	7,667
Tagus	198	11,131	58,806	4	11,135
Guadiana I	90	8,508	48,039	335	8,843
Guadiana II	36	684	4,654	92	776
Guadalquivir	107	8,208	43,293	659	8,867
South	37	1,160	5,212	159	1,319
Segura	27	1,144	6,580	79	1,223
Júcar	47	3,343	17,263	6	3,349
Ebro	151	6,761	40,294	941	7,702
C. I. Catalonia	14	692	2,450	80	772
Galicia Coast	22	688	4,446	0	688
Total peninsula	908	53,694	281,850	2,368	56,062
Baleares	2	11	119	0	11
Canary Islands	114	101	477	0	101
Total Spain	**1,024**	**53,806**	**282,445**	**2,368**	**56,174**

Table 101. Main data on the reservoirs being exploited and exeTagused (September, 1996) within the scope of the different plans.

for a small fraction of the total storage capacity, as can be observed in figure 331 concerning classified and accumulated capacities.

The geographic distribution of reservoirs with a capacity of over 10 hm^3 is shown in figure 332.

The evolution of the construction of these dams throughout the years is shown in figure 333, which contains different maps corresponding to different periods of time. They indicate the situation of dams with a capacity of over 10 hm^3 which to become operational in the last twenty-year periods. Despite the fact that there were about 60 dams in the early 20th century, only three of them –Puentes and Valdeinfierno on the Segura and Villar on the Tagus– had a capacity of over 10 hm^3.

This figure shows that after 1940, the territorial density of these infrastructures is considerably higher.

This territorial analysis can also be made from the point of view of the evolution of the storage capacity, as shown in figure 334, which represents the evolution of the capacity throughout the years, broken down according to the different planning scopes.

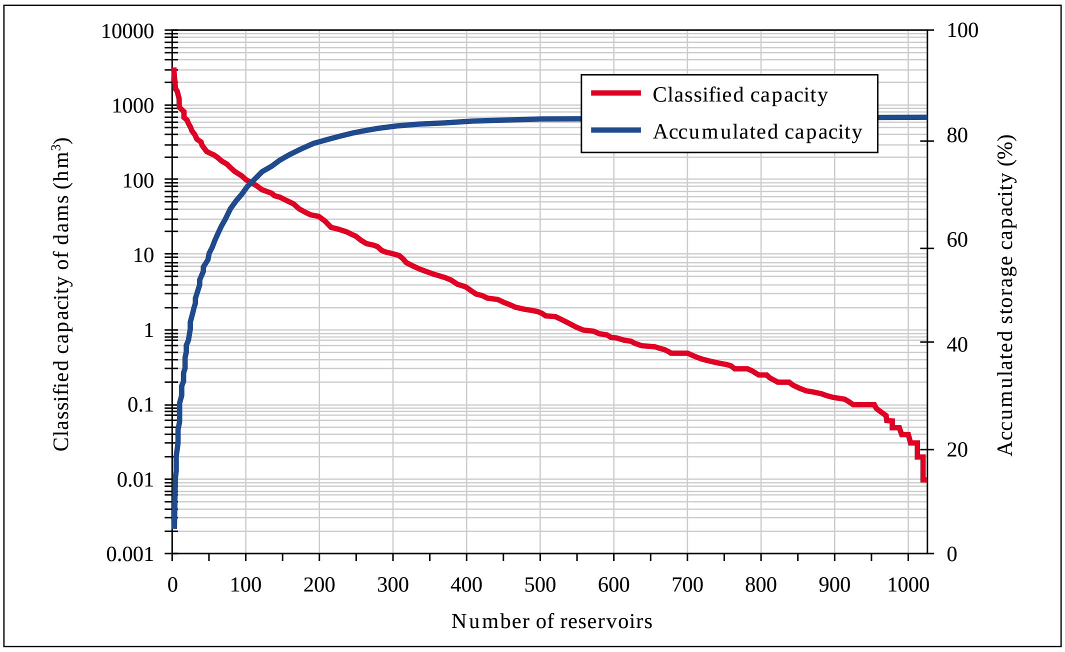


Figure 331. Classified and accumulated capacity of Spanish reservoirs.

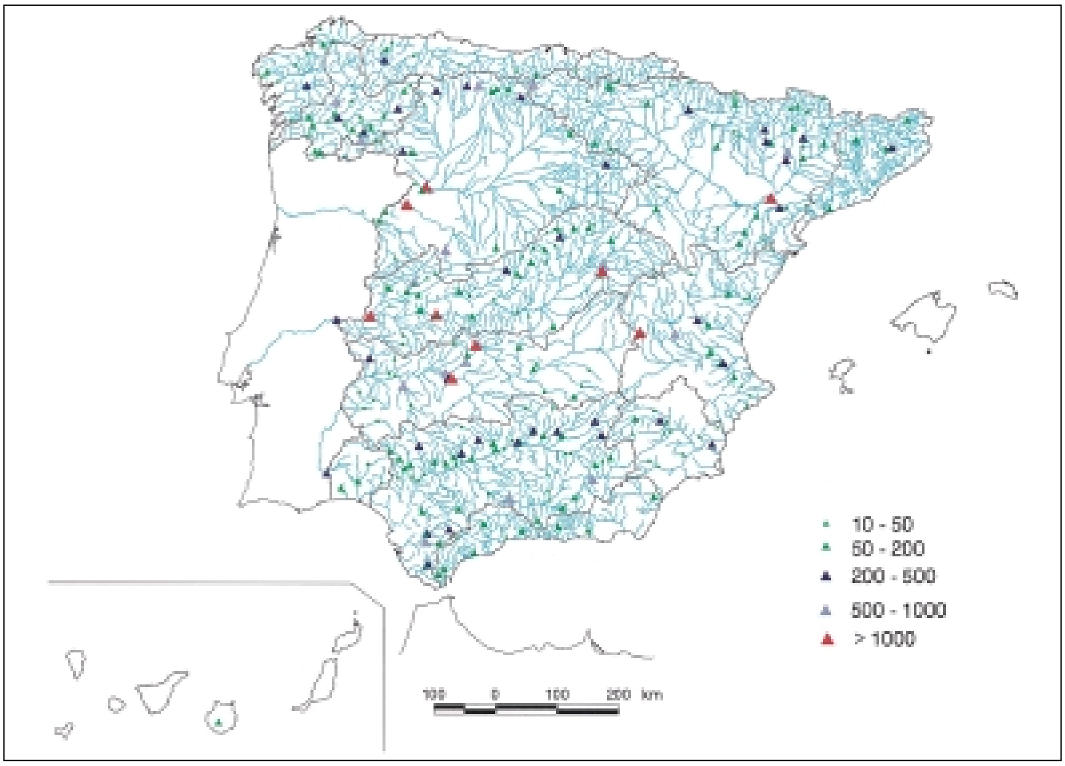


Figure 332. Map of the reservoirs having a capacity of over 10 hm^3.

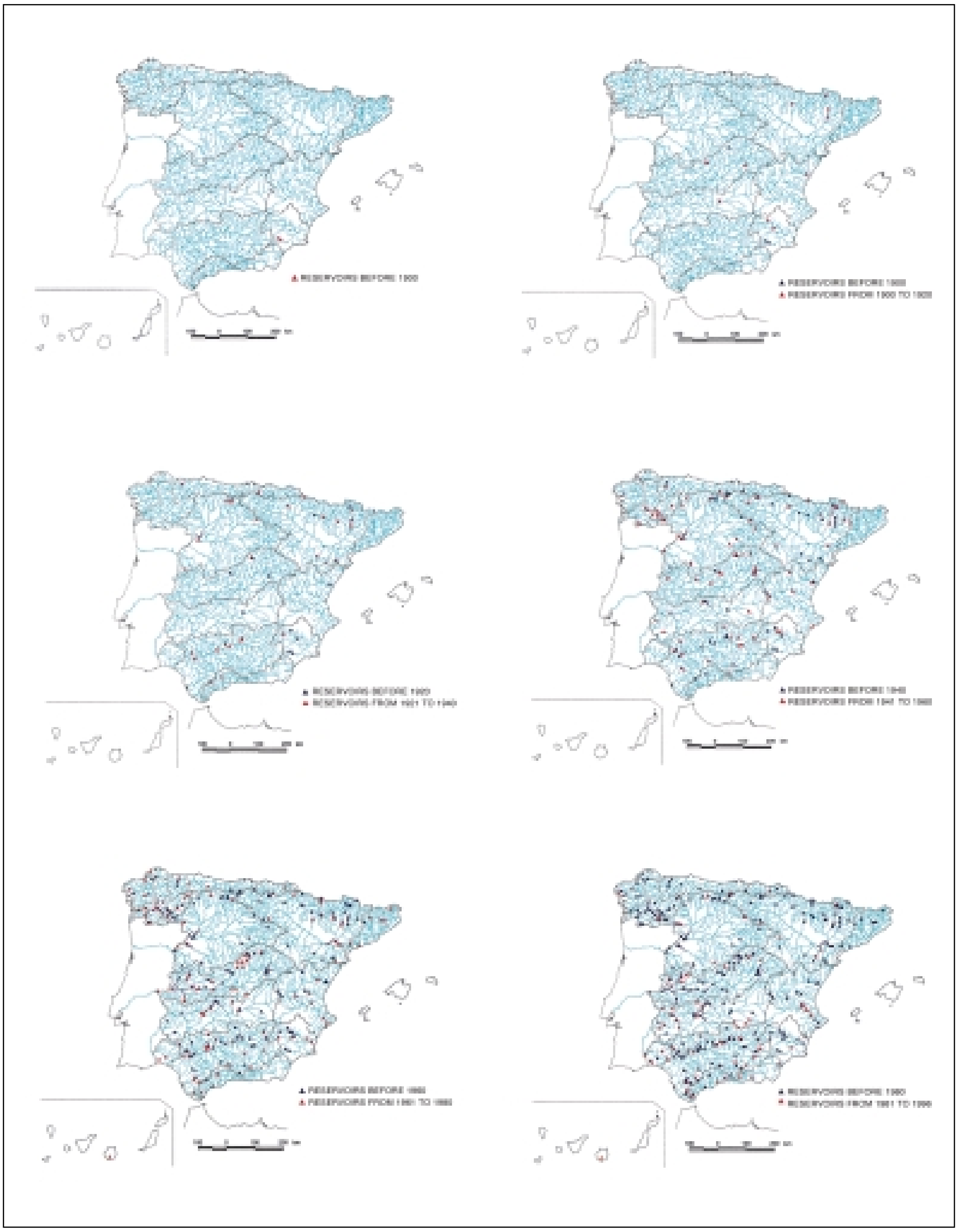


Figure 333. Maps of the evolution of the construction of dams with a capacity of over 10 hm^3.

The figure shows the reduced relative capacity existing in some regions, such as the archipelagos, the Bay of Biscay Coast (except North I), Catalonia Inland Basins, South or Segura.

It also shows the rapid increase in capacity which took place in the Tagus basin in the 60s. In the Guadiana basin, the growth has occurred in stages. At the end of the 50s, there was a relatively fast increase resulting from the constructions related to the Badajoz Plan, followed by a nearly 30-year period of very low activity as regards the construction of dams. Later, the Serena dam brought about the most regular growth, resulting in a sustainable increase in capacity from the 30s, with the exception of a short period in the 70s. In the Ebro basin, there was a strong increase up to the late 60s, but in the last thirty years the growth has practically stagnated.

In order to better assess the relative storage capacity available, figure 335 compares these current storage capacities with the natural cumulative flow in different regions. It can be seen that in some them, such as the Tagus, Guadiana I or Segura, the storage capacity exceeds the total natural cumulative flow registered during one year. In other cases, mainly in the entire Bay of Biscay Coast, the storage capacity is very low if compared with the natural resources.

All this information is clearly reflected in figure 336, which shows the ratio between storage capacity and natural cumulative flow in every region.

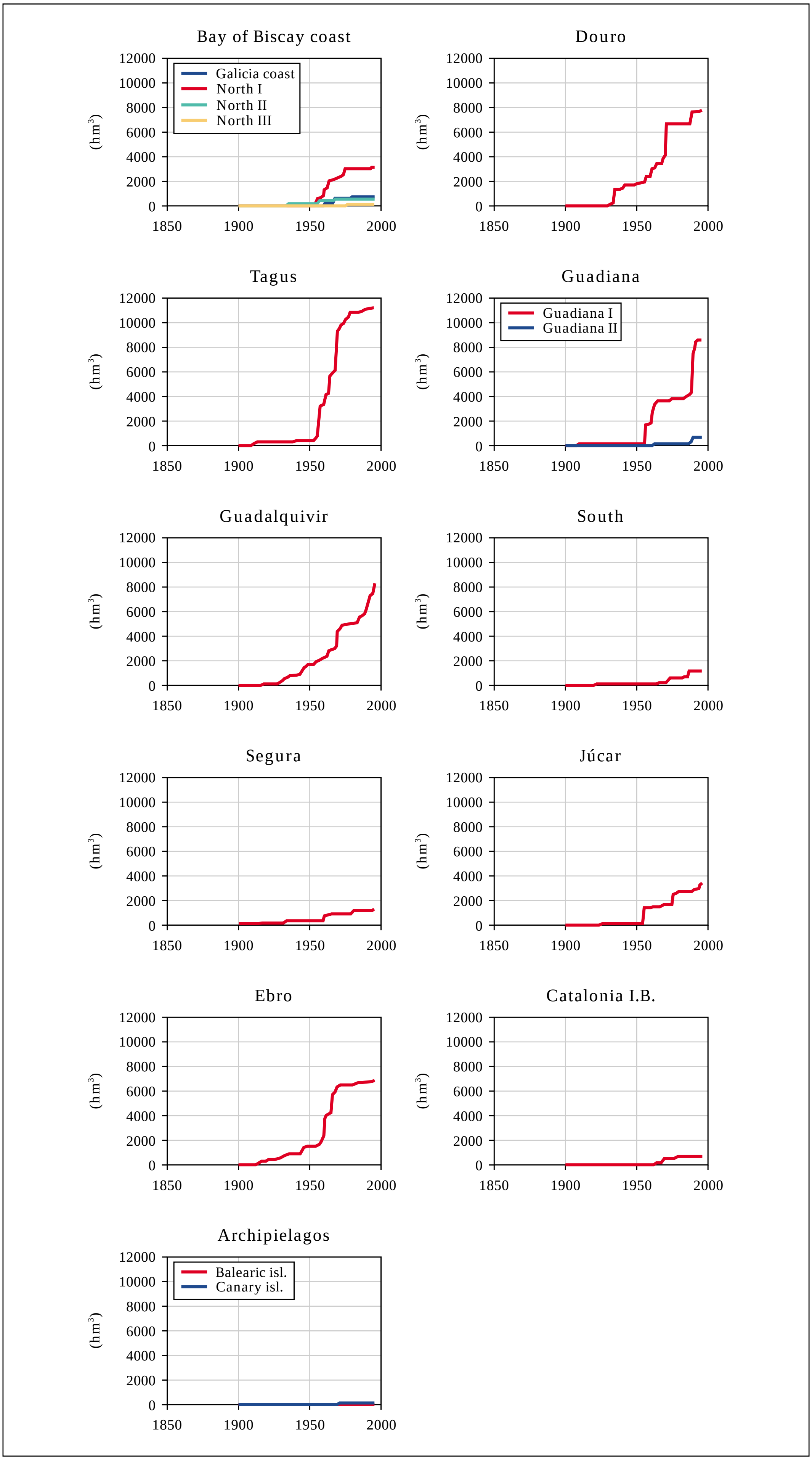


Figure 334.
Increase from 1900 in the storage capacity generated in the different planning areas.

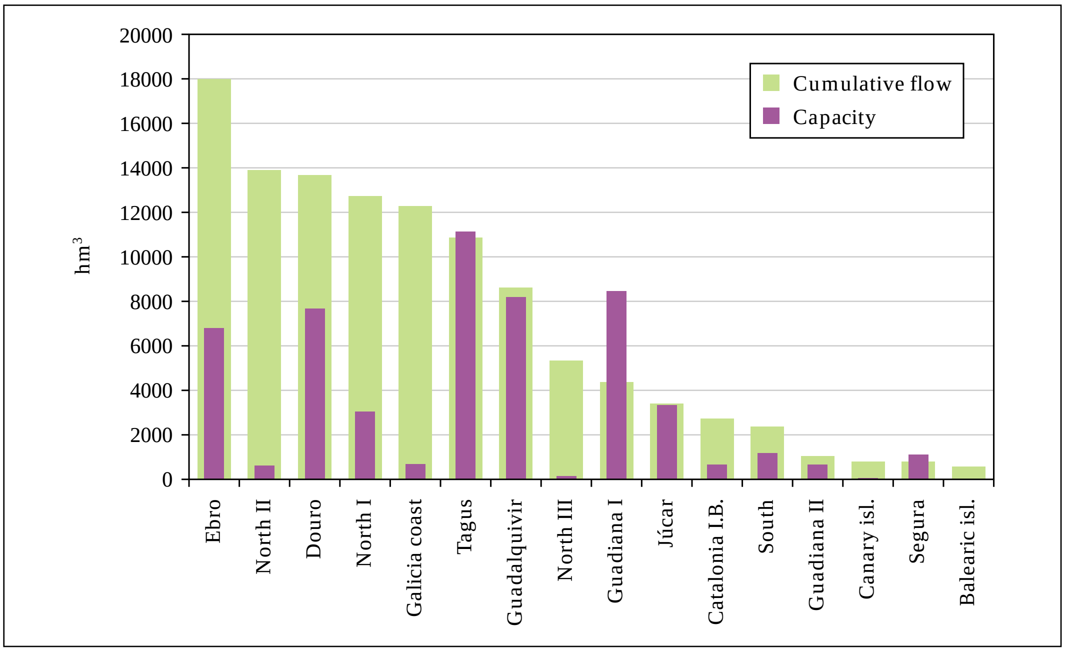


Figure 335. Storage capacity and yearly natural cumulative flow in the different planning areas.

Some basins show a ratio greater than one, such as the above-mentioned Guadiana I, Segura and Tagus basins, which have a high relative storage capacity, whereas the ratio for the Jucar and Guadalquivir basins is close to one. Conversely, basins with a ratio lower than 0.2 include the Canaries, Galicia Coast, North II and III and the Balearic Islands. It must be pointed out that these figures are given as an indication only, since there can be different values in every basin, and they are likely to be governed by different regulations, given the diverse hydrogeological elements of the cumulative flow carried down by the different rivers, and the different pumping capacity installed in each basin. In addition, as indicated above, as a result of the effects of large backwater reservoirs (as is the case of the Douro), these figures have to be qualified and be interpreted with caution.

A different analysis which is also particularly interesting focuses on the evolution of reservoirs in accordance with their owners. In this context, reservoirs can be divided into two main categories. The state-owned reservoirs' category includes those for which the Administration is responsible, whether such administration is central, autonomic or municipal. The remaining ones would be included in the privately-owned reservoirs' category (usually owned by electric companies).

Figure 337 shows the historical evolution of the storage capacity in accordance with these two categories.

As it can be seen, up to the mid-50s, the capacity is very similar in both categories. Throughout the 60s, the capacity in state-owned reservoirs was higher, but after a rapid increase in privately-owned reservoirs at the end

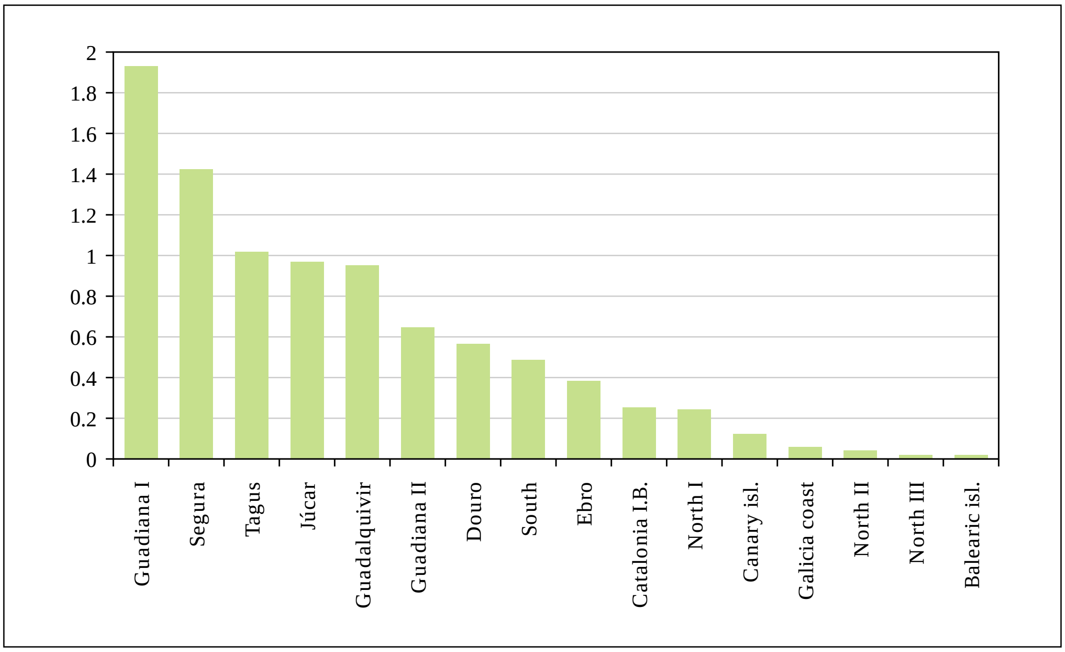


Figure 336. Ratio between storage capacity and yearly natural cumulative flow in the different planning areas.

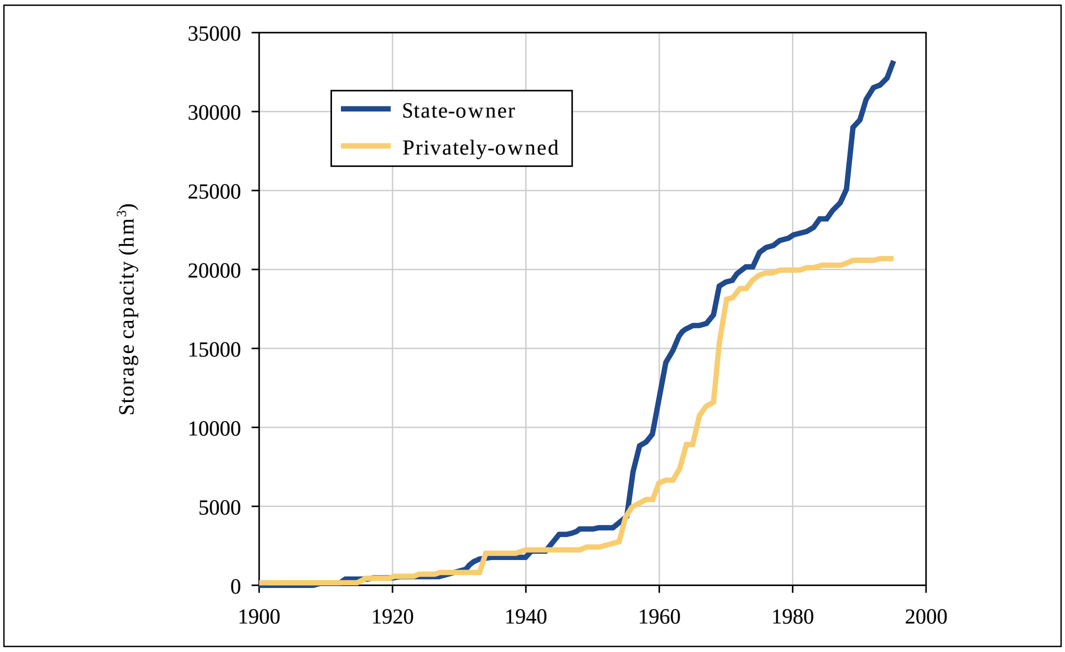


Figure 337. Increase from 1900 in the capacity of state-owned and privately-owned reservoirs.

of the 60s, both types of reservoirs had a similar capacity again by 1970. After this date, however, both categories had clearly different evolutions. The capacity of state-owned reservoirs continued to go up –especially in the late 80s– and reached about 33,000 hm^3, whereas the capacity of privately-owned reservoirs stabilised at about 21,000 hm^3, with only slight changes up to the present.

The territorial distribution of this evolution may be clearly observed in the interesting graphs included in figure 338, which correspond to each of the planning areas.

It is relevant to highlight that most reservoirs are privately-owned in the Bay of Biscay Coast, and particularly on the Douro and the Tagus. On the Ebro, the capacity of privately-owned reservoirs is also slightly higher, whereas in the Júcar and Catalonia Inland Basins, state-owned reservoirs have a slightly higher capacity.

However, the situation in southern basins, such as the Guadiana, Guadalquivir, South and Segura, is totally different. In these cases, nearly all the existing capacity corresponds to state-owned reservoirs, with a very low storage capacity in privately-owned reservoirs.

It could even be said, in broad terms, that in the north-west area, where water resources abound, most of the reservoirs built are privately-owned, mainly by hydroelectric companies, whereas in the southern area, where resources are scarcer, most reservoirs are state-owned, mainly built as a means of protection against different risks.

3.10.1.2.2. Diversion dams and river abstraction units

With these structures, it is possible to elevate slightly the rivers' water sheet in order to facilitate their diversion into other channels. In Spain, there is an extremely long tradition and a large number of diversion dams for privately-owned mills, factories and industries.

In more recent times, these diversion dams have been built to divert water into hydroelectric companies or into irrigation channels in major rivers' fertile plains. The diversion dams in El Bocal on the Ebro, San José on the Douro, Cazalegas on the Alberche, Del Rey on the Jarama, Montijo on the Guadiana, Ojós on the Segura, or Peñaflor on the Guadalquivir, are interesting examples of this kind of infrastructures.

To obtain lower flow, other types of infrastructure for extracting water from the channels are usually installed, mainly pumping stations, direct abstractions or marginal wells, generally for private use.

In some of them, it has been necessary to close the river's bed or channel by means of constructions installed in the bed of the stream.

3.10.1.2.3. Hydrogeologic abstractions

A large part of the water supplied to populations and to privately-owned irrigated land comes from natural springs and wells.

There have been galleries for extracting and conducting groundwaters since the Bronze Age (some of them, for instance, in Almeria), and they were also frequent in the Muslim period. These infrastructures are particularly important in the Canary Islands and in most of the south-east region.

Figure 339 shows the estimated indicative evolution of the volume of groundwater used in Spain according to MOPTMA-MINER (1995), as well as the evolution, from 1940 to

1980, of well flow and gauging boreholes in the Segura basin, according to the Basic Documentation from its Water Plan, and on the basis of data from mining authorities concerning such boreholes. Through these two series, it is possible –with the logical limitations associated to this type of data– to have an idea how dynamically these infrastructures have grown in recent decades, especially in some specific areas of Spain.

It is currently estimated that it should be possible to use groundwater through more than one million wells and abstraction units, which reflects the extraordinary global importance of this source of supply.

By way of example of the extreme concentration of wells, figure 340 shows the number of wells ones (about 70,000) which can be found in the upper Guadiana basin's aquifers.

3.10.1.2.4. Supply Conduits

According to the Basic Documentation from Water Plans, and only for intercommunity basins, the total number of conduits amount to a total length of over 5,000 km for transporting and supplying water to populations, most of which are pipes made of different materials, with different sizes and registered pressures.

Their distribution among the different plans is shown in table 102, drawn up here on the basis of data from the Basic Documentation Summary for Water Plans (MOPU-DGOH, 1990).

The figures indicated on that table represent a threshold, given that the Basic Documentation contains data from the 80s and, in some cases, only conduits with a capacity of over 500 l/s have been included. The table also includes the density, referred to the surface area of every intercommunity Plan's territory.

Several headraces from the Roman period have been recently abandoned and represent now valuable historical remains, like the Segovia or Merida aqueducts.

The Autonomous Communities have assumed the State's former power of assisting municipalities, which are responsible for this type of infrastructures.

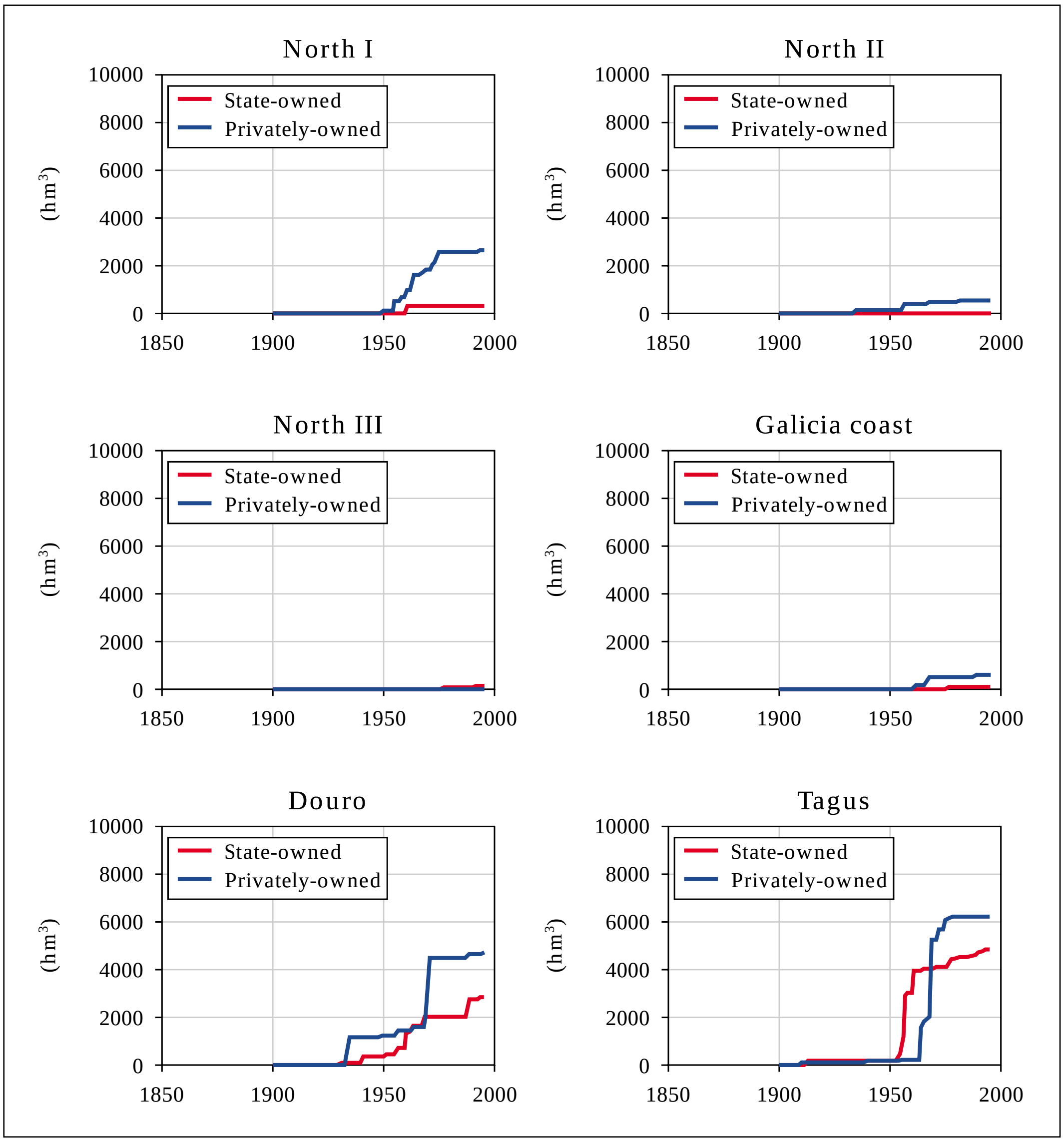


Figure 338. Increase from 1900 in the capacity of state-owned and privately-owned reservoirs in the different planning areas.

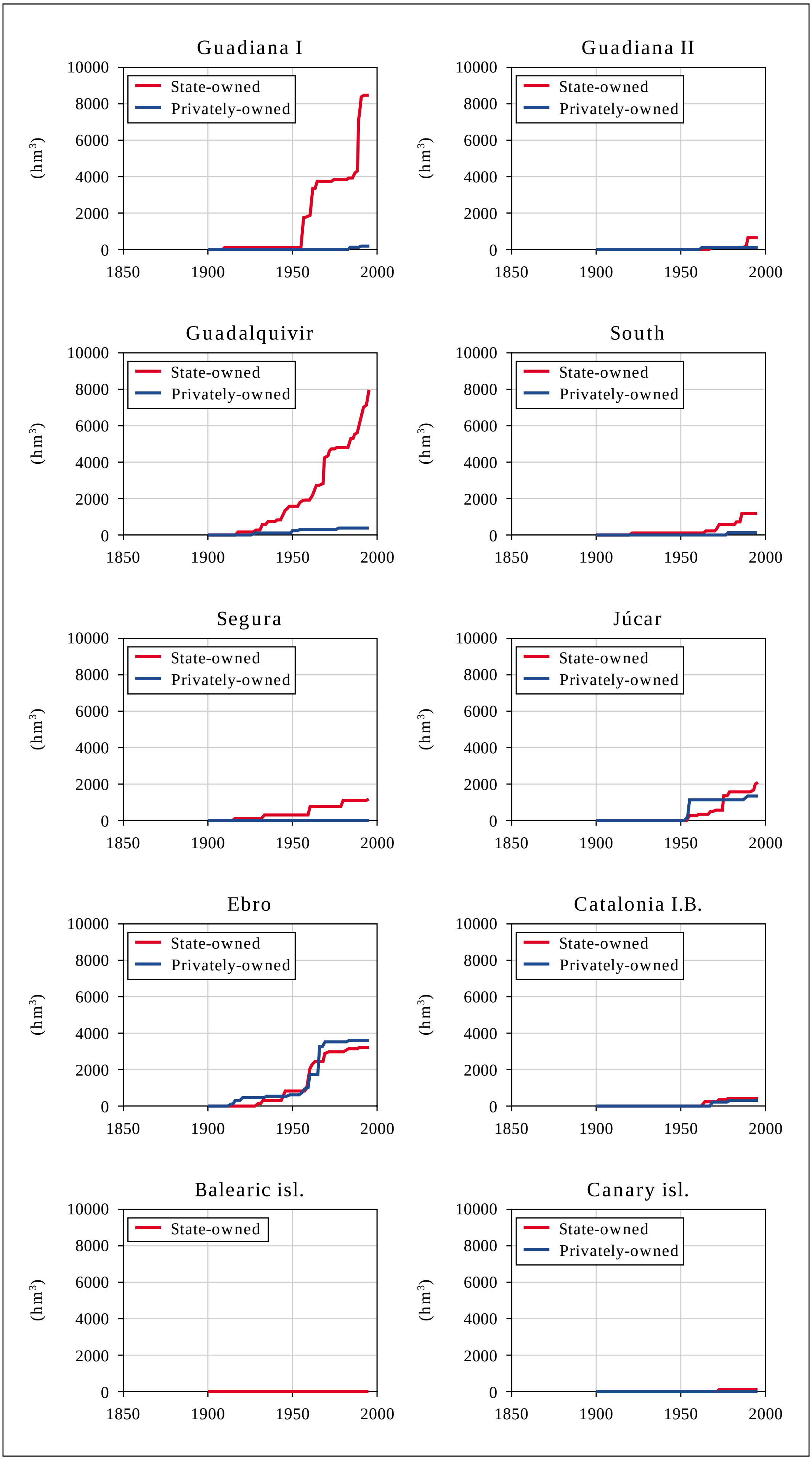


Figure 338.
(Continuación)

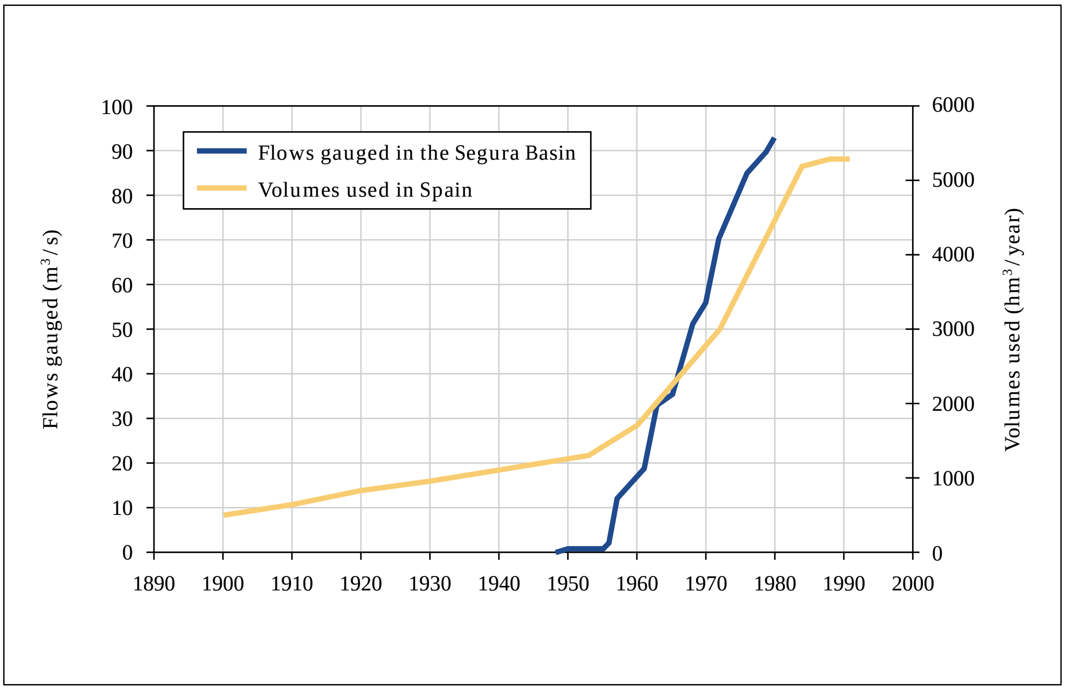


Figure 339. Increase in the volume of ground water used in Spain and of flows extracted from wells and gauging boreholes in the Segura basin.

In addition, as indicated above, there is a general trend towards the creation of municipality pools or Associations for the construction of these conduits, as well as for their exploitation and conservation. The management tends to be carried out by means of agreements with municipal or private companies.

The water distribution networks are the main asset of the entire supply system. These networks are made up of pressurised conducts which are buried in a humid environment with parasite currents; these aggressive conditions result in an ageing process and limit their useful life, provoking occasional leakage, damage-causing breakage and reductions in the quality of the water they transport.

According to the AEAS survey carried out in 1994, including data concerning 16.9 million inhabitants in towns with a pop-

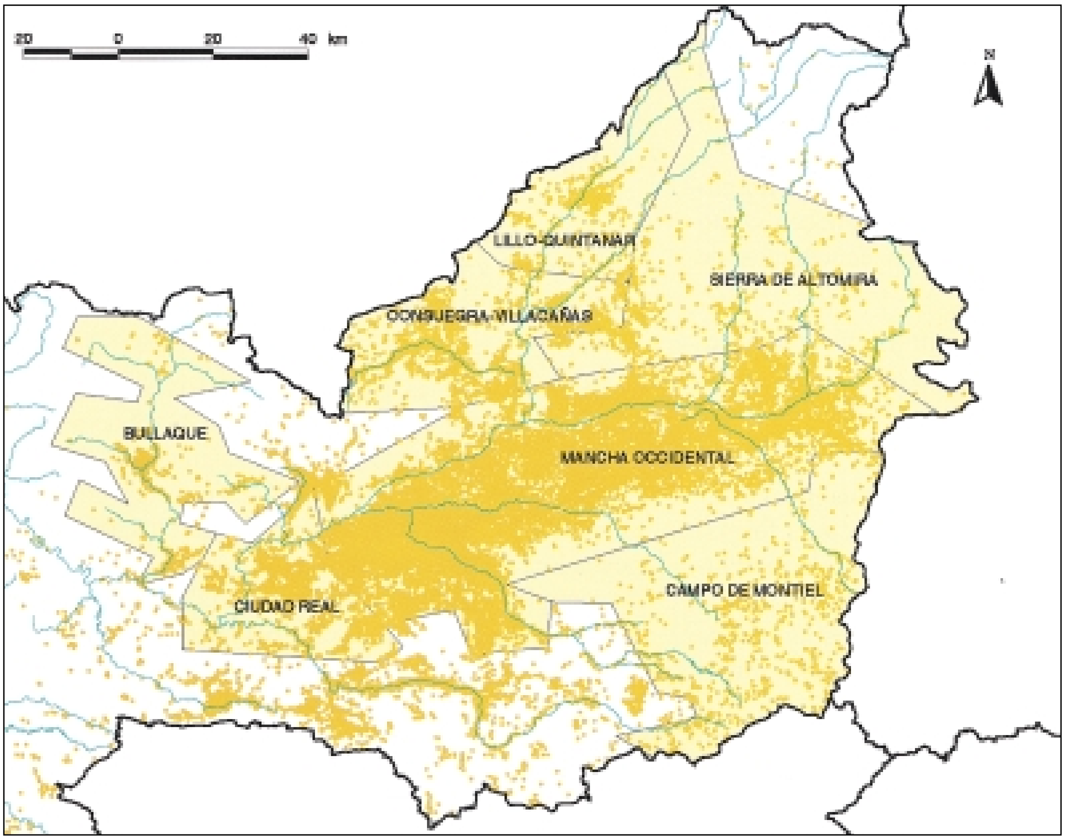


Figure 340. Wells in the high Guadiana basin.

Water Plan	Length (km)	Density (km^2/km)
North I	--	--
North II	178	97
North III	46	124
Douro	258	306
Tagus	444	126
Guadiana I	465	114
Guadiana II	89	79
Guadalquivir	2,751	23
South	72	249
Segura	584	33
Júcar	130	330
Ebro	115	744
Total (intercommunity basins)	**5,132**	**90**

Table 102. Supply conduit network in intercommunity basins.

ulation of over 20,000, the average length of low-level water distribution networks was 1.52 km per 1,000 inhabitants. According to the population strata analysed, the ratio ranged from 0.79 and 1.59 km per 1,000 inhabitants (the second figure corresponds to towns with a population of over 100,000).

However, it is relevant to point out that in the above cases, only the networks managed by supply entities are included. There are also networks which are directly managed by local councils, residential estates and other agents. According to some specialists, the service will only be adequately rendered if the length of the distribution networks reaches a ratio of 2 km. per 1,000 inhabitants, especially in large urban conurbations with second-home areas.

Considering the surveyed population as a whole, the most used material in distribution networks is cast iron (47.9% of the total length), followed by fibre cement (37.6%) and concrete (4.5%). Other materials, such as PVC, are also used. Considering the population strata, in metropolitan areas most of the pipes are made of cast iron (71% of the total length), whereas in towns with a population ranging between 50,000 and 100,000, fibre cement pipes prevailed (70% of the total length).

In order to maintain adequate service levels, reducing both breakage and losses, it is generally accepted by supplying entities that the level of losses should be close to 10-15%, (excluding other non-registered uses for water, such as treatment consumption, watering streets and municipal green areas, as well as other public uses), and the maximum number of breakages should be 0.4 km per km of network. This requires the conduits being 25 years old at most, which implies huge sustainable investments both to replace and to maintain networks. The actual level of losses on the networks usually ranges between 10% (excellent condition and conservation) and 50% (very poor condition and conservation).

As an example of this situation, it is relevant to mention the actions carried out by the Greater Bilbao Consortium, which decided, as a result of the latest drought, to review about 1,000 km of conduits, and detected 1,278 leakage points, resulting in the loss of 210 l/s. After they were repaired, it was possible to save 5% of the total consumption.

3.10.1.2.5. Irrigation conduits

The conduits for transporting and distributing water for traditional irrigation and public uses, given the scale of the flow required, are usually made up of open channels, which are either uncovered or have superficial coatings to improve their transportation capacity and their impermeability.

New irrigation techniques, which imply lower water consumption, are replacing these open conduits with closed, pressurised conduits, usually pipes made of different materials and with different registered pressures.

Distribution networks, which make it possible to carry the water into each plot of land, are usually ramified and telescopic, and their section decreases as they flow downstream. In public-initiative irrigated land, the largest conduits, usually with a capacity of over 250 l/s, were built by the old Public Works Ministry, whereas low-capacity conduits were built by the old IRYDA, within the framework of the programmes known as Coordinated Plans.

The main transport channels are generally exploited by Hydrographic Confederations, whereas Irrigators' Associations exploit distribution networks. Both the contribution to the cost of the works and operating, conservation and maintenance costs are included, in accordance with the water legislation, in the yearly irrigation rates which must be paid by users.

The inadequate system for collecting this rates, together with a poor budgetary availability, result in the progressive deterioration of these infrastructures. It would be convenient to correct such deterioration by means of special rehabilitation programmes, so that the infrastructures may be exploited with maximum efficiency.

Only in intercommunity basins, and according to the Basic Documentation from Water Plans (MOPU-DGOH, 1990), the length of the irrigation conduits currently exploited is estimated at about 10,000 km, with the distribution indicated in table 103.

Water Plan	Length (km)	Density (km^2/km)
North I	115	153
North II	--	--
North III	--	--
Douro	1,598	49
Tagus	478	117
Guadiana I	3,389	16
Guadiana II	--	--
Guadalquivir	1,294	49
South	111	162
Segura	506	38
Júcar	394	109
Ebro	1,717	50
Total (intercommunity basins)	**9,602**	**48**

Table 103. Irrigation network conduits in intercommunity basins.

Figure 341 shows the layout of the main irrigation and supply conduits, as well as the location of the official monitoring points on the channel and conduit network

3.10.1.2.6. Drainage canals and surface drainage networks

Through drainage canal networks, it is possible to collect the unused irrigation water and transport them to other downstream points where it will be used. They are usually made up of uncovered trapezoid ditches, which form a ramified network with an increasing section which flows into the area's streams.

These networks are extremely important, given that, by draining the terrain, they prevent it from being flooded and, therefore, from becoming saline. Their construction, exploitation and maintenance are governed by the same criteria and conditions as distribution networks, even if they have to be cleaned more frequently because of the proliferation of reeds and bulrushes.

3.10.1.2.7. Service road network

In irrigated areas which were transformed by public initiative, service roads have been constructed, which run parallel to and near the main irrigation conduits and opening

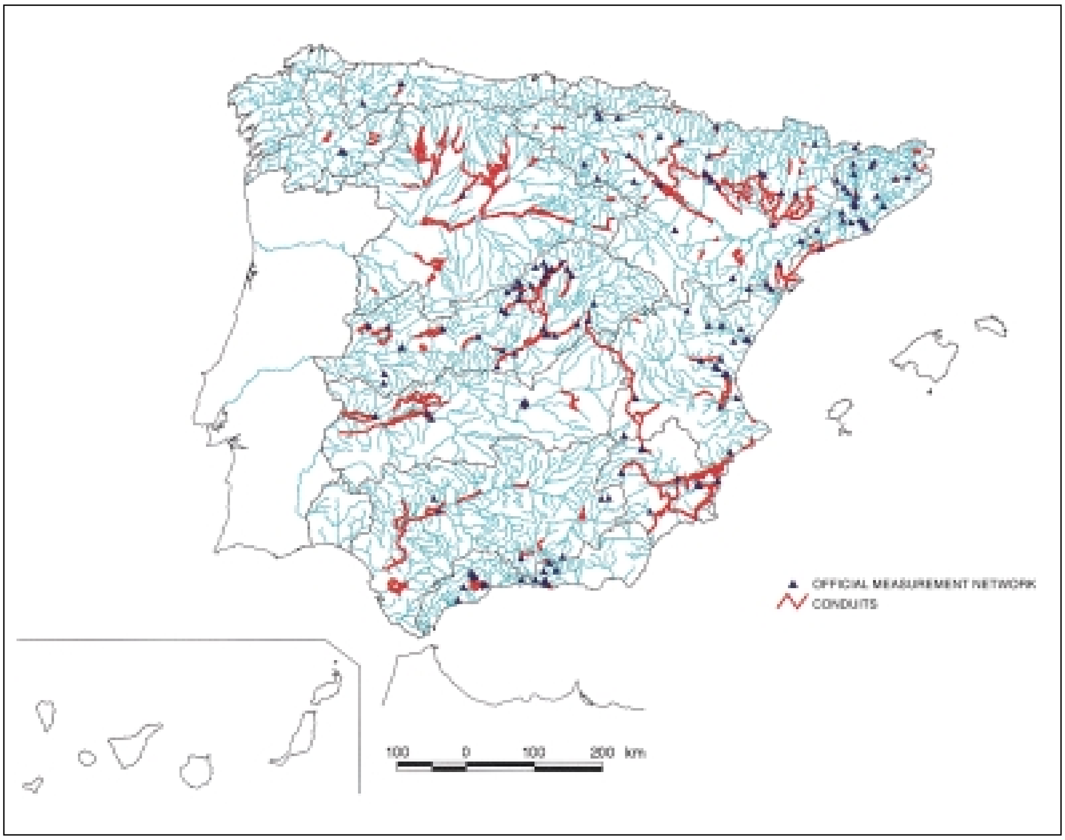


Figure 341. Map of the main supply and irrigation conduits, and official monitoring points.

drainage points. They facilitate the construction and exploitation of the irrigation structure and the access to the different estates. They are generally made of weak road surfacing (macadam or ballast), with practically horizontal, longitudinal profiles and, even if their traffic is slow and light, they are easily deteriorated. This network is currently more than 10,000 km long.

Some of them, such as accesses to towns or cities, are considered as local-interest roads, and are therefore excluded from being rated and their management is transferred to other Bodies which do not belong to the water administration.

3.10.1.2.8. Facilities for treating drinking water

Municipalities are responsible for the construction, exploitation and conservation of these drinking water treatment infrastructures, either independently or grouped in associations, and their management is often allocated to privately-owned companies, as indicated above, or is carried out by government bodies.

There is a large number of infrastructures of this type in Spain. The treatment line generally used includes coagulation-flocculation, sedimentation, sand-based filtration and chlorine-based disinfection processes. However, some plants for treating potable water use additional, more complete treatment processes, such as ozonisation (about 10% of the total number), and filtration through granular active coal (GAC), which aim to eliminate organic compounds dissolved and to improve the organoleptic properties of water.

The new EU Directive on the quality of water for human consumption might result, in certain cases, in the adoption of modifications in the existing treatment plants, especially to adapt them to the maximum limits regarding the by-products generated by the disinfection process (trihalomethanes).

3.10.1.2.9. Facilities for treating waste water

Municipalities are also responsible for these infrastructures. At present, the number of facilities is insufficient to cater for the needs of the entire population, but the National Wastewater Collection and Treatment Plan, which is currently being implemented, as described in previous chapters, sets out the deadlines for its implementation in the entire territory of Spain, by means of coordinated actions carried out by central, autonomic and local administrations.

It can be observed that a relatively important number of plants for purifying waste water, built in the 70s, have failed through lack of technical and financial means to face their management, especially in small municipalities.

The current situation is clearly different, because, even if there are still facilities whose operation is not optimal and whose output is lower than expected, the management of treatment systems has improved, on the one hand, thanks to the increased cooperation of municipal services and companies and, on the other, through the creation of supra-municipal Management Entities and the collection of the decontamination tax in several Autonomic Communities.

The treatments which are most frequently applied are secondary (biological) treatments, in accordance with the guidelines set forth by the Directive of 91/271. The most advanced treatments are applied in urban conurbations affecting sensitive areas as defined under said Directive.

3.10.1.2.10. Facilities for reusing waste water

There are about 125 operational plants for reusing purified waste water, but only 30% of them has some kind of tertiary treatment. About 50% of the total volume reused in Spain comes from the 10 main facilities (Valencia-Pinedo I, Majorca, Valencia-Quart Benager, Murcia, Almeria, Benidorm, Jerez de la Frontera, Cartagena, Elche and South of Grande Canarie), but only three of them apply a regeneration treatment. This fact hinders the optimal use of this resource.

3.10.1.2.11. Desalination facilities

There are more than 300 desalination facilities in Spain, whose size varies considerably. About 16% of them are facilities for treating seawater, and the rest are for brackish water, with a total capacity of 222 hm^3/year.

Over recent years, desalination facilities using old technologies have been gradually replaced with more modern and efficient infrastructures. It can therefore be said that, in broad terms, these facilities are fully operational.

Only Las Palmas I (20,000 m^3/day) and Las Palmas II (18,000 m^3/day) continue to use their original facilities, even if they are not fully operational. Works for replacing the facilities of Las Palmas I are currently being executed.

At first, these desalination facilities were located in Ceuta and Melilla only, but the recent droughts have extended their scope of exploitation to the Mediterranean coast.

3.10.1.2.12. Hydroelectric infrastructures

Spain, with about 17,000 MW of power capacity, is one of the leading countries in the word in terms of hydroelectric facilities. Only big countries such as the USA, Canada or Russia, or countries with major water resources and considerably mountainous, such as Sweden and Norway, have a larger number of hydroelectric infrastructures than Spain.

There is an extensive variety of power plants, both in terms of power generated and of dam height, storage capacity, etc.

There are currently twenty-two plants, with a power of over 200 MW generating about 8,637 MW, i.e., 52% of the power capacity. Another fifteen facilities have an power capacity ranging between 100 and 200 MW, and account for 12% of the total power. Each of the remaining plants, which complete the current aggregate number of 1,300 plants, individually generate less than 100 MW.

Most of the power capacity of recent years is generated by pure and mixed pumping facilities. To be more precise, 4,300 out of the 6,200 hydroelectric MW capacity since 1969 are generated by pumping facilities. The power generated by these hydroelectric plants currently amounts to 4,900 MW, 2,400 of which come from pure pumping facilities, that is, plants whose upper reservoir does not receive a significant amount of cumulative flow.

As regards the distribution of the power capacity per catchment basin, there are considerable differences, as shown by figures 342 and 343 (Source: MOPU 1990). The Bay of Biscay has 376 hydroelectric power plants generating 3,960 MW, and the Ebro basin has 297 plants generating 3,610 MW, whereas the Guadiana basin has only 12 plants generating 211 MW and the Segura basin has 35 hydroelectric power plants generating 75 MW.

The historical evolution observed in the different basins before they reached their current number of facilities is shown by figure 344.

In terms of regulation, the distribution of the hydroelectric power capacity per type of plant is shown in table 104 (UNESA data).

These infrastructures, which are all governed by the regime established by the Reservoir Withdrawal Commission if they use facilities built for different purposes, are only operational if they fulfil other needs which are given higher priority. Consequently, some regulating dams have an equalising reservoir downstream, which provides the necessary modulation to combine the supply of priority uses with the production of hydroelectric power.

They pay the production tax when relevant and, if they derive profit from the regulation, the corresponding regulation tax.

3.10.1.2.13. Navigation and transport facilities

Since time immemorial, river navigation has been considered as a major source of wealth for the riverside cities which could profit from it. There are numerous examples of initiatives undertaken to favour this use, especially from the 16th century onwards, and particularly during the Illustrated Reformism regime, obsessed by communications, and therefore by navigable channels (see, for instance, López Gómez, 1998; or the outstanding Pérez de Oliva's Reasoning, 1524).

However, and with a few relevant exceptions, these initiatives did not materialise into practical projects, and river navigation and transport failed to reach the important development it had in other countries, such as France or England.

The old timber transport activities which were carried out in some Spanish rivers, such as the Segre, the Sorbe, upper Segura or the Tagus, or the transport of coal on barges, disappeared a long time ago. A description of the different navigation projects implemented in the Tagus, and of how river navigation was conceived in the early 20th century, may be found in Lorenzo Pardo (1920).

Navigation by canal has not been successful in Spain either. Some canals which had navigation as one of their main pur-

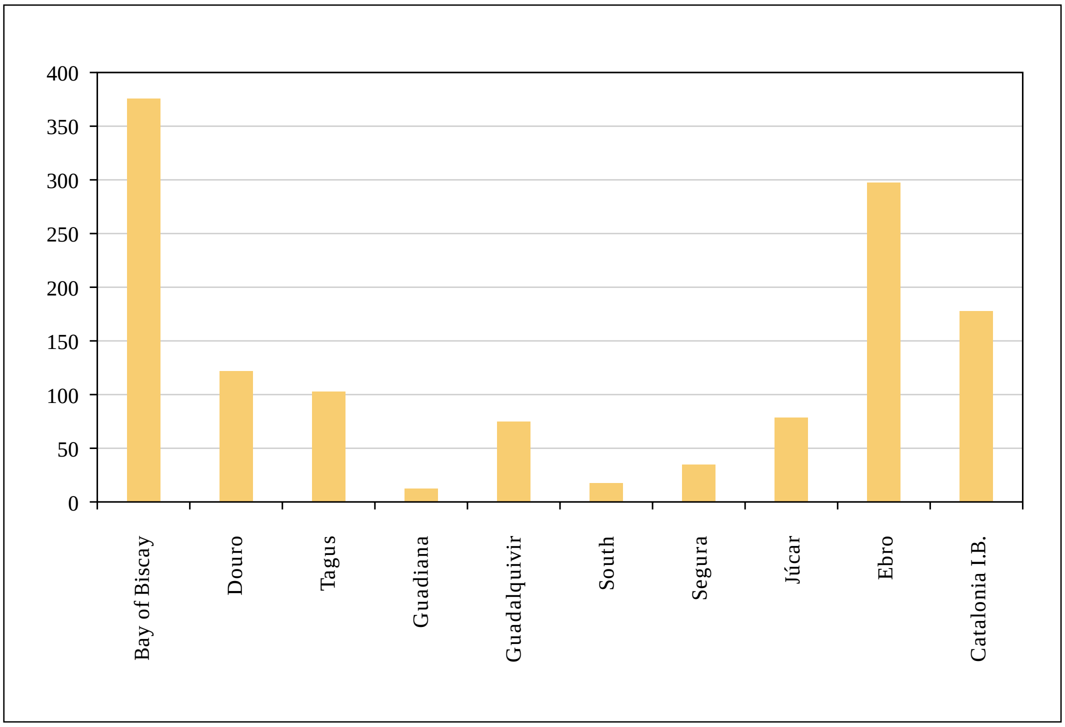


Figure 342. Number of hydroelectric plants in different basins.

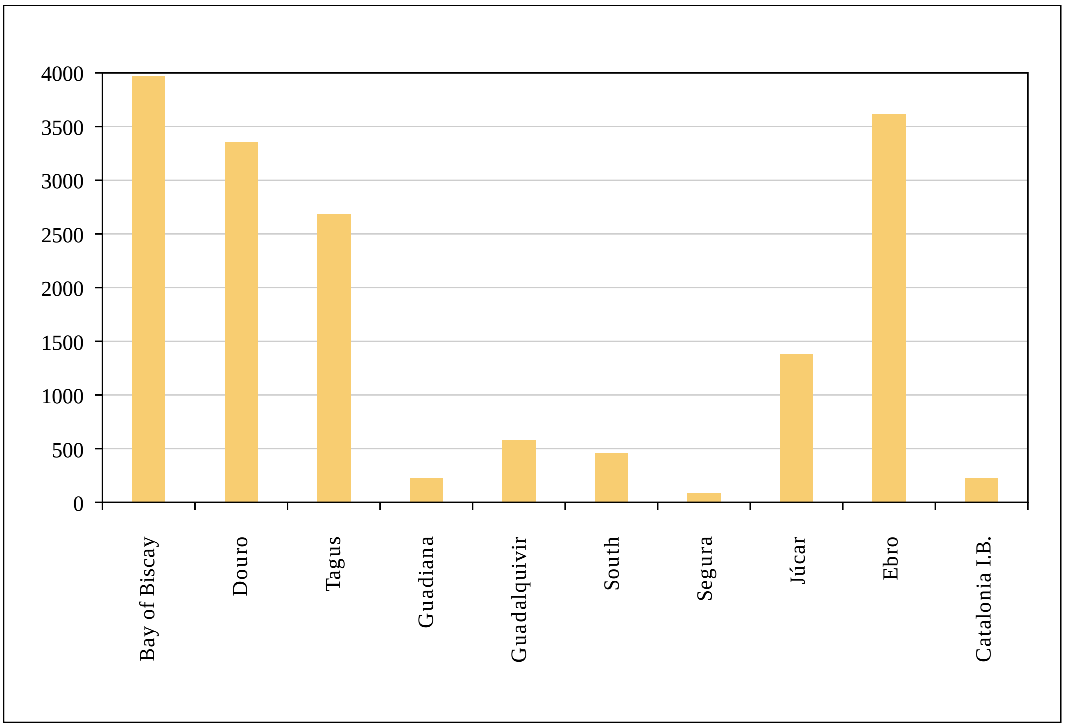


Figure 343. Power generated in the different basins (Mw).

poses, such as the Imperial Canal of Castile, which was used for transporting cereals on barges pulled by horses, are currently only used for irrigation purposes and to supply populations.

Today, commercial navigation is practically limited to the low section of the Guadalquivir, where low and medium-tonnage boats can navigate, by using the locks located near Seville harbour's dock.

Conversely, in recent decades, sports sailing, both in reservoirs and in specially-prepared reaches of some rivers, has considerably increased, but obviously with characteristics which are totally different from its original ones. The examples in the Guadiana and the low Ebro clearly illustrate this point.

3.10.1.2.14. Systems for hydrological-forestry correction

The DGOHCA and the Hydrographic Confederations have traditionally included a department for Forestry Application Services, whose main activities are the correction of torrents and reforestation, acting in coordination with other State or Autonomous Communities' bodies to reduce erosion and prevent rivers from carrying down solids, which lead to silting up and to reservoirs losing their capacity.

The actions carried out have been enormously varied, and their results may be generally described as excellent.

However, in recent years this important Service has suffered a slow abandonment process, and has even disappeared in some Confederations. The recent unification, within the Environment Ministry, of the services offered by ICONA, currently the Directorate General for the Conservation of Nature, and of the Directorate General for Hydraulic Works and Water Quality, to which the Confederations are attached, might result in an organisational restructuring and in giving a new boost to this important issue.

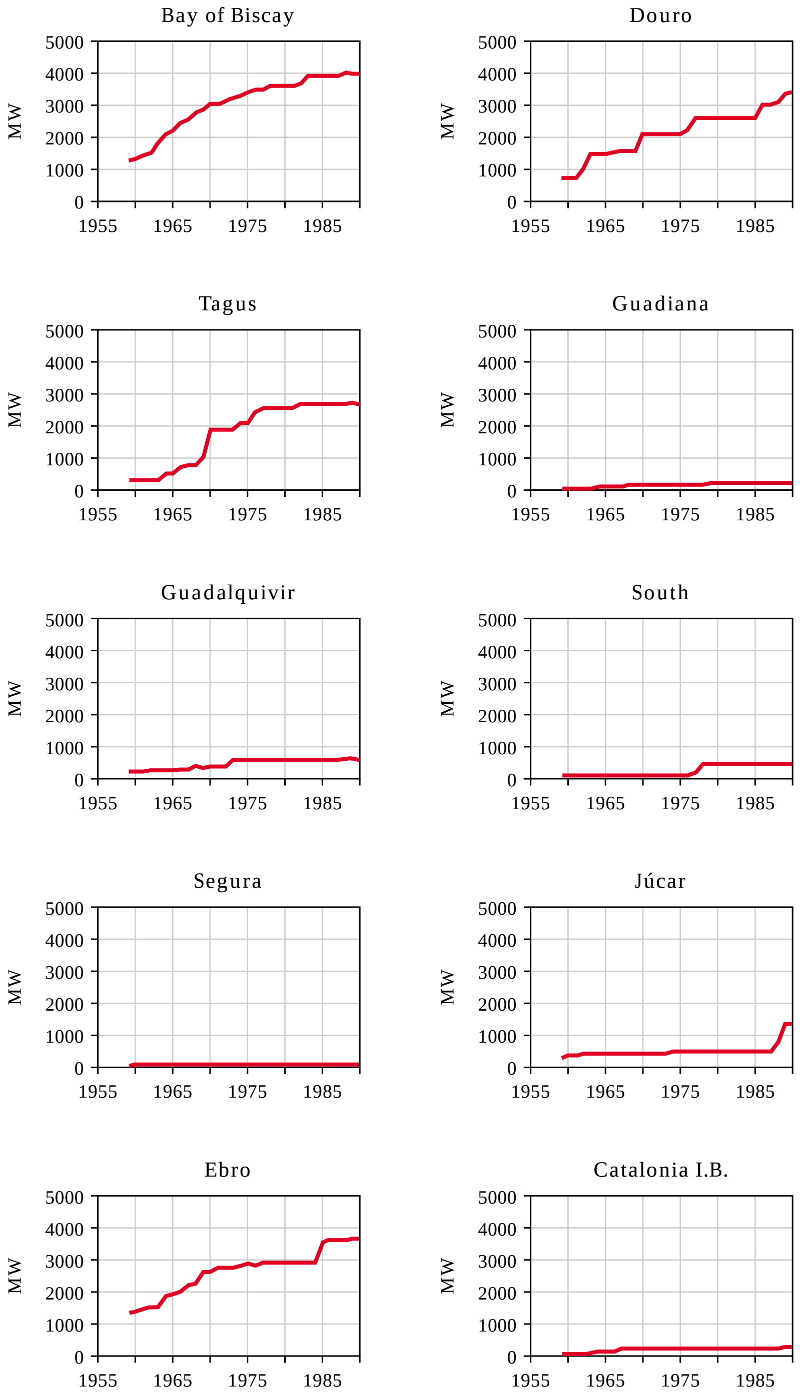
3.10.1.2.15. Fish ladders

According to an inventory prepared in 1995 (Elvira et al., 1995), 108 fish ladders have been classified, 30% of which have been constructed recently (after 1990). Most of them are located in salmon rivers, and only a few facilitate the passage of other migratory fish.

The most common type of construction is based on successive pools, whose use is recommended only if the obstacle is less than 10 meters high, even if sometimes higher obstacles have been installed. Little more than half of the fish ladders studied are deemed useful, i.e., they can be sur-

Table 104. Distribution of the hydroelectric power installed in accordance with the type of plants.

Supply	18
Supply and irrigation	67
Irrigation	15



Source: Statistics on reservoirs and hydroelectric power generation. DGHO, several years.

Figure 344. Evolution of the hydroelectric power installed in the different basins.

mounted and are kept in good condition, whereas the remaining ones need some kind of improvement. The North and Ebro basins deserve to be highlighted, given the level of conservation of their ladders.

In addition to scales, there are other systems for surmounting obstacles, such as artificial rivers, locks or elevators for fish. Physical and behaviour barriers, as well as and diversion services, are used to facilitate downstream migration. Even if it is compulsory to install grids in the outlets and in derivation channels to prevent fish from passing through, in many cases no grid has been placed. A recent monographic study on these systems has been made by Elvira et al. (1998).

Figure 345 shows the fish ladders identified in 1995, indicating their level of difficulty. Subsequently, other actions have been carried out in other areas, such as Asturias. An existing problem is the funding of the scales or ladders which are considered relevant, and which affect exploitation units with old concessions, without any applicable regulating clauses. If it

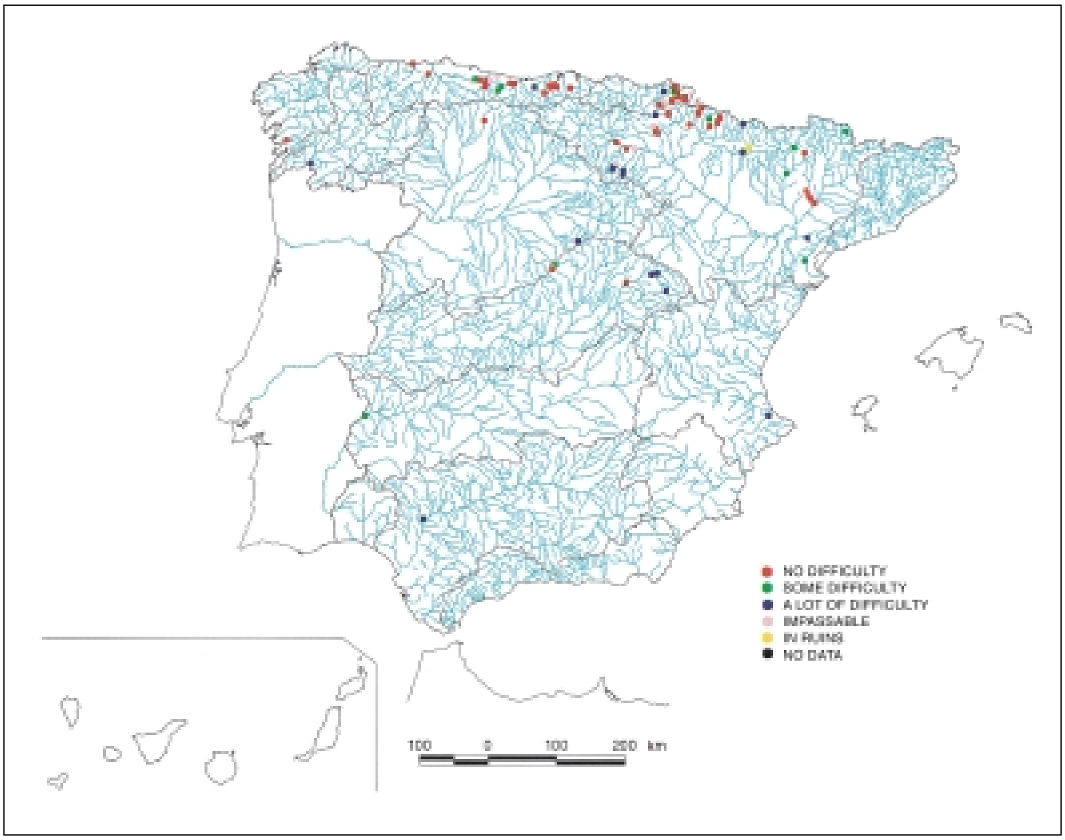


Figure 345. Map of identified fish ladders and level of difficulty

may not be passed on to the concessionaire, the incorporation of this cost into actions related to environmental protection, decontamination and treatment or improvement of riversides may be the best way to solve the problem.

3.10.1.2.16. River channelling and river bank protection

Channelling constructions are designed to provide rivers with a better transportation capacity, which is achieved by increasing their section and reducing their roughness through channel and surface cleanings, or by increasing their incline by shortening and rectifying their layout.

Some examples of this kind of actions are the shortening and channelling works carried out on the river Guadalquivir as it runs through Cordoba and Seville, on the rivers Rubí and Besós in Catalonia, on the river Segura, from Contraparada up to its mouth, or the solution applied south of Valencia, based on diverting the river Turia's water out of the city through a new, 12-km long channel.

It is estimated that the length of the reaches of rivers where these actions have been carried out reaches about 2,500 km, and the resulting problems have been dealt with in previous chapters.

3.10.2. Appraisal of Spain's water assets

The extensive variety of infrastructures, which has been commented above, represents a historical and valid heritage of great importance, in terms of public utility and economy. If we apply the concept of water assets to all the water infrastructures which are owned by the State, according to a recent estimation (MOPT, 1993b) of their economic replacement value, they amount to 2 trillion pesetas as regards reservoir dams, another two trillion as regards supply and irrigation conduits, and 0,7 trillion as regards infrastructures offering protection against floods.

Consequently, the total replacement cost of Spain's water assets may be estimated at almost 5 trillion pesetas.

If these estimations are compared with the figures resulting from the application of the economic and financial regime, as presented in previous chapters, it may be established that the yearly collection by the Water Administration of the fees and taxes related to fluvial regulation does not even reach 0.2% of the regulated public infrastructures' replacement cost, whereas the yearly collection of the water consumption tax accounts for 0.5% the conduits' replacement cost, a percentage which must be reduced by half if the Tagus-Segura transfer is excluded.

In addition, an important number of water assets held by concessionaires was estimated, for companies which joined UNESA, at 2.4 trillion pesetas in 1997, in terms of replacement cost.

3.10.3. Conservation, maintenance, replacement and modernisation of infrastructures

Hydrographic Confederations, in the exercise of the functions allocated to them under the Water Act (section 21), exploit such water infrastructures as have been executed with their own funds

or as have been assigned to them by the State. In performing such functions, they are responsible for maintaining said infrastructures in operation, which implies their conservation and maintenance during their useful life, as well as their replacement after this period.

The considerable magnitude of the assets related to hydraulic infrastructures implies very costly conservation works. In the event of regulation infrastructures, it is estimated that the yearly cost of these works could represent about 0.5% of the value of the investment. For other types of infrastructure, this value can range between 1 and 2% of the investment.

If these percentages are compared with the appraisal of the assets referred to above, and with figures concerning the collection by the water administration of the relevant fees and taxes, it would be necessary, in large numbers, to multiply the collection of the regulation tax by three, and the collection of the water use fee by four (excluding the Tagus-Segura transfer), even if this only covered the annual conservation cost of the constructions.

Part of the conservation and maintenance activities may be carried out with the equipment used to exploit the infrastructures themselves. However, in other cases it is necessary to resort to external services.

The experience shows that, in general, the actual useful life of hydraulic infrastructures is longer than the useful life established by the applicable regulations for depreciation purposes (fifty years for regulation infrastructures and twenty-five for all the others). In other words, once the period fixed for the depreciation of infrastructures has elapsed, they can still be operational. This is why the depreciation rates do not take their replacement into account. However, in some special cases (electromechanical elements, treatment plants, desalination plants, etc.), their useful life is conditioned by the appearance of new technologies which are more complex and costly, which results in additional difficulties with regard to their replacement. Under these conditions, it could be convenient to state that the depreciation fixed by law for these infrastructures should include their replacement cost, in accordance with the relevant technological improvements.

The modernisation of hydraulic infrastructures is a basic means of reaching the essential goal of managing water resources rationally and efficiently.

One major problem resulting from the modernisation of infrastructures is its economic effects on the different agents involved. It is obvious that the advantages of such modernisation should exceed its drawbacks. The high investment required is one major drawback. The water legislation, with the exception of the provisions of the Act of 1911, which is only applicable to the improvement of irrigation, pays little attention to the modernisation of infrastructures, and there are therefore very few provisions on its financing.

In the future, the activities aimed to improve and modernise hydraulic infrastructures are likely to increase, especially in the sector of irrigation. This will require filling the legal loophole which seems to exist in this specific area.

3.10.4. Safety of the infrastructures. Technical regulations

Hydraulic infrastructures, especially reservoir dams, may considerably reduce the damage occurred in areas located downstream from such infrastructures. In the opposite direction, in the event that the infrastructures suffer any structural failure, which is unlikely but not impossible, the same areas could suffer severe damage, which in some cases could even have catastrophic effects.

Several rules have been approved to minimise the risk that dams fail. The instructions concerning the project, construction and exploitation of large dams aim, in their different reaches, to make these infrastructures as safe as possible. In addition, the recent technical regulations on safety of dams and reservoirs, which was approved by the Ministerial Order of the 12th of March, 1996, incorporate new criteria and restrictions, in accordance with the current level of technology.

3.10.4.1. Background

Shortly after the Ministerial Order of the 31st of March, 1967, on *Instructions for the Project, Construction and Exploitation of Large Dams,* was approved, the need to update it arose. For such purpose, from 1979 onwards, the *Permanent Commission for Rules on Large Dams,* created by the Ministerial Order of the 15th of January, 1959, held different symposiums attended by specialists in dams. The bursting of the Tous dam intensified this need for updating said Instructions. However, these technical symposiums highlighted that, given the time elapsed since the approval of the Instructions, the changes required to update them were so substantial, in accordance with the evolution of the safety of dams throughout the world, that it was preferable to draft new Regulations.

This task was assigned to the Permanent Commission for Regulations, which drafted a document which, with the modifications made by the General Directorate for Hydraulic Works, resulted in the current Technical Regulations, which, as indicated above, was finally approved in 1996.

3.10.4.2. Basic concepts

These Regulations conceptually differ from the Instructions in that the current Regulations constitute an open rule, as required by the international trend on this issue. That is, whereas the Instructions contained a series of specific technical solutions which could be applied to each stage of the life of a dam, the Regulations contain general safety criteria which must be taken into account to prevent and reduce the social and environmental risks presented by dams.

When the Regulations were approved, it was considered advisable, given their complexity and their implications, to apply them progressively. In this sense, their application was limited, at an early stage, to dams and reservoirs owned by the Environment Ministry, and to those which, regardless of their ownership, were held under an administrative concession regime granted by said Ministerial Department or by its Autonomous Organs after the date of effectiveness of such Order. As far as the remaining dams and reservoirs are concerned, the Instructions are still applicable.

The essential criterion contained in the Technical Regulations is the classification of dams into three categories, A, B or C, depending on the potential risk which may arise from their potential bursting or from the dams operating incorrectly. Accordingly, different safety requirements are applied to each dam, according to its classification. In addition, the Regulations incorporate other new aspects, such as the special attention paid to safety and to the exploitation of dams. They also impose periodic preventive overhauls on the dams, as well as Emergency Plans for dams in the category A or B (the most hazardous), and they demand a Planning schedule for filling the dams, so that, in connection with all these requirements, a Technical Record of the dam may be permanently kept and updated.

It must be highlighted that the deadlines for complying with the new conditions imposed on the dams, such as their classification according to their potential risks, the updating of the Technical Records, the Emergency Plans and the periodic overhauls, have been fixed in a rather strict way.

3.10.4.3. Current situation

In the light of these factors, the current situation concerning the safety of dams presents the following essential characteristics:

- Regulatory heterogeneity. The Instructions and the Regulations are simultaneously applied, which is inconsistent with safety as a global concept.
- Low legal rank of the Regulations. A Ministerial Order is currently insufficient to regulate such an important issue.
- Insufficient funding to comply with the requirements imposed by the Regulations within the scheduled periods. Consequently, the Regulations are currently far from being fully complied with.
- Insufficient allocation of means to monitor the safety of dams in an optimal way.

The following measures, among others, could be implemented to improve safety conditions:

1. Drafting of a new Act on Safety of Dams. Even if this measure is not absolutely necessary, it would offer several important advantages, since it would avoid the current jurisdictional loophole, its coercive capacity would be stronger than that of the Regulations, and it would eliminate the current regulatory heterogeneity. During the period of time which would elapse until the approval of the Act, it would be convenient to extend the scope of the Regulations to all the dams.
2. Creation of a special organisation which would manage the safety of dams, with sufficient resources and personnel to carry out its tasks.
3. Financial availability, so that the safety requirements imposed by the rules in force may be complied with within a reasonable period of time.

3.10.5. Legal regime of hydraulic infrastructures

After examining the technological aspects of hydraulic infrastructures, it is convenient to analyse their current legal regime in depth. This is a matter of great importance, given that, as we shall indicate below, it has direct effects on decision-making processes, planning and financing processes related to these constructions, and it presents certain complexities and deficiencies which will have to be solved in the short term. A study on the current situation may be found in Embid Irujo (1995).

3.10.5.1. Historical background

The historical legal background of hydraulic infrastructures in their condition as public works may be divided into two main stages or phases. The first one is related to the Ancient Regime (basically when water, reserved by the kings as a royal prerogative, was declared as a public asset), and the second one starts with the approval of the Constitution of 1812, the year in which, as mentioned in other chapters, the basic concepts of the Spanish legal regime on water were established.

During this second stage, which began in 1812 and finally consolidated in 1836, the new principles of the State were formulated, which resulted in the birth of a special public and administrative law, organised under the legislation issued by town councils; in the creation of a jurisdiction for administrative litigation within the administration of justice, but different from the ordinary jurisdiction; in the construction of public infrastructures, regulating navigation and irrigation channels, local roads, railways, mines, etc.

Among the different regulations which were in force before the current Public Works Act, it would be relevant to highlight the Instructions for promoting and executing Public Works, approved by the Royal Decree of the 10th of October, 1845, which for the first time includes within the concept of public works “navigation, irrigation and overflow channels, ... the drainage of ponds and marshy areas ... and any other construction which is executed to satisfy objects of general interest or convenience”, which would entitle the State to assert its jurisdiction over individuals. For the first time, public works were classified into three categories (state, provincial and municipal), and they could be executed through a contract or under administration, although contracts prevailed whenever there were budget items available.

The State issued different acts governing the relation between the regulation of the public works and the way they were executed through mandatory purchases of land. In this framework, under the Mandatory Purchase Act of 1836, all public works declared by the State were considered as public utility works, for the purposes of the relevant mandatory purchases of land. Under the Act of the 2nd of April, 1845, Provincial Councils, as special administrative courts, and the Royal Council, by virtue of the Act of the 6th of July of the same year, were granted jurisdiction over all matters related to the use and distribution of provincial and municipal assets and exploitation units, and over the flow, navigation and buoyancy of rivers and channels, and the works executed on the streams' banks and channels. The Instructions to Governors, approved by the Royal Decree of the 28th of December, 1849, which was divided into three sections, deal in its third one with roads, channels, harbours and other public works, granting full powers to these authorities for the management of these issues. The Royal Order of the 12th of June, 1859 creates a new Development Section, in charge of managing public works, and its Explanatory Memorandum expressly mentions the preparation of the Water Act of the 3rd of August, 1866.

The first draft of the Civil Code of 1851, which would become Spain's first system of legal rules, contained three different concepts consolidated into one single section, 33, in which the subsequent Water Act of 1866, the Mortgage Act of 1864, the Mining Act of 1968 and the Public Works Act of 1877 were reflected. All assets allocated to public use, such as roads, channels, paths, torrents, riverbanks and those allocated to any public service or to the development of national wealth, such as ramparts and other constructions for defending territories, were deemed to be in the public domain. Section 384 established the difference between public domain and private assets. According to section 385, public domain assets were those belonging to the State or the Royal Heritage, or which were allocated to the provinces or municipalities.

Two characteristics therefore define public domain assets: a public use or service, and the fact that they are governed by a series of rules –varied and relatively independent– which failed to define hydraulic constructions beyond their identification as instruments for satisfying general needs or interests.

3.10.5.2. Legislation on public works. Planning background and current situation. Simultaneous acts

On the basis of the historical background referred to above, it may be established that the concept of public works is applicable to the concept of public domain and of public service and use, including the works, supplies, the services and all administrative actions related with public development and utility. Section 1 of the Public Works Act of 1877 sets out that public works are works having a general use and utility, and such constructions as are allocated to services for which the State, a Province or a Municipality are responsible. Accordingly, the State, the Province or the City Council, within the scope or their respective powers, are responsible for preparing the projects and executing such public works, as well as for exploiting and conserving them. The State is responsible for the works included in the General Plans which must be financed with budgetary funds approved by the relevant Act, as well as for works related to channelling, draining reservoirs, lagoons and pools owned by the State, for irrigation channels and for such works as are related to the use and control of water, to the channelling of rivers, drainage of lagoons and plots of land. Individuals and companies may carry out works –with the restrictions set out in the relevant Regulations– assigned to general use or for draining lagoons and reservoirs through an administrative concession.

The economic management of the State's public works will be carried out with funds from the Budgets, which must be approved by the Budget Act or by a special act. The execution of public works implies issuing a public utility declaration. The Royal Decree of the 13th of March, 1903 contains the legislation on contracts for public works, and establishes three procedures (competitive bidding, invitation to tender and piecework) to execute them.

As it can be observed, there is a close relation between public works, public interest and General Plan financed out of budgetary funds approved by the relevant act.

Public Works Plans were first imposed by the Public Works Act as a result of a new, renovating water policy which was fostered by the regenerative trend of 1898, represented by Macías Picavea and Joaquín Costa. Once the Public Works Act was passed, it was decided that the planning of such works had to be included in the Act, and that they would only be executed if the relevant budgetary items had been approved by a different act, the National Budget Act. Therefore, two different acts had to coexist: the act declaring the plans or actions based on the general interest, and the National Budget Act, which had to establish how these works would be financed. The problem was that this coexistence was rarely harmonious, and sometimes the execution of hydraulic works declared by one act had to wait for years or decades –some of them are still waiting today– for the relevant budgetary funding. When the budget act finally allocated funds to these works –when they did at all– the context was usually totally different from the original circumstances which gave rise to the conception and proposal of the project.

In line with this idea, the legislation on Public Works would be responsible for determining the planning concept, by establishing that Public Works and their relevant Plan are linked elements which are part of a whole. In this sense, section 20 of the Public Works Act sets out the

Development Ministry will be responsible for preparing the Public Works General Plans, which will establish the classification thereof by order of priority. This section is the clearest legal antecedent of what had to be known as "planning" (study on options and priorities) and, within this concept, of water planning, since it regulates the reference terms considered when executing the works, such as their geographic location, technical aspects, classification of the works and their uses, preferences and the essential elements for their execution. In reality, such planning and prioritisation was never carried out, and was replaced with a series of acts and decrees, often disconnected, which reflected the different circumstances and problems the county was going through at the time. They often resulted from personal biases and pressures and short-range political interests, and therefore lacked any true coordinating and rationalising elements.

The only positive comment which may be made about the Public Works Act is that the legal technique has not changed considerable since the date on which it was approved in 1877, and that the act was favourably accepted by the doctrine, according to whom the necessary coexistence of the two acts was also established in several European and American countries. The lawfulness of public works was therefore acknowledged on the basis of their execution in accordance with the procedure established in their own regulating rules, and was also deducted from the economic effect related to their approval in the relevant Budget Act. This system has therefore been used as an example inspiring new planning regimes approved after the Constitution was adopted, such as Regional Planning and other types of financial planning, based on the principles of the Public Works Act, which differentiate the works to be executed from the periods established for their completion and from their classification, as a result of the new State's organisation, which distributes the powers between the State and the Autonomous Communities. The relevance of these ideas for the issue of water planning is therefore obvious.

After establishing the concept of public works as regulated in section 149 of the Constitution and, specifically for hydraulic works, in section 44 of the Water Act, which, in a brief, non-systematic way defines them as general interest works or works whose execution affects more than one Autonomous Community, and considering the definition set out by the Public Works Act, which applies this concept to general use works and to the constructions which will be allocated to services for which the State, the Province or the Municipality are responsible, it is relevant to conclude that this issue should be urgently reconsidered and reviewed.

It must be pointed out that such review has already been carried out to a certain extent, given that the Public Works Act is currently not being applied in full as a result of the approval of new acts, such as the Basis Act and the sections of the Local Regime legislation, as well as other acts regulating public domain, such as roads, mines, railways, etc. It can therefore be said that a major part of the sections of the Public Works Acts and Regulations are currently not applicable (for instance, the classification of works as municipal or provincial, the making of Draft bills as an administrative task, the execution of certain works and the regulation of several chapters of the Act, etc.).

Given the circumstances referred to above, it is evident that the provisions on public works have to be reviewed, so that they clarify the concepts and they regulate the issues mentioned in an integrated way, setting out the method and procedures for executing, modifying and completing them, on the basis of specific regulations, such as those on roads, harbours, water, mines, and so that they generally regulate the State's Public Works, as defined in the Constitution and in Autonomous Communities' Organic Statutes.

3.10.5.3. Water legislation

When analysing hydraulic works, we must directly relate them to the part of public domain which is regulated by the Water Act, given that both acts, the Public Works and Water acts, have evolved in a similar way with the approval of their corresponding regulations. They have to be applied simultaneously, and any modification to one of them necessarily leads to a change in the provisions and procedures set out in such act or in both.

A basic difference between the current and the former system lies in the State's organisation, which is completely different from the organisation which applied when the Public Works Act was approved. Now the powers of the State are differentiated from those of Autonomous Communities, and such powers may be exercised by one jurisdiction or the other, whereas in the past all the powers were exercised by one single authority. Accordingly, the new Water Act establishes a new concept of public domain, since its scope covers not only surface water, but also groundwater, it considers the difference between use and resource, and establishes that water planning is a basic element for determining and distributing the uses of water, so that all demands are optimally satisfied and regional and sectoral development may be balanced and harmonised.

As regards such planning, it is necessary to determine if its preparation must be assumed by the State or by the Autonomous Communities, in accordance with the classification included in the Constitution into inter and intra-community streams, regardless of the fact that such planning must be approved by the State. In addition, under the Water Act, with regard to general-interest hydraulic public works, or to those which have to be executed by more than one Autonomous Community, such works have to be approved by an Act and to be incorporated by law into the National Water Plan. This is a basic legal principle which has been adopted by the new acts. Conversely, the former situation, where two acts coexisted (the Public Works and the Water Acts), resulted in the uncoordinated application of both acts. The works were established first pursuant to their own regulations, and then the provisions on water, after the works had been completed, had to approve and authorise the uses and the exploitation of the water in accordance with the its Act, often without having previously fixed the class, amount, quality, flow, uses and region where the new streams were to be exploited.

The actual lack of coordination between the both actions –construction and administration of resources or, in other word, the actions of Hydrological Confederations and those of Water Commissions– resulted, for instance, in the existence of numerous public irrigation systems in connection with which, after the corresponding works were completed by the Confederations and the IRYDA, the proceedings set out in the Act for Agricultural Reform and Development and in the Water Act to regulate the situation of these constructions. Even today, the agricultural structures have not been modified to reflect the existence of these constructions, and no administrative concession has been granted for their exploitation.

According to section 149.24 of the Spanish Constitution, the State is responsible for the above-mentioned works and, on the basis of the concept of public works established in the Public Works Act, the Constitution and other special acts, such as the Water Act, the new concepts and classifications of public works are completely different from those which were assumed in the past. As an example, under the Water Act, the concept of public works is the same as is established by the Constitution, but also includes any other general interest infrastructures owned by the State, regardless of their location and of the inter or intra-community streams. Section 148.10 of the Constitution establishes the events in which Autonomous Communities have jurisdiction with regard to the execution of projects, construction and exploitation of hydraulic infrastructures, channels and irrigation which are considered as being of interest for the relevant Autonomous Community.

The legislation on water has brought further precision as regards planning preparation, thus covering the loopholes which resulted from the Public Works Act on this issue. In this sense, the contents of its Plans, as expressed in section 40 of the Water Act, as well the relevant instructions, technical recommendations, water reserve and terrain, the coordination of the different basin management plans within the National Water Plan, the transfers of resources... amount to an efficient regulation, thanks to which it is possible to justify legally the works which will be incorporated into the Public Works Plan by virtue of an Act.

In short, given the changes in the organisation of Public Administrations resulting from the Constitution, the partial abrogation of the old Public Works Act, and the insufficient provisions on hydraulic works contained in the Water Act, it is advisable to create a specific regulation for this type of public works within the Water Act itself, so that a homogeneous set of rules may be applied, thus avoiding the subsistence legally uncertain areas.

It is also relevant to highlight that the procedure for the General Interest Declaration is frequently used, with little rigour and without applying homogeneous criteria, when the State is assigned the responsibility for assuming the financial cost of works which, under the regulations in force, should be allocated to a local entities, an Autonomous Community or an Irrigators' Association. A legislative clarification on this issue would be convenient.

3.11. THE PROBLEM OF DROUGHTS

3.11.1. Introduction

Even if it is apparently easy to interpret, droughts are a hydrological phenomenon for which the different specialists have not been able to find a general definition. It is usually described in terms of rainfalls or cumulative flow within specific periods of time, or in terms of the water stored in reservoirs, but these definitions are obviously not complete.

In addition, the phenomenon of draught is often mistaken for other concepts with which it is related to a certain extent, such as aridity or shortage of water. If a drought is simply described as a phenomenon leading to shortage of water, one of its most characteristic aspects would be left aside: its abnormality, that is, its nature as an unusual fact. This means, if such shortage of water is considered usual in a specific region, the phenomenon occurring is not a drought but aridity.

Furthermore, it is possible to establish definitions which are not strictly hydrological, such as sociological drought (social perception that there is no water, as broadcast by the media), or economic drought. Even in terms of water availability, there are different interpretations of the concept, which has often resulted in interpretation mistakes concerning historical information.

These terminological difficulties are clearly reflected in the basin management plans themselves, which apply different criteria based on local circumstances which are often disconnected.

According to the Ebro plan, for instance, a dry period starts "when in two consecutive months within the series, the rainfalls registered are lower than 60% of the average rainfalls for such month, and this period ends when the rainfalls registered during a month are equal to or higher than the average of the series used, that is, the period will last until the situation may be considered as normal". According to the Guadiana plan, "a situation of drought will occur when the sum of the rainfalls registered during the twelve preceding months is lower than those registered in 75% of the cases within the period analysed, which must have a series of rainfall data corresponding to at least 30 years, selected among the most recent, and for a group of stations representing the basin which flows into the reservoir or system".

Other Plans, however, establish a relation between supply and demand. For instance, the Guadalquivir plan defines a drought as "a situation in which the resources accumulated are insufficient to satisfy the demand". This is also the case of the North III plan, which, in addition, relates the definition of drought with the period of data considered for planning purposes. Thus, in its action guidelines, it points out that "the works have to be planned in accordance with the demand on the basis of the droughts occurred in the 1941-

43 and 1989-90 periods, without admitting any errors and considering that there are sufficient resources for such purposes within the scope of the plan". This plan also defines "dry year" as the one in which the yearly cumulative flow is half of the average cumulative flow, and "very dry year" as the one in which the cumulative flow amounts to 75% of flow registered in a dry year, that is, slightly more than 35% of the yearly average cumulative flow. As it may be observed, the criteria used in the different basin management plans to define a situation of drought usually fail to take into account any indicators on the condition of groundwater.

This variety of definitions and treatments highlights the conceptual problem existing behind these analyses, which may have been one of the reasons why, unlike floods, droughts have not been studied in the necessary detail and the records of the major droughts occurred in Spain are not sufficiently accurate (Menéndez 1997).

Figures 346, 347 and 348 show some examples of the decrease in rainfalls compared with the average rainfall during the worst three droughts occurred in the 1940/41 to 1995/96 period: the one which took place from October, 1941 to September, 1945; the one which started in October, 1979 and finished in September, 1983; and the drought which took place from October, 1990 to September, 1995.

Table 105 quantifies, per planning areas, the average value of the percentage decrease in rainfalls during the three droughts considered. These three droughts were considerably extensive, and affected most of Spain's territory. They resulted, in basins such as Guadiana, Guadalquivir or South, in about a 30% decrease in rainfalls. If we observe the geographic distribution of these percentages, it is clear that the highest decreases take place in areas which are strongly influenced by humid fronts coming from the Atlantic Ocean, which seems to suggest that the occurrence of an extensive drought might be conditioned by the variability of this type of fronts.

If the analysis is carried out on the basis of two different thresholds, one related to the beginning of the draft based on the decrease in rainfalls with respect to an average percentage of the series, and the other related to the recovery during each draught once the decrease in the accumulated deficits reach a certain level (EWRA, 1995), the most severe drought occurred was the one which took place from 1990/91 to 1994/95. In addition, in accordance with this criterion, this drought could be included within the scope of the one which started in 1979, which would result in a continuous drought period of about 15 years, which was referred to in the chapter on variability of hydrological series.

It is important to take into account that the aforementioned comments on rainfalls cannot be directly applied to runoff, for different reasons: firstly and mainly, because the ratio rainfall-runoff is not linear, and reductions in rainfalls tend to result in higher decreases in cumulative flow. In addition, the resulting average coefficients are, as seen in other chapters, highly variable from the geographical point of view. Furthermore, the time distribution of rainfalls, which may be considerably variable (different effects on the filling of aquifers) is at least as influential as their yearly amount; as

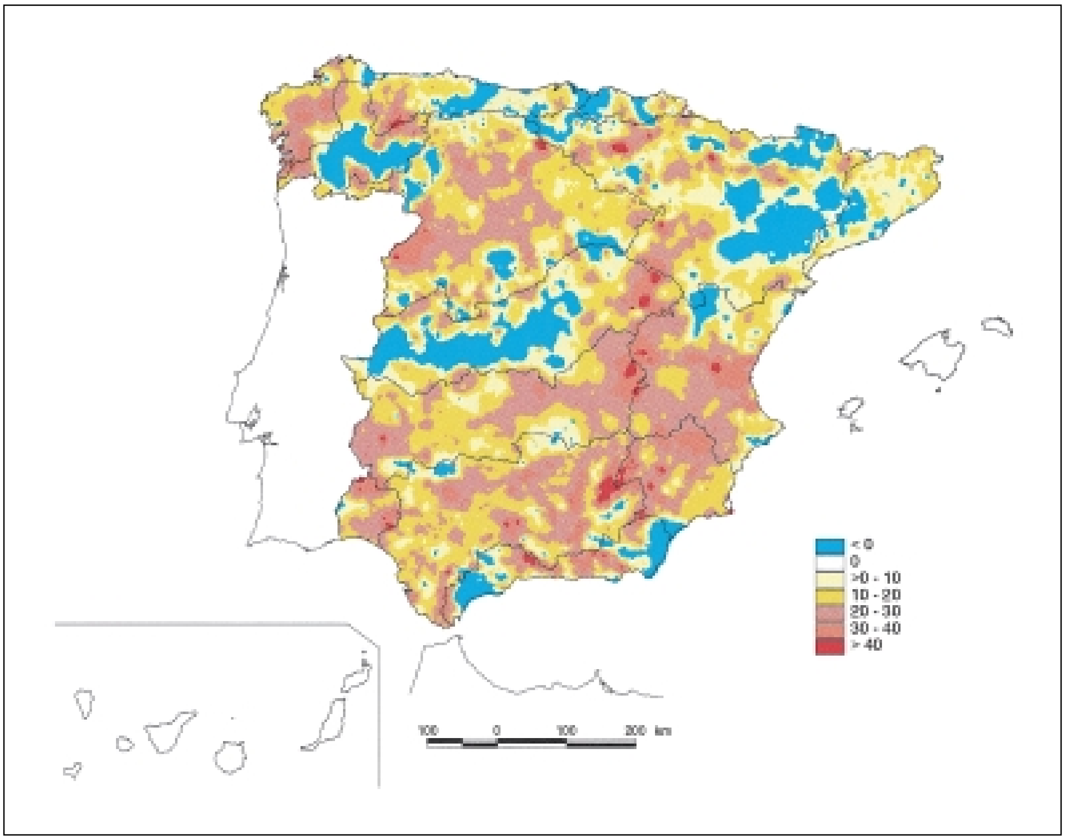


Figure 346. Map of the percentage decrease in average rainfalls during the 1941/42-1944/45 period in comparison with the 1940/41-1995/96 period.

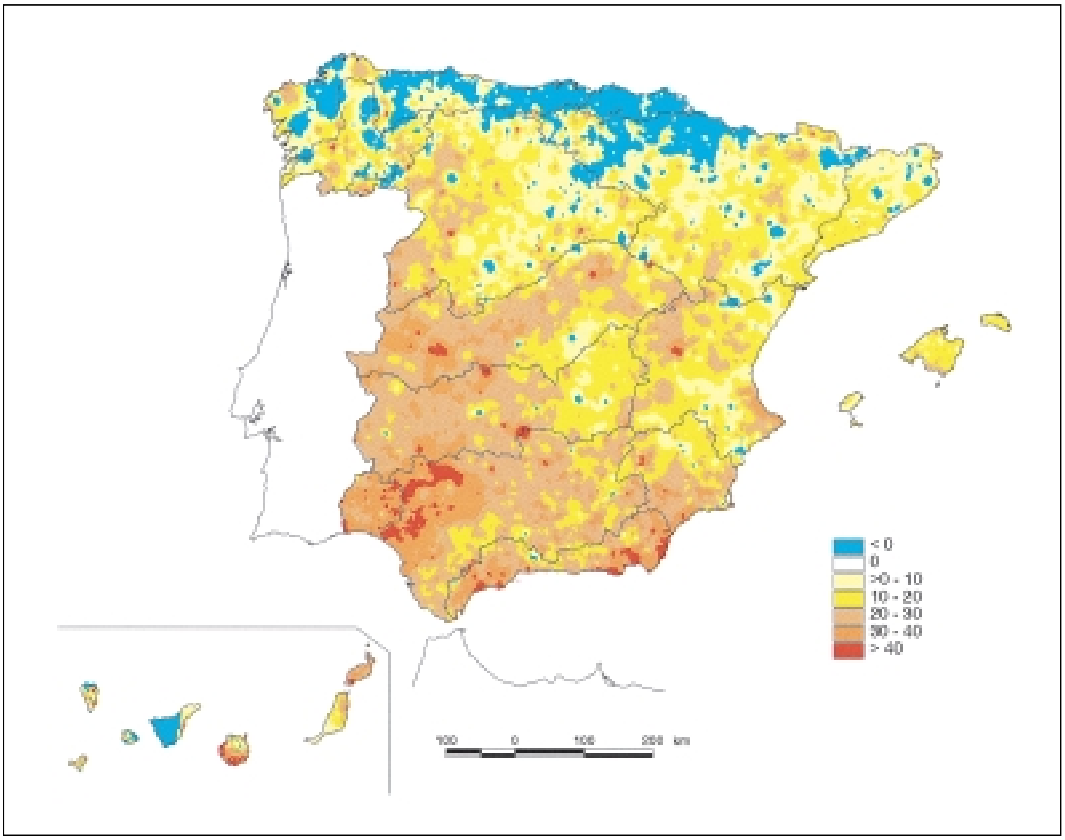


Figure 347. Map of the percentage decrease in average rainfalls during the 1979/80-1982/83 period in comparison with the average rainfalls for the 1940/41-1995/96 period.

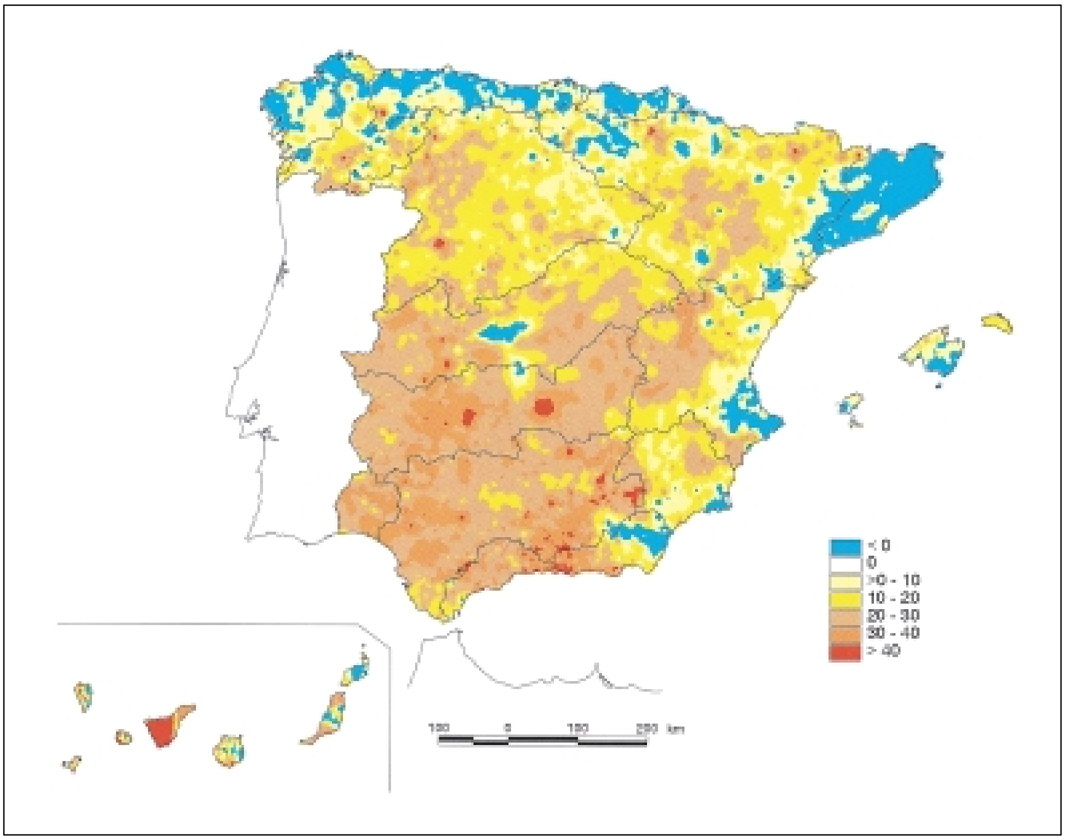


Figure 348. Map of the percentage decrease in average rainfalls during the 1990/91-1994/95 period in comparison with the average rainfalls for the 1940/41-1995/96 period.

Plan	1990-94	1979-82	1941-44
North I	12	10	1
North II	4	0	–6
North III	4	–6	–4
Douro	16	13	15
Tagus	21	23	8
Guadiana I	27	24	19
Guadiana II	30	35	24
Guadalquivir	28	27	20
South	23	28	10
Segura	15	21	24
Júcar	13	18	18
Ebro	11	7	7
Catalonia Inland Basins	–7	9	8
Galicia Coast	1	6	24
Baleares	7	16	–30
Canary Islands	12	22	15
Total	**15**	**15**	**11**

Table 105. Percentage decrease in rainfalls during the droughts in comparison with the average rainfall (the negative values represent an increase in the rainfalls during the drought period).

a last reason, the effects of the same percentage reduction in rainfalls vary in accordance with their absolute value.

As can be observed in figure 349, during the latest drought there was a major reduction in the runoff generated in most of Spain's territory (about 40%). This reduction amounted to more than 70% of the average interannual cumulative flow of the Guadiana and Guadalquivir basins (see table 106). In the South and Tagus basins, the reductions amounted to 60 and 50%, respectively, whereas the Douro, Segura, North I and Ebro basins suffered decreases ranging from 20 and 40%. In the remaining basins, the variation was hardly significant, and in the Catalonia Inland Basins there was an increase with respect to the average figures (about 15%), which means that, instead of a drought, this area went through a humid period.

In addition to the impact on water ecosystems, the direct effect of these reductions, from the point of view of the water allocation system, is the limited availability of the water supplied to populations –even resulting in the imposition of restrictions–, the reduction in agricultural produc-

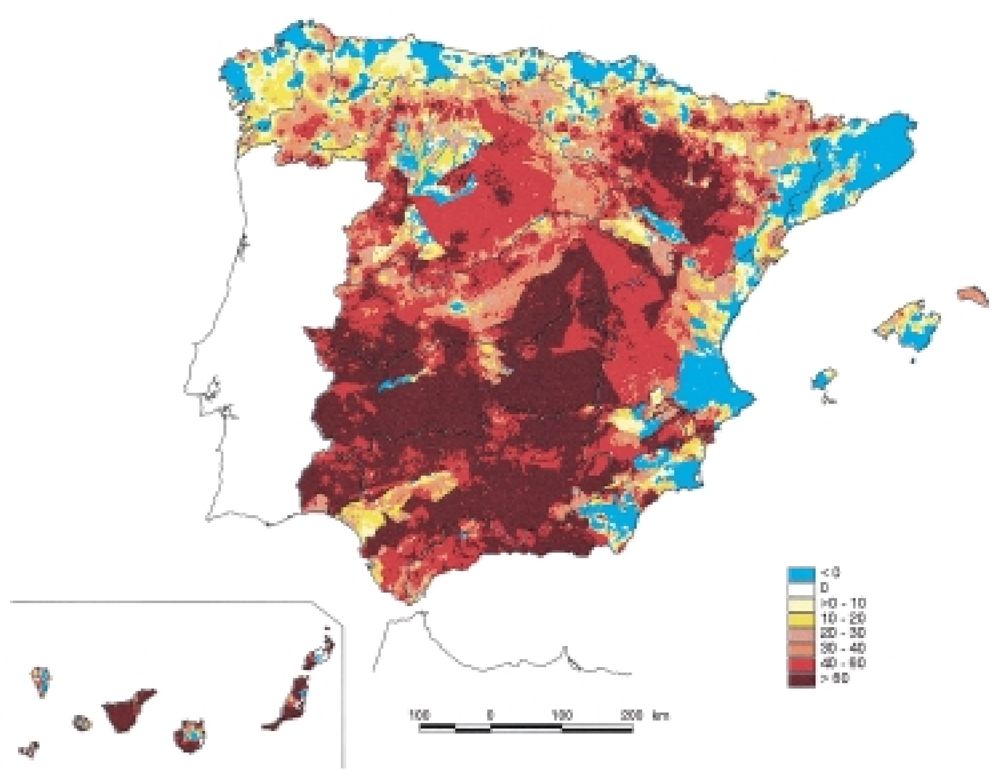


Figure 349. Map of the percentage decrease in average cumulative flows during the 1990/91-1994/95 period in comparison with the average cumulative flow for the 1940/41-1995/96 period.

Plan	1990-94
North I	24
North II	10
North III	9
Douro	36
Tagus	49
Guadiana I	74
Guadiana II	74
Guadalquivir	72
South	59
Segura	32
Júcar	9
Ebro	22
Catalonia Inland Basins	–15
Galicia Coast	4
Baleares	17
Canary Islands	25
Total	**28**

Table 106. Percentage decrease in the total cumulative flows in comparison with the average cumulative flows during the drought occurred from 1990/91 to 1994/95 (the negative values represent an increase in the cumulative flows during the period considered).

tions, both in unirrigated and irrigated land, and the decrease in hydroelectric output.

Figure 350, prepared with data compiled by Villalba Sánchez (1995), shows the evolution of the hydroelectric energy deficit, and its associated cost during the 1988-1994 drought period. During those years, the actual hydroelectric production was lower than the producible hydraulic energy defined for the purposes of the rate file, and it was therefore decided to compensate for that deficit with other sources (coal or fuel-oil), which generated a financial cost associated to the hydraulic deficit which may be assessed, as an average amount for the period mentioned, at about 35,000 Mpts/year.

In addition, figure 351 (prepared with data from MAPA [1998] p. 122) shows the evolution of the agricultural production in irrigated and unirrigated land, expressed in constant trillion pesetas at their 1996 value, on which the supply series (non-dimensional, where 1996=1) for two major urban supply systems, as indicated in other chapters, are superimposed. Together with these series, all on the demand side, the series of average areal rainfall for Spain as a whole, per hydrological years, which was also indicated in a different chapter, is represented as well (following the criterion of representing the value of the hydrological year in the second year; for instance, the datum for 1980-81 is represented in 1981).

It is interesting to point out that the production from both irrigated and unirrigated land increased from 1980 to 84, and then fell until 1986. After that year, there was a recovery and stabilisation period which finished in 1990. From that year to 1995, there was a considerable decrease in the production, and a new recovery period started in 1996.

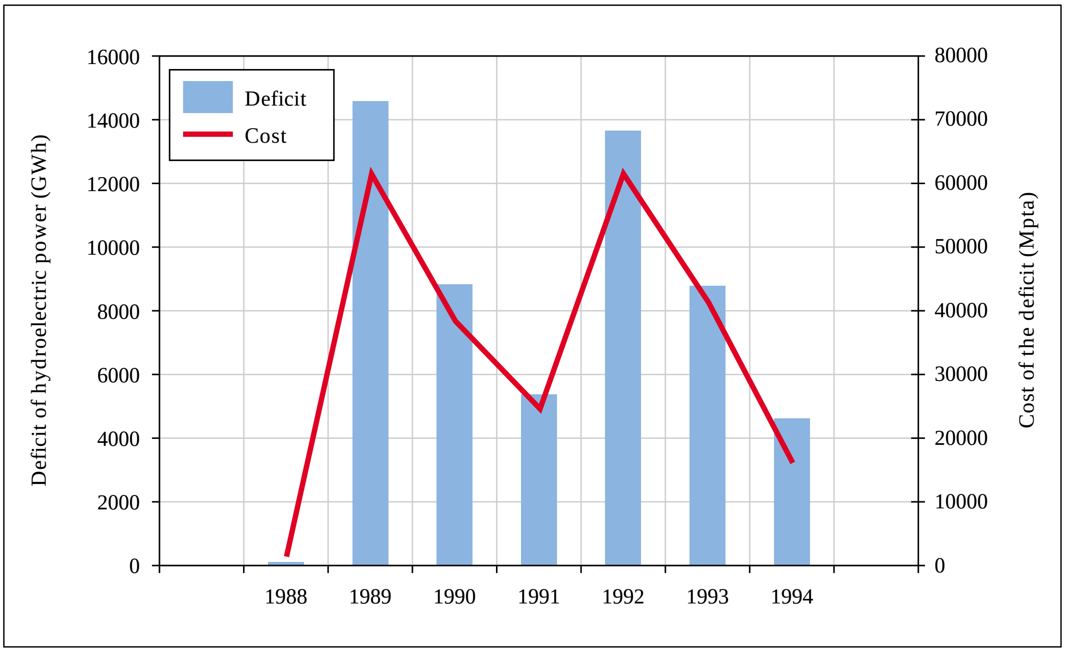


Figure 350. Evolution of the deficit of hydroelectric power production, and its associated cost, in the 1988-1994 period.

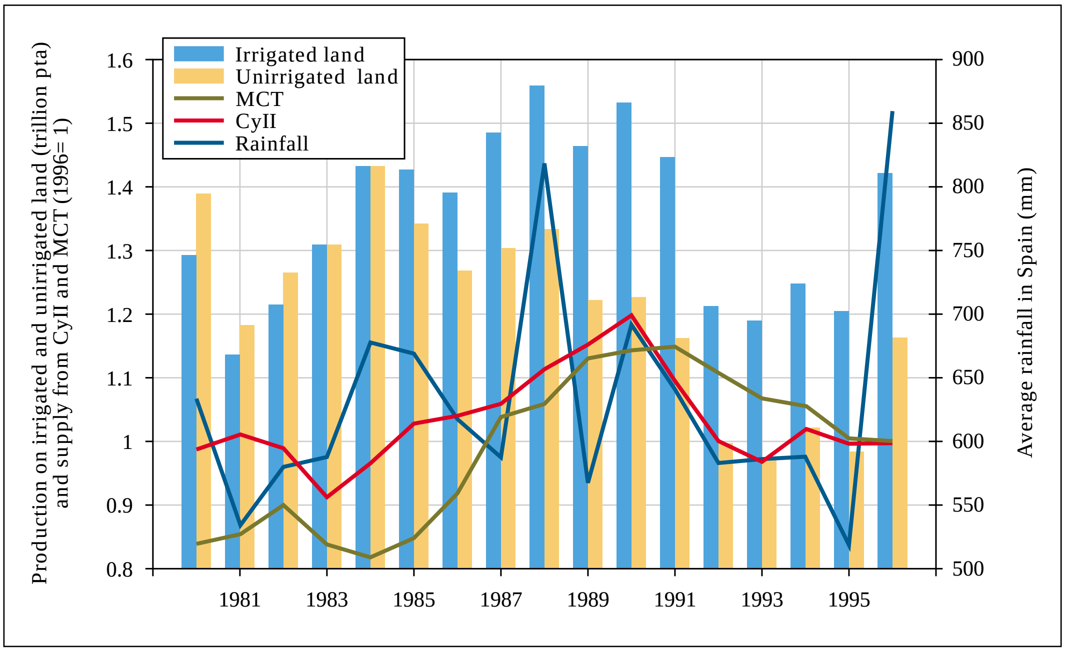


Figure 351. Evolution from 1980 onwards of the total agricultural production on irrigated and unirrigated land, and of the volume supplied to urban populations by some major systems.

The above comment on the evolution observed, made for agricultural production, may also be identically repeated for the urban supplies indicated, and can also be perfectly applied to the average rainfalls.

This shows that, as we have already mentioned for the relation between demands, we can also observe significant crossed-correlation connections between resources and demands. Even if the agricultural economic production, the volume of urban supply and the millimetres of rain are all clearly differentiated series, coming from separate sources and measured in non-comparable units (pesetas, hm3 and mm), their evolution shows common characteristics. The research carried out on such latent structures, which are simply outlined here, is highly interesting as regards the analysis of water resource systems, and must be developed in future water planning studies.

3.11.2. Recent experiences

As indicated above, in recent years Spain went through a serious, relatively extensive dry spell, which had different effects on supply systems. The occurrence of this 1990-1995 drought must be taken into account to draw important conclusions in the shortest time possible, so that the basis for future drought management plans may be established.

Among the specific effects observed, the following must be highlighted:

- During all those years, the restrictions imposed on water supply were particularly strict in cities as Granada, Jaén, Seville, Malaga, Toledo, Ciudad Real and Puertollano, and in areas in the Bay of Cadiz and the Costa del Sol, with restrictions which reached up to 30% of the regular supply and 9 to 10 hours of daily water cutoffs. The Guadaliquivir Hydrographic Confederation was forced to adopt a series of measures including a ban on irrigation from 1993 to 1995. On the eastern part of the Guadiana basin, it was not possible to satisfy the demand for irrigation after 1992, and this situation worsened in 1995, when the demand related to supplying populations could not be satisfied either.

  In the past, there had already been difficulties in supplying cities which, in theory, were not likely to present problems related to shortage of water, such as Oviedo, Gijón, Santander or, in 1990-91, Bilbao and Vitoria.

- The most common measures, in addition to the early imposition of restrictions and special procedures for exchanges between users, were the execution of works for connecting basins, the localisation and exploitation of new ground resources and the use of non-conventional resources.

- The first type of measures included the construction of a large number of conduits through which resources from other basins were transferred, which increased the flexibility of the systems used for supplying populations. There are several examples of this type of constructions, such as the connection between the Low Guadalquivir and Arcos-Bornos, the tunnels for the transfer to the Concepción reservoir, on the river Verde, from the rivers Guadalmina, Guadalmansa and Guadaiza, or the splitting of the Alberche conduit with the aim of supplying Madrid.

- The search for new groundwater resources was carried out on a large scale. The city of Granada, for example, with a population of 300,000 and a yearly demand of about 34 hm^3, had to be supplied with groundwater exclusively. In the area of Madrid, which has a pumping capacity installed of about 4 m^3/s (which accounts for about 20% of the yearly demand), ground resources were also intensely used. In Santander, Pamplona, Burgos, Segovia, Avila, Alcoy and Benidorm, there were several emergency situations related to supplying populations, which were solved by using groundwater. Groundwater was also resorted to in Jaen and Malaga, with substantial improvements in the supply of water to Cadiz, Campo de Gibraltar and Costa del Sol. In Toledo and Seville, however, this solution was not feasible, and it was therefore necessary to resort to direct abstractions from the Tagus and the Guadalquivir, respectively.

- By using groundwater, it was also possible to mitigate the effects of the drought in the irrigated land on the Ebro's left bank, the fertile plains of the Guadiana, the Guadalquivir valley and the Jucar basin. In Ribera del Júcar, the Confederation and the Generalitat of Valencia installed major capacity for pumping groundwater on the left side of the Ribera Alta and in the Royal Irrigation Canal of the Jucar (with a total installed flow of 6,500 l/s), even if its maximum capacity was not used (maximum programmed flow of 100 hm^3/year), whereas in the fertile plains of the Segura, the Confederation constructed or fitted out about 50 drilling units, and authorised users –who had to bear the relevant costs– to open wells to save wooded areas. To execute all these actions, specific regulations on drought wells were approved for this basin, thanks to which it was possible to solve the problem of extreme dryness and social conflicts (Cabezas, 1995).

  Table 107 shows –according to the ITGE– the main actions carried out by the State as regards groundwater during the 1994-95 period.

  As may be observed, about 270 drilling units were installed, and slightly more than 16 m^3/s were mobilised. These figures have to be added to the resources developed on the initiative of individuals, without any public assistance (only in the Segura basin, nearly 2,000 requests for opening wells were processed, and the over-exploitation of beds increased by about 166 hm^3/year).

  A full summary of the emergency actions for extracting groundwater was issued by MIMAM (1999).

- During this drought, other non-conventional methods were applied, such as the mixture of insufficient quality resources with better quality ones. This practice was carried out in the summer of 1995, to supply water to Malaga and the Costa del Sol, where the highly saline reserves in Conde de Guadalhorce and Guadalteba were used, mixed with water from the Viñuela reservoir and from aquifers. There was an increase in the reuse of purified waste water from coastal cities, such as Almería, Murcia, Cartagena or Alicante, and water was even transported by boat to Majorca and Cadiz. Other desalination stations were also projected, but most of them were never constructed.

An interesting example of this situation and of the measures adopted was issued by EMASE-SA (1997a, 1997b).

All these measures adopted in the different areas were implemented in accordance with a considerable number of regulations (indicated in table 108 for the 1990-95 period), approved under section 56 of the Water Act. This section empowers the government, by means of a Decree issued at a Council of Ministers after consulting the basin organisation, to adopt, if an extraordinary drought occurs, *such measures as shall be necessary as regards the utilisation of water public domain, even if a concession has been granted for its exploitation. The approval of such measures shall imply the public utility declaration regarding the relevant works and drilling units, as well as the studies required to develop them, for the purposes of the temporary occupation and mandatory purchase of assets and rights, and of the urgent need for the occupation.*

The Royal Decrees of 531/1992, of the 22nd of May, in force until the 31st of December, 1993, and of 134/1994, of the 4th of February, in force until the 31st of December, 1995, established a series of special measures for the management of water resources, entitling the Confederations, through their Government Boards, to create the so-called Permanent Commissions on Droughts which, among others, had the power to reduce or suspend any water use, and to require users to install regulation, modulation and measurement devices in both public and private irrigation channels, with the additional power to issue a declaration of urgent works to construct small abstraction units or to transport water.

In light of these circumstances, one conclusion which has to be drawn, from the legal point of view, is that our law system lacks an accurate legal definition of drought (see Moreu

Zone of Action	Exploitation bore-holes	Flow extracte (l/s)	Destination of water
Jaén	4	350	supply
Granada	10	1,300	supply
Bahía de Cádiz	22	1,600	supply
Málaga	69	3,440	supply
Costa del Sol	20	750	supply
Campo de Gibraltar	79	2,900	suppl. and irrig.
Ribera del Júcar	50	4,600	irrigation
Huerta de Valencia	6	500	irrigation
Left bank of the Ebro	13	920	irrigation
Total	**273**	**16,360**	

Table 107. Main actions carried out by the State with regard to ground water during the 1994-95 period.

OFFICIAL STATE JOURNAL	PROVISION
Royal Decree Law of 3/1992, of the 22nd of May, adopting urgent measures to remedy the effects of drought.	27-05-92
Royal Decree 531/1992, of the 22nd of May, adopting special administrative measures for the management of water resources.	27-05-92
Royal Decree 995/1992, of the 31st of July, developing the Royal Decree Law of 3/1992.	01-08-92
Royal Decree Law of 5/1993, of the 16th of April, authorising certain actions in connection with the Tagus and the Segura basins.	27-04-93
Royal Decree Law of 8/1993, of the 21st of May, adopting urgent measures to remedy the effects of drought.	27-05-93
Resolution of the 12th of July, 1993, of the Secretariat of State for Water and Environment policies, establishing the territorial scope of the irrigation land affected by the drought.	23-07-93
Royal Decree of 134/1994, of the 4th of February, adopting special administrative measures for the management of water resources under section 56 of the Water Act, correction of mistakes (10-03-94).	18-02-94
Royal Decree Law of 6/1994, of the 27th of May, adopting urgent measures to remedy the effects of the drought.	28-05-94
Order of the 30th of June, 1995, establishing the territorial areas affected by drought, in irrigated and unirrigated land, and fixing criteria for the application of the relief aid set forth by Royal Decree Law of 4/1995, of the 12th of May.	05-07-94
Order of the 29th of June, 1994, of the Ministry of Agriculture, Fisheries and Foodstuffs, developing section 2 of the Royal Decree Law of 6/1994, of the 27th of May.	06-07-94
Order of the 7th of July, 1994, of the Presidency Ministry, fixing the territorial areas affected by the drought in irrigated and unirrigated land.	08-07-94
Royal Decree Act of 1/1995, of the 10th of February, establishing urgent measures in connection with water supplies.	13-02-05
Royal Decree of 615/1995, of the 21st of April, approving additional measures aimed to mitigate the problems related to the supply of water to the municipality of Puertollano (Ciudad Real).	11-05-95
Royal Decree Law of 4/1995, of the 12th of May, adopting urgent measures to remedy the effects of the drought.	18-05-95
Order of the 30th of June, 1995, of the Ministry of Agriculture, Fisheries and Foodstuffs, developing section 2 of the Royal Decree Law of 4/1995, of the 12th of May, adopting urgent measures to remedy the effects of the drought.	01-07-95
Royal Decree Law of 6/1995, of the 14th of July, adopting extraordinary, exceptional and urgent measures in connection with water supplies as a result of the persistence of the drought.	22-07-95
Order of the 27th of July, 1995, of the Ministry of Finance, developing the Royal Decree Act of 4/1995, of the 12th of May, on the offset of fiscal benefits under the Real Estate Tax on rustic properties for Town Councils affected by the drought.	01-08-95
Royal Decree Law of 7/1995, of the 4th of August, authorising the transfer of 55 hm^3 to the Segura basin.	08-08-95
Royal Decree Law of 8/1995, of the 4th of August, adopting urgent measures to improve the utility of the Tagus-Segura transfer.	08-08-95
Order of the 13th of October, 1995, extending the list of municipalities included in schedules I and II of the Order of the 30th of June, establishing the territorial areas affected by the drought, in irrigated and unirrigated land, and fixing criteria for the application of the relief aid set forth by the Royal Decree Law of 4/1995, of the 12th of May.	14-10-95
Resolution of the 18th of October, 1995, of the Secretariat of State for Territorial Policy and Public Works, pronouncing the Resolution of the Council of Ministers concerning emergency works.	25-10-95

Table 108. State legislation on droughts (1990-1995).

Ballonga [1996] pp. 561-563), and the different provisions indicated above are not sufficient to regulate this issue.

In addition, it is also necessary to point out that, in most cases, during the 1990-95 drought, no previous plans specifically designed for this type of emergency situations were implemented; on the contrary, the different actions were gradually conceived and executed –by each Confederation– as the drought continued and its effects became more serious.

This situation, in addition to the problems described above, resulting from the shortage of water, had negative effects from the water administration's point of view, as we shall examine below.

It also had some positive effects, if we take into account the public awareness, the social perception of the shortage, and the moderation and responsibility of the demands for water.

3.11.3. Action guidelines

It can be said, in broad terms, that the latest drought was detected at an advanced stage, which led to the adoption of emergency measures which often solved specific problems, but not in a planned, rigorous way. In fact, the first regulations under which the above-mentioned emergency works could be executed were published in 1992, that is, two years after the beginning of the most intense stage of the drought.

In the light of these circumstances, it is highly recommendable to establish an efficient system for detecting drought situations, under which it will be possible to activate in advance the exploitation plans pre-established for these emergency situations. This early identification of the droughts implies the need for developing alert indicators based on the information which is usually available (rainfalls in recent periods, water stored in reservoirs and levels of aquifers, for instance), so that they may be periodically calculated in order to detect the possible beginning of a drought or to identify its development stage. The recent progress made as regards the study of the possible connection between droughts and other phenomena, such as the level oscillations in the Northern Atlantic or the occurrence of El Niño in the Pacific, is likely to result in the future improvement of the reliability of this type of indicators, even if such improvement is currently a simple hypothesis.

Said Action Plans in the event of droughts, such as the one implemented by the Canal de Isabel II (CYII [1996]) or the plan prepared by EMASESA (EMASESA, 1998), should clearly establish the rules applicable for the exploitation of the systems in these situations, including the criteria for applying restrictions, the conditions for adopting special procedures for the flexibility and the exchange of rights between users and their financial regulation –with the possibility of including the relevant water banks–, the conditions for the temporary increase in the exploitation of aquifers, the mobilisation of hydrologic reserve areas, etc.

In emergency situation, groundwater can usually contribute to mitigating the deficits, by pumping in excess of the regular exploitation, or even by greatly exceeding the average refill of the aquifer.

In several systems for exploiting water resources which are essentially based on surface water, there are aquifers from which it is possible to pump water which will be easily incorporated into a channel, tank, reservoir, or even be directly used. In other cases, it is necessary to execute some type of complementary construction or conduit.

In coastal areas, aquifers are interesting, safe, economical resource for the supply of potable water, but they are even more interesting as freshwater reserve to satisfy peak demands and solve emergency situations, such as droughts.

The function of coastal aquifers becomes particularly relevant if we consider that the movement of the saline front is slow enough to tolerate increases in the exploitation in emergency situations (see, for instance, Bocanegra and Custodio [1994]; Custodio [1996]).

As indicated in some preceding examples, groundwater has offered efficient, economical solutions to mitigate the effects of droughts in emergency situations. But, despite this circumstance, the most efficient solution, rather than waiting until an emergency situation occurs to implement them, is to plan and manage the systems for exploiting water resources in an optimal way, considering the availability of surface and ground resources, and paying special attention to the driest periods.

Finally, an extremely important issue in connection with droughts is the continuous monitoring and participation of the interested parties in the decision-making process, through the corresponding commissions for reservoir withdrawals. The participation of users in the design and development of the measures which will be gradually adopted is essential to overcome these difficult situations.

3.12. HIGH FLOWS AND FLOODS

3.12.1. Introduction

Despite the fact that, as seen above, the average rainfall in Spain is rather low, sometimes the values reached after certain heavy rains exceed the average amount of the whole year, as can be seen in figure 352, which indicates the ratio between the maximum daily rainfall registered and the average yearly rainfall for the 1940/41-1995/96 period.

These extraordinary rains provoke an extremely high flow in rivers, usually known as spates, high waters or floods, which burst their banks and overflow into the fields, affecting people and property.

Given the considerable disproportion observed in some Spanish rivers between their ordinary and extraordinary flow, this problem has become particularly serious.

As it can be observed on the map of the maximum daily rainfall in continental Spain for a return period of 100 years as shown in figure 353, the most torrential rains occur in the Mediterranean coast and in the Bay of Biscay, the Pyrenees and on the Guadiana and Tagus' divides, whereas in the two plateaux the rainfall is generally more uniform (CEDEX, 1994; Ferrer and Ardiles, 1994).

Even if spates are, from the point of view of their origin, a natural phenomenon which is mainly physical and hydrological (high flow as a result of heavy storms), when they occur in areas with human activity they become a territorial problem, with relevant socio-economic effects.

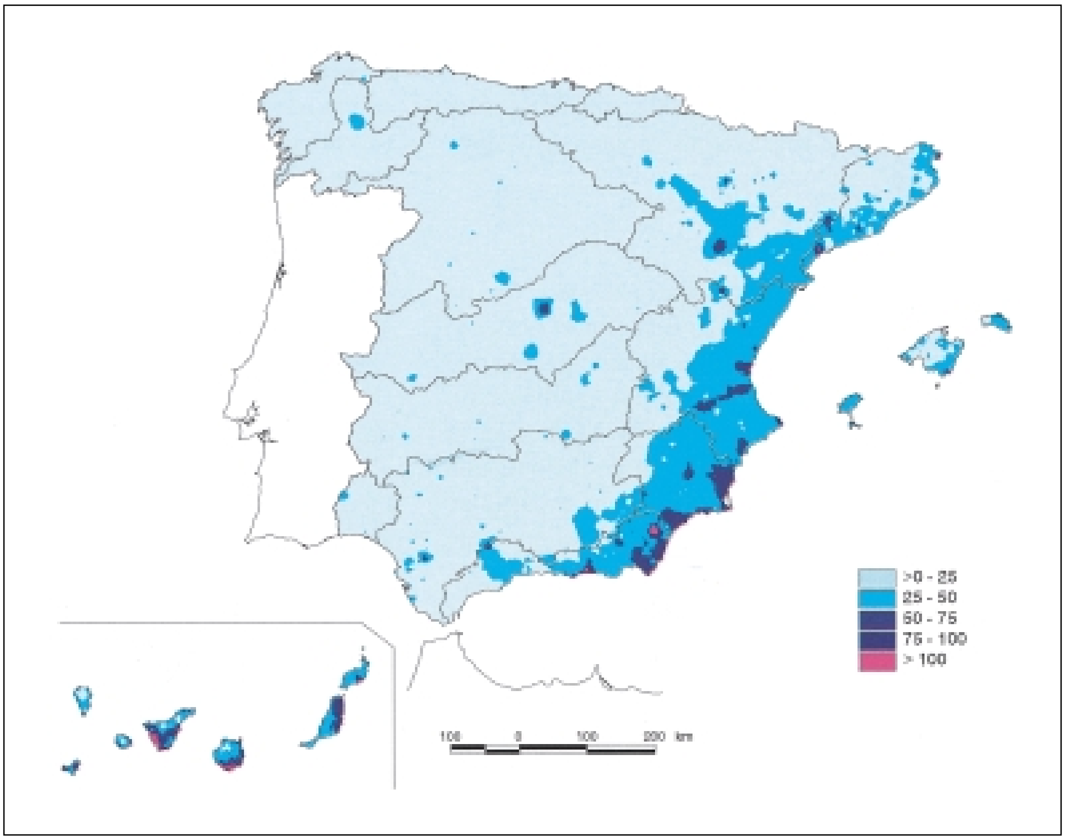


Figure 352. Map of the ratio between the maximum daily rainfall registered and the average yearly rainfall for the 1940/41-1995/96 period.

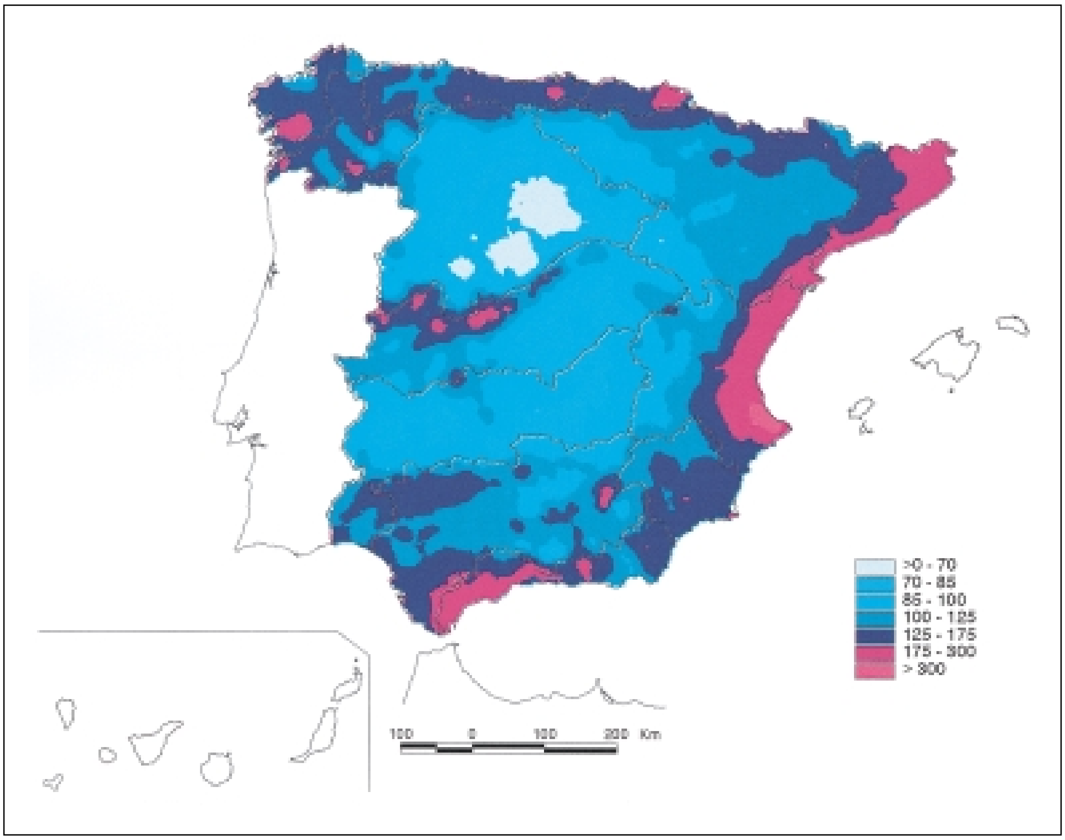


Figure 353. Map of the maximum daily rainfall (mm) in continental Spain for a 100-year return period.

In the following chapters, the basic ideas concerning this problem will be reviewed, and we will establish a global conceptual framework aimed to include and assess the different, complex options and solutions in a coordinated way, within a general, unitary action plan.

3.12.1.1. Origin of high flows

In Spain, floods may result from highly different meteorological phenomena.

A type of flood arises from winter storms with lashing rain which last for several days, affecting large basins and causing damage to property and floods human life. The reason why these floods hardly ever result in casualties is the fact that they can be reasonably anticipated by observing the river. Consequently, the population can usually be alerted and the relevant protection systems may be implemented. The situation is different as regards tributaries and secondary streams, whose short time of response prevents such alert, as we shall see below.

Floods are also provoked by medium or large-scale convective rains. Known locally as *"gotas frías"*, they normally last less than 24 hours, and they can sometimes cover a surface area of about 8,000 km^2. They mainly take place in autumn, and mostly affect medium-sized Mediterranean basins, provoking damage to property and sometimes casualties.

Examples of both situations may be found on the graph in figure 354, which simultaneously shows, as an example of the winter storms, the increase in the river Guadiana's discharge in Merida in January, 1970, which reached its peak at about 4,500 m^3/s during several days, and, as an example of medium or large-scale convective Mediterranean rain, the flood of River Almanzora in Cantoria on the 19th of October, 1973, which reached its peak at over 3,000 m^3/s in less than 3 hours, on a channel which is usually dry throughout the whole year.

There are evidently different consequences, which perfectly illustrate the aforementioned comments regarding the diversity of regimes and the potential anticipation and response capacity.

Finally, spates may result from small-scale convective rain, i.e., the typical summer storms, which are highly intense but short (2 or 3 hours) and not particularly extensive. They usually take place in summertime and cause flash floods in small mountain basins or in the headwaters of rivers.

These spates often claim several casualties, because of their sudden occurrence and the short time for reaction available, if any.

Snow pack floods result from the fast melting of the accumulated snow. In Spain they usually take place during warm, rainy spells in springtime, which leads to accelerated thaw in the summits.

They may be serious in basins such as the Ebro or Douro, even if they are obviously less significant in the rest of the country.

Some other phenomena are linked to heavy rain spells. Among them, spring tides have to be highlighted, since they complicate the draining of other rivers' spates, while intensifying the effects of these spates. They are an important factor on the Atlantic coast, in the gulf of Cadiz, on the low coasts of the Valencian oval, etc.

The graphs included in figure 355 (based on data from Benito et al., 1997) show the monthly distribution of historical floods in different basins. It can be observed that, even if floods occur throughout the whole year, their frequency

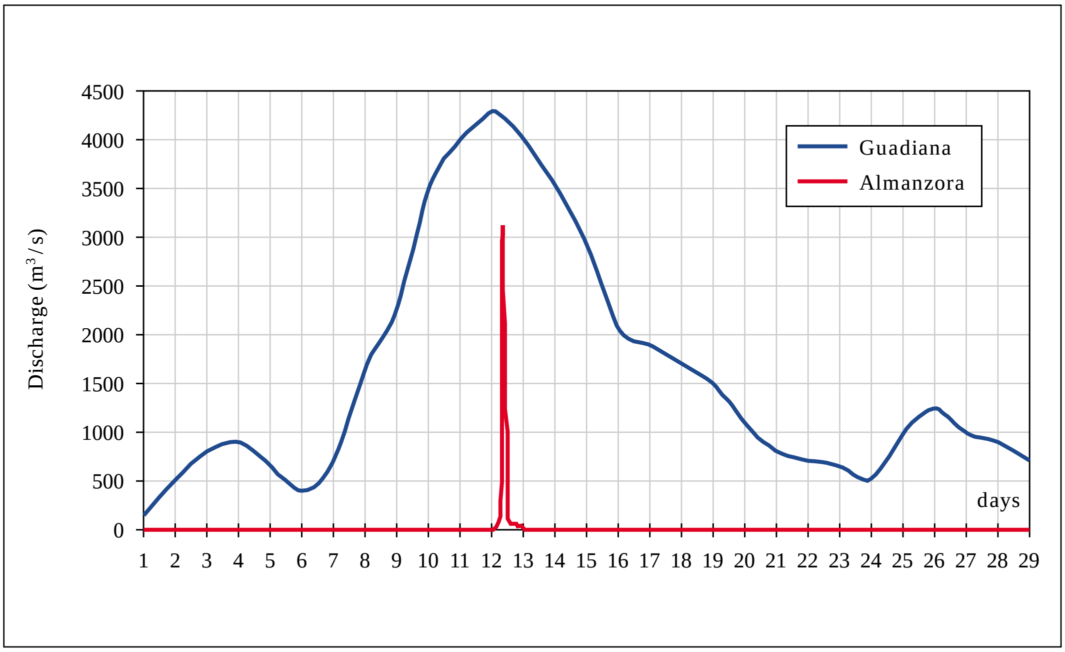


Figure 354. Examples of hydrographs on winter storms in the Guadiana and on Mediterranean convective rain in the Almanzora.

Figure 355. Monthly distribution of historical floods occurred in different basins.

in the Mediterranean area (Catalonia, Júcar and Segura) reaches its top autumn, whereas in all the other basins there is a minimum number of floods in spring and summer.

The geomorphology of the areas affected may result in an intensification of the effects of spates. In headwater valleys, the flow runs in encased channels, without any flood plains. The movement of the water is one-dimensional, and important depths and speeds may be reached. In river valleys with terraces, typical of major rivers, the river covers the bottom of the valley with its smaller channel, and invades the first terrace when such channel is insufficient. The movement of the water is also one-dimensional, but the depths and levels of the ordinary and extraordinary channels greatly differ. The Tagus in Aranjuez, the Ebro in Zaragoza or the Douro in Zamora are classic examples of this type of valleys.

In the final reaches of major rivers, when the smaller channel rises on the flood plain, inverted-relief valleys are created, with depressed lateral areas, extraordinary channels and a two-dimensional circulation. Given that the area is fairly flat, the flood-prone area usually covers several hundred square metres, with an irregular shape. Examples of this type of valleys include the marshy region at the mouth of the Guadalquivir, the Vega del Segura or the Ribera del Júcar, whose simulated flood, which was carried out by the CEDEX in 1982, is shown in figure 356.

The evolution of flow along the Júcar's *Plana* (plain) is shown in figure 357, where the lamination of the hydrograph may observed, as the flood plain is invaded (Estrela y Quintas, 1996a).

When the incline of a river suddenly changes as it flows into an alluvial plain, formations known as alluvial fans are usually created. In these areas, the movement is two-dimensional, with high speeds and shallow water. They are frequently formed in the coastal mouths of small and medium-sized rivers (Guadalmedina in Malaga or Turia in Valencia), and in the outlets to large valleys (river Guadalentín in Lorca) or to a glacial valley (torrent of Arás in Biescas). They are usually found in arid or mountainous areas, and create triangular flood plains.

Anthropic activities can also intensify the effects of spates. The deforestation and the resulting loss of the vegetal cover in headwater basins, mainly in young, mountainous areas, leads to an increase in surface runoff. This vegetal cover has an important mitigating effect in the event of minor or medium-scale spates. However, in the event of catastrophic spates, its effect is less relevant as regards the reduction in flow, but is extremely beneficial when it comes to reducing sediment yield.

In flood-prone areas, human intervention has led to the artificial modification to the reaction of flood plains, because of constructions, crops (altering the natural roughness of the soil), obstacles to transport networks and other obstructions which are even capable of diverting the flood into areas which, but for this human actions, would have suffered no damage.

In some cases, the alteration in the flood plain has even led to a total modification to the river's channel, which is diverted from the bottom of the valley into a side hill. This is the case of the Segura's Vega Baja (low fertile plain): in the 18th century, Cardinal Belluga gave orders to divert its channel for tens of kilometres, which resulted in the drainage of the marshy valley, the recovery of irrigation land, and the settlement of tenant farmers who populated the old marshland while cultivating its soil. This was the work of Religious Foundations, whose actions were similar to those promoted by David Hume in the Netherlands, excellently combining fluvial and social initiatives within the troubled context of the 18th century.

3.12.1.2. Damage caused by high waters

As indicated above, the high waters which cause damage are often very different from those which claim casualties. For instance, the river floods occurred in western Andalusia

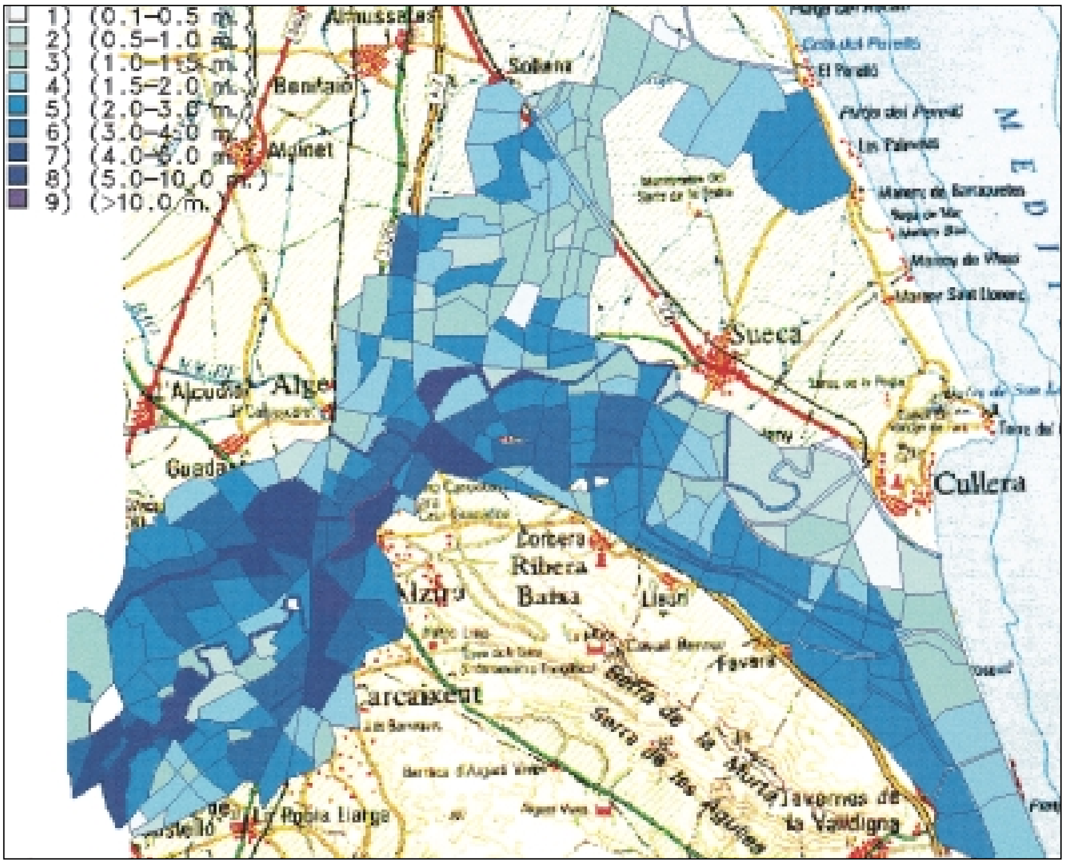


Figure 356. Mathematical simulation of the flood in the Ribera del Júcar (October, 1982).

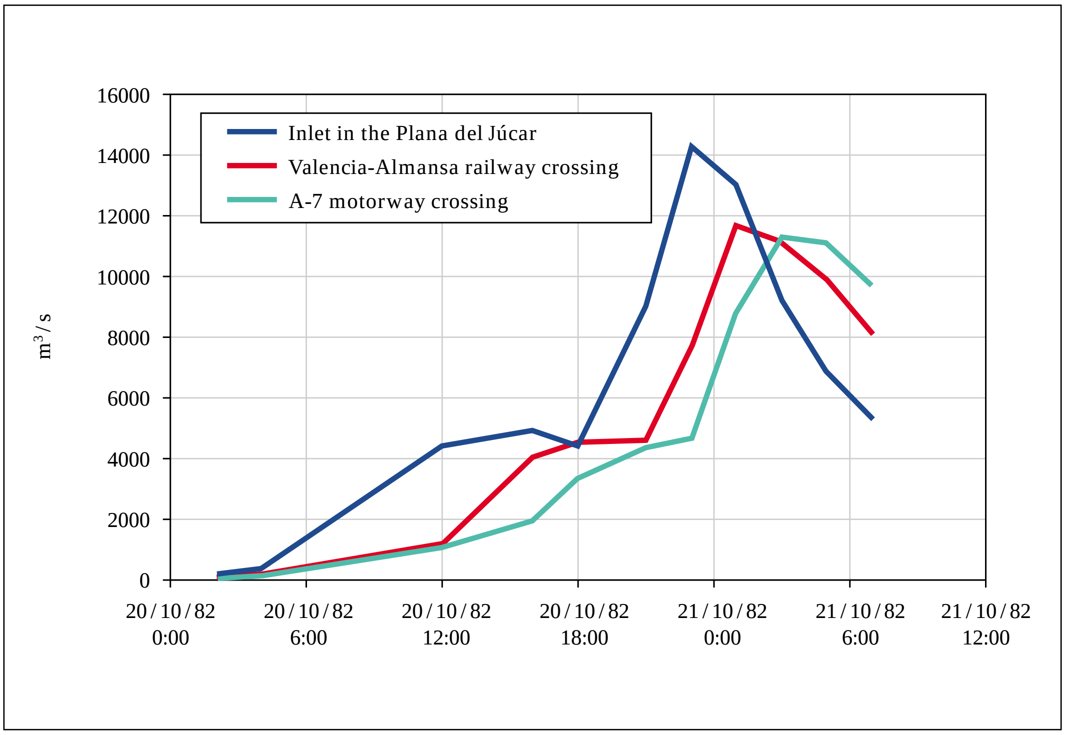


Figure 357. Increase in the flows in the Plana del Júcar (1982 high waters).

in 1996 led to losses and damage to property amounting to 70 billion pesetas and claimed four casualties resulting from car crashes, whereas the flood in Biescas, caused by torrential rain, claimed more than 80 victims and minimum damage to property.

Even if basin management plans contain provisions on structural actions in most of the major cities and industrial, tourist and service areas, given the potential seriousness of floods in these areas, the casualties claimed in these areas do not result from the flood itself directly. Most of these deaths occur in headwater basins or in side tributaries, where the element of surprise, the inadequacy of the infrastructures for crossing the rivers and the isolation increase the risk considerably. A high part of the victims claimed floods in the last two decades died as they were driving their cars, caravans, motorbikes, etc., which become highly unsafe means of transport during high waters. The decrease in the obstacles between the high water and the transport network and the use of alarm systems become key elements for preventing casualties.

In other words, the fact that high waters cause damage to property or claim casualties does not only depend on their intensity. The means implemented to avoid them are also different, and the places where they take place can also vary considerably. A defensive plan against floods should necessarily take these facts into account, and analyse both needs for protection in a coordinated way, but always separately.

The damage to property itself may be considered in different ways in accordance with the economic sectors affected. The length of the flood, for instance, is a highly important factor in agricultural damage, but it is hardly relevant for other sectors. The service sector, on the contrary, is extremely affected by the length of the suspension of activities, which is usually associated to the interruption of the electric supply or the suspension of services for accessing specific areas, which can even affect non-flooded zones. The importance of the damage to public services must be highlighted as well. Even if we consider one sector as a whole, such as agriculture, there are considerable differences in accordance with the type of crop considered (think, for instance, of the substantial differences between unirrigated plots, trees, seasonal irrigated plains or greenhouses for growing early fruits and vegetables, where not only the products could be destroyed, but also the infrastructure itself).

The problem is therefore a complex one, and is closely linked to the uses of the soil. And, like most of the problems related to water, it will be difficult to solve it with universal formulas or generic approaches.

3.12.1.3. Territorial nature of high waters and floods

As indicated above, even if high waters are an extreme hydrological fact (in other words, a natural phenomenon), their most important element is territorial. The alluvial fields adjoining the rivers are flat and fertile, and the human activity has traditionally developed in these areas.

But the characteristics of this land result from the river's regime itself. In this respect, the damage to property caused by high waters could be interpreted as the cost of occupying fields covering a small surface area, but with high territorial value, given that the river often articulates the location of the cities, the irrigation infrastructure, the transport network, etc.

In some cases, the actions carried out to mitigate the effects of high water in a specific area can aggravate them elsewhere. A channelling construction for protecting a city and its land, for instance, tends to accelerate the propagation of the high water wave works and to reduce its lamination, which is likely to worsen the situation in the cities located downstream. This can be observed in the historical evolution of the peaks reached by the Ebro's high water between Castejón and Zaragoza, and this has been the fundamental problem in the latest floods caused by the Rhin.

The adjoining figure and table show what could be described as first-rank flood-prone areas. They include a selection of the reaches of rivers in which the relevant basin management plans have projected the adoption of structural measures. Their execution accounts for 90% of the actions proposed in these plans, and their total cost for the next twenty years amounts to about 500 billion pesetas. Since they have been selected following subjective criteria, these reaches of rivers are obviously not the only ones where problems could arise, as we shall comment below.

Figure 358 and table 109 show what could be described as first-rank flood-prone areas. They include a selection of the reaches of rivers in which the relevant basin management plans have projected the adoption of structural measures. Their execution accounts for 90% of the actions proposed in these plans, and their total cost for the next twenty years amounts to about 500 billion pesetas. Since they have been selected following subjective criteria, these river reaches are obviously not the only ones where problems could arise, as we shall comment below.

The actions projected in these plans are located in about 50 areas, and comprise 25 capitals of provinces (including all the Mediterranean capitals), the metropolitan area of the 7 most populated cities, nearly all Mediterranean cities and their areas for tourists, and the industrial valleys to the north of Spain (opposite figure and table). This means that these actions will be executed in areas where spates are usually torrential, but also where large population settlements, industries and services have developed in recent decades. The urgent need for executing them sometimes results from city-planning pressures or from the invasion of channels. It is therefore clear that basin management plans reflect that the cities' growth to the detriment of rural areas in central Spain and the depopulation of mountain regions have a direct effect on the damage caused by the floods.

Territorial powers concerning floods have been assigned to the Autonomous Communities and to Municipalities. In this respect, it is necessary to point out that the coordination regarding this issue is rather poor, given that Hydrographic Confederations have often projected constructions ignoring the city-planning guidelines issued by municipalities or Autonomous Communities, whereas the latter, in turn, ignore the larger territorial scope of the floods, and their actions, reflected in their regulations, planning instruments and the penalties they impose, usually lack the determination which should be required. In other words, the planning balance and the institutional cooperation required by the complex nature of the problem are frequently not achieved.

In first-rank easily flooded areas, it is necessary to carry out a territorial analysis, in sufficient detail, on the hydrologic

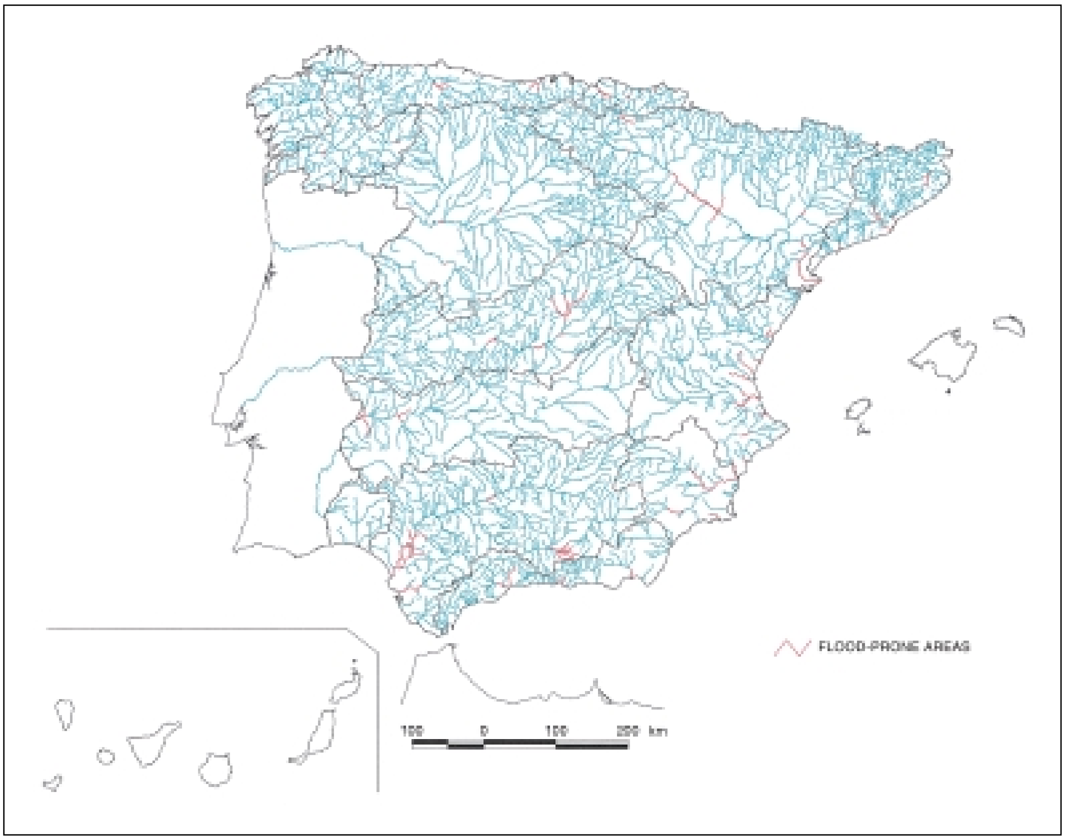


Figure 358. Map of the first-rank flood-prone areas identified in the basin management plans.

PLAN	CITY	RIVER SECTION
NORTH I	PONFERRADA OURENSE	River Sil and Boeza River Miño and Barbaña
NORTH II	TORRELAVEGA AVILÉS MIERES-LANGREO	River Saja from Cabezón de la Sal and Besaya from Corrales de Buelna, to the sea Rivers Arlós, Magdalena and others River Duró and river San Juan in Mieres and Nalón in Barrós and Sotrondio
NORTH III	SAN SEBASTIAN EIBAR/ERMUA BILBAO	River Urumea from Hernani to the sea River Ego River Nervión from Arrigorriaga and Ibaizábal from Amorebieta to Etxabarri
DOURO	ZAMORA SALAMANCA VALLADOLID	River Douro River Tormes River Pisuerga
TAGUS	ARANJUEZ MADRID- . Metrop. TALAVERA TOLEDO	Rivers Tajo and Jarama Rivers Jarama from Belvis de Jarama, Henares from Guadalajara and Manzanares from the El Pardo reservoir, to San Martín de la Vega River Tagus River Tagus
GUADIANA	VALDEPEÑAS MÉRIDA BADAJOZ	La Veguilla Brook River Guadiana and Albarrega River Guadiana, Gévora and Rivillas Brook
GUADALQUIVIR	GRANADA ANDÚJAR-CÓRDOBA SEVILLE	Rivers Darro, Genil, Cubillas and others up to Láchar River Guadalquivir Medio River Guadalquivir from the area of the river to the sea, including River Guadaira from Alcalá, river Pudio from Aljarate and Salado Brook from the La Torre del Águila reservoir.
GUADALETE	JEREZ DE LA FRONTERA	River Guadalete from Barca de la Florida to the sea
SOUTH	MÁLAGA ALGECIRAS ALMERÍA COSTA DEL SOL OF GRANADA (MOTRIL-SALOBREÑA -ALMUÑECAR)	River Guadalhorce from Cártama to the sea, Guadalmedina and others River Palmones River Andarax, from Gádor to the sea, Belén Ravine and others River Guadalfeo from Vélez de Banaudalla and River Verde from Otívar to the sea
SEGURA	MURCIA (The entire valley) LORCA CARTAGENA	River Segura from Cieza to the sea River Guadalentín El Hondón ravine and others
JÚCAR	RIBERA DEL JÚCAR VALENCIA- Metropolitan area CASTELLÓN SAGUNTO GANDÍA-LA SAFOR ALCOY ALICANTE- Metropolitan area ELCHE	River Júcar from Tous, Magro from Llombay and Albaida from Manuel to the sea El Poyo Ravine, Carraixet Gorge and others River Seco River Palancia from Gilet to the sea River Serpis and others River Serpis, Molinar and Barxell Gorges of Orgegia, Juncaret, of Las Ovejas and others River Vinalopó
EBRO	VITORIA LOGROÑO MIRANDA DE EBRO PAMPLONA CALATAYUD ZARAGOZA-. Ebro's Valley and Metropolitan area TORTOSA LÉRIDA	River Zadorra from the Zadorra reservoir to Zuazo River Ebro River Ebro River Arga River Jalón River Ebro from Castejón to Zaragoza, Gállego from Zuera and Huerva from María de Huerva River Ebro from Flix to the sea River Segre
CATALONIA INLAND BASINS	BARCELONA- Metropolitan area GERONA TARRAGONA	Maresme, river Besós and others River Llobregat from Manresa to the sea, including the ravines in El Vallés and river Anoia from Sant Sadurní Ter from Salt and Oñar, up to Cerviá de Ter River Francolí, final section

Table 109. List of first-rank flood-prone areas identified in the basin management plans.

and hydraulic elements and on territorial and city-planning factors, so that the relevant central and autonomic authorities can implement coordinated, consistent solutions, which will be subsequently reflected at different levels in a common plan. It is obvious that the execution of this task will raise difficulties, but this is an objective to achieve with constant determination.

In addition, as indicated above, there are areas which are hardly relevant if compared with the large basin, but which can locally suffer important problems. It seems logical to state that the Autonomous Communities should have maps of the areas exposed to risks of flood, in the relevant scale, which should also be available to city-planning Provincial Commissions, so that these maps may be taken into account when preparing city-planning programmes, which must be designed in greater detail. Today, only the Basque Country and the Community of Valencia can use this type of instruments (Generalitat Valenciana, 1997).

After identifying the problem areas and studying each of these areas in depth, the need for solving these problems at local level becomes obvious, given that it would be impossible and absurd to tackle them at global level, from a central administrative authority. In this respect, if an adequate cartography on the risk and the necessary legal or city-planning instruments existed, the problems associated to the protection of small towns could be tackled more easily by the Autonomous Communities and the municipalities. It does not seem logical to include the protection of scarcely-populated municipalities or villages in the basin management plans.

In addition to the need and responsibility for action at local level, a different issue which has to be analysed is the advisable creation of a national programme for promoting risk maps, which should be jointly coordinated by the competent central bodies and Autonomous Communities' authorities, and should include its corresponding economic and financial programme, in which the Insurance Offset Group should participate through formulas such as the creation of a specific fund, in which a small part of the premiums for extraordinary risks could be deposited to this end. The State organ for Civil Protection could promote and coordinate this initiative.

All these tasks have to be carried out, obviously, in addition to the logical supervision by the Water Control stations for such areas as are established by the legislation. In this respect, the RDPH defines the channel of a stream as the land covered by water during the maximum ordinary spates, and establishes a 100-metre wide surveillance area, which must be horizontally measured from the channel, where certain uses or modified changes may be restricted or even prevented.

The development of the supervision assigned to the Water Control stations over the restricted area comes up against a considerable shortage of means, not only for the river control tasks, but also for the supervision of city-planning programmes. The city-planning Provincial Commissions usually do not have any risk or boundary maps, and systematically send an official note to the relevant Water Control station, giving it notice of the existence of a specific Plan which could affect areas within its jurisdiction. As a result of this notice, the Water Control stations have to submit information about a considerable number of highly technical documents, requiring non-immediate technical studies, and follow certain administrative proceedings within very short periods. Consequently, most of them are automatically approved after the relevant period elapses without the stations replying to the Provincial Commissions. In this respect, the clarification of the functions of concurrent administrations in flood-prone areas should be a priority action.

The making of risk maps, their computerisation and their systematic disclosure and, above all, the identification, classification and categorisation of the problems would allow the different administrations to give an adequate answer to these issues.

A crucial objective should be to prevent Provincial Commissions from approving incorrect city-planning programmes. If one plan is approved, and such plan declares that an flood-prone area will be suitable for development, the change in the use of the land will be impossible, since it would force the administration to pay exorbitant compensations. The land which has already been qualified as suitable for development, if no construction has been commenced on it, currently implies the adoption of structural solutions. Unfortunately, this situation is rather common.

3.12.1.4. Floods and transport networks

The importance of transport in modern societies becomes particularly relevant in the event of floods, given the massive interruptions which may result from them. The subsequent isolation hinders the evacuation and the arrival of emergency services. The situation of the road network in flood-prone areas is therefore a key element in the actions for protection against high waters.

The localisation and, if relevant, modification and even elimination of bridges and insufficient drainage infrastructures, the installation of road signs and the elimination of potholes are highly efficient measures for the protection of human beings.

The current Instruction from the Directorate General for Roads (MOPU-DGC, 1990) has represented a step forward in the search for a solution to these problems, because the new sections of roads which are being constructed are considerably safer than the old ones, where most of the problematic points are located.

Linear works (large embankments in particular) and insufficient drainage infrastructures may divert the flood into other areas or worsen its effects upstream. It is necessary to admit, however, that the effects of the flood cannot be fully eliminated, and that it would not be convenient to raise the value of the infrastructures to uneconomic levels. The common planning of transport networks and of the actions to be carried out in first-rank flood-prone areas can contribute to solving these problems.

In addition, it is relevant to consider that the cost of repairing a flooded road section exceeds the mere out-of-pocket cost of replacing the infrastructure, because the damage caused by the interruption of the service may even be enormous. The creation of system disruption scenarios can facilitate the identification of the crucial points where the adoption of higher safety levels is justified. The situation is similar for railways and for the electric supply network.

3.12.1.5. Floods and large dams

Dams represent a highly efficient structural defensive method against high waters, either through multi-purpose reservoir guards or even through the dam itself conceived as a protective infrastructure.

Dams do not cause any side effects downstream, like channelling constructions, and from the environmental point of view they concentrate the impact on the river ecosystem on a limited section. The beneficial effect of a policy based on constructing large dams on flood storage can be clearly observed in Atlantic basins, from the Sil to the Guadalquivir. Their use is more problematic in short basins in the Mediterranean and in the Bay of Biscay, where the reservoirs are smaller, the rivers carry down a large amount of sediments and there is a considerable disproportion between the peak and the average flow. These peaks are quickly reached, which prevents the spates from being controlled, or makes this task more dangerous, and prevision and assistance systems are therefore required for such purpose. In some exceptional event, the effect of the spate could be aggravated if the floodway was insufficient or if the gates were incorrectly operated. This is why the use of large dams as a method for controlling high waters is considered as an excellent solution, but it requires previously planning the possible impacts and emergency situations.

3.12.1.6. Environmental implications of the protection against high waters

High waters and floods are nothing more than an environmental element, and therefore play a role in the natural ecosystem. Firstly, they are a basic means for transporting sediments, for geomorphologic shaping and, therefore, for renovating the physical substratum of the ecosystem. In addition, spates control the demography of superior animal and vegetal species in the river ecosystem.

This is why the policy for managing spates which currently prevails in most western countries is based on tolerating a certain number of controlled floods in order to reestablish the ecosystem's balance, which has been altered by the decrease in flow oscillations resulting from the regulation carried out by reservoirs.

The extreme protection of property, especially through channelling or fitting-out works, has sometimes led to the complete disappearance of the ecosystem, and to the replacement of rivers with artificial channels. Some European Union countries have recently advised against the methods for protecting of agricultural land which lead to the destruction of riverside ecosystems, and other countries have even put a ban on these methods. The option of taking out agricultural insurance policies is currently considered as the most adequate for this purpose. Another instrument which has not been used in Spain yet, but which has been successfully implemented in the United States, is the purchase of land in order to revert it to the State as a forestry asset. This policy based on purchasing riverside areas and subsequently restoring them is highly interesting, and has been proposed in the Douro's basin management plan.

In other cases, channeling infrastructures are often constructed to solve a sanitary problem. It is a fact that the urban environment of a non-channeled stream tends to deteriorate, and city councils usually demand such channeling works, for public health reasons rather than as means of protection against spates.

3.12.2. Background to defensive actions

Since time immemorial, there have been documented references concerning proposals on defensive actions against floods. For instance, Gómez Ortega et al. (1866) analysed in an interesting study the floods resulting from spates of the Júcar in 1864, considered the advantages and the drawbacks of different protective measures, and proposed a series of actions. In broad terms, as a result of the limited possibilities and the constructive restrictions of those times, the cost of the execution of the different protective works was enormous.

Among other measures, they analysed the effect of longitudinal and transversal dikes, the construction of tanks or dams, the dikes for protecting populations and the effect of reforestation. According to the authors, there were different reasons preventing the adoption of general defensive system for the Júcar's valley, and this conclusion continues to be valid today. Even if their study contains certain conceptual mistakes about the effects of some defensive measures, such as the storage effect of the dams, their works is highly valuable, since it presented a classification of structural measures which is similar to the one used today.

Another significant example of historical defensive plans is contained in the masterful

Anteproyecto de Obras de Defensa contra las inundaciones en el Valle del Segura (Pilot Study on Defensive Constructions against floods in the Segura Valley), presented by Ramón García and Luis Gaztelu in 1886, after the Segura basin was flooded in 1879. The devastating effects of this flood even received international coverage (it is mentioned, for instance, in the Proustian *Recherche*). After analysing the advantages and disadvantages of the systems based on longitudinal and transversal dikes, reservoirs, diversions, repopulation, etc, they reach a conclusion which, surprisingly, could be perfectly applied to the current situation: *We believe that no system can solve by itself, generally speaking, this terrible problem; but an adequate combination of the different systems is likely to provide a solution which, if not totally efficient, might reasonably turn these memorable events which bring grief to so many families into an ordinary, common fact.*

They divide the constructions into three categories: those which directly prevent the overflow; those which modify the regime of the water by reducing the maximum level, and the indirect means. The first category includes the longitudinal dikes, whereas reservoirs, diversion channels and reforestation are included in the second group. The third one includes the means which do not prevent floods directly, but tend to mitigate the damage they cause, such as insurance, the regulations on flood-prone areas or the selections of crops, etc.

The modernity of these ideas, together with their integrated approach to the protection against floods and the use of water for irrigation, which should always be taken into account by the planner, turn this Plan into a clear ancestor of the current water planning, and prove that their authors were true pioneers in the development of hydrological analysis in Spain during the 19^{th} century.

In more recent times, the harmful floods which took place in 1982 in the east of Spain led, together with other factors, to the creation in May, 1983, within the National Commission for Civil Protection, of the Technical Commission for Flood Emergencies (CTEI).

The main objectives of this Commission were the study and classification of areas potentially exposed to a risk of flood, including the corresponding risk maps, the compilation, classification and preparation of the information on the most significant historic catastrophes caused by floods and the making of a study on actions and preventive measures to be implemented, in the medium and long term, in order to correct or mitigate the effects of the potential floods in accordance with the risks established. In this respect, as antecedents which deserve to be highlighted, we should mention several brilliant, exhaustive accounts of historic high waters, such as the one written by Couchoud and Sánchez Ferlosio (1965).

The work of the Commission was coordinated by the DGOH, and a general report was issued (MOP, 1983) which indicated the direct antecedents available and developed a methodology which was suitable for classifying the causes and effects of the floods, assessing the subsequent damage and identifying the activities required for their prevention and mitigation. The partial reports concerning each of the ten river basins in continental Spain identified and analysed the historic floods occurred and delimited and classified the areas exposed to potential risks. In this respect, 2,438 historic floods occurred in the last five centuries were identified, and a sheet containing all the relevant information was prepared for each of the floods. In accordance with this information, 1,036 potential risk areas were identified in Spain, which were classified in accordance with the risk. Maps in a 1:200,000 scale were prepared, fixing the limits of each of the areas, and establishing the priority actions to be implemented in them.

These studies laid the foundations of the subsequent General Defensive Plans against High waters developed by the DGOHCA and of the civil protection plans against the risk of floods prepared by Government Delegations and Civil Governments in recent years.

However, their obsoleteness, the corrective works executed in the different basins and the recent modifications to the legislation on this issue raise the need for reviewing this work in depth. In this respect, the State Coordination Committee, created under the Basic Guidelines on Floods, decided in 1996 to set up a Working Group on Analysis of the Risk of Floods in Spain. Subsequently, the General Directorate for Civil Protection issued a Methodological Guide.

(Bustamante and González, 1997), fixing the guidelines for the homogenous, systematic update of the old Catalogue.

3.12.3. Criteria for action

3.12.3.1. Basic Principles

The defensive actions against floods should be governed by a series of basic principles guaranteeing their efficiency in mitigating the damage. Among these principles, we should highlight the following:

- Coordination. The different authorities and institutions involved must act in a joint, coordinated way, with a clear delimitation of objectives and tasks.
- Decentralisation. First-rank flood-prone areas seem to require actions from the central administration, even if the local and autonomic administrations participate in accordance with the territorial scope of the problem, but in the remaining areas the problems can be solved by the relevant Autonomous Communities, with the advice and the supervision of Hydrographic Confederations in intercommunity basins.
- Damage segregation. It is necessary to develop programmes with different objectives. The actions on the road network and on prevision and alarm systems must have an essential part in the special programmes for reducing the number of casualties, whereas the programmes for reducing agricultural damage must highlight the importance of agricultural insurance.
- Realism. It has to be admitted that the problem of floods has no definitive solution. Therefore, a certain residual risk must always be accepted. It is impossible to guarantee total security in the event of floods, and only the mitigation of the risk can be assured. Consequently, it seems logical to establish structural protection thresholds as an ade-

quate objective leading to homogenous safety levels throughout the country, so that higher risks can be covered through programmes containing non-structural measures.

- Respect for the environment. The unjustified deterioration of river ecosystems must be avoided, and non-structural measures must be promoted. When structural measures are absolutely necessary, the relevant authorities will have to find solutions resulting in minimum deterioration, so that the impact on the environment is minimised.
- Prevention. The problems related to floods must be anticipated before any subsequent actions are required. The best way to avoid these actions is to prevent populations from settling in flood-prone areas and to regulate the cities' growth. It is essential to remember that, in societies which can be described as developed from the hydraulic point of view, the problem of floods is transferred from the field of infrastructures to that of city-planning.
- Transparency. It is necessary to make an effort and realistically present the risks assumed ant clearly explain the objectives of the measures adopted. Risk maps must be disclosed and distributed not only to Administrations and technicians, but to the citizens as well.

3.12.3.2. Technical and economic criteria

From the technical point of view, it is relevant to mention a series of criteria for adequately planning solutions and for the organisation an execution of defensive actions.

Risk maps, which present the main magnitudes (heights and speeds of the water, risks, length of the flood, etc.) associated to floods which occur rather frequently, are particularly efficient instrument when planning defensive actions.

As regards first-rank flood-prone areas, risk maps should be made in a 1:5,000 scale, which is typical of city-planning developments.

In addition to making risk maps, it would be relevant to carry out a previous hydro-geomorphologic analysis, identifying and describing the study areas from a qualitative point of view, a hydrologic study determining the probabilities of occurrence or the return periods of flow with different magnitudes, and a hydraulic study assessing the levels associated to such flow. Finally, the economic analysis will evaluate the territorial impacts of floods from the financial point of view.

Risk maps should represent at least the spates for a 100-year return period, and it would be advisable to include them for a 500-year period.

The parameters defining the seriousness of a flood are the level reached by the water (depth), its speed, the length of the flood and the response time. Other indicators, such as risk or hazard typologies, may be inferred from these basic parameters.

The level of water determines the seriousness of the damage to property. A level exceeding 0.8-1 m usually results in total loss, whereas a level below 0.3-0.4 m implies minimum damage. In accordance with the depths and the return periods, the following risk areas can be established (the Basic Planning Guidelines for Civil Protection against the Risk of Floods fixes a similar classification, but with different return periods and without specifying the depths):

- *Low-risk areas:* In these areas, the floods are not expected to be excessively deep (below 0.4m) and the return period exceeds 25 years.
- *Average-risk areas:* In this areas, floods have an average depth (from 0.4 to 0.8 m) and a return period exceeding 100 years, or a limited depth and a return period of less than 25 years.
- *High-risk areas:* Areas having a an average or high depth and a return period not exceeding 100 years.

Speed is an efficient indicator of the damage to property (especially to crops) and of the bodily injuries. A speed of more than 1 m/s implies a high risk. It is therefore advisable to include in the definition of high-risk area the condition that the speed exceeds 1 m/s, regardless of its depth.

In addition, a critical combination of levels an speeds results in the concept of hazard level of the flood. In this respect, the following three levels can be established, in accordance with the criteria of the ASCE contained in Vallarino (1991):

- No hazard level, if the flood is less than 1 metre high, and the product of the height (m) multiplied by the speed (m/s) is lower than 0.7.
- Average hazard level, or risk for human beings, if the height of the flood exceeds 1 m, or if the product of multiplying the height (m) by the speed (m/s) is higher than 0.7.
- High hazard level, or danger for buildings and structures, when the flood height exceeds 3.6 metres, or the product of height (m) multiplied by speed (m/s) is over 6.

In addition, the length of the flood, at least in Spain, is highly significant as regards agricultural damage and the interruption of the transport network, since the floods are generally short-lasting. Therefore, without prejudice to the practical difficulty as far as formal quantifying is concerned, the inclusion of this factor in the risk maps does not seem essential.

Finally, the response time of a basin is not a variable which can be represented on risk maps; but, as it has been pointed out, it strongly determines the risk for human beings. An approximation can be inferred from the concentration time of the basin: the higher the expected flow and the lesser the response time, the higher the risk of casualties because of the element of surprise. Since a minimum of two or three hours is reasonably needed from the moment a torrential rain takes place until the population can be warned and the civil protection services can be organised, the basins having a lower response time must base their protection on passive means only. On the contrary, when the response times exceed one day, the risk of human casualties is much lower and usually there is only damage to property.

As an illustration of some of the ideas exposed and an example of the flood cartography which can be generated, figure 359 shows some results on levels, speeds and dangers that have been obtained through the real analysis of the flood rate of Las Moreras ravine, in Mazarrón (Murcia) (CARM-INUA, 1992). The surface area studied is 2.88 x 3.63 km, and has been discretised with a 15-m resolution for all the analyses which have been carried out (raster maps with 243 x 193 cells).

In the event that risk maps are available, their comparison with a cartography reflecting the approved city-panning development or the uses of the soil, can constitute an accurate methodology for the territorial analysis of the floods. The elaboration of curves which relate the damages to the flood height for the different uses of the soil and for their connection with risk maps can complement the analysis, as they give an approximate idea of the actual damage to property. After the geomorphologic, hydrological and hydraulic analysis, the fourth stage of the process would be the economic analysis of the floods.

Eventually, a classified inventory on the special areas, such as the equipment, should be carried out, indicating the remaining useful life of such equipment, as well as a systematic evaluation of the operation of the drainage constructions, paved fords and flood-prone sections. All these factors tend to incorporate into the risk map the "black spots" which fail to comply with the criteria of the road instructions or present a specific problem.

Figures 360, 361 and 362 illustrate these ideas by showing the uses of the soil in the area, the functions related to the damage and the cartography on the economic damage associated to the floods, as contained in the above-mentioned analysis of Las Moreras ravine.

Given the conditions of the area and the information available, the potential economic damage for each use of the soil has been defined as an exclusive function related to the height reached by the flood (pts/m^2, according to the height for each use of the soil). Figure 363 shows some of these functions related to the damage, adapted to local conditions, where the behaviour of an initially high increase and the final constant value representing the total damage can be observed. For certain uses, the damage suffered up to considerable heights is limited, but in others –having high economic value, such as greenhouses– the damage sustained is almost total for reduced heights. The process of adaptation and calibration to local conditions is essential to calculate these functions correctly.

If these functions are applied to flood height maps and to maps on uses of the soil, it is possible to prepare the economic damage maps for each return period, as shown in figure 362 (pts/cell).

The economical damage for each return period will be estimated as the sum of the total damage in all the cells comprised in each map. The weighting of these economic results with the probability that they occur makes it possible to obtain the expected yearly damage, or average damage, as it is shown on the opposite figure, which represents the hydrographs for several return periods resulting from the hydrological analysis, and on a logarithmical scale, the flow, the damages, the incremental damage expected (IDE), and the costs of the flood risk (CFR) for the different return periods considered (Chow and others, 1988). As it can be seen, in this particular case the design flow and the damage sustained increase in an almost linear way in proportion with the return period logarithm.

The incremental damage is the expected yearly damage, which is the cost of the flood risk corresponding to one year within the return period, which turns out to be about 200 Mpts/year. This gives an objective idea of the economic importance of this problem, if it is assumed that the damage is immediately repaired or replaced and the present uses of the soil in the land studied are maintained in future.

This expected damage, together with the net profit of the location (improvement of the net income for possible new actions in flood-prone areas as a result of the plan) and the intensification (improvement of the income from current actions carried out in flood-prone areas under the plan), and the total costs of the defensive actions (introduction, preservation and maintenance, including environmental, alarm and civil protection costs), make it possible to assess the net profit or economic efficiency associated with this defensive plan as the sum of the location profit plus the intensification profit, plus the flood reduction profit, minus the total cost of the plan (USACE, 1996). This can be expressed in an algebraic way:

$$NP = LP + IP + E[Dwithout] – E[Dwith] – C$$

The flood reduction profit is expressed in terms of the values expected, as the difference between the damage expected without a plan and the damage expected when a plan is executed, calculated as indicated above. In principle, the plan which will maximise the net profit will be preferred.

As regards the possible actions within the scope of the defensive plans, given their variety and the different scale of the problems, it is recommended to implement a sectoral organisation, by means of horizontal programmes grouping similar measures together. These programmes could be structured as follows :

- Reforestation, in order to reduce solid flow.
- Prevention and alarm systems, such as the Automatic Water Information System (SAIH, according to the Spanish acronym), which is currently operational in some basin Organs and is considered as an essential tool for a modern management of the critical hydrologic situations.
- Structural actions, which could include the sub-programmes on storage dams, river channelling and fluvial actions, and on safety and surveillance of dams.

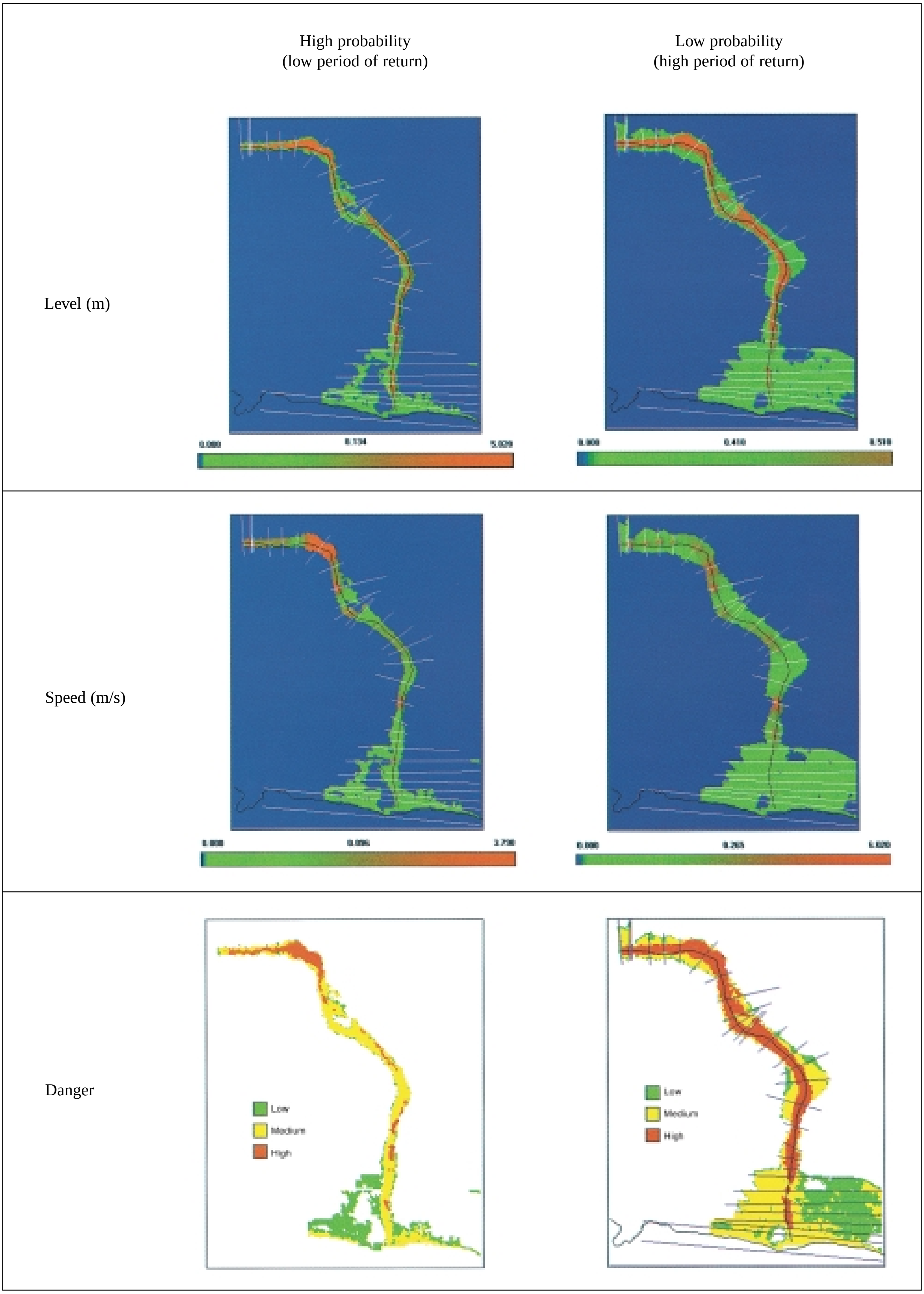


Figure 359. Heights, speeds and hazard level generated by floods in the Moreras ravine.

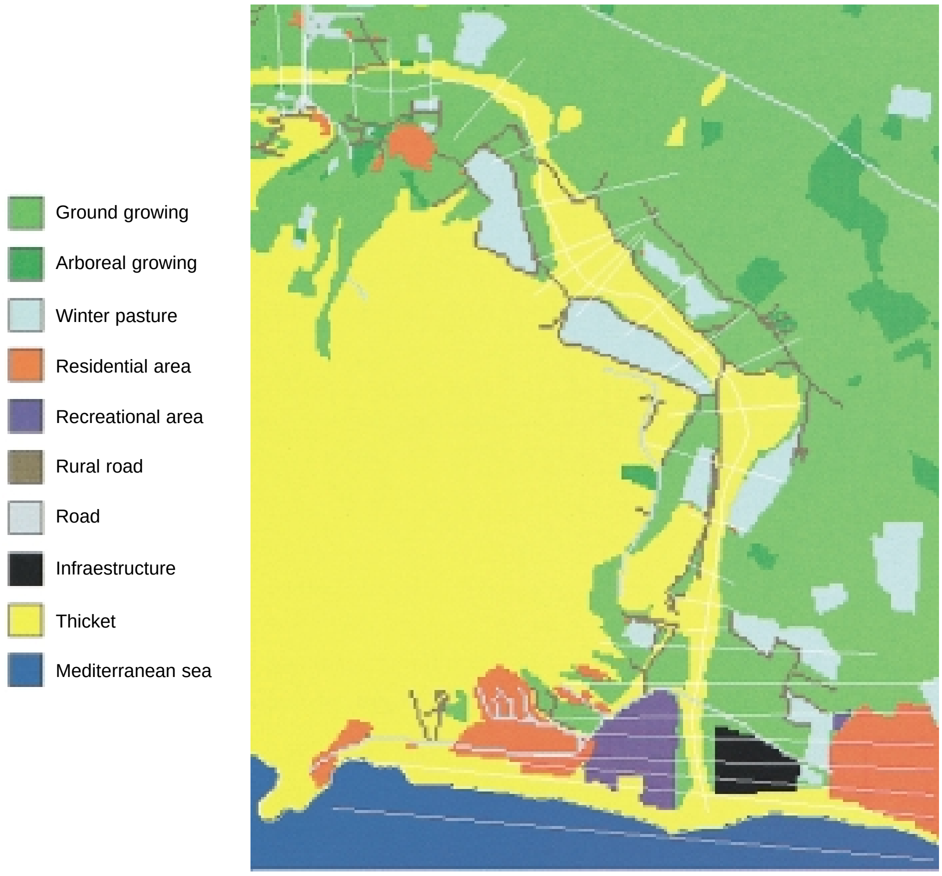


Figure 360. Map of soil uses in the mouth area of las Moreras ravine.

- City-planning measures, including the adaptation of city-planning regulations so that they consider the flood risk within the development procedure, and the approval city-planning regulations including provisions on protection against floods, and the adaptation of the already-approved city-planning programmes to flood risks.
- Actions on the road network, with the twofold purpose of saving lives and reducing the damage resulting from the

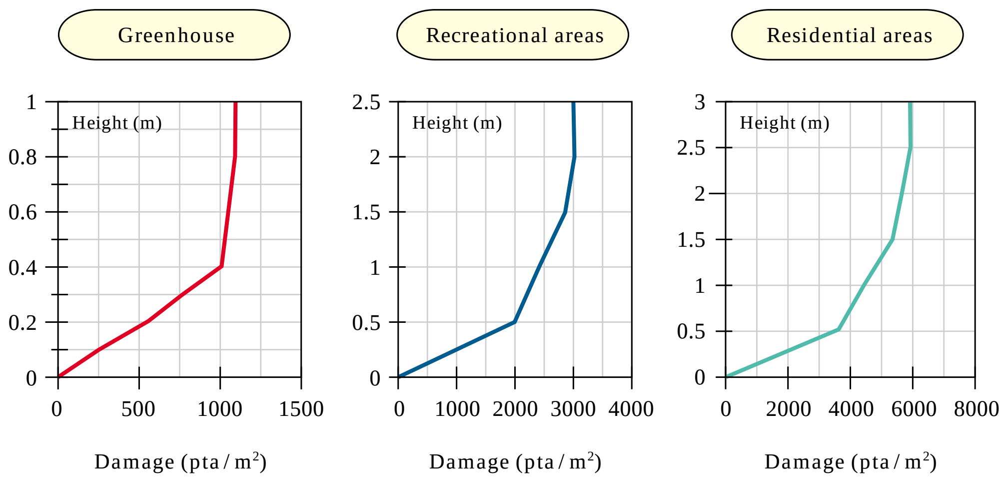


Figure 361. Functions related to the economic damage functions for different uses of the soil.

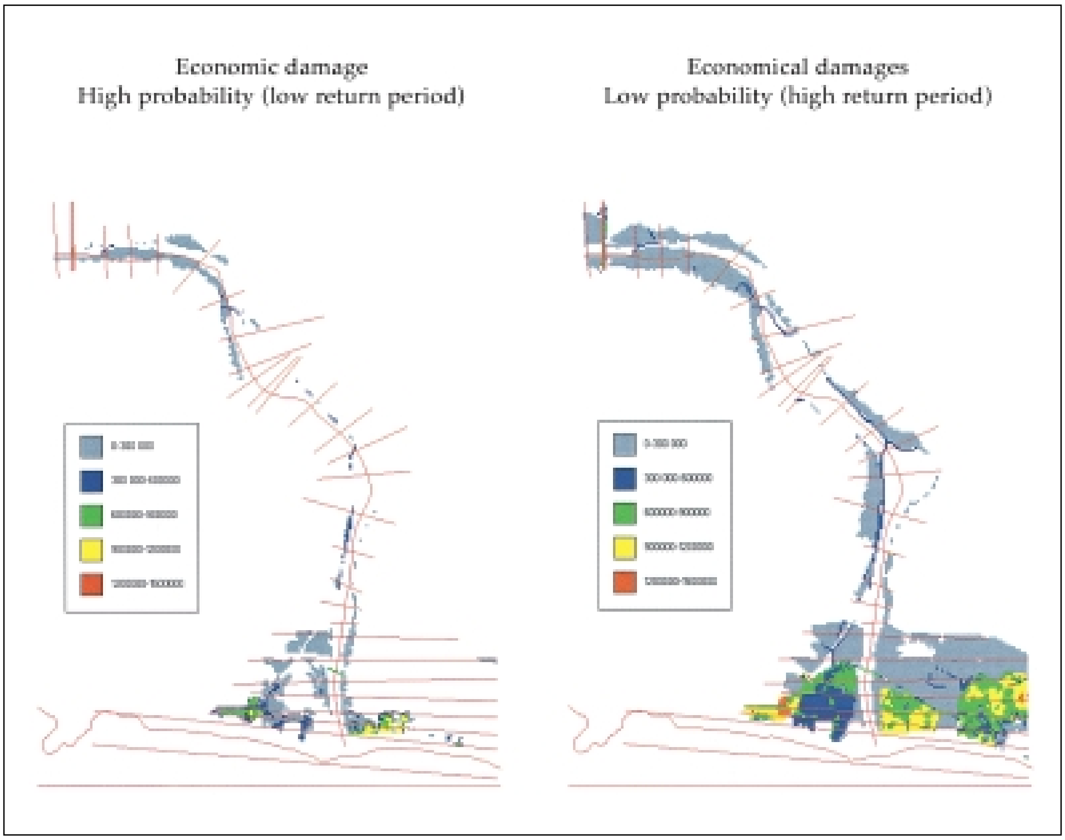


Figure 362. Cartography on the economic damage caused by floods in the Moreras ravine.

interruption of the service, with the inclusion of black spots, road signs and beacons on paved fords and flood-prone sections.

- Insurance plans aimed to protect the agricultural assets.
- Project for purchasing and re-naturalising riverside areas.

In order to guarantee the efficiency of the actions in the main flood-prone areas, it is advisable to group them on each of the first-rank flood-prone areas under an action project coordinated by the different administrations involved. An action project of this type should include risk maps (scale: 1:5,000), city-planning maps on the current development, a hydrological study of the flow, the mathematical pattern of the hydraulic behaviour, a programme on structural measures, an impact study and the programme on environmental adaptation of the solutions, a programme for adapting the city-planning regulations approved, a pro-

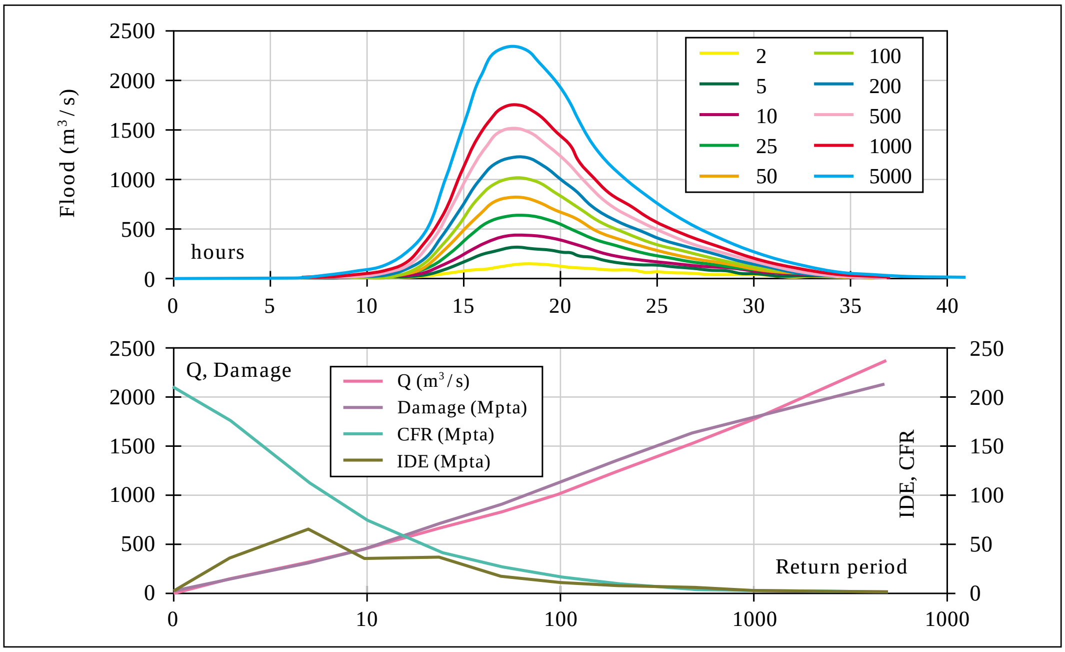


Figure 363. Hydrographs and economic functions on the damage caused by floods in the Las Moreras ravine.

gramme on emergency exploitation of reservoirs, if necessary, an inventory and action programme related to the equipment, an action programme related to the road network, etc ...

Determining the optimum protection level is another question about which several criteria can be adapted. On the one hand, the adoption of a very high level implies huge investments and few interventions every year. On the other hand, the frequent occurrence of flood-related damage is unacceptable. The desirable balance could be reached by protecting the cities which are currently exposed to the risk through structural defensive measures against ordinary and moderately serious spates, so that the flood is sustained only once per generation, and by entrusting the supplementary protection against extraordinary spates to non-structural measures.

On the other hand, the same criteria which have been used when designing large dams (flow with return period 500 or 1,000 years) should not be applied to channelling works. Such high returns are adopted, and must be maintained, because the dam can present a serious additional risk in the event of overflowing. But, in a channelling infrastructure, the overflowing does not worsen the previous situation, unless the water line is well above the land, which should be avoided in all circumstances, although it is impossible to avoid it in some cases, as mentioned previously. A reasonable return period for the design of channelling infrastructures can reach 100 years, but can be reduced to 25 or increased to 500 years in accordance with the characteristics of the protected area and the territorial impact caused.

In agricultural areas, a high level of protection will only be justified in the wide flood-prone areas with highly valuable crops, when the possible damage to be avoided is higher than the cost of the works, plus the possibility of the impact on the river ecosystem. It does not seem logical to design protection measures for return periods exceeding 50 years in these areas.

As regards zoning criteria, table 110 shows a potential theoretical scheme on the various uses of land which can be admitted for new city-planning areas to be developed in flood-prone areas.

As it can be observed, a more severe grading of the restrictions on use is proposed as the risk increases. The criterion adopted intends to generate a smooth city-planning transition between the safe and unsafe areas, avoiding sudden changes which could result in legal conflicts and environmental degradation.

3.12.4. Actions taken into account

3.12.4.1. Structural actions

In Spain, like in many other countries, structural measures have been traditionally implemented. They include the execution of infrastructure works which influence the mechanisms for the formation and propagation of high waters.

If we consider the functions of these measures, three categories can be defined :

- Reduction of peak flow: storage dams, controlled storage areas, emergency and diversion channels, conservation of land and reforestation.
- Reduction of the flood levels for a specific flow : channelling infrastructures, reduction in backwaters coming from downstream water, correction, protection and cleaning of channels.
- Reduction in the length of the flood: constructions for draining the transport network.

Structural measures account for a considerable proportion of the investments scheduled in the different basin management plans as regards protection against floods. The most significant ones are related to storage dams and channelling structures.

TYPE OF AREA / FLOOD RISK	Agricultural	Cattle-breeding	Residential Land		Industrial Land		Annoying Industry, unhealthy or hazardous	Equipment (9)		
			Low Density	High Density	Light ind.- Services	Heavy industry		A	B	C
High risk	YES [1]	NO	NO [3]	NO	NO [3]	NO	NO	NO [6]	NO [6]	YES [7]
Average risk	YES	YES [2]	YES [4]	YES [4] [6]	NO	NO	NO [6]	YES [7]		
Low risk	YES	YES [2]	YES [5]	YES [5]	YES [5]	YES [4][6]	NO	NO [6]	YES [5]	YES

Table 110. Possible scheme of the different uses of the land which can be admitted for new city-planning areas to be developed in easily-flooded areas.

(1) Restrictions in the facilities permitted for agricultural use.
(2) Restriction in heads of cattle.
(3) It will be admitted only if the municipal district is exposed to high risk, the response time exceeds three hours and the SAIH is in good working order, provided that severe City-planning regulations are adopted as regards defensive measures against floods.
(4) Subject to the adoption of the City-Planning Regulations indicated in (3), and provided that the response time exceeds three hours and the SAIH is in good working order.
(5) Subject to the adoption of City-Planning Regulations which are less severe than those indicated in (3).
(6) It will be admitted only if there is no safer alternative land in the municipal district.
(7) The equipment will only be used for the land to be developed.
(8) The response time has to be exceed one hour.
(9) The A,B and C categories correspond to a valuation of the importance of the equipment from vital (A) to parks, sports facilities, etc ... (C).

There is a limited number of dams which are exclusively designed to give protection against high waters. However, the large dams built for other uses in most cases, have resulted in considerable improvements in areas historically attacked by floods, since they have reduced the high waters' peak flow.

Traditionally, channelling constructions have been used as a means of protection against floods in urban areas. Nevertheless, this type of constructions have been recently used out of urban surroundings, leading to mixed solutions which can be used to channel the high waters and to protect the flow against erosion as well. Occasionally, these channelling constructions are the only structural solution which can be applied in ravines and gullies, where the construction of storage dams is hardly possible. Even at considerable heights and because of the strong inclines, they would not supply high retention volumes.

The execution of transfers as an emergency measure against floods has hardly been used and, with a few exceptions, is not reflected in the different basin management plans either. Although these transfers are usually an expensive solution whose hydraulic design is complicated, in some cases they make it possible to carry the water into the nearest reservoir, which makes the construction economically viable. For instance, this is the case of the floodway channel of the Argos-Quípar transfer (two tributaries of the Segura river); or the diversion at Paretón de Totana, which carries the spates of the Guadalentín (a tributary of the Segura) to the Las Moreras coastal ravine (Muñoz Bravo, 1995); or the highly special case of Mina de Daroca, a particular hydraulic construction for urban defence built in the years 1555-1560, which, through a diversion dike and a nearly 700-m long, 6-m wide and 8-m high tunnel, diverts the high waters of the ravine which runs through this city into a nearby channel, which is located further to the south, and drains its water into the Jiloca river (Fuertes Marcuello, 1987; González Tascón, 1996; González Tascón, 1998; Almagro Gorbea, 1998).

The number of controlled flood areas is also limited in Spain. In some cases, this is a solution which may be applied, especially when trying to solve local problems upstream from major cities. The construction of emergency channels is more frequent, especially those which divert high water flow into the sea in cities near the coast.

Eventually, it is indispensable to carry out transversal drainage works where linear infrastructure constructions (roads and railways) cross rivers and streams. In spite of the fact that the various regulations applied to the design and implementation of these works have considerably reduced the over-elevation of levels and the flood times, there are still drainage units which are insufficiently sized or poorly conserved.

3.12.4.2. Non-structural actions

Non-structural measures have been used for some years now. Unlike structural ones, these measures do not act on the high water itself by altering its hydrological or hydraulic characteristics. Instead, they modify the risk of damage to property related to floods in flood-prone areas. These measures can be divided into the following groups :

- Modification of the risk of damage to the existing structures: installation of locks and use of waterproof materials, relocation or protection of the valuable assets inside the buildings, location of buildings and their contents out of an area which can be damaged by floods.
- Control of the prospective development in flood-prone area: zoning in the flood plain and restrictions to the uses of land, insurance against floods.
- Improve of the response to through prevention mechanisms: installation of systems for preventing freshets and alarms with an adequate evacuation plan.

It is relevant to mention that these measures do not eliminate the flood risk, but can highly reduce their consequences. A more efficient protection method would require the development of defence plans which, according to the local circumstances, combine the structural and non structural measures and are adapted to the characteristics of the floods to the place where they take place.

The most significant non-structural actions are commented below.

3.12.4.2.1. Regulation of flood-prone areas

The regulation of flood-prone areas is a non-structural measure which has not been sufficiently developed in Spain. This is illustrated by the few references to these measures established in the basin management plans, even if their expediency is generally admitted and their development is programmed.

But the flood risk must be systematically included in the relevant city-planning instruments. With this aim, the general city-planning programmes should include the delimitation of public water domain assets within urban areas, and the identification of the types of risk considered if risk maps exist. In flood-prone areas where the city-planning development has been approved, the risk should be assessed and, if necessary, modified.

Technical regulations should be developed and applied in the national territory as a whole, given the important legal loophole on this issue. These regulations should be extended to ordinances against floods, modification in the provisions on annoying, unhealthy and hazardous industries, preventing them from being located in flood-prone areas, modification to regulations on electric facilities, preventing facilities exceeding a certain power from being installed in flood-prone areas, compulsory elimination of black spots on roads when any kind of restructuring is projected, adaptation of the regulation on public premises to consider the flood risk, adaptation of public health regulations, including a ban on dumps or cemeteries in flood-prone areas, etc ...

On the other hand, the Water Act and the RDPH define some general criteria for zoning channels and riverbanks, by delimiting easement and police areas such as shown in figure 364. These criteria may be modified in specific cases. The extension of the controlled area is generally fixed at 100 m, and in many cases, these strips fail to contain relevant areas where the use of the land should be restricted.

The following zoning criteria can be used as a reference framework for modifying the controlled area when necessary. A possible guideline could be (Estrela and Témez, 1993):

- In the flood plain, it is possible to differentiate the flood-prone area (which includes a so-called dangerous flood area) from the flow or intensive drainage conduit.
- According to the RDPH, the boundaries of the flood-prone area are marked by the high water with a 500-year return period. Within these boundaries, it is possible to establish a dangerous flood area, where important damage can be sustained (to property and to human beings) with the 500-year return high water. When defining this damage, criteria based on water depth and speed must be used.
- The intensive drainage conduit can be defined as the channel through which the 100-year high water runs without causing an over-elevation which is 0.3 metre higher than the one which would occur with the same high water if the entire flood plain was considered. This over-elevation could be reduced to 0.1 m if the flood increase caused serious damage and, in addition, if other locations for new constructions out of this area were feasible from the technical and financial point of view, or otherwise be elevated to 0.5 m.
- If there are protection dikes on the plain, they should be considered as the boundaries of the intense drainage conduit, provided that the increases in level to evacuate the 100-year high water do not exceed by more than 50% those which are tolerated to establish the limits of this high water without the presence of dikes.
- When a flow circulation analysis shows more than one preferential channel, a multiple intensive drainage conduit has to be created, which will be made up of several strips. One of them will correspond to the main channel, and the other ones to the different passages or preferential conduits for overflowing waters.

The controlled area is related to the concept of intensive drainage conduit, since, according to the Water Act, the regulation of activities and uses of land on such area is intended to protect the stream regime and the public water domain. It is therefore reasonable to extend the police area so that it can be associated with the intensive drainage conduit, an area where the flow concentration takes place and where, consequently, the most serious risk of personal damage and damage to third parties occurs. In the event that the general guideline establishing 100 m on each side of the channel gave rise to an area which is wider than the intensive drainage conduit, the controlled area would not be modified.

3.12.4.2.2. Warning systems

As commented above when analysing hydrologic data, the Automatic Water Information System (SAIH) must play an important part as an element of prevention and information on water in flood-related emergency situations.

In these situations, the SAIH must supply information about rain rainfalls and levels as recorded at checkpoints and reservoirs. With this information, it must be possible to estimate the probable evolution of levels and flow according to the weather forecasts, and to determine the possible flooded areas.

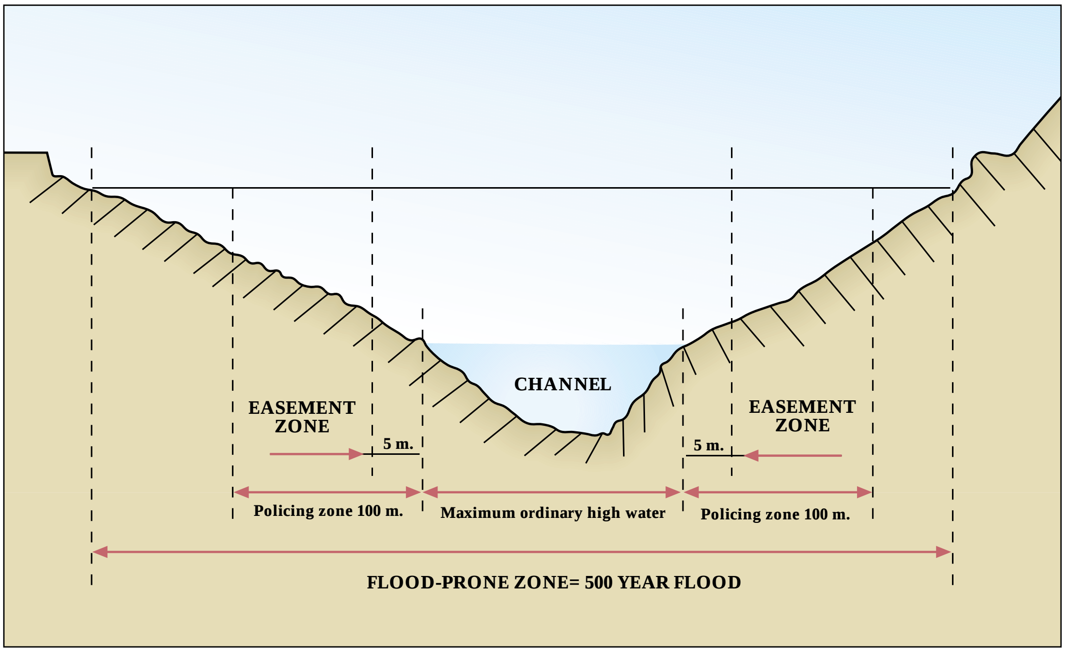


Figure 364. Channel zoning and easily-flooded banks under the Water Act.

This information is collected by sensors and remotely transmitted to the basin's Process Centres of the various SAIH. The estimations on the evolution of the rainfall require the use of mathematical patterns, which make it possible to carry out flow and level forecasts in channels and reservoirs in the shortest time possible, so that the civil protection services can quickly act. The predictions of this modelling system have to be as accurate as possible, in order to avoid unjustified alarms and the occurrence of floods whose magnitude is higher than anticipated. To define the potentially flooded areas, it is necessary to use hydraulic patterns which, on the basis of the flow, the topography and the characteristics of the flood plains, estimate the extension and the depth of the flooded area.

In some of SAIH which are currently operational, the patterns used analyse the rainfall data registered in a storm and issue predictions on high water hydrographs in reservoirs and in gauging units.

In short, this technology is considered as basic for the modern management of flood situations, as it has been possible to observed in several basins recently –with excellent results (for instance, see Cabezas and Yagüe, 1998).

3.12.4.2.3. Insurance

Insurance is an appropriate instrument of protection when defence costs are higher than the value of the protected area, and should be the basic means of protection in non-urban areas, especially when facing damage in agriculture and cattle breeding.

Insurance against floods could be included within the system of agricultural insurance and should cover different kinds of damage: non-harvested crops, damage to trees, loss of farming land caused by the erosion of riverbanks, etc ... This insurance has to be combined with a policy based on the purchase and re-naturalisation of riverbank land, thus harmonising the social demand for environmental conservation with the genuine rights and interests of the owners of these lands.

The development of an insurance programme for urban areas is much more complicated and its results are more uncertain and questionable. Even in countries where the insurance system is extremely developed, the amount of insured homes does not reach 30%, which makes it socially impossible to deny the emergency help to those who have not insured their assets. As a result, those who have actually insured their assets feel comparatively injured.

Throughout Spain's history, the part played by insurance companies as regards the risks related to the floods has been assumed by the Insurance Offset Group (*Consorcio de Compensación de Seguros* or CCS, 1998). Set up as a result of the damage caused by the Civil War, this Group pays compensations for disasters caused by extraordinary events, such as floods, provided that the extraordinary risk is not specifically or explicitly protected by another insurance policy. Furthermore, when the risk is under the protection of the insurance policy, the Group pays the compensation if the company's commitments cannot be fulfilled (bankruptcy, suspension of payments, etc ...).

In the field of insurance against floods, the concept of flood includes those arising from runoff water, overflowing of seas, lakes or rivers, and breaking of the sea against coastal land. Consequently, the risks related to breakage of dams or other hydraulic structures are not included, unless such breakage has been caused by the flood.

In addition, the Spanish system defines the risks according to the potential losses they can generate, but without requiring them to affect a high number of insured parties or a wide territory. Therefore, they do not require the official declaration of catastrophic area (CCS, 1999).

Before the approval of the Act of 21/1990, of the 19th December, on full freedom to offer any type of services other than in life insurance, and updating the legislation on private insurance, the cover for extraordinary risks falls within the exclusive responsibility of the Insurance Offset Group. From that date onwards, the policyholder is entitled to take out insurance for such cover with insurers meeting the conditions established by the current legislation. Consequently, in order to evaluate the premium rates, the private sector has started working on an analysis of the risks caused by floods.

The preliminary drafts of basin management plans have been the main source of technical information on floods used by insurance companies. These plans usually refer to river reacheswith a potential flood risk. However, some insurance companies use the municipal boundaries as an administrative division, adopting the following criterion: when a municipal boundary is affected by a river section where a specific risk has been identified under a basin management plan, the entire municipality is included under the same level of risk.

The map in figure 365 shows the levels of flood risks per municipality as adopted by the Mapfre insurance company in accordance with this idea. The making of risk maps in the manner indicated in this Report should contribute to the essential improvement of this criterion.

3.12.4.2.4. Legal Regulation

Considered within the framework of non-structural measures, a suitable legal regulation tackling the problem in an integrated way and clarifying the various concurrent responsibilities concerning this matter can considerably contribute to reducing the negative impact of floods.

In general, the main characteristics of the existing regulations concerning this matter are the concurrence of highly different jurisdictions, and the lack of a precise division of powers between the State, Autonomous Communities and municipalities.

In addition to this jurisdictional uncertainty, there is an extensive number of regulations, which especially tend to

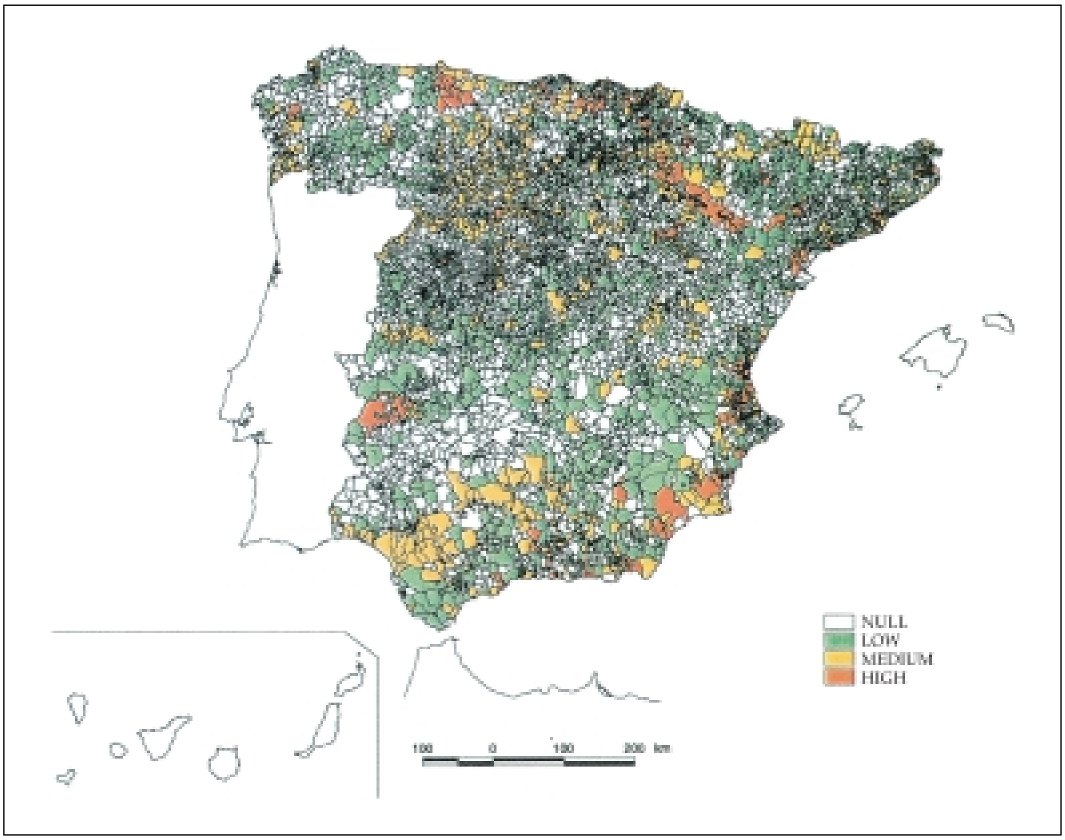


Figure 365. Map on levels of flood per municipality.

regulate the financial assistance which can mitigate the flood-related damage. As an example of this over-regulation, Bustamante and González (1997) point out more than six sets of rules have been issued every year (including Orders, Decrees, Acts, resolutions, etc...) for the last 25 years, concerning the damage caused by floods.

A basic problem is the identification of the risk area and the making of the cartography on the flood-prone area, so that by establishing decentralisation and technical cooperation mechanisms –separating the hydrological, hydraulic and economical analysis– and by linking this detailed cartography to city-planning provisions, the present weaknesses could be jointly overcome.

3.12.5. Civil protection planning against flood risk

In the Council of Ministers held on the 9th of December, 1994, the Basic Guidelines for Civil Protection Planning against flood risk were approved, establishing the minimum requirements on foundations, structures, organisation and operational and response criteria which had to be fulfilled by the different special plans concerning flood emergencies.

In accordance with its scope, the Basic Guidelines considered three types of plans –at State, Autonomous Community or municipal level–, to which a fourth one would be added as regards the so-called emergency plans for dams.

These Guidelines, focused on the decision-making process in emergency situations caused by spates, propose the classification of flood-prone areas into three categories: a frequently flooded area, which would include the flood-prone areas for high waters with a 50-year return period, an occasionally-flooded area for high waters with a return period of fifty to one hundred years, and a rarely-flooded area when the flood occurs with return periods ranging from 100 to 500 years.

The Basic Guidelines also establish that a key element for civil protection planning against a flood risk must be the risk analysis, and propose a similar classification to the previous one, including the concept of damage caused.

In addition, in the event of spate, the Basic Guidelines establish three different stages: pre-emergency, emergency and normalisation.

Generally speaking, the pre-emergency stage starts when weather forecasts announce heavy rainfalls, and finishes when it can be stated that the flood is imminent.

The emergency phase would start then, and four different situations can be established: situation 0, which is the end of the pre-emergency phase; situation 1, when the floods are located in reduced areas and can be dealt with using locally-available means, by means of a municipal emergency plan. Situation 2 arises if the local means are not sufficient by themselves, or if the flood affects several municipalities, which results in the application of an Autonomous Community's emergency plan. Eventually, when the emergencies affect national interests, Situation 3 starts, which implies the application of the State Plan.

The normalisation phase would start when all the measures aimed to protect people and property have been implemented and the basic services have been restored in the affected area. In this phase, the rehabilitation tasks would be carried out first, including the cleaning of homes and urban areas, repairing the most serious damage, etc.

In the event of flood risk, the basic functions of the Civil Protection State Plan are to establish the necessary coordination with the Autonomous Communities' emergency plans if the flood affects national interests, to prepare information systems and processes related to weather forecasts as well as interesting hydrological data concerning possible high waters, and to establish methods for bringing additional means and resources if those included in other plans are deemed insufficient.

When the flood results from dam failure, the Basic Guidelines provide for the application of the programme known as Emergency Plan on Dams: in principle, it has to be implemented by the organisation holding the concession. For each dam, this plan sets up the necessity to determine the causes which may have led to serious failure or even to its breakage, stating the area that can be flooded and the short-term evolution of the flow, and to determine the channels through which notice of any incident will be given to the authorities in charge.

Finally, before projects for the construction of dams are accepted, the Basic Guidelines establish that they have to be classified into three categories according to the potential risk which could arise from breakage or incorrect use. The same classification is included in the Technical Regulations on Safety of Dams and Reservoirs.

3.13. THE INTERNATIONAL CONTEXT

3.13.1. Introduction

This chapter analyses the current situation, as well as the main references introduced by the international context in the management of Spanish water resources. Specifically and in the first place, the engagements assumed and the guidelines issued by several international organs as regards water must be considered; and in the second place, the external conditions of the supply and demand of water must be contemplated, as they are stem from the common Agricultural Policy, and the GATT and Maastricht agreements.

The interest of the first of these questions is obvious and deserves to be mentioned. Especially the European Union, of which Spain is a member, shares certain powers with member States regarding the treatment to be given to water resources. This means that a double-direction relationship must be established between national and European Union authorities:

- Spain has to comply with the EU Directives which are directly or indirectly related to water resources; consequently, the future water policy will have to use these provisions as a reference, and in fact it is already doing so.
- In addition, it is necessary to explain and defend specifically Spanish points of view when defining and applying European policies. It is important that the European Union considers the special and varied geographical, climatic, and hydraulic conditions of Southern European countries, such as Spain, and that it takes into account, within the scope of European policies, relevant problems such as droughts, floods caused by torrential rain, desertification, sea intrusion, etc ...

As regards the following matters, water has always been a basic element in the agriculture of Mediterranean countries, Spain among them, because their agricultural potential depends to a large extent on irrigation activities, where water is the main factor in the production process, as is generally known. As commented above, this fact explains that the hydraulic policy has permanently been under the influence of the specific goals of the agricultural policy and, as it can be anticipated that this situation will continue in the future, it is essential to know the external framework within which this sector is going to evolve. This issue is analysed in great detail in the chapters on agricultural demand. This issue is therefore simply mentioned here, but we insist on its considerable importance.

The matters related to European convergence also have relevant implications for the Spanish water policy; we therefore refer to the corresponding chapters, but their importance is underlined here.

What follows is an outlook of the main agreements and international conferences on water policy, as an approach the specific European Union policy –which concerns us directly–, including a final reference to bilateral relations. The Portuguese case deserves to be analysed individually, and has been dealt with in a separate chapter.

3.13.2. The supranational nature of the water policy

3.13.2.1. International conventions and conferences

As regards water issues, international cooperation started for Spain around the 1950s, under the sponsorship of specialised United Nations organs (FAO, UNESCO, WMO). An example of this was the execution of a well-known hydrological cooperation programme worldwide, under the name of International Hydrologic Decade (1965-1974).

The United Nations Conference on Water, held in Mar del Plata (UNO, 1977), has been an important landmark in the international recognition of the fact that an adequate water resource administration is a key factor for improving the economical and social conditions of mankind. The recommendations approved then essentially referred to the assessment of water resources, efficiency in the use of water; environment, health and combat against pollution; policies, planning and development; natural risks; public information; regional and international cooperation.

As far as policies, planning and development are concerned, special attention was paid to the need for an integral planning on water, in line with the concern for guaranteeing the efficiency in the use of resources. It was also pointed out that water planning should be coordinated city-planning development.

Another reference which is worth mentioning is the International Decade for Water Supply and Collection, sponsored by the UNO between 1980 and 1990.

The International Conference on Water and Environment, held in Dublin in 1992, took firm decisions on water which were later developed by the United Nations Conference on Environment and Development, held in Rio de Janeiro in the same year. In this Conference, the document known as Declaration of Rio was issued, which contained 27 principles establishing for the first time the basis to reach a sustainable development. On the whole, these principles concern resources and can therefore be applied to water resource planning, insofar as these are general guidelines which all signatory States have committed themselves to respect. Besides, in this Conference an Action Plan was approved under the name of Agenda 21, which contains a full chapter on the protection of the quality and supply of freshwater resources; it is divided into 7 programme areas, which shows the importance given by the authorities to the water protection as a necessary condition for development without destroying the environment.

Later on, the International Meeting on Drinking Water and Environmental Collection was held in Noordwijk in 1994, which established the implementation of several action plans related to the Río de Janeiro Conference.

In 1997, the Special Session of the UN General Assembly, which treated matters concerning sustainable development, called for urgent action as regards water; as a result of this Session, and after a long preparation process, the VI Meeting of the UN Special Commission for Sustainable Development took place. It was held in New York in April 1998, and established the basis of the water policy for the 21st century. In addition, the UNESCO has also promoted several International Conferences on water problems.

On the other hand, the Spoo Convention, on assessment of the environmental impact in a cross-border context, and the Helsinki Convention, on the protection and use of cross-border water, both promoted by the UN Economical Commission for Europe, consider situations where water-courses are shared.

Within a European context, the Water Charter issued by the Council of Europe in 1968 is a relevant principle document. It establishes the criteria which must guide collective action at European level when facing water problems. These problems include the condition of water as an indispensable asset for life, the fact that it is a limited resource, the importance of water quality, etc... Two principles deserve to be highlighted: firstly, water is a common asset which has to be carefully used and must not be wasted; secondly, the authorities must establish a plan for the proper administration of water.

The European Council has also promoted the execution of several Conventions which are indirectly related to water policy, such as the Bern Convention of 1979 on the Conservation of European Wildlife and Natural Habitats, or the Madrid Convention of 1980 on cross-border between territorial Communities or authorities.

Finally, there is a considerable number of agreements and treaties on different specific matters. Some of them are commented in other chapters of this Paper, and represent an extensive set of rules as a whole. They have been promoted by a variety of institutions, which have all understood the importance of the problems related to water –and to environmental resources as a whole– as cross-border problems requiring coordination and cooperation between several territorial administrations, beyond political borders.

3.13.2.2. Water policy of the European Union

3.13.2.2.1. Background of the water policy in the European Community

In the mid-70s, an intensive legislation activity within the European Community resulted in five Directives on water, which reflected the quality-related objectives in terms of the final uses given to the water. This is the case of bathing water, pre-treated water, mollusc or fish-breeding water and human consumption. Later on, two additional Directives were approved, which for the first time dealt with the issue of controlling water-polluting emissions. The first one refers to the contamination produced by the toxic and dangerous substances indicated on Lists I and II, and fixes the objectives concerning the emission of 18 specific substances on List I, whereas the second Directive deals with the protection of groundwater.

After the late 1970s and early 80s, the Commission did not issue any new regulations on inland water, which led to new concerns the Community about water policies, basically related to reviewing and updating the existing legislation. In 1988, the ministerial seminar on water of Frankfort reviewed the existing legislation after detecting the need for incorporating certain improvements into the regulations, as well as the existence of loopholes which had to be dealt with.

Consequently, there was a second legislative spell in the early 90s which resulted in new Directives, such as the one on treatment of urban waste water, which inspired the current National Programme for Public Health and Treatment which is being developed in Spain, or the Directive on protection of water against the pollution caused by nitrates, which can be applied to surface and groundwater.

Within the framework described above, the new Framework Directive, which we will analyse below, is based on an integrating approach, since it includes all the separate regulations on water under one single legal body. In addition, it is clearly innovative set of regulations, since it proposes the abrogation and replacement of obsolete provisions. The political approval of the present proposition concerning the Framework Directive on Water, on the 17th of June, 1998, by the Council of Environment Ministers, and with the consent of all Member States, has been an undeniable landmark in the water policy of the European Union.

3.13.2.2.2. The present situation after the Treaty on European Union

The present EU action concerning water policy is based on the regulations of article 130 of the Treaty on European Union of 1992. This article is included in the chapter on Environment, and entitles the Council to adopt measures leading to the following objectives :

- Conservation, protection and improvement of environmental quality.
- Personal health protection.
- Wise and rational use of natural resources.
- At international level, promotion of measures aimed to solve regional or global environmental problems.

To achieve these objectives, the Council is authorised to adopt decisions regarding water quality by qualified majority (article 130.S.1), whereas the decisions concerning the management of water resources must be adopted unanimously (article 130.S.2).

The EU action on water has always been almost exclusively focused on the protection of water, initially with the purpose of guaranteeing people’s health, and later on an integrated basis with other environmental objectives.

Minimum attention, and sometimes none at all, has been paid to issues related to the quantitative problems of resources (assets, deficit, droughts, floods, etc ...) or to characteristics such as the predominance of agricultural uses or the intermittent nature of some river systems, which is easily explained if we consider the hydrological features of central and northern European countries, which are described in other chapters of this Paper, but are –as mentioned above– substantially different from Spanish characteristics.

This situation can lead to a negative imbalance between northern and central European proposals concerning water policy, and the problems, needs and priorities of Spain. It will be necessary to overcome this situation by exposing our water particularities within the framework of the European Union.

In addition, the measures adopted in Europe are relatively scattered and fragmentary, because they aim to solve specific problems.

In the chapters dealing with water quality, these questions are described in great detail. Among the existing Directives, we should mention here the Directive of 1991 on treatment of waste water, whose aim is the reduction of the contamination of surface water caused by nutrients from urban waste water. This Directive is especially relevant, given the major investments that the relevant Administrations of each member State have to make to comply with its conditions and deadlines.

After the approval of the European Union Treaty, the objective of the Commission has been to promote the EU water policy. To this effect, it issued in 1996 a Communication known as “European Community water policy”. This Communication, which inspired the subsequent Framework Directive, which is currently at discussion stage, can become extremely important in the future. Given the importance of this Directive, it will be analysed in greater detail in a subsequent chapter.

The principles of the European Union water policy, as established within the general sustainability principle, are the following:

- High level of water protection for human health.
- Caution or care when making decisions if the scientific knowledge is insufficient.
- Preference for preventive action.
- Correction of the damage at the source.
- Allocation of the costs related to preventive measures to the agents who are potentially responsible for the pollution.
- Promotion of integration policies. This principle especially concerns the authorities responsible for national and local policies, as main managers of the various policies related to water.
- Optimum use of the scientific and technical data available.
- Respect for the diversity of environmental conditions within EU regions.
- Use of methods for assessing costs and profits when making decisions.
- Commitment to the wider objective of achieving a balanced, sustainable development.
- International cooperation.

The general principle of subsidiarity should be added to these criteria, which means that the European Union will act in accordance with the powers assigned to it by the Treaty, but also that, if it decides to take any special action, it will have to justify its intervention adequately.

The Communication has raised criticism from some members of the European Parliament which, in a resolution issued in October 1996, attributed the lack of a coherent global strategy to this document, and insisted that a Framework Directive should define the objectives and the priority action of EU water policy on the basis of a systematic, clearly-defined relation between the provisions on emission and the objectives of quality. In addition, the resolution suggests that the global strategy should strongly consider the problems related to the shortage and excess of water already suffered by some member States.

A description of the current condition and future perspectives of the European Union law on water can be found in Fanlo Loras (1998).

3.13.2.3. The Directive on integrated pollution prevention and control

An interesting environmental Directive, which has not been incorporated into national law yet, deals with the integrated pollution prevention and control, which is briefly described below.

3.13.2.3.1. Objectives and scope

The Directive aims to prevent and reduce the pollution caused by different industrial activities indicated on List I, eliminating or –when this is not possible– reducing their emissions into the atmosphere, water and land. This Directive is based on the *principle of protection* of nature, and intends to hold member States responsible for the measures adopted, so that the competent authorities can verify that, in the execution of the different industrial activities:

a) the suitable measures are taken in order to prevent pollution;

b) therefore, no pollution is generated;

c) production of waste is eliminated or reduced:

d) water and energy resources are used in the most efficient way;

e) indispensable measures are taken to avoid any pollution risk if the industrial activity or exploitation is stopped.

The period for incorporating this Directive into Spain's internal law ended in September 1998.

3.13.2.3.2. Main aspects concerning the application of the Directive

Article 7 of the Directive establishes an integrated approach to the granting of permits or authorisations when different competent authorities are involved in the procedure. Consequently, Member States will have to coordinate fully the procedure and the conditions for the authorisation when, as is the case in Spain, the authorisations concerning an industrial plant are granted by different administrations depending on their respective powers.

The new combined authorisations or permits must specify the maximum emission limits for polluting substances (mainly those specified in Annex III).

The new authorisations will also have to contain provisions guaranteeing the protection of the land and groundwater. The maximum emission limits for the polluting substances declared will be based on the use of the best techniques available. It will also be compulsory to establish the suitable requirements concerning waste control, the methodology for their assessment and the sampling frequency, as well as the obligation to give notice of any irregularity concerning emissions to the relevant authorities.

Upon proposal by the Commission, the Council will fix, in accordance with the procedures established in Treaty, the maximum emission limits for:

a) such facilities as are mentioned in Annex I of the Directive, with a few exceptions.

b) such polluting substances as are mentioned in Annex III.

In the absence of maximum emission limits, those indicated in the Directives mentioned in Annex II may be applied.

These new combined authorisations and permits will have no immediate retroactive effects. A review of the procedures is therefore fixed, so that they may be adapted to the provisions of the Directive.

Finally, the Directive also regulates the access to information and the public participation in the procedure for reviewing permits, and establishes the compulsory exchange of information with the Commission every three years.

3.13.2.4. The Framework Directive on water

3.13.2.4.1. Introduction. Elaboration procedure

After the two legislative initiatives related to the abovementioned European Directives, the proposal regarding the Framework Directive on water was submitted as a reaction to the request made in June 1995 by the Council and the Commission on the Environment concerning the review of the Community water policy. As indicated above, in February 1966 the Commission issued a Communication on water policies, based on the principles of the Treaty's environmental policy, as well as on the V Community Action Programme towards sustainable development. The consultations which were carried out before the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, with the participation of users and other interested parties, reflected the interest and support raised by the proposal submitted.

The proposal document COM(97)49 which was eventually presented aimed to maintain the sustainability of the use of water throughout the 21st century, to improve the cost allocation system related to its use, and to guarantee the consistency of the different European regulations on water policy. All these provisions must be applied at river basin level, by means of integrating instruments for water planning, and by promoting public participation procedures.

The original proposal COM(97)49 has been modified by the Commission twice, prior to the relevant discussions in the Council and the Parliament. The first modification resulted in the COM(97)614, which was meant to contain a review of the Directive 76/464 on discharges of certain dangerous substances. The changes stemming from this modification were incorporated into the original text, thus creating a consolidated modified text. The second modification, COM(97)78, aimed to elaborate the technical specifications for the "good condition" of water as established by Annex V to the proposal. This second modification supersedes said Annex V of the consolidated version.

3.13.2.4.2. Contents and objectives of the Framework Directive

With the essential aim of achieving a sustained, rational use of the resource, this Directive is based on twelve principles. What follows is an outline of the most innovating ones, which might result in certain changes in the current approaches to water policies:

1. High level of protection. The Directive aims to protect human health to the maximum, as well as water resources and the natural ecosystems. Only by aspiring to the maximum will it be possible to achieve acceptable results.

2. The damage is repaired at the source. This is a consequence of the principle of protection, which is applied when the damage has already occurred. The originating source must be identified, and the first measure to implement is the action on such source to solve the environmental problem.

3. The polluter must pay. The costs of the prevention measures to be taken into account must be paid by the potential polluter.

4. The integration principle. Water policies, both at local and national level as well, must be implemented in an integrated way, in accordance with the established structures. Activities such as the land use planning or the management of the water resources will have to integrate the aims of the different policies.

5. The cost-profit analysis of the actions to be carried out. It seems reasonable to consider the profit to be obtained with regard to the cost of the investments to be made under the environmental policies. In this respect, the following instrumental policy methods will be taken into account:

   - The quality standards established in the regulations themselves.
   - The technical improvements available (BAT)
   - The internalisation of the costs of pollution through prices, market incentives and tax-related environmental measures, such as consumption rates, royalties, fiscal incentives, etc ...

The general objective of the Directive is to establish a framework for the protection of the European Union's surface and groundwater, estuaries and coastal water, through a series of main goals or elements. These objectives are:

- The supply of drinking water.
- The water supply for other economic needs.
- Environmental protection.
- The contribution to mitigating the negative effects of droughts and floods.

The Directive proposal tackles the action to be carried out by setting certain general objectives on water quality and quantity. These objectives will be reached through a series of measure programmes whose preparation will be assumed by the Member States.

Among other objectives, the Directive aims at Member States reaching what is described as "*the good condition of water*", which implies not only a proper chemical condition of water, but a good ecological condition as well.

The proposal establishes the concept of *river basin,* which was first introduced in Spain in the early 1900s, as a basic, unitary management element, so that only one authority is established for each basin and the administrative cooperation between member states is promoted.

In addition, the Directive proposes some measures concerning data collection, information exchange, the making of periodic reports submitted to the Committee, indicating that the Directive is being complied with, or reports made by the Committee, which has the power to modify new Directives. This will result in the continuity of the actions recently carried out by Spain in connection with its current policy on management and control of water quality and quantity.

Finally, it is expedient to highlight a relevant aspect for Spain, which was incorporated during the negotiation concerning the Directive: the fact that the Commission recognised droughts and floods as deficit situations, and therefore as factors hindering the achievement of the objectives set in the Directive in countries such as Spain, where, unlike other European countries and given its orographic, geographic and rainfall-related characteristics, rivers have a highly special water regime.

3.13.2.4.3. The implications of the Framework Directive on water in Spain's current water policy

As a matter of fact, most of the obligations arising from the Framework Directive were already contained in the EC legislation in force, regardless of the fact that Member Sates fulfil these obligations or not.

In addition, the difficulties that each country will have to face to comply with this Directive will be different for each of the Directive's provisions, and will depend on several factors, such as the technological development of the country, its infrastructures, constitutional statutes, geographical conditions, etc ... In this sense, the river basins and basin management plans, as basic management elements, will represent a novelty and a major difficulty for some countries, but not for Spain, a country with a long tradition and experience in managing water resources through the Hydrographic Confederations and water planning.

It is therefore expedient to emphasise the future importance of basin management plans within the new water policy designed by the Commission, which will reflect EU demands concerning the water policy. This could result in a certain adaptation of Spain's basin management plans, so that they include all the measures imposed in the new Directive.

In short, the main consequences of this Directive for Spain's current policy can be outlined in the following points:

1. An effort will be required to improve the present quality control networks for inland water, incorporating the relevant biological parameters, so far practically non-existent, so that they can be used when assessing the ecological condition of the waters. The achievement of such good condition has been proposed as the main objective of water planning in the recent amendments to the Water Act.
2. The coordination between the Central and Autonomous Communities' authorities so that they can cooperate in tasks such as:
   - The application of the best techniques available in industrial procedures as a whole.
   - The regularisation and, consequently, the previous treatment of indirect discharges eventually collected by municipal sewers.
   - The application of the principles which inspired the Directive: level of protection of the water resource, the repair of the damage at the source and the application of the principle that the polluter has to pay.
   - The incorporation of the Directive into Spain's legislation within a three-years period.
3. The combined approach must be adopted, under which emission controls will be created, based on the application of the best techniques available or quality objectives.
4. The costs of water must be internalised in accordance with the economic analysis that can be carried out individually in river basins. The Directive does not demand total recovery of the costs incurred; the present proposal is therefore profitable for sensitive sectors such as agriculture.
5. A technological and economic effort must be made to comply with the requirements of the Directive in accordance with the integrated pollution prevention and control.
6. It is necessary to promote basin management plans by providing them with sufficient means and infrastructures, so that they may undertake the necessary tasks and achieve the goals of the Directive.

Since this Directive is likely to be approved soon, with the modifications which could still be incorporated, it seems relevant to analyse in greater detail some of the aspects of the consequences exposed, such as the possibility of legal or organisational reforms, or the cost analysis in view of its adaptation and future incorporation into Spain's legislation.

3.13.2.5. Bilateral relations

In addition to general international policies, it is interesting to highlight the characteristics of the bilateral relations with neighbouring countries.

There had been previous agreements with these countries concerning the exploitation of rivers in border areas, at least from the 19th century onwards. The most recent agreements refer especially, though not exclusively, to hydroelectric exploitation units.

An agreement was signed with France in 1973, concerning the use of the Garonne's upper section. Under this Convention, the Spanish government granted to the French government the right to exploit a waterfall located in Spain. In exchange, France had to give Spain certain amounts of power, free of charge.

The Conventions signed with Portugal in 1964 and 1968 also deserve to be mentioned. Given their special relevance, we refer to them in separate chapters of this Paper.

3.13.3. Conclusions

The conclusions which may be inferred from the international context for Spain's water policy are various and relevant, and obviously create an external reference framework which is completely different from the traditional one. When revising the comments above, together with the information contained in other chapters about the complexity of the agricultural matters and the conditions of the European convergence framework, some basic conclusions can be drawn, which are summarised below.

In the first place, as a result of the growing globalisation, the autarchic production patterns associated to the model of traditional water policies have been rejected definitively. The economical activities related to water (basically irrigation and energy) must explicitly consider their productive potential and the internal and external market situation in an economy which is increasingly and deregulated and interconnected. Consequently, given the current external context, it is relevant to predict an uncertain future for Spanish agriculture in general, and for irrigation in particular, as a result of the important operational changes recently suffered by agricultural markets. Other internal factors which the agricultural policy has not solved yet help to reinforce this diagnosis. Given this situation, as regards water resource management, it seems advisable to adopt solutions in the short term which will not jeopardise major financial resources, resulting in the flexibility margin required to adapt to the new situation.

Obviously, this implies that, given the internal and external conditions, the traditional policy of promotion of hydraulic structures for the massive development of irrigation is no longer valid. In the medium or long term, all the viability perspectives observed seem to be positive for exploitation units reaching a satisfying level of profitability in an increasingly competitive and deregulated environment. At present, the problem to be solved is the extent to which irrigated land can contribute to achieve this objectives, and in what places.

Evidently, the private profitability of exploitation units is linked to the water-related costs allocated to these exploitation units. If the allocation is only limited, the company profit can be increased, but both the competitiveness of Spanish economy as a whole and the efficiency of the use of water resources can decrease. Only a weighted assessment of these circumstances, necessarily combining the environmental effects of the alternatives, can lead to an adequate solution.

In line with these circumstances, as it has been mentioned above, it does not seem advisable to expand continental crops, whether herbaceous or industrial, for several reasons: the limited surfaces or productions entitled to receive subsidies, and the foreseeable situation of downward common agricultural prices, aggravated by the market deregulation brought by the GATT agreements. The surpluses from European countries with the highest productivity on these crops are even likely to replace part of the domestic production. This is why we can predict, with the margin of error which is inherent to this type of estimations, that the regressive tendency which has already been detected in most of Spain's continental internal irrigated land is likely to increase, given its low profitability, despite the protection mechanisms which have been provided by the new CAP for continental products and the relative abundance of water resources available in these areas. However, this situation can be qualified by the fact that Spain's economy is loss-making, since it imports agricultural products from continental crops. The final result of these highly different effects is therefore uncertain.

In addition, as has been noted in the relevant chapter, the economic convergence is considered as a general-interest objective. In this sense, it is expedient to state that the use of these products should pursue, in the next few years, the objective of improving the competitiveness of Spanish economy. It would not be reasonable to improve the convergence with regard to the income level of a group if the total income is decreasing as a whole. In this respect, the mechanisms for diagnosis and inter-territorial rebalance must have a decisive part, and are likely to lead to the obligation of using water resources in a more efficient way, since they are rare and limited in most of Spain's territory. This might require a different allocation of these uses between territories or between the various applicants competing for the right to use them.

This conclusion is reinforced if the environmental aspects which are always related to any use of public water domain are taken into account. Indeed, given that it is impossible to avoid all the negative effects on the environment, and it is inevitable to maintain a certain level of economic activity which precisely causes such effects, it seems obvious that the authorities, comparing different projects causing the same environmental impact within admitted standards, should allocated the use of water to the one offering the highest return.

These considerations would make it rather difficult to justify, for instance, the stoppage of the development of the comparative agricultural advantages offered by Spain's southern and Levante crops, especially if we take into account both the fact that such advantages are rare in the Spanish economy and their strategic opportunity on international markets.

As far as convergence is concerned, considering the public awareness on water-related matters which has already been raised in Spain, the most important actions to be implemented under the new water policy do not have to be necessarily considered within the framework of infrastructures, unlike the traditional model. There is a wide margin in the field of the non-structural measures which can be adopted to improve the current water resource planning.

Among these measures, it is relevant to mention those aiming to promote the allocation of water resources, and therefore the efficiency in the use of water, either by facilitating the assignment of rights to use water to different concessionaires, or by implementing a proper economic and financial regime fostering such efficient use and the respect for the environment. The importance of this kind of measures must be emphasised, especially if we consider the probable shortage of public financial resources, not only because they would solve several structural problems, but also because they have a positive effect on the National Budget.

In line with this, two other kinds of measures have to be taken into account on the supply side. On the one hand, the measures aimed to reduce the expenses associated to the management of water resources, adapting the structures, improving water Administration and promoting the participation of users in the management ; on the other hand, the measures aimed to favour the incorporation of private capital into the investments made in water infrastructures, thus reducing the burden over public resources. The economic rationality that all these measures can bring to Spain's water resource planning has to be especially highlighted.

In addition, unlike the traditional pattern, the considerations on the quality of the resources and the conservation of the environment are among the most relevant demands in the international context. There is an extensive number of European legal provisions calling for stricter quality requirements is –as indicated above–, and there should be even more in the future.

Finally, there is an unmistakable trend leading to the shared management of cross-border, international rivers, and to a supranational water policy for these rivers. This shared management goes well beyond fixing certain cooperation engagements demanded both by the countries' vicinity and by the specific hydrologic and socio-economic circumstances of these rivers. In the Spanish case, it is absolutely necessary to develop and improve these cooperation mechanisms with Portugal, as noted in the corresponding headings.

3.14. COOPERATION WITH PORTUGAL

3.14.1. Introduction

As indicated above, the Spanish relations with Portugal are highly important as regards water resources. These relations have been developed within a framework of coordination and mutual collaboration, consistent with the defence of both parties' legitimate interests.

The development of these relations is obviously conditioned by the geographical framework, the hydrological features of the basins shared –basins of the rivers Miño/Minho, Limia/Lima, Duero/Douro, Tagus/Tejo and Guadiana–, the current EU and international laws applicable to both parties, and the specific bilateral agreements. What follows is a brief outline of these aspects.

3.14.2. Geographic framework

Almost the whole surface area of the Peninsula, about 581,000 km^2, is shared by both countries, with 89,000 km^2 for Portugal and 492,000 km^2 for Spain. The surface areas and the distribution of the five Spanish-Portuguese basins, shown in figure 366, are detailed in table 111.

These five basins, whose global surface area reaches about 264,700 km^2, cover 45% of the peninsular surface and represent 41% of the Spain's total surface area (506,470 km^2) and 62% of Portugal's surface area (91,631 km^2).

These high percentages clearly show the territorial importance of these basins for both countries.

Generally speaking, the Spanish part of these basins is located upstream from their Portuguese part, and there are sections where the channel acts as a border between both countries. As regards river Miño, its final section and the border overlap, without entering Portugal. The case of the Guadiana river is rather particular since it enters Portugal after a first border section before acting again as a border downstream.

3.14.3. Water resources in border rivers

The average natural resources of the five basins are shown on table 112. It has to be observed that this flow is highly irregular, which means that the average values are given as an indication only, and they have to be used carefully when considering the actual availability.

In the five basins in Spain's territory, the important regulations passed have led to a reduction of the seasonal and

Figure 366.
Map of the Spanish-Portuguese basins.

Basin	Total surface area (km²)	Spanish Surface area		Portuguese Surface area	
		(km²)	%	(km²)	%
Miño / Minho	17,247	16,347	95	900	5
Limia	2,423	1,253	52	1,170	48
Douro / Douro	97,670	78,960	81	18,710	19
Tagus / Tejo	80,190	55,810	70	24,380	30
Guadiana	264,652	55,597	83	11,525	17
Total	**67,1222**	**207,967**	**79**	**56,685**	**21**

Table 111. Distribution of the surface areas of Spanish-Portuguese basins.

yearly irregularity downstream, especially in southern basins. If the yearly average flow of the Douro in Saucelles, the Tagus in Alcántara and the Guadiana in Badajoz, excluding the Miño, were considered as Spanish flow (as done by the EEA), the 41 km indicated on the table would be reduced to 25.

3.14.4. Water quality in border rivers

Apart from satisfying a common will and a logical need, the EU Directives themselves and the Convention of Helsinki on cross-border pollution state that, in the short term, the actions to be carried out in connection with the joint management of the water quality have to be coordinated between Spain and Portugal, specifically with regard to a common declaration on quality objectives for the river reaches and aquifers shared by both countries.

On the whole, it can be stated that the quality water flowing from Spain to Portugal is appropriate, except in the Guadiana basin. This is due either to the limited polluting charge or to the water-treatment effect of large reservoirs. Even in the above-mentioned Guadiana basin, a considerable improvement to the water quality has been perceived lately thanks to the progressive implementation of the new EDAR.

Even if the general situation can be described as acceptable, there are some specific problems that must be expressly analysed.

Among the main problems, it is necessary to mention, as stated above, the incomplete treatment level of some urban discharges, which occasionally leads to organic pollution in areas bordering Portugal. The treatment level in towns with a population of over 10,000 in areas near the border do not always conform to the recommendations of the Directive 91/271/EEC, although it has to be remembered that, until 2005, the European legislation will not impose the implementation of a suitable treatment for this kind of discharges, and the considerable circulating flow dilutes this insufficiency to a very large extent. Thanks to the important actions carried out by Spain to clean an and purify water, it will be possible to correct such deficiencies in the short and medium term.

3.14.5. Bilateral conventions

Initially, it must be pointed out that the treaty on boundaries between both countries was executed in 1866. In 1912, an agreement was also entered into concerning the industrial use of water in border sections, which established that both nations would have the same rights and consequently, that each would be entitled to half of the flowing water. On the 23rd of August, 1926, the RDL regulating the Douro waterfalls was issued, which made it possible to construct of Ricobayo, Castro, Aldeadávila and Saucelle on the Spanish side, and Miranda, Picote and Bemposta on the Portuguese side.

In the 1960s, two international agreements were executed, which were essential to regulate Spanish-Portuguese relations on water.

Later, in 1964, an Convention Agreement was signed, under which the hydroelectric potential of the Douro's international section and some of its tributaries was shared. It is based on the allocation of a similar section of the mentioned potential to each country. In addition, Spain was allowed to divert water from the Spanish source of the Túa basin up to the Sil basin. The actions scheduled under this Agreement have been completed, with the exception of the Túa/Sil transfer, still under study.

Pursuant to a second new Convention, signed in 1968 the international reaches of the Miño, Limia, Tagus, Guadiana

Basin	Total flow (hm³/year)	Spanish flow		Portuguese flow	
		(hm³/year)	%	(hm³/year)	%
Miño / Minho	12,205	11,305	93	900	7
Limia	1,912	812	42	1,100	58
Douro / Douro	21,858	13,658	62	8,200	38
Tagus / Tejo	17,253	10,853	63	6,400	37
Guadiana	6,426	4,726	74	1,700	26
Total	**59,654**	**41,354**	**69**	**18,300**	**31**

Table 112. Distribution of natural flows in Spanish-Portuguese basins.

–upstream section in the Badajoz province– and their tributaries were allocated. The possibility of transferring water both from the Guadiana river –assigned to Portugal– and from its tributary, the Chanza river, assigned to Spain, was established, as well as the possibility of transferring the Tagus water in a maximum amount of 1,000 hm^2 a year.

Two international Spanish and Portuguese Commissions were created to apply these two Conventions. They were later integrated into the Spanish-Portuguese Commission for regularising the use and exploitation of international rivers border areas. The actions carried out on the borders of both countries are currently being coordinated by this Commission, which has found solutions to solve the disagreements appeared in the application of the mentioned Conventions of 1964 and 1968. In connection with the Convention of 1968, the works related to the exploitation of the Miño (the attribution of the Sela waterfall to Unión Fenosa and Electricity of Portugal have not been executed yet) and the upper Guadiana (hydraulic infrastructure in Alqueva) have not been completed yet.

The international lower section of the Guadiana river is not allocated yet. The distribution established in the treaty 1912 treaty is therefore applicable, with the reservations stemming from its particular environmental features.

In the current Treaty on Amity and Cooperation of 1977, especially in its article VII, it is precisely stated that both nations have to proceed to the rational use and the protection of the natural resources they jointly hold. Therefore, this generic statement must be applied as a guideline for the administration and management of the water resources of the shared basins.

3.14.6. Present situation and future perspectives

In recent years, the new projects on uses of water which were being studied by Spain and Portugal, and especially the transfer plans scheduled in the draft of 1993 of the National Water Plan (MOPT, 1993) affecting the Douro, Tagus and Guadiana rivers, raised certain logical concern in Portugal. This situation led, on the occasion of the Spanish-Portuguese summit of 1933, to the decision to create a working party for the elaboration of a new collaboration convention on water resources. This agreement would integrate and amplify the two previous Conventions. The aim of the working party was to reach agreements under which each country would obtain maximum profit from its resources, while respecting the lawful water-related interests of the other.

The relevant work was completed last year, on the 30th of November 30, when the Convention on cooperation for the protection and sustainable use of the water from Spanish-Portuguese river basins was executed. This Convention extends the term of the Conventions of 1964 and 1968, as well as their jurisdictional scope, generally limited to the hydroelectric exploitation.

In the new Convention, the cooperation is extended to the improvement of the water quality, the prevention of extreme water phenomena (droughts and high waters) and the mitigation of the phenomena caused by possible incidents due to accidental pollution. The exchange of information and technical knowledge on the subject is also considered, in anticipation of the relevant decisions which, it is expected, will be made under the future EU Framework Directive.

Special attention has been paid to the protection of water (even in the ecosystems depending on water): as regards environmental cross-border impacts, the Convention defines a procedure including a first information stage, followed by a consultation stage. As regards protection of water, the parties have decided to agree by common consent the flow rates required in each basin to combine efficiently the good condition of water with its present and future uses.

The Convention will come into force after it is ratified by the Spanish Parliament.

3.15. RESEARCH AND DEVELOPMENT IN WATER RESOURCES

3.15.1. Introduction

To have an overall view of water-related problems, a proper assessment of the current scientific knowledge on water is an important factor which must be taken into account.

We may know the main physical, chemical and biological characteristics of the water, but we are still far from reaching absolute, comprehensive knowledge of them all.

A better knowledge of water interaction, both in living and lifeless matter, can be useful when establishing the scientific basis of a correct technological evaluation of the various uses of water. In this respect, it is logical to expect major progress concerning the amounts allocated to supply and irrigation, as well as to the production of hydroelectric power. For example, it is expedient to highlight the improvements in irrigation matters resulting from research on the consumption of water by plants. This research has been the basis to establish the allocations and set the necessary flow rates, which means that the world of water technology and that of its legal and administrative regulation may and must be linked, even if they seem independent at first sight.

For all these reasons, it has been considered highly important to include in this White Paper a description of Spain's current research and development activities concerning water resources.

The present and future importance of scientific and technological research on water must be highlighted as the basis for the various ideas and actions leading to a better use and to a more skilful regularisation of the relations between the different uses and their conflicts with the natural environment.

Within the considerable complexity of the Research and Development aspects (R+D) linked to water resources, the different activities tend to be classified according to the different professions, organs and companies involved, as we shall comment below. The concurring sciences and knowledge cover also an extensive range of activities, including engineering, sciences of the earth, biological sciences, economy, law and social sciences, not only in their scientific and technical fields but also in management, administrative and political spheres. As regards the activities actually carried out, given the different treatments and viewpoints, it is usually advisable to differentiate and clarify the aspects of the water cycle, such as surface and groundwater, or its quantity and quality, but without forgetting the interrelation, interdependence and partiality of the of the sectoral approach. Broadly speaking, water is essential and irreplaceable for life, environment, society and economic activities, but its limited availability implies a competition element with regard to its possession which leads to a delicate balance, whose regulation requires research in fields going far beyond technique.

In addition, it would be interesting if the present social sensitiveness towards water policies, which has to be developed in the immediate future, could be used as the basis for a modern R+D policy on water resources, in accordance with Spain's scientific level. It seems illogical to accept the continuity of the present situation, where foreign institutions are often asked to study Spain's own problems, which are completely different from and unrelated to those existing in the geographical and social environment where these institutions usually act.

The appendix to the National Programme on Water Resources of the CICYT is an attempt to classify research areas and to identify the main needs. This appendix is supplemented both by the National R+D Programmes on Climate and Environment as regards water meteorology and treatment of polluted or waste water, and, for certain aspects, by National R+D Programme on Agriculture.

3.15.2. University activities

Basic and applied research is essential to University itself, through its Departments, Institutes and Associated Centres. However, in the field of water resources, research activities are relatively recent. Historically, these activities were carried out in Engineering Faculties, and especially –since the 19^{th} century– in the Civil Engineering Faculty. With a few exceptional cases (such as the Hydrobiology Laboratory created in 1914 by Celso Arévalo), it was in the 1970s when these activities started in other university centres. The growth has been constant ever since.

A major impulse for water research came from the now-defunct Joint Spanish-American Committee for Technical and Scientific Cooperation, which linked Spanish Centres, professionals and professors to research centres in the US. When this Committee ceased to operate, these activities started within the framework of the subsidies granted by the *Dirección General de Investigación Científica y Tecnológica (DGICYT)* –General Directorate for Scientific and Technological Development– attached to the Education and Science Ministry (or its equivalent Ministries) and, later on, to the CICYT, which will be commented below. The Integrated Actions for bilateral exchange organised by researchers in several countries have also had a major part. For Spain, becoming a EU Member state has been an important incentive, thanks to which previously-formed and new groups could join their efforts with groups from other European countries and compete for research funds in the most important areas.

At present, there are research groups on different aspects of water resources in about 25 of the 54 Spanish universities, even if few of them have the size required to carry out an autonomous activity. If we combine the different types of scholarship holders and the researchers, there are about one hundred staff members carrying out full-time or part-time research activities on water resources in universities. The employment unstableness of many researchers makes their research activity rather problematic.

Given the need for external financing of these groups, in order to complement their financial sources or to compensate for their inability to access research funds, or simply the search for income by researches to increase their income, they often accept jobs which have very little to do with the research. The activities in these areas could have some effect on the activities carried out by study and engineering companies and freelance professionals.

Several University Institutes on water have been created with or without economic support from other state-owned or private entities, often with important investments in equipment and facilities, but frequently without any specific research programme or with a preferential interest in rendering external services which, on the one hand, allows them to increase their financial resources but, on the other, often has a detrimental effect on the research work inherent to Departments and Institutes.

It must be especially highlighted that most university research groups have focused their work on groundwater, mostly but not exclusively in connection with the Geodynamics Departments. Most of the remaining Departments carry their work on Civil, Mining, Agronomy and Forestry Engineering, and to a lesser extent Industrial Engineering. As regards surface water research and hydrometeorology (and their local and socio-economic influences), the development has been more limited in University Departments, with some exceptions in newly-created engineering centres. This situation strongly contrasts with the major human and economic state-owned resources allocated by Spain to the development of surface water.

3.15.3. Activities of Public Research Institutions

Among the water-related research Centres, it is expedient to distinguish state-owned Centres from private ones. Among state-owned centres, there are universities and university institutes, as well as Public Institutions for Research (OPI).

There are several Public Institutions for Research (OPIs) interested in water resources. The most relevant of these Institutions as regards research per se is the *Consejo Superior de Investigaciones Científicas* (*Higher Council for Scientific Research)* –or CSIC–, even if its activity in this field is relatively new and limited and has been not been given priority. Such activity is mainly focused on hydrobiology, desertification and basic hydrological procedures. Another OPI to be highlighted is CIEMAT. The fact that Spain has joined the International Geosphere-Biosphere Programme has not been a major incentive yet, but there are reasonable expectations for prominent activities. Between 1965 and 1980, the Hydrology Institute, linked to the CSIC and the *Centro de Estudios y Experimentación de Obras Públicas* (*Public Works Study and Experimentation Center*) (CEDEX) through its Hydrographic Study Center (CEH), has been highlty dynamic as regards hydrological works, mainly concerning surface water, even if, strictly speaking, the work carried out was more focused on making studies than on research. This Centre was eventually closed.

There are two major official centres interested in water resources, whose main activities have been related to studies and projects. One of them is the CEDEX, mentioned above. Through the CEH, the CEDEX has devoted considerable efforts to studying hydraulics, surface water, water quality, desalination, hydrological planning and resource management. Through its Applied Technique Study Centre (CETA), it has also carried out relevant work in the field of isotopic and environmental hydrology, which can be considered as real research to a large extent (Martínez, 1999). The other centre is Spain's Geomining Institute (ITGE, previously IGME, Spain's Geological and Mining Institute), which focused its activity on making or outsourcing studies, especially related to groundwater resources, without a lesser research activity, in the strict sense of the word.

The *Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria* (National Research and Land and Food Technology Institute) or INIA trained many young agricultural engineers abroad, which resulted in the launch of outstanding research programmes in the 1970s, with several highly active centres. The transfer of powers to the Autonomous Communities has split up the INIA, but its centres have remained active within the new organs to which they have been attached and are active OPIs strongly interested in water resources within the agronomy field, maintaining relations with State organ from which they originally stemmed.

3.15.4. Other research and development activities on water resources

In the public or similar sector, the most outstanding activity in recent years has been the outsourcing of studies by the *Empresa Nacional de los Residuos Radioactivos* (State-owned company for Radioactive Waste) or ENRESA. Most of these studies imply considerable research done with University Centres and Companies, but under the specialised, particular aspect of water in low permeability areas. ENRESA is not an OPI and does not carry out any work by itself. The results obtained are disclosed when the company deems fit. The contracts are not allocated under the usual criteria for public invitations to tender.

In 1992, the Centre for New Water Technologies (CENTA) was set up, as a mixed non-profit association, made up of companies and public Organs, whose purpose is to contribute to the activation of the water sector in Spain. Its main activities are focused on research promotion and promoting the water sector and national technology abroad.

Research and development within the privately-owned companies with regard to water resources is limited. The Canal de Isabel II and the General Water Company of Barcelona carry out activities in the field of drinking water treatment, analytic techniques and handling of water resources, executed by their own specialists or through an agreement with University Centres or the CSIC.

Other development and research activities are more sporadic, such as those on surface water, which have been carried out by University Departments at the request of electric companies, or those related to scholarship competitions organised by foundations such as Juan March, Areces or Barrié de la Maza, which only in few occasions have an influence on water resources.

3.15.5. The CICYT and other organs within the Autonomous Communities

In order to avoid scattering the initiatives and carrying out research and development with state-owned funds, with the resulting lack of coordination, duplication of efforts and atomisation, in 1986 the Government decided to create an Inter-ministerial Commission for Science and Technology (CICYT). Its immediate ancestor was the Consulting Commission for Scientific and Technical Research (CAICYT), which became the CICYT after the Act on Development of Technical Research and General Coordination was passed on the 14th of April, 1986 (Science Act), with the responsibility for the elaborating and monitoring the National Plan on Scientific Research and Technological Development (National R+D Plan) in national and international spheres. At present, this Commission is presided by the President of the Government, and is made up of the Ministries with jurisdiction over research matters. Today, as regards water resources, these Ministries are the Environment Ministry, the Agriculture, Fisheries and Foodstuffs Ministry and the Ministry of Development, since the CEDEX is organically attached to this last Ministry.

In 1998, the Science and Technology Office (OCYT) was created, which is the supporting unit for planning. One of its main duties is give support to the CICYT for the functions of planning, monitoring and evaluation of the most important lines of the scientific research policy, technological development and innovation financed by the National Budget.

One of the main objectives of the National R+D+ Plan is to promote scientific and technological development, and to plan the public efforts on R+D matters, according to National Programmes, Sectoral Programmes and Programmes agreed with the Autonomous Communities.

The R+D activities concerning water resources had not been explicitly incorporated into the National Programmes until the notice of 1995, even if R+D priorities had been considered in the Area of Life Quality and Natural Resources with regard to water resources in several National Programmes, such as the Environmental Programme, the Agricultural Natural Resources R+D Programmes, and other similar ones.

In its National Programmes, the current III National R+D Plan, approved by the Government for the 1996-1999 period, includes the Programme on Water Resources, resulting from the collaboration agreement entered into the CICYT and the relevant water management authorities. The Programme has been designed with the purpose of including R+D activities carried out by research centres, companies and administrations, which contribute to supplying the scientific and technical support required for the development of water resource management organisms and for the new technological needs of associated sectors.

The first notice offering subsidies for R+D and infrastructure projects under this new Programme was issued in 1996, and the proposals concerning the 1997 notice are currently being evaluated. It is therefore not yet possible to know and evaluate the importance of this programme, or how it is going to promotion research and development, how the IPOs are going to be involved and how companies and other entities will support them. As shown in table 113, since 1988, 90 R+D projects have been financed, for a total amount exceeding 1 billion pesetas. An amount of 243.3 million pesetas in subsidies has also been approved for the installation and improvement of the scientific and technical infrastructure of research centres. This programme also includes post-graduate and post-PhD educational actions, in Spain and abroad.

In Autonomous Communities, coordination and planning efforts have also been made for their own activities, first in Catalonia in 1980 (Interministerial Commission for Science and Technological Innovation, CIRIT) and later on in other Autonomous Communities, such as Andalusia. Although no specific water resource plan has been implemented so far, some projects on this matter have been financed, and they have had an active part in the recent notice for the allocation of Infrastructures for Water Resources of the CICYT.

3.15.6. Education on water resources

The education on water resources offers some relevant aspects:

a) School education: it is almost non-existent or is episodic. Biased information is often accepted from information media, without the necessary critical appraisal. Some efforts have been made through posters and information leaflets, although they have not always been accurate or neutral enough ; in text books, these efforts have been insufficient. Schoolmasters, teachers and students rarely know where tap water comes from, or can appraise its quality or know the problems linked to its availability and drinkability. In some cases, efforts have been made so that schools can pay visit to special structures such as dams or treatment plants, but the impact has been limited for the time being. The installation of exhibition and information centres can be essential in this respect.

b) University education: the subjects related to the water resources have traditionally been absent or have just been optional, except in some Engineering Schools, or

Year	N.º	M€	Management	Hydrol. Agric.	Hydrol. Surface	Hydrol. Ground	Agricultural Pollution	Wetlands 1	Quality	Others	Programmes
1988	3	0.19		1			2				AGR
1989	3	0.27		1			1	1			AGR+NAT
1990	3	0.22		1			1	1			AGR+NAT
1991	9	0.48		1		1	3	1		3	AGR+NAT
1992	7	0.49			2	3		1	1		ENV
1993	7	0.23		1	3	1		1	1		AGR+ENV
1994	7	0.31	1			4		1	1		ENV
1995	19	1.36	2	3	8	5				1	ENV
1996	32	2.58	4	11	7	6		2	2		HYD
Total	**90**	**6.13**	**7**	**19**	**20**	**20**	**7**	**8**	**5**	**4**	

Table 113. Projects financed by the CICYT on water resource matters.

Nº = Total amount of approved projects dealing with water recourses. The coordinated projects have been considered as a single one. Water biology or water-treatment are not included.
MPta = Total amount in million pesetas, excluding scholarship holders.
NATIONAL PROGRAMMES
AGR = R+D; NAT = Natural Resources; ENV = Environment; HYD = Water resources.
Besides the R+D projects, the 1996 notice for Infrastructures has granted 1.46 M€ in 17 actions.

similar cases as Hydrogeology chairs in Geology Faculties. Last year, higher interest was observed issues related to water, and the disciplines concerning water have grown considerably.

c) Postgraduate education : after the recommendations of the UNESCO International Hydrologic Decade in 1965, several activities leading to the education of hydrology experts in Spain, Spaniards and foreigners as well, have been carried out. The longest activities, such as long intensive courses whose lecturing time ranges from 300 to 600 hours, are:

- Master's degree in General and Applied Hydrology (previously General and Applied Hydrology International Course), Madrid, from 1966 to present. promoted by CEDEX.
- International Course on Underground Hydrology, Barcelona, from 1967 to present, promoted by state-owned and private organisms and set in the *Universidad Politécnica de Cataluña* (UPC), which at present is a member of the Foundation of the International Centre for Groundwater (CIHS). In addition, both institutions have offered a Groundwater Master's Degree since 1985.
- "Noel Llopis" Hydrology Course, Madrid, since 1967, promoted by state-owned and private institutions, and taught in the *Universidad Complutense* of Madrid. Its extent and contents have been reduced over time.
- Master in Irrigation Engineering (previously International Course on Irrigation Engineering), Madrid, since 1972, promoted by the CEDEX.
- Water Technology Courses, Barcelona, since 1987, an activity promoted by state-owned and private institutions, and taught in the *Universidad Politécnica* of Catalonia. It is a modular set focused on the uses of water.
- Master's Course in Engineering and Environmental Management. The water management. Madrid, since 1994-1995, organised by the *Escuela de Organización Industrial* (*Industrial Organization School)* (EOI) of the Industry and Energy Ministry.

A hydrology course has been organised for a long time, with the support of the ITGE, Higher Technical School for Mining Engineers and the Gómez Pardo Foundation. Other Universities have also organised wide educational activities such as the Master's degree in Sciences and Water Technology at the University of Murcia, and the Master's degree in water resources at the *Universidad Politécnica* of Valencia or Alicante.

In addition, an increasing number of short intensive courses on general and specialised orientation are currently organised. Some of them, with a considerably extensive geographical distribution, are especially meant for Administration engineers in different fields and on different matters, although special stress has been laid on groundwater resources. In addition to Universities, the support from central, peripheral and autonomous communities' public Administrations has been outstanding, although professional associations have also contributed to this promotion. The activities related to surface water have been more limited, despite the large number of technicians involved and the major investments made in this field.

The contribution of the *Agencia Española de Cooperación Internacional* (*Spanish Agency for International Cooperation*)(AECI) or its predecessors, and of the *Instituto de Cooperación Iberoamericana* (*Institution for Latin American Cooperation*) has been highly relevant. Thanks to this contribution, specialists from other countries, especially from Latin America, have been trained in Spain, either obtaining a PhD or taking part in studies or research activities. However, the intense activity observed in the 1970s has recently decreased and, in some cases, the activity has been dramatically reduced for institutions or consolidated initiatives which are highly demanded from the educational point of view.

UNESCO has given assistance to foreign specialists, even if its financial contribution has been reduced dramatically in recent years. Its subsidies have been granted only for the above-mentioned courses. The remaining courses have received little more than moral help.

d) PhD education : the doctoral thesis on water resources were limited and occasional up to the mid-1980s, but after a fast growth has occurred, partly thanks to the creation of specialised groups at Universities and the granting of subsidies for research activities, mostly from state-owned funds. In this respect, as an example, in the world inventory of thesis which have been recently defended or are still unfinished, carried out by Hydrogéologie, as regards groundwater resources, 52% degrees are Spanish, 3% of the total amount. The offer concerning PhD courses on water resources has also increased considerably.

3.15.7. Scientific and professional associations for water resources

In Spain, there are several associations and groups of scientists and professionals interested in water resources. It is often necessary to differentiate those focused on surface water resources from those dealing with groundwater resources, although there are common fields. Occasionally, the coordination between them is not implemented as it should be.

The Spanish chapter of the International Water Resource Association (IWRA) has recently been constituted, and the number of Spanish members is growing.

Other international associations with a strong Spanish presence include the International Association for Hydraulic

Research (IAHR), the International Commission of Large Dams (ICOLD), whose Spanish chapter includes the National Committee for Large Dams, the International Commission on Irrigation and Drainage (ICID), of which the Spanish Committee on Irrigation and Drainage is a member, or the International Water Supply Association (IWSA), which has been joined by the Spanish Water Supply and Treatment Association. All of these organisations have a high number of members in Spain and an important activity, as proved by their work and their regular meetings.

The Hydrogeological Science Section of the National Geodesy and Geophysics Commission (CNGG), attached to the International Union of Geodesy and Geophysics, was active during the 1970s, with yearly meetings. But changes in the *Instituto Geográfico y Catastral* (*Geographic and Land Registry Institute*) (today, *Instituto Geográfico Nacional*, IGN), on which it depends, have practically led to its stoppage and lack of effectiveness, after several revitalisation efforts failed. This situation has led to the disassociation of several activities concerning programmes on water resources and international lines.Recently, the IGN has been working to reactivate the CNGG and the Hydrogeological Science Section and its working groups. The UIGG includes the International association of Scientific Hydrology (AIHS). This association has not organised its national chapter in Spain, despite the various attempts to create it and the presence of a few sectoral connections with the relevant international associations.

In the field of science and groundwater resources, the most active association is the Spanish Chapter of the International Association of Hydrogeologists (IAH-GE), which was reconstituted in 1981 and is made up of over 300 specialists today. It organises specialised meetings, courses, conferences, seminars and debates. Their results have been partly published with the help of several official organisms. In addition, a Spanish scientist has been present at the International Council since 1980, given that this is one of the largest and most active groups, and has held the Presidency for four years. Recently, the constitution of working parties, the collaboration with Latin America and connections with the *Asociación Latinoamericana de Hidrología Subterránea para el Desarrollo* (*Ground Hydrology Latin American Association for Development*) (ALHSUD) has been implemented.

Within European scope, several debates have been organised which have been attended by institutions, laboratories and study centres. In all the countries, Spain among them, these debates have the purpose of considering the matters related to water in its different aspects. Among its objectives, these debates intend to simplify the knowledge transmission, identify the common problems or facilitate the cooperation between researchers, without forgetting –as regards the actual condition of the resource– the possible influence on the European water policy, and especially the R+D policy. Among these institutions, it is expedient to mention EurAqua (European Network of Freshwater Research Organisations), TECHWARE (Technology for Water Resources), the Hydraulic Research Laboratories and Water Research Organisations, of which the CEDEX is a member. The CYTED programme can also be highlighted.

Another significant group is the *Asociación Española de Hidrología Subterránea* (*Spanish Association for Ground Hydrology*) (AEHS) with its 300 members, whose main activity is to announce a National Hydrogeology Symposium every three or four years, whose minutes are part of a series of volumes known as “Hydrogeology and Water Resources”. Among its activities, the elaboration of a periodic journal must be highlighted.

Moreover, the Spanish Limnology Association, created in 1981, is made up of about 400 members with an interest in Spain’s inland water, organises professional meetings and issues periodic publications.

In addition, and on informal basis, the Groundwater Club, whose activities started in 1994, has organised some meetings with the purpose of discussing current issues in Madrid. Furthermore, the Forum on Water, which was set up in 1995, aims to exchange ideas and discuss water matters. It promotes several seminars for study and debate.

There are also two informal groups organising meetings relatively frequently, such as those related to water in Andalusia, or the Karst. Among the informal international groups, the participation is highly active in the meetings on Saline Water Intrusion (SWIM) held every two years.

Broadly speaking, the national associations and groups suffer from the same defects as engineering and study companies: the variability of the demand market for hydrologic work. Consequently, it is impossible to achieve a minimum level of specialisation, the considerable training potential of the current post-graduates may not be exploited, and those who started studying courses on water resources often change their professional orientation in times of shortage of contracts or tasks referred to the water administration itself.

3.15.8. Publications and information on water resources

As regards scientific and technical publications specialised in water resources, the activity is rather limited. The technical or informational bulletins issued by official and professional institutions contain an extensive large subject matter without any specialised interest, except *Informaciones y Estudios* (*Information and Studies*), a non-periodic publication issued by the old *Servicio Geológico de Obras Públicas* (*Geological Service of Public Works*) –or equivalent denominations according to periods of time,– the CEDEX Monographs and the *Boletín Geológico Minero* (*Mining Geological Bulletin*). As regards scientific journals in the strict sense, we should mention:

- Ingeniería del Agua (*Water Engineering*), published by the *Universidad Politécnica* of Valencia, seriously attempting quality and high scientific and technical value, which is especially addressed to the Spanish speaking sphere and non-English-speaking European sphere.

- Tecnología del Agua (*Water Technology*), published in Barcelona by Prensa XXI-Elsevier.
- Hidrogeología (*Hydrogeology*), published by the AEHS and the University of Granada, including article comments. Its distribution is limited, with a special focus on the Spanish-speaking sphere.
- Limnética, published by the Spanish Association of Limnology. It has an international vocation and is focused on the biological aspects of inland water.

In addition, there are different scientific and professional journals related to water resources or publishing occasional studies about this matter. This is the case, to mention just a few, of Ingeniería Civil (*Civil Engineering*), published by the CEDEX, with several outstanding monographic issues; the Boletín de la Asociación de Geográfos Españoles (*Bulletin of the Spanish Association of Geographers*); the Revista de Economía Aplicada (*Applied Economy Journal*) ; the Revista de Estudios Agrosociales, Tecnoambiente, Riegos y Drenajes (*Journal on Agrosocial Studies, Technoenvironment, Irrigation and Drainage*) or the Revista de Obras Públicas (*Public Works Journal*). This last journal, which has been published for a long time (almost 150 years), issued in the last years of the 19^{th} century the first technical debates on matters related to the hydrologic cycle and the use of water at national level. Other journals such as Hidrología, Quaderns d'Enginyeria and Revista de Geofísica have disappeared for manifold reasons.

There is no scientific or technical communication vehicle which is widely accepted and distributed, the way it exists in the Anglo-Saxon or French sphere. Its presence would be justified by the importance of water resources in Spain as well as Latin America, and by the similarity of the problems to solve and their solutions. At present, a part of the Spanish scientific production is being published in Anglo-Saxon journals, with a reduced impact in the country, when the subject matter is mainly territorial and should easily reach the authorities responsible for managing water resources.

Moreover, the scattered national production is rarely available in computerised format or easily accessible. Very often, it is impossible to find it in university libraries of state-owned institutions. The same situation applies to reports and monographs on water resources. The efforts are duplicated, the studies are repeated and no advantage is derived from a large part of the infrastructure created, which is fortunately growing and has an increasing quality.

A new highly-interesting resource is supplied by Internet. As an example in Spain, there is a distribution list on management and water policies, AGUA-ES, created in Red-Iris, an academic research network financed by the National R+D Plan and managed by the CSIC.

Finally, a large number of Spanish institutions and entities related to water are already offering information through the net. Their number and the volume of on-line information is also increasing very quickly. There is no doubt that, in very few years, this will be the usual, universal method for disclosing information and exchanging data on water resources.

4. THE BASIS FOR A NEW WATER POLICY

After presenting the situation of water resources in Spain, their defining characteristics, the main problems arising, and the deficiencies encountered in their optimum management in previous chapters, we shall turn to some of the conceptual basis that can inspire or orientate the outline of water policy in the near future.

Therefore, we shall start by examining the concept of water policy itself, analysing the crisis of the so-called *traditional model*, which has inspired this policy since the beginning of the century, and present the legal, environmental, economic, socio-political and technical basis that can reasonably inspire future actions.

4.1. THE CONCEPT OF WATER POLICY

4.1.1. "Hydraulic" policy and water policy

Traditionally –and for reasons stated in other sections of this White Paper–"*hydraulic" policy* has been expressed in work plans, in such a close association, that both concepts have come to look very similar. The term *hydraulic* refers to storage and conduits through which flow is transported, and transmits a mechanistic, physical vision of the problem.

In fact, the expression "*hydraulic" policy* arose at the end of last century when the country was mainly agricultural and immersed in a major political, economic and social crisis. As mentioned above, the stress is on direct intervention by the State in building dams and channels with the objective of irrigating the largest surface of agricultural land, having determined that it is practically impossible for private companies and farmers to carry out these major projects, not even with indirect help from the State.

An almost complete association grew between the concept of water policy and the execution of hydraulic works (dams and channels) in order to develop irrigation, and that relation, explicable and desirable at that historical moment, has been maintained over the years, casting a long shadow over the rest of the activities that could be included within this concept, and additionally considering the studies on the economic and environmental effects of the various actions, and the rest of the possible action instruments in water matters.

In short, we may state that this traditional idea of water policy has meant a simplification of the term, in which concentration was the traditionally predominant and almost exclusive objective (maximum extension of irrigation), with one single instrument to achieve it (execution of hydraulic infrastructure). Water policy has basically been identified with the planning and execution of hydraulic works, in general minimizing the managerial aspects of water resources, as we have just explained. This general idea entails, of course, some simplification, and presents important exceptions basically limited to the most arid territories where, as a result of its great scarcity, the organizing and institutional mechanisms have been developed much more and have historically and sociologically played a decisive role.

In any event, the crisis of these traditional concepts that has been hinted at, and which we will refer to in more detail in this chapter, makes it essential to broaden the concept of this policy, making way for a new idea that integrates desirable forms of development with preserving the environment: *sustainable development*, a concept that will be discussed below in more detail. As we shall see, the concept of sustainable development requires, to a large extent, a reversal in the meaning of associations between development and natural resources. It deals with looking for harmonisation and the fact that it complements interests, maintaining the balance between economic growth and the limits and capacities of the environment itself, not in order to achieve the best immediate results, but the well-being of citizens in the medium and long term.

To reach these complex objectives, it is necessary to reconsider the traditional concept of *water policy,* orienting it towards a more global *water policy*, and understanding this policy to mean all *actions by the public administrations*, on different levels and in various fields that affect the development, allocation, and preservation and management of water resources.

Of course, it is obvious that any individual, group or association can have different opinions and attitudes with respect to such a policy, but it is recommendable to refer to water policy by associating it strictly with the actions taken by public authorities, for it is assumed that they express the will of the majority of society.

It should be noted that we are speaking of actions, of *facts*, and not of ideas or declarations of intention. Clearly, in politics, facts have to be based upon underlying ideas and they have to follow the development of a previous intellectual thought, but unfortunately these thoughts have been brought forward for decades in the water field and with great intensity, and the conceptual and regulatory declarations they have led to, have often not been reflected in the daily routine of public water-related actions. Spanish legislation on water has always been a clear and convincing example of this divergence between theory and practice, in particular the 1985 Act which, 15 years after being passed, to a large extent has not yet been applied.

Furthermore, referring to actions by the different public authorities directly leads to the problem of integrity and unity of such policies, or in other words, to the problem of administrative *coordination*. It is logical that the abstract legal-administrative outline of our legislation must guarantee the integrity and existence of unifying principles. In reality, however, the objectives and actions taken by the different State administrations and bodies are often not coordinated. Even within the same administration these divergences may occur and, even worse, the same agency may implement actions with conflicting objectives.

This lack of coordination and multiplicity of objectives is an important issue in the study of water policy. It goes without saying that this is no recent phenomenon, nor is it exclusively Spanish, but the administrative organization of the State and its Autonomous Regions, and their sometimes confusing relationships regarding competence, has added a broader complexity and has favoured dispersion –if not open opposition– of objectives and territorial and sectoral rules, as has been made clear in other sections of this document. The mechanism laid down by our legislation for this territorial and sectoral administrative coordination is that of water planning, but both the innovation of this technique and the lack of experience in its application –only now the first plans are starting to come into effect– do not allow us to say anything about its true efficiency yet.

It is, therefore, striking that most criticism on this figure is concentrated on underlining its *technocratic complexity*, without considering the much broader legal and jurisdictional complexity, and that political and territorial interests, which cautious, reasonable and agreed planning could integrate and overcome, just like some of the basin plans recently approved have already shown. Below, we will refer in detail to these important issues, to coordination problems and to the options and instruments that could make it possible.

4.1.2. The institutional nature of water policy

Generally, all questions that are related with water have always had a clear institutional character. Water is an element that has been liable to strict regulation, to a larger extent than other resources and assets and especially in areas where it was not abundant. This has paved the way for laws, rules and administrative structures to have greater influence than the initiative of private citizens or market forces, on the final result that can now be seen in the exploitation of water resources.

Concerns to regulate the resource can be explained with the fact that it is absolutely essential to the development of life and, more specifically, for human development, which gives it a symbolic and social value that makes it different from other consumption goods and production factors. Furthermore, the absence of these market elements -with a few very interesting, historical exceptions- can be justified by the fact that its renewal takes place naturally and periodically, and by the perception of relative abundance or, at least, of the existence of global surpluses of flow in relation to existing needs, although questions have increasingly been raised during this century with respect to this situation, especially in arid or semi-arid areas, in proportion to an ever more present scarcity.

Perhaps it is therefore taken for granted in water policy, developed under the outlined premises and circumstances, that promotional actions for hydraulic infrastructure were justified from an economic point of view, although they did not explicitly form part of the projects of justified studies into the investments to be made by the State. These are normally limited to developing proposed solutions from a legal and engineering point of view –albeit correct in most of the cases– so that the socio-economic balance would be favourable. In the context of an autarchic economy, increase in demand for irrigation would undoubtedly be perceived as legitimate by all of us and the stress on economic growth since the 1950s has done nothing but reinforce that perception.

The legal system of rules has been, and still is, a predominant instrument in water policy. However, we must bear in mind that a large part of the content of water rights has an economic significance, insofar as it refers to establishing a framework where activities and economic behaviour by individuals and companies take place. Therefore, most of the criteria and objectives of water rights have immediate economic consequences.

In Spain, this legal regulation of water use has a very long tradition. The modern State, as holder of water-related competence rights, and as a manager of the public water domain, has acted in defining and managing the right to use water. The Water Act of 1879 and the previous Act of 1866 have been the basic rules for water rights in Spain. These Acts declared the public character of surface waters, whose use was regulated by the procedure of administrative concession. The current Act of 1985 has followed in the same way, including groundwater within the public water domain, and has introduced some new aspects, especially those relating to water planning, aiming to rationalize and systematise water policy decisions.

As far as administrative structure is concerned, since the 1920s there has been a decentralized organization in Spain based on the Hydrographic Confederation. In these territorial organisations, somehow State competences on water policy were delegated, aiming at an adaptation of the administrative organization to a reality that demanded the unitary and functional water management, respecting the hydrographic basin as a spacious action environment. The important role played by these Organisations, with their ups and downs, will be examined in the corresponding section, together with the fundamental question about the Water Boards, true holders of administrative powers on the subject of water, and which since their foundation have had a vision, far more associated with the management and administration of water resources than with the execution of works, because of their own nature.

Although since the 1940s the centralist character of the State has been emphasized, the Hydrographic Confederations that existed at that time were still the instruments of water policy, in that period very oriented towards expanding hydraulic works. It was not until the end of the 1970s that a movement began towards giving back more autonomy to the Confederations and the role of organisations that integrated the interests of users of the different exploitation systems, which it originally had. Furthermore, there is no lack of people who consider that the Water Administration does not have an appropriate organization, accusing it of being inefficient, of being too bureaucratic, with too low a technical level and not taking users' interests into account, which in a legal context, with strong administrative control over water would be, according to its critics, an especially significant problem. We shall return to this fundamental issue below.

Furthermore, and as we have said before, the new organization of the State has produced considerable sharing of competence between the Central Administration and the Autonomous Administrations, apart from other Local Administrations. This situation, relatively new in that it is derived from the Constitution of 1978, introduces an additional element to be considered in the current criteria of water policy and orients it in a direction of participation and coordination between the different territorial agencies. In fact, some initiatives from the Autonomous Administrations may have significant repercussion on the planning of water resources, and condition decisions that correspond to the scope of competence of the State and vice versa.

A final aspect that is worth pointing out and that insists on the institutional character of the use of the public water domain, in this case on the demand side, is the requirement that the current Act imposes on the users of one single connection point or concession, creating a Users' Association. This strongly backs a traditional figure of self-administration of Spanish water rights, habitually governed by usage and customs. The mentioned agencies now have the character of Corporations of Private Law, mentioned in the basin organisations and, more importantly, they must look after the fulfilment of their Statutes and Orders and monitor the correct order of exploitations.

As we can see, legislative order, regulating frameworks, administrative structures, State organization, users' associations, usage and customs... all these elements underline the significant institutional character, and intensify it much more than in other economic policy. They have also made water policy less interesting for the markets and prices than for the institutional context, as has been made clear over and over again in the relevant literature (see for example: Ciriacy Wantrup [1967]; Aguilera [1995a]; Maass y Anderson [1978]).

Such institutional influences are, for their part, so diverse, generalized, disperse in time and scope, so difficult to identify and assess, and so related with political preferences and experiences and the personal distortions whoever studies them, that there are abundant descriptive works on their operation (for instance, the numerous works published on the Water Confederations, Commissions and Administrations), they often do not contain organizational and functional analyses that dissect such complexity from an analytical perspective (following the previous example, structural analyses with organizational proposals that are feasible and efficient, that draw conclusions on how to reform and improve these administrations).

Often, when these proposals have been made, they are usually naïve, partial approaches that simplify reality, if not openly childish, such as considering that the Administration's water problems can be solved by incorporating personnel with certain degrees. It is true that increase to the current level of specialization in the Water Administration is desirable (and some steps have been taken in this direction), but this does by no means guarantee an improvement if it is not accompanied by other organizational measures that are much more complex and significant.

This is why none of the institutional, sectoral analyses that have been carried out –however strictly implemented they may have been– have proven entirely comprehensive of organizational and institutional complexity. This is the case, for example, of the water allocation regime in territories with shortage, where the vital nature of this resource has generated a system of real functioning that in no way can be understood by just studying the rules that regulate it.

4.1.3. New concepts and approaches

The new water-related issues that have arisen over recent years, and which we have referred to in previous chapters and sections, have led to a new context in which a new basis is required on which future water policy can be consolidated.

Moreover, its considerable institutional character, explained above, requires a global and multifaceted consideration in which technology, law, economy and sociology combine and come together.

Similarly, such institutional character implies the possibility of different conceptual and ideological orientations, and in the new approaches to how institutions function in water policy, some with a more interventional character, defending the extension of State action in new areas (for example, control over water quality in river channels, or over the reserve in effect of certain water quantities as an environmental value), are combined with others with a more liberal character considering that water is above all a productive asset. This explains the interest in studying the economic aspects of actions included in water policy, in matters such as the perfection of the cost-benefit analyses of private investment in hydraulic works, the search for procedures that balance tariffs and costs, the analysis of the role of prices and the market in the distribution of water, etc. The results from these analyses often question the economic rationality of certain public actions, and start the debate on the expedience of maintaining specific regulations or not.

Later on, we shall look further into this major debate, political as well as social, fully within the crisis of the traditional model, which we will refer to in the sections below.

4.2. THE CRISIS OF THE TRADITIONAL MODEL

It is not possible to make a correct diagnosis of the current situation, nor is it possible, as a consequence, to design any kind of well-founded approach for the future, without knowing what is referred to by the *traditional model* of water policy, and considering its key points and historical meaning.

These issues are reviewed in the following sections presenting the most relevant historical antecedents and circumstances since the last century, in order to analyse the defining characteristics of the present situation, the persistence of characteristics from the past, and the serious mistakes in some of its old axioms.

We will conclude by considering the unequivocal need for a new approach in our perception of water-related problems, and drastic reforms in the objectives and means that have been used in this country to deal with these problems.

4.2.1. Antecedents and historical circumstances

In order to have a better idea of what has been described the *traditional model of water policy*, and the concurrent reasons that have resulted in its crisis, it is expedient to look at the second part of last century, when the intellectual seed took root that produced this model and shaped what were to be its basic, lasting characteristics up to the present day.

This century, however, is the heir to a very rich history, whose roots go back to the medieval disestablishment, already mentioned in the context of legal antecedents to the rights of water use.

4.2.1.1. Private initiative in the second half of the 19th Century

Starting this brief historical description in the 19th Century, we can say that the hydraulic developments in most parts of Spain began with the implicit assumption of an over-abundance of resources in nature for existing use, although with circumstantial shortage in certain areas and in certain periods, which produced a series of early regulatory and water transport actions (especially, dams and channels) propitiated by the needs of private citizens.

In order to meet these needs, in a previous period that we could consider as covering the second half of the 19th century, actions fundamentally corresponded –albeit in general on a small scale and with a lot of ups and downs– with private initiative. The State's role was limited, in this era, to providing the user with security through a favourable regime of water use, establishing tariffs to be charged by the promoting companies of hydraulic works from the beneficiaries of the works, and providing fiscal benefits or subsidies. The attempts to not limit State actions to promotional activities were in practice restricted by their own financial problems and low level of investment, and because of other problems such as the mentioned difficulties in local environments, because of exploitation systems that were already in place, preventing the effective exercise of the state ownership.

Finally, the agricultural crisis that had reduced the sector's investment capacity, apart from the problems mentioned above, led to a very inefficient policy with regard to the expansion of irrigation areas, the main objective of the initiatives of this period. It must be pointed out, however, that there were differentiating details in this historical process between the different territories, between the Meseta and the coastal area of Levante, to be more precise, and even within this latter area, between Catalonia and Murcia, for example.

In this period, the ways in which water was appropriated were still being consolidated (right to use or ownership) and other important legal aspects, such as the relationships between the rights that were derived from acquisition of land and those regarding access to the water that irrigates it. There are situations where there is an association between the two as well as situations where the two are separated (note the importance of this issue, because land-water associations are a foundation stone in later legislation and an issue that has recently been given thought in the modern debate on private ownership and the possible water markets). In this period, the Water Acts of 1866 and 1879 were approved, the last one in effect for more than one century, until in 1985 when the current Act came into force.

4.2.1.2. The need for public intervention and the promotion of irrigation by the State

The little practical importance of the instruments used until then, together with a feeling of crisis and the need for finding solutions to national problems that emerged in 98, without varying the fundamental ideas with regard to water exploitation, made the concept of water policy popular, which called for a more direct intervention by the State. This fact was compounded by the perception of the Spanish production sector's low existing capacity to face, with any chance of success, the challenges that the recent growing implementation of the proper dynamics of the market economy meant for agriculture, and which most developed countries in Europe had already accepted. Specifically, if no important hydraulic infrastructures were executed to transform dry areas into irrigated land, it would be difficult to compete in the markets of agricultural products. The magnitude of these actions called for help from the State, and shaped the foundation of regenerationism.

We should highlight that this policy's main defender, the justification of intervention by the State, so that a water policy of greater depth could be developed in the first place, lies in the need to solve economic problems and the long-standing backwardness in which Spain was submerged. In order to meet this objective, with admirable audacity and perception of the problems of his time, Joaquín Costa focused on the agricultural sector and on the improvement of its productivity, which can and must be achieved through the application of water for irrigation (Costa, 1880). After the crisis of 98, the regenerationist movement advocated a revolution in the national economy, in which self-support was an essential objective. Since agriculture was becoming the basis of the Spanish economy, its soil had to produce much more (making up about 60% of GDP).

In Costa's opinion, and according to the regenerationists, the objective of increasing national wealth needed above all an increase in agricultural production, for which they considered it vital to extend irrigated surfaces, since Spain had a mostly agricultural economy. Accordingly, not only was yield improved, but it also opened a door to the necessary diversification of crops that would allow improved profitability in territories with low productivity up to that time. In a second phase, Costa began to pursue social objectives as well, defending the idea of a water policy that would transform agriculture in order to stop the impoverishment of the farmers and favour the creation of independent agricultural smallholdings. With the last step of this reasoning, two concepts are interrelated: the desired social changes and the management of water resources, starting with the identification of the solution to some of the social problems.

Thus, at that time in Spain, water policy meant agricultural policy, and given the importance of the agricultural sector in the Spanish economy, it meant economic policy. This is one of the central, defining ideas that underlie the idea of the traditional model.

As we shall see when we review the background to water planning, these ideas of Costa's, to a large extent, adopted by the Government when the Plan Gasset of 1902 was passed, included the list of works on reservoirs and channels to be developed in short term.

In short, and from the point of view of what today is understood by exploitation systems, the water policy of the era was developed in a precarious situation and unconnected exploitation, without global perception and coordinated exploitation of water resources, which tried to give individualized solutions to particular problems, and mobilize resources to contribute to the economic development of the country through irrigation. In a sense, this partial vision was also due to insufficient knowledge of the hydrological characteristics of rivers –inventories and detailed maps hardly existed– and the little consideration that the idea of hydrographic basin as an operative concept was given. In short, we could say that there still was no coherent water policy, coordinated with other, globalising, sectoral State actions in the sense we have today.

4.2.1.3. The development of infrastructures *"La Gran Hidráulica"*

The progressive increase in regulation of river flow and exploitation, both for irrigation and for supply and even for hydroelectric production, led to criteria of greater rationality and integration in water-related actions. Accordingly, Lorenzo Pardo (1924) extended Costa's agricultural aspects to industrial and social ones, completing the integral confederative concept.

In fact, a result of this new approach was the creation of the Associated Hydrographic Confederation of the Ebro in 1926**,** whose main objective was to achieve the best use of water, so that the *economic potentiality of the hydrographic territories* was made profitable. Without any doubt, the definitive implementation of the basin concept as a basic territorial unit to develop water management represented an original, pioneering attempt to approach problems in an integral way, and which a few years later would be emulated by the famous Tennessee Valley Authority, inspired by similar principles.

As we will see when we review the antecedents of water planning, an important landmark in this trend towards the integral use of water appeared –still in a very primitive way– with the Hydraulic Works Plan of 1933, and this orientation continued in the plans to follow.

As of the 1940s and especially in the decades of the 1950s and 1960s, as we have seen when we dealt with reservoir dams and explained their evolution, significant development in the construction of hydraulic works took place, especially reservoirs, partly due to the State's preference for regulation works for irrigation, and partly to the major increase that was seen in hydroelectric exploitation systems, through private initiative. Water policy still played a large role in these regenerationist ideas (Díaz-Marta, 1997) and were still basically an instrument of agricultural policy: right after the Civil War, the aim was to increase productivity and achieve national supply and, after 1960, to diversify agricultural production and establish trade balance. An example of this public intervention in a basin, and its institutional evolution with respect to different circumstances, is shown by Melgarejo Moreno (1995).

As a consequence of all the above, water became a regulated resource much more than a natural resource, so that when halfway through the 1960s the Second Development Plan was drawn up, the integral exploitation of resources was considered a necessity, because it was thought that Spain had already entered a phase of water maturity (as an indicator, a phase that is reached when demand is greater than half the natural resources). These drastic technological and socio-economic transformations were enabled by the advent of what, contrary to traditional production methods, has been called *"La Gran Hidráulica" (Major Hydraulic Works)* (Hérin, 1990), i.e., the availability of technical means to operate on a large scale, retain and mobilize great volumes of water over long distances and massively exploit groundwater at depths that until then were prohibitive.

Figure 367 shows joint temporal evolution in recent decades of five basic series, that we have seen in earlier sections, and which clearly indicate the development of water resources in Spain: the existing irrigated surface area, hydroelectric power capacity, the volume of available reservoirs, the volume of groundwater used and the Spanish population. Suffice to consider the extraordinary growth that we have witnessed since the 1950s –not as a fraction in percentages, but as *an absolute magnitude*– to understand the enormous dimension and speed of the processes and transformations mentioned above, and see that current pressure on water resources is a very recent phenomenon, starting only 50 years ago.

The results of these transformations are clear: agricultural landscapes, the geography of water, rural life, agricultural production methods, urban supply, water quality... have

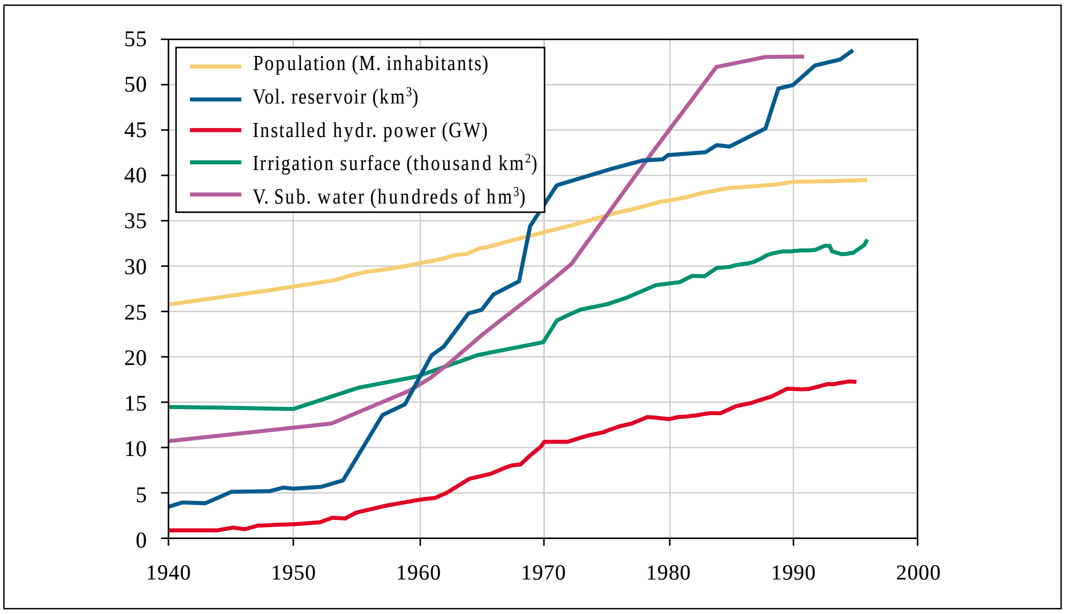


Figure 367. Evolution in the last decades of some basic indicative magnitudes of hydraulic development.

undergone substantial changes, which can be seen within one single generation.

Furthermore, we must point out that this temporal evolution, which accelerated in the 1950s, is not specifically Spanish, but has been observed in many other countries and on a worldwide scale (Postel [1993]).

4.2.1.4. Unrelated exploitation and integral exploitation

As we have pointed out, and summarizing the ideas explained, when setting out to use the water resources of a territory, there is generally a situation of water sufficiency that allows the modest existing needs to be met. As time goes by, the needs tend to grow and discrepancies between needs and availability of resources become apparent. Faced with this situation, the implementation of infrastructures is usually a solution that allows an increase in the regulation of rivers or aquifers, at a specific point, in order to meet this specific, localized demand. As an example of the above, we note that the concepts of hyper-annual basis or multiple regulation have arisen only recently. Possibly Valdeinfierno, in the Segura basin, was the first case of a dam constructed in isolation, without any associated demand, and aimed at complementing the regulation of another (Puentes) situated many kilometres downstream.

This traditional situation, associating regulation work with covering specific demand, on a one-to-one relationship, was therefore structured in stages of hydraulic development characterized by a relative abundance of resources in comparison with demand, in which the water-related problems of a basin were dealt with independently and exploitation was developed in isolation. In these conditions, regulation works were programmed for each specific use without any interconnection. As mentioned above, these are the stages that the *Second Economic and Social Development Plan* (1967) called *unrelated exploitation* or *opportunity*.

As the use of water increased, interdependence appeared between water-related problems of the different sites, covering demand with resources from other sources was made possible, and interconnection between different areas appeared. In this stage of greater water maturity or *integral exploitation*, reservoirs become elements of a broader territorial system with greater technical complexity, where the independent operation of each reservoir or aquifer was not sufficient to solve the management problems the arose, requiring the joint use of the whole system.

We must point out that the term water maturity was used in the sense of a phase of development and evolution subsequent to the initial one, and that by no means is it intended to suggest that the integral exploitation of resources is a desirable condition. Rather, such craving for exploitation has often led to situations of serious degradation and unsustainability which are anything but acceptable. True, definitive maturity comes when these undesirable effects have been overcome, and a rational, prudent and sustainable use of our water resources in all the territory is achieved.

Currently, and after the tremendous hydraulic development of the last decades, the phase of integral exploitation has already been reached in a major part of Spain and on occasions it has even been surpassed, leading to the necessity to exploit external resources, which implies a fundamental change in model and use of water resources, whose consequences go beyond the technical consideration of the exploitation of interconnected systems.

A case in point is the problem of concessions, which, according to the regulations, indicate the specific intake point and river whose water they are entitled to, although this river or area may be fed with water of a different origin. Of course, the regulations consider this possibility of changes in intake points, but not without complicated intermediate procedures. Another case is the problem of modifying water quality due to mixtures of different origin. Or the problem in calculating the regulation rates and irrigation tariffs in complex, interconnected systems, where the effects of improvement in regulation are not separable and evident, the calculation of cost related to the beneficiaries is not evident either, and its accurate calculation turns out to be more complicated than the trivial case of one single dam that exclusively provides one region with irrigation. In short, more development, increased use, more pressure on the resource... new circumstances that generate new technical problems, and which call for the need to reconsider traditional approaches in order to adapt them to the present.

Nevertheless, such a reconsideration has to go much further than that, for together with these new technological complexities, we have seen a process of vast social, economic, political and cultural transformation over the last decades, which has driven the classic arguments and criteria into deep crisis, and should therefore be pondered and reformulated for the future.

In sections below we will review some of these new conditions and arguments, whose appearance in recent years have worsened the crisis of the traditional model.

4.2.2. The appearance of new social agents and the multiplicity of arguments

Along with socio-economic and technological development in the circumstances that have favoured the *change in hydraulic scale*, mentioned above, and perhaps in correlation with this socio-economic development, a very important change took place with respect to the social agents that have traditionally made up classic water policy.

Very penetrating analyses have recently been carried out on this issue, coming from the field of sociology (Pérez-Díaz et al., 1996) concluding with eloquence on the erosion of the traditional *water policy community*, and its transfiguration into a much more complex, extensive community, with changes in its structure, participants and groups of interest.

In fact, we can speak of a community of traditional water policy whose core consists of politicians, administrators, economists and engineers in the service of the administration, irrigation farmers and construction companies. All of them operate in a cohesive way through the organizational political-administrative unit and the tacit consensus with respect to the objectives they have to meet, and the instruments to be used.

In the 1980s and 1990s, as happened in other countries, such community experienced a profound evolution.

For instance, it is doubtful that, there is a unanimity on what is convenient within the administrative sphere and, therefore, on what must be promoted and done. The interests and sensitivity of organizations that used to be unified in the common objective of the amplification of irrigation (like the Directorate General of Hydraulic Works and the Institute for Agricultural Reform and Development, operating together through coordinated work plans) are today very different, if not diverging: in the light of possible amplifications of future irrigation, the Directorate General for Hydraulic Works and Water Quality –now in the Environment Ministry of Environment– has to adopt a position of coordination with other sectoral interests in the core of water planning, without having any particular interest in the orientation these sectoral policies should take beyond their true basic objective that is nothing but to endeavour the rational use of water, its protection, and the conservation of the environment.

On the other hand, this unanimity of criterion does not seem to exist among agents as important as irrigation users either, diverse trends and orientations are seen among them with criteria that do not always coincide with respect to issues as vital as financing and exploitation of works, payment of water, etc.

As well as traditionally well-established concepts such as water *users* or those affected by hydraulic works could also require a certain conceptual reconsideration (Garcés [1998]; Bartolomé [1998]; Sánchez Blanco [1985]).

Apart from these differences between the classic players, an international amplification of agents has occurred (new social movements, political representations, local leaders, pressure groups, etc.), increasing the complexity of the problem, and contributing to the redefinition of social debate, and it has considerably influenced the public opinion, via the media. A very well-known example of this influence is, for instance, Reisner's book (1986) on West-America, or Postel's (1993) on water problems on a global scale.

This influence on the media has not always been answered by political powers with explanations in the same media about their actions, which has created an informative profusion largely critical and unidirectional, that unfortunately has not always contributed to honestly explaining points of view and clarifying the problems, sometimes repeating prejudice and similar opinions for different problems, simplifying to the point of caricatures, that in reality are ignored, and have only made things worse.

Furthermore, logically, this proliferation of voices and opinions has not only generated confusion, but has also brought about significant positive results. The motivated presentation of new arguments and points of view (economic, historical, environmental…) has given us the opportunity to think again about old water-related problems and situations with new perspectives, has shed new light, and has positively questioned the way to deliberate and decide on water policy.

In this respect, we must underline the influential role, from the field of environmental defence, that non-governmental organizations have played in defining a new water policy, especially over the last two decades. Without any doubt, the contribution of these organizations in the creation of a broader social conscience about the necessity to protect natural resources has turned out to be decisive.

On the other hand, some institutions have also proposed certain ideas with alleged innovation, demanded from public powers as urgent and necessary. Without judging the objective interest that many of these proposals might have, in reality, they often make up a predominance of known concepts that were formulated a long time ago, together with some genuinely new and valuable contributions (and even formally included in the legislation), mixed on occasions with some naïve, simplified volunteerism, which detracts from its possible efficiency.

All in all, it is clear that this situation where new social agents and a diversity of opinions arise, is not due to any circumstantial phenomena, but will tend to persist and grow in the future. This is preferable, but we have to point out that greater participation is not positive in itself, but must be carried out from honest, informed and accurate initial positions. The huge benefits that the diversity of ideas brings, and the contrast of points of view can be cancelled out, and transformed into negative and inconvenient ones, when they are replaced by proclamations, trivial simplification, stereotypes, mutual discredit, and self-interest.

Attitudes like these, childish and frivolous, frequently pop up in the world of water –and perhaps not only in this world– from administrations as well as from political movements and social organizations, which we could qualify as the hydraulic opinion leaders, and the media, which makes the desirable debate lose all efficiency and it becomes the sum of monologues, and the excuse for crude assertiveness by each individual with regard to his cut-and-dried, dogmatic point of view.

In the end, all this does not reveal anything but a serious difficulty in finding shared, responsible and mature solutions-in short, democratic solutions – to water-related conflict, and suggests the need for a collective effort of elementary prudence, rigour and self-criticism. In this sense, the role of the media should be of fundamental importance.

4.2.3. Increasing environmental costs

As has been repeatedly made clear in recent decades, the environmental costs of the traditional water policy are clearly and sharply rising, and not circumstantially, and this will probably not change direction in the short or medium term. The explanation for this is clear, and has been pointed out in various sections of this document: an ever-scarcer resource, subjected to stronger pressure and with an increasing competition for its use is obviously heading for a progressive degradation that can only be mitigated through agile, effective control mechanisms, mutual responsibility, regulation, private incentives and public intervention.

As with the other cases observed in this chapter, here, a substantial change also took place with respect to the traditional model, and we are faced with a complex new problem that virtually did not exist some decades ago.

Legal-technical instruments like the procedure of environmental impact assessment, recently implemented in our practical administration, have become decisive in the development of hydraulic works, creating a substantially new action platform, but perhaps not yet fully assimilated.

4.2.4. The uncertainties of costs and benefits

As we have pointed out before, one of the conceptual pillars that enabled the development of hydraulic works in Spain for decades was the conviction –normally true– that the economic benefits of increasing water supply largely justified the public investments that were made to increase this supply. In recent years, this principal has been questioned over and over again from the point of view of production costs as well as the benefits generated by its use.

In fact, criticism has appeared of late, casting doubt on the official estimates on the costs of the works, the financial estimates of the major actions, and their deviations with respect to the finally liquidated results. This means that any economic analysis based upon these estimates shows bias in favour of the actions analysed, and the absence of evaluations ex-post does not allow corrections of such bias in the final data.

Recently, doubts have also been cast on the benefits generated by large hydraulic works, especially in the case of transformations in irrigation. There are a number of experts on agricultural matters who doubt, no longer with respect to profitability, but to the economic feasibility of numerous Spanish irrigation areas, given the ever more demanding conditions of international competition, with much lower basic costs impossible to achieve within the Spanish context of productivity, even in case of subsidies provided by the State.

Naturally, these difficulties and uncertainties should not cause an abandonment of the systematic and regulated implementation of procedures of economic assessment. On the contrary, these procedures have to be perfected and generalized (economic analysis-impact on environment- multicriteria analysis) as routine and prior *assessment* practices in the process of programming and prioritising actions, a process that must necessarily more complex insofar as cost control and budgetary limitations restrain the quota of public investment, and therefore greater refinement in allocation is needed.

In turn, the problem of allocating scarce resources has taken on new perspectives in this respect, since the classic criteria of maximizing national income, as an objective function to optimise through hydraulic works, are also in crisis, as is shown below.

4.2.5. The crisis of the economic objectives of water policy

In fact, as has been clearly demonstrated from economic theory (Ciriacy-Wantrup, 1967), an intellectual movement has taken place over the last decades on what must be the objectives of water policy in the context of State intervention and of public policies. This question is of such importance, from a conceptual point of view, that we will briefly review its basis from the perspective of economic theory, as explained in the reference mentioned above. This reflection will lead us to properly understanding the theoretical basis that the objectives of water policy should adopt. It should be pointed out that these objectives are shared with those of our water planning, as they have been formulated in the Water Act, and as we believe they should be interpreted from the point of view of classiceconomic concepts.

In principle, and admitting the logical hypothesis of global action and unitary political management by governments and public powers, it is obvious that the objectives of water policy cannot be dissociated from the objectives of other policies. All these sectoral objectives are interrelated and have to coincide substantially. Therefore, the policies that develop them have to go into the same direction.

An attempt to formulate the criteria for public policy was carried out in the academic design drawn up by Pareto, at the end of the 19th Century, on the so-called *welfare economy,* whose explicit assumptions refer to differences in preferences and individual income and the problems of comparison and aggregation of individual utilities. The classic and neoclassic economists were aware of these problems and concentrated on the increase of national income as the main indicator of economic welfare.

We should note that this approach is not in principle contrary to Pareto's, since in his opinion an increase in aggregated income and greater equality in its distribution would go hand in hand, implying that if national income increases so will economic welfare, understanding that welfare increases if the situation of at least one individual improves, compensating those who come out negative so that nobody worsens the situation. This compensation principle is one of the fundamental objectives in the study and debate of the welfare economy, as there are hardly any public economies where nobody's situation does not get worse.

From a theoretical point of view, Pareto's criterion with compensation does not strictly coincide with increase in national income, but it can be considered a first practical approach to it, provided there are assumptions such as the fact that the policy in question does not notably increase inequality in the distribution of income, and provided that other policies act independently and constantly in order to achieve more equality in the distribution of income (e.g. progressive income tax, social policies, etc.).

Accordingly, from a theoretical point of view, we can establish with broad unanimity that a correct water policy is one that meets environmental restrictions and does not introduce undesirable imbalance, that manages to *optimise national income,* and that the choice between alternative policies can be made by opting for the one that produces the greatest increase in aggregate income. This theoretical conclusion is of great interest, but is far from being operative in practice because of the fundamental problem how to determine the economic optima.

In fact, since the pioneering work done at Harvard University in the 1950s and which took shape as the already-classic *Design of Water Resource Systems* (Maass et al., 1962) in recent decades, we have witnessed an enormous boom of methods and numerical techniques for the optimisation and mathematical simulation of water resource systems. This boom in new techniques and models has been favoured by the extraordinary development of digital possibilities, vital to numerically approaching such problems.

These optimisation operations have fundamentally been oriented towards minimizing costs directly associated with the non-supply of water in the required conditions, and have sought what could be called *efficiency engineering,* of indisputable utility. But the relationship of these supply deficits with overall economic performance of the system poses serious theoretical and practical difficulties that can only be solved, and in an approximate way, in very small systems.

Note that in these small systems (e.g. evaluating the dimensions of a specific project to supply water), in which an optimisation can be carried out with the aim of maximizing economic performance of the action, the mentioned theoretical principle, maximizing national income, is fulfilled with the classic cost-benefit analysis. But to what extent can the real possibilities of these analyses be applied in proportion to the increase in size and complexity of the systems? Does anybody believe that this could be extended to nothing less than the national aggregated economy? Would it be possible to find parameters, assuming that it is theoretically possible to conceive the structure for such an objective, comprehensive function? How reliable would such an estimate be? What real utility could it have as a decisive instrument in public water policy?

It is clear that, in spite of its interest as an abstract object or undefined legal concept, the greatest public interest and the principle of maximization is a theoretical construction, in Ciriacy-Wantrup's words, *science fiction.*

This is by no means a disqualifying adjective, for all scientific disciplines, even the most basic ones, are full of fiction, up to the extreme case of mathematics, pure science par excellence, and which is in itself, an immense construction of the mind. However, this fiction –deviations from reality– are acceptable as long as they are assumed as such, and if they do not attempt to find a place in reality.

In short, all these circumstances and theoretical-practical difficulties have led the theoretical objective of analytical maximization of income –of course desirable, but of little feasibility– to be substituted by one that analyses its effects on *the conditions that facilitate or obstruct the objective.* Water policy has to give up once and for all choosing development options that maximize the income of a country as a result of a calculation, and should be oriented to establishing the necessary levels of resource use (the minimum, not the optimum), to the mobility and adaptability of water-related production systems, and *to stop supply limitations from hampering the development of sectoral activities,* in terms of direct productivity and contribution to increasing national income.

The result of such dynamics will be that, as a consequence of the elimination of bottlenecks, the national income will increase spontaneously to optimum or near-optimum levels, with no need for previous programming.

Accordingly, from shaping the classic platform of hydraulic development and resource supply, that sectoral demands in the traditional model of water policy would already have generated, and which we have mentioned above, and the effect of an increase in national income was practically guaranteed, given the poverty and immaturity of the original situation, we pass to a supporting role in which we have to safeguard the expedient availability of the resource, in quantity and quality, that the different sectoral policies are going to require, the integration of water management interests and efficiency in order to meet this variety of needs and monitoring and quality control of the resource, preventing pressure from these sectoral needs to cause degradation or unsustainability that is unacceptable.

Note that, as was pointed out, this new orientation of setting limits on use and acceptable conditions, and moving the centre of gravity from increasing the offer to the integration of demand, this is exactly the central objective of new water planning as defined in section 38 WA, which lays down that this water planning will have the general goals of *achieving the greatest satisfaction in water demand ... rationalizing its use in harmony with the environment and other natural resources.* Therefore, water planning must, with the exception of the preservation of the environment and the sustainability of the systems, avoid the bottlenecks of water-related economic activities, since in this indirect way maximization of public interest is achieved not by a previously optimised and comprehensively planned decision, but by successive gradual accumulations, step by step, of the individual initiatives by sector. An analytical example of such economic bottlenecks is offered by Marco (1995) pp. 577-588.

This new orientation, not only from a theoretical economic perspective, as we have seen, of the current legal regulation, represents an encouraging new action program for the Water Administration which, associated with flexible, rational water planning, must be the model for development in the immediate future.

4.2.6. Political and territorial tension

Apart from the major changes in orientation that we have dealt with in previous sections, there is a very important aspect in the crisis of traditional methods in water policy. This is the *enormous increase in political costs* associated with water-related decisions.

Despite the fact that local conflicts traditionally produced by water-related actions (in the sense of categorically rejecting them or wanting them so much that whoever would benefit most from its use is in competition), the current political-territorial structure of the State adds another decisive element when it comes to developing water policy.

Besides the already mentioned circumstances of proliferation and regulatory uncertainty that have arisen in recent years as a result of a proliferation of State and Autonomous rules on water-related issues, the new constitutional legislation has created an entirely new situation in the assumption of political territorial powers, which has extended (and on occasions generated) the historic territorial tensions regarding the availability of water resources. Cases such as the rivalry between Valencia and Murcia for access to the River Júcar, or the paradigmatic conflict of the Tagus-Segura transfer, well illustrate this tension in which political and social authorities in the Autonomous Communities, seeking to defend their territories, have arrived at totally virulent, confrontational positions, and where the territory factor outweighs the real ideological orientation of the political parties involved.

These logical tensions, however, can be transformed into true opportunities for consensus and mutual understanding. The agreements reached on the mentioned cases of water planning for the basins of the Rivers Júcar, Tagus and Segura, are good examples of these possibilities of convergence and political maturity, and they reveal –apart from the evident utility of the often-questioned water planning- how it is possible to solve serious water-related disagreements if they are dealt with carefully and with technical rigour, explanation to the agents involved, search for common interests, complete transparency during the decision-making process, and true political will to reach reasonable, fair agreements.

4.2.7. The international context

Another very new circumstance with respect to conditions from the recent past is that of a substantially different international context from the one of a few decades ago, which, without the criteria of an autarchy, implies and will imply more in the future, global commitments and actions in water matters, completely different from traditional ones. Water policy is taking on an increasingly supranational character and this character requires new ways of tackling old problems, as well as developing new attitudes and skills that were not necessary until now.

In previous chapters we have shown a general situation or international framework in which they currently operate, and the main features of this context with respect to its specific effect on water. We will simply reiterate and underline three basic features of this international context, as mentioned above, and which are highly indicative of the change in circumstances with regard to the traditional hydraulic model: the unification of water policies, market globalisation and economic convergence.

The growing trend towards the *transnational unification* of water policies and towards shared management of international rivers is an consummate fact, and as an immediate result, it involves some loss of national autonomy in laying down regulation policies, especially in the field of quality and preservation of the environment, an autonomy that was one of the basic foundations of the traditional hydraulic model. The mentioned *market globalisation* also contributes to the unfeasibility of this policy *that obviously involves abandoning autarchic objectives* as one of the salient characteristics of the traditional water policy model. Finally, and as mentioned above, economic convergence implies some easement in public budgetary programming and improvement in private competition that, in addition to the conceptual changes in the economic objectives of water policy, make the traditional model unfeasible, requiring a reconsideration of basic questions such as financing public investments in hydraulic works, economic efficiency of current and future water allocation, the decision to intensify the development of non-structural measures as a possible alternative to the classic structures, formulas of water management sharing, etc.

4.2.8. Conclusion. The need for a new basis

In different previous sections we have given evidence of a substantial change in many of the basic ideas that inspired traditional water policies in Spain. The conclusion, already reiterated, is obvious: we have to reflect on the water problems by radically reconsidering current solutions, legal regulations, and their economic, environmental and technological basis.

Furthermore, this is by no means a new task. Suffice to consider the enormous volume of documentation, seminars, publications and works of all kinds and orientation produced in recent decades, to realize that reflection on water-related problems is a very old and widespread concern, frequently with critical positions as regards the existing situation (see, e.g., Llamas [1994]; Martínez Gil [1997]), and new opinions with integrating intentions (e.g., IME [1998]).

Below, the main ideas and conclusions taken from previous sections of this White Paper will be summarized, and the basic guidelines for this reflection will be described.

Firstly, we have to point out that the situation faced by Spanish water policy in the near future has to take into consideration the sharp increase we have seen in water demand in recent decades, compared with limited available resources, with the consequential negative effects that, in many cases, this fact has had on the environment. Among these effects, we could especially indicate the significant drop in the quality of the resource itself, and of the ecosystems that depend upon it. This phenomenon of extraordinary growth, promoted by modern technological possibilities, does not have any comparable historical precedents and places us in a completely new situation where, as we saw when studying territorial balance, in some parts of the country more resources were required than all naturally-existing ones.

At the same time, new elements of all sorts appear that the water policy has to take into consideration. Examples are the growing value that society gives to the correct preservation of natural resources or the possibilities current techniques present us with for increasing the availability of resources (treatment for later reuse, desalination, use of water-saving technologies etc.).

On the other hand, water-related issues are losing their local or regional character and they are increasingly considered as questions that affect the whole planet, especially those that are related with environmental problems on a global level. Anthropic impact on the environment takes on a new dimension on a global scale, as mentioned when we examined water resources and the affected regime, of which this planetary dimension forms a new, second level.

Another element that adds complexity to water policy is its instrumental character, since we cannot forget that, together with the objectives that water policy has to establish, there are others determined by different sectoral plans, initially having nothing to do with this policy. We only need mention, in this sense, hydraulic infrastructures intended to cover agricultural or energy objectives, policies that in turn have to be shaped by the general economic framework. For this reason, it is clear how necessary it is to understand water policy, not as completely autonomous and independent, but as an element of coordination and harmonization of various affected interests, especially if we take into account that this coordination role has to be developed, in all cases, from a respect for all natural resources and for the environment. We will return to this fundamental issue when we refer to water planning, related sectoral planning and its necessary coordination.

This coordination is especially necessary in those areas of national territory where there are already serious problems of limited resources. In these areas it is not possible to cover all sectoral requirements by maintaining models from the past that are fundamentally based upon supply increase, because in many cases there are no significant new water resources to be exploited. In this framework of limited resources, efforts should be concentrated on the sustainability of current uses and the preservation of the environment, preventing its degradation in a context of integral and joint exploitation of the different distribution sources and the constant improvement of managing registers and procedures (knowledge of uses) and measures (knowledge of resources); it goes without saying that register and capacity go before any other action.

Furthermore, there are areas and basins where abundant natural water resources exist, but where difficult distribution is frequent and the increase in regulation is still a clear necessity. Despite this abundance, in general the new water policy's priority has to concentrate on demand management measures, which directly points to the different sectoral policies and even further outlines the environmental role of the Water Administration as an organization that, regardless of promoting water uses -and, with a higher purpose, of uses per se - has to safeguard correct use and rationality in the integration of different sectoral policies.

The trends, as far as the main types of exploitation systems are concerned, will revolve especially around the following aspects: supply, quality problems and distribution guarantees; irrigation, efficiency issues when using the resource, profitability and water prices; and hydroelectric energy, its role in the energy policy as a whole, guarantee of water volume in the power stations that are already installed and debate on the construction of new power stations, all this from the perspective of making the different exploitation systems completely compatible, in order to minimize the negative effects that new facilities will have on the environment and, on the other hand, unite the will of water's main users as regards the treatment, both qualitative and quantitative, that environmental demand should be given, and to the increasingly important recreational uses.

Maintenance or recovery of water quality, protection of ecosystems and defensive actions in the public domain are perhaps the most important of the elements that must orient water policy in the immediate future, because of the investments required as well as the impact it is said to have on human well-being and health, the productive use of water and natural life.

An essential idea, inspiring and sustaining future water policy, is that of its *rational use* in terms of sustainability. Needless to say, efforts made in actions aimed at increasing availability must be maintained, too, provided the previously mentioned priorities are guaranteed. Nowadays, water policy must, therefore be designed as a complex concept that includes all actions related, on one hand, with the resource's use, in its double facet of consumer good and production factor, considering both quantitative and qualitative aspects and, on the other hand, with the management of the public water domain, but seeing it as an integral part of the natural aquatic environment, which has to be conserved, protected and improved.

The need to *rationally use* water is a basic principle (a constitutional mandate) that allows us to lay down and establish other basis related with the prohibition of abuse, the obligation not to waste water (on a private and collective level), the interest in reusing it, if possible, the expedience of allocating the resource efficiently among different alternative uses, etc. This last issue is especially relevant in defining future Spanish policy, bearing in mind the inertia of the current water distribution system and the doubts as to the profitability of some of its uses. However, we need to be aware of a very elementary aspect which is that the constitutional mandate is double: *rationally*, of course, but *use* water, which means not having resources inactive that, without harming the environment and in a sustainable way, may be used for the fulfilment of needs and the improvement of public well-being.

A nation-wide agreement on the issues considered in the paragraphs above is possibly the only way to establish reasonable water-policy actions with respect to, for example, the major socio-political decisions of transferring resources between different basins.

Similarly, an extraordinarily important question is the quality of water management. It has to be a product of a modern, organized, competent and efficient Water Administration. No policy will be successful if it does not pay special attention to this central issue, to which we will return later. In parallel, when the appearance of new requirements leads to a reconsideration of certain aspects of the water policy, legislation is likely to be modified where it is inadequately expressed with regard to the objectives pursued. The legal framework is a fundamental instrument for any policy. Therefore, it is clear that, in order to meet any objective in water-related issues, it is necessary that appropriate legislation and certain institutional and administrative mechanisms –we have already referred to the Water Administration– function correctly. We must point out, though, that neither the passing of new laws is a panacea, nor the application of new rules in water-related matters are simple tasks. It is normal to find considerable resistance when these clash with traditional cultural customs or when they imply significant individual or collective sacrifices.

In Spain, the approval of the Water Act of 1985 meant a serious attempt to move towards such adaptation to new considerations and situations, mentioned above. Unfortunately, and due to several circumstances, we cannot say that the intended aims have been reached. Therefore, insofar as it is considered expedient to modify some of the main guidelines of future water policy, we will have to amend certain aspects of Act, with respect to the parts that consider and regulate practically all the basic instruments of water resource management (rights to water use, economic-financial regime, contents and scope of water plans, administrative organisation etc.).

Finally, a basic instrument of water policy is water planning. The current Water Act confers it major relevance, with the introduction of figures from the National Hydrological Plan and the basin management plans. These plans contain strategic instruments for water policy, but are certainly not the only instruments. We will devote large sections of this White Paper to analysing these figures, their scope, their current situation and the role they are intended to play in the near future.

4.3. THE LEGAL BASIS

Although for systematic reasons, we have included this section and will deal with it just as the rest of the basis, in reality, as we have pointed out before, legal aspects have penetrated and shaped the world of water in such a way, with such intensity over the centuries, that in spite of the fact that abstract considerations might be formulated with respect to such basis, it is preferable to consider legislative aspects together with a general description of the sectoral situation and technical problems and those that cross over between the two.

This the system used in this White Paper with the global institutional framework and constitutional competence, with rights to use water, with the situation of registers, with the economic-financial regime, with water planning, with the legal regime of hydraulic works, with the situation of historical rights, etc.

Accordingly, legal concepts appear intermingled and pervading other considerations and data, throughout the text, and eliminating the need for a specific isolated and separate chapter.

Moreover, the application for an amendment project of the Water Act, widely distributed and debated in recent months, and recently passed, has given the opportunity to express, although not exhaustively, some of the biggest concerns and problems related with the legal regulation of water. This draft amendment obviously presents explicit legal indications and criteria that, given the current affairs and public recognition of the process, need not be repeated here.

In any case, and as global ideas, we should reiterate that the recent bureaucratisation of management, the greater demand for water, the increasingly scarcer resources, the deterioration of quality, the increase in social pressure and demands... are factors that come together in a growing complexity of water management and, consequently, in a legal development and proliferation of considerable proportions that, as was shown when we explained the current situation, does not always show the necessary desirable coordination, unity and integrity. In addition, the appearance of complex new collateral legal constructions, like environmental law (Martín Mateo [1977]; Jaquenod [1989]), which in turn pervade water law and require a dynamic adaptation or reformulation of some of its principles.

Growing scarcity exacerbates economic interest in the resource and competition for its use, creating an increasingly complex network of interests, expectations, rights and need for action; In short, of a higher complexity of water policy. For this reason, we must give a great importance to appropriate legal regulation that makes its efficient implementation possible.

It is usual, and it has historically been so, that new problems and situations that occur over time go ahead of regulation, and therefore also of water law. It should be no surprise, as has been stated in previous chapters, that different legal problems have been detected in practice with the current water policy, or related economic, social or environmental problems, due to the current legal regulation of resource exploitation.

It should be pointed out that, for obvious reasons, we can only focus on some issues that we consider significant, but which by no means are the only parts of the problem. More than that, the legal basis that could make up the water policy does not end with analysis of legislation, but we would have to deal with the efficiency of administrative acts that it generates or the agreements established by certain interest groups, such as different irrigators' associations, which truly form legal action and which because of their scope cannot be dealt with in this White Paper.

To conclude, a final comment on the fundamental questions that we should consider with caution when the arrangements are made to lay down the legal framework regulating water resources in Spain. First of all, offering *legal security* has always been a basic premise, meaning protection of water rights, in such a way that the owners enjoy sufficient security to be involved in medium and long-term commitments (particularly, investment-related decisions). Secondly, a certain margin of *flexibility* is desirable to be able to adapt to changes, both in environment (technical, economic and social), and in private situations. The extent to which water rights expediently solve this binomial and combines the frequently-opposing objectives of *security and flexibility,* will largely depend on an efficient application of the current law and consequently on the issue of whether water policy can fully reach its objectives.

4.4. ENVIRONMENTAL BASIS

4.4.1. Considering water as a natural resource

Before we deal with the specific environmental aspects of water resources that need to be considered for the outline of a future water policy, it is expedient to establish some conceptual specifications that allow us to focus on the issue and establish a framework for common reference.

Although it is not difficult to give an intuitive definition of what natural resources are, it is more difficult to unequivocally formulate such a concept and to set the precise limits of the term *environment,* as an object of our study in relation with water.

It is common to distinguish, in a generic way, between the *natural physical* environment (that can be associated with the biosphere or physical atmosphere), the *artificial physical environment* (or *technosphere*), and the *social and institutional environment* (or *sociosphere*). Related to water, these different perspectives have been observed in this White Paper, but it is now interesting to narrow the concept of environment down to its common acceptation and understand it as a *natural physical environment.* Accordingly, water is considered as one of the essential components (perhaps the most important) of the natural physical environment and it carries out a number of basic functions that will be examined in sections below. The *economic or non-economic nature* of these functions lies in the centre of the debate on natural resources and environmental policies (see. e.g. Azqueta and Ferreiro, 1994; Pearce and Turner, 1995), to which we will refer extensively later, when we examine the economic basis of water policy.

4.4.1.1. Concept of natural resource

Possibly the broadest definition of natural resources is that which refers to all assets that form part of Nature. This would therefore include all those resources of the land, air or water, generally valued by mankind, but without mentioning the fact that they are used, or not, as input in a productive process.

There are other, maybe more conventional, definitions such as the one that describes natural resources as *all attributes of the earth, animate or inanimate, that mankind exploits as a source of nutrition, raw materials and energy.* From this more limited perspective and which reproduces more faithfully the classic economic approach, we would deal with factors such as effect on production or consumption processes, which have their origin in phenomena beyond human control. These phenomena follow natural processes that can be biological, geological or chemical and have long or short duration.

In this conventional economic view, we could say that the environment or the natural resources are equal to the term *earth* in classical literature: they are factors that affect production activities, but they have not been made by man, nor have they been created through a manufacturing process created by man. It therefore refers to all the resources "in situ".

It is essential to understand that, despite these definitions, there is no totally clear distinction of a natural environment in many cases, especially in those resources associated or related with agriculture. In fact, there are vegetable species, like agricultural crops, and animals, like cattle, that are subject to exploitation by agricultural activity and which logically are not considered natural resources insofar as the reproduction process has been manipulated or controlled by man. Notwithstanding this fact, numerous timber plantations are forests that many people have traditionally perceived as natural, although they actually consist of silvicultural exploitation. In contrast, we can find resources, such as pastures or natural meadows, which although they are subject to regular exploitation, their regeneration takes place naturally.

It is relevant to say that, although they have not caused as intense effects as the urban process has, agricultural practices have also meant important modifications to the affected environment for years and years. The ecosystems that we can find nowadays all over our countryside (surface areas dedicated to agricultural uses) are the result of multiple accumulated alterations over the years.

A large part of the so-called public water domain can be seen in a similar situation, and it is not easy to find river reaches whose hydrological regime is strictly natural. Just as we showed in the section on anthropic impact on the hydrological cycle, the actions of existing regulation, together with the numerous exploitations that historically have been implemented in the different basins, create a new atmosphere, different from the natural one.

Understanding this fact is essential: only a small fraction of all our rivers can be properly qualified as an unaltered natural environment. Most of them have been anthropically affected in a more or less significant way, which occasionally has entirely transformed not only the natural fluvial regime, but also the conditions of the environment and even, in the most extreme case, the route and channel of the river itself. Any debate on water and the environment must take these fundamental circumstances into account.

4.4.1.2. Classification of resources. The issue of extendibility/renewability

To classify natural resources, different criteria can be adopted, leading to different typologies. From the perspective of water as a natural resource and as an economic asset, it is perhaps the time criterion that gives the best conceptualisation regarding the pursued objective of managing natural resources from respect for the environment and future generations. Following this criterion we can distinguish two basic types of resources, renewable or non-renewable.

Renewable resources. Renewable resources are those that when they are used can be consumed or not, but in both cases a regeneration takes place in a continuous and automatic way according to natural mechanisms. This regeneration can take a long or short time, or even be instantaneous (as is the case of air and solar energy) and follow the rhythms of biology (as animals and plants do) or not (like water through the hydrological cycle).

The relevant aspect is that the use of these resources *does not necessarily imply a global decrease in the existing reserve levels.* In order to maintain its condition as renewable, the restriction must be met that the rhythm of use does not exceed the periodical renewal rate or threshold that determines its regeneration capacity. The case of aquifers and their recharge level is a classic example of sustainable use of renewable resources.

Among this type of resources, we should also include the environment's capacity of self-purification or assimilation to absorb a certain amount of wastewater, converting it into a harmless product and returning it into the ecological system (on the condition that, as we said before, they do not exceed a specific threshold). In the event that such restriction is not respected, the stock of the resource will diminish, or even disappear, if the situation persists, with no possibility of recovery afterwards: in other words, they would no longer be renewable. The case of rivers that allow a certain level of pollution and eliminate it through processes of self-purification is a good example of this.

There are numerous aquifers, wetlands and river reaches in Spain in critical condition, because of exceeding the renewal capacity of the resource (especially in coastal areas and those with very slow recharge), subject to excessive discharge of polluting substances. Similarly, there are large areas that suffer from loss of fertile soil and face processes of erosion or salinisation, which can also be compared with this concept of excessive use of natural resources, above the possibilities of environmental renewal.

Non-renewable resources. Unlike renewable resources, these, once they are used, are not liable to natural regeneration, at least not in terms of historical time, and they therefore necessarily reduce the reserve level. Seen from a different angle: they are renewable resources, but their recovery rate is practically zero.

Among these, we could mention fossil fuels or mining exploitations, as the best-known cases; however, there are also resources with these characteristics within the natural water environment (e.g. aquifers whose recharge is so slow that it could be practically considered zero).

Resources of this kind are sometimes called exhaustible, although, as we indicated before, this is a characteristic that can be shared with the renewable resources, if certain thresholds are exceeded. In this respect, we have to point out that both types allow, in some cases, recycling processes that reduce their exhaustibility. In any case, it is interesting to highlight that the *exhaustibility* implies that the exploitation of said resources at the considered levels *cannot be carried out sustainably.*

4.4.1.3. Functions of water as an environmental resource

Now that we have typified the concept of natural resources and their basic classification according to the criteria of renewability, we turn to considering water from this point of view and show the diverse economic and environmental functionalities that it presents.

An interesting schematic representation of the relationships of the natural environment with the economy, and the different functionalities that result from it, is shown in figure 368, adapted from Reed (1994), and is recommendable to take into account.

The economy is shown in the upper half, represented through the classic relationship of production and consumption of goods and services. This half is therefore the fundamental question with which until very recently neoclassic economy has dealt with.

The natural environment is shown in the lower half (for instance, a river reach), and can be seen from three points of view: a stock R of natural resources, which is input for economic production processes (for example the water necessary for agricultural production through irrigation, which comes from this river reach); a stock S of natural deposits of wastewater produced because of production and consumption (for example the previous river channel, which acts as a receiver of waste); finally, a stock A of recreational services associated with the enjoyment of environmental assets (for instance, the observation of scenery or bathing in our river reach), and which do not imply any decrease in this stock.

As it has been represented, there are areas of intersection between A, R and S, and *management of natural resources* is actually nothing more than *deciding on the relative quantity of these intersections*.

With this perspective, we can state that the natural water environment has a very broad and diverse generic function that could be summarised as serving as a support for any form of life. Accordingly, all activities by mankind, those intended to meet the basic needs of survival as well as economic ones (whether they are productive or not), require, to

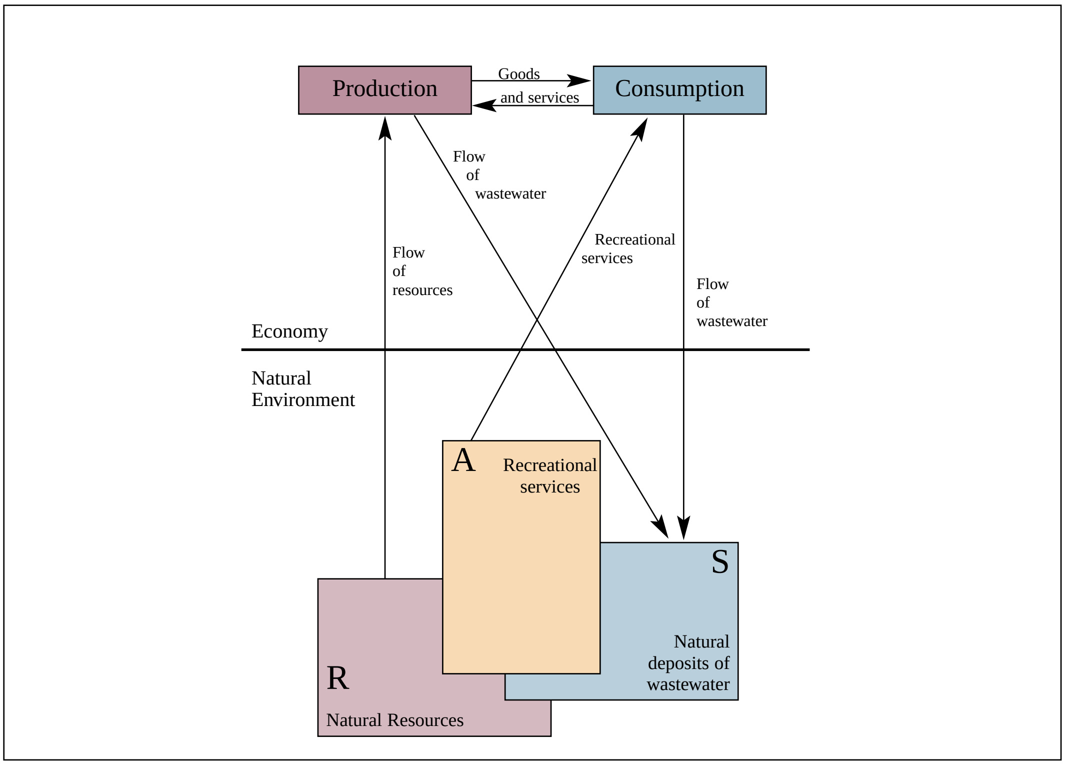


Figure 368. Scheme of the interrelations of the economy with the environment.

a greater or lesser extent, the natural water environment in order to support themselves, and therefore, there are a number of close relationships that associate all human activities with the natural environment, either through production processes or simply because these require a physical support for implementation.

Describing these relations in more detail, the components or specific perspectives of the general environmental function would be:

– Water resources provide **input for the economy,** for they form part of the production of almost all economic activities (R). The bulk of these need to include, for the goods they produce or use in some of the stages of the manufacturing process, a small or large amount of water, with certain quality conditions according to its use. Thus, water is an essential input factor for a wide range of economic activities, which range from the agricultural sector to services, through practically all industrial processes. It is also vital, without necessarily being consumed, for a number of activities that are carried out in the channels themselves, with more or less regulation, as is the case of transport or navigation, hydroelectric power, cooling of power stations, fishing, etc.

– The natural water environment acts as **receiver of wastewater** and waste of different kinds, the result of production activities as well as consumption by society (S). On some occasions this waste has been previously treated to reduce its pollutant contents, and on other occasions it is directly discharged without any previous treatment. Production activities are not the only source of wastewater, because natural systems themselves also generate their own; however, with the difference that natural wastewater tends to be easily assimilated and incorporated into the ecological balance. As we have pointed out, the environment has the capacity to absorb all these residuals to a certain extent and transform them into harmless or even beneficial substances (and are thus released without cost) thanks to its assimilation and self-purification capacity.

  Waste causes a deterioration of variable intensity in the natural aquatic environment. Urban-type waste is characterized by a high content of nutrients (specificly phosphorous and nitrogen) that deteriorate water quality in rivers and cause eutrophication problems in reservoirs. Normally they have an advantage, in terms of their necessary previous treatment, that through the collection network the waste concentrates in specific points and it is possible to take advantage of economies of scales.

  The most defining characteristics of industrial wastewater are diversity and lack of capacity to biodegrade. Such diversity makes it very complicated to establish standard processes that comprise all types of waste from sectors. The reality is that for many of these industrial contaminators there is no applicable technology that allows their elimination once they are diluted. Another added characteristic is the toxicity of some of the substances.

  Agricultural activities, in turn, are characterized by diffuse waste, which especially affects groundwater through pollution by chemical fertilizers, insecticides, etc. which dissolved in water are filtered into the ground. To treat these and to restore the quality of water and soil that are affected would be very costly and we should therefore pay special attention to this problem from now on.

– Finally, they also provide direct utility or well-being, in a sense of **aesthetic enjoyment or spiritual satisfaction for people** (A). They form part of the environment of individual utilities and domestic economies.

There is no doubt that all these functions have *a positive economic value* and they are recognized as such by society; however, society does normally not perceive the price it would have to pay to enjoy it in a hypothetical market of this type of services, because such a market simply does not exist. In fact, the loss of quality because of water pollution means some clear direct economic costs insofar as it has repercussions on other activities that use the resource downstream, and certain environmental costs as a result of the reduction in value of water used as a natural resource and the degradation undergone by its surroundings.

There is no doubt about the positive economic value of these functions. The basic problem that we consider is to determine this economic value in quantitative terms, an essential question to which a variety of studies have been dedicated and on which there is abundant literature (see e.g., Pearce and Turner [1995]; Azqueta and Ferreiro [1994]; Azqueta [1997]).

A fundamental conclusion that is derived from consideration of the environment-economy interaction and the functions of water as a natural resource is that linear and open considerations (where the environment is considered as an external element of the system), which are traditionally used in economic models, merely reflect a partial reality and they ignore the role of natural resources in the economy. Introducing the environment modifies this vision and transforms it into a closed system, with only one relevant external energy source: the sun. No matter what the resources used are, in the end they have to be somewhere inside the global environmental system. Everything is an input for the rest, and everything becomes an endogenous and interrelated entity.

Finally, it is expedient in this context to refer to recycling and reuse. Its interest in relation to water resources has already been mentioned above, and its role in the described closed system mainly consists of reducing the waste distributed over the environment and of joining the natural resources used at the beginning of the chain. The increase in reuse and recycling is, in principle, desirable, but we must not forget that there are physical and economic restrictions. In some cases it is impossible to recycle materials unless we incur irrational costs; in others, it is technically impossible because of its great dispersion; finally, others, such as energy resources, are not recyclable.

In the case of water, we have insisted on the importance of the techniques to improve the management of the resource over recent years, but this simple and generic idea needs qualifying in all specific cases and circumstances: *reuse is not an objective in itself*, but a way to reach a true objective, which is basically the *rational use* of natural resources. In general, a more rational use of water in a specific system would require the increase of reuse, but this is not always necessarily so.

4.4.2. Difficulties in the management of natural resources

Before we proceed to the analysis of environmental concepts such as water policy, it is important to explain some special difficulties that its management raises (Azqueta and Ferreiro [1994]; Franco Sala [1995].

Unlike other economic resources, these differential traits introduce certain singularities that need special treatment or socio-political preference.

4.4.2.1. Uncertainty and irreversibility

As we have already commented, one of the main difficulties the management of natural resources faces is the high level of existing uncertainty in many of the essential aspects that are involved.

In the first place, there is major *scientific uncertainty.* We do not have any clear knowledge about the interactions that take place between the different elements that make up the ecosystems. Neither do we completely understand some important natural processes nor the laws that rule them; suffice to mention, for example, the role of some of the variables in the formation of climate and its components, to which we have to add the recent emission of residual gases; nor the form in which it influences vegetation cover in the protection of soil, in the hydrological characteristics of basins or in the formation of microclimates, and nor do we know the level of existing reserves of some natural resources. This uncertainty and confusion about the stale concept of *ecological volume of water* and its practical determination is a good indicator of this absence of stable and consolidated theories that are vital to effectively approaching these problems.

In the second place, we do not really know the scope of the *relations between the environment and the economy.* Furthermore, we know that we will run out of non-renewable resources (and here we have to include the renewable ones that are used at a faster pace than their natural regeneration) if their consumption continues, but we do not know to what extent this reduction can be compensated by the increase of renewable ones (substitution of fossil fuel by solar energy, for instance) or by the evolution of technology. Furthermore, we think it would be possible to maintain the level of life, or what is the same, the services that we extract from natural resources, by consuming less of them, which implies a necessary increase in efficiency in their use, also based upon better technology.

In the third place, and in the same line, we could propose the substitution of natural capital by something artificial that would broadly replace the services that are produced by natural resources. However, and as we have said before, *there are environmental functions and natural resources that cannot be replaced by human invention.* Therefore, we cannot say if expedient solutions lie ahead of us in the future, at least on a large scale.

In the fourth place, the *technological process.* All of the afore-mentioned points somehow depend on technological development, trusting that innovation in this field will help to reduce the consumption of natural resources and maintain the level of life at the same time. But the reality is, that this is merely an act of faith and we do not know at what pace, in what way and how far we can go by taking this road.

Finally, what we do know for certain is that *anthropic actions* can imply *irreversible changes on a large scale* in the natural environment, and it is- this is very important - *the first time that this has happened* in the long history of mankind on earth. There are many examples of this kind in the actions of water policy. The simultaneous presence of a situation of incomplete information, added to the impossibility of reversing errors, definitely suggest *adopting conservative attitudes towards decisions that imply substantial and definite changes in the environment,* without considering the possible risks at times of catastrophes of any kind.

4.4.2.2. Free access

Natural resources and the environment in general can be seen as resources of common property (not private, nor public, nor without owner) to which in many cases, there is free access or at least access that is not sufficiently controlled. Although it was recently reformulated in the context of considerations on environmental economy, the concept is very old, there already existing references to communal property of water in the Laws of Alfonso 10th. It is curious to note that such communal property of the air, the sea and water in the Laws extends to *all living creatures,* and not only to mankind.

There is a generalized awareness in the economic world that this characteristic of common property might be responsible for the bulk of abusive acts that are currently occurring against the natural environment and for the numerous deficiencies that are observed in the management of this type of resources.

The explanation of this argument is based on the idea that there are no price (or cost) systems that transmit the message that natural resources are progressively scarce, of the extent to which we are depleting them or degrading part of the characteristics that make them valuable. It is evident that there cannot exist prices for these resources if certain *property rights* have not been made clear previously.

Therefore, and according to this criterion, the last cause of environmental deterioration and the depletion of the resources is not only in economic growth or development, but also in the absence of efficient mechanisms that produce rational behaviour in the use of certain assets that are starting to become scarce. This behaviour is conventionally ensured in the largest part of assets whose allocation is confined to the market. This is what in the economic context has been defined as *the tragedy of common property resources*, on which extensive literature is available (see, e.g., Aguilera [1992], part III).

There are a number of examples where we can see that the search for individual interest does not lead to achieving the most desirable political interest. We could mention the cases of many aquifers or a large part of the public water domain that exercises the function of natural deposit for wastewater. In all of these, the negative externalities caused to the other users or to the rest of society do not have compensation in terms of costs for the causer, to pass on the damage caused by his action.

Different solutions have been proposed to correct or at least mitigate such situations. Some, the most radical ones, defend the privatisation of all natural resources, considering that the existence of one single owner will safeguard its maintenance. Others, the majority, maintain that the solution to these problems lies in some type of collective management that restricts the individual rights of property, although it simulates some of the market mechanisms in the efficient management of the resources. We shall return to these significant issues when we analyse the economic basis of water policy.

4.4.2.3. The economic value of natural resources

The interest in economically evaluating environmental actions lies in at least two fundamental aspects. On one hand, it is an essential step towards trying to identify, with any accuracy, the level of economic activity compatible with the natural environment that is socially acceptable, which requires, as we have seen, calculation of external costs. On the other hand, it allows us to evaluate and judge the rationality of actions of environmental policy, whose financial costs can be perfectly quantified, but whose benefits are generally seen more diffusely, such as in improvements in the quality of life, not necessarily reflected in the National Accounts.

Even from the environmental point of view of preservation, natural systems could have more probabilities of protection if they had an economic assessment of the services they offer (Postel, 1997).

The problem of economically assessing natural resources and the environment requires a reference for the different functions they fulfil in the economic system and this is anything but simple. In any event, we should state that it is necessary to use a common pattern to measure the losses or gains in utility, in satisfaction, in well-being and in short, in individual and social preference.

The indicator that best adapts to the mentioned objectives is the monetary unit, although it is the centre of frequent criticism and sometimes even practically impossible to implement in the final stages; it should therefore be restricted to mere estimated approximations. However, this does not mean that the resulting monetary assessment has to be the one that the market decides. In fact, the largest part of environmental assets and services do not have a market, nor do they have a price.

In these situations, the amount of the *benefits* obtained from environmental improvement or of the *losses* due to impact on the environment, have an important technical complication and need adjustments in the usual parameters, but it is enough to point out that in either case two possibilities arise: the assessment based on the *willingness to pay* or the valuation based on the *willingness to be paid.* Although in theory these quantities should not be too far apart, empirical evidence shows that there can be major differences between them, (where compensation is always bigger than the other) which is source of some problems in making the evaluations. This data reveals an important reality: the enormous value that society gives to the loss of something that forms part of their *status quo* and considers its own.

We still have to solve how to measure or quantify the said concepts in terms of environmental assets. In the first place, we could propose that they be obtained by aggregation of the individual preferences shown by different people (there is a variety of methodologies for the purpose); however, there are a few inconveniences, some of which might be partially mitigated by making some corrections to take the previous distribution of income into account. In the second place, we can opt for a procedure that shows collective preferences, those of individuals as members of a social group, instead of, as we suggested in the previous one, private consumers. In this second method, we would attempt to go beyond the individual interest and confer the power of showing preferences to the agencies that represent society. In this case there would be a greater guarantee that issues such as personal, territorial and generational fairness are taken into consideration.

Finally, it is worth pointing out briefly the nature of the different elements that can make up the total economic value of environmental assets. Although there is no complete agreement on the subject, two main components can be distinguished (Pearce and Turner [1995]; Azqueta [1994]; Ferreiro [1994]):

Utility value. Refers to the value that arises as a consequence of possible benefits that real use of the environment generates. It would be obtained by adding up the values given from the following distinction:

- **Current utility value.** Derived from the current direct use by users.
- **Option value.** Although it is also related with use, in this case, it reflects the preference to conserve a certain natural resource to distribute potential benefits in the future, either directly to the same individual, or through other

people's use, or to their descendents or generations to come, sometimes calling it in this last case *legacy value*. In the case of water it would be the value given to a reserve of water volume that will be used in the future.

Existence value. This value source is much more diffuse and difficult to define, and understandably might seem strange from an economic perspective, because it is not related to any actions by human beings, not now and not potentially. In the case of water, it would be the value of a water volume that nobody has ever used before, or ever will use, and is not environmentally necessary. Its intention is to bring together the concern of people about the "rights" and the well-being of creatures and non-human property and reflect the wish that these be adequately respected. This concept is not exactly the same as *intrinsic value*, which recognizes a value that lies *in* something and which is absolutely unrelated with human preferences. In this case it would be about the value of the ecosystems themselves. The most radically conservative alternative movements defend this attitude that considers the problem of how these rights have to be taken into account in the assessment of the different actions.

4.4.2.4. Future discount

An essential subject that we have to face when we analyse the management of natural resources is the temporal distribution of its use. The problem of evaluating the different alternatives requires –as we know very well from our economic analysis– assessing the flow (profits and costs) that will most likely appear in the future, which is usually dealt with by introducing a discount fee that updates such flow and determines its present value (Azqueta and Ferreiro [1994]; Romero [1994]).

The introduction of this discount rate, which is always positive, is justified from two points of view: on the one hand it reflects the fact of temporary preference that the present society has with respect to the future; and on the other hand, the marginal opportunity cost of capital (the yield in the best possible alternative). In the case of investment projects that do not involve the use of natural resources this fee is usually at least the interest rate on the capital, and the consideration described does not cause problems in general.

However, in the case of the environment and natural resources, the adaptation of criteria of this kind usually leads to excessive discount fees, which can lead to the selection or recommendation of a certain project, whose profitability is guaranteed at the expense of an overexploitation of the current resources. This means sacrificing the well-being of future generations in favour of present ones. The discount does not seem to be compatible with the ideas of maintenance and preservation of the environment. In this sense, the overexploitation of a coastal aquifer (and its consequent total degradation due to marine intrusion), for example, would be equivalent to overestimating current profits and underestimating the costs that this would have in the future.

In short, there are a number of criticisms of the use of discount fees, at least in their most common implementation. As a result, these should be reduced and from more conservative positions, the opinion is even defended that it should be zero. Notwithstanding this fact, this type of consideration is also problematic, as in practice there is not one relationship between high discount fees and the deterioration of the environment, as we simply argue.

The answer to how the choice of discount fees exactly affects the general guidelines of use of natural resources and the environment is not immediate and it is debatable whether this is the best way to integrate environmental concerns when taking decisions.

4.4.3. Rational use and sustainable development

4.4.3.1. The development-environment controversy

In previous sections we have pointed out the relationship between water uses, its economic application, the degradation of the environment and the special theoretical difficulties in analysing environmental resources. In the concepts of classic economy, zero productive use means loss of economic wealth and prosperity for nations which is not considered desirable. The extreme opposite, a high productive economic use means degradation of the environment which would be equally undesirable.

Having pointed out this simplicity, the debate on both options has on occasions been quite bitter. On one hand, the *developers* argue that the need for economic development and productive activities, convinced that most wealth has to be generated at present, and faith in technology will resolve future problems. On the other hand, the *conservatives* argue that it is essential to stop this development in order to prevent an irreversible degradation of the environment that cannot be solved by technology, and which puts life on the planet at risk.

To reconcile both positions, the concept of *sustainable growth* arises, which is considered to be the modern environmental paradigm despite being anticipated by the physiocrats of the 18^{th} century, who defended the need for increase in the production of *renewable wealth* without deteriorating *basic resources* (Naredo and Parra, 1993).

In the following sections will we review these questions, explaining the main features of political water policy that can help to overcome this false dilemma, and explain the meaning of sustainability.

4.4.3.2. Negative effects arising from the exploitation of the environment

It is clear that the incorporation of natural resources by man and the economic activities for the production of goods and services on many occasions involves additional consequences that are undesired, on the natural environment itself and on society. In the case of water, the exploitation of the resource fundamentally means its abstraction from the natural environment in order to be consumed or used (reduction in circulating flow downstream), the modification of its regime of natural water volume (regulation), and the degradation of its quality (pollution). These manifestations are not necessarily and intrinsically negative for the environment, but they can become so, depending on relative quantity and incidence.

The possible negative effects of water use– that often go beyond the affected agents in the first place– have always been present to some extent, but it is only recently that there has been more awareness about the problems, as a result of the worsening in some of these effects, and there have been warnings about the need to deal with them using new instruments with economic perspective, as we shall see.

Depletion or degradation of the natural water environment has become apparent in many ways, but in general it has affected some of the characteristics that distinguish some of the components of this environment or make them valuable. The implications of this fact are more or less serious depending on whether they affect renewable or non-renewable resources, and within each of them, according to the variety of existing casuistry (aquifers, humid areas, etc).

An important characteristic of the depletion of Spanish water resources (shared with the rest of the Mediterranean countries, dry and semi-arid, with significant agricultural vocation) is the specificity that it shows with regard to central European countries (more industrialized). In fact, as regards these, the risk comes from the quality side while not respecting the natural environment's wastewater assimilation capacity, in our country there are two dangers: the loss of quality and the risk that is caused by frequently exceeding the renewal rate in terms of quantity.

4.4.3.3. Socially acceptable environmental impact

Economic activities, we could even say practically all human activities, always go hand in hand, inevitably, with some type of impact on the environment. This impact can be produced in terms of pollution or, in general, as environmental damage of certain magnitude.

As we stated before, there are levels of environmental impact or degradation, without reaching extreme situations of exhaustion that are admissible and are socially accepted.

In this sense, it is important to distinguish between the mere physical effect caused on the natural environment, which can be of different type and impact, and the human reaction to this physical effect, since there does not necessarily exist any significant correlation between the two. Social reaction usually takes the perceived loss of satisfaction or well-being as a reference, and this is shown in an economic assessment, in the broad sense that affected people have in such a situation. In this last case, there is an economic impact and which therefore involves an externality. Consequently, the existence of physical impact does not imply an economic impact and vice versa. But rather, there are very often paradoxical situations where citizens make claims because of some phenomenon of environmental degradation (for example, the claims with respect to the poor quality of river water), and opposition to economically contributing so that this situation can be mitigated.

Notwithstanding these contradictions, and according to economic theory, it is common that with a specific technological level, environmental impact grows on a par with the level of economic activity, and this reaches a point that is basically determined by private benefits of the producing agents, precisely the ones that cause the impact. At this point, marginal private profits (or the difference between marginal income and marginal costs) become zero, as conventional economic analysis shows under certain simplistic conditions. However, it might happen, and in fact it does, that this level of activity is not the most efficient for the group, since the external costs are usually not included. The problem that we are trying to solve is: what level of economic activity and, in short, of production and economic growth, causes environmental impact that is socially efficient. The addition of external costs to private costs of the producer reflects the social costs, and its inclusion in the economic analysis leads to another point of balance (the one in which marginal social costs equal marginal private income, or in which the marginal private profits compensate external marginal costs), consisting of a lower level of economic activity than the previous one.

We could conclude that there is an efficient level (in this sense it would be the optimum level) of externalities, that is, a production level that generates an environmental impact that is acceptable or admissible for society. When approaching this, *it is very debatable that all environmental impact has to be eliminated.* For this reason and for others that have been pointed out in earlier parts of this White Paper, the situation of *zero impact* is not only illogical but also physically impossible. It is true that the assimilation capacity of the environment, up to a certain level of waste, qualifies this statement in the sense that it allows for the existence of economic activity that does not cause any damage to the environment.

Establishing this optimum entails not a few difficulties in practice, and all the more if we bear in mind that it is based upon simplistic hypotheses that no longer work when, as is normal, market imperfections or defects appear. Simplified here, we will highlight these specific questions in further detail in the analysis of economic basis.

4.4.3.4. Economic growth, efficiency and sustainability

As we have indicated in previous sections, there is a point between the extremes of use-preservation that offers the greatest common utility, and this intermediate point is the one that corresponds to rational use or sustainable development, expressions that come to mean the same in this context.

The discussion on the physical limits to growth, the appropriate role of market forces in the process of development and the effects this has on the degradation of natural resources has been the central axis of analysis into the matter over recent decades. Although in principle it seems we have reached the acceptance that natural resources are enough to meet human needs in the long run, there is no agreement on the scope and intensity of the inefficient and irrational uses of these resources, especially in small and medium sized environments. Nowadays, economic and environmental thinking have reoriented the problem under the term *sustainability,* to which we will dedicate the considerations below.

Economic growth is today broadly interpreted as a necessary instrument to improve the quality of life. Obviously, the precise definition of this concept is debatable, but it seems clear that it has to reflect something more than real income per capita, although we recognize the importance of this in social well-being. Other elements of satisfaction should also be included; among them, without any doubt, the enjoyment of services the environment offers. This question is based on discovering how to manage natural resources so that they can fulfil these functions over the years.

In this sense and although it is not easy to define the concept of *sustainable development* (in fact there are numerous alternative definitions), we could understand it as that which maximizes net profits of economic growth, on the condition that maintenance of services and the quality of natural resources for generations to come are guaranteed.

This apparently simple approach raises a number of question marks from an economic perspective. In the first place we can ask whether the threshold has not already not been exceeded in some aspects; in the second place, a crucial subject, the methodology used in economy is not able to completely guarantee that stable ecological balance can be associated to any economic optima (the budgets on which the welfare economy is based for the best allocation of goods do not bother if the physical activity scale for optimum risk is sustainable or not). Furthermore, little is known about preferences of future generations, alternative technologies they will have at hand nor the costs of these, or how dependent their welfare will be on some of the natural resources that we consider indispensable today. Whatever economic model we may adopt (free market, centralized or mixed) it is not possible to ensure a satisfactory answer to these problems.

We can say that the experts relate economic growth and the preservation of natural resources in a complex way and in two broad directions. According to the first, in an initial stage and to a certain level of development, there is a complementary relationship, that is, growth can only be obtained by increasing natural capital. According to the second, in later stages, having exceeded the mentioned level, it seems that economic growth is achieved at the expense of the environment, that is, the loss of some of its functions. Despite all this, this interchangeability is only possible up to a certain point (it is possible for the function of aesthetic enjoyment and provision of input, for instance, but not for the function of residual assimilation, nor life support).

In any event, it does not seem very likely that, even assuming that the State were able to correct the possible market failures in the management of natural resources, our economy will take the correct path that leads to growth spontaneously.

The joint consideration of all these issues in the analysis of the problem seems to lead to the general conclusion that economic efficiency, understood as the maximization of total profits that can be obtained with scarce resources (or the minimization of consumption of resources to obtain a certain profit), is a necessary condition, but not enough to guarantee sustainability; apart from this, it is necessary to include some criteria of intergenerational fairness. Although we accept there is a risk of error that this could imply insofar as it arrogates the will of future generations.

Having explained the above and at the expense of including the new considerations, two possible alternatives to reach sustainable development arise:

- **Maintain the stock of total capital constant.** This proposal consists of ensuring that each generation leaves a quantity of capital for the next (natural plus what is man-made) that at least equals what he inherited from his predecessor.
- **Maintain the stock of natural capital constant.** This seems to distrust interchangeability between natural and artificial capital, and contemplates the joint consideration of renewable and non-renewable resources, allowing a certain degree of interchange between them, at least partially. At the same time, we can discuss whether this level of natural capital has to be the current one, or whether there is an optimum level, different from this one, that is also compatible with the objective of sustainability.

The debate on both alternatives will be looked at later on when we draw our conclusions, but it is interesting here to highlight the underlying difficulties of all these analyses and the problems that their practical implementation pose. Thus, in the case of water resources: up to what levels of development can we expand the users' systems? What are the optimum thresholds for environmental reserves? To what extent should available resources be granted for use?

These are problems that do not have an appropriate answer from the sole perspective of preservation of the environment, and which need the help of the economy to be efficiently approached. It will be therefore necessary to come back to them when we explain the economic basis of water policy.

4.4.4. Environmental impact

Environmental Impact Assessments have the objective of identifying and measuring or assessing the magnitude of impact of a certain project in a systematic way, firstly to determine if the environment has the capacity to absorb the consequences of such actions without being seriously damaged itself, and if so, to choose the solutions that ,considering all factors, are most favourable, and to accompany the project with a number of preventive and corrective measures for the impact. A crucial point for a positive result in the process is knowledge obtained from the reception capacity of the environment that is subject to the assessment (such as the capacity of self-purification in the case of reservoirs).

Environmental Impact Assessments stem legally from the approval of the *National Environment Policy Act* (NEPA) as federal legislation of the United Sates of America in 1969, the result of concern about uncontrolled demographic growth and economic development in that period, as well as theories on sustainable development. Public processes of decision taking changed when the environmental variable was included in the different instruments of analysis, up to that moment strictly technical and economic.

In 1985 the EEC published Directive 85/337/EEC, on the assessment of the effects of certain public and private projects on the environment. This Directive considered that *the best environmental policy consists in preventing the creation of pollution or nuisances at source, rather than subsequently trying to counteract their effects,* and *development consent for public and private projects which are likely to have significant effects on the environment should be granted only after prior assessment of the likely significant environmental effects of these projects has been carried out.* The projects that should be subject to Environmental Impact Assessment can be found in the Appendices to the Directive (Appendix I) and those that will be subject to said Assessment when the member states consider that its characteristics require an assessment (Annex II).

In March 1997 the EU issued Directive 97/11/EU that modified Directive 85/337/EEC. This modification intended to clarify, complete and improve the rules that relate to the assessment procedure and lays down that the projects of Appendix I are subject to prior consent and that environmental assessment will be carried out before that consent is granted. At the same time it completes the list of projects that have significant repercussions on the environment and obliges the member states to establish selection thresholds or criteria to determine what projects must be subject to the Environmental Impact Assessment. It introduces the obligation for a promoter to provide, among other things, alternatives to the projects he plans to submit for approval and, finally, it reinforces regulations regarding the assessment of effects on the environment in a cross-border context, according to the Convention of Spoo (Finland) of February 1991. Likewise, this Directive allows the member states to establish a single procedure that satisfies all its needs and those of Directive 96/61/EC of September 1996, on integrated pollution prevention and control (IPPC). This Directive grants member states a term of two years to adopt the necessary legal regulations to incorporate its requirements in their respective national legislation.

Also in March 1997, the Union presented Directive Proposal 97/C 129/08 to the Council, on to the Assessment of the effects of certain Plans and Programmes on the Environment, aimed at achieving a high level of its protection, ensuring the implementation of environmental assessment for certain plans and programmes, and whose results be taken into account during the preparation and adoption of such plans and programmes. It is laid down that the plans and programmes to which the Directive refers be adopted in the decisive-making process related to the territorial planning, with the objective of establishing a framework for later decisions on consent, including strategic plans and programmes that are adopted in the sectors of energy, wastewater, water resources, industry (including the extraction of minerals), telecommunications and tourism, and certain plans and programmes of transport infrastructure. Also, the modifications of existing plans and programmes are expressively included for the management of water resources, among others. This Directive Proposal is still pending approval.

The incorporation into state legislation of Directive 85/337/EEC led to the Legislative Royal Decree 1302/1986, of the 28th of June, on Environmental Impact Assessment for the purpose of *introducing the environmental variable into decision-making on projects with a significant effect on the environment* consolidating the separate sectoral regulations existing at that moment and our particular case in the Water Act 29/1985 of the 2nd of August, which lays down that in the proceedings of concessions and consent that affect the public water domain and at the same time imply risks for the environment, the presentation of an assessment of its effects will be mandatory (section 90), and thus completes and normalizes this important administrative procedure. A phase of public information is also included in the procedure that invites the public to participate. Projects relating to National Defence or those specifically approved by a State Law are expressively excluded from its application. Likewise, the Council of Ministers, in exceptional cases and through a motivated agreement, will be able to exclude a certain project from the procedure of impact assessment.

This will apply to works, facilities or activities that are started two years after its coming into effect, (Official State Journal 30/06/1986).

LRD 1302/1986 contains one single Appendix as a list of projects that are subject to an Environmental Impact Assessment, including all those indicated in Appendix I of EU Directive 85/337/EEC, in addition to some of those in Appendix II. Those related with the sector that we are interested in are:

- Large dams.
- First reforestations, when they contain risks of serious negative ecological transformations.

This grouping, excluding the rest of the projects of Appendix II of the mentioned Directive, has given rise to sanction procedures from the EU by understanding that the incorporation was not correctly implemented by completely excluding the rest of the projects in said Appendix. An explanation of the legal regulations of impact assessment of hydraulic works can be found in Rosa Moreno (1996).

LRD 1302/1986 was developed through the Royal Decree 1131/1988, of the 30th of September applicable by the State Administration and, directly or supplementary, by the Autonomous Communities according to their respective powers on environmental matters. There are two Appendices. Appendix 1 defines various technical concepts and Appendix 2 contains specifications related to works, facilities or activities comprised in Appendix of the LRD 1302/1986.

Act 4/1989, of the 27th of March, on the Conservation of Natural Areas and Flora and Fauna, lays down that transformations of soil use will be subject to environmental impact assessment if they involve an elimination of the vegetation cover, bushes or trees and involve a potential risk for the infrastructures of general national interest, provided that these transformations affect surfaces that are greater than 100 hectares.

This state legislation has a character of basic rule and many of the Autonomous Communities have developed environmental legislation within the scope of their competence and statutory development.

Currently, and in order to adapt to the recent Directive 97/11/EU, the State Administration is preparing a Preliminary Design of the Environmental Impact Assessment Act which includes as an innovation the *Estimative Assessment*, through a simplified procedure, of the significant effects that the Plans and Programmes of Territorial Planning can have on the environment, before they are passed by the competent Authority, as well as the adaptation to the Spoo Convention, as far as possible, of affected environmental cross-border effects. It includes three Appendices: Appendix I contains the projects of works, facilities or other activities that are subject to Environmental Impact Assessment and must obtain the corresponding Declaration of Environmental Impact; Appendix II determines the projects of works, facilities or whatever other activity that must be subject to a prior Environmental Impact Assessment, when the Environment Agency deems fit, in a *case by case* analysis. This decision, which must be grounded, will be adapted to the criteria laid down in Appendix III.

It is expedient to highlight the interest that the analysis and environmental assessment of Plans and Programmes has generated, through what has been called strategic environmental assessment, as a way to consider more general scenarios and alternative options, where the environmental factor is taken into consideration, to generate feasible environmental projects. Otherwise, there is a danger that the procedure of Environmental Impact Assessment applied to an individual project is only used as an instrument to correct impact instead of being a preventive tool, given the difficulty that this method involves in dealing with the most basic causes that are the origin of some environmental imbalance.

For a process of this kind to be efficient from an operative point of view, it is expedient that the tasks of planning and assessment are carried out with more or less simultaneously, so that the assessment is not just a formality once the works of the Plan are completed.

The current competence framework is established by considering the competence that corresponds to the Autonomous Communities on the one hand, and to the State on the other, which can independently exercise such competence by virtue of two criteria: supraterritoriality and general interest. Section 5 of 1302/86 stipulates that *an environmental agency is considered one that exercises functions in the Public Administration where the substantial competence lies in implementing or authorising the project.*

The fundamental part of the assessment processes is the Environmental Impact Study, which has to give sufficient information to base its assessment on. The aim of this Study is to make a forecast on the environmental effects (impact) that the project, to be carried out as is proposed in the considered alternative, may produce, as well as an assessment of the impact.

The responsibility for carrying out this Study lies with the promoter of the project, although some Autonomous Communities, such as Castile-León, have established prior public control in their regulations, on the technical capacity of the teams authorised to draft impact studies (section 5.1 of Act 8/1994, of the 24^{th} of June).

The exact contents of the Study will depend on the action, but in any case, and as a minimum compulsory content, it must comply with the following:

- Description of the action that is to be carried out.
- Environmental inventory
- Identification and assessment of impact
- Proposal for protective and corrective measures
- Programme of environmental monitoring
- Summary document

The procedure of Environmental Impact Assessment is carried out, in this case, in parallel with the approval of the project and concludes prior to the Evaluation, and involves certain procedural phases. The different phases of the Assessment Procedure are:

- Start-up. Notification to the environmental agency of the intention to implement the projects, accompanied by a summary.
- Previous consultations. From the environmental agency to people, organisations and institutions.

- Implementation and presentation of the Study. Together with the project documentation.
- Public information. Of the Study together with the file and project documents.
- Delivery of the file to the environmental agency. Prior to approval of the project.
- Impact declaration. Issued by the environmental agency with or without conditions.
- Decision on approval. The competent agency, once the Impact Declaration is received, will carry out the approval procedure, incorporating the decision into the Impact Declaration.

The administrative procedure of assessment normally concludes with the Declaration of Environmental Impact: it is a prior, instrumental act of substantive procedure, discretional in character and which therefore must be appropriately grounded. The Declaration of Environmental Impact will determine, only for environmental purposes, whether it is expedient or not to carry out the project, and if so, it will lay down the conditions under which it should be carried out, the corrective measures that must be applied and will include the pertinent regulations on periodical monitoring of its adequate implementation.

4.4.5. Environmental indicators

Apart from impact assessment techniques, another interesting instrument to consider in water resources from an environmental point of view is that of the so-called *environmental indicators.* Unlike the impact assessment, which is developed for the specific project or action analysed, indicators have a continuous and permanent character. They refer to the general situation and to global environmental policies and are not specifically related to any particular action.

Environmental indicators arose as an answer to the triple need for having appropriate information for decision-taking in environmental policy, to be able to make an objective follow-up of the results of these policies and to satisfy the needs of public information, and all this by reducing the large amount of available information into a reduced and manageable set of parameters.

Accordingly, indicators add up the environmental information and present it concisely, obtaining added value associated with social interest in the environment and, as a result, with policy decision-making.

A first classification of indicators, according to the criteria of the OECD that deals with its different possibilities of use, is:

1. Indicators of *sectoral integration,* which provide information on the interrelation between economy sectors and the environment, contributing to the integration of environmental policy with sectoral policies.
2. Indicators of *economic integration,* which inform on the environmental costs associated with economic activity and allow the economic quantifying of environmental externalities.
3. Indicators of evaluation, which reflect the environmental situation quantitatively for the most interesting or relevant issues, within a framework of causality *pressure-state-response* that allows a classification of these three concepts. In fact, human action puts *pressure* on the environment and modifies the conditions (quantity and quality) of the natural resources. Society *responds* to these changes with environmental, social and economic *policies*, thus generating a cycle against pressure actions. These steps make up the cycle of perception of a problem, formulation of policies, and their monitoring and assessment.

   Assessment indicators are those that currently show the highest level of accuracy.

In Spain, we have recently started to develop this type of technique, and a first general proposal of assessment indicators already exists (MIMAM, 1996b), as a specific group of indicators for water (MIMAM, 1998c).

The Spanish system of pressure-state-response was structured in 4 main areas: atmosphere, waste, urban environment and natural resources; and this last one is subdivided into another 6 sub-areas: biodiversity, forests, coasts, marine environment, soil and water.

Table 114 shows the proposed indicators for water, together with two identified key issues or concerns to which they refer (scarcity of water and quality decrease), and the type of indicator (E=state, P=pressure, R=response).

The calculation of these assessment indicators of the water sub-zone shows that the situation of the resource is worrying, due to the unfavourable trend of numerous indicators (in general, revealing the deterioration of water quality), although some positive progress can also be seen in others (such as the population connected to EDAR).

Notwithstanding the deficiencies of the statistical data involved, the simplicity, innovation and as a consequence, the relative immaturity of these techniques, and their necessary review, calibration and continuous perfection, we should underline their unquestionable interest and expedience of continuing their exploration and development, moving them from theoretical fields of proposal to their conversion into really operative instruments in the ordinary process of environmental decisions and policies in water resources.

4.4.6. Conclusions

Now that we have presented some of the aspects and techniques of interest inherent in the management of natural resources, it is possible to superficially outline a proposal for the management of the natural water environment, from

Code	Indicator	Quantity (Scarcity)	Quality		
			Surf.	Subterr.	Ecological
A1	Aquifers contaminated with nitrates			E	
A2	Coastal aquifers made salty by marine intrusion	E		E	
A3	Rivers with high quality according to biotic indices		E		E
A4	Rivers with a high quality according to ICG		E		
A5	Eutrophised reservoirs		E		
A6	Endangered or extinct fish				E
A7	Overexploitation of aquifers	E			
A8	Natural water resources per inhabitant	E			
A9	Intensity of water use	P			
A10	Population with treatment of residual water		P		
A11	Public expenses on residual water management		R		
A12	Defined channels				R

Table 114. Environmental indicators for water.

the point of view of sustainability. Apart from these global ideas, we will need economic instruments focused jointly on existing problems, as we will see in the corresponding section.

Firstly, it is important to stress that all the mentioned considerations mostly lead to opting for one of two alternatives mentioned (constant stock of natural capital or constant stock of total capital), aimed at achieving sustainable development. In fact, insofar as we have no further means of improving our current information and comprehension level of problems, the most plausible proposal consists in *maintaining the stock of natural capital and, moreover, at its current level (or better).*

This proposal implies somehow that we should give up looking for an optimum level, presumably lower than the current one, assuming that we are actually above it. There are good reasons for this. In the first place, and similar to the ideas on the crisis of economic objectives in water policy, it is practically impossible to identify this optimum level (the multi-functionality of natural resources, their key role in supporting life and the risks of irreversibility show this): secondly, the idea of an optimum refers to efficiency criteria, leaving out the objective of fairness both with respect to current generations and to future ones; finally, recent empirical work suggests that people value a loss of something they owned much more than a gain, even in marginal terms. In short, maintaining the current environment is the only way society has to ensure that their welfare will not reduce the options of generations to come.

There are a number of ways, however, to interpret this proposal of maintaining the level of environmental assets constant. It can be understood in aggregate physical terms, but in that case the problem arises of how to add up the quantities of resources whose characteristics are sometimes very different. Assuming that they could be expressed in a common unit, such as for example monetary (which requires a correct assessment of all the functions that operate in the economy, which is extremely difficult), and we might add that natural resources cannot be substituted. In contrast to this, if it is understood in non-aggregate terms, the condition can be too restrictive. Another possible interpretation could consist of maintaining a constant flow of services from the natural environment.

No matter what interpretation is adopted, it is never free of difficulties and the specific characteristics of each case will suggest opting for one solution or another. There is no doubt that a wide margin will open for the management of the environment and natural resources. In any event, there seems to exist less difficulty in converting some simple practical rules to the conditions of sustainability in our economic and environmental systems (maintenance of services and of quality of resource supply over the years). These guidelines for sustainability are as follows:

a) *Use of the renewable resources at a rate that is slower or equal to its natural regeneration.* This condition has bearing on two basic aspects:

- The abstraction of resources for use as input in the production system, which requires, for instance, the elimination of uncontrolled over-exploitation of aquifers and the establishment of measures that prevent this process, or the establishment of maximum levels for the concession of water from a river.
- The discharge of wastewater into the environment, which requires, for example, the control of waste and its limitation to predetermined levels.

b) *Optimisation of the use of non-renewable resources, subject to the restriction of guaranteeing the substitution of said resources through technological process.* This rule also suggests two action plans:

- Compensate the reduction in resources that are not renewable with the increase in or the incorporation of renewable resources, which would allow, for example, controlled isolated over exploitation.
- Reduce, thanks to improvement in efficiency, the unitary requirements of resources to maintain the same quality and quantity of services, that brings about the whole range of water-saving policies, efficiency in use and preservation of the resource.

Dealing specifically with water exploitation systems, maintenance of current environmental assets can be carried out by means of the conceptual model that is described in the sections dedicated to natural and available water resources. As described there, once the natural assets that are to be preserved are identified, they *will be excluded* from natural resources, not forming part of the water exploitation system.

It is interesting to point out that almost all these criteria suggested by environmental theory are completely concordant –if not completely accepted– by the current regulation on water matters. The fact that the practical results obtained are far from desirable stems, once more, from the problem of practical implementation of the rules more than from the rules themselves.

These are very important issues, such as suggestion of limiting future concessions as a precautionary measure to help conserve the environment, of considerable political and socio-economic significance, and may be laid down through the legal instruments of national water planning.

4.5. ECONOMIC BASIS

4.5.1. The need for an economic approach to the preservation of natural resources

When we refer to the economic basis of water policy, we should make it very clear that the *absolute necessity to introduce criteria of economic rationality for appropriate management and preservation of natural resources* is a water principle that needs to be understood right from the outset.

The reason for this is quite simple and has been repeatedly expressed in this document: That what until recently seemed unlimited is now scarce and the domain of what is scarce is the natural domain of the economy. Discipline is therefore requested, beyond distortions and sectoral interests, to introduce more rationality in the debate on water.

Having established this, it is necessary to specify that economic reasoning should not be confused with what is sometimes called *economicism,* and even less with an economicism that is seen as contrary to environmental concerns. Conversely, the economy has developed some analytical techniques and assessment guidelines that amply exceed the conventional, reductionist vision of economic problems, and this extended vision is what this White Paper postulates. The classic differentiation by Aristotle between *chrematistic* (related to money) and *economic* (related to administration of the house, and by extension, of the planet) turns out to be very clarifying (Aguilera, 1995b).

On the other hand, in no case we can deny the possibility that socio-political consideration can qualify or even refute the fact that the results of political analyses and decisions of public intervention act in such a way, but always doing so with transparency, and after correct and honest quantitative knowledge of the involved economic flow and the indicators that result from them.

We will deal with the study of the economic basis of water policies from two different points of view although, as we explained before, closely related: one where water is seen as a productive economic asset, used as input for economic activity and one where water is seen as an environmental asset, that has to be conserved and preserved from degradation.

The first perspective directly leads to the question of economic-financial rules, costs and prices of water, considered as an economic asset, just as we explained in the previous sections dedicated to the water economy. The second leads to the question of environmental economic policies and their possible use for the protection and improvement of the aquatic environment.

4.5.2. The concept of water as a productive economic asset

In previous chapters we described in detail the current situation as far as the sectoral economic incidence of water is concerned and its current legal and financial-economic regime.

From what we explained, we clearly deduced a situation that, although it has tended towards improvement over the last years, cannot be considered fully satisfactory yet, nor optimum from an economic rationality point of view.

In fact, as we have seen, and in accordance with the existing social perception, commented on in the sections on socio-political basis, the current legislation lays down that water is a *free* asset, as if we were dealing with an abundant resource. However, Spanish hydrological reality does not corroborate this consideration and society itself admits that it is a scarce and certainly precious natural resource, on a national level at least.

This legislation only foresees compensation aimed, basically, at repaying the Water Administration part of the necessary investment in order to guarantee the availability of the resource (regulation tax, user tariff and discharge tariff), not taking other opportunity costs for society into account, with the consequent loss of welfare that this might imply for the whole, and conversely, the profits that may be generated.

The most relevant aspect from an economic point of view is that these levies are designed as the required works in order to obtain water and treat it, but *there is no relation with the scarcity of the resource* and its economic values are therefore not considered, nor is the willingness of consumers to pay.

But this situation, which may be conceptually admitted as a valid model, is notably downgraded in case of discrimination, claims, protectionism, moratoria and practical difficulties of charging, leading to these quantities not even being fairly calculated and fully collected by the Water Administration. Such deficiencies in the system should be progressively overcome if the intention is to maintain it, as seems reasonable in the short term.

In short, the absence of a system that transfers the real costs arising from use of the resource to users, together with the precepts of the concession regime, do not facilitate an economically efficient allocation among those who compete for it. The non-economic deficiencies that this system causes in concession-granting arise in the difficulty of defining terms such as "demand" (without an associated price, as commented in the sections on its analysis), "rationality and economy in water use", "ecological volume of water" and therefore "redundant", etc, sources of many of the problems that managing water resources faces when defining and quantifying its objectives, explaining its policies and specifying its decisions.

Moreover, from the sectoral point of view, and as we have seen in the description of economic impact, a certain reallocation seems desirable or, at least, a reorientation of legal priorities for the purpose of granting future concessions. The preference for the standard established irrigation in the Water Act –unless water plans specify otherwise–, and inherited from previous regulations, is of doubtful rationality, as a generalized criteria in the socio-economic Spanish reality of the moment, and this despite the varied situations and possible classification of water demand, beyond its classic use (López-Camacho, 1993).

Summarizing, it is clear that, in most cases water has historically changed from a free, abundant asset into a scarce asset, liable to degradation, and used as input in productive economic processes. The current economic-financial system does not explicitly consider this condition of the resource, limited to the recovery of the costs of its availability. This model presents problems and deficiencies that were commented in other chapters, but for reasons that were explained there as well, for the moment it seems reasonable to maintain and improve it in those isolated and necessary aspects.

Nevertheless, and in spite of the need for improvement and maintenance in the current regime, it is expedient to analyse alternative models in the medium and long term that adapt best to current socio-economic circumstances, which explicitly consider economic assessment of the resource and which overcome the restrictions of the current models.

4.5.3. Economic water policy considered as an environmental asset

It seems to be commonly accepted that the regular method of approaching conventional economy is unable to satisfy and adequately respond to the concerns of society in relation with the treatment of the environment and its integration into the current growth models. Whereas the objective of economic efficiency (which has a predominant and almost exclusive role in the response of neoclassical economy to allocate scarce resources) does seem to adequately represent collective interest, when it deals with goods and services that may be exchanged in the market, however, in case of environmental assets, generally without price, there is evidence that people include other additional objectives in their concern.

In fact, aspects such as the right and fair access to natural resources, combined with the conviction that many of them are essential to actual survival (and also to provide quality of life), and moreover cannot be substituted, lead to serious doubts as to the utility of classic instruments of optimisation in terms of costs and benefits.

However, these issues, far from invalidating the traditional economic analysis for the management of natural resources, reinforce its role in that it contributes to improving the necessary understanding of the relationships between the ecosystem and economic activities, allowing a development of theoretical extensions to approach new problems. Only by complementing, with methodology and rigour in the treatment of information, the valuable contributions of natural sciences and the economy, will it be possible to find a better solution to such a broad and complex subject as is environmental management, and particularly of the natural resources involved in the hydrological cycle, with an eye on its protection and preservation. The controversies about the best management of these resources have been particularly intense in recent decades, and issues such as public or private opinion, state intervention, market efficiency, etc. are at the heart of the economic debate on water. The following sections will approach these issues. In any event –it goes without saying– the question is open and subject to many controversies, whenever world views converge, so varied in some cases that it is difficult to establish a common starting point.

In any case, and as we have reiterated, between the extreme position of maximum exploitation of resources oriented towards growth, with blind faith that technological innovation will mitigate the scarcity of the resource in the long run, and the opposite position, completely *ecocentric* and in favour of absolute preservation, and between the position of complete liberalization and leaving the allocation of water to market forces, and the position of total public regulation and a strict administrative system of allocation, there are middle positions, of greater general utility, and greater practical rationality.

4.5.3.1. Public and private in the environmental management of water

4.5.3.1.1. The markets as instruments of environmental policy

A rational approach to the economic policy of water as an environmental resource, and to the instruments of protection of the environment and combat against pollution, has to begin, as in any other case of economic management of a resource, with the study of market possibilities, of the feasibility that contaminators and those who are damaged by pollution can reach economically optimum, voluntary agreements, and to a level of society's general satisfaction with its aquatic environment.

If the results from these studies indicated that such market allocation and voluntary agreements are possible, and if a generalized satisfaction with the environmental situation existed, the establishment of specific public intervention would not be necessary, and it would not be necessary to develop a public water policy specifically oriented towards preventing its degradation; and public intervention would be justified.

We will therefore start with finding out *the market possibilities* regarding the specific environmental assets, relating to the protection of the environment. Obviously, this White Paper is not the appropriate place to discuss concepts of economic theories on natural resources, broadly covered since the 1970s in numerous manuals and specialized literature, but the importance of the subject and the generated controversies are such that we think it expedient to briefly introduce some of these concepts and results of economic theory, especially relevant to our analysis of water as an environmental asset.

We should therefore start by recalling that the markets are based on the principle of *sovereignty of consumers,* and function through the *system of prices.* These prices, in competitive markets, and under certain conditions, are indicators of scarcity (even in imperfect markets), guide the choices of consumers, and facilitate an optimum allocation of resources, which constitutes an important series of advantages.

However, *there is wide theoretical agreement on the fact that the market does not work regarding certain environmental assets,* and with relation to the protection of the environment. Following the description by Franco Sala (1995), among the possible reasons for this failure we could underline the following.

The incidence of negative externalities

As is very well known, we say there is a negative externality, an external diseconomy or an external cost when the activity of an economic agent provokes a loss of welfare (or utility or satisfaction) in another economic agent and, moreover, this loss is not compensated. Both conditions are necessary to speak of negative externality, given the fact that in the opposite case (if there is a compensation, for example), we say the effect is internalised.

Even though negative externalities can be generated by decisions taken about resources of private property (for instance, the felling of a private forest can cause erosion and contribute to the destruction of reservoirs and increase floods), this is not the assumption that is most interesting here, however, and we concentrate attention on public property resources.

The appearance of negative externalities is very usual in the case of common resources and, in particular, in the public water domain, and can affect both other users of the same common resource (generating conflicts between them), and society as a whole, or all at the same time. Suffice to mention, for example, the situations that occur when water is abstracted from aquifers, water quality deteriorates in rivers or associated ecosystems degrade. In this sense, the environmental damage (like pollution) would be basically a possible particular case of negative externality.

Producers as well as consumers can cause negative externalities. In the case of water resources, externalities occur frequently in the supply phase (construction of infrastructure of regulation and transport, transformations in irrigation), and users also generate externalities at the moment they use resources (pollution because of discharge into the public water domain, degradation of ecosystems and aquifers because of water abstraction, etc).

From the production point of view, any economic agent buys the resources they use (raw materials, work, patents, etc.) causing *private costs.* Moreover, he occasionally makes use of environmental resources that are degraded because of their use (e.g. discharge into the water), this meaning some *external costs,* since they cause damage to third parties (e.g. farmers that irrigate with polluted water), and the polluter does not compensate the injured party for this. S*ocial costs, w*hich are the real costs for carrying out this activity as a whole, is therefore the sum of private costs plus external costs.

Although we have referred to externalities with a negative character, there are also positive externalities. In any case, we can demonstrate that the presence of one thing and another – the divergence between private and social costs – does not work and leads to behaviour by agents involved that gives rise to market distortions, causing the point of balance not to be socially optimum, that social loss reduces the collective well-being as a whole and that an incorrect allocation of resources takes place.

The nature of water as a public asset

Pure public assets are those whose consumption has two characteristics: it is at the same time *non-exclusive* (one cannot be excluded from the consumption supply even though one is not willing to contribute to its costs, as in national defence, for example), and *non-rival* (its exploitation by one agent does not prevent the consumption by others, such as public lighting in a street). Public assets that only have one of both characteristics are on occasions called *impure public assets.*

There are many environmental assets that have the nature of public assets, because they fulfil one of the conditions, and of pure assets, because they fulfil both (like for instance air quality as a result of combat against atmospheric pollution). In the case of water considered as an environmental resource, some of its utilities can be seen as a public asset both non-exclusive and non-rival (for example the decontamination of a river for general environmental enjoyment downstream). The impossibility of excluding someone if a price is not paid, is a market failure that would lead to over-exploitation and degradation, absence of real indications of the preferences of the users of the asset and absence of incentives for producers to produce an asset that, once it is on offer, it is impossible to prevent its free, open access to anyone who wishes.

Public intervention is inevitable, in the cases of environmental assets where the principle of exclusion is not applicable.

The nature of water as a preferential asset

The assumption of *preferential assets* is that in which the market can generate an efficient supply of assets, but the public sector has to intervene for different social, political or ideological reasons, giving incentives or obligations to consume. Cases of this type are:

a) The ignorance or irrationality of consumers that can claim less consumption than would be optimum for them or for society (like, for example, education and training).

b) Preferential assets generate positive externalities (such as the clear case of education level) that favours society as a whole.

c) The supply of preferential assets ensures at least a minimum consumption supply to the public, regardless of their interests or their income (case of free and compulsory public education).

In the case of water, it is clear that minimum supply for all the basic needs of supply have the nature of a preferred asset, for it does not depend on the market, but is a requirement of the current standard of living that can socially be demanded, and produces an improvement in public health and quality of life. Other market offers can later be added to this basic offer of the public sector (supplies of larger quantities or better quality according to areas and costs, sumptuary improvements of urban areas etc.).

The functioning of the market in the short term

It is normal to consider that the *total economic value* of an environmental asset is the sum of the *benefits for the users* (comprising the value of consumption and the value of activities that do not imply consumption), plus the *option value* for potential users of the current generation (who do not use them now, but might do so in the future), plus the intrinsic benefits or *existence value* for the rest of the planet and for generations to come (value attributed to the asset itself for its mere existence, regardless of all its private use by the current generation).

The market, however, basically functions in the short term, considering the consumers that are willing to pay or start to pay in that term. As a consequence, it ignores the existence of an optional demand and future generations, which implies its imperfect functioning from the natural resources point of view and their exploitation in the long run. When we undervalue them, it favours their degradation and over-exploitation.

With regard to optional demand, this is caused by economic agents that do not consider consumption at this moment, but have the intention to have the asset at their disposal in the future. A market with environmental assets acts in the short term and does not consider this option, meaning that the resources are allocated while undervaluing the environment.

With regard to the generations to come, not considering them causes a low valuation of the environmental asset, while environmental preservation and rational use require criteria based upon the long run. A possible solution to this problem would be the incorporation, through public intervention, of a type of social discount in the cost-benefit analysis, but this poses problems and questions that are far from solved. What will be, for example, the valuation of future generations regarding virgin areas of the channels, fluvial emergences, springs for drinking water, water scenery? There is no answer to these questions, but we can know intuitively that it will be high, much higher than it is nowadays.

Irreversibility

Physical and economic irreversibility (because of exorbitant costs) of many actions that are undertaken in relation with the environment prevents us from adequately evaluating these assets through the market, and it is directly related with public intervention with an effect on the environment. We will return to this question further on, when we refer to the objectives of public economic policies in relation with the environment.

The lack of a system of property rights

We have already explained in depth the process through which water is no longer an abundant asset, a *free* asset, becoming a scarce asset, and therefore *economic*. The move from a free asset to economic asset goes hand in hand with the transformation of its legal nature, turning into an asset with a holder, or owner (public or private).

From some authoritative perspectives, such as Coase (1960), the thesis has been supported that the absence of a system of property rights (regardless if it is in the strict sense of full property, or in the sense of concession ownership) gives rise to a use for environmental assets that is not optimum.

The absence of a system of rights implies the absence of incentives to save and preserve, and favours over-exploitation and degradation. Moreover, the absence of owners means that nobody in particular claims the loss of utility of the derived assets in his territory: there will be no compensation for the externalities of degradation and the market will work incorrectly.

In the case of water, the system of ownership and access to its use, and the situation and problems of the registers, where these rights are registered, have been extensively commented in other sections of this White Paper, and we refer the reader to those sections. The feasibility of improving the allocation of resources through voluntary transactions, once the rights of the interested agents are clearly defined, is a question of central importance in the modern debate on economic water policies, giving rise to inflexibility in legal concession and the possibility of water markets and banks, burning questions on which broad, passionate, and not always rigorous debate has recently been seen in our country.

4.5.3.1.2. Voluntary negotiations

As we have indicated in the previous section, one of the causes for market failure in the presence of external costs because of pollution is the absence of a well-defined property system for environmental assets.

As regards this issue, we can pose the following problem:

Assuming there is an established and well-operating rights system for water (registers, concessions, authorizations, registrations…), and allowing full negotiating power for the exchange of rights between owners, could a voluntary negotiation between these owners lead to an optimum allocation of water use, without any need for public intervention?

A basic contribution to the answer to this problem was given by Coase (1960), who showed, in his famous theorem, that the absence of transaction costs and with a well-defined rights system, the causers of an externality and those affected by that externality, are capable of approaching the volume of the contaminating activity through negotiation and the external effect to an optimum social level (in other words, considering private benefits and externalities), and, what is more, reaching the same (objective) regardless of who initially is entitled to the rights.

According to this, in the case, for example, of a company that discharges waste in a river, and an agricultural exploitation downstream uses that water for irrigation, negotiations between the two would reach a level of waste for the company that would be situated around a socially optimal magnitude, independently of the fact that the agricultural exploitation is initially entitled to not be polluted and the company does not have the right to pollute, or if the agricultural exploitation initially does not hold the rights to water quality and the company has the right to dump its waste. Or, for instance, in case of an irrigators' association that abstracts water from a river, and downstream there is an electrical power plant. The exploitation by the irrigators is causing an impact downstream in the decrease of circulating volumes of water, that results in external costs for the hydroelectric station. Negotiations between them will lead to a level of extraction for irrigation that is a social optimum, regardless of the whether the initial exploitation right is for irrigation or for the hydroelectric plant.

This result, of unquestionable theoretical brilliance, has been invoked on occasions in order to maintain the non-necessity of public intervention –whose only action would be to look after the rights system– and the feasibility of obtaining optimum levels of natural resource allocation through private negotiations and the market. In the case of water pollution, the theoretical operative process would be to establish discharge authorizations through the Administration, and to let private agreements between economic agents generate transactions of these rights, that the Administration would only register, which would thus lead, driven by the market, the social optimum as far as the problem of water pollution is concerned. In the case of resource allocation, the Administration would give concessions and allow negotiations between owners to transfer rights, registering these rights.

Despite great theoretical interest in the proposal, there are certain restrictions that should be explained, and which, as we shall see, imply that in practice feasible negotiated solutions are very few. Quoting Franco Sala (1995), among these restrictions we can point out the following:

a) Negotiations require that the participants be clearly defined, which is not always the case in real situations. Going back to the case of the polluted river, the pollution is usually generated by not just one well-identified company, but by many contaminators, which may be very far away, and the affected party is not one single exploitation system that abstracts water from the river, but rather many more that use water. Only in the case where we can determine with precision who and to what extent are the contaminators, and who is affected, will they be able to get together, for if not, the problem of impact on third parties could invalidate the agreements reached. Although it poses certain difficulties, this requirement would not be, in principle, insurmountable for approaching the problem of fluvial pollution.

b) There have to be few participants in the negotiations, otherwise, the administrative costs of coordination will become prohibitive; then there is the problem of the free agent who, aware of the fact that it is not possible to exclude him from the benefits of the agreement, does not pay to cover his costs; and if all those affected do not suffer from the same externalities, subgroups or coalitions may emerge with different interests in the negotiations, which makes a positive result complicated. Avoiding these difficulties in fluvial pollution in practice would be very difficult indeed.

c) The parties negotiate on equal terms, otherwise, the influences of, for instance, major contaminators would give them much more negotiating weight than those who are affected by the externality (citizens with few resources and little influence). This would lead, through unfair competition, to ethically and environmentally questionable results, and contrary to social cohesion.

d) It is considered that there are no transaction costs, or that they are negligible. These transaction costs are those that we need to mobilize so that the voluntary transaction takes place and the market operates (it would be, in other words, the costs to access negotiations and the market). The reality is that it is necessary to know who are the other parties, to inform what needs to be negotiated and on what terms, make contracts, check through inspections that what is agreed upon is also carried out, etc. All this has a cost that goes against the benefits of the negotiations and can come to prevent voluntary agreements. In these cases public intervention is justified if it can reach a solution that represents a greater benefit for the parties than the costs of the public action.

e) It is assumed that the initial allocation of rights is irrelevant, but in reality assigning rights to the environment in favour of the contaminators is not the same as assigning them to the affected parties, since this implies, from the outset, choosing who charges and who pays in order to reach a balance.

f) It is assumed that all agents act rationally seeking the highest economic benefit, but this does not happen with all environmental assets. The special conditions of water, historically imbued with social and emotional values, are especially significant in this respect, and add a special complexity to the problem that does not happen with other natural resources. The reality is that there is a real rational behaviour, guided by politics, customs, and institutions apart from reasons of economic optimisation.

In short, the objections and restrictions of the voluntary negotiations that have been explained allow us to conclude that *an optimum result will only be possible in a small number of pollution cases that occur in the real world.* Specifically in the case of water pollution, the lack of accurate knowledge and the large number of contaminating agents and affected people, the inequalities of socio-political interest, or the transaction costs (e.g. monitoring and control of waste that the affected parties have to organize in order to check if the conditions agreed with the contaminators are met) mean that we should generally discard this possible theory, and adopt the principle of public intervention.

In the case of the resource allocation, there are many current and potential users that generate and receive externalities from other users; moreover, it is clear that not all users have the same influence and ability to put pressure on the situation, which would unbalance possible agreements; finally, they would have to organize a flow control system that safeguards the fulfilment of the conditions agreed upon. All this means that, as in the case of pollution, there are major deviations from the theoretical conditions that would strictly justify the non-intervention of the public Administration, and the need that this intervention appears as manifest.

4.5.3.1.3. Experiences of the water markets

With previous sections having explained some of the theoretical characteristics of the markets and their management possibilities for natural resources, and given the importance that the debate on water markets has been given in recent years, it is expedient to concisely show some experiences in the practical application of these specific markets, and consequently suggest some ideas to reflect upon.

In the first place, we have to point out that, far from what one could think, water markets are not a new mechanism, nor unknown in our hydraulic history. In Spain, organized and regulated water markets have existed for a very long time, with a history and experience that are still unknown and have to be assimilated in the new reinterpretation that is being carried out right now (see e.g., Ruiz-Funes [1916]; Gil Olcina [1988]; Gil Olcina [1993]).

What is more, although we cannot speak of a market in the full economic sense of the term, current legal regulation in Spain has always accepted various forms of transferability of water rights (s. e.g. Menéndez Rexach [1996] pp.139-177; Moreu Ballonga [1997]; Caro-Patón [1997] pp.324). A summary of this issue can be found in Embid Irujo (1996). Likewise, in other countries with sources and principles of rights that are historically related to the Spanish ones, such as Chile, recent experiences of free transferability of rights have been carried out, whose studies turn out to be of major interest in the context of modern legal thinking on water markets (Vergara Blanco [1998], pp. 257-293, 483-513).

The origin of modern water markets is similar in all the places where they were established. In such places, the allocation of water rights and the register of its use are the result of complex historical processes, reflecting changing social needs, political decisions from the past – that are consolidated by different laws–, and changes in society and institutions. When the imbalance between those patterns and current circumstances reach a certain level, the new and changing social demands are gradually frustrated, and we perceive that the weight of history and past regulations have become impediments for the present. Besides this legal inflexibility, governments usually intervene with subsidies, and other programmes that distort prices, while increasing demand, including environmental demand, have highlighted the economic value of water, and the need to assign it to more efficient uses.

In this context, it is argued that the market can be the mechanism that breaks with the past and introduces economic rationality to water management, which is its basic defending argument.

Against it, however, it is said that a water market is not capable of solving a number of varied and complex problems of a public kind. So, the free exchange of private rights usually has an impact on third parties, whether they are other users or the environment. Moreover, the price mechanism is not able to reflect some of the social values that are more qualitative than quantitative (such as fairness, justice, cultural traditions, etc), not to mention the inevitable necessity for a strict register system and accreditation of rights.

In places like California, which is a common place to refer to where they have installed these mechanisms in a pioneering way, a very small number of private water market transactions have been made, despite new favourable legislation, and the facilities of the Water Administration, with reports that in almost all cases were favourable of the requested transfer. On top of that, some very well-known cases have underlined the fact that the water markets face certain institutional and political difficulties, making it clear that the existence of significant conflicting interests made legislation in favour of the transfer insufficient, and that major public intervention was necessary.

In recent years, and in order to confront the crisis of water shortage in the State, the Governor ordered the temporary creation of a *water bank* administered by the State, to facilitate the redistribution of uses that were not assessed correctly. Through the Water Bank, the Administration signed three types of contracts with voluntary sellers (they did not sell their rights but their use for the following period), offering a price calculated so that the sale was more profitable than its agricultural use, but without allowing bigger profits. In the first type of contract, an irrigator sold his surface water and stopped planting; in the second, he sold his surface water and pumped the groundwater to continue with irrigation; and in the third he sold the water that he had in reservoirs. A total water movement of over 1.000 hm^3 was achieved, of which 51% corresponded with the first, 32% with the second and 17% with the third type of contract.

The representatives of the involved local communities tended to be against these transactions, not because of the short-term effects, rather because of their long-term effects. They feared the sustained transfer of water and, therefore, the reduction of agricultural activities would harm other related companies and would undermine the economy of the area. It was also argued that, in the long run, there should be some kind of compensation for the affected rural communities, perhaps through taxes on the transfers. In short, the Water Bank turned out to be an efficient solution, but partial and immediate to a circumstantial problem. The effects on third parties, economic as well as environmental, were quite manageable in the short-term and the biggest problem seemed to be the impact on groundwater. The effects could be much more serious if the transactions continued in the long run.

Environmental problems are also basic. Ecologist groups were divided at the time with regard to the water market. Some argued that they had to be used as a tool to reform the current system and reduce the obsolete predominance of agriculture, giving water back to the ecosystems, deteriorated by a hundred and fifty years of major economic development. But others held that measures of economic assessment would introduce rationality and efficiency into the use of water, which in the long run would benefit the environment.

In short, we should bear in mind that, although when we speak of water markets, we tend to imagine a situation of free interchange and buying and selling of the resource, ruled by the classic economic theory of balance between supply and demand, the reality is that, even in countries of very liberal tradition, the amount of legal, political, historical, and geographical factors that operate on the interchanges transform the water market into an *institutional mechanism*, of efficient but certainly restricted *functioning*.

In this line, the current reform project of the Water Act is progressing and, far from *privatising* water, as we have heard on occasions, is trying to make the mechanisms of allocation flexible, respecting in all cases the basis of administrative concession, intervention and administrative safeguarding of the public water domain.

4.5.3.1.4. Conclusions

The above clearly shows, in the most conventional economic analysis, that there are different theoretical defects in the market which mean that the application of these economic mechanisms for the management of natural resources, and more specifically of water, does not necessarily give us efficient nor socially optimum solutions.

Therefore, there are no clear reasons, based upon economic theory, that advise against public intervention in the world of water, and the free movement of markets and agreements between interested parties. This is by no means a guarantee that with this policy social optima are reached (that means, of private benefits plus externalities). Proposing public intervention or not is, therefore, not an ideological option, but a technically solvent determination, and that, regardless of its recent theoretical justification, to which we have paid some attention, it has been perceived as necessary for a long time in the Spanish hydraulic history.

Of course, there is room for debate on the scope this intervention should have and this debate is pervaded, of course, with ideological and political details, but still, we can state that territorial aspects and peculiarities have in fact always outweighed ideology in this field. In fact, to some extent the necessity for administrative interventionism in water matters has always had a direct relation in our country not with the government in power but with water-related conflicts of territory. It is no coincidence, giving a significant example, that in 1931 an agency was set up with the Water Authority in the Segura basin, almost 30 years before its generalization in the rest of the peninsular basins, or that in this basin a Water Commission has existed since 1940, 19 years before the other basins (Fanlo Loras, 1996).

4.5.3.2. Instruments of economic policy for the best management of the resource

Having explained the need for public intervention in previous sections for the best management of water as a natural resource, we can consider the scope and the ways and instruments that are necessary to execute this public intervention.

As is logical, the complexity of the questions posed leads us to think that the solutions to the problem that we are facing cannot be simple or single, and predictably we could adopt a variety of instruments that, covering partial aspects, help to get closer to a global objective.

The strategy has been oriented, as we have also pointed out in relation with economic objectives of the water policy, towards the establishment of socially acceptable environmental impact –although not necessarily optimum–, which cannot be reached except through successive approximations via the different policies and compromised solutions based upon rationality.

Among the multiple instruments of economic policy for the protection and improvement of the environment, and which could be applied or perfected in our country, we mention the following.

4.5.3.2.1. Use of economic incentives for the best allocation of resources

The use of these instruments reveals acceptance of some advantages of the market model to reach the pursued objectives, even though we admit that impact on the environment reflects one of its known failures. As in this case such a market does not exist, we will try to simulate some of these mechanisms. According to how much faith is placed in this model, two major groups of instruments appear:

Levies

One good solution consists in establishing a levy (or subsidy) of the same quantity as the external costs generated by the level of economic activity estimated as the optimum or socially most efficient. With this solution we achieve a reduction (or an increase) in private profits of a magnitude that is comparable to the level of activity and impact on the environment at the desired point.

One of the major characteristics of this instrument is that it stimulates the use of technology appropriate for the reduction of the impact level. Until now we had simply assumed that the logical relationship was a decrease in the level of activity, but in practice, the decision in favour of one or another alternative depends on the determining factors and the specific characteristics of the economic agents.

One of the most important examples of this type of instrument is the application of the polluter-payer principle, or *who pollutes pays*, in other words, passing on all environmental costs to the causer of the pollution. We have to indicate that this approach to the problem has been criticised by those whose argue that this could be understood as an authorization to pollute by means of payment, without any other considerations that are not purely economic. Because of this, and the as-yet scanty and questionable knowledge of the true environmental costs of pollution, the majority of the administrations that manage water resources impose, in all cases, some limits or thresholds for a series of parameters, either measurements of wastewater either at points on river channels or on reservoirs or lakes where waste is discharged.

Although many problems arise that prevent its generalized application, especially those that refer to the quantity of the levy, it does give, on the other hand, the major advantage of being one of the methods with lowest costs. The current economic-financial regime of water resources, despite being an imperative system as well, is not founded on the criteria explained, and therefore the levies foreseen by the Act simply aim to achieve compensation for the investments made by the State.

Establishment of property rights

As we have pointed out, the use of this approach aims to correct market deficiencies with respect to the environment, while avoiding excessive state intervention, since without any doubt we can also identify administrative failures or failures from "governing" (lack of control or protection in some valuable natural spaces, for example), through the clear establishment of a rights system. We have to specify that here property right should be understood as the right to use a natural resource and moreover, as regards assets of common property, as is the case of water, some collectively representative agency generally grants this right.

The first consequence of this measure is that somehow the negative externalities are "internalised" (damage to society because of impact on the environment) as the main source of concern. The final expected result is that after a process of negotiation between the affected parties, the foreseeable externalities are initially reduced to a socially acceptable level.

As we have explained in detail, the practical application of this scheme has not a few difficulties and apart from that, it would only be recommendable for very specific cases. Notwithstanding this, its force in achieving efficiency and its apparent simplicity suggest not discarding it out of hand. In this line of action we could note, for example, the transferability of rights to use water (water markets and banks), compensation to donor basins from receiving basins in cases of transfers, or the transferability of discharge permits.

4.5.3.2.2. Regulation through fixed rules

The establishment of fixed rules in relation with specific environmental parameters and other more general aspects aims to guarantee, in the most direct way possible, compliance with standards considered satisfactory, in view of related criteria, either to do with public health, or with the conditions of the conservation of ecosystems. The system needs to be complemented with the incorporation of penalties in the event standards are not met.

The problem that this type of regulation poses is that its suitability regarding the social optimum is not guaranteed. Therefore, two conditions would be required: first, that the penalty is equal to the external marginal costs which go together with the socially efficient optimum and which would also be guaranteed in its case (which is highly improbable) and, second, that the fixed standard or limit would imply an environmental impact that determines a level of economic activity that coincides with the optimum desired (also improbable). It also has another inconvenience: it does not encourage the reduction of environmental damage below what is required in the regulations. From an economic point of view, even though they are considered necessary, they are solutions that have higher social costs than those described in the section above.

In accordance with this, arrangements are made, such as the restriction of emissions (into the air, into water, etc), ecological volumes of water, even the declaration of certain perimeters (or entire rivers) as protected natural spaces. In any event, these measures usually lead to two important questions: quantitative limitation in the use of the resource where we have to respect certain ecological requirements to allow the maintenance of ecosystems, and compliance with appropriate levels of water quality in the environment, which obliges us to systematically control pollutant waste, and to treat wastewater.

A preliminary solution that has been posed in Spain consists in respecting, in general, minimum volume of water in the region of 10% of the average volume of water in order to maintain aquatic life. In most parts of the Spanish rivers the non-regulated volumes of water and the volumes of water withdrawn for other consumptive uses in summer meet this requirement in times of high water. Only the rivers near the Mediterranean coast do not meet this requirement, in general, in their final stretches, above all when natural cumulative flows from the aquifers that supply them have been taken out upstream. However, this issue needs to be looked at more closely and has to be adapted to each specific situation.

4.5.3.2.3. Execution of projects with specific environmental objectives

Within this category we analyse those projects whose specific objective is either restoration or the reduction of environmental impact caused by certain activities (generally public or private investments); or compensation for irreversible damage caused in one specific area. This *compensation* can be carried out by means of the regeneration of a similar environmental asset in the same area or in a different area. The actions, whose environmental impact we are trying to neutralize, should be considered together at the programme level. If not, unacceptable extra costs would most likely be generated.

4.5.4. Economic assessment of hydraulic projects

The objective of the economic assessment of projects is to determine their feasibility from a strictly economic point of view. In this sense, it forms part of the normal set of feasibility requirements that any project needs to meet (technical, environmental, financial, social or political).

Economic feasibility is verified if the total profits that result from the execution of the project exceed the benefits that would be produced without its execution, in a larger amount than the actual costs of the project. In other words, if the difference in profits that correspond with the situations achieved *with* the project and *without* the project is greater than its costs. It is therefore important to remember that this type of analysis should be based upon the comparison of situations *before and after* the project that could lead to the consideration as results from the project of some effects that might be caused even though it is not carried out, therefore overestimating its profits.

It is clear that economic feasibility is closely related with technical feasibility, for a project that is not capable of achieving the predicted results in its design will not obtain the necessary profits for its economic justification.

It may also be expedient to remember the differences between economic and financial feasibility. A project is considered feasible from a financial point of view if it is simply able to obtain the necessary funds to pay for its implementation and subsequent operation. In this way, a project would be economically feasible and financially unfeasible if profits, though sufficient, were not specific enough so that the beneficiaries could appreciate its true value, or if it were distributed among such a large number of beneficiaries that its payment would be of little practicable use, or, for whatever circumstances, it did not have the capacity to attract capital in order to start up. Furthermore, a project could be economically unfeasible and financially feasible if somebody were available to pay for the non-economic objectives. These rather extreme examples can illustrate the differences between the economic or financial assessment of a project.

The expedience of economic assessment in analysing the feasibility of public projects is evident. As some authors have pointed out, in the public sector, unlike the private sector, there are no forces that put pressure on identifying and adopting the cheapest methods to carry out public functions. As a consequence of this absence of incentives, the allocation of funds in the public sector can sometimes follow the path of least political resistance of the moment, doing without objective evaluations, which may lead to the execution of projects that are economically unfeasible (James and Lee, 1971). In this context, the final objective of the techniques of cost-profit analysis is to achieve decisions based on the objective assessment of the merits of each proposed project, thus achieving the best possible allocation of public funds.

The introduction of this type of economic criteria in decision-taking of a hydraulic nature is a practice that was assumed a long time ago by the Spanish Administration, and there exist methodological manuals drawn up by the former Ministry of Public Works, regarding the application of these procedures (MOPU-SGT, 1980; MOPU-SGT-DGOH, 1980a, 1980b).

The parameters most often used in the cost-profit analysis are the *profit-cost rate,* or relation between the updated profits and the updated costs, the *net profits,* defined as the sum of all updated profits minus the sum of all updated costs, and the *internal return rate,* defined as the interest rate that equals total flow of costs with the total flow of profits. As we know, these parameters are not consistent with the selection of the best project, so the most appropriate project according to some does not necessarily have to be appropriate according to others. Furthermore, the value of the interest or discount rate assumed in the updating of costs and profits is extremely important and can change the preference of the first parameters for a certain project.

As far as costs are concerned, we usually distinguish between the investment, or cost, initially established, which includes the sum of all the necessary costs to complete the execution of the project, and annual costs, which usually refer to the operation and maintenance of the project.

The determination of profits that can be attributed to a certain project is one of the aspects that is generally one of the most complex in its economic assessment. In a broader sense, and keeping the numerous–and often confusing-existing categorizations in mind, profits can be classified according to two different criteria. In the first place we can speak of direct or primary profits and indirect or secondary profits. We normally consider direct benefits the immediate results of a project, such as the production of energy, the prevention from damage of floods or the increase in agricultural production. The indirect benefits are those that result from the project on a second level, such as higher industrial activity or the increase in profits of all the companies that supply goods or acquire products from the direct beneficiaries of the project.

In the second place we can speak of tangible and intangible profits. The tangible profits are those that can be expressed in monetary units. The intangible profits, on the other hand, are of difficult monetary valuation –if not impossible–, such as greater security for human lives, improvement in the countryside, and control of pollution or leisure possibilities. As we have already indicated before, these intangible profits are becoming increasingly important in our country. In parallel with these intangible profits we can speak of intangible costs, like the destruction of natural spaces of great scenic value or the loss of some ways of life of displaced populations as a consequence of the project.

The tangible direct profits usually make up, together with costs of the project, the main elements of the cost-profit analysis. The secondary profits, however, and because of their nature, are more controversial. In the first place, because they are so difficult to determine that their calculation usually seems arbitrary and, in the second place, because it can be considered that any kind of investment has secondary profits, and therefore is of little use in the decision-making process. For these reasons, and from the public investment point of view, secondary profits have little relevance in the formulation of the project and its economic justification.

As far as intangible costs and profits are concerned they can become very important, as we have pointed out, and they must be kept in mind in a real and effective way during the decision-making process. Precisely its inadequate consideration or simple lack of consideration can, on occasions, lead to very unwise decisions. Notwithstanding this, we do not have any generally accepted and sufficiently contrasted methodologies that allow correct assessment, which contributes to an undesirable lack of attention to these intangible effects.

In any case, and despite the limitations of the cost-profit analysis and the difficulties of its correct application in some cases, there is no doubt about its utility in the process of decision taking on public investment projects. Therefore, it is desirable to have a systematic practice of habitual method. An example of the application of these techniques to water quality can be seen in Azqueta (1994).

4.6. THE SOCIO-POLITICAL BASIS

Having examined water in previous sections as an object of legal regulation, as a productive economic asset, as a natural resource, we now turn to another of its important facets which, on occasions, makes the others less significant and dominates them up to the point of cancelling them out: its consideration as an emotional and political-social object.

Without entering the passionate field of the anthropological considerations that make water –like fire or the night– a primary, ancestral element of myth, in the intimate core of our consciousness and in the human heart, its role as a social articulator has been a subject of major interest in a number of historical-economic and sociological investigations for years (see, e.g., the studies on the Canary Islands, Murcia, Valencia, Aragón, Andalusia and Catalonia included in Pérez Picazo and Lemeunier [1990], or those on Levante, southeast, Andalusia and America included in Romero and Giménez [1994]).

These investigations clearly show a conclusive result to remember, and this is because water has always been controlled by the wealthy and powerful (a Spanish saying goes, "*el agua remonta el cauce hacia el dinero" ("Water runs down its channel to the money"),* and it has played a politically essential role in those territories where it was most scarce.

In paragraphs to come we will show this social, community vision of the resource and some important lateral issues will be dealt with that are related to this perception.

4.6.1. Water as a social asset

A frequently shared opinion, especially in areas where there has historically been scarcity of resources, is that water is a special *resource.* As an essential element for the quality of life and to assure the future, the inhabitants of these regions have always felt that water has a *value that means more* *than just benefits* from agricultural activity, a value that is associated with lifestyle, traditions, group sentiment structured by deep symbolic, cultural and emotional shared values. This is what we call *communal value or social value of water.*

What the real meaning of this value is, and how it is related to economy, has been the subject of an intense controversy for years, and which, because of its interest, we will refer to in following sections.

4.6.1.1. The controversy over the social value of water

As we have said before, controversy over the meaning and true dimensions of its social value has existed for decades, and it does not seem that agreement has been reached between the two major represented doctrines of the different perceptions of the problem.

So, from some conventional economic points of view, of which we can consider a paradigm the classic article by Kelso (1967), it is argued that water is a production factor whose main problem is not scarcity but the inefficiency of the policies and institutions that deal with the problems, and that there is a syndrome that *water is different*, which, wrongly, leads to treating it in a different way from the rest of natural resources. This syndrome attributes a series of false, mythical characteristics to water, and it is the reason that policies and institutions have been developed that have lost contact with economic reality.

In contrast to this thesis, another way of thinking, which could be represented by the also classic article by Brown and Ingram (1987), postulates that water possesses, in some territories, social and communal values that cannot be strictly deduced from their economic values, and that despite the always necessary economic rationality, this does not cover all the dimensions of the problem.

As we have said before, both points of view have been, and still are, source of heated debates in American academic literature, which has been dealing with the socio-economic and political analysis of water, while only colaterally, and occasionally, as a response to that, it has generated a parallel debate in the fields of Spanish intellectuals that are interested in similar issues.

However, and very curiously, the North-American academic debate seems to concentrate both points of view on two paradigmatic models that can be associated with the *Anglo-Saxon one* (which would represent an economicist orientation), and with the *Hispanic and indigenous* (which would represent the social and community orientation).

So, the Spanish colonial mark on semi-arid territories in the southeast of the United States (16^{th} to 19^{th} centuries) meant the establishment of a water rights system through which concessions would be granted on lands through documents issued on the king's authority, and as a complement to the use of land, the reasonable use of water was an associated right. In practice, there were few conflicts over this use of water, and they would be solved by courts and public servants on the basis of property rights, but also considering previous use, needs, rights of third parties, public priorities, municipal preferences and ideas of fairness and common assets. So, formal property rights were basically not divergent from the needs and expectations of the people. An interesting analysis of these hydraulic institutions of Hispanic heritage can be seen in Rivera (1998).

Returning to our territory, and as has been explained when we described the Spanish physiographical framework, our country truly comprises a synthesis of diversities and an anthology of different situations and sharp contrasts. In the context that we are now dealing with, we could suggest that the mentioned duality of ideas represented by the Anglo-Saxon/Hispanic concept would in this case have a certain parallelism with the Spanish/Arabic duality, basically indicative of the different situations of availability of resources and consequently, of the different legal medieval ideas that, as we have seen when we studied the historical legal background, prevailed in our country for centuries.

A classic contribution to these analyses is the one by Maass and Anderson (1978) in their excellent study of six irrigation communities in the United States and Spain (the crop fields of Valencia, Murcia and Alicante), from which suggestive conclusions are drawn that we will comment on further ahead.

It is curious to note that while in our country we usually refer to the North-American model (and more specifically the Californian one) as a paradigm of scientific rigour and correct water management, from there, they look back to the old Hispanic heritage and to old Spanish hydraulic institutions and organizations. Institutions and organizations so close that –in very Spanish way– they are ignored because of trivial propaganda of a false, misunderstood modernity.

4.6.1.2. The symbolic and emotional value of water

Anybody who has had the occasion to experience water-related problems in semi-arid areas, of endemic scarcity and high demand, knows that the supply of flow and the practice of its collection and distribution are imbued with emotional, passionate values, transcending its immediate economic-productive value.

Perhaps as an atavism of poverty and famine in the past, when for large parts of our territory access to water was an escape from misery and a guarantee of access to food, this sentiment has lasted until our days in the traditional irrigation areas, and popular sayings such as *"el agua emborracha más que el vino" ("water inebriates more than wine")* or *"el agua es la sangre de la tierra" ("water is the blood of the earth"),* express this idea very clearly. Ignoring these deep feelings has often been one of the main causes of water-related conflicts.

4.6.1.3. Community value and fairness

Fairness is, like water itself, basic for social planning. Therefore, communities have always shown concern for a fair distribution of water. Accordingly, in the tradition of Spanish planning, objective criteria –such as property rights or occupation– were moderated by subjective reasons to do with fairness, and the interests of the community were more important than individual rights.

An excellent example of this is what is laid down by irrigation regulations in Valencia, establishing the generous principle that all farmers have the obligation to *help those in most need.*

Mechanisms of fair distribution and conflict resolution are the traditional common law irrigation courts, in the very core of the community, and, without assistance from external arbitrators, they settle the problems that arise from the distribution of water with fairness and efficiency.

4.6.1.4. Community value and the cost-free status of water

Among the consequences and aspects relating to the community value of the resource is the widely extended social belief of water's cost-free status.

Perhaps as a result of the historical application of our legal regulations, or maybe due to the fact that the resource is indispensable for life, it is true that this perception is deeply-rooted and it is socially considered that water is and should in the future be a free asset, without price, understanding this not in terms of necessary costs for its production (which are accepted), but in terms of the value which, as a scarce asset and, therefore, economic, that it would have *per se* even in case of, for instance, when permanent flow water volumes are used.

Probably this image of cost-free status is closely associated with the notion of an asset of free use, the absence of property, which it originally had, and the fact that the State, when it acquired the water rights, subsequently also considered it under the same premises. There have even been efforts to provide free basic service (public fountains, watering places, etc.) and until very recently supply of much greater magnitude, including production costs.

However, we have to say that the Spanish Constitution does not contain in any of its articles a basis to unequivocally establish such a cost-free status. Neither is it possible to find in the mentioned Constitution any provision that opposes the introduction of a price for private use of inland water, and this is a reference of immense magnitude that cannot be put aside when we try to define the horizon of the new water policy.

Concluding on all that has been explained we could state that, whether right or wrong, maintaining these deeply-rooted principles in the habits and the culture of the people, any substantial innovation in this field should, apart from being based on solid, rational argumentation, be incorporated *cautiously and gradually.*

Therefore, and according to what was presented in the section on experiences and problems in the current economic and financial regime, it seems expedient that, despite possible isolated improvements and modifications, these possible major structural reforms should be left for the future, while aiming to achieve a more appropriate, fair and rigorous application of the current system.

4.6.2. Territorial sense and the expectations of prosperity

A basic aspect of the social value of water refers to the community expectations of prosperity, or, similarly, to territorial awareness –we could say *tribal*– of collective ownership and usage for generations to come. Such problems of appropriation and territoriality of water resources, of tension between production areas and consumption areas, have always been one of the main sources of water-related conflict.

The subject has been extensively studied in our country in different territories and from different perspectives. Some of the numerous existing references are, e.g., Pérez Picazo and Lemeunier [1985]; Romero and Giménez [1994]; del Moral Ituarte [1994]; Mairal et al. [1997]; Melgarejo Moreno [1997]; Mateu and Calatayud [1997]; etc. The events of Yeste, described by Goytisolo, clearly illustrate one of many hydraulic convulsions.

It is a fact that water, both surface and groundwater, has always had a special association with the land it flows through or where it is stored, and breaking this association has been the origin of a number of conflicts. The rights of riverside inhabitants (remember the fluvial origin of the word *rival*), existing in some countries or, to a much more limited extent, the particular rights of exploitation that Spanish legislation grants to the owners of properties, mean the recognition of such an association. Suffice to give as an example the case of pluvial water that flows through properties, and stagnant water, within its boundaries, or in the case of springs and groundwater when the total volume does not exceed a certain flow.

Even in frequent cases where there was an absolute separation between water and land this subtle association was also present, since the area of application of the resources was not just anywhere, but was restricted to local or regional zones where barter and auctions took place.

This feeling of a certain *domain* over the natural resources that make up the territory proper has evolved with the passing of time. Starting from an basically local idea of this association, its scope has been broadened alongside the growing awareness of the use given by inhabitants downstream of surplus water from further upstream, and the political-administrative structure of the territory and its popular perception have been consolidated on ever bigger scales.

Accordingly, and by way of example, the conflict in 1567 between the millers of Aguilar de la Frontera and the farmers of Monturque, due to the fact that the irrigation of the crop fields was consuming the water from the river, and not allowing the flour mills to operate due to a lack of water to move them (Al-Mudayna, 1991, p. 353), simply anticipated, although a long time before and on a very small scale, the recent point of disagreement from hydroelectric producers on the River Júcar with irrigators from La Mancha. Separated by more than four centuries, both archetypical conflicts are virtually the same, although their spatial scales are obviously very different.

For a long time artificial transport of water from rivers or springs has been frequently used either to supply towns or for irrigation. The transported volume of water and the distances and differences in level to be overcome, have increased according to the improvement of the technical level of society, so that the territories, which are liable to receive water from areas far away from their natural channels, have progressively become larger. The development of waterwheels and pumping installations has been crucial in this respect.

This shared use of water from one single river and in a more general sense water from one single drainage basin is slowly helping to shape and gain acceptance for the concept of the hydrographic basin as a unit of exploitation. Nowadays, nobody is surprised that water is used in places far away from its place of origin –it is the most normal situation– and that the connection takes place not just by taking advantage of water's natural flow due to gravity.

These actions, when they mean artificially diverting water from one territory to another, have often been the cause of conflicts between inhabitants of places where water was taken and the inhabitants that received water, and this even happened when they were in the same hydrographic subbasin.

A different situation arises when the transfer of water between different large basins is considered, not because of opposite interests, environmental impact or because technical problems to be solved are very different, but because the elimination of a culturally assumed physical barrier arouses an opposition that has a strong emotional, symbolic component, uniting the socio-political feelings of the group.

Therefore, it is mainly the possibility of transferring water between different basins which has centred debate on territorial imbalance as regards the availability and use of water. At this point, we should state that, on an economic and territorial level, the considerations we could make in this case are not conceptually different from those that arose when trying to select options faced by inhabitants of the upper reaches of a river with respect to those from the lower reaches, all of them users of resources from the same fluvial currents. Socially and culturally, however, the reality is more complex and shows us there are barriers that are difficult to get round.

The importance of the socio-political debate forces us to take into consideration, besides the economic effects that inter-basin water transfers might produce, the notion of fairness, and the moral and constitutional obligation of public powers to favour a balance between these regions. A description of this panorama is completed when we consider the implications that stem from the territorial organization of the State in the Constitution of 1978 and the competence of the Autonomous Communities as regards planning and management of economic activity, as well as of natural resources in the environment, within their territory.

The legitimate socio-political capacity of these territorial entities to make their interests heard, when it comes to transferring water resources that run through their administrative area to another one, is beyond any doubt. Apart from any other economic considerations, it is a question of the existence value of the resource itself. Among the options, this could be considered as a possibility in territorial compensation for the transfer of water resources. This is a matter of utmost importance, not legally regulated, and which should be analysed in the context of the economic conditions and the regime of the water transfers, which will be examined in the next chapter.

4.6.3. The nature of hydraulic solidarity

The principle of *solidarity* has very often been quoted in taking water resources away from some areas, supposedly abundant, in favour of other, supposedly at a disadvantage.

The reality is that, without examining other considerations, and despite its constitutional proclamation, solidarity is a value of individual nature, not collective, and that when it is expressed collectively it is nothing but the aggregation of personal and individual values. We cannot demand that one territory takes care of another; it is desirable that the public is caring, since if they are, the central, moral tone of society will allow the problems of redistribution to be broached –and in general any other problems– in a responsible, mature and constructive manner.

While it is obvious that these are general conditions that are socially desirable, history has some very clear lessons in this respect: in territories of scarcity, solidarity was never a driving force for water. Rather, the hydraulic history of these territories is nothing but a permanent confrontation for control of the resource, and for the power and influence that it provided.

The associations, the groups, the agents that, as we have commented, explicitly show water's social and communal values, and make it an element of fairness and social cohesion, were always on a very small scale of traditional communities, of smallholdings, virtually *neighbourhoods*. How do we compare this situation with the dimensions of the current water exploitation, where there can be major exploitation systems hundreds of kilometres away from the origin of its resources, with effects that cross international borders, and with the massive displacements that modern technology of water transport and distribution have made possible?

As we have already suggested, research into mechanisms of compensation between territories could for the moment be the most efficient way to overcome –Assuming this is possible– the problems described, and to bring the debate on hydraulic fairness back to a state where reasonable agreements, socio-political consensus and convergence of interests can be achieved.

4.7. THE TECHNICAL BASIS

We have examined the different perspectives (legal, economic, environmental, socio-political...) on water policy that jointly contribute towards new reflections and approaches to this policy in the immediate future. We will now explain some issues of a more technical type, which, like the others, also contribute to outlining future water policy.

4.7.1. The traditional approach and future perspectives

As we have already explained, the Water Administration in Spain has traditionally been based on the management of supply, understanding this to mean an increase in availability of the water resource through the construction of hydraulic infrastructures for regulation and supply. This approach responded to the assumption of continuous growth in demand, starting from a very small natural supply.

However, more rational behaviour in economic terms, and more respectful with the environment, is not necessarily based upon the continuous increase of that availability but should favour a reduction in consumption through more efficient use of water. Consequently, the idea of integrated management of supply and demand arises, where, through economically efficient and environmentally acceptable use of the resource, the distribution of different supplies can be guaranteed.

We should, therefore, not consider the false debate between preservation of water and new infrastructure, given the fact that the implementation of new supply infrastructure and management and preservation actions for water would require joint, coordinated consideration within the framework of what is today called environmental engineering.

Accordingly, the technical basis for new water policy will require new scientific and technical ideas, characterised by their multidisciplinary nature and by their necessary adaptation to the new peculiarities of the environment that we are coming to know and quantify. Looked at in this way, environmental engineering means one step more in the evolution of the classic proposals towards integrating environmental aspects into the actual concept of action (stages of prior studies or preliminary design).

4.7.2. Possible measures and actions

4.7.2.1. Managing demand

Progress in the knowledge and management of water resources has shown the need to take advantage of available resources more efficiently, in coordination with the increase of these resources from new sources (surface regulation, abstraction from aquifers and diversions) when necessary.

The need for efficient management of resources is rooted in the seriousness of the problems of water shortage in developed countries, where squandering in the consumption of water, the deterioration of quality, impact on ecosystems, etc., are not acceptable.

The concept of water-saving is today comprised within a broader idea of *water conservation*, which includes all the techniques that are oriented towards water-saving or improving resource management, such as actions to modernize and restore, volumetric gauging, low-consumption sanitary equipment, educational development and public information, reuse of wastewater, re-cycling, crops and gardening that require less water, etc.

Managing demand, therefore, concentrates on the ways water is used and consumed, on the tools that promote a more efficient use of the resource, and on the socio-economic and environmental repercussions of such efficiency.

4.7.2.1.1. Urban demand

The different activities that we can contemplate in a conservation programme in water supply to towns can be expressed in sectoral programmes that may be classified into five groups:

- Infrastructure programmes: these try to refine the basic system of distribution in order to reduce losses and to enable control of consumption by different users (repairing networks, elimination of leakage and installation of individual meters).
- Saving programmes: these try to reduce consumption through programmes of public awareness and metering programmes.
- Efficiency programmes: these try to reduce consumption through the introduction of technical modifications in facilities (improvement in efficiency in hydraulic equipment and interior domestic sanitary fittings, design of public and private gardens, oriented towards minimizing water consumption).
- Substitution programmes: these promote the situation in which the use of drinking water from the network is substituted with water from a different source, fundamentally reuse.
- Management programmes: these include bylaws as regards hydraulic efficiency, surcharges or discounts on

the connection fee, commercial incentives and discounts, hydraulic audits, loans and subsidies.

Normally, programmes of conservation and management of demand include a variety of the above sectoral programmes structured through an integrated approach (Estevan [1997]; Villarroya Aldea [1998]).

However, we should bear in mind that many of these actions do not have a high degree of social acceptance. Although we can appeal to environmental arguments, that, at least nominally, are very attractive for the public opinion, in short, it is about restricting the use of an asset (generally with a low price) and sacrificing to a certain extent the commodity or habits of the user. Furthermore, we must not forget that the margin for saving decreases considerably along with the level of water allotment.

One of the most important sources of saving is the reduction in losses brought about in the networks, fundamentally in the oldest ones. The volume of water for urban use that is not registered in Spain, in which public use and losses in treatment and distribution are included, stands at an average level of 28%, ranging between a little over 10% to an exceptional case where 50% is reached. These numbers show the need to carry out measurements of water describing public use and differentiating the real proportion lost. There is, however, a technical and economic limit to losses that some specialists place at between 10% and 15%.

Another possible way to obtain water savings consists of using of domestic equipment (cisterns, shower heads and taps) with lower water consumption. However, economic incentives or information campaigns may not be enough to implement this. Official approval of this type of facilities could be established in the framework of a regular saving strategy.

The restrictions in garden irrigation cannot be a measurement of permanent savings either. Notwithstanding this, the practice of *xerophytic landscape* which is being implemented in some countries provides us with some interesting perspectives.

So far, of all the possible actions, the only one that seems to be generalized in our country is the evolution of rates towards a block structure with increasing prices. However, there is a series of aspects, like the fixed part of the invoice that has to be paid regardless of the invoiced consumption, which reduces the efficiency of this measure. In a recent informative report (OCU, 1997) based on an opinion poll on water rates in 51 large Spanish towns, it was shown that in thirteen cities this fixed part is established as *minimum consumption* which, although in some cities this is a reasonable limit (60 m^3/year), in others it may be excessive, and become an element that does not encourage saving. This is the case of Santander, with 160 m^3, or Melilla and Soria, with 120 m^3. In the mentioned report it was also shown that in some cities concepts unrelated with supply and treatment become so significant that they take up more than half the invoice. These concepts should be excluded, to prevent the water invoice from being used as an instrument to raise money for other objectives.

Generally speaking, saving techniques in supply can help to mitigate local problems and they have above all a pedagogical and awareness value, but their global results are not very relevant in a national context of water resource use. This is because of the low percentage (13%) of urban demand compared with total demand. Savings in urban demand of 15%, feasible according to the techniques that were applied during recent droughts, would represent savings of just 2% of total demand. These figures are even smaller if we take real consumption into account, and if we accept that urban return is about 80%.

4.7.2.1.2. Agricultural demand

We have already alluded extensively to these questions in previous chapters; therefore, we now offer a short summary of technical concepts to orientate the possible management of agricultural demand.

The basic initial assumption is that the measures and actions established in relation with agricultural use have to be inspired by the objectives which, regarding the use of water resources, are aimed at sustainable agriculture: the conservation of water, the conservation of the environment (increasingly important), economic feasibility and social acceptance (FAO [1991]; Jímenez Díaz and Lamo de Espinosa [1998]). In this line, the current orientation of Common Agricultural Policy suggests a certain redefinition of the role of agriculture, according to which the farmers should produce food while preserving the environment. This can lead to changes in crops, irrigated surfaces, etc.

Managing the demand for irrigation, the main agricultural use, considering the route of water in the conventional water framework in an irrigation zone and its area of influence, from abstraction from the environment to its return, we can differentiate the following sections:

- Main network of channels and irrigation ditches
- Secondary network of distribution irrigation ditches
- Conduits in plots, irrigated plots and irrigation drainage ditches in plots
- Secondary drainage network
- General collector

The management of the main network of channels and irrigation ditches and the general collector corresponds to the basin organisation and the secondary network of distribution irrigation ditches and drainage to the Irrigators' Association, while management at plot level corresponds to the irrigation users. Shared and alternative water handling over long time periods and long routes brings about, firstly, the execution of specific actions designed to achieve, on the one hand, the necessary coordination level between the basin organisation, the Irrigators' Association and users, those responsible for the global management of the plots in each unit, and on the other hand, that the basin organisation transfers responsibility to the Irrigators'

Association, if it has not done so yet, inherent to the functions and obligations that according to the legislation correspond to them, at present and in the way they are laid down.

As regards demand management in relation with the use and handling of water, a comparison between the situation of some high-productivity irrigation areas with limited water resources, with the average national conditions of irrigation, show a broad margin of improvement.

In this sense, we can differentiate between two types of actions: those related with activities that are common to agencies responsible for *high level* distribution and control of irrigation water (basin organisation) and *low level* (Irrigators' Association), and those that correspond to the irrigators as direct users.

Among the measures and actions relating to the common activities of the agencies mentioned, the following need to be promoted:

- Appropriate knowledge, by each entity, of the gross volumes and volumes of water that are really needed to satisfy demand; which means having an assessment of losses in reaches of the network under its control .
- The expedient implementation of repair and conservation work and improvement to the infrastructure of its competence.
- The systematisation of available information, and if necessary the preparation of additional information, on possible coordinated actions to modernize infrastructures, in accordance with the multi-criteria assessment of each one, to establish the expedient order of priority in implementation and to promote its execution.

As regards the actions relating to the activities of the irrigators, we include the following to be promoted:

- Appropriate knowledge of the dates and volumes of irrigation, and the assessment of the application methods used, reinforcing the corresponding information and extension services.
- The formulation of proposals for the improvement and modernization of application methods, assessment of these methods and, if necessary, their execution.

In new irrigation, demand management should be considered by taking productive irrigation with limited water resource as a reference, characterized by tight control and good water exploitation.

These measures and actions are, in general, laid down in the basin plans, where they are defined as the basic rules on improvements and transformations in irrigation, including the most appropriate irrigation methods for two different types of climates, land and crops, the allotment of necessary water, the conditions for drainage or those for the reuse of irrigation water. A summary of the planned measures for the modernization of irrigation within the framework of water planning is offered by Saura (1995).

In order to achieve rational use of natural resources, some of the established specific measurements for managing demand are: the improvement of regulation and control facilities in the main networks through automation of its operation, the construction of deposits for storage on the banks of the main channels, the improvement of conduits, the installation of measurement and control systems, the increase in the availability of conservation equipment, the reduction of costs for conservation and the exploitation of the infrastructure, the transfer of competence to the communities as regards management and maintenance of networks, the improvement or replacement of irrigation methods, the modernization of agricultural structures in such a way that the size of exploitation systems increases and that cooperativism is promoted, the promotion of applied research and the implementation of specific studies on modernization and improvement of irrigation, etc.

A good example of how some of these measures were adopted, and of the high technical level of traditional irrigation with endemic shortage, is the Modernisation Plan for the Irrigation of Mula, where outstanding technological and managerial innovations have been introduced (del Amor et al., 1998). The experiences in Almería (see, e.g., López-Gálvez and Losada, 1997) are also illustrative of these efforts to improve and innovate.

Furthermore, we should also indicate, as recent studies in irrigation zones in our country show (Sumpsi et al. [1998]; National Federation of Irrigation Communities in Spain [1999]), some measures that traditionally have been considered in managing irrigation demand, such as pricing policies, do not necessarily achieve reduction effects on consumption, and can, on the other hand, introduce costly diseconomies in the sector.

Generally, in every basin plan a list of areas is included where it is proposed to carry out modernization and improvement actions. In plans where the extension of such areas is specified, total surface are is about 1.2 Mha, which represents approximately 50% of the surface area that is currently irrigated by those Plans, and gives an idea of the current importance of optimisation in the use of water. This is true despite the fact that it corresponds to the National Irrigation Plan to define at any time the activity of the General State Administration as regards modernization and improvement of irrigation, as we explained in detail in the corresponding section.

In the framework of the prior studies for the National Irrigation Plan, evaluations have been done on possible savings in areas that can be irrigated in the country, but we do not have precise estimates on what the modernization and improvement of Spanish irrigation can globally mean as regards savings in total demand for water consumption, on the scale of exploitation systems. Modernization usually produces savings, but it also brings about a reduction in returns downstream, whose effects on the environment and on third parties should be taken into account in the analysis of such user systems.

Moreover, and as we have suggested, some authors have shown that not all modernisation programmes necessarily lead to water savings (Playán et al., 1999).

Finally, we should mention that this section does not deal with issues such as concessions and the economic regime, and those that refer to the plot structure of agricultural exploitation, all of which bear a relation to demand management. We will deal with them specifically in other chapters of this White Paper.

4.7.2.1.3. Industrial and energy demand

The RAPAPH lays down that, in energy and industrial use, the basin management plans, in addition to existing and foreseeable demand, will also take into account possible changes arising from the application of new technologies, as well as possibilities of water reuse within the same industrial process.

In almost all industries, water savings have a positive result on the decrease in waste, which is often a major problem. In general, the first step to reduce the effects of industrial waste on receiving water and treatment plants is to reduce its volume.

Conservation programmes that can be applied are similar to those of urban supply, with sectoral infrastructure programmes (refining the distribution system to reduce losses), savings (with programmes of awareness and metering), efficiency (improvement in the efficiency of the hydraulic equipment), replacement (reuse of regenerated urban water and especially recycling of water in the same facilities) and management (regulations as regards hydraulic efficiency, surcharges or discounts on the water price, hydraulic audits or inspections, loans and subsidies).

Reuse (application of treated residual water) and above all, recycling (application of the same water a number of times in the industry) stand out because of their efficiency, in conjunction with the rationalization of the production process.

Achieving modifications in existing industries will always be more difficult than demanding certain conditions from new industries and therefore, most pressure should be exercised on these industries.

Progressive increase in the cost of water has been the cause for reviewing the production processes of major consumers, with the objective of reducing demand per unit of product obtained. Likewise, recycling processed water has been developed sufficiently to confirm that it is a solution that in many cases has covered a growing demand arising from the rapid industrial development of recent years.

Current experiences in saving water in industries are concentrated on sectors of industrial activity that are major consumers and, among these, on operations such as refrigeration, washing and transport of materials. Savings in consumption arising from recycling are considerable, as illustrated by table 115 (data from the Seminar on Industrial Residual Water. Technical University of Catalonia, Barcelona, June 1991), giving the average savings values for some industrial sectors.

The repercussion of savings in industrial use on the total national demand is small, as in the case of savings possibilities in urban supply, although it may be extremely significant in terms of quality.

4.7.2.2. The increase in water

The increase in supply is considered to be a process of location, development and exploitation of new water resources.

4.7.2.2.1. The increase in surface regulation

The traditional option for increasing water availability in a basin is the construction of storage reservoirs. This option is still important for hydraulic development of some of the country's territory, but it is obvious that despite the efficient and imaginative solutions implemented to encourage this regulation (Altadill Torné [1995]), its marginal utility is less and less, and its costs greater and greater. Therefore, we cannot consider massive, generalised increase in fluvial regulation as a reliable option for the future water policy of our country.

In order to set boundaries for such maximum possible increase in surface regulation, the basin management plans have drawn up lists with reservoirs that are historically identified in their territorial environments.

We do not have any recent, global and homogeneous estimates of what the construction of these reservoirs could mean as regards an increase in available resources in every field, although, naturally, the marginal performance of each new reservoir is improving all the time.

In some studies (Martín Mendiluce, 1996b), prior estimates of the potential capacity of reservoirs on the peninsula have been made, calculating it at about 76,700 hm^3, which, with

Industrial sector	Savings percentage
Iron and steel industry	94%
Basic chemistry	70%
Refining	80%
Fertilizers	76%
Paper	85%

Table 115. Savings in industrial demand due to recycling.

all the provisos of this type of estimate, would be the absolute theoretical maximum that can be reached. Reaching such potential would mean an increase in current capacity (about 56,000 hm^3) of approximately 35%. According to these studies, the available resources would be increased by approximately 20%, with a decrease in regulation performance, to 0.60 down from 0.90 in the 1970s.

We can state that the reservoirs in the plans form a range of possibilities with one fairly generalized failure: verification of feasibility. This means that the future execution of such infrastructures can only be carried out after technical, environmental, economic, financial and social justification of its feasibility, something most actions seem to lack at this moment. In this sense, the lists of reservoirs included in the plans must be interpreted in general as action frameworks, as catalogues from which to select certain future actions, but whose execution must in all cases be subject to compliance with all the necessary requirements of environmental feasibility, and adapted to the pace of financing possibilities.

4.7.2.2.2. The increase in groundwater exploitation and joint exploitation

Currently, groundwater provides a major part of consumption demand in Spain, estimating that the quantity of abstractions amounts to around 5,500 hm^3/year.

The integration of groundwater and surface resources in joint exploitation schemes can be, as we have seen in the chapter on water resources, a very interesting alternative to increase availability and improve supply guarantee. However, certain natural, economic factors, as well as already-existing hydraulic infrastructures, limit the effective possibilities of applying joint use to some resource exploitation schemes.

As a consequence, in the MIMAM (1998b), 27 schemes have been selected, in which 70 hydro-geological units are integrated with 71 reservoirs and 16 major infrastructure-piping systems. The studies and analyses of necessary systems have been defined and assessed to determine the increase in obtainable resources in every one of these 27 schemes and the feasibility of the integration of both types of resources, economic aspects and management and organization by users. Until such time as these studies have been concluded, we can advance some of the preliminary figures given, to offer an idea of the scale of magnitude of additional resources that can be obtained in every basin through the implementation of joint use schemes (Table 116).

Figure 369 shows the geographical situation of the selected schemes and the hydrogeological units they include.

Furthermore, to gain an initial idea, although theoretical and purely indicative of possible maximum increase in the sustainable exploitation of groundwater, the adjoining table –drawn up here with data from the Basin Plans, White Paper on Groundwater and the simulation model applied in this White Paper– shows an estimate of the potential increase of abstraction from peninsular hydrogeographical units currently exploited, taking into consideration natural recharge through rainfall infiltration and exploitation. Natural recharge through rainfall infiltration is not conceptually the same as the renewable resources of a hydrogeographical unit, but it gives an initial estimate of these resources.

Two hypotheses have been considered, arising from assuming, or not, that part of these abstractions are used to reduce problems of over-exploitation. In the first hypothesis the upper limit would be the natural recharge in each planning area, while in the second, it would be greater by not considering overexploitation. The estimates would be higher if extraction from other aquifers that are not currently exploited was taken into account.

As we can see in table 117, and despite the fact that we have already pointed out the simplified and theoretical character of this approach, the most important potential increase in the exploitation of groundwater corresponds to the basins of the North, Douro, Tagus, Guadalquivir and, to a lesser extent, Catalonia Inland basins.

In the case of the Ebro the global result of the increase is zero, given the low number of exploitation units that additionally extract more than natural recharge through rainfall. If we also took irrigation returns and the transfers from other units into account, the potential increase would stand at 400 hm^3/year.

Although in both hypotheses examined the potential increase of exploitation for the whole peninsula is greater

Planning field	for add. resources (hm^3/year)
North II	20 – 25
Douro	40 – 80
Tajo	Not significant
Guadiana	Not significant
Guadalquivir	50 – 80
South	60 – 90
Segura	Not significant
Júcar	90 – 120
Ebro	20 – 30
Total	**280 – 425**

Table 116. Possible additional resources per planning area in the 27 schemes of identified joint use.

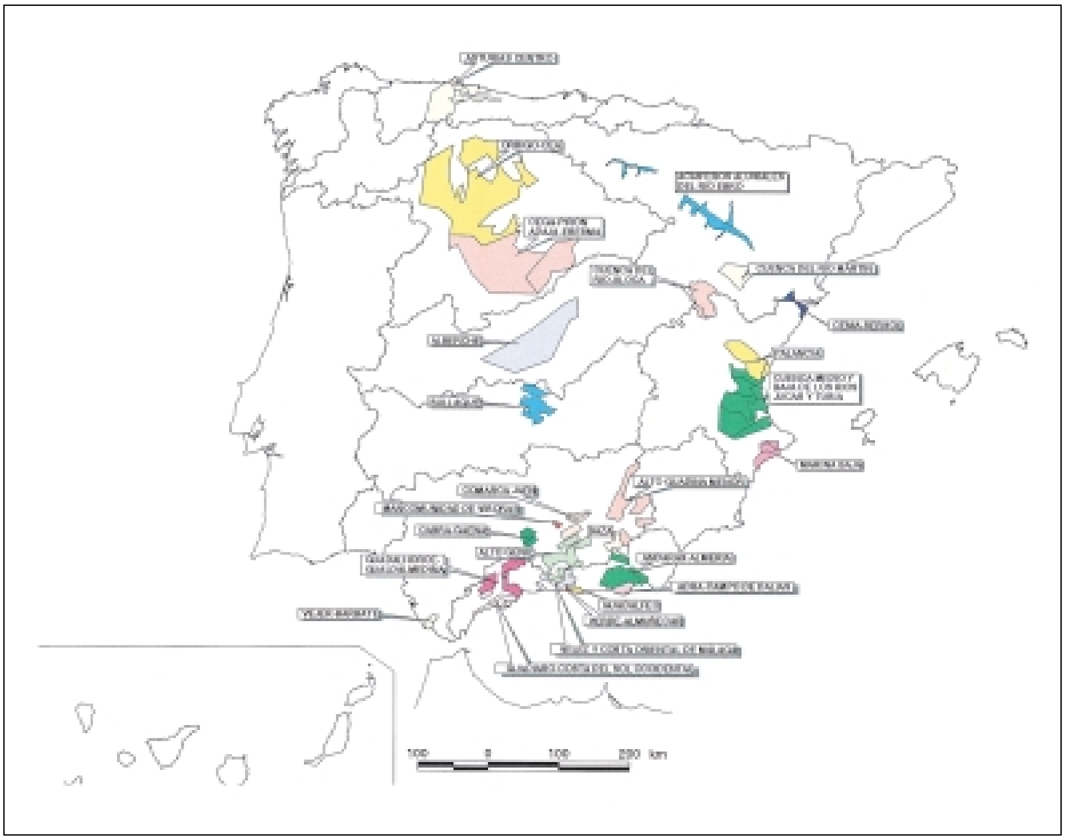


Figure 369. Map of the schemes of joint identified use.

than its current use, if we only considered the basins that in general have most problems of water scarcity (Guadiana I, South, Segura and Júcar), this increase would be reduced to 5% and 53%, respectively, the first figure corresponding to the most realistic hypothesis and showing, in short, practical exhaustion of the possibilities in increasing water availability in these basins through intensifying the use of groundwater. Rather, it would be necessary in many cases to reduce current pumping and reorganise existing abstraction to achieve a situation of sustainable exploitation.

Although we could make some specifications about units that are not exploited and the simplification of the model, we should note that the volumes given are estimates of the *impossible absolute theoretical maximum*, as in its calculation we have ignored possible natural upwelling which is

Planning area	Natural Recharge (hm^3/year)	Current pumping (hm^3/year)	Increase in pumping in hydrogeological units in exploitation (considering over-exploitation)	Increase in pumping hydrogeological units in exploitation (not considering over-exploitation)	Percentage of increase in pumping regarding current pumping (considering over-exploitation)	Percentage of increase in pumping regarding current pumping (not considering over-exploitation)
North I	2.745	--	--	--	--	--
North II	5.077	19	983	983	5.173	5.173
North III	894	33	320	320	970	970
Douro	3.000	371	2.293	2.293	618	618
Tagus	2.393	164	450	450	274	274
Guadiana I	687	738	0	250	0	34
Guadiana II	63	76	0	7	0	9
Guadalquivir	2.343	434	1.376	1.406	317	324
South	680	420	0	190	0	45
Segura	588	478	46	405	10	85
Júcar	2.492	1.425	117	783	8	55
Ebro	4.614	167	0	0	0	0
Catalonia I.B.	909	424	393	650	93	153
Galician coast	2.234	--	--	--	--	--
Peninsula	**28.719**	**4.748**	**5.978**	**7.738**	**120**	**163**

Table 117. Theoretical maximum possible increase in the exploitation of groundwater.

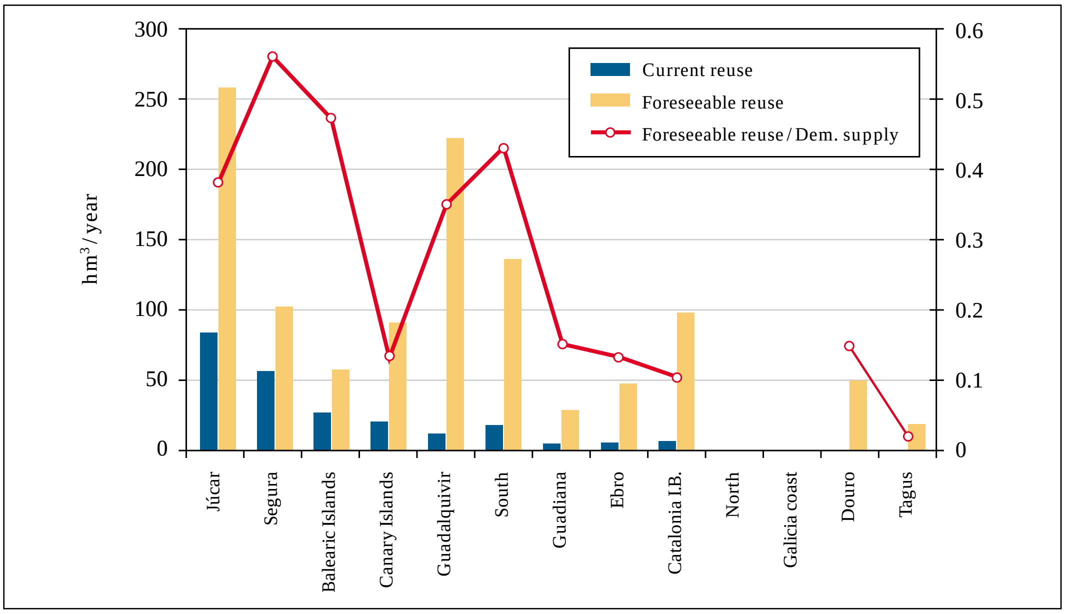


Figure 370. Volumes of current and forecast reuse in the long run in the different basins.

already regulated by reservoirs downstream, and we have accepted that all natural upwelling can be suppressed through regulation by means of a pumping device, which obviously is unacceptable from an environmental point of view. In fact, if such upwelling were associated with wetlands or natural areas of interest, the increase in exploitation would be virtually nothing, regardless of recharge balance.

The potential increase in the exploitation of groundwater would cause, in any event, a drop of similar magnitude, although deferred in time, in cumulative flow to the fluvial network. This time deferral and its appropriate programming is, as we have already indicated in other sections of this White Paper, the key to joint use of surface and groundwater.

4.7.2.2.3. The increase in reuse

The potential for reuse is high, because in a second stage it would allow achieving, according to estimates from the basin plans, volumes of regenerated water of around 1,100 hm^3/year. Its distribution over hydrographic basins would probably be as shown in figure 370, although the predictions for this evolution are subject to significant uncertainty and vary according to the source of the data. The figure also shows the relationship between the volume of reuse and of supply; this allows us to see the relative differences between basins. Rates of around 50% of the total supply can be considered very high, and indicative of considerable exploitation of these resources.

In some basins, such as South or Júcar, foreseeable reuse may eventually represent a very significant percentage of available resources.

So that the volumes mentioned above may be regenerated, and effectively incorporated into the system of reuse, there has to be regulation at state level to lay down the basic conditions for direct reuse of regenerated wastewater, as well as the adoption of new financial incentives to set up substitution programmes –in uses that do not require high water quality– of drinking water in municipal networks, by regenerated wastewater.

4.7.2.2.4. The increase in desalination

The main limiting factor for the application of desalination is exclusively economic. Today, we can still say that the cost of sea-water desalination marks the threshold of what can be obtained in coastal areas, which will decisively influence studies of the different alternatives considered in order to solve the existing deficit.

Having said this, we also have to add that, as we have explained in detail in the corresponding section, the costs of desalinated water have become increasingly lower in recent years, basically as a result of the reduction in energy costs (main component of water desalination costs) and technological improvement and development of markets. No matter what technology is applied for desalination, energy costs always represent between 50 and 75% of real exploitation costs. Therefore, the possible increase in desalination is directly associated with the costs of energy which, as we have seen, have tended towards stability or decreased over recent years.

Likewise, the reduction in costs of desalinated water will not contribute to its expansion, but might serve as a catalyser for a major technological breakthrough in the development of these processes.

In our country, the forecast for desalination in the short and medium term, taking the works that are currently under construction and those soon to be carried out into consideration, the current figure would increase by more than 400 hm^3/year, as the graph in Figure 371 shows.

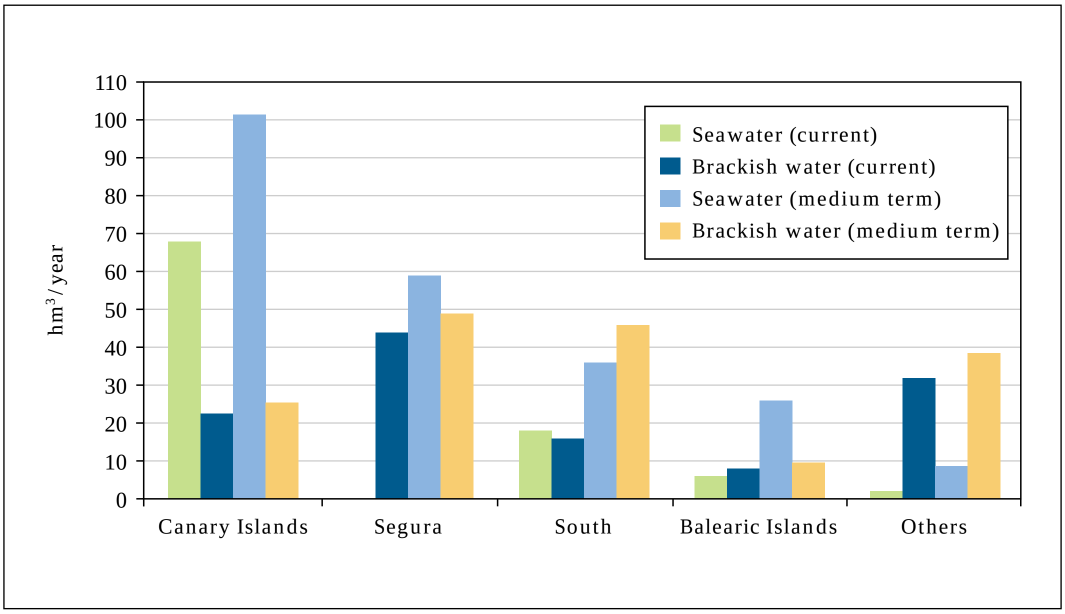


Figure 371.Current and forecast volumes of desalination in the short and medium term in the different planning fields.

However, if recently detected trends continue in the coming years, it is possible that these forecasts may even be surpassed.

In any case, and despite such favourable perspectives, we must stress what has been said above with respect to the high dependency on energy costs in production process. These circumstances suggest acting with caution with respect to the possibility of massive regeneration of this water, and advise strategically considering alternative options in such a way that the global supply system depends less on energy.

4.7.2.2.5. The alternative of inter-basin transfers

The alternatives for increasing supply (new regulation reservoirs, increase in the exploitation of aquifers, joint exploitation of surface and groundwater, reuse, desalination, etc) and demand management (programmes to reduce losses in the infrastructure, savings, efficiency, substitution or management) are established at the level of basin water planning. When all these alternatives are exhausted and the water demand of the basin still cannot be met, the only alternative that is left consists of resorting to external supply from different basins. With the current legal regulation, these transfers have to be considered and solved at a higher level than the basin plans, such as national water planning, and they have to be approved by Law.

In Spain, inter-basin transfers have always been considered as a necessity, with antecedents from a very long time ago. Among the currently existing transfers, the most important is the Tagus-Segura, which diverts water from the upper basin of the Tagus to the basins of the Guadiana, South, Segura and Júcar.

The most recent and significant historical antecedent took place in April, 1993, when the Draft Report and Preliminary Design of the National Hydrological Plan Act (MOPT, 1993b) was published. A complex network of transfers between basins was established (more than 10 significant transfers) that received the name of *the general interconnection* of the basins (Cimadevilla and Herreras, 1993).

These transfers totalled 3,768 hm^3/year and were divided into 1,347 hm^3/year between the Atlantic y Mediterranean coasts, 1,855 hm^3/year within the Mediterranean side and 386 hm^3/year within the Atlantic side. The most important transfer took place between the Ebro, Júcar and Segura with 1380 hm^3/year. The second most important was from the North-Douro-Tagus to the Southeast, with 630 hm^3/year and the one from the Ebro to the Eastern Pyrenees, with 475 hm^3/year. In the report, with a consultative character that the National Water Board presented to the National Government, it was suggested that these transfers should be slightly reduced.

Furthermore, we have to mention the existence of some recent initiatives toward the creation of international hydraulic networks, with a trans-European character. The Resolution by the European Parliament on the 28th of January of 1998 points in this direction.

A transfer of this kind, which would contribute resources to Spain from other countries –like the recent proposal from the Rhone to the area of Barcelona– would not legally be an inter-basin transfer in the sense of the Spanish Water Act, and as a result of that it would not be subject to the National Hydrological Plan Act. It would be legally regulated by means of an International Agreement, despite the fact that the technical-economic-environmental study fits completely into the analysis of water planning.

4.7.3. The improvement in procedures and methodologies

In this section we will refer to some of the technical instruments already developed, whose generalised use in every-day life can lead to improvement in the knowledge and management of water resources. We have to point out the importance of the role that new information technology, emerging today, must play in the near future (Cuena, 1996).

4.7.3.1. Databases on water

It is not necessary to highlight the tremendous importance of having databases on water, at a national level, covering three fundamental aspects of water planning: resources, demand and exploitation systems.

Knowledge about water resources is the aspect that is best included in the database at national level, due to the existence of networks with specific dimensions.

In fact, the most important databases are associated with the networks with the dimensions that were described in another section of this White Paper.

The National Institute for Meteorology (NIM) has a meteorology database that collects and organizes the information flow from Territorial Centres, where registered data from the weather stations is gathered (precipitation, temperatures, atmospheric humidity, wind, etc). They also have auxiliary data, such as historical events (extreme values of the series), inventory of climatological documents, collaborators and control tables (classification of clouds, meteors, towns, etc.). They are all available through payment of a subscription fee at the General Subdepartment Users Service of the INM.

At the Centre for Hydrographic Studies of the CEDEX there is a HIDRO database (Quintas, 1996), belonging to the DGOHCA, that collects hydrological data on continental surface water from the network of gauging stations on rivers, channels and reservoirs. The data comes from the Water Commission of the Hydrographic Confederation and is compiled in the CEDEX for treatment, validation and publication in the Gauging Yearbook, as well as for distribution on an analogic recording.

The Spanish Technology and Geomining Institute (ITGE) has developed the AGUAS database where data is collected in the field for preparing the Groundwater Research Plans for Management and Preservation of Aquifers and the Supply of Urban Areas, carried out by the Institute. The starting-point of the AGUAS Database is the inventory of aquifer points with geographic-administrative, technical and hydrogeological data. Associated with these aquifer points, there are time series of data on piezometry, hydrometry, marine intrusion and chemical analyses. The data can be obtained by paying a submission fee.

At the General Subdepartment for Treatment and Control of Water Quality of the Ministry of Environment there are databases on the quality of surface water obtained from the networks of COCA, COAS, ICTIOFAUNA and RADIOLOGICA, merged in 1993 into the ICA network. It deals with physio-chemical data from more than 800 measurement stations on the most important Spanish rivers.

Likewise, the General Subdepartment for Water Planning prepares and maintains some periodical hydrological Newsletters, updated on a weekly basis, that can be found on the Internet (under the Environment Ministry).

As regards consumption, it is not possible to have complete and continuous databases on a national level, as there are no specific networks for measurement. In the National Irrigation Plan Horizon 2005 (MAPA, 1996) the creation of the Network for Assessment of the Needs for Irrigation Water (NENIW) was proposed, which would supply databases with water demand for crops, supply, etc., which would allow water consumption to be monitored. There are no systematic databases on urban and industrial demand on a national level, either.

Of the elements that make up the exploitation systems, we can mention the database of the Inventory of Dams, which is periodically updated, and in which the main characteristics of all the dams in Spain are collected.

There are also a lot of databases on water or related to water, in other organisations, like for example the National Centre for Geographical Information of the IGN. In this centre we can make use of cartographical information, in particular referring to geographical zones, such as the National Cartographical Basis on a scale of 1:200.000 called BCN200 or the CORINNE LAND COVER on soil uses.

In spite of the large amount of available hydrographic information in databases, there is near unanimity on the fact that the current panorama on information on water in Spain is not the most desirable. The hydrological databases are scattered, with little coordination, over different organisations, partially covering necessities, and without the necessary homogeneity as far as contents and formats are concerned. Nowadays, it is very difficult for the user, even for specialised organisations, to have access to all the information on water that might be interesting.

It is understandable, therefore, that it is necessary to establish criteria and procedures in order to improve the current situation. We can cite the following:

- Definition of the type or types of databases that are wanted. A decision to take is if there should be one single database that collects all the information on water, if we should go towards a distributed system of databases, clearly specifying who is responsible for the information and how existing data is organized, listed and coordinated, or if intermediate databases are to be set up between the previous ones.
- Clarifying, and if necessary, establishing mechanisms for collecting, compilation, storage and management of certain information on water. It is important to choose what type of registered information in the measurement networks is stored in databases and with what frequency.
- Establishment of guidelines to update a certain type of hydrological information and indication of the organisation that is responsible for it.

- Degree of accessibility to information according to the user's level and a definition of information costs. Currently, these are extremely high, and they depend on the organisation. In some cases, they not only refer to delivery costs.
- Establishment of quick procedures of access to information according to the user's level. Certain types of selected information must be easy to consult and there has to be easy access to digital recordings and to the Internet. The aforementioned initiative of Hydrological Newsletters is a good example of this access.
- Need to incorporate the databases on water into the field of Geographical Information Systems (GIS), in such a way that the information can be found according to georeferences and that it is possible to carry out simple consultations and analyses related to space in an easy way.

Within the framework of the studies carried out to draw up this White Paper, a major effort has been made to compile all the available information on water resources (both on quantity and quality), demand and exploitation systems. This information has been subject to homogenisation into one single system, uniting the alphanumerical and graphic information in the Centre for Hydrographic studies of the CEDEX through the application of Geographical Information Systems.

4.7.3.2. Simulation and optimisation models

There is a clear necessity to progressively implement technological, modern and homogenous procedures (mathematical simulation models of cumulative flow, of simulation and optimisation of the exploitation systems of resources, of influence of demand, etc) which considering all the intervening elements, allow dealing with the analysis of the water systems in a common, drastic way.

Below, some of the basic techniques are described, vital to water planning.

4.7.3.2.1. The simulation of cumulative flows to the natural regime

According to the RAPAPH the Basin Plans have to contain, as much as possible, statistical data that shows the evolution of the natural regime of flow, storage and water quality of water over the hydrological year, the interrelations of the considered magnitudes, especially between surface and groundwater and between precipitation and cumulative flow from rivers, or aquifer recharge.

In the Basin Plans, natural cumulative flow has been achieved through very varied procedures, what has led to considerable heterogeneity in the reliability of the results. In general, there is no clear establishment of relationships between precipitation, aquifer recharge and cumulative flow in the rivers. On the other hand, the information used corresponds to different periods, which, overall, and given the preparation date, do not include data of the hydrological years of this decade. Therefore, the effect of the last drought has not been taken into consideration, at least not its full extent. In short, we have not always dealt with the different processes that form the hydrological cycle, and more specifically, the interrelations between surface and groundwater, in an integrated and systematic way for all the basins.

As we can clearly understand, this panorama has to improve in the successive review of the plans, and therefore we will have to use simulation models allowing a homogeneous, accurate assessment of these variables and interrelations. During recent years, different models have been developed whose main objective is to simulate a natural cumulative flow series in the basins on the basis of meteorological information and the basin's characteristics. The characteristics that a model of this type should have in order to be used in the assessment of a hydrographic basin's natural resources are as follows:

- It has to simulate the main components of the hydrological cycle: precipitation, evaporation, degree of humidity in the soil, surface runoff, recharge of the aquifer, storage in the aquifer and groundwater runoff.
- It is recommendable that the simulation is distributed, to be able to consider accordingly the spatial distribution of the variables and the parameters.
- It has to be possible to estimate the parameters of the model, or at least, to characterise them based upon the physical characteristics of the basins (soil uses, edaphology, lithology, etc)
- The minimum period of the simulation has to be one month.
- It is necessary to simulate a time series of cumulative flow at any point on the fluvial network and recharge in the aquifers.

In this White Paper we have used a simulation model of cumulative flow that has all these characteristics, and which was described in previous chapters when we explained the assessment of water resources. It is a conceptual and distributed hydrological model, which in a natural regime, simulates monthly cumulative flow at any point in the fluvial network, and aquifer recharge. It compares the simulated data with historical data from the gauging control stations, allowing calibration. The model has been used to make an exhaustive new assessment of natural resources in the Spanish peninsular territory over a common period in all basins, in the period of hydrological years from 1940/41 to 1995/96.

4.7.3.2.2. The simulation and optimisation of exploitation systems

The study of resource exploitation systems must contain the definition and characteristics of the available water resources, according to the rules considered for water use, the determination of the elements of necessary infrastructure and the fundamental guidelines for its exploitation, natural resources that are not used in the system and, if necessary, from other territories.

There are usually two types of models used for the study of water resource exploitation systems, simulation and optimisation. The aim of the first is to simulate in detail the operation of the system with some given management rules, while the optimisation models try to find the optimum management of the system and calculate water flow and storage in such a situation.

The basic conceptual elements that an optimisation model for resource exploitation systems has to take into consideration are:

- Junctions without storage capacity. - These are useful to include river junctions, points where a inflow takes place, derivation points, and connection points.
- Junctions with storage capacity. - These are used to incorporate reservoirs.
- Channels. – They may include natural channels (river reaches), as well as irrigation channels and ditches and transfers between basins.
- Demand. - It must be possible to define monthly demand and a priority for each demand.
- Hydrological inflow. - This corresponds to the natural cumulative inflow to the system. This is usually obtained with the simulation models of natural cumulative flow that we mentioned before.
- Returns. - We must consider the return from excessive diversions that are not consumed and which return to the surface system for later exploitation downstream.
- Aquifers. - In general this type of model does usually not explicitly consider groundwater although it is incorporated in the cumulative flow and there are simplified mechanisms that allow correct assessment of its effect.

Furthermore, the simulation models require a more detailed representation of the system of water resources than the optimisation models. They make use of more types of elements, and their physical characteristics have to be described in more detail. They also have to be given operation rules for each element and for the system as a whole.

The huge amount of data in this type of models requires a lot of work during the process of entering data. The importance of a graphic interface that the database includes is bigger than in the case of optimisation models, aiming at facilitating work and avoiding mistakes. The basic conceptual elements that have to be considered in a simulation model of the resource exploitation systems are:

- Junctions without storage capacity. - They should allow for including river junctions as well as hydrological inflow, diversions and connections.
- Junctions with storage capacity. –Necessary for incorporating surface reservoirs.
- Channels. - They have to be able to incorporate different types of channels: a) without loss or connection with the aquifer; b) with loss due to infiltration into an aquifer; c) with hydraulic connection to an aquifer. Depending on the piezometric levels, the aquifer can extract volumes of water from the river or vice versa.
- Consumption demand. - They have to be able to include monthly data on demand in irrigated areas, towns and industrial areas. They should also be able to consider the different efficiencies of irrigation and the possibility of surface returns to different points of the system.
- Hydroelectric plants (non consumptive demand). - They make use of water, but do not consume any significant amount.
- Aquifers. - It must be possible to explicitly include groundwater and through distributed modelling.
- Other types of elements such as returns, installations of artificial recharge, or additional pumping installations.

In a model of this type, apart from the physical characteristics of components, operation rules must also be specified for the individual elements, as well as for the system. This can be structured as follows: the target curves of volume and zoning of the reservoir, the relationships between reservoirs, the minimum water volume target for channels, the target supply for demand areas, the target volumes of water for turbines for hydroelectric power stations, the relation between different demands, the relation between channels, given by priorities, or the relation between elements.

For the drafting of this White Paper, and as a preparation for the analyses of national planning, we have extensively used both types of models (optimisation and simulation), according to the algorithmic implementations and developments carried out in the Technical University of Valencia (Andreu, 1992; Andreu et al., 1992; Andreu et al., 1995; Andreu et al. 1994), implementations that constitute these technologies' current state-of-the-art.

5. WATER PLANNING

The chapters above having described the current situation, existing and foreseeable problems, and the features and possibilities for water policies in the near future, we shall now consider the main technical and legal instruments by which this water policy is expressed, in other words water planning.

It is true that, as we have reiterated, water planning it is not a new technique, nor the only instrument by which these policies are implemented, but current legal regulations on this issue have underlined its basic, pre-eminent character, and have granted these a instruments statutory nature and a formal relevance which, up to now, they had lacked.

5.1. HISTORICAL BACKGROUND OF THE PLANNING PROCESS

Although planning understood as rationalisation is as old as water-use itself, the first systematic attempts in our country at formulating and anticipating water problems, analysing alternatives, and proposing action, date from the second half of the 19th century.

Dating from that time are plans like the one by Gómez Ortega, Lizárraga and Churruca (1866), to defend the Júcar, or the one by García and Gaztelu (1886), to defend the Segura, and it was when the first hydrological studies took place, fundamental pioneering work carried out in systematizing basin data, fluvial cartography and incipient water planning, implemented by the hydrological divisions of the Development Ministry (Mateu Bellés [1995] pp. 69-105; MAP-MAP - MOPU [1988] vol. 1, pp. 53-56).

Later on, at the beginning of the 20th century, the first Structures Plans were set up, beginning with the National Hydraulic Structures Plan of 1902 and its successive updates in 1906, 1909, 1916 and 1922, and going on with the Hydraulic Structures Plan of 1933, the General Public Works Plan of 1940 and its successive adaptations, the First and Second Economic and Social Development Plans in the 60s and 70s,… Accordingly, historical continuity in the creation of Plans has been implemented in Spain for many years, and at very different economic, political and social times.

Sections below will briefly review some significant landmarks in this historical evolution.

5.1.1. The Plan Gasset of 1902 and its imitators

Without considering 19th-century background, at the beginning of the 20th century, water policies for Spain were no more than agricultural polices, and, in view of the importance of the agricultural sector for the Spanish economy, economic policies. This is one of the central, defining ideas that underlie the concept of the traditional model, as described above.

Costa's ideas were partly assumed by the Government when it approved the General Irrigation Channels and Marshes Plan, or Plan Gasset, in 1902, the first systematic proposal for hydraulic actions on a national scale (Ortega Cantero, 1995).

Apart from the technical and financial criticisms that could be made, the main defect of this Plan, and of the water policies of the time in general, was the lack of an integrating concept of water planning, to interrelate different needs and the actions necessary to cover them, which is why this Gasset Plan has often been described as a mere list of marshes and channels, without relationships between them, and which lacks regulation reservoirs, hydroelectric use and other major elements of water management.

This criticism, which came from Lorenzo Pardo himself in his Plan in 1933, should nevertheless to be broadly qualified, as revealed by the study of subsequent actions, and the controversy that arose in technical sectors of the period.

5.1.2. The National Hydraulic Structures Plan of 1933

The progressive increase in regulating fluvial channels and in exploitation, both for irrigation and for supply and even hydroelectric production, led to an approach of increasingly greater rationality and integration in water-related actions. An example of this new focus was the creation, of the Hydrographic Confederation Union of the Ebro in 1926, one of whose main objectives was to obtain the best use of water to profit from the hydrographic territories' economic potential. Without a doubt, the creation of the basin concept as a fundamental unit in developing a broad sense of water management was an effort towards approaching problems in an integral way.

It was no longer a question of acting without coordination, but of encouraging the balanced coexistence of the different sectoral interests such as irrigation, hydroelectric production, supply or even river transport, all converging in water use. Additionally, the increasing regulation of rivers, especially through state-promoted actions, recommended finding ways to reconcile state and private interests, a clear example of which was the initial organization of the Hydrographic Confederations, consisting of an assembly (with representatives from the state, from the exploitation and from some organisations such as chambers, banks, etc), a board of management, appointed by the assembly, and two executive committees.

A significant advance in this trend towards integral water exploitation took place in the decade of the thirties, with the National Hydraulic Structures Plan of 1933, drawn up by Manuel Lorenzo Pardo, with the collaboration of Clemente Sáenz, Angel Arrué and Joaquín Ximénez de Embún. In this fundamental plan –on which numerous studies and exegesis have been made (see, e.g., Ortega Cantero [1992]; MOPT-MA [1993]; Romero González [1995])– a reasonably joint, structured approach is made regarding national hydrological problems, but which is based on hydrographic basins in order to avoid the temptation of homogenising. Also, it does not only take exclusively hydrological issues into consideration, but also other geographical, climatic and economic questions. This approach was possible because there was so much data available, and much more accurate and complete studies than those existing at the beginning of the century, thanks to work carried out by the ministry's own technical services, and due to some excellent thematic work done on geology, hydrology, etc. allowing better knowledge of cumulative flow, demand etc. in Spanish rivers.

The conclusions made by Lorenzo Pardo, responsible for drawing up the plan, from analysing the data was that, in Spain, the geographical economic reality was marked by two opposing situations of imbalance. The first imbalance was hydrological, and consisted of significant inequality in the volume of available water in the Atlantic and Mediterranean areas. The second indicated that it was precisely the Meditaterranean area, the one with least water, which offered better possibilities for irrigation, the main economic objective underlying his considerations.

The corollary logic drawn by the plan's editors, a consequence of its objective to maximise national income, is that, considering the water deficit in the Mediterranean area and the greater potential productivity of its irrigation, the solution consisted of transporting water from Atlantic basins to Mediterranean ones for use in the latter, by means of structures planned and implemented by the state, as the maximum representative of general interest.

Furthermore, the 1933 Plan considered, following the same line of thinking in creating the Hydrographic Confederation Union of the Ebro, that in order to overcome the stage of disordered river exploitation, public and private interests had to be combined in each basin, by applying rationality approaches; this gave rise to the remaining Hydrographic Confederations, based on the administrative model defined when Ebro confederation was set up, but also adapting them to the particular characteristics of each territory. This accordingly laid the foundations for solving the growing need that appeared with greater possibilities of conflicting water interests, since the state had taken a material interest in hydraulic structures, and the hydroelectric industry was an emerging reality. These conflicts concentrated especially on using surface water for irrigation, which continues to be a high priority as a stimulus to increasing productivity, but also in the uses of electricity production, which were already taking on a second, and very important role.

5.1.3. The Public Works Plan of 1940

After the Civil War, the General Public Works Plan of Alfonso Peña Boeuf was approved, which explicitly quotes, as regards hydraulic structures, the forecasts and studies of Lorenzo Pardo's Plan. The economic and social situation of 1940 Spain, however, recommended social actions over and above economic questions. That is to say, the state invested in hydraulic structures even in the knowledge that future users of regulated water would have difficulties not just to collaborate in financing them, but even to cover operating expenses and maintenance.

As mentioned above when analysing the traditional model's crisis, the increase in agricultural production was justified in advance, and was absorbed by the nation's interior consumption. As in Costa's time, it was thought that irrigation was doubly profitable: firstly from a social point of view, but also, with no doubt or need for analysis, from an economic point of view.

5.1.4. Economic and social development plans

As of the decade of the forties, and especially in the fifties and sixties, considerable development took place in the construction of hydraulic structures, as we clearly saw in the corresponding section, particularly reservoirs and wells, partly as a consequence of the state's preferential focus on storage structures for irrigation, and partly of the significant increase in hydroelectric exploitation, under private initiative.

Water policy continued to participate to some extent in regenerationist ideas, and to be basically an instrument of agricultural policy; in the period immediately after the war, with the aim of increasing productivity to provide for the nation and, from 1960 onwards, to diversify agricultural production and achieve a healthy trade balance. It was in the 70s when this concept really began to be questioned.

As a consequence of the these multiple causes, water became a regulated resource more than a natural resource, so when in the middle of the 60s, the II Development Plan was drawn up, *integral exploitation* of resources was put forward as a requirement, because it was considered that Spain had entered a stage of water maturity (a stage theoretically reached when demand exceeds approximately 50% of natural resources).

In summary, the decade of the 70s began to show clear signs of crisis in the traditional model of water policy, commented above in another chapter of this White Paper, in particular as regards the priority given up to then to developing irrigation by implementing hydraulic works financed by the State.

In comparison with practices carried out in the immediately previous development period, when public works had been strongly promoted, but without really responding to any hydraulic works plan, this gave way once more to the idea of regulating state actions with planning criteria such as socio-economic profitability, contribution to cost by beneficiaries, capacity of adaptation to changes, etc. (Martín Mendiluce [1993] pp.333-369).

These criteria, which had already begun to include the new ideas on water planning and were spreading through the main developed countries, meant a decrease in the indiscriminate implementation of hydraulic structures (dams and channels) in water plans, unlike what had taken place in plans that had been approved, or there had been an attempt to approve, throughout this century in Spain, and in which this type of action was always a fundamental element, easily justified from a social and economic point of view.

5.1.5. The plans for specific areas and exploitation plans

Apart from the national plans, which included general concepts for the whole Spanish territory, different specific water plans were also developed, conceived to be applied in a specific part of the territory. This is the case of the Almería or Tarragona plans which, with provincial scope, gave rise to different actions in those areas.

5.1.6. The Decree of 1979, Avance-80 and prior studies

These Documents have major importance in the recent planning process. Since they are relatively unknown, and they constitute the true immediate antecedent of the current situation which to a large extent has been brought about by them, it is worth examining them in some detail.

In fact, there have been numerous technical and legal concepts, for many years, pointing to the general consideration of water use as an activity subject to planning, but the most significant, immediate and conceptually similar antecedent to current planning is Royal Decree 3029/1979, of December 7th, regulating the implementation of prior studies for water planning, considered as an essential instrument in the new hydraulic policy.

In accordance with this Decree, these prior studies had to include an inventory of water resources with current and future availability, both quantitative and qualitative, forecasts for the use of such availability, the foreseeable evolution of water demand, the regulation of the resources to cover this demand, and the most expedient structures to achieve such cover. The necessary administrative measures also required study for development, and order of priority in implementing infrastructure work.

This Royal Decree, short in length, but of great importance in its effective duration, extended water-use regulation to the whole national territory for the first time, and established that this general use shall be subject to water plans, even when the structure and contents of such future plans had not been established, only the above-mentioned prior studies.

In developing the Royal Decree, and in order to orient the plans' design and to coordinate participation from different ministerial departments, a simple ruling was made at that time that institutionalised these studies as administrative tasks, and adopted the necessary coordination measures, measures that took shape with the creation of the Inter-ministerial Water Planning Committee, sole superior governing body in implementing the prior studies, chaired by the Minister of Public Works and Urban Planning, and initially made up of the Ministerial Departments of Public Works and Urban Planning, Industry and Energy, Agriculture and Fisheries, Health and Social Security, Territorial Administration and Transport, Tourism and Communication, with the General Director of Hydraulic Works acting as secretary. This composition was to be modified by Royal Decree 2383/81, of August 20th.

The first meeting of this Committee, held on February 21st, 1980, and with the objective of making its work more operative, agreed to set up the Working Party on Coordination and Rules, under the presidency of the General Director of Hydraulic Works, and with a permanent secretariat, under the Centre for Hydrographic Studies.

In the second meeting of the Water Planning Committee, held on June 12th, 1980, the proposal for contents of the water plans was approved, presented by the Working Party on Coordination and Rules, and the proposal for organising its execution, by setting up Regional Working Parties, one for each basin, which, under the Directors of the Hydrographic Confederations, would be responsible for drafting the specific plans for each basin. Both the Coordination and Rules Party and the regional ones included representatives from different organisations which, belonging to the above-mentioned Ministerial Departments, had some relationship with water resources. Finally, the National Hydrological Plan had to act in bringing together the different water plans of each basin.

The above-mentioned Coordination and Rules Party agreed to request the regional groups to provide an initial draft of the plan, to be carried out by the end of 1980, although finally, lack of time led to its being handed over well into 1981. In complying with this request, each basin drafted some documents known as *AVANCE-80*, which can be considered, in the current terminology, as a rough draft and antecedent of the basic documentation for the water plan.

These documents were gathered, summarised and published jointly in a volume by the Inter-ministerial Committee (MOPU-CIPH [1980?]).

Once Avance-80 had concluded, as a summary and synthesis of data and works existing at that time, and seeking the greatest possible homogeneity in developing and writing different future works, prior to the plan proper, the General Secretary of the Hydrological Plan laid down some basic guidelines by means of the working paper called Terms of Reference (also known as the *Instructa*), which, apart from the list of studies to carry out, suggestions and comments were included on all aspects that should be taken into account in designing the plan.

On the basis of these recommendations and conditions laid down in the Instructa, and bearing in mind the particular characteristics of their territorial areas, each Regional Working Party undertook, with all consultation considered expedient, to implement the above-mentioned prior studies that largely formed the technical and informative bases for everything subsequently carried out in planning issues.

5.1.7. Water planning as of the Water Act of 1985

After Avance-80 was made available, and with the prior studies being carried out in the different basins, a landmark appeared with the preparation and approval of the Water Act of 1985, whose preamble qualifies water planning as indispensable, and whose provisions devote a complete Heading to defining the contents, method of approval, etc. of the two planning figures that the whole scheme should be based upon: the basin management plans and the National Hydrological Plan.

The Act designs a water planning process of combining certain coordination aspects that are reserved for the National Hydrological Plan and the Government, who shall approve the basin management plans in the terms they deem reasonable as regards public interest, and certain aspects of territorial autonomy and decentralisation which gave rise to the basin management plans being drawn up by the Hydrographic Confederations, and forwarded to the Government for approval by the Water Council of each basin organisation.

These organisations are conceived as the elements that must organise the participation of the other water-related Ministerial Departments, of the different users, and of the Administrations of the Autonomous Communities where the basin is located. It is worth noting the contents of section 1.3 of the above-mentioned Act here: *Water planning shall be the responsibility of the state, in all cases and in the terms laid down in this Act, to which all action upon the public water domain shall be subject.*

New aspects highlighted in the objectives of water planning, as defined by the Act of 1985, are water quality protection, moderation of demand and respect for the environment.

Sections below will give a detailed examination of the different changes, the current situation, and the results of this process.

5.1.8. Summary of the planning process' historical typologies

As a summary of the above, and in an attempt to systematise the different historical figures set out, administrative actions carried out in Spain with respect to the availability and use of water resources, and which could be grouped under the term "plans", can be classified into four basic categories, going back to the beginning of the 20th century.

The first would be what we could call Structures Plans, and which are usually simple catalogues of hydraulic structures, studied with the technical criteria of the time, not very rigorous by today's standards, without economic assessment, and having neither coordination with each other nor with the official budgets, so many were finally never carried out.

It has often been said, quoting Lorenzo Pardo, that such plans cannot be considered as representative of a true water policy in the modern sense, but simple physical cataloguing, locating possible infrastructures. As mentioned above, such a declaration may be substantially subject to reconsideration.

Examples of this type are the Channels and Marshes Plan (1902), the Hydraulic Structures Plan (1909), or the National Wealth Development Plan (1919), which we shall refer to in more detail when analysing the situation and specific circumstances of the Segura basin.

The second category, which could be called **Exploitation Plans**, arose with the creation of the Hydrographic Confederations, whose basic functions include *setting up general exploitation plans for its basins' water.*

These plans always refer to agricultural water uses, apparently intended for economically developing the areas affected by irrigation. These plans' basis is to establish the uses of a specific flow of public water, and regulate its exploitation.

Examples of this concept are the above-mentioned National Hydraulic Structures Plan of 1933, which was conceived as a technical and economic plan, not exclusively hydraulic, and which incorporated agro-economic studies, or the General Public Works Plan of Peña Boeuf, of 1940, which regulated, together with the Development Plans, the implementation of hydraulic structures until just a few years ago, or, strictly within the area of a single basin, the exploitation plan of the River Segura set out in the Decree of April 25th, 1953, assessing the future availability of resources and allocating them to the different irrigated areas. The Development Plans represent a generalisation of these concepts to the whole national territory.

A third category, mentioned above, could be grouped under the term **Hydrological Plans for specific areas** which, designed to identify and remedy problems in very specific areas, and usually deficit or near-deficit areas, are based on an inventory of current water uses, together with a forecast of future demand and availability, seeking the future balance of demand and resources, and not the allocation of a flow for use, as in the exploitation plans.

Examples of this are the *General Hydrological Plan of the Lower Ebro*, laid down by Decree of August 28th,1970; the Act of June 30th, 1969, providing for the implementation of a *regional study of total water resources* for the Balearic Islands which must *act as a basis for adopting measures oriented towards their optimum exploitation, to cover current and future demand in the different consumptive uses of the water*; or the Act of March 3rd, 1980, on *urgent actions in the province of Almería* which stipulates, in section 3, the *drafting of the Integral Water Plan of the province of Almería*.

The fourth and last category would reserved for **water plans in the sense of the new Water Act** considered here, and which stands as the genuine landmark, due to its scope, rigor and all-encompassing character, in the history of Spain's water plans.

In fact, for first time, and unlike previous considerations, water planning was extended, in a global and unitary way, to the whole national territory, and was harmonized with other sectoral planning and expressly with general economic planning.

Additionally, the development of irrigation ceased to be a high-priority concern, by introducing, with a different historical perspective, objectives of increased water availability, to protect its quality and to rationalise its use, in harmony with the environment. Strict development policy was substituted by another, considering the quality of life and the correction of sectoral and territorial imbalance.

Furthermore, planning was structured hierarchically in the basin plans and national plan, which is a basic instrument for defining the State's water policies.

Unlike previous plans, the new ones are not limited to a specific time horizon, but are permanent, and in process of review and continuous update, introducing for the first time the participation of users in the planning process, through the Water Council of the Hydrographic Confederations.

Lastly, we should mention that the new plans have greater legal relevance, because on the basis of them, other regulations are established on the public water domain (concessions, authorisations, discharge, basic infrastructures, etc.).

A noteworthy fact is that in the new legislative system, the water planning activity has grown from a purely technological concept (mathematical procedures for rationalising water exploitation systems), and has become, for first time, a legal mandate and a regulated administrative technique, also clearly harmonised an advance with the new guidelines proposed by the European Framework Directive on management plans for hydrographic basins.

5.2. LEGAL REGIME OF WATER PLANNING

In recent years, widespread doctrinal analysis has been seen on the basis, scope, nature and legal regime of water planning, and some associated collateral problems.

Given the fundamental importance of this matter, the cause of considerable doctrinal controversy, the sections below will briefly describe, and in way that is neither systematic nor exhaustive, some basic ideas and criteria for reflection. Systematic descriptions of the legal regime of water planning can be seen in Embid Irujo (1991) or Ortiz de Tena (1994).

5.2.1. The need for administrative planning

Obviously, the need for administrative planning arises at all levels where the Administration acts, because it is the most common way of regulating it, establishing coordination and control mechanisms in the event of conflict, and acting as a guarantee instrument for those under it, who know the framework they operate in and what rights and participation formulas the Administration grants them in their different legal capacities.

The principle of the European Water Charter of 1968 that for appropriate water administration it is necessary for the competent authorities to establish the corresponding plan, has been faithfully reflected in the Water Act of 1985, whose section 1.3 states that all actions upon the public water domain is subject to water planning.

Therefore, as of 1985, administrative intervention as regards water should be channeled through, or without contradicting, the Water Plans.

It is expedient to wonder if since the introduction of the Water Act of 1985, the Administration's position, and the degree of administrative interventionism in the sector, have changed with respect to the previous system. It seems that the introduction of the planning technique in itself denotes greater intervention by the Administration, although this will also depend on the plans' content, on their internal and external character, on the binding force attached to them, on their effective implementation and execution, and, in short, on the greater or lesser degree of the Act's application.

Additionally, an increase in shortage of the resource in turn increases the need for public intervention in its distribution. Planning involves public intervention prior to the granting of exploitation, because the State assesses environmental requirements, geopolitical conditions, and the possibilities of exploitation, and thus anticipates private initiative, specifying possible water uses quantitatively, and safeguarding the coordination of territorial and sectoral interests. Only to the extent that these action criteria are respected can individuals be entrusted with the use of the water.

Planning, however, while it constrains, provides an element of certainty, of guarantee for those affected, by allowing them to know the measures and actions that the Administration undertakes to implement. Individuals are also called upon to act and collaborate, although in this case from the position and rights of grantees.

Water-related issues require, however, with even more urgency –if possible–, administrative planning, and this is due to the multiplicity of uses and policies involved in water resources which, it should not be forgotten, are defined legally as a public domain asset, which is why planning is an instrument of public safety, with respect to what the Administration can or cannot do as regards the resource whose ownership it holds.

Accordingly, water planning may be seen not as an instrument of administrative intervention and economic orientation in a sector of activity previously subject to free public initiative, but, on the contrary, as an instrument for the self-limitation of the Administration in its governing powers, limitless in principle, on publicly owned property. Water planning is, in short, an instrument of legal certainty for those administered, by delimiting the possible scope of administrative discretion.

5.2.2. Constitutional basis for planning activity

A basic study of the constitutional text does not produce any explicit reference to water planning, nor even to the public domain of water resources. Only sections 149.1.22. and 148.1.10 specify the distribution of powers between the State and the Autonomous Communities on water-related issues.

However, in the principles laid down by the Constitution of 1978, and with the double description of a social and democratic State of Law, and a decentralized State of Autonomies, we can find some basis for planning activity that it is expedient to briefly summarise.

1.- The planning process involves rationalisation in the management of a scarce resource –now at a stage of hydrological maturity– which involves prior intervention by the State to define the most efficient social uses of the resource (in other words, use priorities). The relative abundance of the resource in the first historical stages made it public intervention unnecessary, or when it occurred it was only to control or authorise uses established by individuals.

   Planning's implicit recognition appears in article 149.1.22 by using the word "resource", because economically it means the shortage of a property which, apart from a collective property that should be used in most beneficial socio-economic alternative.

2.- Although the Constitution does not establish a specific planning model, nor does it mention this, it does lead to the implicit understanding of planning in the term "regulation" used in article 149.1.22, as a process of effective and rational management of a scarce resource by public powers, specifically by establishing the exclusive powers of the State.

   However, some doctrine claims that although water planning means regulation, this can be carried out by means other than plans. What is unquestionable, however, is that the Constitution's legislators intended to grant a certain importance to the planning, rationalisation, regulation or definition of water uses.

3.- As article 149.1.22. confers the faculty to regulate, legislate and grant water resources and uses to the State, it is expedient to consider the restriction of this planning possibility for the Autonomous Communities and other public agents.

   The decentralized State designed by the Constitution means that the State must integrate the diversity of powers and affected Administrations in a unitary and operative system or group, thus recognising the principle of coordination between the State and the Autonomous Communities, asserted by the jurisprudence of the Constitutional Court (Sentence 45/1991, of February 28th; Sentence 104/1988, of June 8th; Sentence 18/1982, of May 4th; Sentence 227/1988, of November 29th).

   Article 128 of the Constitution, on public wealth, implicitly suggests an answer, because this extends to the whole public sector: State, its Autonomous Agencies and public companies.

   Such public wealth can be understood, according to doctrine, both from the point of view of ownership, and as a reserve of certain volumes of public water. In the first case it would be the exceptional faculty granted to the public sector to exploit public property, such as water, this public ownership recognised in the Water Act of 1985.

   In the second, when reserve is understood as flow of public water, and although not recognized by most of the doctrine, this would mean granting to the public sector, either the State, its Autonomous Agencies or public companies, a certain planning faculty for such reserve or a rational determination of establishing priority of uses for such flow.

4.- The constitutional text specifically mentions general economic planning in article 131, and within the scope of which some authors include water planning, as sectoral planning directly involved with general economic planning, due to the structural socio-economic consequences of the development of the different regions that it encompasses.

   Additionally, the Constitution, in article 149.1.13., mentions the competence of the State to establish the bases and coordination of general planning for economic activity, enabling the State not only to establish such basis for regulating the economy in general, but specific economic sectors, such as water. This interpretation has been recognised by jurisprudence of the Constitutional Court, extending the terms of article 131 to planning oriented to specific economic sectors.

   The consideration made when studying the crisis of traditional water policy's economic objectives throws some light on this fundamental question, and allows reasonable interpretation to be made as to the nature, not economic in the constitutional sense, of water planning.

5.2.3. Competence in water planning

The integration of water-related actions is established under the criteria of water planning. This question has been considered by Constitutional Court Sentence 227/88, particularly legal basis 20, from which we quote the following:

- *Water constitutes a resource of vital importance, indispensable for carrying out numerous economic activities. For this reason, the regulation of water resources, wherever they are, cannot be taken away from the competence that the State must exercise to establish the basis and coordination of the general planning of economic activity, by virtue of the terms of Article 149.1.13. of the Constitution. This competence does not encompass all planning activity for the State, but only the establishment* *of basis and of coordination for planning that affects objects or areas outside State competence, insofar as it directly affects the regulation of economic activity*.

- The powers of the Autonomous Communities in drawing up and reviewing the management plans of inter-community basins *should be exercised respecting the principles laid down by Arts. 38 to 44 of the Act, in communication with the State Administration (section 16.1 c)), in coordination with the different plans that affect them (section 38.4) and subject to the final approval of the plans by the Government (section 38.6) (...) the approval required by the contested legal provision does not represent control over the exercise of competence exclusive to the Autonomous Communities. The basin management plans whose content is regulated by section 40 and which are binding according to section 38.3, comprise a series of provisions on the protection and use of water resources (priority and compatibility of uses, environment, territorial regulation, agriculture and forestry, infrastructure, energy uses, civil protection, etc.) that influence the activity of different Public Administrations, that of the Autonomous Communities, in the first place, but also those of the State and other territorial and institutional agencies, demonstrating both their direct relationship with the general regulation of economic activity and the obligation to respect them and all that they encompass. As a result, if it were assumed that each Administration could carry out the activities of its competence in a regime of strict separation, water planning would become impossible.*

  It follows that as regards water policy, the need is highlighted for specific coordination among the different interested administrations; a coordination which (...) pursues the integration of the various parts or sub-systems in the group or system, avoiding contradictions or reducing defects which, should they remain, would impede or hamper, respectively, the system's very reality and which, for the same reason, should be understood as the establishment of means and relationship systems that enable reciprocal information, technical homogeneity in certain aspects and the combined action of the authorities (...) state and community in exercising their respective powers (...) in this case the act of approval stipulated by section 38.6 of the Water Act is in fact a coordination activity, since it acts to integrate, within a single, regulated system, the actions undertaken by various agencies or bodies, in such a way that it is the definitive, unitary determination of the plan that enables homogeneous action by all of them as regards one same resource. Apart from this, there is no doubt that regulation of the contested precept does not attempt to substitute the planning intention of the Autonomous Community for that of the State, but rather it only aims to integrate it within in the higher set of the general water policies, avoiding the defects that could take place

- *Conversely, the final provision of Section 39.2 on subsidiary action by the Government, in the event of lack of proposal of basin management plans, cannot encompass the Autonomous Communities competent to formulate this proposal, since it is a form of substituted control that is not considered by the Constitution in ordinary relationships between the State and the Autonomous Communities.*

Water planning is structured on the basis of defining two instruments:

- The National Hydrological Plan.
- The basin management plans. With respect to these, the distribution of powers gives rise to the existence of the basin management Plans:
- Corresponding to state competence when they affect inter-community basins.
- Corresponding to autonomous competence when they affect intra-community basins. Approval of the basin management plans corresponding to the Autonomous Communities is competence of the Government, as laid down by the Water Act.

The National Hydrological Plan is enacted by law.

5.2.4. Relationships of the Public Administrations. General principles

The inter-relationships of competence that converge on the question of waters, considered in itself an issue of competence, in which the Constitution makes both a distribution of powers on territorial criteria (resources) and on the criteria of interest (hydraulic exploitation), and which gives rise to the assumption of competence by the Autonomous Communities and the attribution to the State of its own, would justify by themselves the need for regulation, not only from the competence itself but governed by the principles that should inspire and the relationships between Administrations, and be present within them.

But if we also take into account the remaining competence rights that also converge in relation with this competence, and which are attributed to one agency or another, state or autonomous, according to the level of competence reserved for the State or assumed by the Autonomous Communities, it is no longer expedient but necessary that the actions of both agencies, state and autonomous, are closely bound to these principles.

In terms of respect for their *respective competitions* the essential principles in article 2 of Act 30/92 can without a doubt enable the exercise of such respect.

Furthermore, the criteria derived from the jurisprudence of the Constitutional Court when referring to the principle of cooperation as an element which, though not formulated constitutionally, is the very essence of our model of State, would be especially applicable in the scope of such competence.

The principle of cooperation applied as a complementary element in water planning would allow more effective integration of *water planning's* content. This would not be, in this case, a renouncement or an invasion of competence by one agency or another, but an application of cooperation techniques to *planning* itself.

From the scope of cooperation, actions could also be approached that, from the scope of their specific competence, each Autonomous Community could carry out, and which could bear a relationship with competence on *waters.*

In the same way that certain provisions, included in the respective plans –national or basin, inter-community or intra-community– demanding or requiring the intervention of another Administration, could be assumed by the Administration competent for its development and execution without being questioned in terms of a hypothetical *invasion of competence.*

5.2.5. Cooperation and joint planning. Financing

Joint planning, seen especially in the technique of national plans, is a technique or action procedure that is of special interest for *water*-related matters.

Joint planning can structure territorial actions that the different Administrations are to carry out in a common or general framework, acting as an aggregation of the specific interests of each territory into a common or general interest.

The execution of hydraulic infrastructures, the construction of infrastructures for hydraulic exploitation, planning of actions in a complementary way by the different Administrations would allow not only better exploitation of the *water* resource itself, but of the economic and financial effort carried out.

As for financing, we would have to take into account, on one hand, the rules of the Autonomous financing system and, on the other, the principles of co-financing or financing through national plans.

The financing of Autonomous Communities as regards assumed competence arises from the financing that they receive through the process of transferring services for the actual *cost of the service*.

The methodology established for assessing this actual cost determines what cost components are part of this actual cost or not. Accordingly, compared with an initial principle in which the new investment new did not form part of the cost of the service, as of 1995 this investment has been included as part of the actual cost of the services assumed.

However, the supply corresponding to Chapters 4 and 6 is generally not included in assessing the cost of the service, and corresponds to the concept of *subsidies.*

These rules have given rise, throughout the process of transfer of services, to the corresponding treatment of transfers made to the Autonomous Communities in the sections both on *water resources and exploitation* and on *hydraulic structures for supply, channeling or repair*.

Furthermore, the transfer of services in questions of *water resources and exploitation* is associated with the existence of the corresponding *intra-community basin* in the territorial area of the Autonomous Community. This situation, arising from geographical conditions, brings about a situation where although all the Autonomous Communities have competence rights, not all actually exercise the competence as it does not exist in all intra-community basins.

5.2.6. Water planning and the Water Act. The duality of law and plan

As mentioned above, the planning concept applied to water management is very old and deeply-rooted in Spanish tradition. It was a constant preoccupation of the 1866 legislator, although was eventually not expressly included in the text of the Act, and a large number of precedents of water plans could be mentioned, certainly with very different scope and perspectives, at least since the 19th century. The true innovation of the present moment is not therefore, as has been said, the express consideration of this technique, but the legal regulation it has been subject to and which, due to its peculiar characteristics, represents an unprecedented landmark in the history of water legislation in Spain.

Accordingly, the Water Act of 1985, combining antecedents from previous drafts, extensively developing their concepts, and introducing new technical and legal ideas, has conceived Basin Plans as the central instrument in regulating water, to which, according to text of the Act, *all action on the public water domain is subject to*. Numerous general determinations and aspects are referred to them, as fundamental for individuals as, among others, the order of preference for exploitation, the regime of concessions, the protection of water quality...

The Plans accordingly fulfil *a double mission*: to complete, develop and modernize the general provisions of the Act, and to specify, in each territorial area, the general determinations that the Law lays down. In a sense, the Plans take legal regulation to the territory in a phenomenon that has been qualified by some authors as *de-territorialisation* of water law. Thus, the Act deals with highly varied questions, although it could be said that its application is not direct, but through the filter of the water plans, which specify, in each basin, the general framework for actions, and involve a kind of intermediate inlay between the legal regulation and its particular execution, adapted to the peculiarities of each hydrographic basin (Menéndez Rexach and Díaz Lema, 1986).

There are even numerous references to the plans in legislative rulings that cannot really be considered as development, nor are they regulated by law, and which, in a strict sense, represent a sort of transfer from the legislator to the government, and from there to the planner. There may be discussion on the relevance of such references, or on the scope they should have, and which some doctrinal opinions consider excessive, but there can be no valid discussion on the relevance of the figure of water planning as a global, flexible and revisable framework to regulate the action of the public powers on waters, and which specifies and supports, in the last instance, what is essentially the philosophical and constitutional principle of *rationality* in the use of natural resources.

In short, and it is a fundamental idea that is expedient to underline, the development and application of the Act cannot be understood without the complement of the Basin Plans. The absence of a plan could not be replaced with parallel regulatory measures. It would be, in itself, a complete failure of the structure laid down by the Act, which would lead inevitably to the need for its revocation.

5.2.7. Relationships of Water Planning with other planning instruments, and in particular with the National Irrigation Plan

The basin management plans have certain theoretical relationships with other plans and actions by the Central State Administration and by other public administrations. In particular, they may influence, or be affected by, the territorial and land-use regulation plans approved by Autonomous Communities and local corporations. We should also clarify their relationship with sectoral plans regulating certain business activities associated very closely with water use and, very particularly, with the National Irrigation Plan, since its relationship with the National Energy Plan causes no doubt as –unlike the Irrigation Plan– it is a plan regulated by law as regards its content and scope.

The considerations made below on the National Irrigation Plan are based on the one currently in effect, Horizon 2005, which was approved by the Council of Ministers on February 26th, 1996, in compliance with the mandate of the Plenary Session of Parliament, by means of Motion 173/69, approved on February 21st, 1995, urging the Government to forward to Parliament, together with the National Hydrological Plan, an Agricultural Plan on Irrigation. This Motion reiterated the contents of Motion 173/31, dated March 22nd, 1994.

We should begin by clarifying that the National Irrigation Plan, as it was approved by the Council of Ministers in February, 1996, *is not a new source of law*, but a set of provisions and orientations approved by the Government, whose legal effectiveness lies entirely in its appropriate development through the channels foreseen by agricultural legislation.

In fact, after examining its most important material and formal aspects, it is expedient to conclude that the National Irrigation Plan is *not an order in a general sense understood to be a source of legal regulation.*

Certainly, unlike other sectors of administrative activity, where the plans approved are included as *rulings in legislation through the technique of regulatory reference* –this is the case of the urban or water plans with respect to which the Land Act or the Water Act makes a legislative cross reference, making these plans complementary to them, and whose effectiveness is conferred by the Act that authorises them and regulates the framework that must conform to– the National Irrigation Plan (hereinafter NIP) does not have any express regulatory cover: there are neither legal orders nor regulations that establish the preparation procedure, the content or, in short, the legal effectiveness that it must be attributed with.

The same conclusion may be drawn in view of the NIP's content, which *does not regulate future actions* establishing obligations and rights as regards their material purpose, *nor is it designed as parameter of legality* for actions by the Administration or by individuals, nor, in short, does it seem to have an indefinite term of effect, characteristic of all legal regulations, its time horizon limited to the year 2005, without any legal mechanism for monitoring or review. Furthermore, even the language used in the text is uncharacteristic of legal rulings, defining the Plan as a mere *...instrument to consolidate the Spanish agricultural system and a basic factor for the efficient use of water resources and inter-territorial balance...*

In conclusion, we should state that the NIP responds legally to the concept of *governmental decision*, comprising the main planned orientations on the issue, *of unquestionable political value, but not immediately legally binding insofar as it lacks the appropriate development through the instruments laid down by agricultural legislation.*

This statement is not contradicted by the material *transformation of irrigated land*; without intending to be exhaustive, and adhering exclusively to state legislation on the matter (Consolidated Text of the Agricultural Development and Reform Act, approved by Decree 12-1-1973), the economic and social transformation of irrigable areas should be carried out in accordance with the complex procedure regulated by sections 92 and following of the mentioned legal text, which begins with the Decree approving the area's transformation declared of general interest to the nation, followed by the approval of the Transformation Plans, *which will certainly and directly affect the property and rights of individuals* (Sentence II of the STS 10-11 - 1994, RJ 1994/8418).

Since the NIP is not immediately binding, it should be understood that its provisions as regards the transformation of irrigable areas cannot be developed outside the procedure that is commented above: The General Transformation Plans currently in effect will continue bringing about the effects conferred on them by agricultural legislation insofar as they are not duly adapted to the NIP (which by itself does not have legal power to modify them). Similarly, the NIP's new provisions as regards the transformation of irrigable land, will have immediate legal effect insofar as they take shape in the different stages of the procedure legally regulated by the Consolidated Text of 73.

According to the criteria above, the distinction between the effectiveness of the basin management plans and that specifically of the National Irrigation Plan, is clear: the basin plans complete the function conferred on them by the Water Act and, particularly, as regards irrigation, the function of guaranteeing, in the resource's planning, existing concessions and reserves for future uses, without adopting any decision regarding the promotion of new irrigated land, because their legal effectiveness in this matter only covers water reserve, a basic, indispensable aspect in any decision in irrigation promotion, but not enough.

If water exists, according to the provisions of water planning, the decision to promote new irrigated land will correspond to whoever, in compliance with the legal regulation, can adopt the promoting initiative, that is to say, to the administrations with competence on the matter –the Central State or Autonomous Community Administrations with transferred competence– or to the farmers themselves, in exercising the constitutional right of free enterprise, within the determinations of Agrarian Law. The National Irrigation Plan, as a programming document of the Government of the Nation, will simply define the Central State Administration's initiative on the matter.

As regards coordination, according to the Constitutional Court, coordination must be understood as... *the establishing of means and relationship systems that enable reciprocal information, technical homogeneity in certain aspects and joint action of the state and community authorities in the exercise of their respective competence...* a definition which, obviously, is applicable to the relationships between agencies of the same State Administration that exercise different powers. Particularly, ...*the coordination of the basin management plans whose design is the responsibility of the State Administration or Agencies dependent upon it, with the different planning that affects them, must be carried out primarily through the design procedure of the former, as stipulated by section 38.4 of the Water Act itself...* (STC 227/88, legal basis 20).

Therefore, and as we have just seen, the principle of coordination, with respect to water planning, is fundamentally instrumental in character, without material content *per se* that implies the prevalence of some planning instruments over others.

In other words, following the constitutional doctrine, it may be stated that the coordination required by section 38.4 of the Water Act may be achieved –as the question currently stands it has been achieved already– *following the formal channel of design of Plans* that foresees the presence of representatives from the various administrative sectors with influence on the question in the Water Council of each basin organisation (section 18 WA) and culminates, we might add, with approval by the Government.

The occasional discrepancies between the basin plans' content and the rest of sectoral planning –which cannot be referred to non-compliance with the often-quoted principle of coordination of section 38.4 of the Water Act– should be solved, where relevant, in consideration of other legal principles such as with respect to the exercise of own competence or the legal content and effectiveness of each one of the plans contrasted.

In this sense, and in relation to agricultural planning , we can very briefly conclude that, although the rules of the basin plans "...on improvements and transformations in irrigation that ensure the best use of water resources and available lands" (mandatory content, ex-article 40f) of the Water Act) they must be limited to "... achieving a better or more rational use of inland waters, as essential economic resources and do not extend to other prescriptions on agricultural policy..." (F.J. 20 STC 227/1988), it is no less certain that the prescriptions on agricultural policy and specifically, on the transformation of irrigated areas that must take water planning into account are those that have taken shape as agricultural plans in force and with direct legal effectiveness (see gr. General Transformation Plans of irrigated areas) which have priority over political orientations, of maximum value, but not legally opposable to transformations into irrigation agreed through the procedures and methods laid down by agricultural legislation.

5.2.8. Situation of conflict between Plans of the Administrations. The principle of coordination

Notwithstanding what has been specifically stated above with respect to the coordination of water planning with irrigation planning, and entering the scope of competence between central and autonomous administration, water planning has intrinsically, and regardless of its territorial area, a marked *concurrent* character from the perspective of the distribution of powers. Such concurrence is not only derived constitutionally from the distribution established in relation to water-related matters, article 149.1.22 and 148.1.10 of the Constitution, but also from a series of competence rights empowering both the State and the Autonomous Communities, in matters related with water resources (territorial regulation, basis of the energy regime, environmental protection, forests, legal regime of the Public Administration, public works, administrative concessions, river fishing, etc.).

If conflict exists among the different plans, the stillborn LOAPA (Organic Act on Harmonisation of the Autonomous Process), declared to be unconstitutional, foresaw subjecting the question to the Council regulated by article 131 of the Constitution. The Constitutional Court declared that the functions of participation agency in the Council's standard economic planning did not conform with the competence conferred by the LOAPA, and, additionally, because it was creating a mechanism of conflict-resolution unforeseen constitutionally. This possibility was therefore discarded.

In the event the conflict occurs between different planning administrations, the divergences may have administrative character, or constitutional if competence conferred by the Constitution is in dispute. The Constitutional Court is responsible for solving these competence conflicts; but additional mechanisms should also be laid down between the state and autonomous administration for this purpose. In short, they would be a continuation of the necessary coordination between both administrative areas. Such coordination has been repeatedly considered by the Constitutional Court as essential for the appropriate functioning of the State of Autonomies (STC, August 5 1983).

With respect o the need for collaboration, Embid Irujo has expediently pointed out the relevance of *an inherent concept in water legislation that gives major significance,… essential, to the presence of the Autonomous Communities in the legal regulation of waters*. Specific examples of this principle of collaboration include autonomous representation in the administration and planning agencies of the basin organisations (Governing Board and Water Council of each Hydrographic Confederation), as well as, fundamentally, their participation in the National Water Council, responsible for informing on water plans. The author mentioned above has highlighted that *the potentialities of this institutional participation are immense and, certainly, one of the fundamental guarantees for the correct functioning not only of the regulated exploitation of water - both intra-community and inter-community -, but of exploitation of the same territory seen from sectoral perspectives.*

Therefore, the intervention of the Autonomous Communities in designing planning instruments that affect their legitimate economic interests cannot be reduced to the simple procedure of a formal hearing or a mere briefing, but the full sense of the principle of administrative collaboration implies that the participation of the Autonomous Communities should be able to substantially condition the content of planning projects designed by the Government.

The Constitutional Court has ratified that, in the basin plans, the coordination required by the Constitution is carried out through a double mechanism: *The integration of affected proposals and activities in the procedure of designing the plan whose implementation corresponds to the Autonomous Communities ... and a subsequent declaration of approval by the Government through which the decision of water policy's particular requirements are coordinated.*

Furthermore, and in keeping with encouraging and promoting cooperation mechanisms, the creation of a Sectoral Conference on Water could be considered, as an agency for formalising the expedient treatment of the questions described, both with respect to organising state and autonomous competence in the scope of different matters, and to exploring the cooperation mechanisms and setting up joint planning instruments.

5.2.9. Temporal priority between basin management plans and the National Hydrological Plan

It is well known that water planning is legally arranged on two levels: the basin management plans (inter- or intra-community), with the territorial area comprising a basin or basins, and the National Hydrological Plan, with global scope, and of whose primacy or superiority with respect to the basin plans is in no doubt.

The organisation of these two different levels is the main problem. Firstly, the Law does not stipulate any term for preparing the plans and, secondly, says nothing about the priority in time of one type of plan over another.

This problem of temporal priority of basin plans over the National Plan has brought about considerable, intense doctrinal, social and political debate in recent years. Finally, the motion approved by the Senate, on September 28th, 1994, in the framework of the debate on The State of the Autonomies seemed to have solved the problem, by postulating the temporal priority of the basin management plans over the National Hydrological Plan.

This same criteria of granting temporal primacy to the basin management plans, with respect to the National Hydrological Plan, has been repeatedly held up by both Houses of the Parliament of the Nation, in successive decisions. Accordingly, Non-legislative Motion 162/97, approved by Parliament on April 8th, 1997, and Motions numbers 44 and 45, of the Plenary Session of the Senate, approved on March 14th 1997 as consequence of the debate on the state of the autonomies.

Nevertheless, the fact that a concrete decision has been taken politically, and the problem has already been surpassed by events with the approval of the basin plans, does not mean we should not make some considerations here in this respect.

In fact, a sector of the doctrine (Menéndez Rexach and Díaz Lema [1986] p.675; Bermejo Vera [1995] pp. 23, 33, 124, 147; Martín Rebollo [1993] pp. 181-182), considered that basin management plans should have priority over the National one, with primacy of the resource's location with respect to criteria of efficiency, rationality or general interest. Summarizing this position, Martín Rebollo has stated the conditioning factor that basin plans' provisions involve for adopting transfers, plans which *from this point of view, appear as prior to the National Plan proper in verifying some of the legal conditions of the said transfers. It is certain that the opposite is certainly true. That there exists an interrelation and interdependence making both types of plans mutually conditioned and that, for the same reason, it is not always possible to wait for all the basin plans to come into effect in order to design the National Hydrological Plan. Nevertheless, despite all this, and although it is not legally a requisite condition, in my opinion, the basin plans condition the National Plan more than the other way round, and for that reason it would be at least desirable that the latter be designed in view of the forward studies of the basin plans, even though it is not necessary to wait for their conclusion.*

Conversely, another doctrinal sector (González Pérez [1991] pp. 37-39; Embid Irujo [1993] pp. 49-59) considered the basin plans' priority was unnecessary, and that the National Plan could be approved first, establishing the general coordination framework that the basin plans must be subject to, and thus avoiding possible heterogeneities and defects. The data and specifications of the basin plans, still in draft phase, could be known by the National Plan, thus guaranteeing the necessary interrelation.

This was, in fact, the position maintained officially when in April 1993 a Preliminary Design of the National Hydrological Plan was developed and presented without the basin plans even being concluded. As we have said, this debate has been surpassed by events, but it should be mentioned that it was, to a large extent, a purely theoretical, nominal discussion that could only cause concern –and relatively– if water planning is necessarily conceived as an operation of confrontation and hostility, either between the Autonomous Communities and the Government or inside them. Historical experience has repeatedly demonstrated that it is not by legal action that the major hydraulic problems have been solved - genuinely solved. Basin plans incompatible with national water regulation, or a National Plan ignorant of the decisions of the basin plans, would be in any event, and notwithstanding their statutory hierarchy and legal rulings, simply unfeasible.

If planning is conceived as an operation of State, integral and unitary, whose execution on two levels is merely operational and instrumental, and which must respond –each of these levels operating in its own scope of competence– to the harmonious and reasonable defence of general public interests, the problem of the temporal priority disappears, and becomes completely devoid of practical relevance.

5.3. HISTORY AND SITUATION OF THE BASIN MANAGEMENT PLANS

5.3.1. The process for drawing up the Plans. Experiences and consequences

The relatively long preparation process for the basin management plans, laid down in the Water Act of 1985 and not entirely and physically available until 1997, twelve years later, leads us firstly to ask as to the reasons of such a long delay. It is evident that, notwithstanding the fact that it would be legally inadmissible, such terms cannot be repeated in the future if the intention is for basin plans to be genuinely flexible and effective instruments, so it is expedient to reflect on this problem and suggest some measures that contribute to solving it.

In accordance with section 99 of the Public Administration Water and Water Planning Regulations (RAPAPH), the design of basin management plans in inter-community basins has been carried out in two stages. In the first stage, the plans' guidelines were laid down and in the second, the plans proper were drawn up.

The stage of laying down guidelines began by preparing the basic documentation of each plan, selecting, summarizing and systematising the fundamental data from the studies and works carried out by the Ministerial Departments and by the other public administrations with participation in the Water Council of each basin. Preparation of the basic documentation of all the inter-community plans was concluded and published in the month of December, 1988. Subsequently, the MOPU published several summary editions of this documentation (MOPU-DGOH [1990]).

Simultaneously, the basin organisations began to draw up the guideline projects for the plan, which had to contain, on one hand, the description and evaluation of the basin's most important water-related situations and problems and, on the other, the corresponding proposal for guidelines. These projects were forwarded to the ministerial departments and the Autonomous Communities with participation in the Water Council of the corresponding basin, for the presentation of the proposals or suggestions that were considered expedient. At the same time, the projects were made available to the agencies and individuals who wished to consult them, for their information and the contribution, where relevant, of observations and suggestions.

On the conclusion of these consultations, frankly long, meticulous and laborious, the corresponding Planning Committees of the basin Water Council, considering the guideline project and the report on the proposals and suggestions presented, approved the guidelines for the basin management plans on the dates shown in table 118.

We should note that in the case of the South Hydrographic Confederation, not set up as a basin organisation according to the new legislation, there is no Water Council, and this agency's functions have been carried out by the Governing Board. Furthermore, in the case of the Catalonia Inland Basins, intra-community in classification, the general process for designing the Plan does not have to be followed, and the guidelines stage may be assimilated to the establishment of criteria for up-dating the plan, which was carried out by the Water Plan Study Committee, created in 1992 by the Parliament of Catalonia.

With approval of the guidelines by the Planning Committees or similar agencies, the first stage ended and work began on drawing up the water plans proper. To do this, the basin organisations drafted the corresponding plan proposal, in accordance with the guidelines approved, and after a long discussion and debate process in the Planning Committees.

After these proposals were approved by the Commissions, they were forwarded to the Water Council or corresponding equivalent agencies, which declared their conformity on the dates shown (Table 19).

Finally, on October 14th, 1997, the Environment Ministry, in accordance with the provisions of section 104 RAPAPH, forwarded the proposals for the basin management plans to the National Water Council, for this agency to issue the mandatory report stipulated in section 18 of the Water Act, a highly relevant report which, as we shall see, was issued by the Plenary Session of the National Water Council on April 27th, 1998.

Proposed Basin Plan	Dates on which the Water Council Planning Committee approved the guidelines
01 North I	24 June 1993
01 North II	8 July 1993
01 North III	21 July 1993
02 Douro	10 November 1993
03 Tagus	30 July 1993
04 Guadiana I	23 November 1993
04 Guadiana II	23 November 1993
05 Guadalquivir	
Guadalquivir	7 October 1993
Guadalete-Barbate	7 November 1993
06 South	9 November 1993 (J. Gob.)
07 Segura	28 January 1994
08 Júcar	31 November 1994
09 Ebro	30 December 1993
Catalonia Inland Basins	21 December 1992 (C.E.P.H.)

Table 118. Dates on which the Water Council Planning Committee approved the guidelines.

This brief chronology shows that the preparation process for the plans has been a slow, complex and extremely laborious process. From the publication of the basic documentation (December, 1988) up to the proposals being forwarded to the National Water Council (October, 1997) almost nine years have passed, a period of time which, curiously, is longer than the one laid down in section 110 RAPAPH for the obligatory full review of the plan (eight years from the approval date), that is to say, the plans had not yet been approved when, reasonably, they should have been undergoing their first review.

We may interpret that basically three causes exist for such a long delay of the process of drawing up the Plans.

Firstly, their actual content, extensive, ambitious and very heterogeneous, with the obligatory inclusion of inventories, technical specifications, standards, guidelines, criteria on action, statistical data, etc. The need to begin the planning process on the basis of data that was very heterogeneous, scattered and not automated, and compiled in its day for other purposes, meant that an initial effort had to be made to gather a considerable amount of accumulated information which, logically, will not be repeated with the same intensity. Additionally, this technical complexity has not generally been backed by a multi-disciplinary administrative structure, sufficiently equipped with means.

Secondly, relative inexperience in the design of plans of such characteristics. In fact, although in Spain there is a long tradition of water planning, the Plans carried out up to now had been conceived, in general, as fundamentally technical documents, and with a far smaller sectoral scope. The current plans, not forgetting the complex technical aspects they should be based on, are now conceived as real legal-administrative instruments, which involves a radically new position that has required a period of development and adaptation, and which, in all likelihood, has still not been completely assimilated. Proof of this statement is the final design adopted by the regulatory documents of the plans presented, which, while divided into in articles, are deficient as legal texts. The absence of experienced models and of a coordinating National Hydrological Plan contributed, without a doubt, to this situation.

Proposed Water Plan	Dates of conformity with the basin management plans by the corresponding Water Council
01 North I	29 June 1994
01 North II	29 June 1994
01 North III	29 March 1994
02 Douro	2 April 1995
03 Tagus	18 April 1997
04 Guadiana I	11 April 1995
04 Guadiana II	11 April 1995
05 Guadalquivir	
Guadalquivir	5 April 1995
Guadalete-Barbate	14 July 1995
06 South	8 June 1995 (J. Gob.)
07 Segura	8 July 1997
08 Júcar	6 August 1997
09 Ebro	15 January 1996
Catalonia Inland Basins	31 January 1994 (Commission of Government of the Meeting of Waters)

Table 119. Dates of conformity with the basin management plans by the corresponding Water Council.

Thirdly, another reason for the delay in preparation could that of an excessively meticulous and complicated formal procedure which, for the purposes of greater regulation and intervention, has to some extent sacrificed the procedure's agility. Naturally, the necessary guarantees of coordination and public participation in a question as important as the water plans require a certain process of formal guarantees that neither cannot nor should not be avoided, but it may be appropriate, in the light of recent experience, to simplify it in the future, as recommended by the National Water Council in their report on the basin plans. It is also expedient to indicate that it does not seem advisable for the review procedure to be identical to that of the initial preparation, because the basic conditions are significantly different.

Accordingly, and by way of example, it is doubtful that new basic documentation should be physically re-drafted, because the up-date of data that makes it up must be carried out by the planning offices in a permanent way, and it would be enough with simple formal homogenisation and publication of such data. Also, a large part of such statistics can be collected and drawn up globally on a national scale, simplifying the work for the basin organisations and gaining in homogeneity.

With respect to the above, it is interesting to note that the whole regulation of the procedure of preparation, approval and review of the plans is regulatory, and Water Act does not stipulate anything in this respect beyond reference to regulations. In the agreement to approve the basin plans, the Council of Ministers has decided, in fact, to review this regulation.

Furthermore, the excessive length of the preparation period for the plans has had certain practical consequences that are worth noting. Accordingly, most of their technical specifications are based on data and statistics compiled in the basic documentation and the prior studies, which, given the time lapsed since this summary, leads to a supposition that certain estimates could be obsolete. In the same sense, the situation that some plans consider to be current should be strictly interpreted as the existing situation when the plan was prepared which, for the reasons mentioned, may be described and evaluated by means of data gathered nine or ten years ago.

On the other hand, this time lapse has given rise to some actions outlined in the plans having already been implemented or started up, and to others being definitively discarded, without this periodic verification having been carried out.

This time delay should also be taken into account when interpreting the economic evaluation of actions foreseen in the plans, which would not represent current cost, but the cost corresponding to the year of preparation. Nor would it be correct to make direct comparisons of the cost of actions between the different plans because not all were drawn up at the same time.

This all leads to suggesting the expedience of temporal harmonisation so that, in the future, distortions such as those mentioned do not take place.

Additionally, during the plans' preparation process different initiatives were carried out aimed at achieving certain harmonisation and systematisation of the water planning structures. The then Ministry of Public Works and Urban Planning drew up interesting documents on objectives, recommendations and standards in connection with the different sectoral policies, for consideration by the basin management plans.

Similarly, in 1992, and taking advantage of the possibility laid down by section 88 RAPAPH, certain instructions and complementary technical recommendations were published, with respect to the preparation of inter-community basin management plans, approved by Order of the Ministry of Public Works and Transport of September 24th, 1992.

These Instructions contain general provisions, such as those on the plans' horizons, and other specific provisions, organized in various chapters relating to the inventory of water resources, existing and foreseeable uses and demand, allocation and reserve of resources, water quality, improvements and transformations in irrigation, protection perimeters, forestry water plans and soil conservation plans, overexploitation, aquifer salinisation and protection, energy uses and extreme hydrological situations.

Apart from general approaches, the Order of 1992 included specific recommendations on supply quantities for population supply, net supply quantities for the most representative crop types in each basin and for different industrial sectors, guarantee levels and returns for urban, agricultural and industrial uses, etc.

5.3.2. The situation of absence of Plan. Experiences and consequences

Besides the various problems mentioned in the above section, and referring now only to the legal consequences of the delay in approving the plans, we should state that, in view of the above-mentioned interrelation of the Act and the plans, a legal loophole has existed for years with respect to many basic determinations, making the application and validity of the Act, in a sense, precarious.

Beyond the exceptional suppositions where the absence of Plan was expressly considered (such as the criteria for granting concessions laid down by transitory provision 6 WA), the Act does not have a general regime of legal regulation in the absence of a water plan, and this difficulty has often been avoided by including, in administrative decisions, the condition of precariousness and provisionality, while these plans remain without approval, and until such time as they are finally approved. It is clear that the Hydrographic Confederations could not continue in this state of legal uncertainty without being serious prejudiced.

Recourse to previous compatibility with the draft plan allowed the Water Administration certain orientation in its actions with respect to conformity with the drafts, but the weakness in this procedure is clear insofar as such drafts did not acquire solid validity, only to be achieved through approval by the Government.

The practical result of this situation has been, as mentioned above, a certain precariousness in administrative action, together with a kind of accumulation and deferral to the future of many determinations by the Water Administration, whose actual effectiveness was thus weakened and delayed.

The fact that this was accepted by the public authorities and by users, contributed to a large extent to the serious drought that occurred for years. This drought generated, with greater or lesser basis, a philosophy of hydraulic exceptionality and widespread discretionality which, backed by successive emergency decrees, and possibly acceptable in such circumstances, should under conditions of relative normality be definitively eliminated.

Furthermore, it is essential, beyond the framework of specific measures that the plans may lay down (concessions, reserves, supply quantities, efficiency, quality objectives, etc.), to have realistic scenarios for the possibilities of covering future demand, not just in the different sub-basins, but also on the global level of each plan's area. These scenarios represent basic data, and a fundamental consideration for national planning.

In short, and in the current circumstances, we could state that the situation of absence of plan could not last any longer without there being a far-reaching collapse of the legal and administrative regime for water in Spain, together with legal uncertainty and precariousness, totally incompatible with the regulated enforcement of the law and with the normal development of water-related activities.

It was therefore necessary, either to immediately approve the plans, under the conditions considered appropriate by the Government to grant such approval, or to urgently and radically review the Water Act, building a substantially different regulation model to the present one.

In this complicated situation, the continuous procedure with the mandatory report by the National Water Council which, considering the multiple concurrent circumstances, eventually drew up a dense, fundamental document that unblocked the situation, allowing the planning process to continue. Sections below deal with this significant reporting process.

5.3.3. The reporting process for the plans by the National Water Council

With the process of drafting the basin management plan proposals concluded by the different agencies responsible for preparing them, as described above, and the inter-community basin Water Council or corresponding intra-community basin planning agencies having expressed their conformity with such proposals, and their approval being perceived as positive and generally necessary, the continuation of the regulatory procedure for approving the water plans required the verdict of the National Water Council.

Accordingly, and in compliance with this procedure, the plan proposals were forwarded by the basin organisations to the Environment Ministry, which, prior to forwarding them to the Government, presented them to the National Water Council for its mandatory report.

In view of the historical importance that this has had –the first approval of basin plans–, the process continued and the main conclusions and recommendations expressed by the Council through this document are described below.

5.3.3.1. The preparation of the report

As mentioned above, on October 14th, 1997, and after a long period of inactivity, the first meeting of the Plenary Session of the National Water Council was held, its composition renovated in accordance with the Decrees issued and organizational changes both to the Central and Autonomous Administration. In this session, the members of the Permanent Committee were appointed, and the procedure for the preparation of reports on basin management plans was laid down (and on the Preliminary Design Amending the Water Act), instructing the Permanent Commission to prepare a draft.

On the 6th and 19th of November, 1997, and March 31st, 1998, two sessions of this Committee were held, where three successive versions of the report were discussed and perfected, finally reaching, in the last session, acceptance for a final text that was agreed by considerable majority (19 votes in favour, 2 against and no abstentions).

The Report thus approved by the Permanent Commission was taken to the Plenary Session of the National Water Council on April 27th, 1998, which approved by very significant majority (71 votes in favour, 14 against, and no abstentions) the text prepared by the Permanent Committee, with no more modification than the addition, proposed by the MAPA, of an Annex with the transformation surface areas foreseen by the National Irrigation Plan 2005 in force.

Finally, this report by the National Water Council on basin management plans, together with the 14 particular votes received in this respect, was forwarded to the Government for its consideration and appropriate effects.

Having briefly described the chronological process followed, it should be noted that, in the same way as the organisation of the Council and its action procedure for preparing the report on the basin plans is regulated, there existed neither regulation nor any antecedent to guide or orient what their content and scope ought to be.

In view of the advisory character of the agency that prepared it, the transcendence and complexity of the matter on which it is ruled, its absolute innovation and absence of precedents, and the relevance of the report's final destination, which is the Government of the Nation, the expediency of making a special effort of reflexion was considered, which, going beyond the mere description and summary of the plans' problems, introduced considerations of greater scope on their very nature, and laid the bases for the essential technical and legal criteria, under which the planning process should continue.

A summary of the report's main determinations as regards the contents and conditions for approving the plans examined is given below.

5.3.3.2. Main conclusions

As regards the question of describing and analysing the plans, different questions arose that should be considered by the Government in its approval. Accordingly, and by way of example, the necessary uniqueness of the Guadalquivir Water Plan despite having two separate documents for the Guadalquivir basin and for those of Guadalete-Barbate; the fact that the plans received do not amount to all those foreseen by the regulations even when all the inter-community basins are considered; the need to clarify some borders of territorial areas; the recommendation to the Government, in exercising its rule-making powers, to review and perfect the regulation of the preparation and approval procedure for the plans; the low level of compliance with the technical coordination instructions, with their negative effect of heterogeneity of treatment, and the need to homogenise criteria in the future; the recommendation on hydrogeological polygonal units; the need for formal homogenisation; subordination to the National Irrigation Plan and to the National Hydrological Plan in their respective scope of action and effectiveness, etc.

Furthermore, it was seen that this heterogeneity also had its correlation in the plans' legal heterogeneity, because these included various legal techniques (administrative acts, binding determinations, orientations for internal action by the Administration, content of document and statistics without legal effects, catalogues of possible actions that delimit administrative discretionality, etc.) jointly forming a very complex and peculiar category.

The Council noted that, in spite of such complexity and technical difficulties, the plans reported had generally complied, with varying degree and depth, with the terms of the Water Act, at least in their basic contents, and they incorporated, certainly with different penetration and scope, the determinations required by law. In short, their heterogeneity had not impeded compliance with the terms of the Act, and there were therefore no significant reasons to prevent the Government from proceeding with their approval. The National Water Council suggested unequivocally that the Government act in this sense.

Moreover, analysis of water planning's legal relationships with the Water Act showed that, as seen in sections above, the development and application of the Act cannot be understood without the complement of the Water Plans. Absence of a plan cannot be substituted by parallel regulation measures. It would be, in itself, a complete failure of the construction foreseen by the Act, leading inevitably to the need for its revocation and radical re-consideration.

Additionally, it was underlined that, as mentioned above, the situation of absence of plan gave rise to provisionality in fundamental determinations of the water administration that could not go on for much time without there being a significant collapse of the legal and administrative regime on water in Spain, and a legal precariousness and uncertainty that is wholly incompatible with the regulated enforcement of the law, and with the normal development of water-related activities. The discretionality of the water administration had to be constrained to the framework and sense conferred by regulation, and it could not, under any circumstances, undertake determinations that the Act had expressly reserved for the Water Plans. The verification of defects in the plans examined, something to be expected in view of their technical complexity and the absence of previous references and of legal-administrative praxis, need not, in any way, and for reasons both legal and of opportunity, paralyse the major process under way.

In short, and due to the various concurrent reasons described, the National Water Council insisted in that was necessary to proceed, either with the plans' immediate approval, under the conditions in that the Government deemed fit to for such approval, or to begin urgent, radical review of the Water Act, building a substantially different regulation model to the current one. The National Water Council's recommendation to the Government was inclined, fully without any reserve, towards the first of the two options.

Having established this, it was noted that, as mentioned and verified in the description of the plans' structure and contents, the determinations required by the Act were not necessarily compiled in an single document of the plans examined (law), but rather they often appeared scattered over several different texts (reports, annexes, basic documentation,…). There was not, in general, a collection of laws liable to exclusive approval and direct official publication, because, notwithstanding some problems of regulatory repetition and deferrals to the future that could be overcome by simple formal re-drafting, certain determinations could have been left out that, while available, were in other parts of the documentation.

This general situation of substantial interrelation among the documents, and an absence of systematic, legally-drafted texts, and liable for approval and direct publication, in opinion of the Council, led to the need, not just theoretical but also in practice, for considering the whole water plan as a unit, and recommended considering the set of interrelated documents for unitary approval as such.

This unitary consideration and approval should not, however, be confused with the possible legal consideration of a part of the plans determinations, and which may be assimilated with the regulations with binding legal content laid down by section 40 WA. It is therefore necessary to differentiate obligatory content (section 40) from legal content, but this differentiation would, in all likelihood, be complicated to specify.

On the other hand, the option of integral publication of all the documents contained in each plan, which in principle could be suggested to overcome the above difficulties, was clearly unadvisable. As a result, having discarded this possibility, the National Water Council suggested that the Government, notwithstanding the fact that it should urgently approval of the Plans as a whole, and obviously provide any interested party with free access to the documentation that makes them up, and the right to obtain copies of such documentation, proceed to publish, in the Official State Journal, a systematic text that defined, from the documentation available in each plan, its regulatory contents, notwithstanding specific aspects it may be expedient to include in each case.

It should be understood that such a consolidated text would be a systematic regulation of already-existing determinations. Therefore, in no case could it initially redefine or modify the proposals approved by the basin organisations, except by express decision of the Government in its act of approval. For further certainty in this sense, the National Water Council suggested that, prior to its official publication, a report be made by the corresponding Water Council, or equivalent agency, of each basin organisation, and even, eventually, by the National Water Council itself.

It concluded by stating that, in the opinion of the National Water Council, with the recommended approval and publication mechanisms, the legal requirements would be appropriately complied with, and, once the basin plans had been approved, the procedure could continue immediately with the decision process of National Planning.

5.3.4. The process of approval of plans by the Government

Having come to the moment of the plans' approval, and the Government informed as regards the report on these Plans, the long procedure arrives at its culmination. The following sections describe the conditions and legal circumstances of this approval, and the conclusion of the process in August of 1998.

5.3.4.1. The legal conditions of the approval

With respect to the approval of the basin management plans, the only existing determinations are section 38.5 LA. by which *the government shall approve the basin management plans in the terms that it deems expedient according to the public interest, notwithstanding the terms of the following paragraph*, paragraph 38.6 stipulating that *the basin management plans that have been drawn up or reviewed under the terms of section 16.* [or intra-community, according to the terminology of the regulation, in this case Catalonia Inland Basins], *shall be approved if they conform with the regulations of sections 38.1* [general objectives of water planning] and 40 [obligatory content of the basin management plans], *do not affect the resources of other basins and, where relevant, conform with the specifications of the National Hydrological Plan.*

Thus, in the case of inter-community plans there is express reference empowering the Government so that, in its act of approval, it may introduce amendments to the proposals forwarded by the basin Water Councils. It is clear that such possible modifications cannot be indiscriminate, but rather they must be motivated by, and oriented towards, criteria of public interest.

In the case of intra-community basins, approval is quasi-regulated if the above conditions are fulfilled, broad enough so that, in general, and more at present when there is still no National Hydrological Plan in effect whose specifications could be contravened, no concrete difficulty has arisen.

5.3.4.2. The culmination of the process

After the changes described, the Council's report concluded, and the legal conditions for approval considered, the Council of Ministers agreed to approve the basin management plans by Real Decree 1664/1998, of July 24th (Official State Journal No. 191, of August 11th).

Finally, and developing the provisions of this Decree, between August and September of 1999, successive Orders were published in Official Journal with the legal texts of the different basin plans.

This concluded a planning process that has taken over a decade of work, and in a climate of substantial consensus between the users and the administrations involved.

5.4. HISTORY AND SITUATION OF THE NATIONAL HYDROLOGICAL PLAN

Having described the complex history and situation of the basin plans, we shall now turn to outlining a similar description with respect to the National Hydrological Plan. To do so, we shall firstly examine the procedure followed in the only firm attempt of a National Plan implemented to date (that of April of 1993), concluding with a brief presentation of current circumstances.

5.4.1. The Preliminary Design of the National Hydrological Plan Act of 1993

In developing the provisions of the Water Act and Royal Decree 927/1988, approving Regulation 592 on the Public Water Administration and on Water Planning, the Ministry of Public Works and Transport drew up a Preliminary Design of National Hydrological Plan which, consisting of a Report and a Text divided into articles, were published in the month of April, 1993 (MOPT, 1993b).

Apart from many other questions that they were approached in those documents, a fundamental diagnosis on the main problems that existed in Spain as regards water centred these problems particularly on deficit in certain basins, current or foreseeable in the short term, especially the Mediterranean basins, as a consequence of the continuous growth in demand (Baltanás, 1993). The main remedy proposed for this problem was a widespread system of water transfers (general interconnection) from basins that had unused resources, to basins with shortage.

This proposal caused considerable controversy, partly due to the standard rejection that any transfer causes, and partly due to the generalisation of the interconnections and to the relatively high volumes of water that, according to the calculations made, had to be transferred.

This does not mean that the NHP did not contain other lines of action intended to achieve, among other things, water planning objectives, but generally dealing with matters where there existed relative agreement, and the discussions were to do with to the greater or lesser emphasis they ought to be given, so they received far less public attention. For example, the major issue of non-conventional resources (saving, re-use, desalination, etc) (Segura, 1996).

Additionally, the articles of the text included, without serious legal reasons, and with a technique that was highly criticised by doctrine, numerous modifications to the Water Act itself, creating the perverse situation whereby an instrumental law modified the basic law that regulated it (see, e.g., Bermejo Vera [1995]; Martín-Retortillo [1997].

Despite this, the debate focused on aspects relating to hydrological balance, and proof of this is that the National Water Council, in the stage of reporting on the NHP draft, requested a more detailed study of the planned implementation of 600,000 ha. of irrigated land, or that an analysis and calibration be made of future demand increases. Questions such as regulation of the territory were studied by doctrine (see e.g. Sánchez Morón, 1993), but they were totally ignored by public debate.

This process was substantially affected by an Agreement of the Plenary Session of Parliament on March 22nd, 1994, which demanded, among other things, that the NHP be accompanied by an Agricultural Irrigation Plan, a National Plan on Applicable Measures for the Saving and Reuse of Water in its various uses, that the MOPTMA establish a Master Plan for the Purification and Sanitation of Waters, that the documents of the NHP included the forecast and conditions of the inter-basin water transfers, the establishment of various alternatives for the transfers proposed, the financing of the NHP, and several other questions.

Some of these demands did not only mean the need for new terms to carry out the requested works, but that, in cases like the Agricultural Irrigation Plan, could affect a basic factor in the calculation of foreseen future water demands. It is obvious that this left very important aspects of the NHP in question, because one of its central decisions was the system of widespread inter-basin resource transfers, and which without agreement on the quantification of future demands for each basin, it became very difficult to effectively advance towards their conclusion and approval.

On the other hand, there was rejection of the document by users' representatives in the National Water Council, which represented an enormous obstacle in the possibility of it actually going ahead, even with abroad arithmetic majority in the advisory body.

Another fact that contributed definitively, together with rejection by the users, in delaying the procedure of the NHP, was the Agreement of the Plenary Session of the Senate on September 28th, 1994, by which the Government was urged to approve the basin management plans prior to the National Plan. This legal question of temporal priority has already been commented, so we shall simply point this out here, mentioning that it was, without a doubt, another decisive factor so that, although work technically continued in the Directorate General of Hydraulic Works, in the year 1994, there was a definitive bureaucratic paralysation and socio-political blockage in the water planning process in Spain, to be restarted some time later with the conclusion of the necessary basin management plans, and the formal approval of all of them by Decree of the Council of Ministers.

It is interesting to highlight that this termination of the process took place both due to parliamentary decisions and, very particularly, the mentioned rejection by users in the National Water Council. The fact that the votes were arithmetically favourable to the Administration –as would foreseeably occur in most cases considering the Council's composition– did not mean that the procedure could continue without further difficulty, but rather, quite the contrary, it caused the practical social blockage of the whole process. This effectively shows, with full clarity, the fundamental importance of the participation of interested parties, and the over-riding need, for the socio-political viability of water planning, to reach –on solid and transparent technical bases– the necessary agreements and majority consensus between the parties involved.

5.4.2. The current situation. Some basic criteria

In the near future, when the new Preliminary Design of the National Hydrological Plan comes under debate, it can make use of all the approved basin management plans, at least those of the inter-community basins and some of the intra-community basins. Therefore, a National Plan need not be conceived in the same way as the basin plans in fact are, but, this time, with greater territorial scope. This position would mean rendering basin planning useless, reiterating it or reviewing it outside the legal procedure for such a review.

As is well known, the National Hydrological Plan is conceptually different in its content, structures, integral parts and method of preparation and approval, to the basin management plans. The National Hydrological Plan is not a basin management plan for the national area. In fact, insofar as the basin management plans, notwithstanding their express regulatory specifications, largely define the framework of action of the Central Administration in a negative sense (limiting discretionality, or what cannot be done), the National Hydrological Plan does so in a positive sense, what should be done at all times.

It is important to understand that, as mentioned in other parts of this White Paper, the National Hydrological Plan should not be confused with the set of measures necessary to mediate a water policy for the start of the 21st century. The National Hydrological Plan must necessarily be a part –as the essential component– of the design of this new water policy, whose conceptual foundations are explained in previous chapters of this White Paper, although water policy goes far beyond the content that the National Hydrological Plan must include, and is not wholly comprised within it.

It is particularly important, as mentioned above in connection with the Plan of '93, not to confuse the National Hydrological Plan with a review of Water Legislation, since it is the Water Act itself that defines, in its section 43.1, the mandatory contents of this Plan. Only should it be instrumentally essential, for the operative effectiveness of the regulatory content that the Plan itself modified the Water Act in force in any way, would it be expedient to include such a modification in the Plan Act.

In accordance with the basic criteria described, below we present, as elements for the appropriate social debate, the contents which, in opinion of the Environment Ministry, should be included in the Preliminary Design of the National Hydrological Plan. One of the basic objectives of this White Paper is thus fulfilled, which is to promote social debate, as broad and basic as possible, on the National Hydrological Plan, seeking the greatest feasible prior consent in this respect.

5.5. THE CONTENTS OF THE NATIONAL HYDROLOGICAL PLAN BILL

Adhering to the criteria described above, limiting the standards of the National Hydrological Plan to terms expressly laid down by the Water Act, and not to introduce other matters different from those prescribed, the content of the National Hydrological Plan should be, in all cases, as follows (section 43.1 WA):

a) The necessary measures for the coordination of the different basin management plans.

b) The decision on the possible alternatives that these may offer.

c) The forecast and conditions of transfers of water resources between the territorial areas of different basin management plans.

d) The modifications foreseen in planning the use of the resource, and which affect existing exploitation systems for population supply or irrigation.

Sections below formulate an initial proposal of content to be given to the National Hydrological Plan in connection with each and every one of these matters.

5.5.1. Necessary measures for the coordination of the different basin management plans

The Water Act does not lay down that the National Hydrological Plan coordinate the basin management plans in the sense that it modifies them to make them coherent or homogeneous, but rather it requires the National Hydrological Plan adopt the necessary measures so that coordination exists. Therefore, it is a question of the National Hydrological Plan regulating, with its superior legislative power, the matters that are not covered in the basin management plans, or are insufficiently covered or with incoherent solutions, provided that they affect matters which, in applying the principle of public interest, require homogeneous solutions on a national level. Not all incongruity or difference of criteria in the basin management plans should be coordinated by the National Hydrological Plan, but only those matters where for reasons of public interest, coordination measures need to by ruled by law.

The fact that the different basin management plans give different solutions to conceptually similar problems should not simply be interpreted as a requirement for the National Hydrological Plan to coordinate them. The legislator has designed a planning model that is plural and decentralized in origin, scope and execution, which should only be corrected –coordination measures by the National Hydrological Plan– when a reason of national public interest is identified for it, or when the option of a basin management plan should clearly be rejected for the same reason of going against national public interest.

The Royal Decree incorporating Council of Ministers Agreement by which the basin management plans were approved, July 24th, 1998, (Official State Journal of August 11th, 1998) identifies, without limit, at least three areas where it is expedient for the National Hydrological Plan to adopt coordination measures. These areas are as follows:

a) Establishing a single exploitation system in each plan, which includes partial systems, in a simplified way.

b) Identification and definition of hydrogeological units shared between two or more basins.

c) Methodology to homogenize the procedures and techniques to apply, to establish the consolidated demand and the balances of resources and demand.

Below, we shall examine each of these questions.

Establishment of a single exploitation system in each plan

With respect to first of the issues mentioned, the water resource utilisation system, designed in the preparation of this White Paper, and which is explained in detail in other chapters, provides a procedure methodology and a technological instrument that could allow the National Hydrological Plan to establish some common standards for creating a single exploitation system in the territorial area of each Plan, which includes, in a simplified way, but more clarifying for overall perception, the partial systems that each basin plan comprises.

In this respect, it should be taken into account that the basin management plans must include an inventory of water resources that refers both to natural resources and to available resources, derived from the different exploitation systems considered. The reality is that the various processes making up the hydrological cycle, in particular interrelations between surface water and groundwater, in addition to a joint approach on aspects of quantity and quality, have not always been given integrated, systematic consideration systematic in all the basins. All the above prevents us from having a good general overview of Spain's water resources in a territorial area greater than that of hydrographic basin.

Specifically, as regards natural resources, this question concerns the relationships between precipitation and aquifer recharge (including their current definition) and cumulative flow in rivers, where the methodology used for assessing them has been highly varied, starting with the actual period considered for obtaining the historic series.

With respect to available resources, derived from incorporating hydraulic infrastructures under certain standards of exploitation to cover demands in the time horizon considered, a need has been detected for harmonizing the terms of the plans on this matter. We should mention, for example, that the time horizons adopted are not the same. Finally, it is striking that complete information does not exist with respect to water ownership and therefore to the resource.

Without going into further detail, suffice to state that the exploitation system described in this White Paper allows these complex, significant questions to be systematised, with a unique, rigorous methodology, giving rise to the modelling of plans' basic data on exploitation systems, among other things.

Identification and definition of shared Hydrogeological Units

Regarding the second of the matters subject to coordination measures in accordance with the above-mentioned Council of Ministers Agreement, it is essential that the National Hydrological Plan revises and defines, with the greatest possible rigor, shared Hydrogeological Units, located in the territorial areas of two or more basin plans, as well as the allocation of resources to each of them. This need stems from the fact that some plans have used different identification methods for shared Hydrogeological Units, their borders and allocated resources.

Establishing consolidated demand and balance of resources, with homogeneous criteria

A correct estimate of current demand and a good forecast of future demand on the water planning horizons are vital for drawing up the water balances and, in short, for outlining the proposals of the NHP. These are certainly complex issues that the basin plans have solved with greater or lesser expediency but, in any event, in a very heterogeneous way.

The NHP must consider approaching this question as a necessity, and to do so appropriately it would be expedient to include the harmonisation of, at least, the following aspects:

– A homogeneous consideration of current demand at least in the uses of population supply, agriculture, energy and industry. Also it would be expedient to unify criteria on returns according to uses, so that balances for all the basins could be drawn up with comparable methodology and accuracy.

– As regards future forecasts, and in the case of population supply, it would be necessary to insist on uniform treatment of guarantee levels for supply, the requisite quality conditions and, certainly, some common demographic projections. In any event, the NHP is a magnificent opportunity to establish basis to subordinate the State's collaboration in supply structures to agreements with Autonomous Communities and local councils that include matters such as passing on to users, through correct tariff rates, infrastructures and modernisation (reduction of leakage and improvement to networks) and, in general, saving policies.

– As regards agricultural uses, apart from the general, common considerations mentioned in the above paragraph (guarantee, returns, etc.), action by the General State Administration will conform with the terms of the National Irrigation Plan. Therefore, foreseeable demand will be conditioned by this conformity, and consequently, so will the corresponding investment plans. It could also be generally laid down that Act 11 is not applied as coverage for the State to finance 100% of all structures.

– With respect to industrial demand, there should be clear definition as to whether, except for supply to low-consumption industries located in urban areas and connected to the municipal network, all industrial supply is included or only electric power production, basically cooling for thermal or nuclear power stations.

– The NHP's preparation could be made use of to include, from an integral point of view, the criteria of using, for hydroelectric purposes, reservoir dams or channels wholly or partially built with funding by the State or by the basin organisations. At the same time, the conditions should be stipulated, particularly the economic conditions, for such use.

– Finally, the basin plans frequently make indiscriminate use of the terms *demand* and *requirements* to refer to water consumption, either at the present time, or in the foreseeable future. Although this concept is dissociated in all the cases from any relationship with the cost that the users pay for using the resource, it would be advisable to correct this consideration in the NHP with a view to a more accurate, reliable prediction of future demand.

Protection of the natural environment

As specified by Council of Ministers Agreement approving the basin plans, it is necessary to draw attention to the consideration some plans give to environmental requirements, including them more as a use. To be accurate, and as intended in this White Paper, these requirements are actual restrictions on the traditional use of natural resources, so they represent a limitation of resources available for the activities of demand. It should be considered thus in the analysis made by the NHP, which should be required to make a significant conceptual contribution to this matter. Apart from the conservation of the aquatic environment in terms of flow (so-called ecological flow) requirements on other parameters will also be incorporated, such as volumes in longer or shorter periods, levels, physio-chemical characteristics of the water etc., so that the objectives pursued have a greater guarantee of success. It would also be necessary to lay down rules for exploiting reservoirs with environmental criteria, compatible with their other functions.

On the basis of intensifying analysis of these matters, there should be further study into the quantification and assessment of the environmental impact to be expected from the proposed investment projects. Only then will it be possible to make comparisons between alternatives, and eventually be able to select one of them with more specifically environmental criteria, based on the EIA.

It seems reasonable the National Hydrological Plan includes a study of the expedience of laying down coordination measures with respect to, at least, the following questions:

– Protection perimeters and conservation and recovery measures for the affected resource and environment. This includes those referred to in section 82 RAPAPH (which prohibits the exercise of activities that could represent a hazard of pollution or deterioration of the public water domain), those in sections 172 and 173 (protection perimeters for aquifers, whose purpose is the protection of water abstracted for population supply or of areas of special ecological, landscape, cultural or economic interest) and other non-compulsory measures.

  The lack of attention, in addition to the variety of criteria and detail used by the Plans in this respect recommends that the NHP clarify these questions within a global policy of broader scope, in view of the issue under discussion. On the other hand, competence-related problems and the need for effective cooperation between administrations cannot be ignored, questions that are provided with an ideal framework in the NHP for converging these complex and innovative issues. There could even be an attempt to integrate these protected areas with declarations of other natural areas and to try and systematise the classification of these different areas and their conditions of protection.

– Hydrological-forestry plans and soil conservation plans. The importance of actions in soil conservation hydrological-forestry protection for the administration of water resources is clear. Not only due to the effect they have on erosion control and therefore on the loss of reservoirs' capacity due to silting up (which need a natural non-renewable resource), but due to the high environmental value that the upper parts of basins have in general, where these actions are mainly focused.

  As in the case above, this it is a matter that requires coordination between administrations, particularly between Central and Autonomous Administration, who occasionally also have their own planning in this respect. Integrating these questions in the NHP would allow joint efforts to be made towards this, and lay the bases for criteria of convergence in the medium term.

– Protection and recharge of aquifers. With respect to the over-exploitation of aquifers, it would be necessary to clearly identify the situations where this physical phenomenon already exists and, in coherence, attempt to reflect this fact by means of the expedient declaration of over-exploitation in an administrative sense. In this case, there should be a differentiation between provisional and definitive declaration. Special attention would be given to coastal aquifers and their protection against saline intrusion.

  Considering the heterogeneity of treatment and the low level of compliance that some plans show with respect to their commitment to establish standards in granting research authorisations or concessions in each hydrogeological unit, it would be necessary to recommend that the NHP lay down some common bases in all these crucial questions.

Basic infrastructures

It could be expedient for the National Hydrological Plan to establish some minimum standards on execution, by the State, of hydraulic infrastructures according to the criteria co-financing by users and the rest of the interested administrations.

Additionally, the National Hydrological Plan could establish criteria, procedures and terms for transferring the infrastructures currently owned and exploited by the Central State Administration to local administrations and the irrigator's associations, without there actually existing a legal reason for doing so.

Both types of rules would homogenize the Central State Administration's action in this respect in the territorial areas of the different basin management plans, thus contributing to a greater fairness and rationality in public expenditure.

As regards infrastructures, it also seems expedient that the National Hydrological Plan foresee a distribution of public expenditure associated with hydraulic structures, by programmes, so that as of the year 2000 they start to dedicate the necessary economic resources to maintenance and exploitation, in view of the considerable amount of hydraulic structures existing in Spain. This would mean establishing a reasonable proportion between the cost of implementing new infrastructures and the cost of maintaining existing ones, moving away from the historically poor definition and improvisation that has characterized this issue.

Extreme hydrological situations

The management of extreme hydrological situations would require a much more extensive consideration than it receives in the basin management plans, and for several reasons. Firstly, because some important conceptual and methodological questions need to be clarified on the matter, and secondly, due to the concurrence of powers and the mutual responsibilities of the different Administrations.

The lack of homogeneity and general consideration both as regards prevention and protection against high water and floods, and situations of drought, suggests recommending that the NHP provide doctrine and new solutions based on the management of such situations.

Another chapter of this White Paper, examining these extreme hydrological situations, contained analysis and suggestions that could be extremely useful in defining the future contents of the National Hydrological Plan in this respect.

5.5.2. Solution of the possible alternatives given by the basin management plans

After a detailed analysis of each basin plan, it has not been deemed that the terms of section 43.1.b) of the Water Act are applicable, since no basin management plan outlines alternative hypotheses different from those referring to the possible transfers of external resources, a question which, by mandate of section 43.1.c of this Act, must be specifically dealt with in another section.

To be specific, the plans that lay down contributions of external resources as possible alternatives are those of the Ebro, Júcar, Guadalquivir, Guadiana I, South and Segura.

5.5.3. Forecast and conditions of the transfer of water resources between territorial areas of different basin management plans

The Law obliges the National Hydrological Plan, with respect to transfers, to include them (or reject them) and to lay down conditions for them, understanding these to mean legal, socio-economic, environmental, and technical conditions. In this respect, we should make three types of considerations:

The first thing to do in this regard is to clarify the actual concept, because the term transfer appears nowhere in the Act. We shall consider transfer to refer strictly to the terms of 43.1.c, that is, a transfer of water resources between territorial areas of different basin management plans. Any interconnection of rivers that does not comply with this condition, is not a transfer and it is not, therefore, a matter referred by Law to the National Hydrological Plan.

Secondly, and as regards planning, it seems expedient to expressly reject in the short and medium term the option of generally interconnecting all the basins, as technically unjustified, extremely difficult, and environmentally questionable. Conversely, there should be further analysis of the options a priori most justified, according to the territorial analyses and the results of the utilisation system proposed by this White Paper, which objectively identify the chronic shortage situations in basins. The decision must be taken after this analysis has been carried out on three levels, although all are in some way related.

The first level concerns the balance between costs and benefits, in a broad sense. Initially, a transfer is not in itself desirable because it breaches the principle of basin unit that inspires all our legislation. It should only be implemented if powerful reasons of a national order so recommend. These reasons must be proportional to the transfer's importance (in environmental impact, investment, transport distances, affected territories, etc.). The need to justify any hydraulic structure –due to its cost and environmental effect– is specially demanding in the case of transfers.

The condition of positive balance requires that reasons of a social and economic order used to justify the transfer are not circumstantial or unpredictable. With the available data, these should be structural reasons, responding to trends verified in the past and with a reasonably certain future. In the event of doubt or purely circumstantial need, it is not justifiable to consider the expedience of a transfer. Obviously, requisites should be a positive EIA and economic rationality of the investment, via price paid for the water transferred in the receiving area.

The second level concerns purposes. Accordingly, we could say that a transfer would be only justified in the following cases:

- For supply, if no other alternatives exist and the demographic growth of the receiving area is shown to be constant, and there are objective reasons to suppose that it will continue in the future.
- For irrigation and agricultural uses, a transfer may be justified if the agriculture is optimum in terms of saving, modern techniques, not dependent on subsidies and transitory regulations, and with its own capacity to dominate markets due to specific characteristics apart from water availability, and with competitive prices outside the current system of subsidies (changing and circumstantial).
- For ecological needs, a transfer may be justified as a means of restoring balance to remedy over-exploitation

problems, especially in groundwater, when it cannot be solved with less aggressive techniques.

The third level refers to a more diffuse –though significant– matter, which is the perspective of territorial regulation. When an area with structural water deficit is strangled or its future economic and social development threatened by uncertainty of water supply, the transfer will seem more acceptable. Particularly if that area shows past growth trends on demography, tourism, agriculture, etc., and signs of continuing in the future.

Taking these three analysis levels into account, this White Paper considers it expedient to at least propose advancing in the study of the possible transfers referred to in sections below.

Finally, with respect to the conditions for the transfers, these should be based on the perspective that although, in reality, water is public property, this legal definition cannot, and should not, cancel out a social, historical, psychological and political reality, which we have already mentioned in chapters above as water's social or community value. Obviously, it is clear that riverside towns have something to do with the water that flows before their eyes.

The decision on possible transfers should therefore take into account both the needs of the receiving basin, and those of the donor basin, in an integrating, non-exclusive context. It is neither socially nor politically possible to decide a transfer by only considering that in the donor basin there is water and in the receiving basin there is a lack. To carry out a transfer involves a common project, a joint development plan for donor and receiving basin, so that grantees see their futures guaranteed thanks to the water transferred and the grantors cannot objectively see their futures threatened because the water they need for themselves is going to other areas.

The regulation laid down in the National Hydrological Plan regarding transfers cannot be a simple approval of work to be done, because, in following such a technique, it would be hiding that fact that definitive viability of the corresponding infrastructures will depend on certain Environmental Impact Studies, Economic-Financial Analyses, and compliance with a series of conditions for development and regulation, both in the donor basin and the receiving basin that the National Hydrological Plan Act itself is not able either to advance, or guarantee.

Therefore, the National Hydrological Plan, in this matter, should authorize transfers that can be carried out, as well as the necessary infrastructures to do so, but also laying down the conditions that should be fulfilled for implementing the corresponding works and transfers, conditions that must refer, at least, to the following parameters:

- Existence of surplus resources in the donor basin (technical-hydrological feasibility).
- Environmental Assessment, according to its legal regulation (environmental feasibility).
- Economic-financial regime of the works (economic feasibility).
- Compensation and guarantees for the donor basins, in terms of public investment, regulation, participation in the economy of the transfer, etc. (social feasibility). We should add in this respect that, as seen when studying the economic regimes of existing transfers, the concept of compensation is not a novelty in Spanish legislation, because *all the transfers carried out up to now have included it* in one way or another.

Accordingly, the National Hydrological Plan will outline the scope of possible transfers to be carried out in Spain, and will define the conditions that should be fulfilled for the works to go ahead.

5.5.4. Modifications foreseen in the planning of resource use and which affect pre-existing uses for population supply or irrigation

Section 43.1.d. of the Water Act refers, as content of the National Hydrological Plan, to the *modifications foreseen in planning the use of the resource and which affect existing exploitation systems for population supply or irrigation.*

Furthermore, Section 94 of the RAPAPH slightly modifies the above by stating that in the drafting of the National Hydrological Plan *modifications shall be specified which, in accordance with planning the use of the resource affect existing exploitation systems for population supply or irrigation.*

Notwithstanding some doubts as to interpretation that could arise, these provisions may in all cases be understood as complementary to the terms of the three previous sections of section 43.1 WA, in the sense that they regulate specific compliance with what these sections stipulate as regards the modification of pre-existing exploitation systems.

In fact, it is expedient to consider that national planning, precisely through the provisions of the three sections mentioned, and which precede this (measures for coordinating the basin plans, solution of possible alternatives that they offer, and forecast and conditions of resource transfers), lays down planning for the use of the resource that is obligatory, and which may give rise to modifications in the use of the resource that affect pre-existing exploitation systems, expressly highlighting those of population supply and irrigation. It is in this sense that paragraph d) would be complementary to the previous ones, because its function would in fact be to regulate the specific implementation of what these three sections lay down in terms of modifying pre-existing exploitation.

Additionally, the majority of doctrine has highlighted the relationship between this paragraph d) of section 43.1 of the WA, and section 51.3 of the same Act, on the extinguishment of the right to exclusive use of the water, and according to which, "when the destination given to the waters granted is irrigation or population supply, the holder of the concession may obtain a new one with the same use and destination for the waters, and must present the request in the procedure of hearing in the file on declaration of extinguishment or during the last five years of its validity. In the event that application takes place, and provided that the National Hydrological Plan does not oppose it, the basin organisation shall process the file excluding the procedure for projects in competition."

As may be seen, both precepts refer to population supply and to irrigation, and both the modification or the continuity of use is subject to the terms of the NHP.

As for population supply, this preferential treatment is considered obvious because it is the high-priority use that must necessarily be continued. Nevertheless, the modification laid down by section 43.1.d. may be relevant in a positive interpretation, for example when, for the purposes of a transfer, water of a better quality than that being used is available to supply an area or a city.

With respect to irrigation, it is also considered that its continuity makes full sense, because irrigation of land is, in principle, intended to continue for an indefinite term. Mention is made of the fact that, as stated when examining concessions, the Water Act of 1879 laid down the perpetuity of water concessions, and it was the State Property Act of 1964 that established the concession term of 99 years maximum, reduced to 75 by the WA of 1985. The question of whether this reduction in terms could represent a restriction of rights was considered in Constitutional Court Sentence 227/1988 (Basis 11), concluding that the time limitation of perpetual uses is not a privation of rights *but a new regulation of the same rights with no impact on its essential content*. What is certain is that, with the formula laid down by section 51.3, concessions for irrigation can be considered practically perpetual, and, in cases where it is not expedient to consider them thus, paragraph d) of section 43.1 WA lays down possible modifications in the planning of resource use, modifications that the regulation of section 51.3 of the same Act would be subject to, in favour of irrigation.

Accordingly, it seems that the general sense of 43.1.d WA: *in principle, and except for other specific circumstances that may be considered, in concessions for population supply and irrigation a new concession may be obtained with the same use and destination, unless the NHP has ruled otherwise.*

Having described these conceptual and interpretative considerations, we should indicate that no situation has been identified where it is expedient for national planning to modify existing planning for supply or irrigation, so in principle the National Hydrological Plan does not include any specific provision, unless a well-founded recommendation arises in this respect during the period of social debate, prior to the draft Plan's approval.

5.5.5. Other possible contents of the National Hydrological Plan

Since at present there already exists in Spain a series of transfers each regulated by specific legislation, passed when the structures were approved, we might consider the possibility that the National Hydrological Plan homogenize the legislation on transfers, substituting the laws currently in effect, and regulating each transfer, with some common rules - notwithstanding the particular adaptations that may apply. In particular, and as mentioned above, it could be expedient for the National Hydrological Plan to study laying down some common criteria on the economic regime of the different existing and future transfers, although the complexity and difficulties involved made finally made such a unification unadvisable.

Furthermore, the National Hydrological Plan should only modify the Water Act if it is deemed essential in some particular aspect for the effectiveness of the measures included in the Plan itself.

5.6. POSSIBLE TRANSFERS TO BE APPROVED BY THE NATIONAL HYDROLOGICAL PLAN

5.6.1. Introduction

The decision on transfers is probably the most delicate and potentially conflictive, in political and social terms, of the measures the National Hydrological Plan must include. Any option for a setting up a new transfer ultimately involves, like any other major public action, a strictly political decision, but this does not mean that, so as to be reasonable and not arbitrary, such political judgement of opportunity should not be based on a rigorous analysis, as objective and contrasted as possible, of real data, recommending for the transfer or against it, as well as the decision on where the water should come from, and the demand to be covered with resources transferred between the territories of different basin plans.

In this respect, the position of this White Paper is not to prejudge criteria, nor to adopt an abstract political decision on whether there should be transfers or not, nor the specific question of which ones should be made, where appropriate. This White Paper aims to provide the most objective basis possible for making a judgement, so that the corresponding political decision adopted is founded on facts and on reason. It aims to provide a prior social debate on this presentation of facts and reasons, in order to forward the conclusions of such a debate to the Government and the Parliament, who will eventually decide on the approval, respectively, of the preliminary draft of the National Hydrological Plan Act firstly, and the Act itself, secondly.

5.6.2. Water Balances. Deficit and surplus in the territorial planning areas

Previous chapters have explained the system of cartographic analysis and water use designed by the Environment Ministry as foundation work for this White Paper, in order to determine the territorial balance between resources and needs, and to initially identify possible decompensation and imbalance. Those sections gave a detailed description of the methodology used on the basis of the cartographic modelling operations necessary to obtain a general spatial representation of the current water use system, and a mathematical optimisation model of water resource management which, considering the aggregated results of the cartographic model, and including detailed data on infrastructures and management, allows the systems' performance to be assessed in detail and their dimensions to be calibrated.

With the above-mentioned work instruments, the maps of potential resources and demand were calculated, based on the hypotheses described in those sections.

As a precautionary measure and for the whole territory, this process reserved a volume of 20% of total natural resources, intended to meet environmental requirements and to cover possible uncertainties in the estimates of future resources. This reserve volume (over 20,000 hm^3/year) is therefore excluded from the productive water allocation system, so it is not included in the balances, which are made by only considering the remaining potential resource. Similarly, satisfactory compliance with geopolitical restrictions was observed on Hispano-Portuguese rivers.

Furthermore, the balances made obviously refer to physical volumes of water in terms of their consumption, so they refer to the material existence of resources and do not consider possible non-consumptive concession limitations. These limitations will be analysed in later stages, in the context of the technical-economic conditions of possible future transfers.

With the final resulting maps, after the necessary territorial aggregation by exploitation systems and planning areas, it has been possible to draw up the maps identifying those systems and territories of plans that have structural deficit, or which show a surplus.

To accurately assess this identification of deficit systems, we should take into account that the aggregate balance by exploitation systems has been carried out presupposing the complete use of potential resources generated in the whole territory of the system, as if all the necessary infrastructures and requisite quality conditions for the resource were available, also adding resources from sea-water desalination and transfers currently effective from other systems, together with the maximum level of direct and indirect reuse of resources, including the use of all existing renewable brackish groundwater, and including the consumption reductions achieved by the saving. In mathematical terms, this supposition could be identified as *an absolute maximum limit of the possible use of current resources* in the deficit systems.

This implies that the territories defined below as deficit are those that still turn out to be such *even in the extreme theoretical hypothesis of exhaustive exploitation, saving, absolute regulation of all existent resources, and optimisation of the system's management.*

In other words, systems identified here as showing deficit *are structurally so*, whatever the infrastructures they are equipped with, even though they optimise policies of usage and saving to the maximum theoretical possible, and taking into account currently existing demands. That is to say, territories that can only resolve their current problems of resource shortage –let alone future problems– by means of transfers from other areas.

As regards systems defined as showing surplus, this assessment means that their resources are globally greater than their consumption needs, which does not imply that, in its territorial area, there may not occur spot problems with supply. These problems can arise due to deficiencies in infrastructures or quality problems, but not due to shortage of resources.

In any event, we should take into account that this assessment of surplus refers to the location of current uses in systems showing surplus, so any decision on the transfer of resources will also take into account the potential or future uses that may appear and, as a consequence, qualify such surplus in the system in question.

Bearing this circumstance in mind, some new balances have been drawn up supposing the long-term maximum demands that are included in the basin plans. Accordingly, the systems that, even in this supposition, show surplus, would in no way undergo limitations in the forecasts and expectations of future growth specified in their water plans.

Reflecting the above with respect to deficit systems, this supposition could be described, in mathematical terms, with *an absolute minimum level of the possible current and future surplus* in systems showing such surplus.

Consequently, the procedure followed rigorously establishes a scale allowing transfer needs and possibilities to be identified. On one hand it ensures that these needs do not respond to future expectations and cannot be covered any other way, and on the other hand, that the transfer possibilities do not reduce, in any way, all the forecasts for long-term growth considered by the basin management plans.

After this prior cartographic territorial identification of areas, obtaining quantitative results and definitive conclusions on the transfers requires a meticulous technical analysis, carried out by means of the above-mentioned mathematical models of water system management, considering the variability of demand, existing regulation, infrastructures, returns, environmental restrictions, hydrological irregularity, etc.

Obviously, such detailed work is beyond the reach of this White Paper, and its conclusion, together with the combined consideration of other economic and environmental aspects, should correspond to the National Hydrological Plan itself.

5.6.3. Identification of systems with deficit

The map in figure 372 shows the situation of exploitation systems in structural deficit, that is, those where the poten-

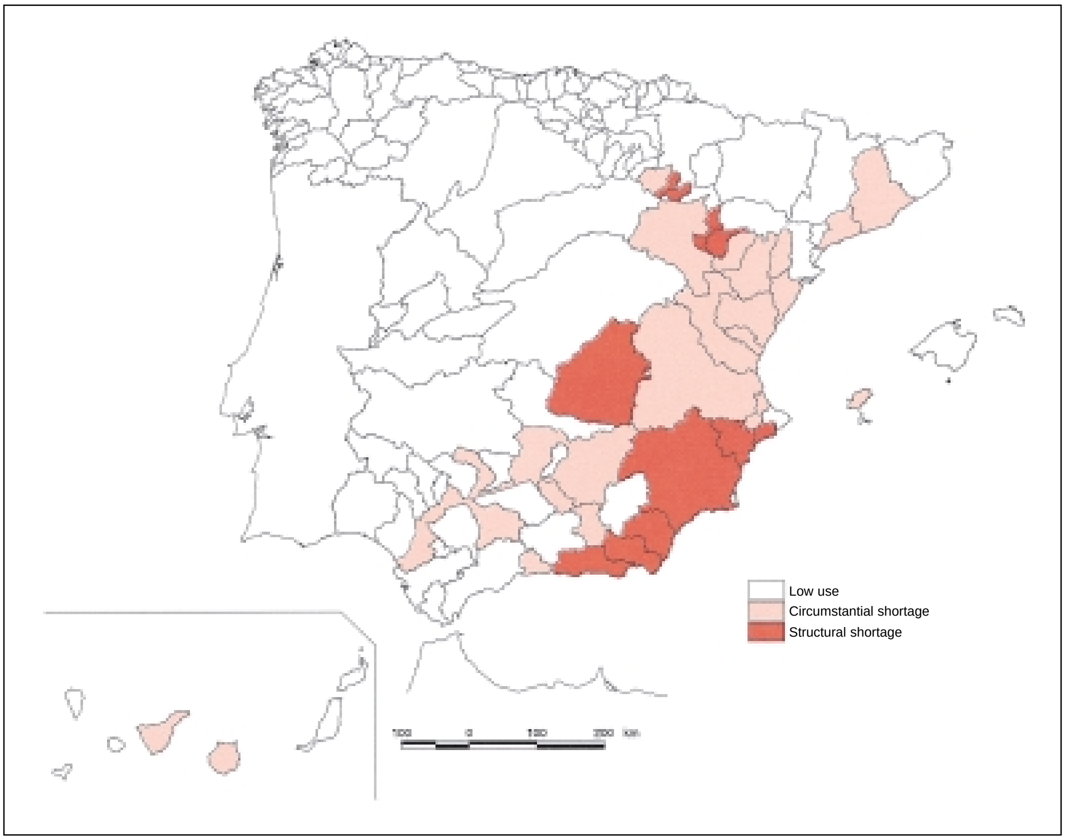


Figure 372. Map of risk of shortage in exploitation systems of the basin plans.

tial resource (including desalination, direct and indirect reuse, and transfers currently in effect) is systematically lower than the current level of consumption intended to cover. Systems are also identified with a risk of undergoing circumstantial shortage and which could have spot supply problems due to lack of resources in adverse hydrological circumstances.

The map in figure 373 shows the same information as above, but here adding territorial areas of the basin plans. Figure 374 identifies the existing deficit, by exploitation systems of the basin plans. Aggregating, as above, the existing balances by territorial area of the basin plans, gives figure 375.

Study and analysis of this set of figures clearly suggests that:

- The only basin plan whose territory shows structural deficit, whichever analysis perspective is used, corresponds to the Segura.
- In the basins of the Guadiana, South, Júcar and Ebro, exploitation systems in a situation of structural shortage exist, although the territory of the corresponding basin plan as a whole is not.
- In the territory of the basin plans of the Guadalquivir, South, Júcar, Ebro, Catalonia Inland Basins, Balearic and Canary Islands, there exist some exploitation systems in a situation of circumstantial shortage. In view of this, it is necessary to make the following observations:
- The exploitation systems identified as showing structural deficit in the basin of the Guadiana, the South, the Segura, and the Júcar, could only efficiently overcome this deficit by means of external supply, from the territories of other basin plans or from the sea.

  a) In the case of the Júcar, all its exploitation systems –except one– are liable to risk of circumstantial shortage, which would impede the possibility of internal compensation, especially considering the global situation of circumstantial shortage in its water plan. The same is true in the case of the South.

  b) In the case of the Segura, where one single exploitation system has been defined, coinciding with the area of its basin plan, its deficit can only be overcome by increasing the external supply that it currently receives.

  c) In the case of the Guadiana, the headwater location of a system showing significant deficit would require, in practice, an external transfer.

- The exploitation systems identified as showing structural deficit in the Ebro basin are localised, and they could in principle be corrected by means of actions within the area of the basin plan itself. Additionally, there exist situations of circumstantial shortage that could receive the same treatment in the future.
- There exists a geographical area in the south-east clearly identified as showing structural deficit, and it consists of

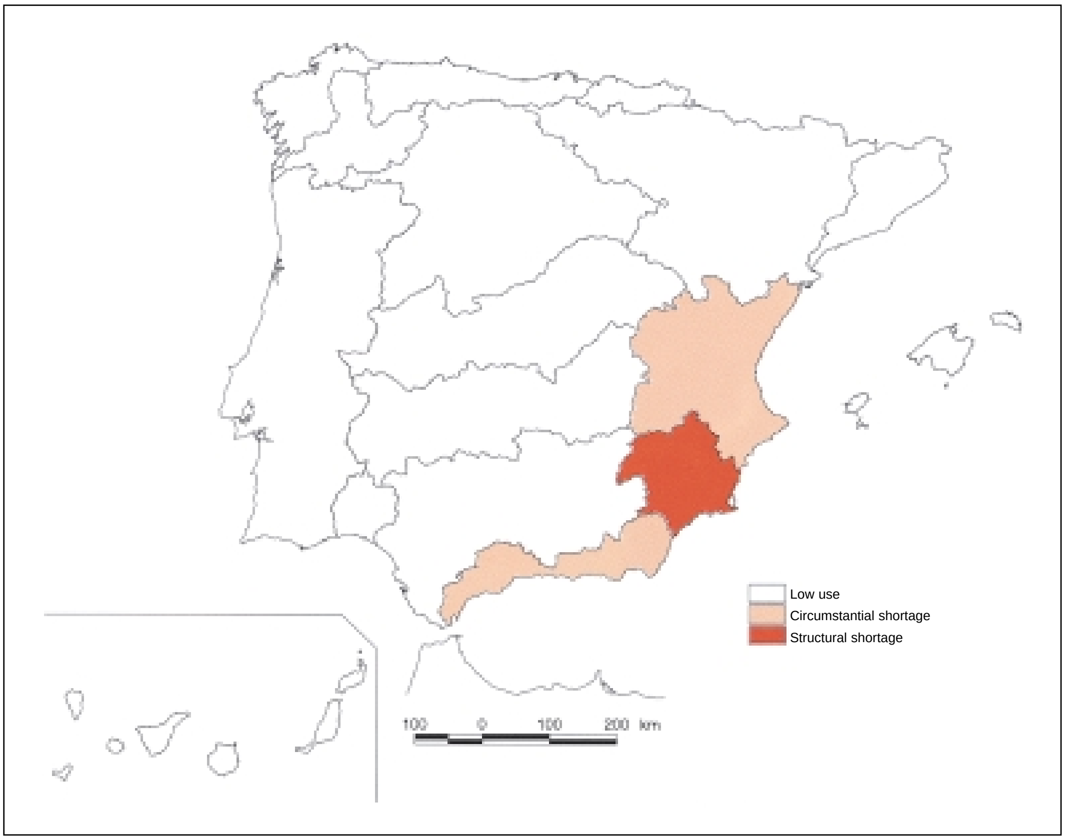


Figure 373. Map of risk of shortage in the territorial areas of the basin plans.

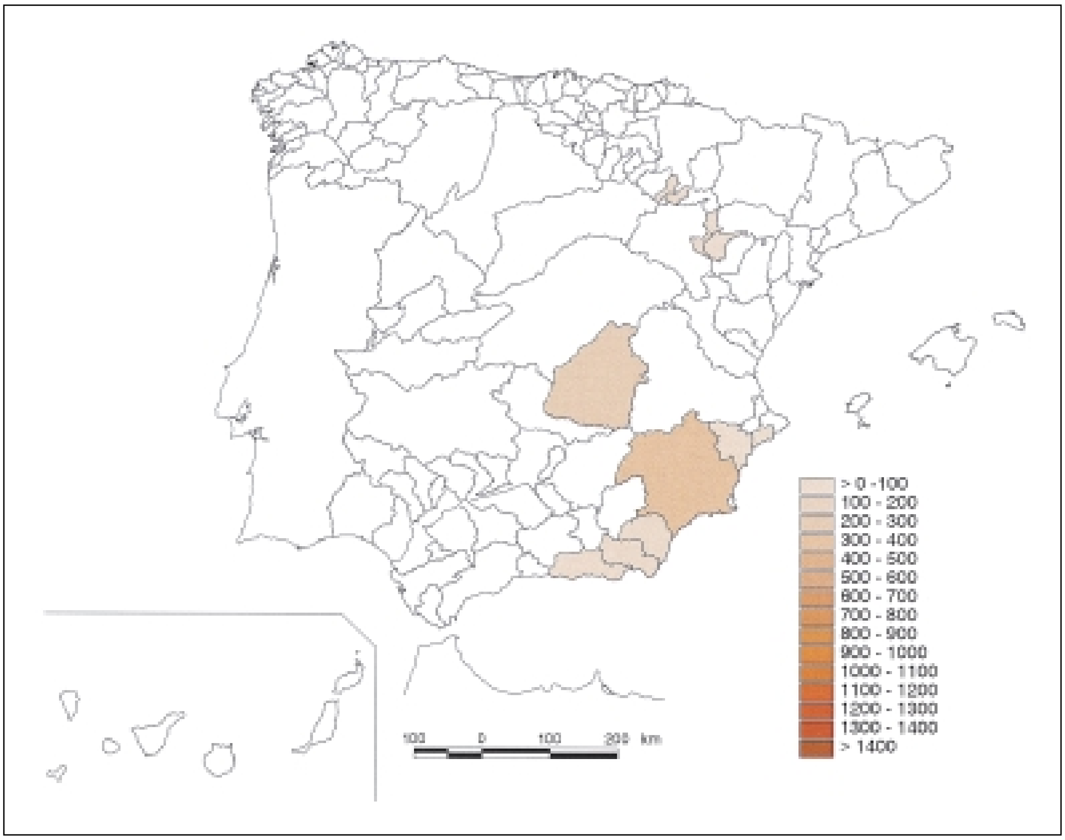


Figure 374. Deficit map (hm^3/year) in the exploitation systems of the basin plans.

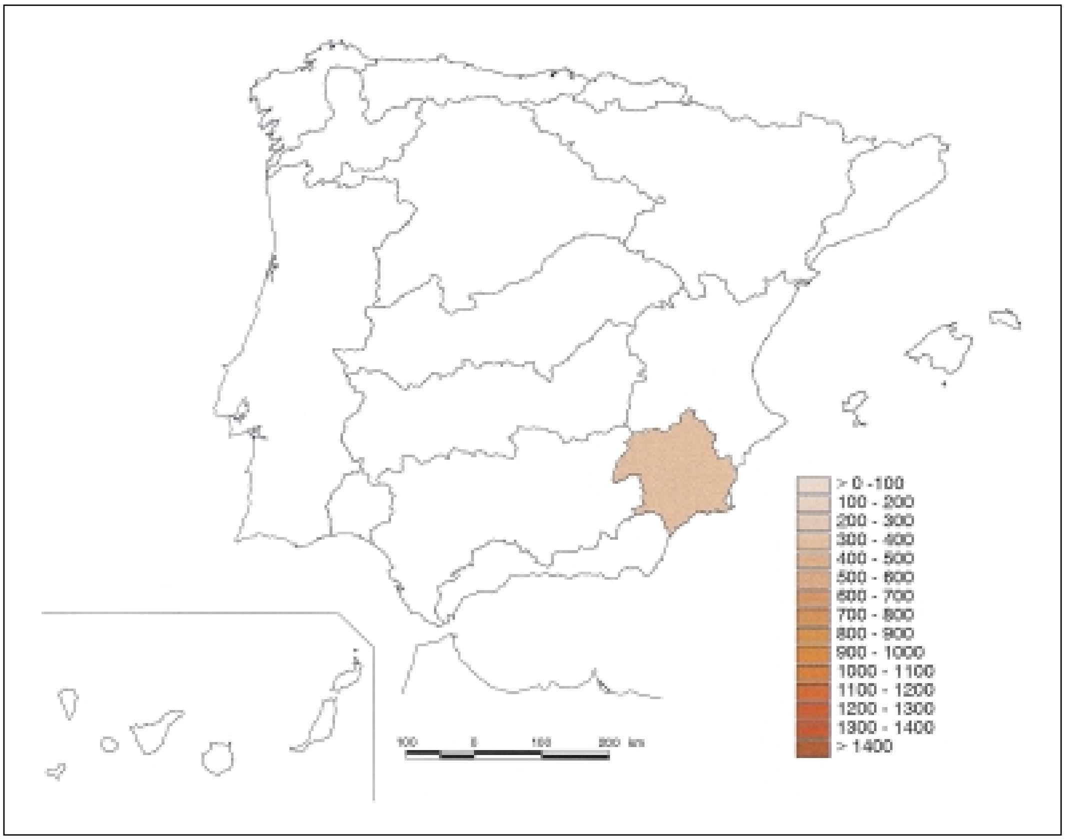


Figure 375. Deficit map (hm^3/year) in the territorial areas of the basin plans.

the southern systems of the Júcar, the Segura, and the eastern systems of the South. The clear geographical unit that these territories make up suggests unitary treatment of the possible solutions that may be outlined.

- If it is deemed necessary to eliminate the risk of circumstantial shortage, the exploitation systems that are currently in this situation in the basins of the Guadalquivir and Catalonia, should be studied with respect to the possibility of overcoming such shortage by means of internal transfers of their basin plan, or by means of external resources.

5.6.4. Identification of systems with surplus

The map in figure 376 shows existing surplus in the different exploitation systems of the basin plans.

Figure 377 provides, as above, the same information, but here aggregated by territorial areas of the basin plans. These figures as a whole clearly suggest that:

- By exploitation systems, most of the systems of North I and North II clearly show surplus, together with the Esla-Valderaduey system in the Douro, the macrosystem on the headwater and middle reach of the Tagus, and an large part of the systems of the left bank of the Ebro.
- By basin planning area, clearly showing surplus are most of the Cantabrian coast (North I, North II and Galicia-Coast), the Douro, and the Ebro. Also showing global surplus, although to a lesser extent, is the Tagus.

In summary, we may state that, taking into account the relative location of the exploitation systems we are referring to, the Ebro basin and the macrosystem on the headwater and middle reach of the Tagus are, due to their geographical location and existing surplus, liable to be initially studied as possible source areas for water transfers to deficit systems. Douro and North show clear possibilities from the point of view of their resources, but with more geographical difficulties due to their relative location with respect to the deficit areas.

Repeating, as mentioned above, the previous calculations, but with the long-term future demand included in the basin plans, provides the maps in figures 378 and 379, basically confirming the results described, and underlining the solidity of the conclusions obtained.

5.6.5. Possible transfers

We may clearly deduce from the analysis made in the previous sections, from a strictly hydrological point of view, which areas of the peninsular territory may be initially and reasonably studied regarding the feasibility and expedience of possible transfers, both for donor systems, and for receiving systems. This obviously does not exclude the fact that any another option may be put forward and analysed.

The proposal is limited to the debate on transfers in the National Hydrological Plan, to the suppositions where a priori it seems reasonable to study the political expedience of backing this solution to achieve a future hydrological balance on the basis of rational hypothesis.

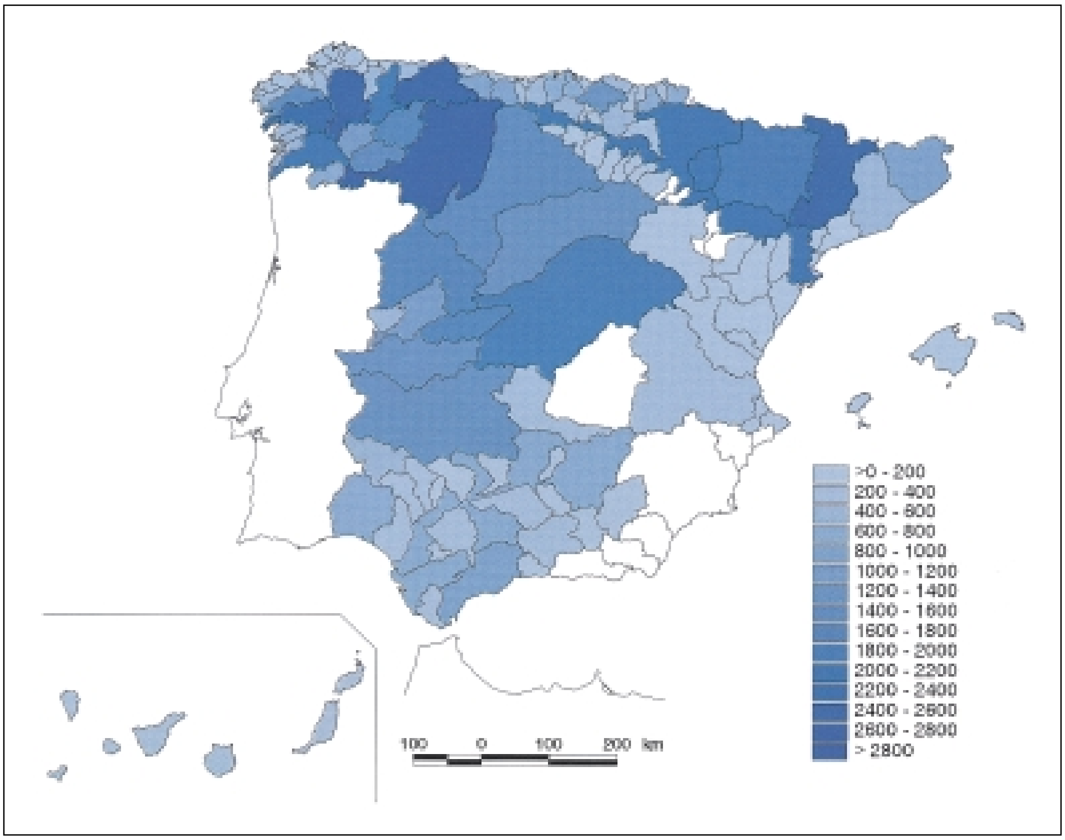


Figure 376. Surplus map (hm³/año) in the exploitation systems of the basin plans.

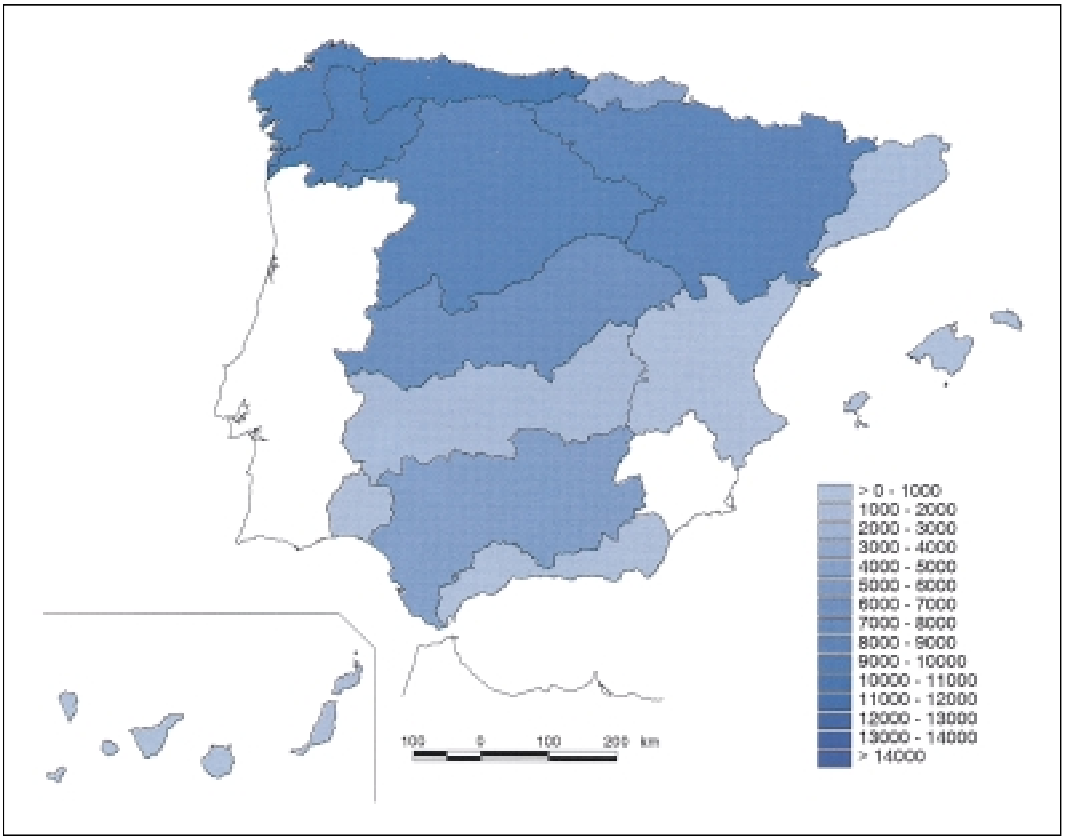


Figure 377. Surplus map (hm³/year) in the territorial areas of the basin plans.

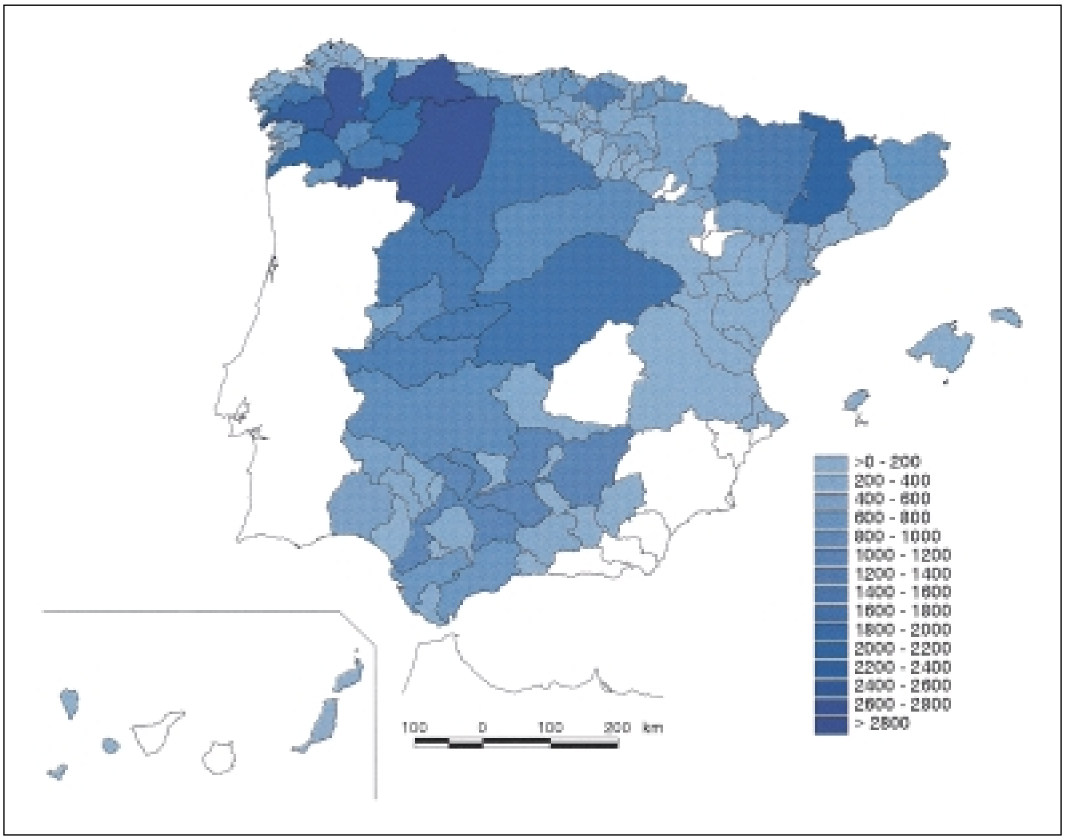


Figure 378. Surplus map (hm³/año) in the systems of exploitation considering the maximum demands foreseen in the Basin Plans for the second horizon.

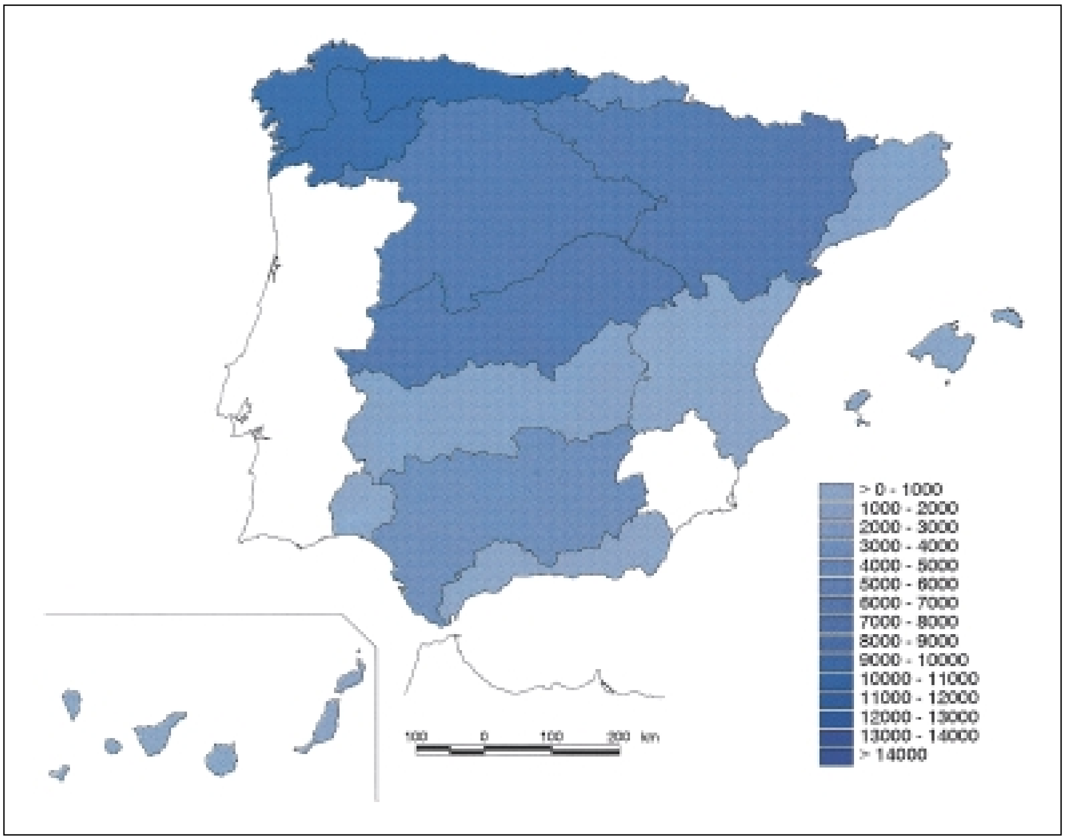


Figure 379. Map of surplus (hm³/year) in the territorial areas of the basin management plans considering the maximum demands foreseen in them for the second horizon.

It is appropriate to remember what was mentioned above on the different parameters that should be taken into account in deciding in favour or against transfers. Hydrological data, water balances, are indispensable elements to keep this debate rational, but they are certainly not the only fact to take into account for a political decision that must have as much to do with economic and agricultural policies, trends in industry, demographic development, investment and employment, the positive and negative effects on the environment, costs of the transfers and the mechanisms for their costing them, and ultimately, with a global vision territorial regulation, in the medium and long term, for Spain as a whole.

The decision on possible transfers cannot be, in any case, a unilateral undertaking by the Water Administration, but rather it should be both the result of a committed effort by the social participants and the Public Authorities involved, who must undertake to ensure the projects defined are reasonable, making an active commitment to put them in practice, both in terms of presenting the pros and contras of such solutions to the public opinion, and in terms of the design, preparation and financing of the corresponding structures.

The State Water Administration is responsible for basic work in defining the problem, identifying the solutions and, ultimately, the political and regulatory validation for their approval. However, it is not the function of this Administration to define a closed solution and, unilaterally, legally impose it upon public and political opinion, as if this were of no consequence, but rather with previous and concomitant character, with the active support of the affected sectors and potential beneficiaries, in all sectors. Social debate on the text of this White Paper and, particularly, on this matter, should also be conducive to concluding to what extent there is an actively committed social majority with respect to possible water transfers, and in profiling the options and bases that the White Paper is proposing.

5.7. OTHER PROPOSALS FOR A NEW WATER POLICY

In addition to what has been presented in sections above, we now turn to a series of important questions and proposals related with water policy, both from the point of view of outlining new conceptual perspectives, and of highlighting significant deficiencies and possible improvements that contribute to overcoming them.

5.7.1. The limitations of the Plan and the need for other instruments

In approaching the task of remedying the current problems of Spain's water resources, the figure of the National Hydrological Plan immediately arises. However, passing from a selection and identification of the most relevant questions to the definition of this Plan's contents is not such a simple operation as it may seem at first sight: firstly, because the Plan Act is not the appropriate instrument for solving all the problems that have been commented, since not all require legislative decree; and secondly, because the scope and contents of this Plan Act are largely predetermined by the Water Act proper.

In this sense, the first observation to be made is that, as mentioned above, the National Hydrological Plan should not be used to simply modify the Water Act. If, as diagnosed, this Act requires amendment to solve some of the more significant problems, it will be necessary to act in consequence, but without distorting the contents laid down for the Plan Act by the Water Act itself. We should not fall into the erroneous mechanism of the Budget Act, which modifies the General Budgetary Act that regulates it.

At the same time, we should note that the time is long gone when it was believed that establishing something in a law published in the Official State Journal was enough to make reality comply with the rule.

Rules that ignore habits, circumstances and social unrest will hardly be effective, and those that have shown most quality and resilience are those that, like the Water Act of 1879, reflected the concerns, habits and customs of the moment, and drew up a rigorous, systematic body of work, firmly rooted in that reality.

The existence of many laws that aim to regulate everything exhaustively has caused, not just the legalisation of reality, but the discredit of the law and general phenomena of social non-compliance, faced with the impotence of the Administration and the Courts and Tribunals. In fact, over recent years, legislation has often been passed with grand theoretical declarations, while reality has continued along its road, unaffected by such rules that aimed to transform it.

For these reasons, the National Hydrological Plan should not contain provisions without legal effect, not generating rights and obligations. Pompous, useless precepts *(shall be studied..., a Plan shall be made…, rules shall be laid down on...)* should not appear in the text. For the law, what corresponds to the law, and to the administrative management and the politics of expenditure, what corresponds to them. The series of problems described requires plans, actions, public expenditure from the Public Authorities, but that is no content for the National Hydrological Plan, because it is not appropriate subject matter of an Act.

Furthermore, throughout this White Paper reasons have been provided to suggest that the National Hydrological Plan should not be a Public Works Plan, although water planning has historically been, to a large extent, works planning. And it should not be so because, as shown above, works neither are, nor will they be in the future, an essential pillar of water policy, since this is not where the solution to the main problems of the immediate future are to be found. Additionally, it is absurd to make an instruction for implementing hydraulic works legally binding, when their feasibility will be determined "ex post" by the EIA and the economic-financial analysis, while allowing for legal catalogues of zero legal effect, degrading the Law.

This criteria is coherent with the contents of the basin management plans, which already identify the necessary basic infrastructures with very broad criteria; the amendment of section 44 of the Water Act (in course) is oriented along the same lines. The exception is the transfer of resources between territorial areas of different basin management plans which, by express mandate of section 43.1.c) of the Water Act, should be laid down by the National Hydrological Plan Act.

In short, the solutions proposed from the new water policy cannot be reduced to one single instrument, considering the existing diversity in the origins of the problems detected and in the multiple levels from where they have to be approached. In this context, the National Hydrological Plan is the foundation stone of Spanish water policy, but it is not the whole water policy. In the short term, this policy needs to be supported by other pillars, the main ones being commented below.

5.7.2. Water services. A shared responsibility with respect to the competence of the different Territorial Administrations

Habitually, users and in general citizens who use different water services have a global perception, both of the service proper (highly influenced by its final characteristics) and of the process leading to its supply. However, it is true that these services are possible, in general, thanks to the part played by several agents, mostly public, that cover intermediate stages, some of which have no immediate or clear relationship with the final service.

For this reason it is of great interest to point out this fact, not only in recognition of the work carried out by these agents, but basically to try to perfect the operativity of the model consecrated by the legal regime in effect in this respect, and promote the participative character that it specifies. A description of the legal regime of population supply, together with some observations and suggestions for its improvement, can be seen in Delgado Piqueras (1998). Unquestionably, the effectiveness of the financial resources involved, the rationality of actions carried out in this field, in terms of respect for the environment, and in short, service quality, will be increased to the extent that coordination of all the Public Authorities taking part, with each other and with the private sector, is a reality.

The sections below focus attention on the quantitative aspects of water supply to the population, since this is the most important use insofar as it affects people's basic needs, and briefly describe the framework of competence of the territorial Public Authorities in this respect.

Water supply to populations is unquestionably the first and foremost use of water, given its character as a basic resource for life. This fact explains the high degree of concern it raises among the different territorial Public Authorities. It is probably also the reason why, both in the legislation and in the daily implementation of administrative activity, situations arise in which the Administrations partially overlap, crossing over and even getting mixed up.

The question is complex, because competence as regards water supply is a long way from being perfectly and clearly defined. In any event, an attentive study of the profuse legal regime of the State, the Autonomous Communities and of Local Agencies (Municipal and Provincial), helps to establish three clear levels of administrative responsibility in the matter:

The State. The State's relevance in rendering all the services, among them those of supply, is evident, bearing in mind that section 2 of the Water Act, in accordance with article 132 of the Constitution, confers inland waters, both surface waters and renewable groundwater, the character of public water domain of the State.

Under its exclusive competence, in accordance with article 131 and 149.1. 13, 22 and 24 of the Constitution, the State is responsible for safeguarding the high-level availability of the resource, with the requisite guarantee level, when this resource originates from inter-community basins. For this purpose, it plans the water resource globally, ordering available flow in time and space, water uses, demand and consumption, with criteria of rationalisation and optimisation. It assumes competence on the programming, approval, implementation and exploitation of hydraulic works of general interest to the State and those of an extra-community character, infrastructures that will be necessary to coordinate integral action. Lastly, it exercises, in the same scope, competence on the resource's concession.

The State, in accordance with the above, has the obligation to make available to each Autonomous Community, at a point in its territory, the necessary flow of water to satisfy the different needs, with special priority for those of supply. As of the connection at this point, the Autonomous Communities assumes their level of responsibility, consisting basically of the "high-level" distribution of the resource. Only for reasons of general interest (prior declaration in this respect) or due to the mere fact of being works that affect more than one Autonomous Community, may the State surpass the functions described.

Notwithstanding the above and in execution of the principle of cooperation between the different Public Administrations, the State can and should collaborate with the Autonomous Communities and Local Corporations, helping these territorial Administrations economically and technically in their responsibility in the service of water supply both "high level" and "low level", via agreements on the matter, but always respecting their scope of competence. Furthermore, the State grants, in application of the State Programme on Local Economic Cooperation and with participation by the European Union Structural Funds, several capital subsidies intended for local councils for water supply.

State responsibility for the hydraulic infrastructures necessary to comply with this undertaking will be in accordance in all cases with needs and forecasts of water planning (National Hydrological Plan and basin management plans).

The Autonomous Communities. The Autonomous Communities, under their exclusive competence in regulating the territory, public works of autonomous interest and projects, construction and exploitation of hydraulic systems, channels and irrigated land of interest (article 148.1.3, 4 and 10 of the Constitution) can and should program, project, approve and execute where relevant, the hydraulic exploitation systems, among these water supply, and other hydraulic works carried out in their territory, when such actions are in their own autonomous interest and their execution does not affect another Community, unless they refer to works that have the legal consideration of general interest, a circumstance in which State competence will prevail over autonomous competence.

It should be understood that the actions mentioned are those intended to provide the services of movement or transport of water, consisting on one hand of carrying out abstraction and storage work where necessary, that is, the facilities that allow, within their territory, connection with the resource provided by the State at the supply point established (in the case of inter-community basins) and on the other hand, the transfer of the resource, through appropriate channeling and pumping, where necessary, to distribution networks on a supramunicipal level or, should such not exist, a municipal level. From this point onwards, a minimum respect should be observed for local autonomy in the matter. In any case, the use of water, if supplied from flow originating in inter-community basins, will require the prior granting of concession over the resource which, as mentioned above, corresponds to the State.

Also, Autonomous Communities must carry out two more important types of functions in particular: to grant, where necessary, economic aid to Local Corporations for the implementation of municipal water-supply and sanitation works and assume responsibility for works in their interest as regards channelling and defence of riverbanks in urban areas.

Apart from the competence rights above, which should be understood as exercised at a minimum, the Autonomous Communities can legislate, plan, program, project, approve, execute and exploit the hydraulic exploitation systems intended, among other uses, for water supply; even establishing their own taxes as a specific instrument to compensate for the cost of the above-mentioned works. Obviously, under the same conditions and in the same territorial area mentioned above. Apart from coordinating the municipal service of water supply and authorising the corresponding tariffs, they may also intervene in "low-level" or residential water distribution, provided that this is established in an autonomous planning instrument.

Works of autonomous responsibility, following the various existing legal precedents (Catalonia, Madrid, Asturias, Galicia, and to a lesser extent the Canary and Balearic Islands, Valencia Community and Navarre), can consist, either of a basic network framed within systems of general infrastructure (usually when they affect an intra-community basin), or of a primary network or "high-level" supply, allowing connection with the secondary network or "low-level" distribution (under municipal or supramunicipal responsibility). Obviously the expedient competence of concession on the resource must be respected.

It is important to mention that these actions of autonomous responsibility constitute a clear execution of territorial regulation, for which the Autonomous Communities are exclusively responsible.

Autonomous competence on hydraulic works, in accordance with article 148.1.10 of the Constitution, can also cover inter-community basins, provided they are of autonomous interest and do not correspond to the general interest of the State (the case of Canal de Isabel II). This situation requires permanent coordination between the autonomous water administration and the corresponding basin organisation, as well as between the different plans that affect the territory and the regulation of water resources.

Local Agencies. In accordance with the terms of Act 7/1985 on the Basis of Local Government, all the **Municipalities**, by themselves or in association, are responsible for rendering, as a minimum service, domestic supply of drinking water (section 26.1.a); although they may request, from the respective Autonomous Community, dispensation from such an obligation (section 26.2) when the Municipalities, due to their particular characteristics, find this function impossible or very difficult to execute. In such a case, it is understood that the Autonomous Community will provide this service by the procedure deemed fit.

Municipal responsibility is interpreted as consisting of providing the "low-level" water distribution service, by connection with the primary or basic network at a supramunicipal level, either through deposits or general intakes or, should there be none, abstracting the resource directly from an aquifer, through pressurised equipment and distribution by means of a secondary network of pipelines and other urban municipal channels to private intake points.

Notwithstanding these minimum functions, municipal action in the matter can also involve planning the secondary distribution network; drafting projects, construction, exploitation and maintenance of "low-level" supply infrastructures and associated facilities; the organization of the service, its control and management (for provision under a monopoly, the approval of the Government agency of the Autonomous Community is required); the purification of water by means of secondary treatment and powers of establishing tariffs. In short, a set of actions that may be grouped under the concept of integrated administration (González Antón [1997]).

The **Provinces**, through the Provincial Governments or other Corporations, must exercise the functions of coordinating the municipal services to guarantee the full, appropriate provision of water supply, as well as assistance and cooperation. The Provincial Governments may also (by autonomous delegation) plan, program, execute and where relevant exploit the “high-level” network; and at the same time implement “low-level” infrastructure works in accordance with the Provincial Plan of cooperation in works and services.

Finally, the Local Agencies may also assume the faculties conferred on them by sectoral, state and autonomous legislation, by means of delegation, which may generally be organised through inter-administrative agreement.

Conclusions. Basically, it may be deduced from the above that the competence framework that empowers the State in the matter differs significantly from the real application that the State makes of such competence. In fact, the practical demonstration of the autonomous competence framework in water supply shows that the functional decentralisation carried out has not been transformed into efficient assumption of obligations by the Autonomous Communities, which have basically carried out functions of aid or coordination for the Local Agencies.

Accordingly, the State, through the widespread use of competence on works of general interest, in many cases distorting it from its proper context, has assumed excessive relevance by undertaking, in recent years, a large part of new “high-level” infrastructure facilities in most of the Communities, thus dealing with those facilities for abstraction, transport and treatment on a supramunicipal level which are the unequivocal responsibility of the Communities, a question that should be taken into account if the Autonomous Communities are to effectively assume their true competence on the matter in the future.

Exceptions to the exercise of competence rights described above is to be found in very few Autonomous Communities that have sufficiently assumed the exercise of the competence conferred on them by constitutional rights on this matter (Catalonia, Madrid, Asturias, Galicia, and to a lesser extent the Canary and Balearic Islands, Valencia Community and Navarre).

In any event, even in these Autonomous Communities, state intervention in the matter is still not limited to its strict scope of competence because, notwithstanding the mechanisms of collaboration via agreement, as carried out with the rest of the Communities, occasionally, and for different reasons, “high-level” supply structures continue to be carried out which, although implemented under the declaration of works of general interest, could be perfectly approached from the perspective of autonomous interest, and would therefore be under exclusive autonomous competence.

Compliance with municipal obligations laid down by basic state legislation, can be generally described as satisfactory, notwithstanding the serious current problems of drought (which have, in many aspects, become structural), and excepting the few occasions of interrupted supply which, even today, take place in small municipalities and in smaller local organisations. This generally favourable situation is due both to the significant effort of the state in recent years, by means of different forms of action (works of interest general, old agreement financing with aid legislation, new assistance mechanisms, etc), and thanks to the significant contribution, in this respect, of virtually all the Autonomous Communities.

As mentioned above, historical experience shows that the State, without any logical criteria, not even with the ups and downs of influence from political change, implements any type of works whether or not they lie within its competence, causing major discrimination between one territory and another and interrupting the functional logic of public expenditure.

Mechanisms must be laid down to avoid fraudulent use of the legal formula of declaring certain works as general interest, so as to transfer the economic responsibility for implementing them from the actually competent Territorial Administration to the General Administration of the State, and to promote co-financing mechanisms between the actually competent Administration and that of the State, when reasons of general interest really exist, so that State promotes works which, in principle, do not lie within its competence.

At the same time, it should be noted that the State manages, administers and maintains a large number of hydraulic infrastructures, associated with supply, that are not within its competence. The appropriate administrative procedures should be promoted so that these infrastructures are transferred to the competent Administration, according to the legislation applicable.

5.7.3. Private participation in the financing of infrastructures

The inclusion of the private sector in the financing of hydraulic infrastructures, which has been taking place in Spain for centuries and with very varied methods of organisation (se, e.g., Bernabé Gil, 1996, pp. 67-88; or López Gómez, 1998, pp. 121), also represents a major element in the new orientation of water policy. And this is true for several reasons, among which, although not the most important perhaps the most immediate, is the fact that it contributes to generating financial resources in a context where budgetary resources are liable to considerable restrictions, and will continue to be so in the near future.

In fact, the extra-budgetary financing instruments designed in Act 13/1996, mentioned above in the corresponding sections of this White Paper, show their main value by observing the effect that can be expected from them in relation to the efficiency of the financial resources applied.

We may be certain that no initiative that provides profits to some sector will be ignored, even though it lacks the attention and the economic backing of the Water Administration. All that is required is the corresponding application to be requested before the competent office in the terms established. The procedure laid down additionally guarantees the correct combination of the private and general interest.

Finally, the application of these mechanisms will also necessarily lead to a significant improvement in the existing relationship between the expenditure on hydraulic infrastructures and their contribution to the national product.

The historical commitment of state budgets to the creation of irrigation infrastructures is no longer justified, at least in a general sense, in the context of an agricultural system progressively opening up to competition from other transnational markets, and when competence as regards irrigation corresponds exclusively to the Autonomous Communities. As mentioned above regarding supply, it will be generally necessary to promote initiative and participation by the irrigators themselves in financing the hydraulic infrastructures that they need or request, notwithstanding the fact that the State can lend its support in situations, even partially, of general interest.

In the same way as occurs, as mentioned above, with certain supply infrastructures, the State maintains and exploits irrigation infrastructures that should be transferred to the corresponding Irrigators' Associations, and which are only in the hands of the State for historical reasons, today lacking all validity. It is therefore expedient to start the administrative process of transferring such infrastructures to the irrigators themselves, thus freeing the State Budgets of an economic burden that there is no reason for them to maintain.

5.7.4. Reform of the Water Administration

Neither appropriate water legislation, nor perfect water planning, nor an abundance of budgetary resources, nor any other regulation or statutory instrument can be fully and effectively deployed without real, sufficient capacities of the Water Administration. The reform of the Administration thus occupies a central position in any in-depth consideration of water policy in the near future.

The Water Administration needs to adapt to new situations and this will unquestionably imply introducing certain modifications, both in the Central Administration Agencies (Environment Ministry) and in the Autonomous Organisations that depend upon it (basically the Hydrographic Confederations).

In the first case, it is necessary to redefine the organisational structure of the Administration, in accordance with the need to respond to the new challenges of competence that the recently-created Environment Ministry is facing, where water is just one of its elements, although of very particular importance due to the central role that the hydrographic network plays within the natural domain. The current structure of the administrative units that manage water do not consider this environmental dimension of water to the extent that would be desirable; nor on the other hand do they have enough human resources specialised in the appropriate areas to be able to fulfil objectives set for this new orientation.

In the second case, the expedience of reforming the basin organisations stems from their serious administrative difficulties to comply with their current functions –qualitatively different and quantitatively extended by the Water Act of 1985– without any significant change taking place in its organizational structure and its human resources.

It is also worth remembering that the primordial aim of managing water from the point of view of governing the public water domain has been overshadowed by the decision to bring together, under a single authority, the competence rights of the old Water Commissions and those of the Hydrographic Confederations, and in contrast to clearly favourable opinions as to this unification, others have pointed out the risks in the new organizational model. The matter is complex, has been broadly debated by doctrine, and deserves some brief consideration here.

The Hydrographic Confederations, put very simply, had the fundamental mission of giving technical support in drafting projects and in executing and exploiting the works paid wholly or partially by the State, which almost exclusively had the purpose of developing irrigation, under the terms of the Act of 7th July, 1911. This activity, carried out by the old Confederations with success and diligence, is simply a particular case of a holder that acquired the right to the exclusive use of water, the same as the grantee for a of water supply system or a hydroelectric exploitation system. Conversely, the Water Commissions were simply peripheral agencies of the Central State Administration, and as such, agencies of hydraulic authority, governing the public domain, and the technical and administrative control and of exploitation systems (see, e.g., Fanlo Loras [1996]).

Conflict existing between the purposes of the two administrative bodies (the development of works and their exploitation, and the control of water use), and the non-integration but mere juxtaposition that their unification consisted of, has occasionally given rise to negative situations in the appropriate administration and conservation of the public water domain and the environmental values supported by it. Following the historical tradition of promotion, the function of works promoter ended up hampering and over-riding, in the Ministry of Public Works (and as a consequence, in the new Hydrographic Confederations), the administrative function of monitoring and control of the public domain, always historically relegated to secondary consideration.

As illustrative anecdotes of this historical bias, we could mention the second-rate consideration that, already in the last century, was given to posts in the Hydrological Divisions (responsible for capacity gauging, itineraries, cartography of exploitation systems, etc.), compared with the greater value of posts in infrastructure construction, with more corporate and social prestige (Mateu Bellés [1995] p. 92); or the scanty supply of means of the old Water Commissions compared with the Hydrographic Confederations; or the salary differences for public employees in Hydraulic Works according to whether they worked on projects, works and budgets, with more bonuses than those dealing with the study, monitoring and protection of the public domain. There is little need to comment on how expressive the three examples are.

Furthermore, we should particularly consider the public functions of policing the waters attributed to the Commissions which have an irrefutable character that cannot be subject to discussion or transactions in any professional organisation, Government Board, Assembly, or Water Council of the Hydrographic Confederation. The solution of intra-agency duality or differentiation has dubious practical effectiveness since all the agency's executive functions are unified in its president.

Besides these organizational questions, it is indispensable in the very short term to carry out an analysis of the Water Administration's internal procedures, to define those processes where it is expedient to grant the fullest autonomy to the basin organisations, and those where intervention by the central agencies of the Environment Ministry is justified, to contribute some added value to the definitive resolution. It is not hard to imagine that some of the supervision and control mechanisms with respect to the basin organisations that are nowadays in the hands of the Directorate General of Hydraulic Works and Water Quality, are historical reminiscences without current objective justification, which may perfectly disappear in favour of the Confederations' necessary autonomy, of the simplification of administrative procedures, and of the global effectiveness of the Water Administration. We will return to this crucial question of effectiveness when referring to problems the public contracts.

The reform of the Water Administration should also be made from the perspective of accepting the fact, repeatedly explained in this White Paper, that as an administration it will no longer be either high-priority nor, essentially, a works promoter. The historical period when the staff of the Water Administration included the best experts on hydraulic works in the country have passed, and the moment has probably arrived when the Administration renounces the status of being a designer and director of projects, to become a client that defines its requirements, and contracts what is necessary to meet them from other companies, without the need for having its own large technical structure, logical and necessary when it was really the designer and promoter of its own projects. This will involve the need for these companies to fully assume the responsibility arising from their works, and individuals to take on responsibility for the quality of their projects and the accuracy of their data. The Administration should, however, increase its concern for controlling the resource, environmental conditions, the maintenance of existing hydraulic property, technical quality and the economic analyses of its actions.

As explained when examining the economic basis and the crisis of the traditional model, it is not appropriate nowadays to invest public money in hydraulic works without previously and fully analysing the costs and benefits, of all kinds, that it involves. It will be necessary to draw up an administrative regulation to be applied to public investment projects. In shaping the basis for this reform there should also be contributions from new financial mechanisms for collaboration between the Water Administration and users in financing public works, which we have referred to in other parts of this White Paper.

5.7.5. Reform of procedures on control and registration of rights

The current situation of the registration of exclusive rights to water use deserves a special mention, and whose historical development, achievements, deficiencies and shortcomings have been commented in detail in previous chapters of this White Paper. The most significant examples of these are:

- The absence of an unified register of rights, because the historical one, existing in the Directorate General of Hydraulic Works and Water Quality, was substituted, as of 1985, by each Confederation's own register, without the regulatory duplication procedure foreseen being made effective.
- The manifest inability to effectively implement the Transitory Provisions of the Water Act in force as regards groundwater.
- The non-registration of rights acquired by extinguishment.
- The absence of registration of concessions for a large part of supply and of State-run irrigation.
- The lack of real definition of situations registered, due to inadequacy of specifications in the registration.

As repeatedly mentioned, the correct management of water resources is incompatible with this situation of undefined rights and deficiencies in the registration of existing rights. The approval of the basin management plans is a historic opportunity to make progress in this matter, for the purposes of which it seems essential to reconsider the administrative registration system associated with the Water Commissions existing today.

Possibly, attributing the responsibility for the registration of water use rights to the agencies specialized in such rights registers, with demonstrated, tested effectiveness in other areas of the legal classification (Property or Company Registers, for example), could be an option in overcoming a historical situation, manifestly inefficient, although it would give rise to complex coordination problems, essential to solve. Another possible approach to the problem that could also be studied is, considering the complementary character of both registers, to focus analysis on the possibilities of their interrelation, and undertake, in the Water Administration itself, the legal-administrative actions and reforms necessary to make it effective.

5.7.6. Reform of contracting procedures

A circumstance that contributes significantly to the inefficiency of the public Water Administration's management system is to do with the administrative procedures of contracting works and technical studies. It is obvious that all action by the Administration must be subject to inevitable general principles of transparency, publicity, equality of opportunities and public control, but procedures governed by the means by which these general principles take shape can give rise to such distortion that, confusing the instruments with the purposes, the system is perverted and does not achieve the objective actually pursued, which is the *best service of general interests.*

The inefficiency of the Spanish administrative system, and the process of the *flight from administrative law* that has taken place, has been recognized and studied for a long time, finally receiving a very negative doctrinal evaluation (see, e.g., Nieto [1996]; Martín-Retortillo [1996]; García de Enterría [1997]; Ariño et al. [1997]).

To understand the reasons for this inefficiency, in the specific area of administrative contracting, it is illustrative to review the series of requisite actions for the ordinary procedure of consultancy and technical assistance contracts, and works contracts (both laid down by Act 13/1995, of May 18th, on Public Administration Contracts). It is hard to imagine an agile, effective Water Administration if such common, simple and routine procedures of public expenditure are not equally agile and effective.

For consultancy and technical assistance, from the moment when a lack or a requirement is detected in the study of a specific question, it is first necessary to request authorization for drafting the corresponding List of Specifications, which involves opening a file and identifying it. Afterwards, authorization must be granted for drafting the List of Specifications. When this has been received, the List of Specifications is drawn up and forwarded for approval and subsequent processing. The next step is the technical approval of the List of Specifications, followed by the file's economic analysis, with approval of the corresponding expenditure and of the list of particular administrative clauses that must govern the contract; after this, there is an invitation to tender for the contract, normally through tender and by open or restricted procedures; in the event of an invitation for bidders, report and selection of bids, applying criteria that, by attempting to be objective, which is necessarily subjective, introduce artificial rigidity that distorts the result of the selection; once put to tender, the contract is adjudicated, followed by its formalisation, after which work on the prior study can begin.

The requisite terms for each of these stages, and the operative experience of the mechanisms that affect the process, make this whole procedure, in the hypothetical event that it evolves satisfactorily and there are no intermediate incidents to delay it, takes somewhere between *one and two years.* This simply means that from the time *a need is detected* for study of some problem, up to when it is possible to *begin* to study it, one to two years goes by, supposing that everything goes according to plan without incidents or delays.

Although these terms may not be critical for some actions, in other cases they will mean that the problem intended for study will have changed when the study begins, the conditions will be different, priorities will have altered and, in short, an effective, rapid administrative response will have become far more difficult –if not impossible– in the changing circumstances and problems of water-related issues, increasingly subject to greater emergencies and rapid alterations.

As regards *works contracts*, the following actions are comprised: request for authorisation to draft the Project, which involves opening and identifying a file; granting authorisation for drafting the Project; drafting the Project (either directly by the services of the Administration itself, or else, more commonly, by formulating The corresponding consultancy and technical assistance contract) and forwarding it for approval and subsequent processing; technical approval of the Project and authorisation to submit it to the procedure of public information, together with forwarding it for environmental impact declaration (in the event that due to the nature of the work this is a legal requisite); approval of the public information dossier carried out for the Project and its definitive approval (having taken into account, where relevant, the requirements laid down by the declaration of environmental impact); economic processing of the file, with approval for the corresponding expenditure and list of particular administrative clauses to govern the contract; tender contract, normally via auction or competitive bidding, and in both cases by open or restricted procedure; adjudication of the contract and its formalisation, after which the work may begin implementation.

This whole process, in the hypothetical event that there exist no intermediate incidents to delay it (such as the frequent need for compulsory purchase of land, with its parallel procedures), comes to an average duration of *between three and five years*, according to the greater or lesser importance of the work itself, and the complexity of the procedure necessary to develop it according to its characteristics.

In short, and as mentioned above, these bureaucratic-administrative processes and procedures mean that the long period of time that passes from when the need arises to carry out a study or implement works, to the formalisation of the contract that enables this to be done, frequently gives rise to situations where, due to the passing of time, some of the conditions or circumstances initially considered or existing have varied, which requires often-substantial modifications to be made during the contract's development, with the resulting delay in its conclusion and increase in cost in most cases. In other cases, the results obtained from the study contracted, although they may be valid in themselves, are no longer wholly applicable or fully effective for the purpose their need was designed. Although not as severe as in the case of studies, the delay in contracting a certain type of works may also mean that they are unable to comply with the function for which they were planned, although they may do so with respect to the future.

As a consequence of the above, and for the purposes of a more effective public management of water-related matters, the need can be seen to adopt measures which, notwithstanding the necessary public guarantees, drastically simplify and reduce the duration of current administrative procedure. Additionally, in implementing expedient, flexible and rigorous programming to prioritise actions to be contracted, according to their typology and characteristics, and the amount of annual credit available, there is a need for the different departments necessarily involved in the administrative procedure to be developed without unjustifiable delay, and that the different documents and stages that comprise it are prepared with expedient quality for the purpose intended.

Control and intervention procedures must also be oriented towards optimum achievement of these same public service objectives, on the understanding that such objectives must coincide significantly with those of the agencies controlled. Accordingly, a better and more efficient control mechanism is that which achieves that the objectives of the agency controlled (basically those of the government) are met with the greatest efficiency and adherence to rules, and not that which, with an erroneous concept of its function, does not contribute to a better or more rigorous fulfilment of such objectives.

5.7.7. Reform of the Water Act

In view of the above, there can be no doubt as to the need for a reform of water-related legislation. On one hand, the new requirements arising from society's commitment with sustainable development with respect to the basic natural resource that is water, requires certain adaptations to the legal regulations in force. On the other hand, to overcome some of the deficiencies highlighted by this White Paper make it advisable to amend the Act of 1985, which is partially obsolete or insufficient.

Basically, the aspects that could be considered for reform are, at least, as follows:

– Consider new realities such as desalination or reuse.

– Regulate hydraulic works as a specific type of public works, thus covering an existing legal loophole that cause legal uncertainty.

– Correct the main deficiencies in management and utilisation of water resources, highlighting their environmental dimension, and introducing new concepts, such as good ecological state, or environmental conservation as a restriction of exploitation systems.

– Enable the real application of the economic-financial regime from the Act in force, ensuring that widespread situations of general non-compliance do not arise, and improving the regulation of those spot circumstances deemed expedient.

– Introduce transparency in the system through consumption measurements and regulation of information rights so as to promote a policy of saving that, as things stand today, is essential.

– Set up effective mechanisms to avoid the discharge of pollutants into inland waters, so as to achieve operative instruments to regularise existing discharge, overcoming a situation where it is more profitable to pollute than to legalise the discharge.

– Promote the functions and powers of the groundwater users' associations and flexibilise the rigidity of the current concession system, adapting it to situations which change at a rate that does not accommodate the concession review system.

– Create effective collaboration between the state water administration and the Autonomous Communities, in a constitutional and statutory context where the simultaneous action of both responds to the logic of serving general interests.

– Strengthen the powers of the participative agencies of the Hydrographic Confederations.

– Adapt systems of acquisition of private rights over water use to the current situation of a scarce resource whose new demand cannot be covered without limit as presupposed by the concession system, with the need to establish transfers between users, socially optimising existing use.

In consideration of these aspects, with the recent approval of Act 46/1999, of 13th December, amending Act 29/1985, of 2nd August, on Water, a step forward has been made in perfecting our regulation of the subject, so that without substantially altering the pre-existing legislation, a better response may be given to its deficiencies, to the complex, changing circumstances of the present moment, and to the need to grant the maximum protection to this natural resource, as an environmental asset of the first order.

6. ABBREVIATIONS AND ACRONYMS

AEAS. Spanish Association for Water Supply and Sanitation (Asociación Española de Abastecimientos de Agua y Saneamiento)

APROMA. Association of Environment Professionalos (Asociación de Profesionales del Medio Ambiente)

TSA. Tagus-Segura Aqueduct

CCS. Insurance Compensation Consortium (Consorcio de Compensación de Seguros)

CDWR. California Department of Water Resources. State of California.

EC. European Commission

CEDEX. Centre for Public Works Studies and Experimentation (Centro de Estudios y Experimentación de Obras Públicas)

CEH. Hydrographic Studies Centre (Centro de Estudios Hidrográficos)

CIMNE. International Centre for Numerical Engineering Methods (Centro Internacional de Métodos Numéricos en Ingeniería)

CIPH. Inter-ministerial Water Planning Committee) Comisión Interministerial de Planificación Hidrológica)

CNAE. National Business Activities Code (Código Nacional de Actividades Empresariales)

COAS. Oficial Supply Control (Control Oficial de Abastecimientos)

COCA. Oficial Water Quality Control (Control Oficial de la Calidad del Agua)

CSN. Nuclear Security Council (Consejo de Seguridad Nuclear)

CYII. Canal de Isabel II

CH. Hydrographic Confederation (Confederación Hidrográfica)

DGC. Directorate General for Roads (Dirección General de Carreteras)

DGCN. Directorate General for Nature Conservation (Dirección General de Conservación de la Naturaleza)

DGMA. Directorate General for the Environment (Dirección General de Medio Ambiente)

DGOH. Directorate General for Hydraulic Structures (Dirección General de Obras Hidráulicas)

DGOHCA. Directorate General for Hydraulic Structures and Water Quality (Dirección General de Obras Hidráulicas y Calidad de las Aguas)

EDAR. Wastewater Treatment Station (Estación Depuradora de Aguas Residuales)

EEA. European Environmental Agency

EMASESA. Empresa Municipal de Abastecimiento y Saneamiento de Aguas de Sevilla S.A.

ERHIN. Study of Water Resources from Snowfall (Estudio de los Recursos Hídricos procedentes de la Innivación)

EWRA. European Water Resources Association

FAO. Food and Agriculture Organization

FEDER. European Regional Development Fund

GEI. Greenhouse Effect Gas (Gases de Efecto Invernadero)

IFIM. Instream Flow Incremental Methodology

INE. National Institute of Statistics (Instituto Nacional de Estadística)

INM. National Institute of Meterology (Instituto Nacional de Meteorología)

IPCC. Intergovernmental Panel Climatic Change

ITGE. Spanish Institute for Technology and Geomining (Instituto Tecnológico y Geominero de España)

WA. Water Act

SCI. Site of Community Interest
MCGA. Models of General Atmospheric Circulation
MCT. Canales de Taibilla Joint Community
MIMAM. Environment Ministry
MINER. Industry and Energy Ministry
MOP. Public Works Ministry
MOPT. Public Works and Transport Ministry
MOPTMA. Public Works, Transport and Environment Ministry
MOPU. Public Works and Town Planning Ministry
MSC. Health and Consumption Ministry
OCDE (OECD). Organisation for Economic Cooperation and Development
OM. Ministerial Order
OMM (WMO). World Meteorological Organisation
OSPARCOM. Oslo Paris Commission
PG. Presidency of the Government
PHABSIM. Physical Habitat Simulation
PIAM. Integral Water Plan for Madrid
PNOH. National Hydraulic Works Plan
PNSD. National Collection and Treatment Plan
POMAL. Operative Local Environment Programme
RAPAPH. Public Water Administration and Water Planning Regulation
RDPH. Regulation of the Public Water Domain
Red ICA (ICA Network) Integrated Water Quality Network
ROEA. Official Gauging Stations Network
SAICA. Automatic Water Quality Information System
SAIH. Automatic Hydrological Information System
SEO. Spanish Ornithological Society
SGOP. Geological Public Works Service
UE (EU). European Union
UIMP. Menéndez Pelayo International University
UNESA. Unidad Eléctrica S. A.
UNESCO. United Nations Educational, Scientific and Cultural Organisation
USDA. United States Department of Agriculture
ZEPA (SPA). Special Protection Area for wild birds

7. REFERENCES

AEAS, *Suministro de Agua Potable y Saneamiento en España (1996). V Encuesta Nacional de Abastecimiento, Saneamiento y Depuración.* Publ. AEAS, 1998. [Drinking Water Supply and Collection in Spain (1996). 5th National Study of Supply, Collection and Treatment].

AGBAR (Sociedad General de Aguas de Barcelona), *Simposium La economía del Agua,* Barcelona, mayo 1993. [Symposium Water Economy].

Aguilera, F. (coord.), *Economía del agua.* MAPA, serie Estudios, nº 69. Madrid, 1992. (2ª ed. 1996). [Water Economy].

Aguilera, F. (ed.), *Economía de los recursos naturales: un enfoque institucional. Textos de S. V. Ciriapy-Wantrup y K. W Kapp.* Colección Economía y Naturaleza, nº 2. Fundación Argentaria. Madrid, 1995a. [Economy of natural resources: an institutional focus].

Aguilera, F., El agua como activo económico, social y ambiental. *El campo,* nº 132. Servicio de Estudios del BBV. Bilbao, 1995b. [Water as an economic, social and environmental asset].

Alba Tercedor, J. y Sánchez Ortega, A., Un método rápido y simple para evaluar la calidad biológica de las aguas corrientes basado en el de Hellawell (1978). *Limnética,* nº 4, pp. 51-56, 1988. [A quick and simple method for evaluating the biological quality of running water based on Hellawell's (1978)].

Albacete, M. y Peña, M., Consideraciones sobre algunos aspectos económicos de la ordenación y las disponibilidades de agua para riego, incl. en: *Agua y futuro en la Región de Murcia.* M. Senent y E. Cabezas (eds.). Asamblea Regional de Murcia, 1995. [Consideration of some economic aspects in the regulation and availability of water for irrigation].

Alcaín Martínez, E., *El aprovechamiento privado del agua y su protección jurídica*. José María Bosch Editor. Barcelona, 1994. [Private water use and its legal protection].

Aldana, A. L., Estrada, E. y Cabezas, E., Modelación hidrológica y de la gestión hidráulica en el sistema automático de información hidrológica: modelos PLU y CREM. *Ingeniería Civil,* nº 104, pp. 81-88, 1996. [Hydrological modelling and water management in the automatic hydrological information system: PLU and CREM models].

Almagro Gorbea, A., La Mina de Daroca, en *La Ciudad. Recorrido por su Historia,* pp. 153. ed. Grupo FCC. 1998. [La mina de Daroca].

Al-Mudayna, (Asociación cultural de la Facultad de Geografía e Historia de la Universidad Complutense). *Historia de los Regadíos en España (... a.C.-1931).* Ed. MAPA, 1991. [History of Irrigation in Spain (... a.C.-1931)].

Altadill Tomé, A., Five solutions for increasing availability of regulated water in a hydrographic basin, incl. en: *Reservoirs in River Basin Development,* pp. 97-106. Balkerna, Rotterdam, 1995. [Five solutions for increasing availability of regulated water in a hydrographic basin].

Álvarez Rico, M., Fernández Ordóñez, R. y Alcaraz Calvo, A. J., *Cánones de regulación y tarifas de riego motivados por obras hidráulicas.* Impr. Lago. Madrid, 1981. [Regulation rates and irrigation fees arising from hydraulic works].

Andreu, J., *Modelo OPTIGES de Optimización de la Gestión de Esquemas de Recursos Hídricos.* Manual del Usuario. Serv. Publ. Universidad Politécnica. Valencia. 1992. [OPTIGES Optimisation Model for Water resources management Plans].

Andreu, J., Capilla, J., Sanchís, E. y Sánchez, S., *AQUATOOL: Sistema Soporte de Decisión para la Planificación de Recursos Hídricos. Manual del Usuario.* Serv. Publ. Universidad Politécnica. Valencia. 1995. [AQUATOOL: Decision Support System for Water Resource Planning. User's Manual].

Andreu, J., Capilla, J. y Cabezas, E., Los sistemas soporte de decisión en la planificación y gestión racionales de los recursos hídricos. *Ingeniería del Agua,* Vol. 1, nº 2, 1994. [Decision support systems in the planning and rational management of water resources].

Andreu, J., Capilla, J. y Ferrer, J., *Modelo SIMGES de Simulación de la Gestión de Recursos Hídricos, Incluyendo Utilización Conjunta. Manual del Usuario.* Serv. Publ. Universidad Politécnica. Valencia. 1992. [SIMGES Simulation Model for Managing Water Resources, Including Joint Use. User's Manual].

APROMA, *I Congreso sobre Caudales Ecológicos, Museo de la Ciencia y de la Técnica de Cataluña,* Tarrassa, 1999. [1st Congress on Ecological Flow].

Aragonés Beltrán, J. M., Las aguas subterráneas en el Plan Hidrológico de la cuenca del Júcar incl. en*: Las aguas subterráneas en las cuencas del Ebro, Júcar e Internas de Cataluña y su papel en la planificación hidrológica.* Actas de las Jornadas celebradas en Lleida (AlH-GE), pp. 177-184. Febrero de 1996. [Groundwater in the Júcar basin management plan].

Aragonès, M., El projecte de reutilització d'aigua per al reg agrícola en el Camp de Tarragona, incl. en: *Jornadas Técnicas. La gestión del agua regenerada* (R. Mujeriego y LI. Sala eds.), pp. 85-96. Consorcio de la Costa Brava. Palamós, jun. 1998. [The water reuse project for agricultural irrigation in Campo de Tarragona].

Arenillas, M. y C. Sáenz. *Los ríos.* Guía Física de España. Alianza Editorial. Madrid. 1987. [Rivers].

Ariño, G., de la Cuétara, J. M. y Martínez López-Muñiz, J. L., *El nuevo servicio público.* Ed. Marcial Pons. Madrid, 1997. [The new public service].

Arrojo, P. y Bernal, E., El regadío en el valle del Ebro, incl. en: *La gestión del agua de riego.* J. López Gálvez y J. M. Naredo (eds). Colección Economía y Naturaleza, nº 8, pp. 139-182. Fundación Argentaria. Madrid, 1997. [Irrigation water management].

Avilés, J., Toro, M. y Peña, R., Indicators of Aquatic Ecosystems Quality in Spain. *Euraqua Technical Review,* nº 4, 1997. [Indicators of Aquatic Ecosystems Quality in Spain].

Azqueta, D. y Ferreiro, A. (eds.), *Análisis económico y gestión de recursos naturales.* Alianza Economía. Madrid. 1994. [Economic analysis and management of natural resources].

Azqueta, D., Aplicación del análisis coste-beneficio a modificaciones de la calidad del agua, incl. en: *Análisis eco-*

nómico y gestión de recursos naturales. D. Azqueta y A. Ferreiro (eds) Alianza Economía, 1994. [Application of the cost-profit analysis to water quality modifications].

Azqueta, D., *Valoración económica de la calidad ambiental.* McGraw-Hill. Madrid. 1997. [Economic assessment of environmental quality].

Baltanás, A., El Plan Hidrológico Nacional. Presentación. *Revista de Obras Públicas,* nº 3.321, pp. 7-18, mayo 1993. [The National Hydrological Plan. Presentation].

Barceló, L., Compés, R., García Álvarez-Coque, J. M. y Tió, C., *Organización Económica de la Agricultura Española*, Fundación Alfonso Martín Escudero, 1995. [Economic Organization of Spanish Agriculture].

Barcelona Llop, J., *La Utilización del Dominio Público por la Administración: Las Reservas Dominiales.* Ed. Aranzadi. Pamplona, 1996. [Public Land Use by the Administration: Public Land Reserves].

Barciela, C., La colonización agraria en España (1939-1951), incl. en: *Agua y modo de producción,* M. T. Pérez Picazo y G. Lemeunier (eds.), Editorial Crítica, Barcelona, 1990. [The agricultural colonisation of Spain (1939-1951)].

Barriendos, M., Gómez, B. y Peña, J. C., Series meteorológicas instrumentales antiguas de Madrid y Barcelona (1780-1860). Características documentales y de observación, incl. en: *Avances en Climatología Histórica en España.*, J. Martín-Vide (ed). Oikos-Tau. Barcelona, 1997. [Old instrumental meteorological series from Madrid and Barcelona (1780-1860)].

Bartolomé, J. L., El agua, dominio público jurídico y bien público económico. incl. en: *Congreso Ibérico sobre Gestión y Planificación de Aguas,* pp. 595-605. Zaragoza, sep. 1998. [Water, legal public domain and and public economic assets].

Baumann, D. D., Boland, J. J. y Michael Hanemann, W., *Urban water demand management and planning.* McGrawHill, 1998. [Urban water demand management and planning].

Becerril, E., *La regulación de los ríos*, Consejo Superior de Investigaciones Científicas, Madrid 1959. [The regulation of rivers].

Benito, G., Machado, M. J. y Pérez-González, A., Respuesta de las inundaciones al Cambio Climático: Datos del último milenio, incl. en: J. J. Ibáñez, B. L. Valero Garcés y C. Machado (eds.). *El paisaje mediterráneo a través del espacio y del tiempo. Implicaciones en la desertificación,* pp. 203-219. Geoforma Ediciones, 1997. [The response of floods to Climatic Change: Data from the last millennium].

Bentabol, H., *Las aguas de España y Portugal.* Est.Tip. de la Vda. e hijos de M. Tello. Madrid. 1900. Ed. facsímil publicada por el Instituto Tecnológico Geominero de España, con presentación de C. Caride de Liñán. 1995. [Water in Spain and Portugal].

Bermejo Vera, J. (director), *Constitución y planificación hidrológica.* Cuadernos Civitas, 1995. [Constitution and water planning].

Bernabé Gil, D., Política Hidráulica en la España de los Austrias, incluido en *Cuatro Siglos de Técnica Hidráulica en Tierras Alicantinas*. Edit. A. Alberola, Instituto de Cultura Juan Gil-Albert. Diputación Provincial de Alicante. 1996. [Water Policy in the Spain of the Austrias].

Bielza de Ory, V., Estado actual de la demografla histórica de Aragón desde 1850 hasta la actualidad, incl. en *Demografía histórica en España.* V. Pérez Moreda y David-Sven Reher (eds.), Ediciones El Arquero. Textos Universitarios. Madrid, 1988. [Current state of Aragón's historical demography from 1850 to the present].

Bocanegra, E. y Custodio, E., Utilización de acuíferos costeros para abastecimiento. *Ingeniería del agua*, Vol. 1, nº 4, pp. 49-78, 1994. [Use of coastal aquifers for supply].

Bolea Foradada, J. A., *Los riegos de Aragón.* Ed. Grupo Parlamentario Aragonés Regionalista de las Cortes de Aragón. 2ª ed., 1986. [Irrigation in Aragón].

Brown, L. e Ingram, H., El valor comunitario del agua: Consecuencias para los pobres de las zonas rurales del sudoeste (1987), incl. en: E. Aguilera (coord.), *Economía del Agua,* 1992. [The community value of water: Consequences for the poor in rural areas of the south-west (1987)].

Bru Ronda, C. y Santafé Martínez, J. M., eds. *Agua y Espacios de Ocio.* Fundación Caja del Mediterráneo. Universidad de Alicante. 1995. [Water and Leisure Areas].

Budyko, M. I. y Zubenok, L. I., The determination of evaporation from the land surface. Izv. Akad, Nauk SSSR, *Ser. Geogr.*, nº 6, pp. 3-17, 1961. [The determination of evaporation from the land surface].

Bustamante, A., y González, S., *Guía Metodológica para la Elaboración del Catálogo de Inundaciones Históricas*, Dirección General de Protección Civil. Madrid, marzo 1997. [Methodological Guide for Drawing up the Catalogue of Historic Floods].

Caballer V. y Guadalajara, N., *Valoración económica del agua de riego.* Ed. Mundi-Prensa. 1998. [Economic assessment of irrigation water].

Cabezas, E., *Trasvases intercuencas y regulación conjunta. El caso Tajo-Segura.* XIV Jornadas Regionales Europeas de la ICID. La Manga (Murcia), mayo 1986. [Interbasin transfers and joint regulation. The Tagus-Segura case].

Cabezas, F., Consideración de los recursos hidrogeológicos y no convencionales en el Plan Hidrológico de la cuenca del Segura. Antecedentes históricos. Incl. en: *Recursos hidrogeológicos y recursos hidráulicos no convencionales,* Seminario de la UIMP de Santander. MOPTMA, 1994. [Consideration of hydrogeological and non-conventional resources in the Segura basin management plan. Historical background].

Cabezas, F., *Informe sobre los pozos de sequía,* Confederación Hidrográfica del Segura, Curso sobre las sequías en España. CEDEX, 1995. [Report on drought wells].

Cabezas, F. y Yagüe, J., Use of the S.A.I.H. for flood managernent in dams, incl. en: *Dam Safety*. L. Berga (ed.), pp. 1.253-1.260. Balkerna, Rotterdam, 1998. [Use of the S.A.I.H. for flood management in dams].

Cabildo Insular de Gran Canaria, *Las aguas del 2000. Plan Hidrológico de Gran Canaria, 1995.* [Water in 2000. Gran Canaria Hydrological Plan, 1995].

Cabrera, E., Espert, V. y López, P. A., El suministro de agua potable en épocas de sequía. El caso de España. Incl en *Gestión de sequías en abastecimientos urbanos*. Editado por E. Cabrera y J. García Serra, pp. 3-26, publ. Universidad Politécnica de Valencia, 1998. [Drinking water supply in periods of drought. The case of Spain].

Cabrera, E. y García-Serra, J., *Problemática de los abastecimientos urbanos. Necesidad de su modernización*, publ. Universidad Politécnica de Valencia, 1997. [Problem of urban supply. The need for modernisation].

Calvo Charro, M., El *régimen jurídico de los humedales*. Instituto Pascual Madoz. Universidad Carlos III de Madrid-Boletín Oficial del Estado. Madrid, 1995. [The legal regime of wetlands].

Candela, L. y Varela, M. (eds.), *La zona no saturada y la contaminación de las aguas subterráneas*. CIMNE. Barcelona, 1993. [The non-saturated zone and groundwater pollution].

Caride de Liñán, C., Evolución histórica de la política hidráulica española respecto a las aguas subterráneas. Incl. en *Política Hidráulica,* Seminario de la UIMP de Santander. MOPT, 1992. [Historical evolution of Spanish water policy with respect to groundwater].

Carles, J., Avellá, L. y García, M., Precios, costos y uso del agua en el regadío mediterráneo. incl. en: *Congreso Ibérico sobre Gestión y Planificación de Aguas*, pp. 231-256. Zaragoza, sep. 1998. [Water prices, costs and uses in Mediterranean irrigation].

CARM-INUA. *Ramblas Costeras de la Región de Murcia. Hidrología e Inundabilidad.* Consejería de Política Territorial y Obras Públicas-Instituto Universitario del Agua (M. Albacete, F. Cabezas, J. T. P. Caris, F. Estrada, M. Senent). Murcia, 1992. [Coastal Ravines in the Region of Murcia. Hydrology and Flood Risk].

Caro-Patón, I., *El derecho a regar. Entre la planificación hidrológica y el mercado del agua.* Marcial Pons, col. Monografías Jurídicas, 1997. [The right to irrigate. Between water planning and the water market].

CCS, *El Consorcio de Compensación de Seguros y la cobertura de los riesgos catastróficos en España.* Madrid, 1998. [Insurance Compensation Consortium and catastrophe hazard coverage in Spain].

CCS, *Las catástrofes naturales y su cobertura aseguradora. Un estudio comparativo*. Madrid, 1999. [Natural catastrophes and their insured coverage. A comparative study].

CDWR, *California Water Plan Update,* Bulletin 160-98, Sacramento CA, 1998. [California Water Plan Update].

CE, *Groundwater And River Resources Action Programme on European Scale* (GRAPES). Contract ENV4-CT95-0186. First Annual Report, Febr. 1997. [Groundwater And River Resources Action Programme on European Scale (GRAPES)].

CEDEX, *Ordenación de zonas inundables*. Madrid, diciembre 1991. [Regulation of flood-prone areas].

CEDEX, *Determinación de las dotaciones de riego en los planes de regadío de la cuenca del Duero.* Madrid, 1992. [Establishing contributions for irrigation in the Douro basin irrigation plans].

CEDEX, *Estudio de máximas precipitaciones diarias en la España peninsular,* Madrid, 1994. [Study of maximum daily precipitation in peninsular Spain].

CEDEX, *Las sequías en España.* Madrid, 1995. [Droughts in Spain].

CEDEX, *Delimitación y síntesis de características de las unidades hidrogeológicas en España según los Planes Hidrológicos de cuenca*. Madrid, 1998a. [Delimitation and summary of characteristics of hydrogeological units in Spain according to basin management plans].

CEDEX, *Estudio sobre el impacto potencial del cambio climático en los recursos hídricos y demandas de agua de riego en determinadas regiones de España.* Madrid, 1998b. [Study of the potential impact of climatic change on water resources and irrigation water demand in certain regions of Spain].

CEDEX, *Análisis comparativo de caudales naturales y caudales registrados con caudales ambientales determinados según la metodología Physical Habitat Simulation*, Madrid, 1998d. [Comparative analysis of natural flow and registered flow with certain cases of environmental flow according to the Physical Habitat Simulation methodology].

CEDEX, *Curso sobre contaminación de suelos y aguas subterráneas.* Madrid, 1998e. [Course on land and groundwater pollution].

CEDEX. *Metodología de cálculo de regímenes de caudales de mantenimiento.* Madrid, 1998c. [Calculation methodology for maintenance flow regimes].

CEH, *Inventario de Recursos Hidráulicos*, Madrid, 1971. [Inventory of Water Resources].

Cimadevilla, C. y Herreras, J. A., Las transferencias de recursos en el Anteproyecto del Plan Hidrológico nacional. *Revista de Obras Públicas,* nº 3.321, pp. 45-63, mayo 1993. [Resource transfers in the Draft Project of the National Hydrological Plan].

Ciriacy-Wantrup, S. V., Economía del agua: relaciones con el Derecho y la Política (1967), incl. en: F. Aguilera (coord.), *Economía del Agua,* 1992. [Water economy: relationships with Law and Politics (1967)].

Coase, R., El problema del coste social (1960), incl. en: *La empresa, el mercado y la ley.* Alianza Editorial, 1994. [The problem of social cost (1960)].

COM(97)49 COM(97)614 COM(98)76 final, *Propuesta modificada de Directiva del Consejo por la que se establece un marco comunitario de actuación en el ámbito de la política de aguas.* Bruselas, marzo 1999. [Amended Proposal for the Council Directive laying down a community framework for action in the scope of water policy].

Consejo Nacional del Agua, *Informe sobre los Planes Hidrológicos de cuenca.* MIMAM. Madrid. 1998. [Report on basin management plans].

COP7 Ramsar, *Resoluciones de la Convención.* San José de Costa Rica. 1999. [Decisions of the Convention].

Costa, J., Misión social de los Riegos en España (1880). incl. en: *Política Hidráulica.* Ed. Colegio de Ingenieros de Caminos, Canales y Puertos. Madrid, 1975. [Social Mission of Irrigation in Spain (1880)].

Couchoud, R., y Sánchez Ferlosio, R., *Hidrología histórica del Segura*. Centro de Estudios Hidrográficos. Madrid, 1965. [Historic Hydrology of the Segura].

Cubillo, E, Casado, C. y Castillo, V., *Caudales ecológicos.* Agencia de Medio Ambiente de la Comunidad de Madrid. 1990. [Ecological Flow].

Cuena, J., El futuro de las tecnologías de gestión del agua: el papel de los sistemas inteligentes en línea, *Jornada Técnica sobre Sistemas de Información y Control en la Gestión del Agua*. Iberdrola Instituo Tecnológico, 1996. [The future of water management technologies: the role of intelligent online systems].

Custodio, E., Recarga artificial de acuíferos. *Boletín de Informaciones y Estudios,* nº 45. Servicio Geológico. MOPU, 1986. [Artificial recharge of aquifers].

Custodio, E., Papel, utilización y gestión de los acuíferos litorales españoles entre el Cap de Creus y Alacant (Alicante). *Las aguas subterráneas en las cuencas del Ebro, Júcar e Internas de Cataluña y su papel en la planificación hidrológica.* Actas de las Jornadas celebradas en Lleida (AlH-GE), pp. 177-184. Febrero de 1996. [Role, use and management of Spanish coastal aquifers between Cap de Creus and Alacant (Alicante)].

CYII, *Manual de Gestión de Sequías.* 2 vols. Canal de Isabel II. Madrid, 1996. [Manual of Drought Management].

Chapa, A., *La construcción de los saltos del Duero 1903-1970. Historia de una epopeya colectiva*. Ed. Universidad de Navarra, 1999. [The construction of the Douro dams 1903-1970. History of a collective drama].

CHD, *Jornada sobre caudales ecológicos y caudales de mantenimiento.* Conferencia Regional del Agua. Ed. Confederación Hidrográfica del Duero. Valladolid, 1997. [Conference on ecological flow and maintenance flow].

CHG, *Control de urgencia del régimen de explotación del recurso hidráulico de los acuíferos de la Mancha Occidental y del Campo de Montiel.* Año 1996. TT. MM. varios (Albacete, Ciudad Real y Cuenca). Informe resumen del acuífero de la Mancha Occidental. 1997. [Emergency control of the water resource exploitation regime in aquifers of Western La Mancha and Campo de Montiel. Year 1996].

Chow, V. T., Maidment, D. R. y Mays, L. W., *Applied Hydrology.* McGraw-Hill. 1988. [Applied Hydrology].

del Amor, F., Gómez, J. y Sánchez, M. I., *Modernización de los regadíos tradicionales de Mula*. Comunidad de Regantes pantano La Cierva. Cajamurcia, 1998. [Modernisation of traditional irrigation in Mula].

del Moral Ituarte, L., Elementos para una teoría de los conflictos territoriales sobre el agua. *Boletín de la Asociación de Geógrafos Españoles,* nº 18. 1er semestre, 1994. [Elements for a theory of territorial conflicts over water].

del Saz, S., *Aguas subterráneas, aguas públicas (El nuevo derecho de aguas).* Marcial Pons, col. Monografías Jurídicas, 1990. [Groundwater, public water (New water laws)].

Delgado Piqueras, E., *Derecho de aguas y medio ambiente,* Ed. Tecnos, 1992. [Water and environment law].

Delgado Piqueras, F., El abastecimiento a poblaciones en la Ley de Aguas. Análisis para una posible reforma. *Revista de Administración Pública*, nº 145, enero-abril 1998. [Population supply in the Water Act. Analysis for a possible amendment].

DGOHCA. *Preservación de los acuíferos de interés estratégico.* Madrid, 1997. [Preservation of aquifers of strategic interest].

DGPT, (Dirección General de Planificación Territorial. MOPTMA), Recursos hídricos y marco territorial, *Ciudad y Territorio. Estudios Territoriales,* Vol. III, nº 105, otoño 1995a. [Water resources and territorial framework].

DGPT, (Dirección General de Planificación Territorial. MOPTMA), El regadío español: evolución reciente, competitividad y perspectivas en el contexto europeo y mundial, *Ciudad y Territorio. Estudios Territoriales,* Vol. III, nº 105, otoño 1995b. [Spanish irrigation: recent evolution, competition and perspectives in a European and world-wide context].

Díaz Cassou, P., *Topografia, Geología, Climatología de la Huerta de Murcia. 1900-1924?* Ed. facsímil librerías París-Valencia. Valencia, 1993. [Topography, Geology, Climatology of the Murcia farmlands. 1900-1924].

Díaz-Marta, M., *Las obras hidráulicas en España.* Ed. doce calles. Fundación Puente Barcas, 1997. [Hydraulic works in Spain].

Doadrio, I., Elvira, B. y Bernat, Y., *Peces Continentales Españoles. Inventario y clasificación de zonas fluviales.* Colección Técnica. ICONA, MAPA. 1991. [Continental Spanish Fish. Inventory and classification of river zones].

Docampo Pérez, L. y García de Bikuña, B., The Basque method for determining instream flows in Northern Spain, *Rivers,* nº 4, v. 4, pp. 292-311, 1995. [The Basque method for determining instream flows in Northern Spain].

Dolz, J., Gómez, M. y Nieto, J., El Ebro en el Delta. *Revista de Obras Públicas,* nº 3.368: pp. 7-14, sep. 1997. [The Ebro at the Delta].

Dueñas, C., El Sistema Automático de Información Hidrológica (SAIH) y su aplicación a la Protección Civil. incl. en *Jornadas sobre el SAIH en la gestión hídrica.* Confederación Hidrográfica del Ebro. DGOH. MOPTMA. Zaragoza, 3 al 7 abril 1995. [The Automatic Hydrological Information System (SAIH) and its application in Civil Protection].

EEA, *The Dobris Assessment.* EEA. Denmark. 1995. EEA. *Surface Water Quantity Monitoring.* Topic Report 3, Inland Waters. Agencia Europea de Medio Ambiente. Copenhague (Dinamarca). 1996a. [The Dobris Assessment].

EEA, *Requirements for Water Monitoring.* Topic Report 1, Inland Waters. Agencia Europea de Medio Ambiente. Copenhague (Dinamarca). 1996b. [Surface Water Quantity Monitoring].

EEA, *Groundwater (quantity and quality) monitoring in Europe.* Agencia Europea de Medio Ambiente. Copenhague (Dinamarca). 1996c. [Groundwater (quantity and quality) monitoring in Europe].

EEA, *Surface Water Quality Monitoring.* Topic Report 2. Agencia Europea de Medio Ambiente. Copenhague

(Dinamarca). 1996d. [Surface Water Quality Monitoring].

EEA, *Water Demand in the European Union.* Contribution from the European topic Centre on Inland Waters (European Environment Agency) to RIVM's DG XI study on priorities. CEDEX. Madrid, marzo 1998. [Water Demand in the European Union].

Elvira, B., Nicola, G., Almodóvar, A., Doadrio, I., Perdices, A. y Velasco, J. C., *Impacto de las obras hidráulicas en la ictiofauna y análisis de viabilidad de algunas medidas correctoras.* ICONA. Madrid, 1995. [Impact of hydraulic works on fish-life and analysis of the feasibility of some corrective measures].

Elvira, B., Nicola, G. G. y Almodóvar, A., *Sistemas de paso para peces en presas.* Monografías CEDEX, 1998. [Systems for fish ladders on dams].

EMASESA, *Crónica de una sequía 1992-1995* (con una introd. de M. Palancar). Sevilla, 1997a. [Chronicle of a drought, 1992-1995].

EMASESA, *El final de la sequía 1996-1997.* Sevilla, 1997b. [The end of the drought 1996-1997].

EMASESA, *Manual de sequía.* Sevilla, 1998. [Drought Manual].

Embid Irujo, A., *La Planificación hidrológica: régimen juridico.* Tecnos. Madrid, 1991. [Water planning: legal regime].

Embid Irujo, A. (Director), *El Plan Hidrológico Nacional.* Civitas. Madrid, 1993. [The National Hydrological Plan].

Embid Irujo, A. (Director), *La calidad de las aguas.* Civitas. Madrid, 1994. [Water quality].

Embid Irujo, A. (Director), *Las obras hidráulicas.* Civitas. Madrid, 1995. [Hydraulic works].

Embid Irujo, A. (Director), *Precios y mercados del agua.* Civitas. Madrid, 1996. [Water prices and markets].

Embid Irujo, A. (Director), *Gestión del agua y medio ambiente*. Civitas. Madrid, 1997. [Water and environment management].

Embid Irujo, A., Condicionamientos jurídicos de una política de precios del agua, incl. en: A. Embid Irujo (Director), *Precios y Mercados del Agua*. Civitas. Madrid, 1996. [Legal conditioning factors for a policy of water prices].

Erhard-Cassegrain, A. y Margat, J., *Introduction á l'économie générale de Veau*. Masson. París. 1983. [Introduction to general water economy].

Erruz, J., Reasignaciones, concesiones sucesivas y aprovechamientos compartidos, incl. en: *La gestión del agua de riego.* J. López Gálvez y J. M. Naredo (eds). *Colección Economía y Naturaleza,* nº 8, pp. 203-232, Fundación Argentaria. Madrid, 1997. [Reallocations, successive concessions and joint exploitation].

Escobar Gómez, G., Ordenación del territorio y planificación hidrológica, *Ciudad y Territorio. Estudios Territoriales,* Vol. III, nº 106, invierno 1995. [Territorial organisation and water planning].

Estevan, A., Las nuevas técnicas de gestión integral de la demanda eléctrica y su aplicación a la economía del agua, incl. en: *La economía del agua en España.* J. M. Naredo (ed). Colección Economía y Naturaleza, nº 7, pp. 103-120, Fundación Argentaria. Madrid, 1997. [New techniques for the integral management of electric power demand and its application to water economy].

Estrada, E., *Garantía en los sistemas de explotación de los recursos hidráulicos.* Monografías CEDEX, Madrid, 1994. [Guarantee in water resources exploitation systems].

Estrela, T. y Témez, J. R., *Planning criteria for flood areas in Spain*. Proc. XXV IAHR Congress. Tokyo. Japon, aug-sep. 1993. [Planning criteria for flood areas in Spain].

Estrela, T. y Quintas, L., El modelo de flujo bidimensional GISPLANA, *Ingeniería Civil,* nº 104, pp. 13-21, Madrid, 1996a. [The GISPLANA bi-dimensional flow model].

Estrela, T. y Quintas, L., El sistema integrado de modelización precipitación-aportación SIMPA., *Ingeniería Civil,* nº 104. pp. 43-52, Madrid, 1996b. [The SIMPA integrated system precipitation-contribution modelling].

Estrela, T., Ferrer, M. y Ardiles, L., Estimación of precipitation-runoff regional laws and runoff maps in Spain using a Geographical Information System. International Hydrological Programme (IHP). UNESCO FRIEND AMHY. Thessaloniki, Greece. 1995. [Estimation of precipitation-runoff regional laws and runoff maps in Spain using a Geographical Information System].

EWRA, *Water Resources Management under Drought or Water Shortage Conditions.* Nicos X. Tsiourtis (ed.) Balkerna. Rotterdam, 1995. [Water Resources Management under Drought or Water Shortage Conditions].

Fanlo Loras, A., La evolución del derecho comunitario europeo sobre el agua, incl. en: A. Embid Irujo (Director), *El nuevo derecho de aguas: las obras hidráulicas y su financiación.* Civitas. Madrid, 1998. [The evolution of European community law on water].

Fanlo Loras, A., *Las Confederaciones Hidrográficas y otras Administraciones Hidráulicas.* Ed. Civitas. Madrid, 1996. [Hidrographic Confederations and other Water Administrations].

FAO, *Programa de acción internacional sobre el agua y el desarrollo agrícola sostenible.* 1991. [International action programme on water and sustainable agricultural development].

Federación Nacional de Comunidades de Regantes de España, *Impacto de la política de precios del agua en las zonas regables y su influencia en la renta y el empleo agrario*. Madrid, 1999. [Impact of water price policy on irrigable zones and its influence on agricultural income and employment].

Ferreiro, A., Valoración económica del agua, incl. en *Análisis económico y gestión de recursos naturales*. D. Azqueta y A. Ferreiro (eds). Alianza Economía, 1994. [Economic assessment of water].

Ferrer, F. J. y Ardiles, L., Análisis estadístico de las series anuales de máximas lluvias diarias en España. *Ingeniería Civil* 1994 (95), pp 87-100, 1994. [Statistical analysis of annual series of maximum daily rainfall in Spain].

Font Tullot, I., *Historia del clima de España. Cambios climáticos y sus causas.* Ed. Instituto Nacional de Meteorología, MTTC. Madrid, 1988. [History of climate in Spain. Climatic change and its causes].

Franco Fernández, F. J., *Un modelo alternativo de trasvase: El Real Canal de Carlos III.* Ed. del autor, Murcia. 1999. [An alternative transfer model: The Carlos III Royal Canal].

Franco Sala, L. *Política económica del medio ambiente.* Cedecs Editorial. Barcelona, 1995. [Economic environment policy].

Fuertes Marcuello, J., El túnel o mina de Daroca, obra hidráulica del siglo XVI. *Revista de Obras Públicas,* pp. 253-261, abril 1987. [The Daroca tunnel or mine, 16th century hydraulic works].

Gallego Anabitarte, A., Menéndez Rexach, A. y Díaz Lema, J. M., *El Derecho de Aguas en España,* A., 2 vols. Ed. MOPU, 1986. [Water Law in Spain].

Garcés, A., Aspectos prácticos de la planificación y de la gestión institucional del agua. La gestión privada de intereses públicos, incl. en: *Congreso Ibérico sobre Gestión y Planificación de Aguas*. pp. 649-656. Zaragoza, sep. 1998. [Practical aspects in water planning and institutional management. The private management of public interests].

García de Bikuña, B., Problemática de la determinación de caudales ecológicos y de su aplicación: sistema RECE, incl. en: *Conferencia Regional del Agua. Jornada sobre caudales ecológicos y caudales de mantenimiento,* pp. 79-87. Ed. Confederación Hidrográfica del Duero. Valladolid, 1997. [Problems in establishing ecological flow and its application: RECE system].

García de Enterría, E., *Democracia, Jueces y Control de la Administración.* 3ª ed. ampliada. Civitas. Madrid, 1997. [Democracy, Judges and Control of the Administration].

García de Jalón, D., Regímenes de caudales ecológicos o de compensación: el método IFIM o del APU, incl. en *Conferencia Regional del Agua. Jornada sobre caudales ecológicos y caudales de mantenimiento,* pp. 9-23, Ed. Confederación Hidrográfica del Duero. Valladolid, 1997. [Regimes of ecological or compensation flow: the IFIM or the APU method].

García de Jalón, D. y González del Tánago, M., Métodos biológicos para el estudio de la calidad de las aguas. Aplicación a la cuenca del Duero. Monografías del ICONA. MAPA, 1986. [Biological methods for studying water quality. Application to the Douro basin].

García Sanz, B., *La sociedad rural ante el siglo XXI,* serie Estudios, MAPA, 1996. [The rural society on the threshold of the 21st century].

García, R., y Gaztelu, L., *Proyecto de Obras de Defensa contra las inundaciones en el Valle del Segura.* 1886. [Project for defensive works against floods in the Segura valley].

Garrido Colmenero, A., *La economía del agua: Métodos de evaluación económica del uso del agua en la agricultura. Teorías y trabajos empíricos.* MAPA. Serie Recopilaciones Bibliográficas. Madrid, 1995. [Water economy: Economic evaluation methods for water use in agriculture. Empirical theories and works].

Garrote, L., Rodríguez, I. C. y Estrada, F., Una evaluación de la capacidad de regulación de las cuencas de la España peninsular. *VI Jornadas Españolas de Presas.* Vol. 2, pp. 645-656. Málaga, 1999. [An evaluation of storage capacity in the basins of peninsular Spain].

Gaviria, M. y Grilló, E., vol. recopilatorio *Zaragoza contra Aragón*. Los Libros de la Frontera. Col. Realidad Geográfica. Barcelona, 1974. [Zaragoza against Aragón].

Generalitat de Catalunya, *Pla Director del delta de l'Ebre.* Departament de Política Territorial y Obres Públiques. 1996. [Regulation Plan for the Ebro delta].

Generalitat de Catalunya, *Memòria econòmica de l'avantprojecte de Llei d'ordenació i gestió de l'aigua.* Departament de Medi Ambient. 1999. [Economic Report on the draft bill on water regulation and management].

Generalitat Valenciana, *Delimitación del riesgo de inundación a escala regional en la Comunidad Valenciana.* COPUT. Serie de Cartografía Temática, nº 1, F. Francés, Valencia, 1997. [Delimitation of flood risk on national scale and regional scale in the Valencia Community].

Gil Olcina, A., Evolución de los grandes regadíos deficitarios del sureste peninsular, incl. en *Demanda y Economía del Agua en España,* ed. A. Gil Olcina y A. Morales Gil. Instituto Universitario de Geografía de la Universidad de Alicante. CAM-Diputación de Alicante. 1988. [Evolution of major deficit-bearing irrigated areas in the peninsular south-east].

Gil Olcina, A., *La propiedad de las aguas perennes en el sureste ibérico.* Publ. de la Universidad de Alicante, 1993. [Ownership of perennial water in the peninsular south-east].

Gil Olcina, A., Desequilibrio de Recursos Hídricos y Planteamiento de Trasvases en Territorio Valenciano, incl. en *Planificación Hidráulica en España.* Ed. de A. Gil Olcina y A. Morales Gil. Fundación Caja del Mediterráneo. 1995. [Imbalance of Water Resources and Transfer Proposals in the Territory of Valencia].

Gil Olcina, A., y Morales Gil, A. (coords.), *Hitos históricos de los regadíos españoles,* Serie Estudios, MAPA, 1992. [Historical landmarks in Spanish irrigation].

Gobierno Vasco, *Red de vigilancia de la calidad de las aguas y del estado ambiental de los ríos de la Comunidad Autónoma del País Vasco,* Departamento de Urbanismo, Vivienda y Medio Ambiente, Vitoria, 1995. [Surveillance network for water quality and the environmental state of rivers in the Autonomous Community of the Basque Country].

Gómez Ortega, J., Lizárraga, F. y de Churruca, E., *Estudio de las Inundaciones del Júcar de 1864,* informe fechado en 1866. Ed. facsímil de la Confederación Hidrográfica del Júcar. 1988. [Study of Floods on the Júcar from 1864].

González Bernáldez, E., *Ecología y paisaje,* Editorial Blume, Madrid. 1981. [Ecology and Landscape].

González Bernáldez, E., *Los paisajes del agua: terminología popular de los humedales,* J. M. Reyero, Madrid. 1992. [Water landscapes: popular wetland terminology].

González del Tánago, M., Las riberas, elementos clave del paisaje y en la gestión del agua. incl. en: *Congreso Ibérico sobre Gestión y Planificación de Aguas*. pp. 395-407. Zaragoza, sep. 1998. [River banks, key elements in the landscape and in water management].

González Pérez, J., El Plan Hidrológico Nacional. *Revista de Administración Pública*, nº 126, sept-dic 1991. [National Hydrological Plan].

González Pérez, J., Toledo, J. y Arrieta, C., *Comentarios a la Ley de Aguas*. Civitas. Madrid, 1987. [Comments on the Water Act].

González Tascón, l., Caps. 1-7 de *Felipe II. Los ingenios y las máquinas. Ingeniería y obras públicas en la época de Felipe II*. Edit. Sociedad Estatal para la Conmemoración de los Aniversarios de Felipe II y Carlos V Madrid, 1998. [Philip II. Inventions and machines. Engineering and public works in the time of Philip II].

González Tascón, I., Ciencia y Técnica Hidráulicas en la España del Quinientos, incluido en: *Cuatro Siglos de Técnica Hidráulica en Tierras Alicantinas*. Edit. A. Alberola, Instituto de Cultura Juan Gil-Albert. Diputación Provincial de Alicante. 1996. [Hydraulic Science and Technique in the Spain of 1500].

González-Antón, C., *Los Servicios Públicos Locales del Agua. Régimen Jurídico de su Gestión Integrada*. Publs. de la Universidad de León, 1997. [Public Local Water Services. Legal Regime of its Integrated Management].

Gundermann, H., An estimate of the future demand for water in a region. Forecasting techniques, incl. en: AGBAR *Simposium La economía del Agua*, 1993. [An estimate of the future demand for water in a region. Forecasting techniques].

Heras Moreno, G., Planificación hidrológica y caudales ecológicos, incl. en: A. Embid Irujo (Director), *La calidad de las aguas*. Civitas. Madrid, 1994. [Water planning and ecological flow].

Heras, R., Experiencias en problemas de regulación de caudales y máximas crecidas, en ONU (1977). *Conferencia de las Naciones Unidas sobre el Agua*. 1977. [Experiences with problems regulating flow and maximum high water].

Hérin, R., Agua, espacio y modos de producción en el Mediterráneo. Incl. en: *Agua y modo de producción*. M. T. Pérez Picazo y G. Lemeunier, eds. Editorial Crítica, Barcelona, 1990. [Water, space and production methods in the Mediterranean].

Hernández-Pacheco, E., *Fisiografía del solar hispano*. Real Academia de Ciencias Exactas, Físicas y Naturales, 2 vols. Madrid, 1956. [Physiography of Spanish Territory].

Hervás, J. L., *Aguas de Murcia: su evolución como empresa mixta*. XVII Jornadas Técnicas y Asamblea General. AEAS. Murcia. 1996. [Water in Murcia: its evolution as a mixed enterprise].

Ibáñez, C., Prat, N., Canicio, A. y Curcó, A., *El delta del Ebro, un sistema amenazado*. Bakeaz. Bilbao. 1999. [The Ebro Delta, a threatened system].

IIE-ITGE-UNESA, *El agua en España*, Instituto de la Ingeniería de España, Madrid, 1991. [Water in Spain].

IME, *El agua como elemento integrador de España*, Fundación IME (Instituto para la Modernización de España). Madrid, 1998. [Water as an element to integrate Spain].

INE, *Proyección de la población española para el periodo 1980-2010*. 2 vols. Madrid. 1988. [Forecast of the Spanish population for the period 1980-2010].

INE, Proyección de la población española. Cifras provisionales. Publicaciones electrónicas. Madrid. 1994. [Forecast of the Spanish population. Provisional figures].

INE, *Anuario estadístico 1995*. Madrid, 1995a. [Statistical yearbook 1995].

INE, *Proyecciones de la población de España, calculadas a partir del Censo de población de 1995*. Madrid, 1995b. [Forecasts of the Spanish population, calculated from the 1995 population Census].

INE, *Estadísticas Ambientales. Precios del Agua*. Madrid. Septiembre 1998. [Environmental Statistics].

INM, *Homogeneidad y variabilidad de los registros históricos de precipitación en España*. MIMAM, serie monografías, 1996. [Homogeneity and variability of historical rainfall registers in Spain].

IPCC, *Cambio Climático 1995*. 2ª Evaluación. Informe del Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC), 1995. [Climatic Change 1995].

ITGE, *Las Aguas Subterráneas en España. Estudio de síntesis*. Madrid, 1989. [Groundwater in Spain. Summary Study].

ITGE, *Medida y evaluación de las extracciones de agua subterránea* (Ballester, Fernández y López Geta, eds.), Madrid, 1999. [Measurement and evaluation of groundwater abstractions].

James, L. D. y Lee, R. R., *Economics of Water Resources Planning*, McGraw Hill, 1971. [Economics of Water Resources Planning].

Jaquenod, S., *El Derecho Ambiental y sus Principios Rectores*, MOPU-DGMA. Madrid, 1989. [Environmental Law and Its Governing Principles].

Jiliberto, R. y Merino, A., Sobre la situación de las Comunidades de Regantes, incl. en: *La gestión del agua de riego*. J. López Gálvez y J. M. Naredo (eds). *Colección Economía y Naturaleza*, nº 8. Fundación Argentaria. Madrid, 1997. [On the situation of Irrigator's Associations].

Jiménez Díaz, R. M., y Lamo de Espinosa, J. (coords.), *Agricultura sostenible*. Ed. Mundi-Prensa, 1998. [Sustainable Agriculture].

Jové Vintró, J. L., Financiación de las grandes infraestructuras del ciclo integral del agua, incl. en: AGBAR *Simposium La economía del Agua*, 1993. [Financing major infrastructures in the integral water cycle].

KeIso, M., (1967) El síndrome de “el agua es diferente”, o ¿qué está pasando con la industria del agua?, incl. en: F. Aguilera (coord.), *Economía del Agua*, 1992. [The “water is different” syndrome, or What is going on with the water industry?].

Krinner, W., García Cantón, A. y Estrada, E., Method for estimating efficiency in spanish irrigation systems, *Journal of Irrigation and Drainage Engineering*, ASCE vol. 120, nº 5, pp. 979-986, sep-oct 1994. [Method for estimating efficiency in Spanish irrigation systems].

Labajo, A., Posibles efectos del Cambio Climático de origen antrópico sobre el régimen de precipitaciones en la Península Ibérica. Incl. en: *Los Recursos Hídricos en* *los Países Mediterráneos,* pp. 337-355. 2ª Conferencia Internacional de Hidrología Mediterránea. Iberdrola Instituto Tecnológico. Valencia, 1996. [Possible Effects of Climatic Change of anthropic origin on the regime of precipitation in the Iberian Peninsula].

Linés Escardó, A., *Cambios en el sistema climático.* Ed. Instituto Nacional de Meteorología, MTTC. Madrid, 1990. [Changes in the climatic system].

López Bosch, L. El abastecimiento de agua a las comarcas de Tarragona, incl. en: *El agua en Catalunya.* L. Berga (ed.). Barcelona. 1995. [Water supply to the districts of Tarragona].

López García, J. A., de Juana Garciaecheverría, I. y del Río Gil, F. J., La reutilización integral de las aguas residuales urbanas en Vitoria, incl. en: *Congreso Ibérico sobre Gestión y Planificación de Aguas,* pp. 151-169. Zaragoza, sep. 1998. [The integral reuse of urban waste water in Vitoria].

López Geta, J. A. y Murillo, J. M., Recarga Artificial de Acuíferos. Experiencias Realizadas por el Instituto Tecnológico Geominero de España. *XI Congreso Latinoamericano de Geología.* Caracas (Venezuela). 1995. [Artificial Recharge of Aquifers. Experiments carried out by The Geomining Technology Institute of Spain].

López Gómez, A., *La Navegación por el Tajo. El Reconocimiento de Carducci en 1641 y Otros Proyectos.* Real Academia de la Historia. Madrid. 1998. [Sailing on the Tagus. Carducci's Reconnais-sance in 1641 and other Projects].

López-Camacho, B., Método simplificado de gestión de acuíferos para una integración en sistemas de explotación conjunta. *IV Asamblea Nacional de Geodesia y Geofísica.* Zaragoza, 1981. [Simplified method for managing aquifers to integrate joint exploitation systems].

López-Camacho, B., La gestión del agua, incl. en: Naredo, J. M., y F. Parra (comps.), *Hacia una ciencia de los recursos naturales.* Siglo XXI. Madrid, 1993. [Water management].

Lopez-Gálvez, J., y Losada, A., Uso del agua de riego en Almería, incl. en: *La economía del agua en España.* J. M. Naredo (ed). Colección Economía y Naturaleza, nº 7, pp. 143-176, Fundación Argentaria. Madrid, 1997. [Use of irrigation water in Almería].

López-Galvez, J. y Naredo, J. M. (eds.), *La gestión del agua de riego*. Colección Economía y Naturaleza, nº 8. Fundación Argentaria. Madrid, 1997. [Irrigation water management].

Lorenzo Pardo, M., El Ebro y Zaragoza (1920), incl. en *La Conquista del Ebro,* pp. 103-127, Editorial y Fotograbado Heraldo de Aragón, Zaragoza, 1931. [The Ebro and Zaragoza (1920)].

Lorenzo Pardo, M., Política hidráulica (1924), incl. en *La Conquista del Ebro,* pp. 25-46, Editorial y Fotograbado Heraldo de Aragón, Zaragoza, 1931. [Water policy (1924)].

Llamas, M. R., *El Agua en España: Problemas Principales y Posibles Soluciones.* Papeles del Instituto de Economía y Mercado, nº 2. FAES. Madrid, 1994. [Water in Spain: Main Problems and Possible Solutions].

Llamas, M. R., Las aguas subterráneas en España. El campo, nº 132. Servicio de Estudios del BBV Bilbao, 1995b. [Groundwater in Spain].

Maass, A., Hufschmidt, M. M., Dorfman, R., Thomas jr., H. A., Marglin, S. A. y Fair, G. M., *Design of Water-Resource Systems. New Techniquesfor Relating Economic Objectives, Engineering Analysis, and Governmental Planning.* Harvard University Press, Cambridge, MA, 1962. [Design of Water-Resource Systems. New Techniques for Relating Economic Objectives, Engineering Analysis, and Governmental Planning].

Maass, A., y Anderson, R. L., *...And the Desert Shall Rejoice. Conflict, Growth, and Justice in Arid Environments*. The MIT Press, Cambridge. 1978. […And the Desert Shall Rejoice. Conflict, Growth, and Justice in Arid Environments].

Maestre Rosa, J., *Comunidades de Regantes. Concepto, Naturaleza Jurídica y Regulación positiva.* Ed. Bosch, Barcelona, 1969. [Irrigator's Associations. Concept, Legal Nature and Positive Regulation].

Mairal, G., Bergua, J. A. y Puyal, E., *Agua, tierra, riesgo y supervivencia.* Prensas Universitarias de Zaragoza. 1997. [Water, land, risk and survival].

Maluquer de Motes, J., La despatrimonialización del agua: movilización de un recurso natural fundamental. Incl. en: *Historia agraria de la España contemporánea.* A. García Sanz y R. Garrabou (eds.) Editorial Crítica, Barcelona, 1985. [The privatisation of water: mobilisation of a fundamental natural resource].

Maluquer de Motes, J., Las técnicas hidráulicas y la gestión del agua en la especialización industrial de Cataluña. Su evolución a largo plazo. Incl. en: *Agua y modo de producción.* M. T. Pérez Picazo y G. Lemeunier (eds.) Editorial Crítica, Barcelona, 1990. [Hydraulic techniques and water management in industrial specialisation of Catalonia. Its long-term evolution].

Mandelbrot, B. B. y Wallis, J. R., Noah, Joseph and operational hydrology. *Water Resources Research,* vol. 4, pp. 909-920. 1968. [Noah, Joseph and operational hydrology].

MAPA, *Anuario de Estadística Agraria*. Madrid, 1991. [Agricultural Statistical Yearbook].

MAPA, *Plan Nacional de Regadíos. Horizonte 2005.* Madrid, febrero 1996. [National Irrigation Plan. Horizon 2005].

MAPA, *Anuario de Estadística Agraria*. Madrid, 1997. [Agricultural Statistical Yearbook].

MAPA, *Plan Nacional de Regadíos. Horizonte-2008.* Borrador de marzo de 1998. MAPA-ICONA. *Mapa de estados erosivos*. Madrid, 1994. [National Irrigation Plan. Horizon-2008].

MAPA-MAP-MOPU, *Historia y Evolución de la Colonización Agraria en España.* 4 vols. Madrid, 1988. [History and Evolution of agricultural colonisation in Spain].

Marco, J. B., El agua como factor de estrangulamiento de la economía en las Comunidades Valenciana y Murciana, *Ciudad y Territorio. Estudios Territoriales,* Vol. III, nº 105, otoño 1995. [Water as a factor in strangling the economy in the Valencia and Murcia Communities].

Marchena Gómez, M., Agua y turismo en la Andalucía mediterránea, incl. en: *Demanda y Economía del Agua en España,* ed. A. Gil Olcina y A. Morales Gil. Instituto

Universitario de Geografía de la Universidad de Alicante. CAM-Diputación de Alicante. 1988. [Water and tourism in Mediterranean Andalusia].

Margalef, R., Planas, D., Armengol, J., Vidal, A., Prat, N., Guiset, A., Toja, J. y Estrada, M., *Limnología de los embalses españoles*. MOP-DGOH, 1976. [Limnology of Spanish reservoirs].

Margalef R., Diversidad de especies en las comunidades naturales, *Pub. Inst. Biol. Apl.*, 6, pp. 59-72, Barcelona, 1951. [Diversity of species in natural communities].

Margalef, R., *Ecología.* Planeta, 1981. [Ecology].

Margat, J., *The overexploitation of aquifers.* Selected Papers AIH. Ed. Heiser. Hannover, (Alemania) 1992. [The overexploitation of aquifers].

Mariño, F. J., Aplicación de la metodología IFIM para la determinación del caudal ecológico en una minicentral hidroeléctrica, incl. en: *Conferencia Regional del Agua. Jornada sobre caudales ecológicos y caudales de mantenimiento*, pp. 73-77, Ed. Confedera-ción Hidrográfica del Duero. Valladolid, 1997. [Application of IFIM methodology to determine the ecological flow of a hydroelectric mini-power station].

Martín Gaite, C., *El Conde de Guadalhorce. Su época y su labor.* Ed. Colegio de Ingenieros de Caminos, Canales y Puertos. Madrid, 1983. [The Count of Guadalhorce. His life and times].

Martín Mateo, R., *Derecho Ambiental.* Ed. IEAL. Madrid, 1997. [Environmental Law].

Martín Mendiluce, J. M., Evolución histórica de los conceptos y de la práctica de la planificación hidrológica, incl. en: *Conceptos y métodos para la planificación hidrológica.* J. Andreu (ed.). CIMNE, Barcelona, 1993. [Historical evolution of concepts and practice in water planning].

Martín Mendiluce, J. M., Un posible escenario del futuro de los regadíos españoles, *Ingeniería Civil*, nº 103, 1996a. [A possible future scenario for Spanish irrigation].

Martín Mendiluce, J. M., Los embalses en España. Su necesidad y trascendencia económica. *Revista de Obras Públicas*, nº 3.354, pp. 7-24, mayo, 1996b. [The reservoirs of Spain. Their economic necessity and importance].

Martín Mendiluce, J. M., y Gil Egea, J. M., La infraestructura hidráulica española. Consideraciones sobre su desarrollo en los próximos años (1990-2010), incl. en: *Las infraestructuras en España: carencias y soluciones.* Publicaciones del Instituto de Estudios Económicos. Madrid, 1990. [Spanish Hydraulic Infrastructures. Considerations on their development in coming years (1990-2010)].

Martín Rebollo, L., Las transferencias de recursos hidráulicos en el Anteproyecto de Ley de Plan Hidrológico Nacional, incl. en: A. Embid Irujo, *El Plan Hidrológico Nacional.* Civitas. Madrid, 1993. [Water resource transfers in the Draft National Hydrological Plan].

Martínez Gil, F. J., Historia de la hidrogeología española. Incl. en: *Recursos Hidrogeológicos y Recursos Hidráulicos no Convencionales*. Seminario de la UIMP de Santander, pp. 41-87. MOPTMA, 1994. [History of Spanish Hydrology].

Martínez Gil, F. J., *La nueva cultura del a*History of Spanish Hydrology*gua en España.* Ed. Bakeaz. Bilbao, 1997. [The new culture of water in Spain].

Martínez, F., Los centros de Investigación. *Revista de Obras Públicas*, nº 3.388, pp. 208-214, jun. 1999. [Research centres].

Martín-Retortillo, S., Competencias constitucionales y autonómicas en materia de aguas. *Revista de Administración Pública*, nº 128. Madrid, 1992. [Constitutional and autonomous competence on water-related issues].

Martín-Retortillo, S., *El derecho civil en la génesis del derecho administrativo y de sus instituciones.* Civitas. Madrid, 1996. [Civil law in the genesis of administrative law and its institutions].

Martín-Retortillo, S., *Derecho de Aguas.* Civitas. Madrid, 1997. [Water Law].

Martín-Retortillo, S., Martín Rebollo, L., Bermejo Vera, J. y Martín-Retortillo, L., *Aspectos jurídicos del trasvase del Ebro*, Caja de Ahorros de La Inmaculada, Zaragoza, 1975. [Legal Aspects of the Ebro Transfer].

Marzo, E, Reutilización del agua en la Costa del Sol Occidental, incl. en: *Jornadas Técnicas. La gestión del agua regenerada*. (R. Mujeriego y Ll. Sala, eds.) pp. 75-84. Consorcio de la Costa Brava. Palamós, jun. 1998. [Water Reuse in the Western Costa del Sol].

Más Hernández, J., La ictiofauna continental de la cuenca del río Segura. Evolución histórica y estado actual. *Anls. Biol.* Publs. de la Universidad de Murcia (Biol. Amb. 2), nº 8, pp. 3-17. 1986. [Continental fish life in the River Segura Basin. Historical evolution and current state].

Matés Barco, J. M., *La conquista del agua. Historia económica del abastecimiento urbano.* Publ. Universidad de Jaén, 1999. [The conquest of water. Economic history of urban supply].

Mateu Bellés, J., Planificación Hidráulica de las Divisiones Hidrológicas (1865-1899), incluido en: *Planifi-cación Hidráulica en España.* Ed. de A. Gil Olcina y A. Morales Gil. Fundación Caja del Mediterráneo. 1995. [Water Planning of Hydrogeological Divisions (1865-1899)].

Mateu, E. y Calatayud, S., Control del agua y conflictividad social en la expansión del regadío: la Acequia Real del Júcar. *Áreas*, nº 17, pp. 51-77, 1997. [Water control and social conflict in the expansion of irrigation: the Júcar Royal Irrigation Canal].

MCT, *Canales del Taibilla. 50 años creando futuro.* Publ. MIMAM, 1995. [Canales del Taibilla. 50 years creating future].

MCT, *La gestión del servicio* (sucesivas Memorias anuales). Publ. MIMAM, 1998. [Service management. (successive Annual Reports)].

Melgarejo Moreno, J., *La intervención del Estado en la cuenca del Segura, 1926-1986.* Institut de Cultura Juan Gil-Albert. Diputació Provincial d'Alacant. Colecc. Textos Universitaris. 1995. [State intervention in the Segura Basin, 1926-1986].

Melgarejo Moreno, J., El trasvase Tajo-Segura en el centro de la tormenta política de la transición. *Áreas*, nº 17, pp. 129-145, 1997. [The Tagus-Segura transfer in the centre of the transition-period political storm].

Méndez Gutiérrez del Valle, R., *Las Actividades Industriales*, col. Geografía de España, ed. Síntesis, 1990. [Industrial Activities].

Menéndez Rexach, A., Reflexiones sobre un mercado de derechos de aguas en el ordenamiento jurídico español. Incluido en: A. Embid, ed. *Precios y Mercados del Agua* [1996]. [Reflexions on a market of water rights in the legal regulation of Spain].

Menéndez Rexach, A., y Díaz Lema, J. M., La Ley de Aguas de agosto de 1985: Análisis Institucional. Vol. 1, parte tercera de *El Derecho de Aguas en España*, A. Gallego Anabitarte, A. Menéndez Rexach, y J. M. Díaz Lema. Ed. MOPU, 1986. [The Water Act of August, 1985: Institutional Analysis].

Menéndez, M., Management and prevention of crisis situations: Floods, Droughts and Institutional Aspects in Spain. *Third Technical Review of Euraqua*. Coblenza, 1997. [Management and prevention of crisis situations: Floods, Droughts and Institutional Aspects in Spain].

MIMAM, *Estado actual de la calidad y la contaminación de las unidades hidrogeológicas. Propuestas de actuación*. DGOHCA 1996a. [Current state of the quality and pollution of hydrogeological units. Proposals for action].

MIMAM, *Indicadores ambientales. Una propuesta para España*. Ministerio de Medio Ambiente. Madrid. 1996b. [Environmental indicators. A proposal for Spain].

MIMAM, *Catálogo de acuíferos con problemas de sobreexplotación o salinización*. DGOHCA-ITGE. 1997a. [Catalogue of aquifers with over-exploitation or salinisation problems].

MIMAM, *Una regla de explotación para la programación de trasvases del Acueducto Tajo-Segura*. Dirección General de Obras Hidráulicas, Madrid, noviembre 1997b. [An exploitation rule for programming transfers via the Tagus-Segura Aqueduct].

MIMAM, *Programa de ordenación de acuíferos sobreexplotados/salinizados. Formulación de estudios y actuaciones*. DGOHCA-ITGE. 1998a. [Regulation programme for over-exploited/salinised aquifers. Form-ulation of studies and actions].

MIMAM, *Integración de los acuíferos en los sistemas de explotación*. DGOHCA-ITGE. 1998b. [Integration of aquifers in exploitation systems].

MIMAM, Sistema español de indicadores ambientales: subáreas de agua y suelo. Madrid, 1998c. [Spanish system of environmental indicators: sub-areas of water and land].

MIMAM, *Terceras Jornadas sobre Suelos Contaminados*. Madrid, 1998d. [Third Workshops on Polluted Land].

MIMAM. *Segunda Comunicación Nacional de España. Convención Marco de las Naciones Unidas sobre el Cambio Climático*. Madrid, 1998e. [Second National Communication by Spain. Framework United Nations Convention on Climaqtic Change].

MIMAM. *Compilación de actuaciones de emergencia por sequía relativas a aguas subterráneas en las cuencas hidrográficas del Guadiana, Guadalquivir, Sur, Júcar y Ebro*. 3 vols. Madrid, 1999. [Compilation emergency groundwater-related actions due to drought in the hydrographic basins of the Guadiana, Guadalquivir, Sur, Júcar and Ebro].

Ministerio de Sanidad y Consumo, *Calidad de las aguas de baño en España. Año 1997*. Serie de Informes Tecnicos, nº 11. Madrid. 1997. [Bathing water quality in Spain. Year 1997].

MOP, *Informe sobre el Aprovechamiento Integral del Ebro*. Madrid, 1974. [Report on the Integral Exploitation of the Ebro].

MOP-CEH, *Datos físicos de las corrientes clasificadas por el CEH*. Madrid. 1965. [Physical data on water courses classified by the CEH].

MOP-CEH, *Clasificación decimal de los ríos*. Madrid. 1966. [Decimal classification of rivers].

MOP-CEH, *Anteproyecto General de aprovechamiento conjunto de los recursos hidráulicos del Centro y Sureste de España*. auts. J. M. Martín Mendiluce y J. M. Pliego. Madrid, 1967. [General Draft Project for the joint exploitation of water resources in the Centre and South-East of Spain].

MOP-DGOH, *Estadística sobre embalses y producción de energía hidroeléctrica*, Madrid, (varios años). [Statistics on reservoirs and hydroelectric energy production].

MOPT, Las inundaciones en España. Informe General. 1983. [Floods in Spain. General Report].

MOPT, *Estudio de las zonas húmedas de la España peninsular. Inventario y tipificación*. Madrid, 1991. [Study of wetland areas in Peninsular Spain].

MOPT, *Atlas Nacional de España. Secc. 2, Grupo 7. Edafología*. 1992a. [National Atlas of Spain].

MOPT, *La nieve en las cordilleras españolas. Programa ERHIN*. DGOH, 1992b. [Snow in the Spanish Mountains].

MOPT, *Delimitación y síntesis de las características de las unidades hidrogeológicas intercuencas*, 1993a. [Delimitation and summary of characteristics of inter-basin hydrogeological units].

MOPT, *Plan Hidrológico Nacional. Memoria y Anteproyecto de Ley* (2 vols.), abril 1993b. [National Hydrological Plan].

MOPTMA, *Mapa de zonas regadas. Origen del agua*. DGOH. 1987. [Map of irrigated areas. Origin of water].

MOPTMA, *Plan Nacional de Obras Hidráulicas*. Manuel Lorenzo Pardo (1933). Edición Comentada (varios autores). 2 vols. Madrid, 1993a. [National Hydraulic Works Plan].

MOPTMA, *Inventario de Recursos de Aguas Subterráneas en España*. CE., 1993b. [Inventory of Groundwater Resources in Spain].

MOPTMA, *Instalación, Mantenimiento y Operación de Redes Oficiales de Control de Aguas Subterráneas. Piezometría, Hidrometría y Calidad*. DGOH-DGCA. 1993c. [Installation, Maintenance and Operation of Official Groundwater Control Networks. Piezometry, Hydrometry and Quality].

MOPTMA, *Estudio de la situación actual y programación de actuaciones futuras en el ámbito de las aguas subterráneas en España*. DGOH, Madrid, 1995a. [Study of the current situation and programme for future actions in the field of groundwater in Spain].

MOPTMA, *Plan Nacional de Recuperación de Suelos Contaminados (1995-2005).* Madrid, 1995b. [National Plan for the Recovery of Polluted Land (1995-2005)].

MOPTMA, *Programa Nacional sobre el Clima*. Borrador. Comisión Nacional del Clima. 1995c. [National Programme on the Climate].

MOPTMA, *Proyectos de apoyo técnico a los planes hidrológicos de cuenca en aspectos relacionados con zonas húmedas.* Madrid, 1995d. [Technical support projects for basin management plans in aspects regarding wetlands].

MOPTMA, *Lagos y humedales de España*, 1996a. [Lakes and wetlands in Spain].

MOPTMA, *Las cuentas del agua.* Madrid, 1996b. [Water accounts].

MOPTMA-CHE, *Jornadas sobre el SAIH en la gestión hídrica.* Dirección General de Obras Hidráulicas-Confederación Hidrográfica del Ebro. Zaragoza, abril 1995. [Workshops on the SAIH in water management].

MOPTMA-MINER, *Libro Blanco de las Aguas Subterráneas.* DGOH-DGCA-ITGE. Madrid, 1995. [White Paper on Groundwater].

MOPTMA-MINER-UPC, *Inventario de Recursos de Agua Subterránea en España, 1ª fase. Coberturas temáticas*. Madrid, 1993. [Inventory of Groundwater Resources in Spain, 1st phase. Thematic coverage].

MOPU, *La nieve en el Pirineo español.* DGOH. 1988. [Snow in the Spanish Pyrenees].

MOPU-CIPH, *Planificación hidrológica nacional* (Avance 80), sin fecha, 1980? [National water planning].

MOPU-DGC, *Instrucción 5.2 IC Drenaje superficial.* Madrid, 1990. [Instruction 5.2 IC surface drainage].

MOPU-DGOH, *Plan Hidrológico. Síntesis de la Documentación Básica.* Madrid, 1990. [Hydrological Plan. Summary of Basic Documentation].

MOPU-DGOH-CEH, *El agua en España*. Madrid, septiembre 1980. [Water in Spain].

MOPU-SGT, *Metodología general para la evaluación de proyectos de inversión pública.* Madrid, 1980. [General methodology for evaluating public investment projects].

MOPU-SGT-DGOH, *Metodología para la evaluación de proyectos de inversión en regadíos.* Madrid, 1980a. [Methodology for evaluating investment projects in irrigation].

MOPU-SGT-DGOH, *Metodología para la evaluación de proyectos de inversión en defensas contra las avenidas y en encauzamientos.* Madrid, 1980b. [Methodology for evaluating investment projects in defence against floods and in channelling].

Mora Alonso-Muñoyerro, J., Criteria for the determination of a regimen of minimum srearaflows in regulated rivers- The Spanish situation, incl. en: *Reservoirs in River Basin Development.*, pp. 321-331. Balkerna, Rotterdam, 1995. [Criteria for the determination of a regimen of minimum streamflows in regulated rivers- The Spanish situation].

Morales Gil, A., *Aspectos geográficos de la agricultura de ciclo manipulado en España.* Ed. Universidad de Alicante. 1997. [Geographical aspects of manipulated rotation agriculture in Spain].

Morales Gil, A., Trasvases de recursos hídricos en España, incl. en: *Demanda y Economía del Agua en España,* ed. A. Gil Olcina y A. Morales Gil. Instituto Universitario de Geografía de la Universidad de Alicante. CAM-Diputación de Alicante. 1988. [Water resource transfers in Spain].

Moreu Ballonga, J. L., *El nuevo régimen jurídico de las aguas subterráneas.* Publ. Universidad de Zaragoza, 1990. [The new legal regime of groundwater].

Moreu Ballonga, J. L., Los trasvases de recursos hidráulicos entre cuencas y el caso particular de los trasvases del Ebro. *Revista Jurídica de Navarra,* nº 15. Homenaje al profesor Sancho Rebullida, enero-junio 1993. [Water resource transfers between basins and the particular case of transfers from the Ebro].

Moreu Ballonga, J. L., *Aguas Públicas y Aguas Privadas.* Ed. Bosch, Barcelona, 1996. [Public Water and Private Water].

Moreu Ballonga, J. L., Sobre la conveniente reforma de la Ley de Aguas. Observaciones al borrador de proyecto de ley de mayo de 1997. *Revista Aragonesa de Administración Pública,* nº 11, 1997. [On the expedient amendment to the Water Act. Observations on the draft bill of May, 1997].

MSC, *Calidad de las Aguas de Baño en España.* Año 1997. Serie de Informes Técnicos. Madrid, 1998. [Bathing Water Quality in Spain].

Mujeriego, R., La reutilización planificada del agua: elemento básico de la gestión de los recursos hidráulicos. Incl. en: *Recursos Hidrogeológicos y Recursos Hidráulicos no Convencionales.* Seminario de la UIMP de Santander, pp. 237-260. MOPTMA, 1994. [The planned reuse of water: basic element in water resources management].

Munné, A., Solà, A., Prat, N., QBR: Un índice rápido para la evaluación de la calidad de los ecosistemas de ribera. *Tecnología del Agua,* nº 175, pp. 42-47, 1998. [A quick index for evaluating the quality of riverbank ecosystems].

Muñoz Bravo, J., Historical evolution of an ingenious hydraulic structure, incl. en: *Reservoirs in River Basin Development.*, pp. 185-195. Balkerna, Rotterdam, 1995. [Historical evolution of an ingenious hydraulic structure].

Muñoz, C. y Robert, O., Caudales mínimos de mantenimiento. Aplicación práctica en la provincia de León, incl. en: *Conferencia Regional del Agua. Jornada sobre caudales ecológicos y caudales de mantenimiento,* pp. 31-45. Ed. Confederación Hidrográfica del Duero. Valladolid, 1997. [Minimum maintenance flow. Practical application in the Province of León].

Naredo, J. M., *La Evolución de la Agricultura en España (1940-1990).* Reed. en Biblioteca de Bolsillo. Universidad de Granada, 1996. [The Evolution of Agriculture in Spain (1940-1990)].

Naredo, J. M., y Parra, F. (comps.), *Hacia una ciencia de los recursos naturales.* Siglo XXI. Madrid, 1993. [Towards a science of natural resources].

National Research Council (NRC), *Opportunities in the Hydrologic Sciences.* National Academie Press. Washington D.C. 1991. [Opportunities in the Hydrologic Sciences].

Nieto García, A., *La "nueva" organización del desgobierno*, 2ª ed. Ariel. Madrid, 1996. [The "new" organisation of dis-government].

Nieto Llobet, A., El proyecto LINDE. *El campo*, nº 132. Servicio de Estudios del BBV Bilbao, 1995. [The LINDE Project].

OCDE, *Eutrophication of Water: Monitoring, Assessment and Control*. Paris, 1982. [Eutrophication of Water: Monitoring, Assessment and Control].

OCU, El agua del grifo. rev. *OCU-Compra Maestra*, nº 198, feb. 1997. [Tap water].

Olivera, A. y Abellán, A., Las características de la población, Cap. 8 de R. Puyol (ed), *Dinámica de la población en España. Cambios demográficos en el último cuarto del siglo XX*. Ed. Síntesis. Madrid. 1997. [Characteristics of the population].

OMM, *Guide to hydrological practices*. Volume I. Data acquisition and processing, nº 168. Ginebra, 1981. [Guide to hydrological practices].

OMM, *Water Resources Assessment*. Ginebra, 1991. [Water Resources Assessment].

ONU, *Conferencia de las Naciones Unidas sobre el Agua*. Mar del Plata. Argentina. Marzo 1977. Contribs. españolas en nº especial de la *Revista de Obras Públicas*, 3.144, abril, 1977. [United Nations Conference on Water].

Ortega Cantero, N., El Plan Nacional de Obras Hidráulicas, incl. en *Hitos históricos de los regadíos españoles*. A. Gil Olcina y A. Morales Gil (coords.), serie Estudios, MAPA, 1992. [The National Public Works Plan].

Ortega Cantero, N., El Plan General de Canales de Riego y Pantanos de 1902, incluido en: *Planificación Hidráulica en España*. Ed. de A. Gil Olcina y A. Morales Gil. Fundación Caja del Mediterráneo. 1995. [The General Irrigation Canals and Reservoirs Plan of 1902].

Ortiz de Tena, M. C., *Planificación Hidrológica*. Marcial Pons. Madrid, 1994. [Water Planning].

Palau, A., Los mal llamados caudales ecológicos. Bases para una propuesta de cálculo. *Revista OP*, nº 28(2), pp. 84-95, 1994. [The mis-named ecological flow. Basis for a calculation proposal].

Pearce, D. W. y Turner, R. K., *Economía de los Recursos Naturales y del Medio Ambiente*, Colegio de Economistas de Madrid-Celeste ediciones, 1995. [Economy of Natural and Environmental Resources].

Pedrero, A., *Las redes de medida en Hidrología. Hidrología Mediterránea. Los Recursos Hídricos en los países mediterráneos*. Seminario Permanente Ciencia y Tecnología del Agua. Iberdrola Instituto Tecnológico, pp. 75-79. Valencia, 1996. [Measurement networks in Hydrology Mediterranean Hydrology. Water Resources].

Pérez Crespo, A., *Responsabilidad Patrimonial de la Administración Pública y del Estado Legislador: Especial Referencia al Trasvase Tajo-Segura*. Real Academia de Legislación y Jurisprudencia de Murcia. 1996. [Public Responsibility of the Public Administration and of the State Legislator: Special Refrence to the Tagus-Segura Transfer].

Pérez de Oliva, E., *Razonamiento sobre la navegación del Guadalquivir* (1524). Edición crítica y anotada por G. George Peale. Publicaciones del Monte de Piedad y Caja de Ahorros de Córdoba, 1987. [Reasoning on the navigation of the Guadalquivir].

Pérez Pérez, E., *Propiedad, Comunidad y Finca Registral*. Ed. Colegio de Registradores de la Propiedad y Mercantiles de España. Centro de Estudios Registrales. Madrid, 1995. [Property, Community and Registered Real Estate].

Pérez Pérez, E., Marco legislativo a la gestión del agua de riego. Incl. en: *La gestión del agua de riego*. J. López Gálvez y J. M. Naredo (eds). Colección Economía y Naturaleza, nº 8, pp. 293-355, Fundación Argentaria. Madrid, 1997. [Legislative framework for irrigation water management].

Pérez Pérez, E., La propiedad del agua. Ed. Marcial Pons. Madrid. 1998. Pérez Pérez, E. y A. Reverte Navarro, *Comentarios al Código Civil y Compilaciones Forales, Tomo V, vol. 3º Arts. 407 a 427 del Código Civil y Ley de Aguas*. Editorial Revista de Derecho Privado. Madrid, 1991. [Water property].

Pérez Picazo, M. T., y Lemeunier, G., *El Proceso de Modernización de la Region Murciana (siglos XVIXIX)*. Editora Regional de Murcia. 1984. [The Process of Modernising the Region of Murcia (16th-19th centuries)].

Pérez Picazo, M. T., y Lemeunier, G., Agua y Coyuntura Económica. Las Transformaciones de los Regadíos Murcianos (1450-1926). *Geocrítica*, nº 58. Universidad de Barcelona. 1985. [Water and Economic Circumstances. The Transformations of Murcia irrigation (1450-1926)].

Pérez Picazo, M. T., y Lemeunier, G. (eds.), *Agua y modo de producción*. Editorial Crítica, Barcelona, 1990. [Water and production methods].

Pérez-Díaz, V., Mezo, J. y Álvarez-Miranda, B., *Política y economía del agua en España*. Ed. Círculo de Empresarios. Madrid, 1996. [Water politics and economy in Spain].

PG, *II Plan de Desarrollo Económico y Social. Recursos hidráulicos*, Madrid, 1967. [2nd Economic and Social Development Plan. Water Resources].

Plata Bedmar, A., *Composición isotópica de las precipitaciones y aguas subterráneas de la Península Ibérica*. Monografías CEDEX. 1994. [Isotopic composition of precipitation and groundwater in the Iberian Peninsula].

Playán, E., Faci, J. M., Cavero, J., Dechmi, F. y Lecina, S., Casos de estudio: ahorro de agua en los regadíos de Aragón, incl. en: *Nuevas fuentes de suministro de agua*. 5ª Conferencia Internacional del Seminario Permanente Ciencia y Tecnología del Agua. Iberdrola Instituto Tecnológico. Valencia, 1999. [Study cases: water-saving in Irrigation in Aragón].

Postel, S., *El último oasis. Cómo afrontar la escasez de agua*. Ed. Apóstrofe. Barcelona, 1993. [The last oasis. How to deal with water scarcity].

Postel, S., *Reparto del agua. Seguridad alimentaria, salud de los ecosistemas y nueva política de la escasez*. Cuadernos Worldwatch. Bakeaz, Bilbao, 1997. [The distribution of water. Food safety, health of ecosystems and new scarcity policy].

Prat, N., El agua en los ecosistemas. *El campo*, nº 132. Servicio de Estudios del BBV Bilbao, 1995. [Water in ecosystems].

Prat, N., Estado ecológico de los ecosistemas acuáticos en España, incl. en: *Congreso Ibérico sobre Gestión y Planificación de Aguas*, pp. 45-62. Zaragoza, sep. 1998. [Ecological state of aquatic ecosystems in Spain].

Puigdefábregas, J., Erosión y desertificación en España. *El campo*, nº 132. Servicio de Estudios del BBV Bilbao, 1995. [Erosion and desertification in Spain].

Puyol, R. (editor), *Dinámica de la población en España. Cambios demográficos en el último cuarto del siglo XX*. Editorial Síntesis. Madrid. 1997. [Dynamics of the population in Spain. Demographic changes in the last quarter of the 20th century].

Quintana Petrus, J. M., *Derecho de Aguas*, 2ª ed. Bosch, 1992. [Water Law].

Quintas, L., La base de datos hidrológicos HIDRO del CEDEX. *Ingeniería Civil*, nº 104. pp. 117-126. Madrid, 1996. [The HIDRO hydrological data base of the CEDEX].

Reed, W. J., Una introducción a la economía de los recursos naturales y su modelización, incl. en: *Análisis económico y gestión de recursos naturales*. D. Azqueta y A. Ferreiro (eds). Alianza Economía, 1994. [An introduction to the economy of natural resources and their modelling].

Reisner, M., *Cadillac Desert. The American West and Its Disappearing Water*, Penguin Books, 1986. [Cadillac Desert. The American West and Its Disappearing Water].

Rico, A., Olcina, J., Paños, V. y Baños, C., *Depuración, desalación y reutilización de aguas en España*. Oikos-Tau, Barcelona, 1998. [Treatment, desalination and reuse of water in Spain].

Rivera, J. A., *Acequia culture. Water, land, & community in the southwest*. University of New México Press, Alburquerque, NM, 1998. [Acequia culture. Water, land, & community in the southwest].

Rodríguez Osuna, J., *Población y territorio en España*. Ed. Espasa-Calpe. Madrid, 1985. [Population and territory in Spain].

Rodríguez-lturbe, I., Dinámica no-lineal de la humedad del suelo en la relación entre clima e hidrología. *Ingeniería Civil*, nº 82, pp. 15-22. Madrid, 1991. [Non-linear dynamics of soil moisture in the relationship between climate and hydrology].

Romero González, J., El Plan Nacional de Obras Hidráulicas. Precedentes y Condicionantes, incluido en *Planificación Hidráulica en España*. Ed. de A. Gil Olcina y A. Morales Gil. Fundación Caja del Mediterráneo. 1995. [The national Hydraulic Works Plan. Background and Conditioning Factors].

Romero, C., *Economía de los recursos ambientales y naturales*. Alianza Economía. Madrid. 1994. [Economy of environmental and natural resources].

Romero, J., y Giménez, C. (eds), *Regadíos y estructuras de poder*. Instituto de Cultura Juan Gil-Albert. Diputación Provincial de Alicante. 1994. [Irrigation and power structures].

ROP, El Delta del Ebro, *Revista de Obras Públicas*, nº monográfico 3.368, sep. 1997. [The Ebro Delta].

Rosa Moreno, J., Evaluación de impacto ambiental de las obras hidráulicas, incl. en: A. Embid Irujo (Director), *Gestión del agua y medio ambiente*. Civitas. Madrid, 1996. [Environmental Impact Assessment of hydraulic works].

Rosenzweig, C., y Hillel, D., *Climate Change and the Global Harvest*. Oxford University Press. 1998. [Climate Change and the Global Harvest].

Ruiz, J. M., *Modelo distribuido para la evaluación de recursos hídricos*. Monografías CEDEX, Madrid, 1999. [Distributed model for evaluating water resources].

Ruiz-Funes García, M., *Derecho Consuetudinario y Economía Popular de la Provincia de Murcia*. 1916. Reimpres. Academia Alfonso X el Sabio, Murcia, 1983. [Common Law and Popular Economy in the Province of Murcia].

Sáenz Lorite, M., *Geografía agraria. Introducción a los paisajes rurales*. Ed. Síntesis. Madrid, 1990. [Agrarian Geography. Introduction to rural landscapes].

Sáenz, C., Sustrato histórico de los usos del agua en España. incl. en *Política Hidráulica*, MOPT, 1992. [Historical substratum of water uses in Spain].

Sahuquillo Herráiz, A., Posibilidades del uso conjunto de aguas superficiales y subterráneas en la planificación hidráulica. *Las aguas subterráneas en las cuencas del Ebro, Júcar e Internas de Cataluña y su papel en la planificación hidrológica*. Asociación Internacional de Hidrogeológos-Grupo Español. Actas de las Jornadas de Lleida, 1996. [Possibilities for joint use of surface water and groundwater in water planning. Groundwater in the Ebro, Júcar and Catalonia Inland Basins and their role in water planning].

Sala, Ll. y Serra, M., Experiència pràctica y situació actual de la reutilització de l'aigua en el Consorci de la Costa Brava, incl. en: *Jornadas Técnicas. La gestión del agua regenerada* (R. Mujeriego y Ll. Sala eds.) pp. 15-27. Consorcio de la Costa Brava. Palamós, jun. 1998. [Practical experience and current situation of water reuse in the Costa Brava Consortium].

Sánchez Blanco, A., Usuarios e intereses generales en I Ley de Aguas de 985. La dinámica entre un modelo de producción agrario y el equilibrio intersectorial y los intereses generales. *REDA*, nº 45, pp. 25-44, 1985. [Users and general interests in the Water Act of 1985. Dynamics between an agricultural production model and inter-sectoral balance and general interests].

Sánchez González, A., Evaluación de la demanda, incl. en *Conceptos y métodos para la planificación hidrológica*. J. Andreu (ed.). CIMNE, Barcelona, 1993. [Demand evaluation].

Sánchez González, A., Problemas actuales y potenciales: recursos y explotación. *Jornadas sobre el Libro Blanco de las Aguas Subterráneas*. Organizadas por el Club del Agua Subterránea. Madrid, 1995. [Current and potential problems: resources and exploitation].

Sánchez López, J. L., La sequía y los abastecimientos urbanos. Incluido en el volumen *Las sequías en España*. CEDEX. Madrid. 1995. [Drought and urban supply].

Sánchez Morón, M., Ordenación del territorio, urbanismo y medio ambiente en el anteproyecto de Plan Hidrológico Nacional. *Revista de Administración Pública*, nº 131, pp. 35-60, mayo-agosto 1993. [Territorial regulation, town planning and environment in the draft national Hydrological Plan].

Sánchez-Mata, D. y de la Fuente, V., *Las riberas de agua dulce.* Unidades Temáticas Ambientales. MOPU, 1986. [Freshwater river banks].

Sanz Pérez, E., La regulación de los manantiales y su incidencia en España. *Boletín Geológico y Minero*, T. XCVIII-VI, 1987. [The regulation of springs and its incidence in Spain].

Sanz Pérez, E., Los manantiales de España: clasificación según caudales y litologías y estimación de sus aportaciones. *Boletín Geológico y Minero,* Vol. 106-1, 1995. [Springs in Spain: Classification according to flow-rate and lithology and contribution estimates].

Sanz Pérez, E., Captaciones y uso del agua para abastecimiento público en la zona rural de España. *Revista de Obras Públicas*, nº 3.345, julio-agosto 1995. [Water abstraction and use for public supply in rural areas of Spain].

Sanz Pérez, E., El karst del sur y oeste del Moncayo. Tesis doctoral. *Boletín de Información y Estudios del Servicio Geológico*, nº 47, 159 páginas, 1987. [Karst in the South and West of Moncayo].

Sanz, F. J. y Martínez, A., Utilización de la inventariación fluvial en la aplicación de la metodología IFIM, incl. en: *I Congreso sobre Caudales Ecológicos*, APROMA, Tarrassa, 1999. [Use of river inventory-taking in the application of the IFIM methodology].

Saura, J., La modernización de regadíos. *El campo*, nº 132. Servicio de Estudios del BBV. Bilbao, 1995. [The modernisation of irrigation].

Segura, R., Consideraciones sobre los recursos hídricos no convencionales en el PHN. incl. en: *Economía y racionalización de los usos del agua*, pp. 211-218. Seminario de la UIMP de Santander. MOPT, 1996. [Considerations on the use of non-conventional water resources in the NHP].

Senent Alonso, M., *La recarga artificial de acuíferos.* Tesis Doctoral. E.T.S. de Ingenieros de Minas. Madrid. 1985. [The artificial recharge of aquifers].

SEO/BirdLife, *Ríos de vida. El estado de conservación de las riberas fluviales en España* (C. Ibero), Madrid, 1996. [Rivers of Life. The state of conservation of fluvial banks in Spain].

SEO/BirdLife, *Plan Delta XXI. Directrices para la conservación y el desarrollo sostenible en el Delta del Ebro* (C. Ibáñez y cols.), Tarragona, 1997. [Plan Delta XXI. Guidelines for conservation and sustainable development in the Ebro Delta].

Serrano Sanz, J. M., Bandrés, E., Gadea, M. D. y Sanau, J., *Desigualdades Territoriales en la Economía Sumergida*. Confederación Regional de Empresarios de Aragón. Zaragoza, 1998. [Territorial Inequalities in the Submerged Economy].

SGOP-UPV, *Utilización conjunta de aguas superficiales y subterráneas*, coord. M. Varela, dir. A. Sahuquillo. Madrid, 1983. [Joint use of surface water and groundwater].

Solís, C., *Los Caminos del Agua. El Origen de las Fuentes y los Ríos.* Biblioteca Mondadori, 1990. [Water Paths. The Origin of Sources and Rivers].

Sumpsi, J. M., Garrido, A., Blanco, M., Varela, C. e Iglesias, E., *Economía y Política de Gestión del Agua en la Agricultura*. MAPA-Mundi-prensa, Madrid, 1998. [Economy and Policy of Water Management in Agriculture].

Tamames, R. y Rueda, A., *Estructura Económica de España* (23ª edición). Alianza Universidad. Textos-Banco Urquijo, 1997. [Economic Structure of Spain].

Tello, B. y López Bermúdez, F., *Los lagos. Guía Física de España*. Alianza Editorial. Madrid. 1988. [Lakes. Physical Guide to Spain].

Thót, J., Mapping and interpretation of field phenomena for groundwater reconnaissance in a prairie environment, *Bulletin International Association of Scientific Hydrology,* nº 9, pp. 20-68. Canadá, 1966. [Mapping and interpretation of field phenomena for groundwater reconnaissance in a prairie environment].

Tió, C., La Política Agraria Común y los nuevos regadíos. *Revista de Estudios Agrosociales,* nº 1, 1997. [Common Agricultural Policy and new irrigation].

Tomlin, C. Dana., *Geographic Information Systems and Cartograpític modeling.* Prentice Hall, 1990. [Geographic Information Systems and Cartographic modelling].

Torobin, M., Tools for source water protection: Regulation and Incentives, actas del *Source Water Protection Symposium*, San Francisco (USA), oct. 1998. [Tools for source water protection: Regulation and Incentives].

UNESA, *Comparación de los precios de la electricidad en los países de la Unión Europea*. Madrid. 1998b. [Comparison of electricity prices in countries of the European Union].

UNESA, *Memoria Estadística Eléctrica 1997.* Madrid, 1998a. [Electrical Statistics report 1997].

UNESCO, *Carte de la repartition mondiale des régions arides.* Paris. 1979. [Map of world-wide distribution of arid regions].

USACE (U.S. Army Corps of Engineers), Federal Perspective for Flood-Damage-Reduction Studies. Cap. 27 de *Water Resources Handbook*, L. W Mays, McGraw Hill, 1996. [Federal Perspective for Flood-Damage-Reduction Studies].

USDA, *Soil Classification. A comprehensive system. 7th approximation.* Soil Conservation Service, Soil Surbvey Staff. 1960. [Soil Classification. A comprehensive system. 7th approximation].

USDA, *Supplement to soil classification system (7th approximation).* Soil Conservation Service, Soil Surbvey Staff. 1967. [Supplement to soil classification system (7th approximation)].

Valero de Palma, J., La opinión del usuario del agua, incl. en *Economía y racionalización de los usos del agua.* Seminario de la UIMP de Santander. MOPT, 1996. [Users' opinion of water].

Vallarino, E., *Tratado Básico de Presas.* Colección SEINOR, nº 11 Colegio de I.C.C.P. -Servicio de publicaciones de la ETSICCP. Universidad Politécnica de Madrid. 1991. [Basic Essay on Dams].

Vallee, B. L., El alcohol en el mundo occidental. *Investigación y Ciencia,* nº 263, pp. 56-61, agosto 1998. [Alcohol in the Western World].

Varela, M., Gestión de recursos hídricos y desarrollo sostenible. APHR. *2º Congresso da Água em Portugal. Lisboa*, abril 1994. [Water resources management and sustainable development].

Velarde, J., *Hacia otra economía española*. Ed. Espasa, Madrid, 1996. [Towards another Spanish economy].

Velarde, J., La habitación del Barba Azul español. *Época*, 1998. [The Spanish Bluebeard's Room].

Vera Rebollo, E., Los recursos hídricos como factor condicionante del desarrollo turístico en el litoral alicantino, incl. en: *Demanda y Economía del Agua en España,* ed. A. Gil Olcina y A. Morales Gil. Instituto Universitario de Geografía de la Universidad de Alicante. CAM-Diputación de Alicante. 1988. [Water resources as a conditioning factor in tourism development on the Alicante Coast].

Vergara Blanco, A., *Derecho de Aguas*, 2 vols., Editorial Jurídica de Chile, Santiago, 1998. [Water Law].

Vilar, R., Presentación del libro *Agua y modo de producción*, M. T. Pérez Picazo y G. Lemeunier (eds.), Editorial Crítica, Barcelona, 1990. [Introduction to the book *Water and production methods*].

Villalba Sánchez, J., Sequía. Afección al sector eléctrico. Incluido en CEDEX (1995) *Curso sobre Las sequías en España*. Madrid. 1995. [Sequía. Influence of the Electricity Sector].

Villarroya Aldea, C., *La delimitación del dominio público hidráulico y de sus zonas inundables. El proyecto LINDE*. Madrid, 1997. [The delimitation of the public water domain and its flood-prone areas].

Villarroya Aldea, C., Sistema de gestión de la demanda del agua de usos urbanos. *Aplicación en Alicante. XVIII Jornadas de la AEAS*. Alicante, 1998. [Management system for water demand in urban uses. Application in Alicante].

Vinuesa, J., El crecimiento de la población y los desequilibrios en la distribución espacial, Cap. 7 de R. Puyol (ed.), *Dinámica de la población en España. Cambios demográficos en el último cuarto del siglo XX*. Ed. Síntesis. Madrid. 1997. [Population growth and imbalance in spatial distribution].

Viñuales, V., Zaragoza, ciudad ahorradora de agua. *Tecnoambiente,* nº 79, pp. 51-53, ene/feb. 1998. [Water-saving city].

Zamora, E., El futuro de la población española, Cap. 9 de R. Puyol (ed.), *Dinámica de la población en España. Cambios demográficos en el último cuarto del siglo XX*. Ed. Síntesis. Madrid. 1997. [The future of the Spanish population].