Principles & Constraints in River Restoration

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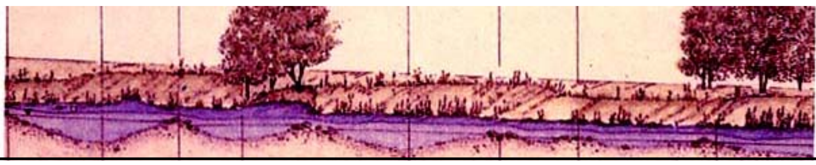
Presented to the international seminar
Restauracion de Rios, Madrid September 2006

Five Principles for River Restoration

1. Approach restoration in context of historical changes
-What is "restoration"?
2.Riverine species depend on connectivity/dynamics
-Restore (preserve) process, not form
3.River restoration still largely experimental
-Learn by post-project appraisal, adaptive management
4.Approach larger spatial and temporal scale
-Understand processes and historical changes at basin scale
-Prioritize actions in larger context
5.Set goals in context of constraints/opportunities
-Urban-wilderness continuum



How we got here – degradation of rivers

Catchment land-use impacts on water quality
 - agriculture, urbanization, deforestation
Dams, diversions
 -change flow regime, trap coarse sediment
Navigation - snagging, channelization/simplification
Flood control
 - Levees disconnect floodplains
 - Reservoirs reduce peak flows
Floodplain conversion
 - to agriculture, urban uses, loss of riparian habitat
Bank stabilization
 - Rocking banks to stop erosion/migration
Result: Loss of species diversity, ecosystem function

River Restoration now enormously popular

wide popular support, large public investment
NRRSS National River Restoration Science Synthesis
Compiled data on nearly 50,000 projects in the US
Over $17 billion invested
Very little scientific monitoring/evaluation (<5%)
Comparable efforts in Europe, Canada, Australia, and increasingly Asia
Lack of evaluation hinders progress in the field

Essential to understand physical and ecological processes, history of change. Based on this, develop

Clear objectives suitable to context and river history

Restoration is fundamentally a social activity

- *societal decision to improve quality of life,* preserve species, etc. (first world activity)
- *can be informed by science*, but ultimately reflects maturation of society, social and political context
- *Must first address severe water quality problems* (e.g. no longer dumping raw sewage into rivers)

-only then can

-bring people into contact with rivers,

-restore ecosystem

-River restoration reflects evolution of environmental movement, *from doom-gloom to pro-active, positive*, local action (neighborhood creek)

-As a social decision, goals/objectives will vary with social context (ecological goals only one category!)

What is restoration? *Some definitions:*

Reestablishment of pre-disturbance aquatic functions and related physical, chemical and biological characteristics. *NRC 1992*

Return of an ecosystem to a close approximation of its condition prior to disturbance *NRC 1992*

The process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems *Jordan et al 1987*

Complete structural and functional return (of a river) to a pre-disturbance state *Cairns 1991*

Return to an ecosystem that closely resembles unstressed surrounding areas (recovery enhancement) *Gore 1985*

All: state/imply returning towards pre-disturbance state

But what if earliest historical evidence reflects not a pristine, pre-human-disturbance state, but a long-occupied landscape like Europe?

Other ‘reference sites’ with desired values? Subjective preferences can come into play.

Napoleanean cadastral map of the Eygues River, Vinsobres, France, 1830 showing intensive land use up to the bank (Kondolf et al.2006)

What is restoration? ***Terminology***

Many authors have observed that true ‘restoration’ is rarely possible, alternative terms suggested:

- ***enhancement***
- ***rehabilitation***
- ***reclamation***
- ***revitalization***

Usually these are to designate lesser levels of transformation, eg restoring certain functions (not necessarily pre-existing state)

Another take (Presidio, SF)

Restoration – for sites so trashed they must be ‘rebuilt’

Enhancement – less damaged, need only small intervention

Mitigation – a matter of intent. Often creating ecosystems that did not exist before.

What is restoration? *Terminology Continued*

Prompted recovery – intervene to encourage natural processes of scour, deposition, vegetation establishment

'Passive' vs 'active' restoration – negative connotations, but the distinction useful between building habitat and allowing natural processes to do so, with prompting

Often restoration is simply using "greener" methods to manage floods, stabilize banks, relocate channels

What is restoration? *A 'garbage-can' term*

'Restoration' is often applied to "greener" methods to manage floods, stabilize banks, relocate channels, etc. *Positive connotations, sometimes applied to projects that are really environmentally damaging.*

"Gradient Restoration Facility" on the Sacramento River, ca 1999. Structure across the channel to raise level for diversion

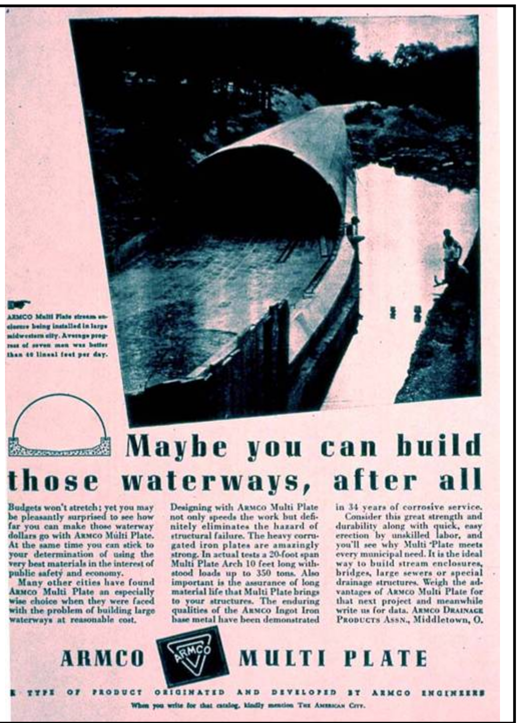
Restoration 'on-the-back' of:
Flood control, bank stabilization, highway construction
These projects have money!

As 'mitigation' for environmental impacts of large construction projects
Ethical issue:
Can the restoration really compensate for the loss?
Does restoration facilitate environmental damage?

Restoration often driven by human uses:
***recreation, community involvement, aesthetics*.**
Highly urban settings: ecological potential limited, social benefits more important, ecological education
Worth daylighting Strawberry Ck in downtown Berkeley?

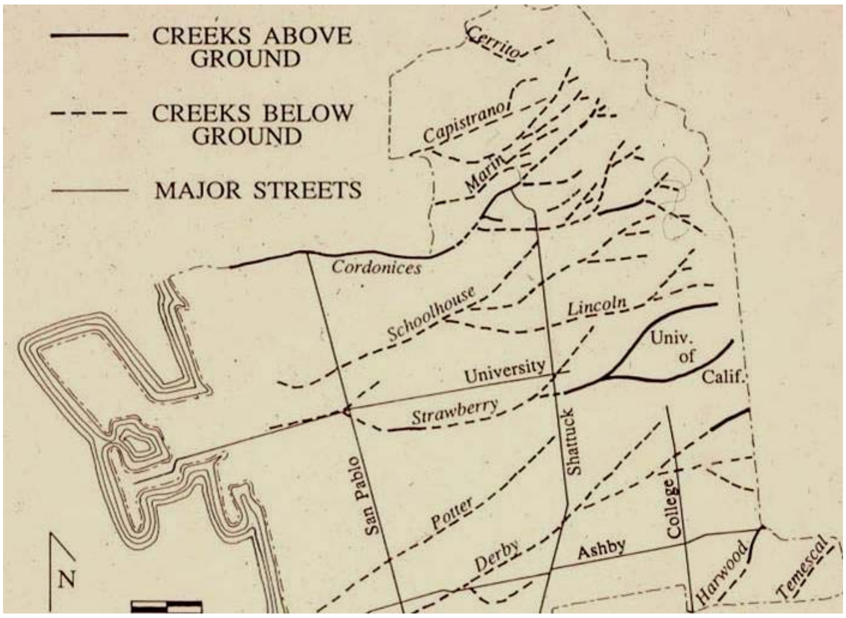
The Love River being put underground in Pindong, Taiwan

It’s understandable that city officials sought to isolate these contaminated waters away from human contact at the time



Even today the practice persists *Temescal Ck, Emeryville, Calif*

To experience Temescal Ck, get on the grate!



Most Berkeley creeks have been put in underground culverts

A Berkeley creek
group has marked
the paths of our buried
creeks with stencils

Derby Creek's symbol
is a frog

Where is the
River Westbourne?

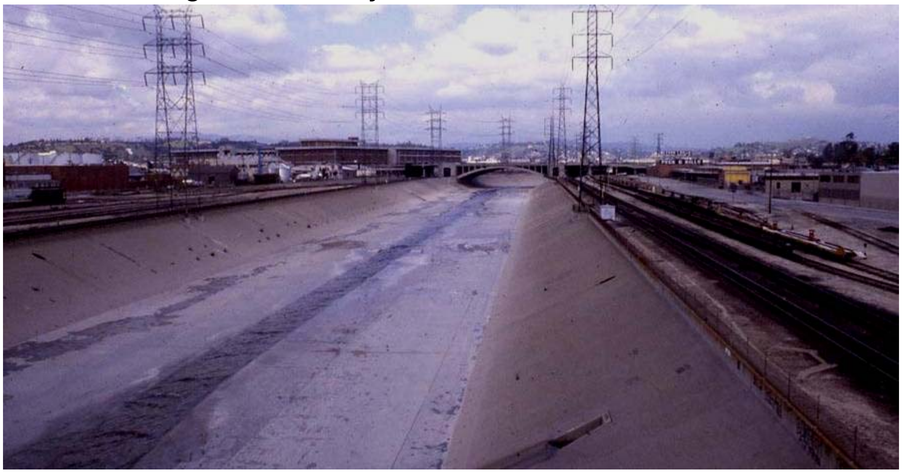
Streams and rivers
in urban areas seen as
drainage utilities

River Westbourne
Sloan Sq tube stop
London

Flooding, exacerbated by urban runoff,
motivated canalization of urban rivers

Los Angeles River, 1938

In response, nearly 400 mi of concrete channel constructed
In the Los Angeles River system



Creating hydraulically-smooth channels designed for super-critical flow

And with limited habitat value

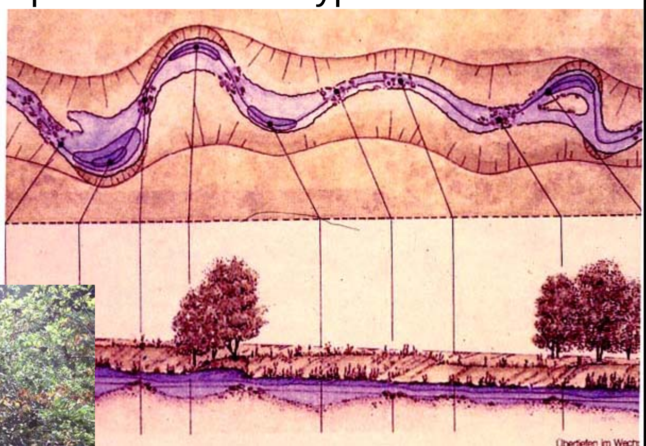
Riparian overstory, Los Angeles River

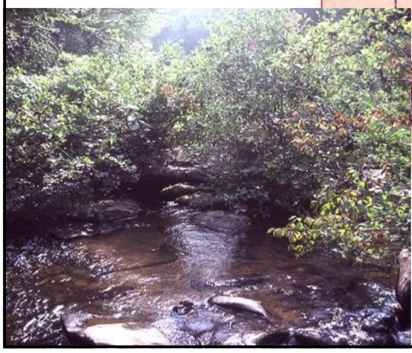
Contrast Jacoby Ck (complex channel, poor flood conveyance but excellent habitat) with canalized Alamo Creek (simplified channel, efficient flood conveyance, poor habitat)

Jacoby Creek, Arcata, California

Alamo Creek, Dublin, California

Restoration projects often seek to recreate complex channel forms that provide habitats typical of natural streams.



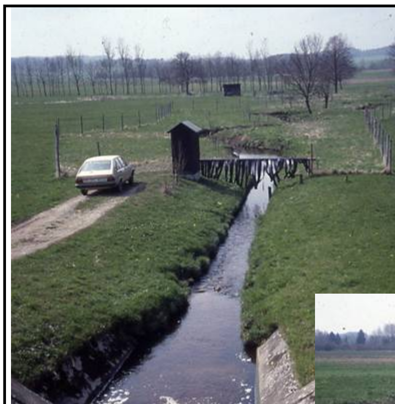


Re-Meandering channelized rivers

Very 'imageable' (eg Kissimee R)

Very common in Europe, because channelization so extensive

Danube, Baden-Wittenberg, Germany



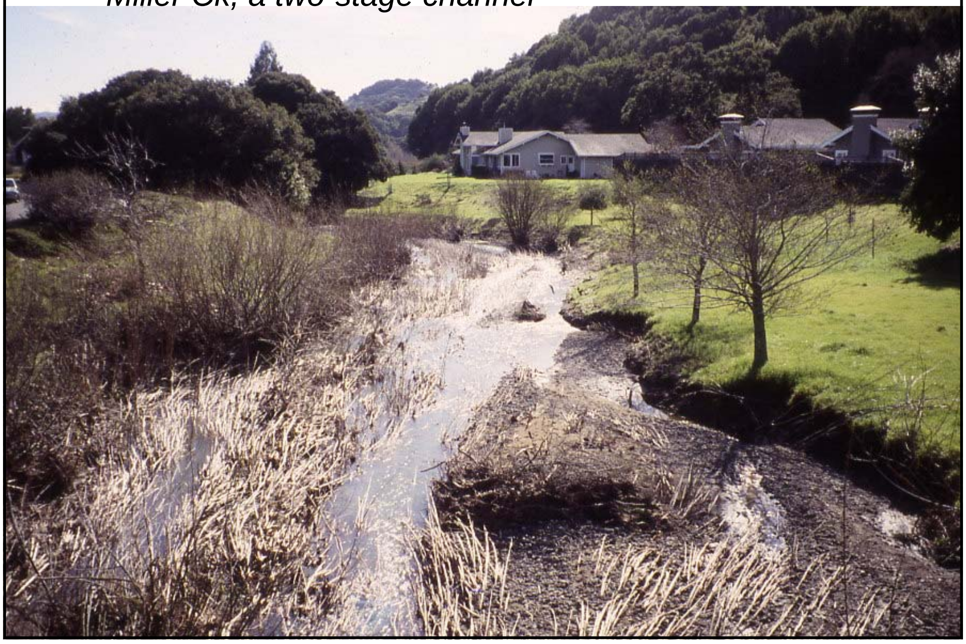
The Boyerbach, Bavaria

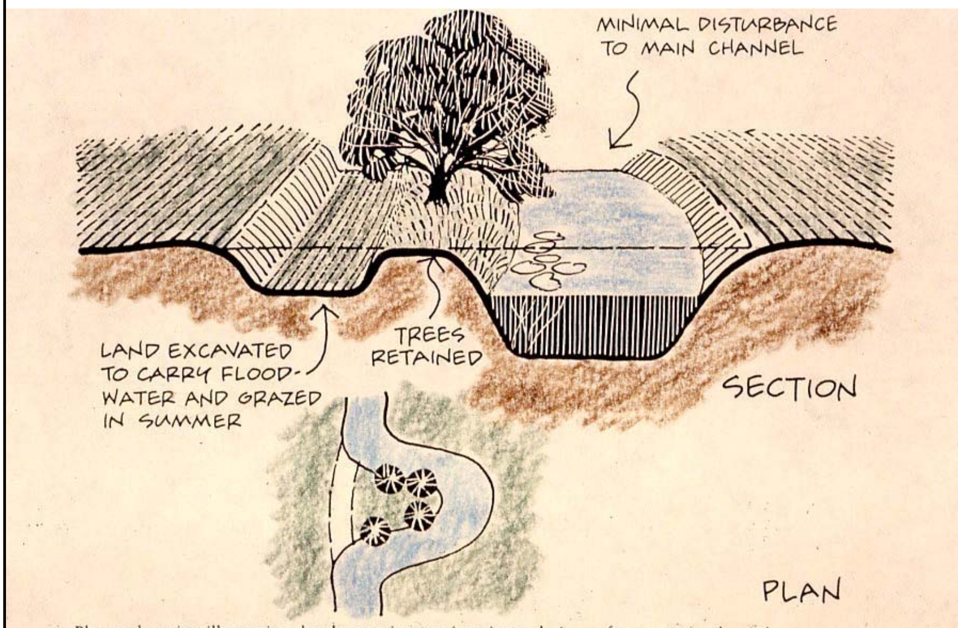
One of many projects implemented by Walter Binder and co.

In the US, Kissimmee River is now being re-meandered

Restoration features in flood control projects

Miller Ck, a two-stage channel





Plan and section illustrating the elegant river-engineering technique of a two-stage channel

How to set realistic goals for restoration?

- Need to understand history and functioning of the system
-Identify changes in controlling factors as well as channel conditions
- Can define a gradient in restoration potential:

wilderness <---------------------------→ ***highly urban***

unchanged Q, Qs	- Q, Qs highly altered
no urban encroachment	- highly encroached
can restore historical channel "carbon copy approach"	- can't restore historic cond's "gardening" – can choose elements to include, but must withstand forces

Urban and wilderness end members easiest.
(the two extremes)

Most challenging are sites with modified Q, Qs
-Need to design for modified independent variables
- i.e., changed processes, can´t recreate historical form
-Can restore some processes?
Below dams – release high flows (artificial floods), add gravel to counteract sediment starvation

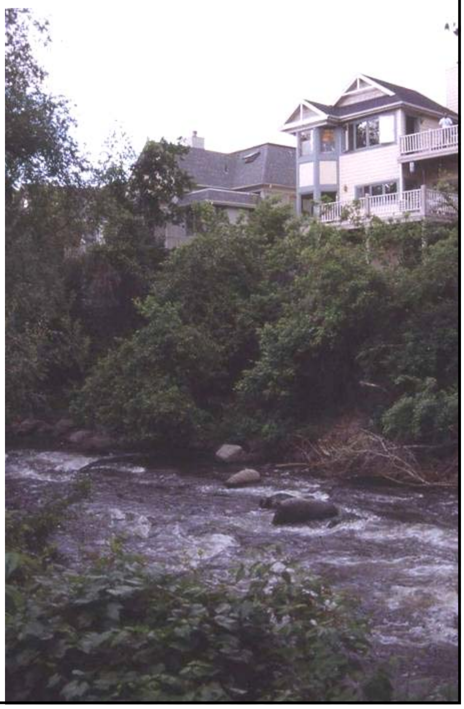
What is "realistic" changes over time with politics.
Eg restoring flow in the San Joaquin R –

Urban River Restoration
Natural process vs "naturalistic"

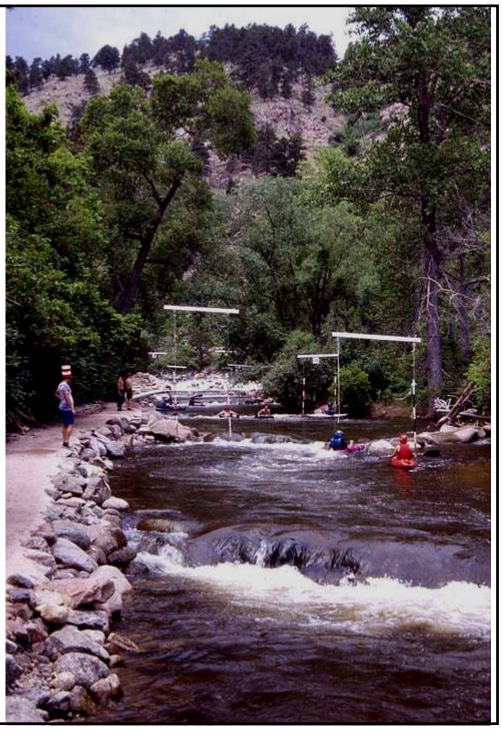
Sometimes straight edges are OK in urban environments. In California, creek groups want to plant salix along urban streams, residents oppose it because of safety

An urban stream restoration for recreation:

Boulder Creek, Colorado

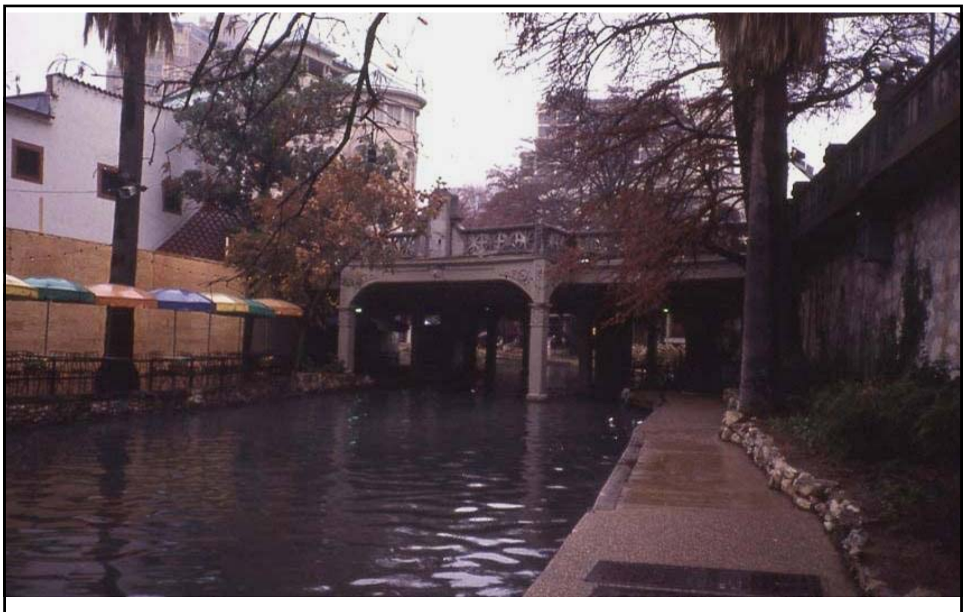


Kayak run in steeper, upper reach of Boulder Ck

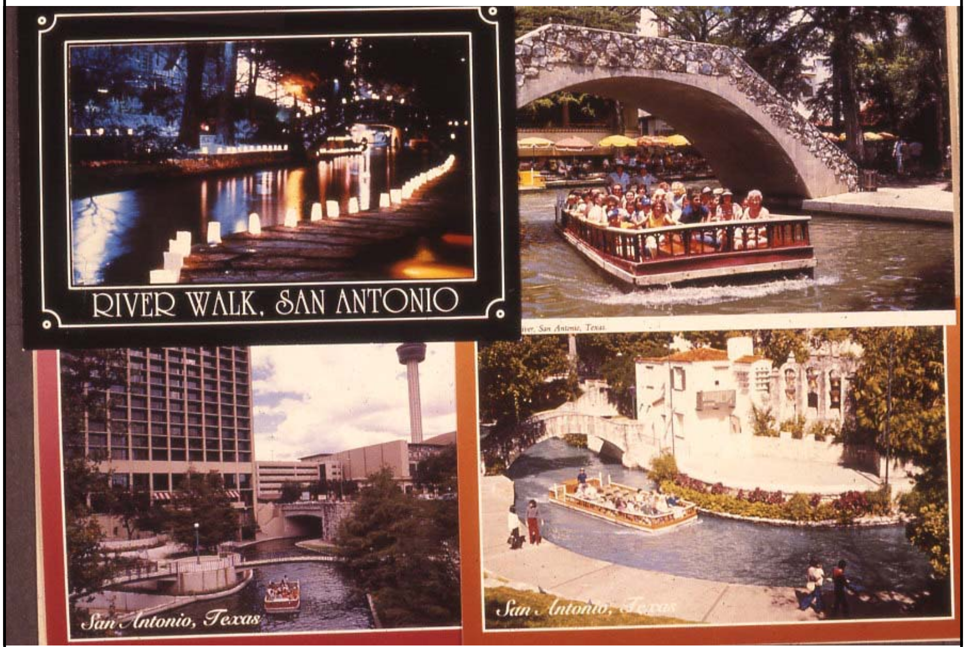


And downstream an underwater observatory

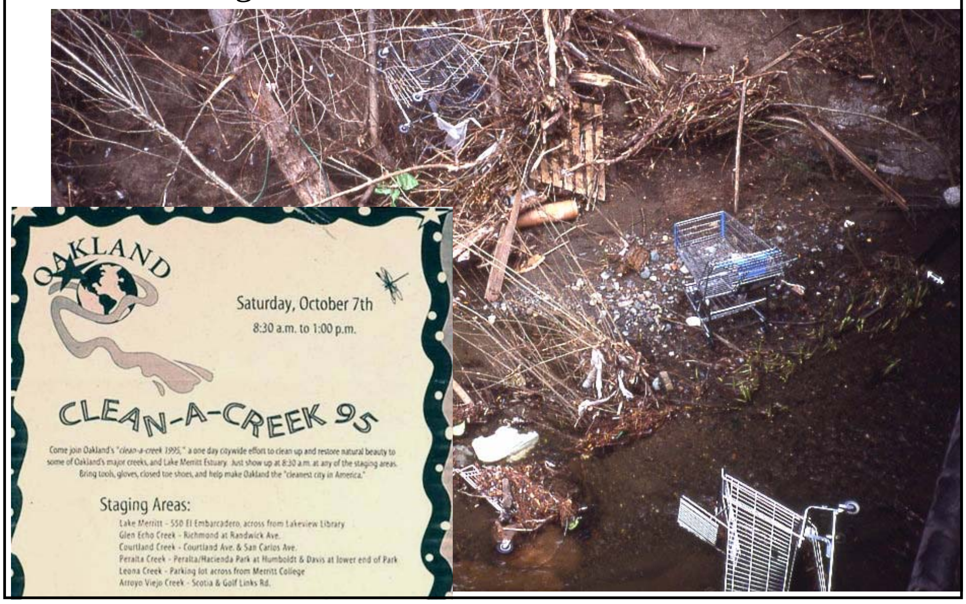
It’s possible to see fish and other aquatic organisms in the creek through the glass porthole



The San Antonio “River Walk” , Texas: a very successful urban waterfront – but there´s nothing ecological about it



A common activity in urban stream restoration:
removing trash



‘Daylighting’ buried urban creeks

One of the first: Strawberry Ck Park, Berkeley 1980s

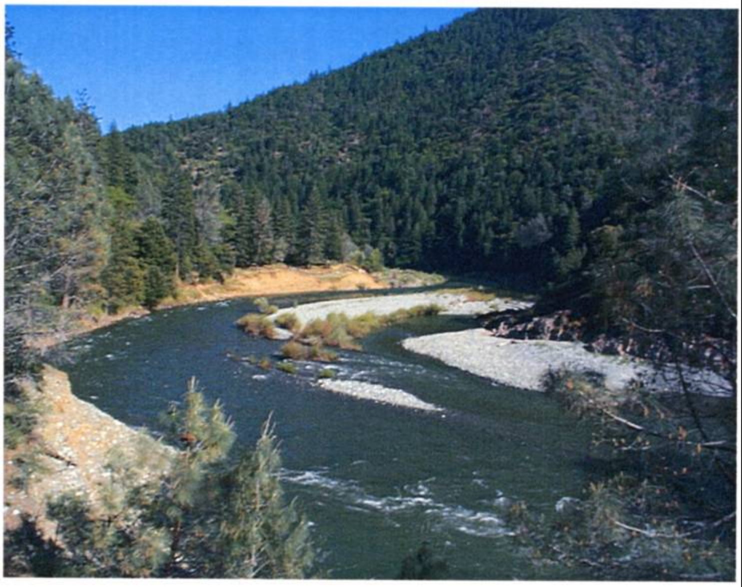
“Daylighted” channel of Strawberry Creek,
banks formed by concrete rubble from destroyed culvert

Less Urban Context:

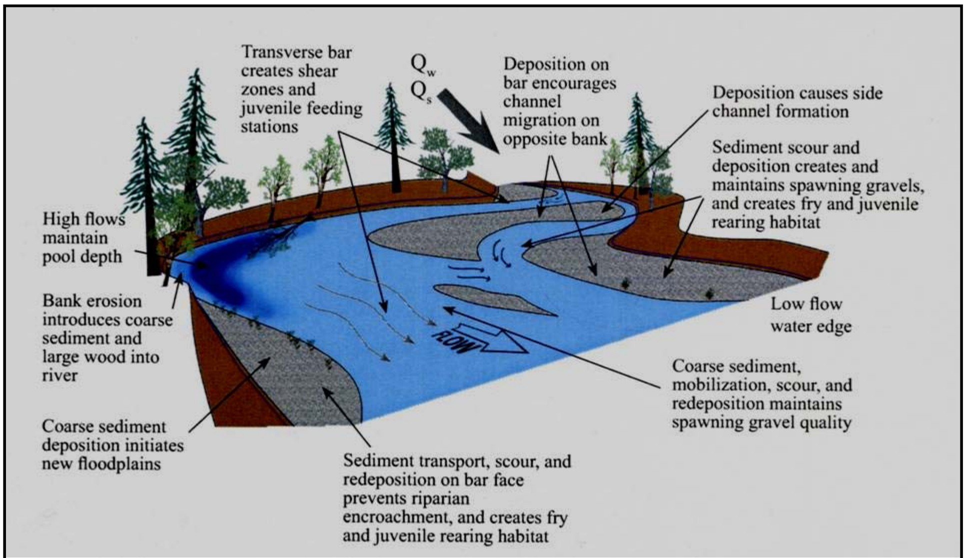
Where possible
Restore processes, connectivity, flow dynamics

Examples:
Restoring longitudinal connectivity
Restoring floodplain connectivity by removing levees (eg, Rhine, Sacramento)
Re-Naturalizing flow regimes below dams (St Mary River, Alberta, San Joaquin R, California)
Adding gravel below dams

Ecological importance of dynamically migrating channel



Trinity River, California



Important habitats depend on active channel migration

Source: McBain and Trush

Restoring Connectivity in River Systems

Longitudinal connectivity: dam removal, gravel augmentation

Lateral connectivity: breach/setback levee, raise incised bed

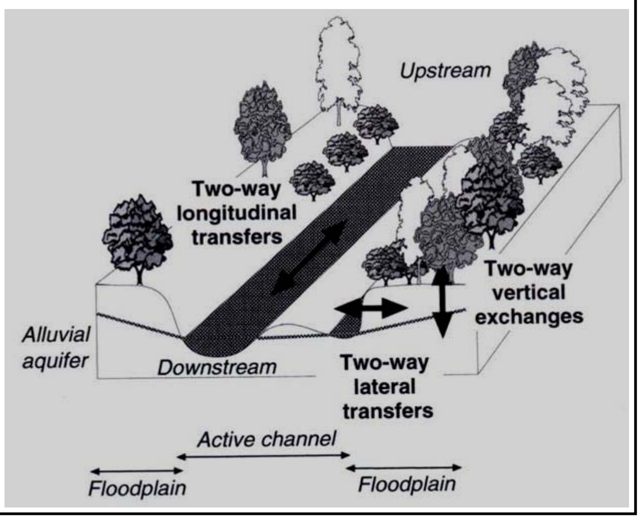
Vertical connectivity: removing fine sediment from beds of former channels

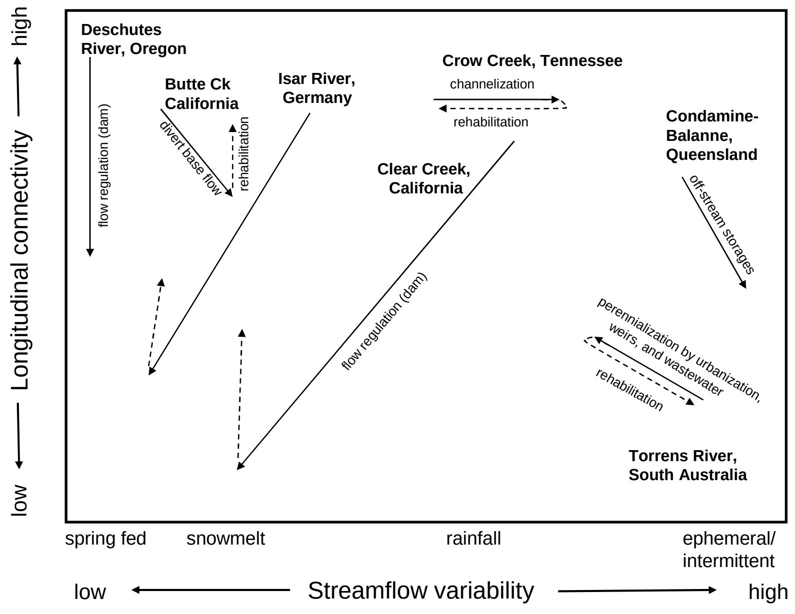
and

Flow Dynamics

Channel Dynamics

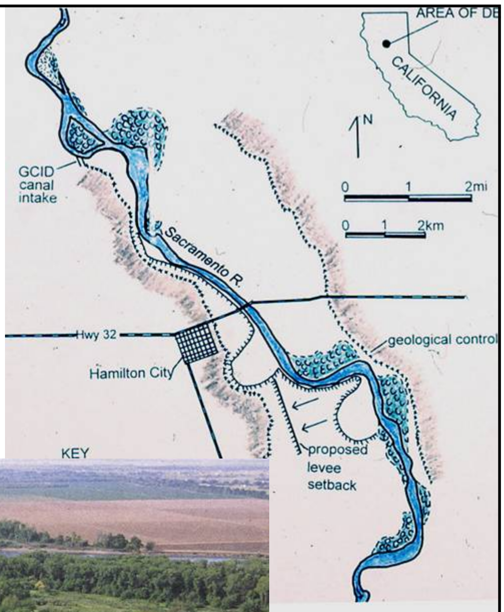
Often trajectories of restoration do not parallel those of degradation



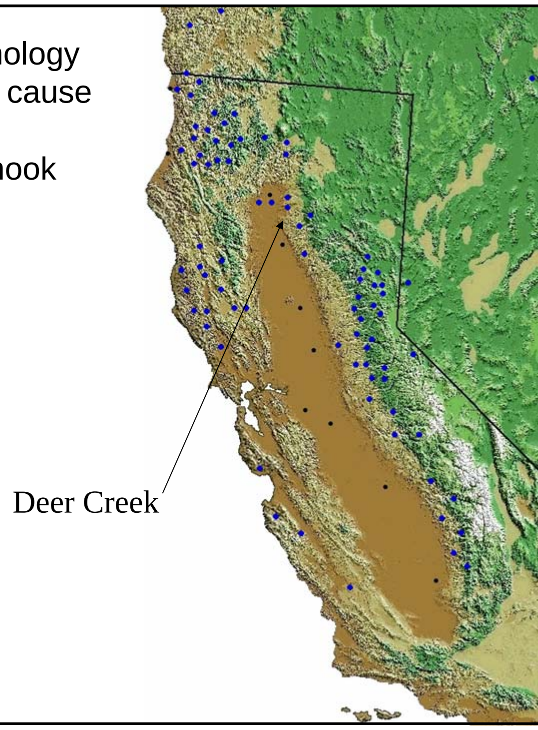


Kondolf et al. 2006

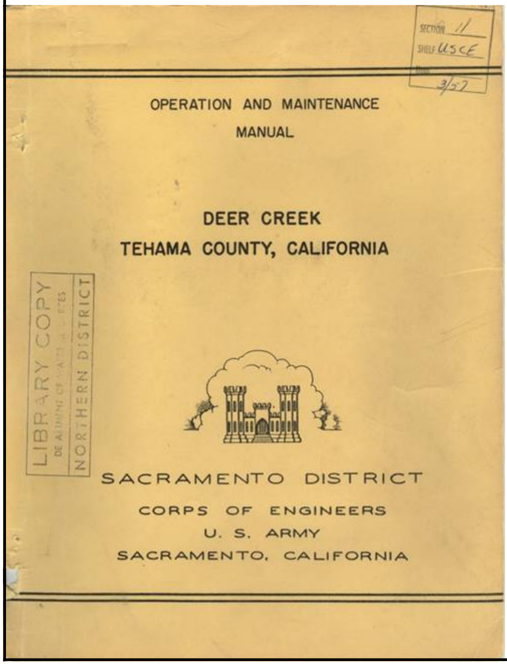
Reconnecting the Floodplain of the Sacramento River by setting-back the levee, Partly restoring lateral Connectivity.
(But floods also reduced by Shasta Dam, so lateral connectivity still reduced)



Applying fluvial geomorphology
to understand underlying cause
of problem: Deer Creek
Habitat for spring-run chinook

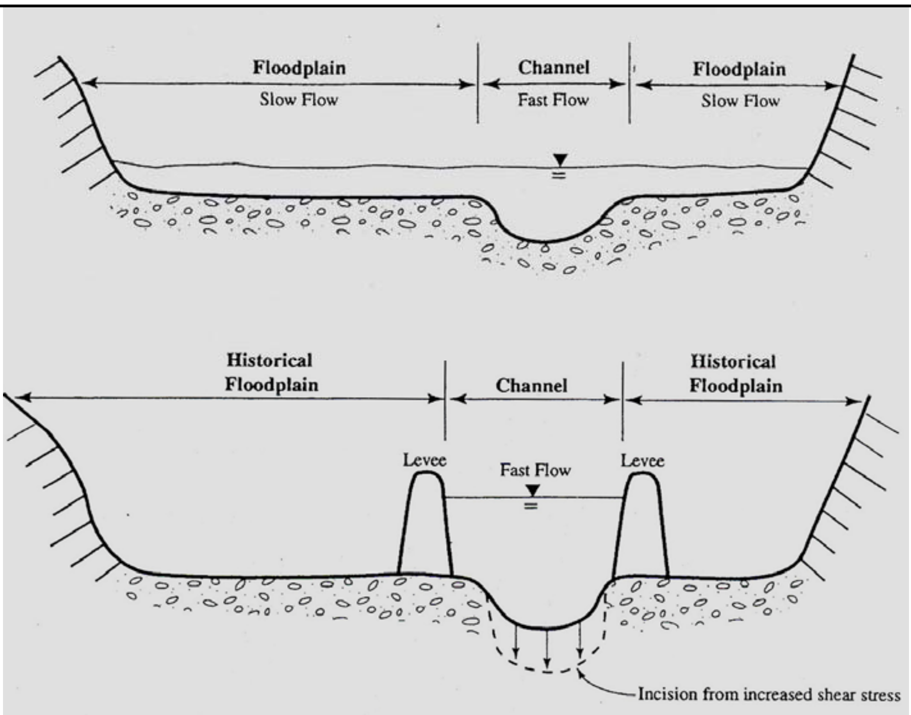


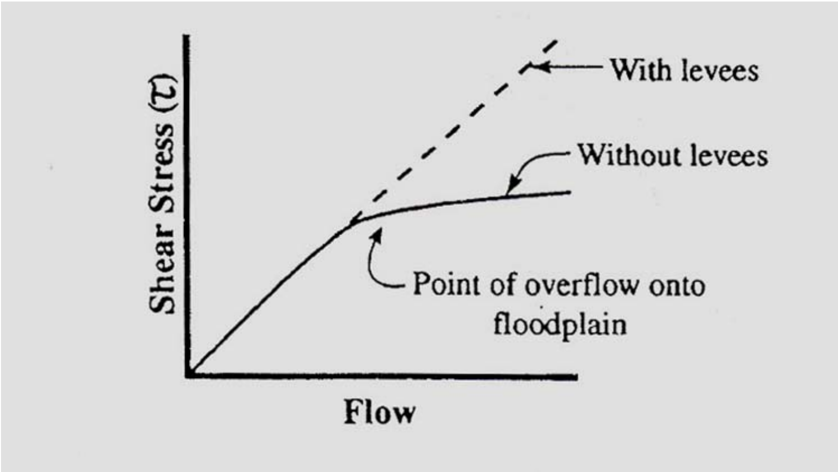
Restoration planning documents for salmon in the Sacramento River system identified the need for smaller gravels and more riparian trees in Deer Ck, recommended adding spawning gravel and planting trees (restore form)



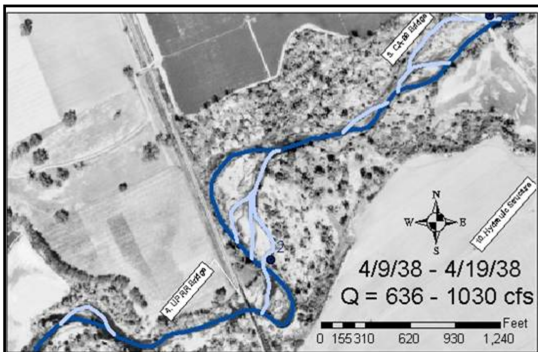
But a geomorphic analysis showed that the conditions of large gravel and lack of vegetation along low-flow channel were consequences of a 1949 flood control project

Thus, understand how processes have been altered

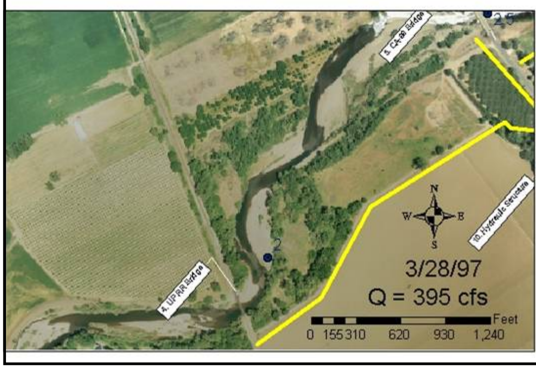




Confinement by levees increases bed shear stress during high flows



Historical-geomorphic analysis showed that 1949 flood control project changed channel from multi-threaded, complex, shaded, frequent pool-riffle alternations
to

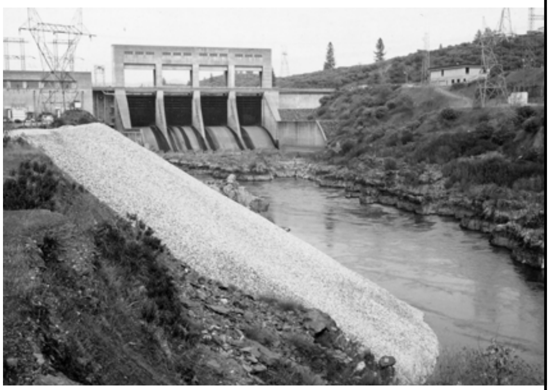


simplified, wider channel with high shear stress in floods. (Added gravels and planted trees would scour) Less complex habitat, less hyporheic interaction. To restore habitat, restore floodplain connectivity!

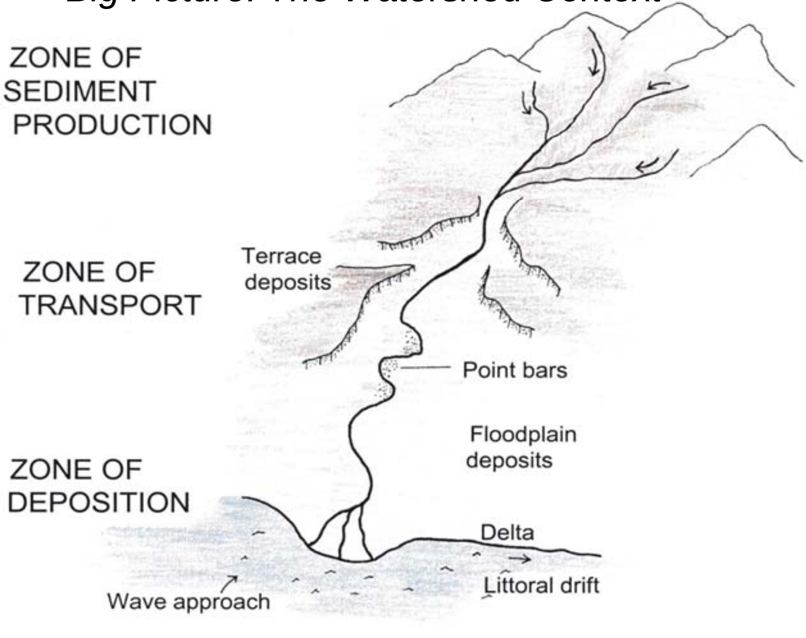
Gravel Augmentation Below Dams
widely implemented in northern California
Goals:
salmonid habitat enhancement,
protect infrastructure from incision,
restore coarse sediment load

Two approaches:
1. Build artificial riffles (restore form)

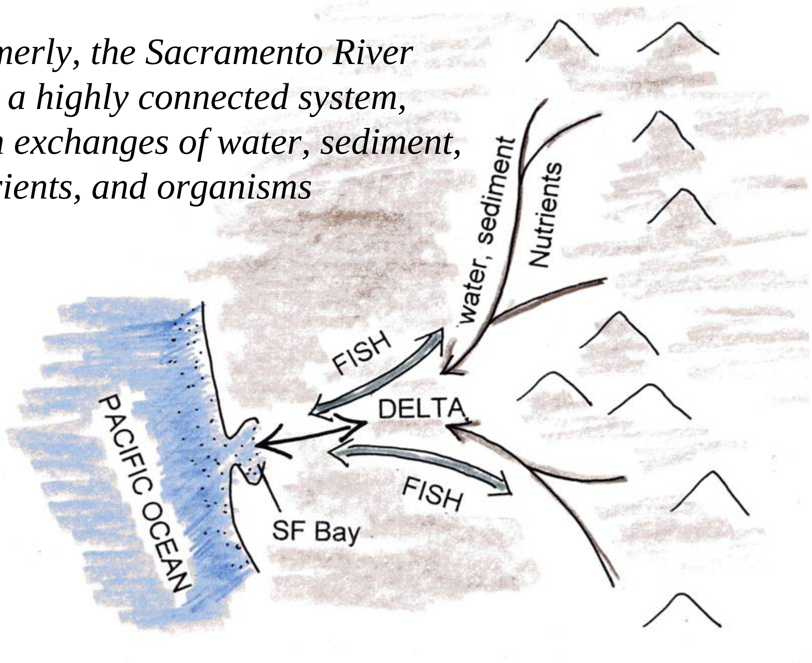
2. inject gravel for redistribution by flows (restore process)



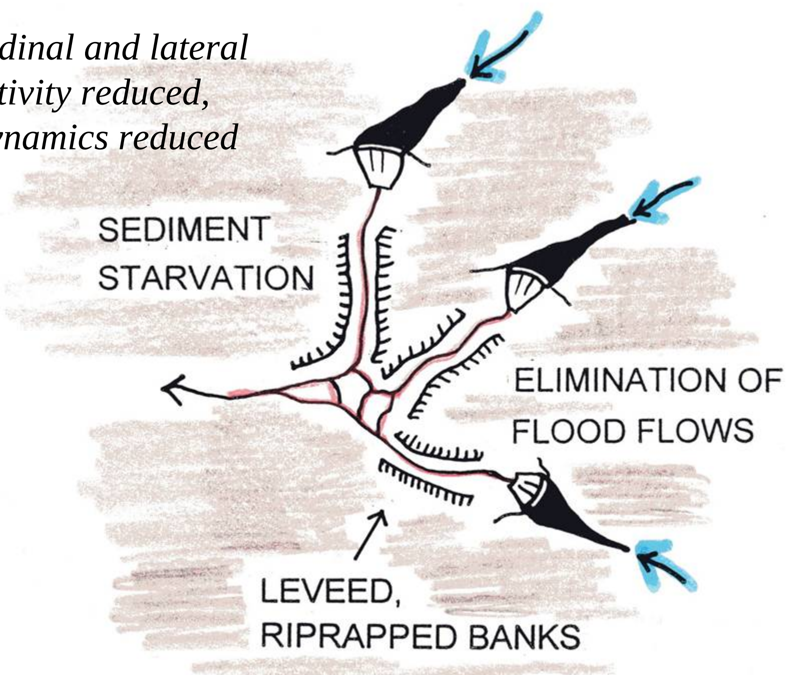
Big Picture: The Watershed Context



Formerly, the Sacramento River
was a highly connected system,
with exchanges of water, sediment,
nutrients, and organisms



Now:
Longitudinal and lateral
connectivity reduced,
Flow dynamics reduced



Consider Catchment Context

Reduced sediment supply – "Hungry Water"

Dams cut off all bedload, some susp

Gravel mining – gravel sinks

Bank protection

Channelization/dredging legacy effects

Account for tributary inputs

Changed sediment transport capacity

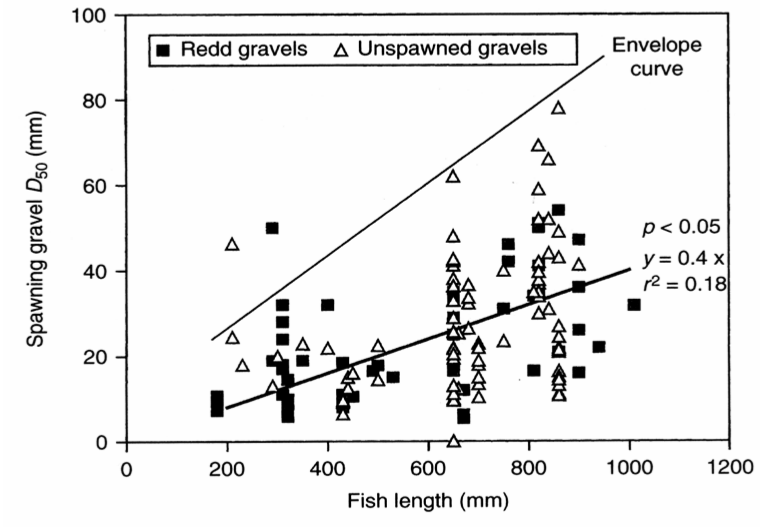
Decreased xport capacity below dams

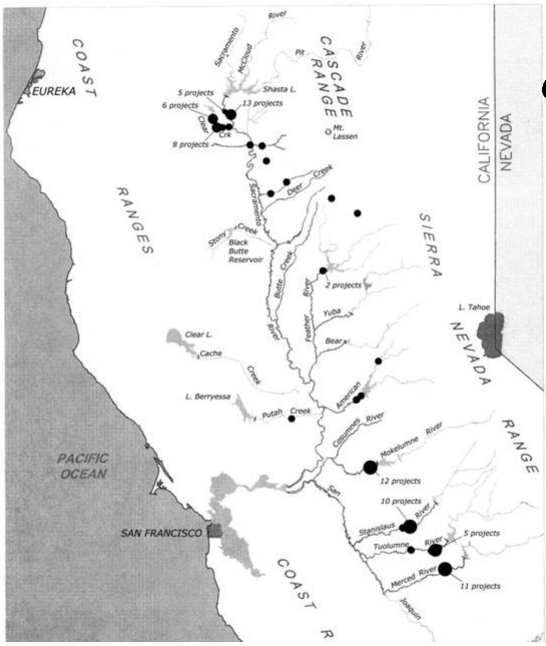
Sediment transport capacity changes with addition of sediment due to changed supply, grain size

Counteracting: narrower channel, higher shear?

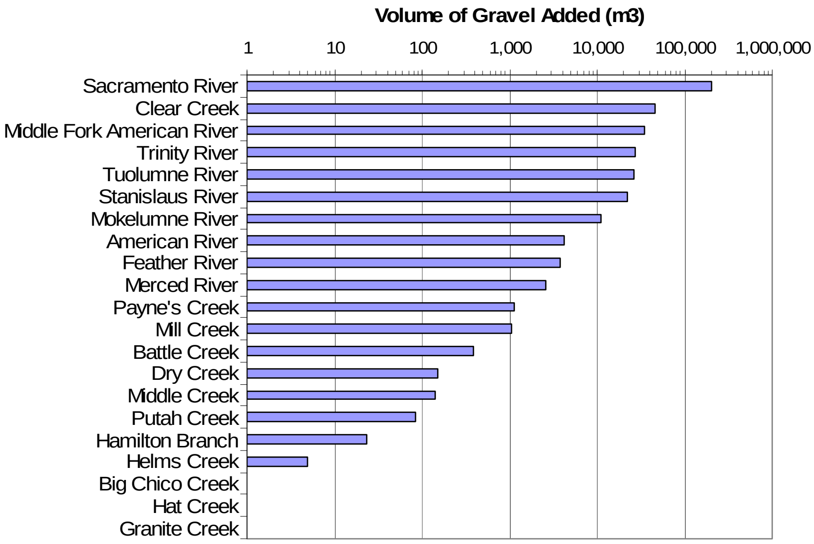
Many uncertainties*, so must manage adaptively*

For spawning gravel augmentation, framework size should be movable by the fish



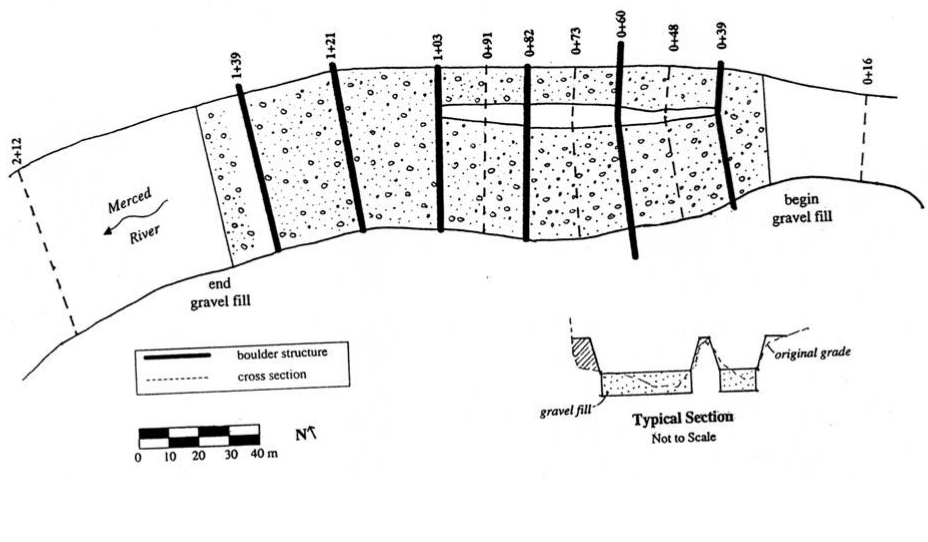


Over 500,000 m3 gravel added to rivers below dams in northern California, all to improve salmon spawning habitat



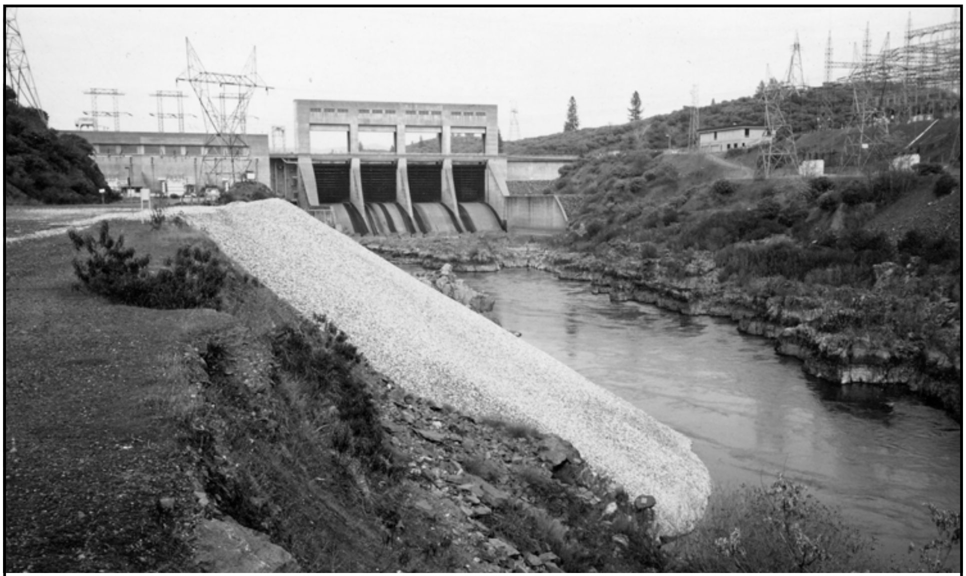
Artificial riffles designed to create spawning habitat by creating the forms

An example of an artificial riffle construction: the Merced River



Gravel scoured and transported from constructed riffles after 4 drought years

-Application of Shields' criterion shows the imported gravel was mobile at the *post-dam* Q1.5



Gravel injection below Keswick Dam

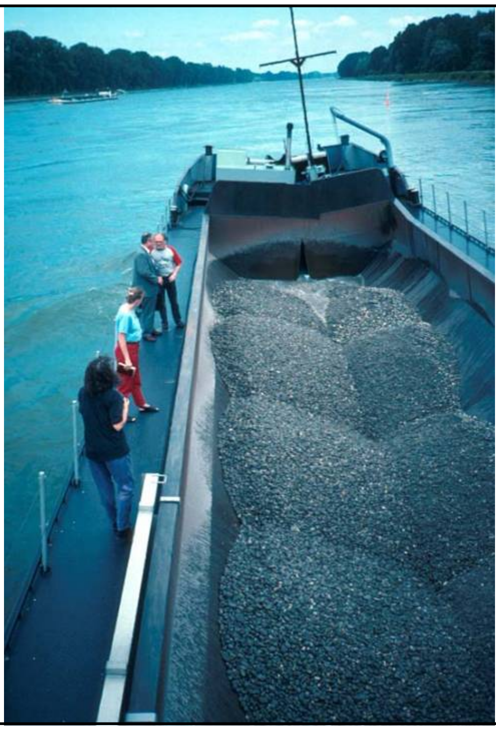
How to define success?
Artificial riffles
-Still functioning?
Gravel injection
-Is gravel moved downstream
and deposited in suitable forms?

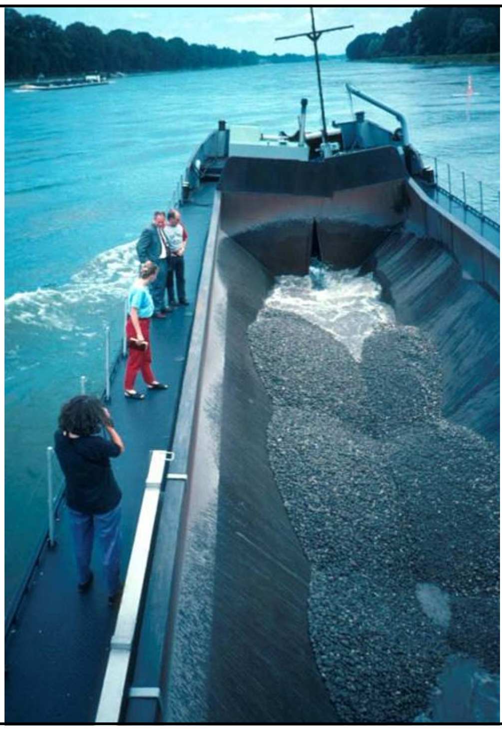
For both:
-Used by fish? Used by the *RIGHT* fish?
-Is spawning limiting?

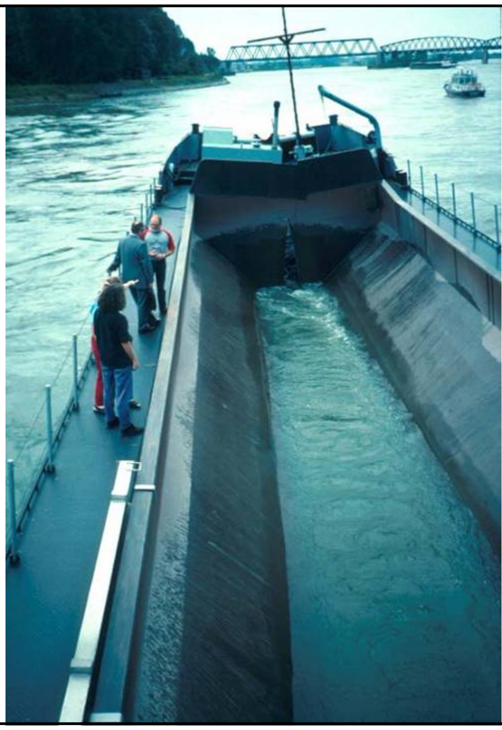
New Approach:
Restore sediment supply so river will
create complex habitats (not just spawning riffles)

Gravel augmentation on the Rhine:
to prevent undermining of infrastructure

Iffezheim: the downstream-most dam







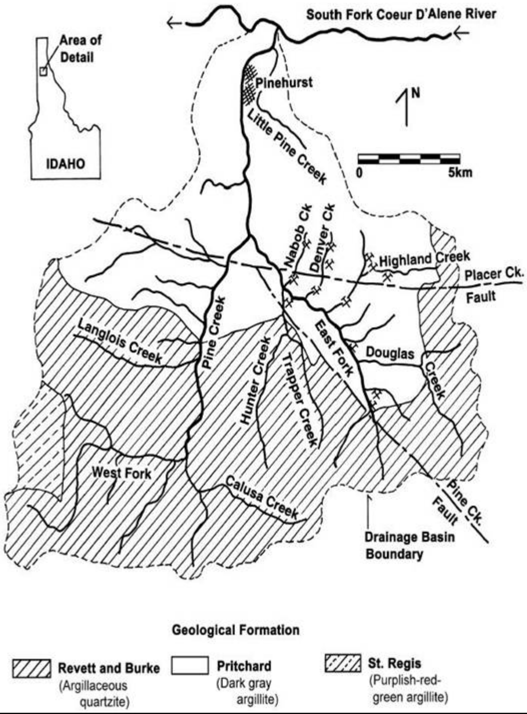
What do we mean by restoration?
Objectives will be different in different places…

Examples: Watershed change, channel change in two contrasting catchments

- Pine Ck, Idaho
- Drome R, SE France *(Kondolf, Piegay, Landon 2003)*

Both underwent large changes in bedload sediment yield since 19th century, but in opposite directions.

In both cases, managers seek to “restore” to prior conditions



Pine Creek

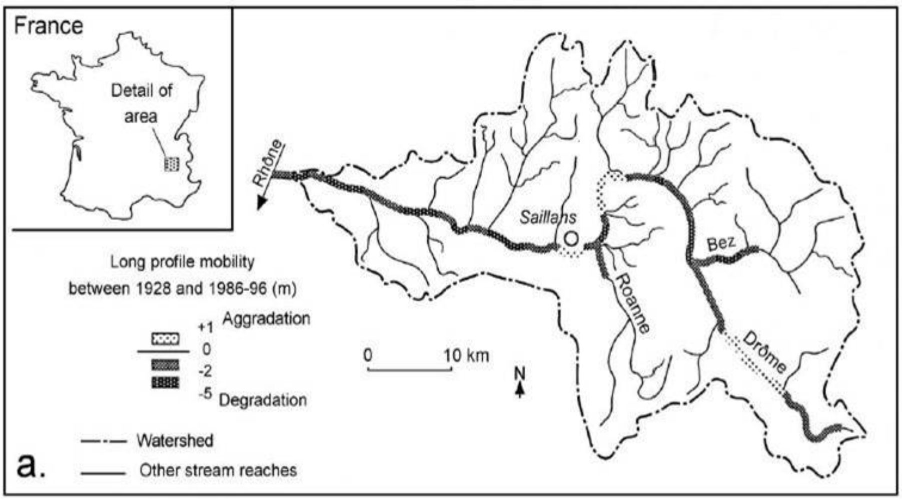
-Tributary to South Fork Coeur d'Alene River at Silver Valley

-Basin underlain by preC metasedimentary rx

-20th century mining increased bedload supply, caused aggradation, widening, washed out highway.

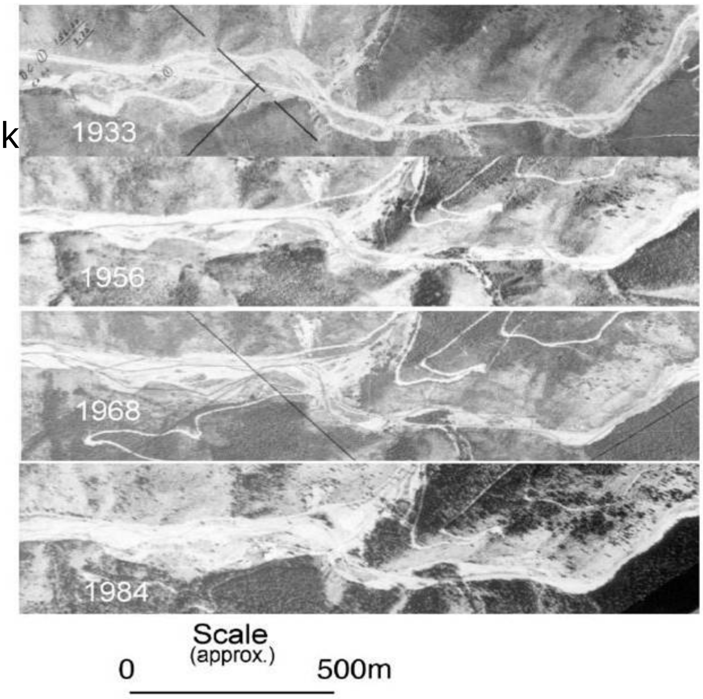
-Flood hazard (1996 damage)

Drome River basin drains preAlps, K marl, limestone. Since 19th C, reduced land use pressure, resulting in reduced bedload supply.

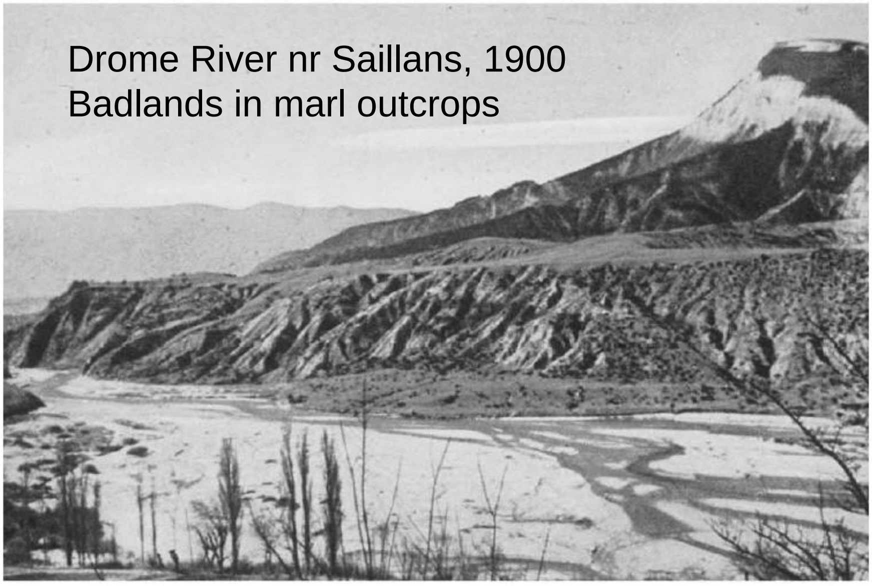


Rock waste pile feeding Highland Ck, Pine Ck trib

Input of
rock waste
to EF Pine Ck
caused
channel to
widen 50%
1933-1984



Profound landscape change since 19th century:
Reduced population density and land use in mountains



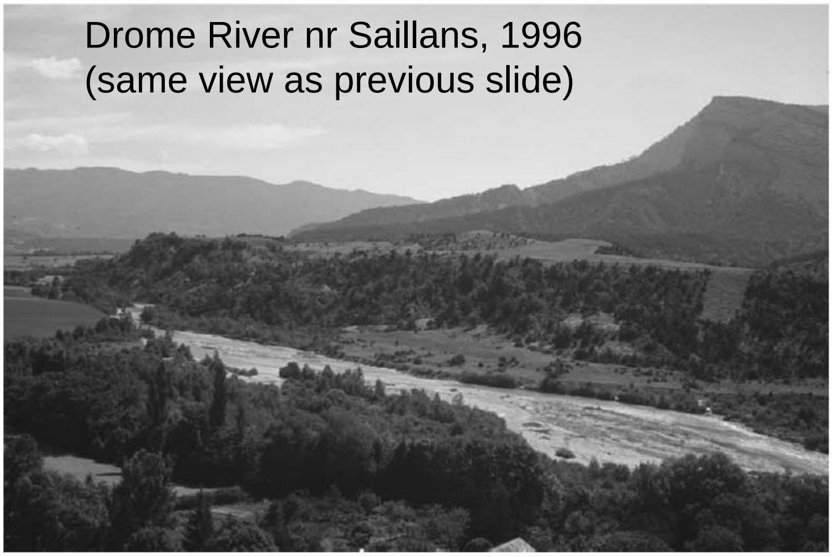


Image courtesy Herve Piegay and Norbert Landon

Restoration Actions: Pine Creek

- Remove tailings
- Stabilize rock waste dumps (sediment sources)
- Stabilize channel
- dredge aggraded sediments above Pinehurst

Objective: reduce bedload supply, stabilize channel, reduce flooding risk

Restoration Actions: Drome River

- Gravel mining outlawed in 1980s
- Sediment no longer removed for routine maintenance, even landslide sources
- Proposals to *increase* bedload by re-activating landslides, removing check dams

Objective: increase bedload supply to recover incised bed

Both Pine Creek and Drome restoration programs have been successful so far because:

- they take a basin-scale approach
- address sediment supply
- they don't look only at the reach scale, but look upstream

"Restoration" in opposite directions:

-Pine Ck – flooding problems, unstable channel;
Restore via narrowing and stabilization

-Drome R – incision, water table decline and loss of alluvial aquifer;
Restore via aggradation

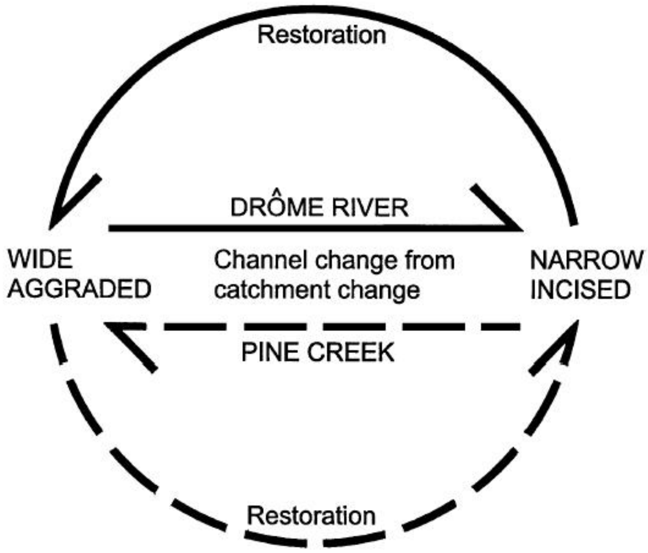
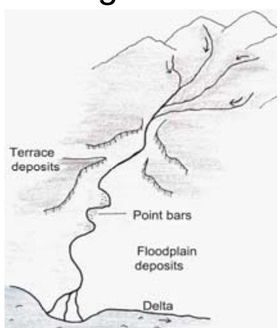


Fig. 14. Diagram illustrating contrasting directions of channel change due to catchment change, and contrasting directions of intended restoration, in Pine Creek and the Drôme River.

Problems are typically formulated by managers
- on short time scales
- at the reach scale



Yet solutions require understanding
- ***catchment/systemwide context***
- ***longer time scales***

This may seem obvious, but most restoration projects are designed at the reach scale, many don't account for catchment-scale influences

Restoring process vs form
- must understand catchment to restore process

Very popular in North America is form-based:
design ***stable, single-thread, meandering channels***
based on Rosgen classification scheme

Uvas Creek, California Jan 1996, 2 mo post-construction
(Are we in Denmark?)

Uvas Ck (same view as last photo) July 1997
Channel failed Feb 1996, 3 months after construction

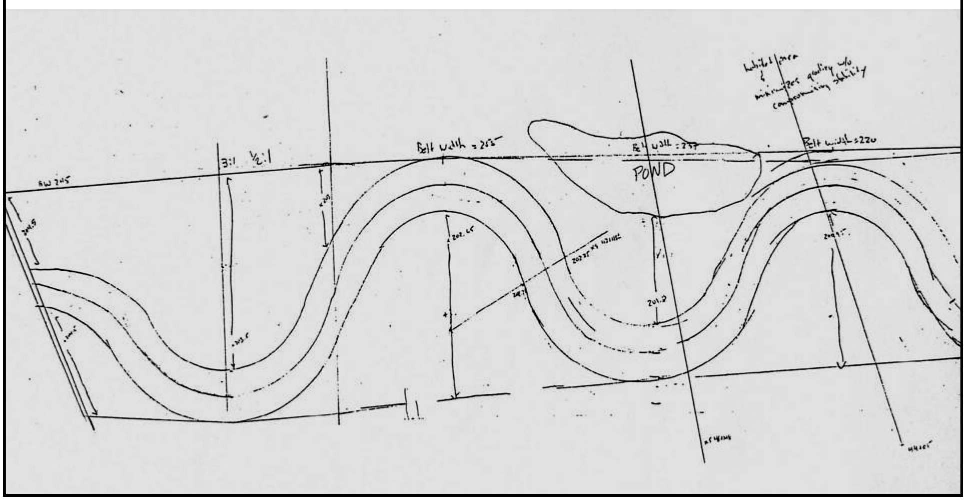
Basis of channel design: excerpts from plan

The channel was once a stable C4 channel (Rosgen, 1985, 1993). C4 channels have well defined point bars and floodplains, which are used as energy dissipating features during high stage, high energy events. Energy is also dissipated by the sinuous meander pattern (Leopold, Wolman, Miller, 1964).

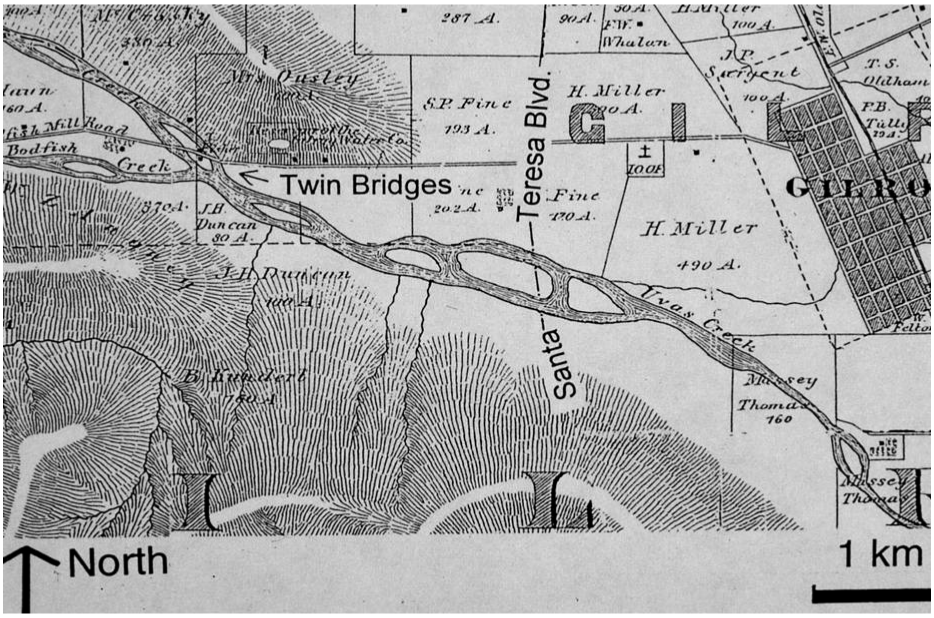
Levee construction, gravel extraction, and ill-fated flood control efforts resulted in a deepening and straightening of the channel. The effects of these activities on channel stability and behavior are to convert the stable C4 channel to F4 and G4c channels. This conversion results in:

- an increase in mean velocity,
- a higher entrenchment ratio (bankfull width to width at 2x bankfull depth
- an increase in sediment contribution from banks (manifested by bank collapse, lateral channel migration),
- a decrease in fish and wildlife habitat habitat,
- disturbance to native riparian plant communities,
- an increase in channel roughness caused by hydrologic instability.

Channel design based on
- Classification as C4 type channel
- Meander geometry relations (e.g., wavelength and amplitude scaled to bankfull channel width)

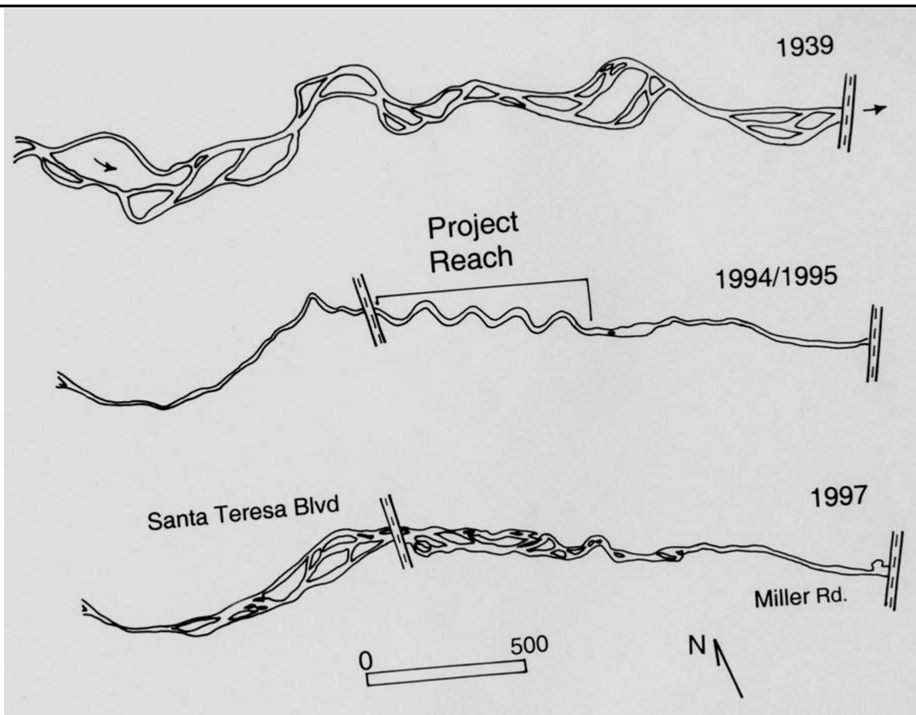


Historical evidence: channel was not formerly a meandering channel, but braided. 1879 map:



The channel was wide, unvegetated, braided.
1894 photo from Twin Bridges (1 km upstream project)

The project reach was braided in 1939: reflects climate (Mediterranean) and lithology (Franciscan Formation)



Why did the Uvas Creek project fail?

The designers didn't understand the system:

- drains the California coast ranges, Franciscan fm
- episodic, Mediterranean-climate runoff
- high sediment loads

They didn't take a longer-term, historical view to see that this reach had never been a single-thread meandering channel

Tried to restore form, ignoring process

Uvas Ck is one of many such projects built in California whose fate has been the same

C4/C3 Meandering Channels in California

(Some dates below appx, being checked in NRRSS)

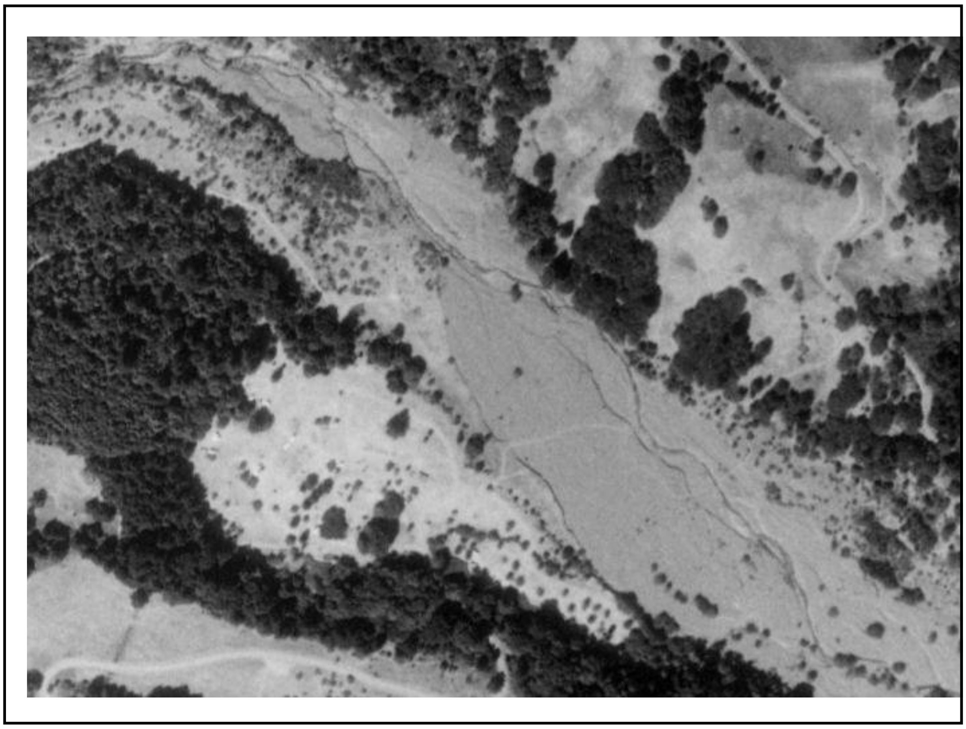
1990	Wolf Ck, Sierra Nevada	Washed out, buried
1990	Cuneo Ck, Coast Ranges	Washed out
1993	Mattole Cyn Ck, Coast Ranges	Washed out
1994	Greenhorn Ck, Sierra Nevada	Washed out
1995	Jamison Ck, Sierra Nevada	Washed out
1995	Uvas Ck, Coast Ranges	Washed out
1996	Cold Ck, Lake Tahoe	Filled then scoured
1997	West Walker R, Sierra	Rocked meanders
1999	Bear Ck, Cascades	Channel moved to meadow (success), Many constructed riffles (undulating bed cut into clay) washed out
2001	Ackerman Ck, Coast Ranges	Washed out

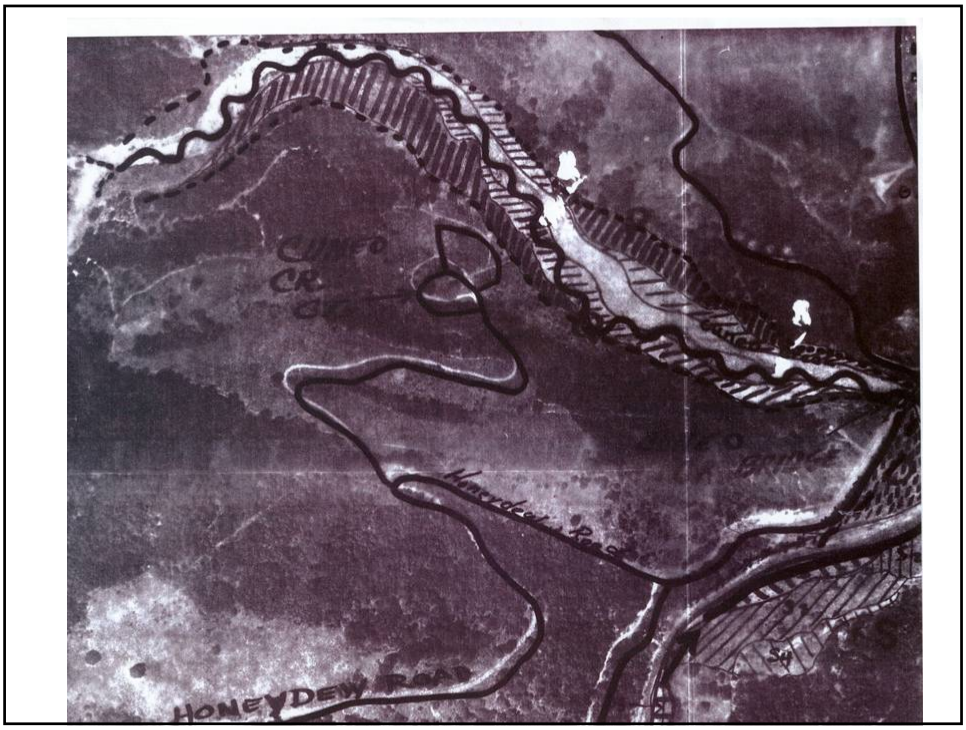
Cuneo Creek,
Tributary to Bull Ck
Humboldt Redwoods
State Park, California

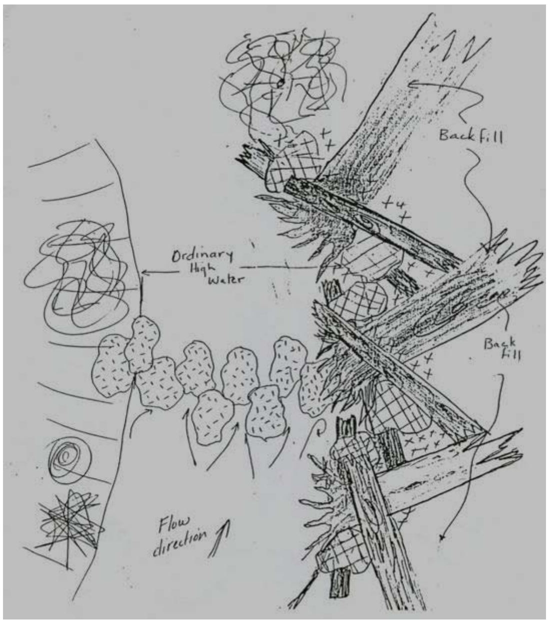
Basin logged in
1950s-60s, high
sediment yields.

Aggradation (7m),
braided channel

Landslide in
Upper Cuneo Ck
basin




Honeydew Road
HONEYDEW ROAD

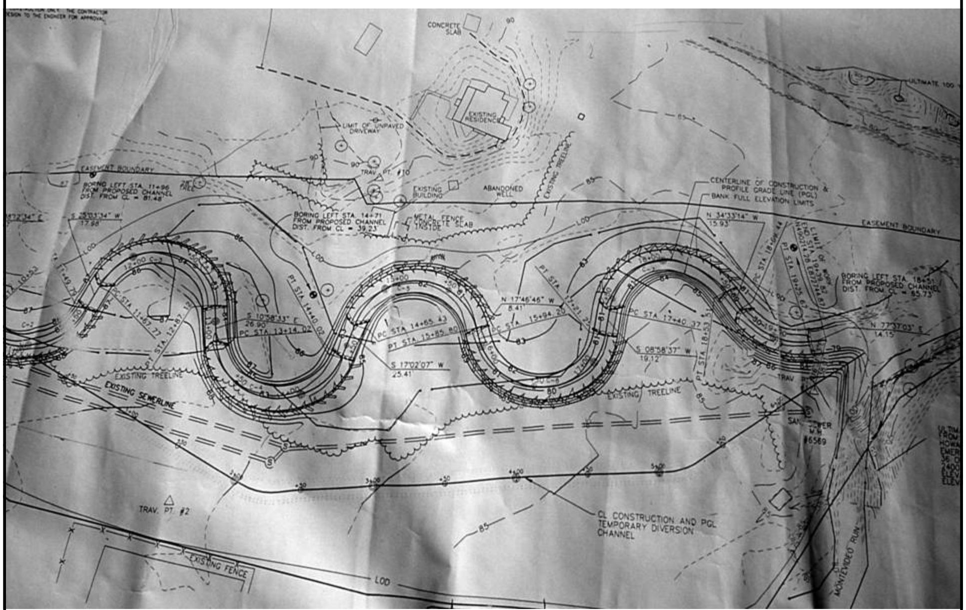

Back fill
Ordinary
High
Water
Back
fill
Flow
direction

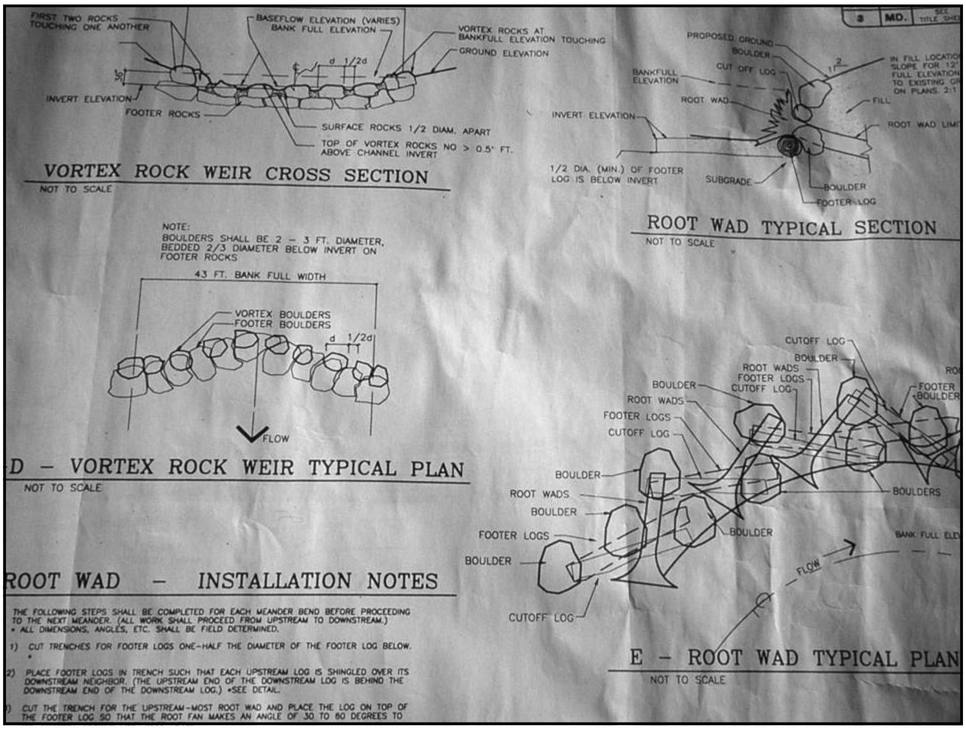
Why did the Cuneo Ck project fail?

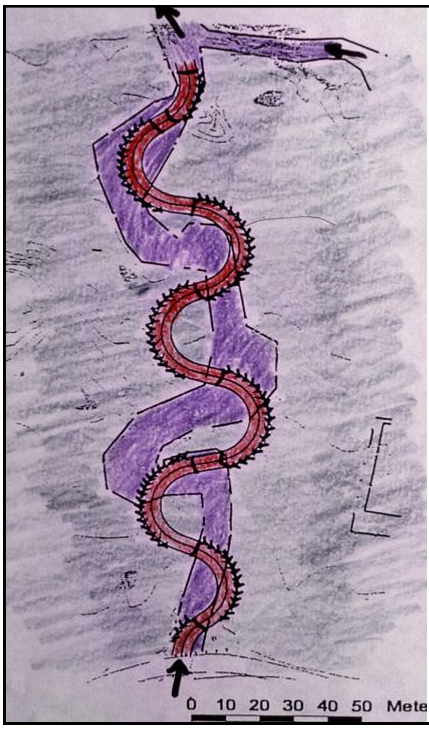
Designers did not look upstream at high erosion rates, did not account for evidence of historical aggradation

Tried to impose a channel form inconsistent with the runoff regime and sediment supply (process)

At fall line, gravel deposition zone
Old mining pits downstream, ‘wetlands’ filling with sed
DOT built bridge, filled ‘wetlands’, needed ‘mitigation’.
Money looking for a project!
Deep Run channel assumed to be eroding, sed source.
Designer didn’t look upstream, at urbanizing catchment
Logic: Build ‘proper’ geometry, no more erosion!





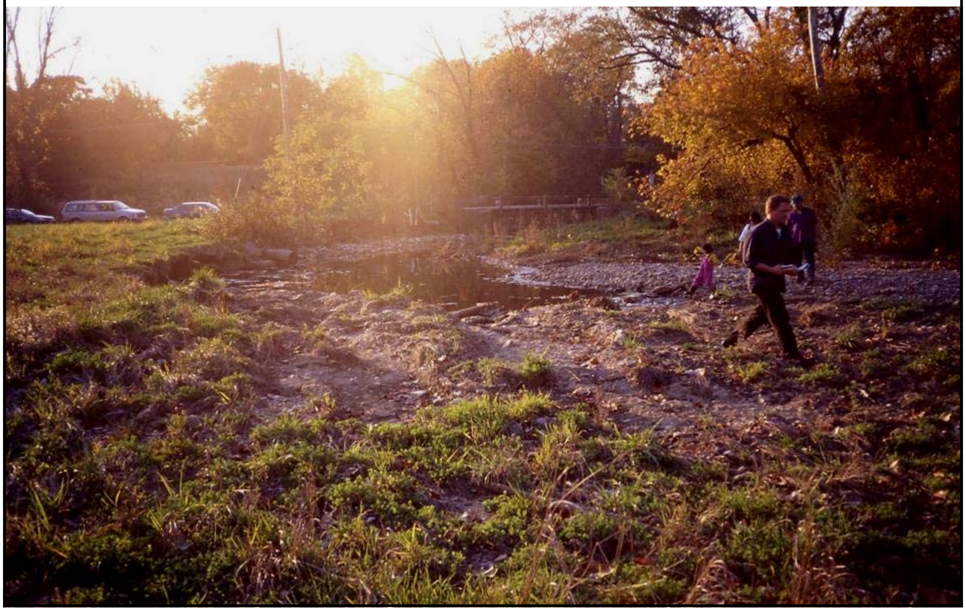


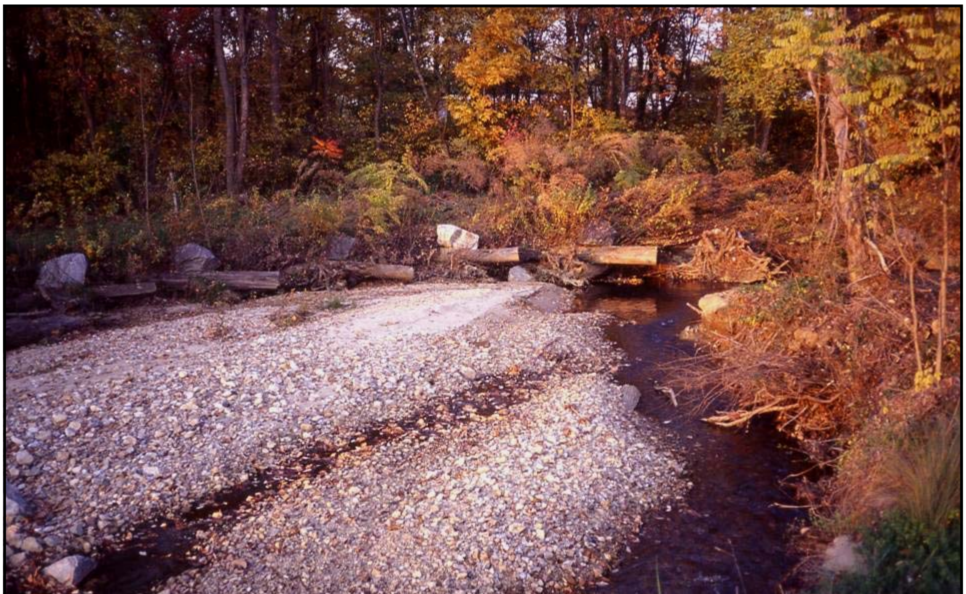
Narrower, symmetrical
C4 channel
predicted to be stable.

Existing riparian vegetation
removed

Smith (1997) found
overbank velocities higher
post-project
(reduced roughness)

Looking upstream at erosion from overbank flow.
No rip veg, low roughness, high overbank velocities





Channel shifted away from protected banks

Why did the Deep Run project fail?

Better to ask:
Why was the project built in the first place?

- Mitigation money looking for a project
- Designers didn't look upstream in catchment
- Designers didn't look at historical evidence to understand site context and history

And, as at Uvas and Cuneo Creeks, an attempt to impose a symmetrical meandering channel form, ignoring process

Why stable, symmetrical meandering channels so popular for design?

Easy to design by cookbook: standard elements, e.g., such as rootwads, rock weirs.
Practioners know how to build them!

Classification system predicts they are stable.

Cultural preference for stable, narrow, single-thread channels. (trout streams!)

Imposed on channels because designers don't take a long-term and catchment view of process

Cultural Preference for Meanders

-Appleton (1975): “deflected vistas” e.g.paths, rivers, valleys, as line of sight deflected, curved

-Cullen (1961): “anticipation”, curving city streets

-Kaplan & Kaplan (1984): “mystery” in landscape

-18th-19th Century English landscape ideas: Beautiful, picturesque, sublime

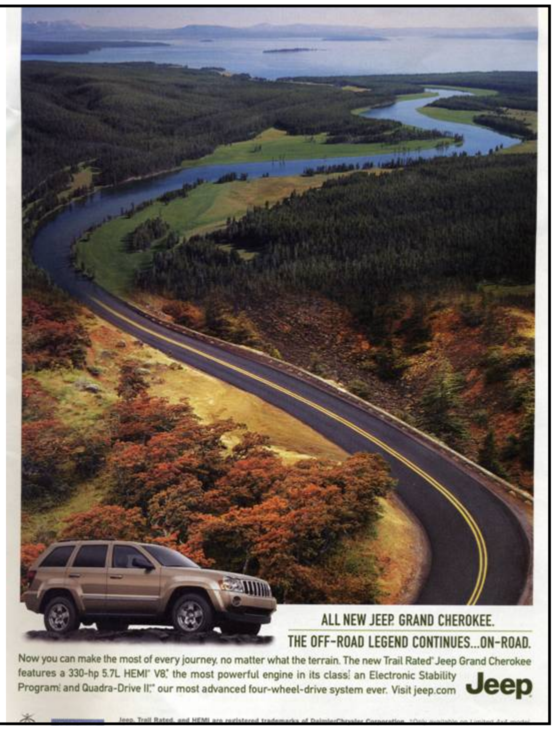
-“Find the S-curve”

The Thames viewed from Richmond Terrace, considered an ideal landscape

A Brownian landscape (*above*) and the same landscape (*below*) made picturesque, from Richard Payne Knight, *The Landscape: a didactic poem* (1794)

Meandering channels built by Capability Brown (and other landscape architects) on the estates of their wealthy clients in 18th-19th centuries.

There is something compelling about the serpentine line!

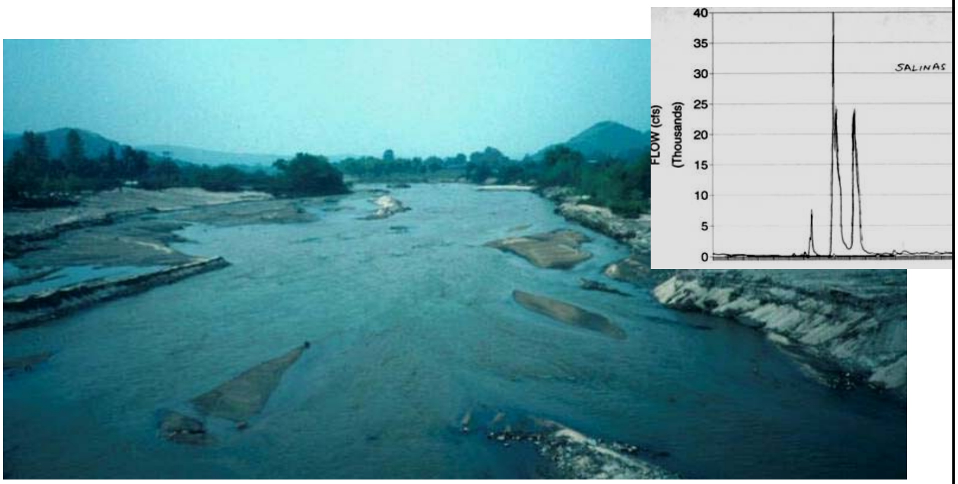


Mediterranean-climate rivers:

-high variability seasonally and inter-annually

-episodic geomorphic processes

-greater motivation for water storage, flow regulation



An ***Arizona crossing*** over the San Luis Rey River

Woops!

Carmel River above San Clemente Dam 1987,
after high flows of early-mid 1980s

Carmel River 1993, 1993 after 6 years of drought

Carmel River 1995, after flood

Temporal and Spatial Distribution of Water Supply and Demand

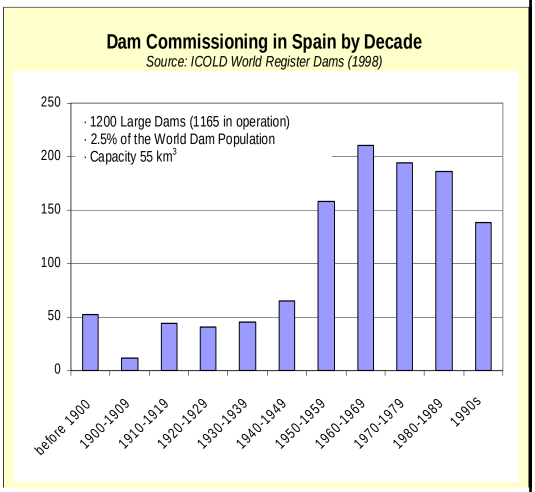
Water supply variable, out-of-phase with demand.
Climate suited to irrigated agriculture, so demand high
Result: *need seasonal, year-to-year storage*
Med-climate rivers have much higher rates of impoundment/hydrograph change than humid rivers

Irrigated rice fields, Sado River Portugal

Big Water Projects: Political Role

US: TVA, Central Valley Project,Calif State Water Project
Portugal: Salazar's "Estado Novo“, e.g. Sado R project
Spain: Franco's dam program, Spanish Hydrological Plan

1400 large dams
In California



Together Calif and Spain have about 5% of world's dams

Impounded runoff index:

IR = $\dfrac{\text{reservoir capacity}}{\text{mean annual runoff}}$

- IR is a rough indicator of the degree to which reservoirs alter flow regime

-Can calculate IR using total storage or active storage (latter less widely available but should be more appropriate)

- Theoretically a measure of residence time, though in practice the sequence of years is very important

Humid climate rivers

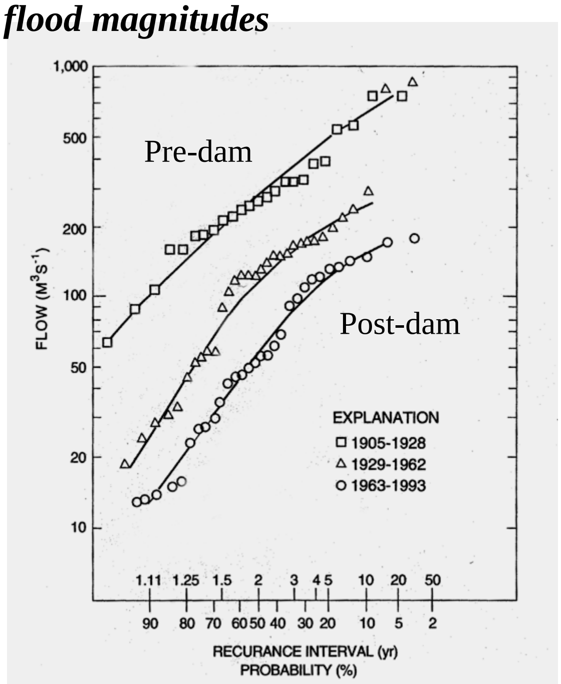
Potomac River:	IR < 0.20
Elbe River:	IR < 0.05
Rhein River:	IR < 0.15

Mediterranean climate rivers

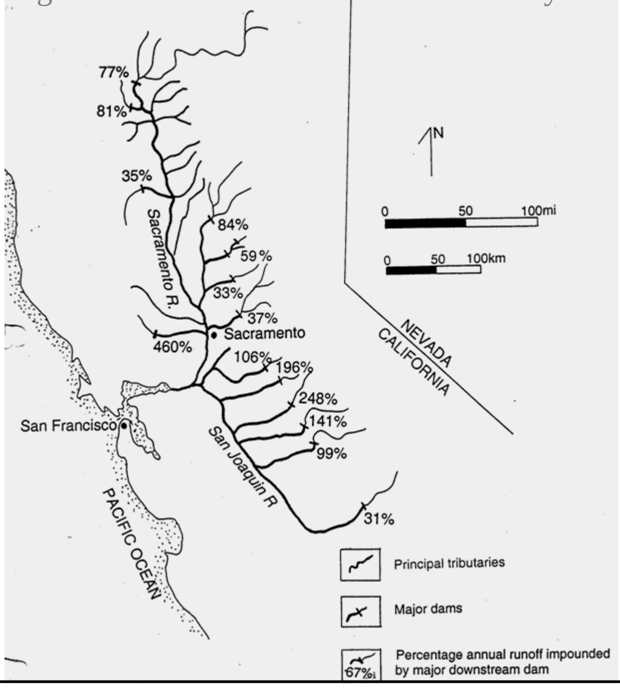
Ebro R, Spain:	IR = 0.57
Spain overall	IR = appx 0.40
Sacramento R	IR = 0.80
San Joaquin R	IR = 1.20

The result is reduced flood magnitudes

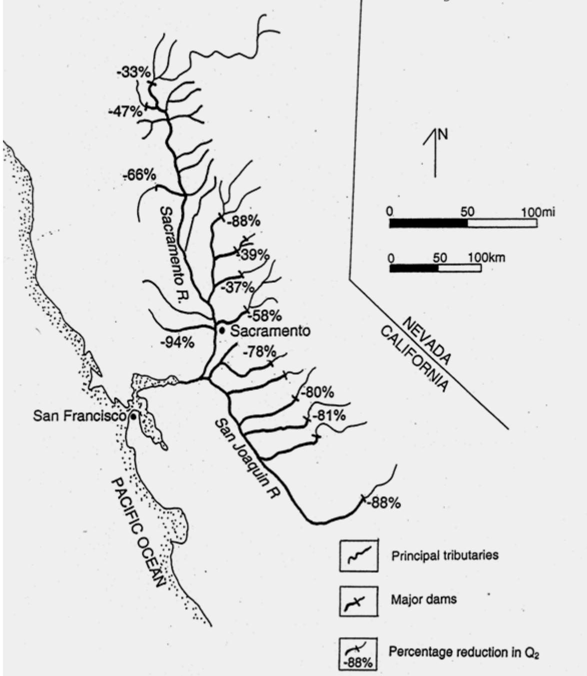
Mokelumne River
Flood Freq. Analyses

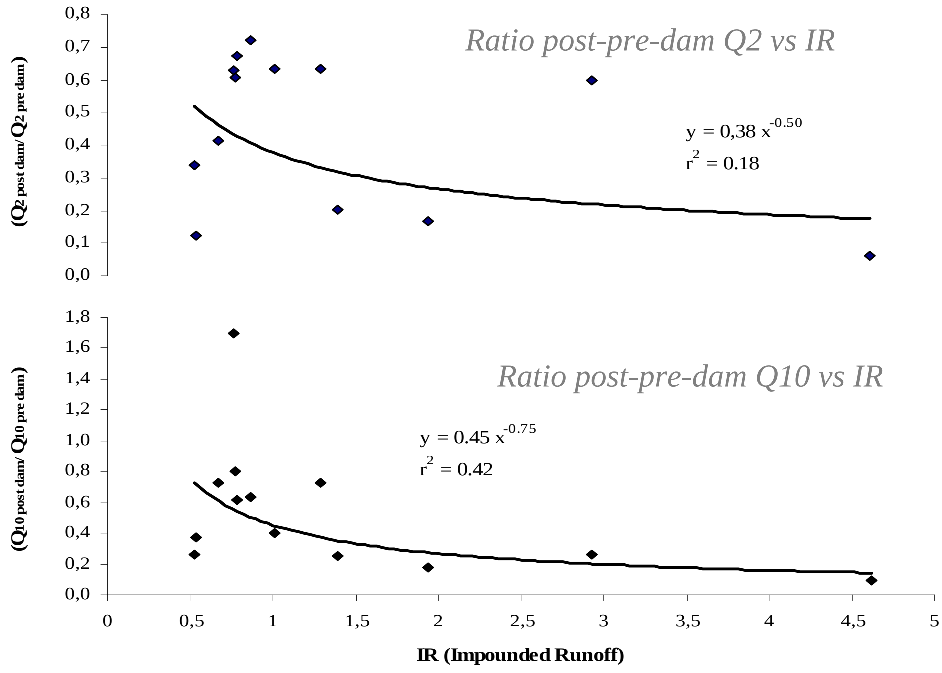


IR for large “foothills” dams in the Central Valley of California

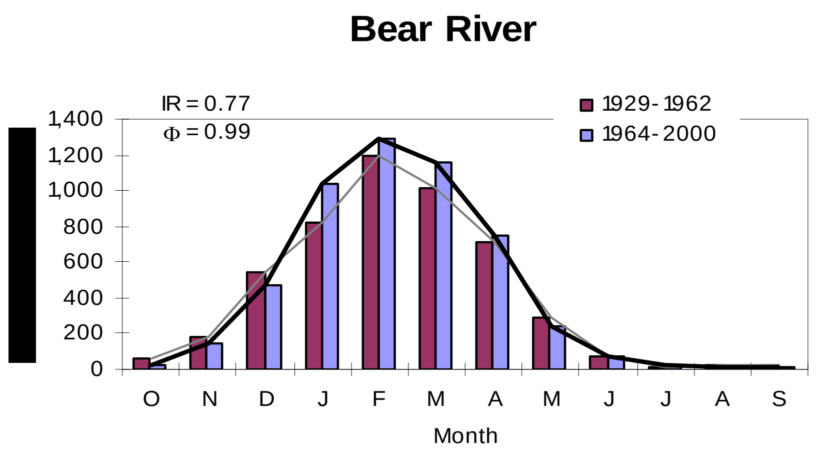


Dam-induced reduction in Q2 on major tributaries



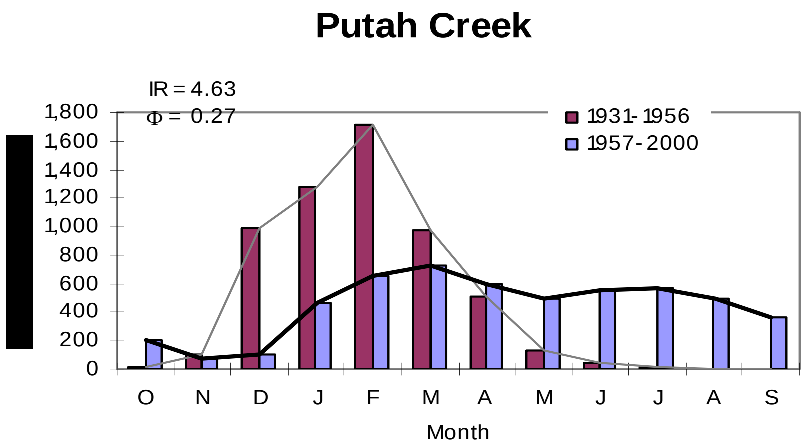


Mean monthly flows pre- and post-dam,
Relatively small reservoir, no flood control function



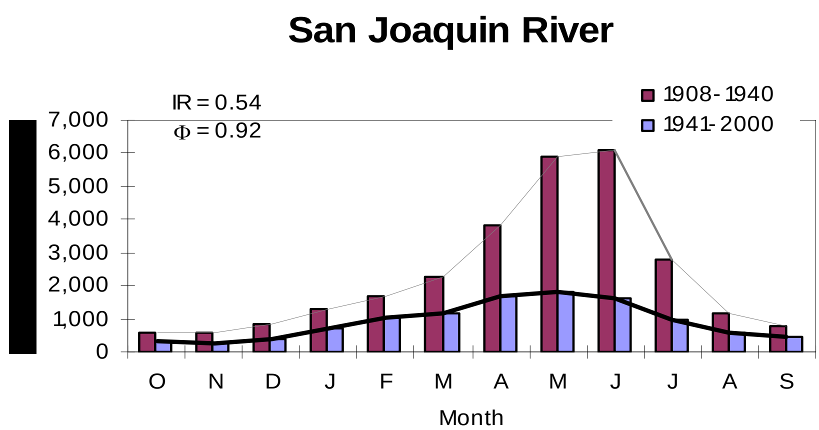
Rainfall (winter) runoff

Mean monthly flows pre- and post-dam,
changed seasonal distribution
(Big dam on a small river)



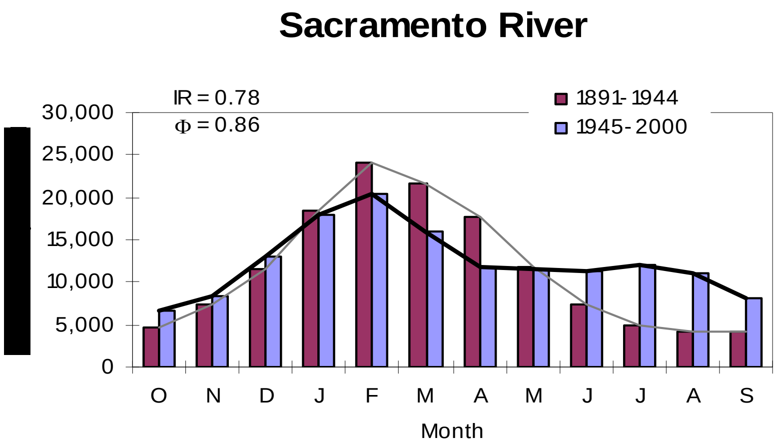
Rainfall (winter) runoff

Mean monthly flows pre- and post-dam,
With large agricultural diversions from dam



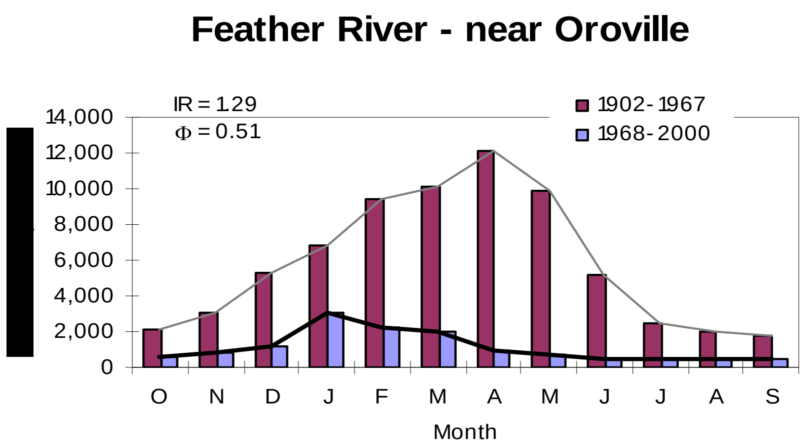
Snowmelt dominated runoff)

Mean monthly flows pre- and post-dam,
Changed seasonal distribution of flows, flow augmentation



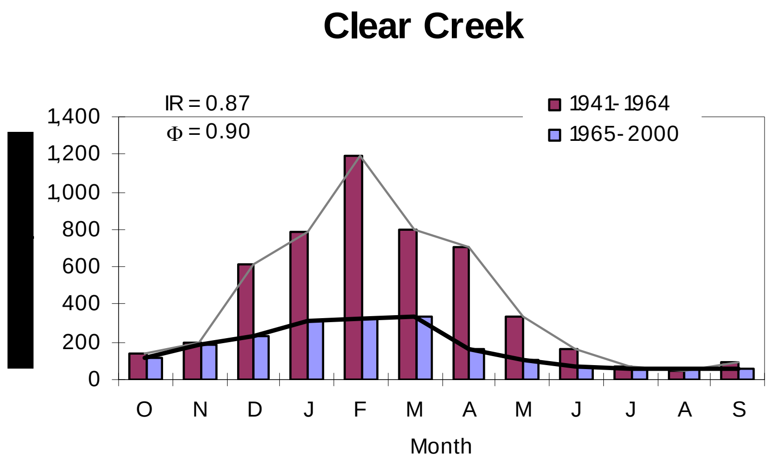
Mostly rainfall-dominated runoff.
Implications for establishing cottonwood forest

Mean monthly flows pre- and post-dam,
Dewatered reach below hydroelectric diversion



(rainfall-dominated runoff)

Mean monthly flows pre- and post-dam,
With export from basin



(rainfall-dominated runoff)

Compare with Ebro River basin:

(Batalla et al. 2004)

Q2 and Q10 decreased by 30%
(compared to 60% decrease in Sacramento-San Joaquin)
Overall IRs: Ebro 0.6, Sacramento 0.8, SJoaquin 1.2

Q2 and Q10 against IR:
R2 of 0.52 and 0.60 for Ebro vs 0.32 and 0.42 Sacto-SJ

Implications for Restoration of Hydrograph change:

Do you restore a shrunken river below the dams?
Or try to increase flow releases?
Or some combination?

Prioritizing Restoration Efforts

Even well-funded restoration programs small compared to magnitude of historical change

"Low-hanging fruit"

"Bus shelters" (gravel augmentation in Calif?)

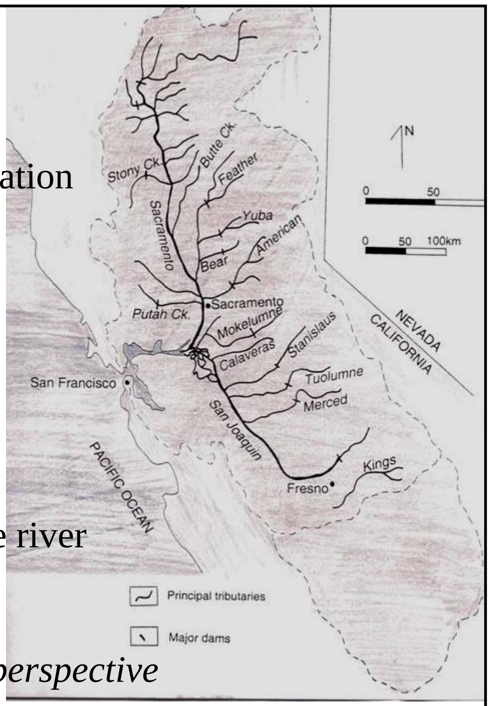
We need a catchment/systemwide, long-term perspective to understand how individual projects might fit into the bigger picture

Prioritizing at the basin scale for the Sacramento River:

Acknowledge scale of modification
Less than 5% tidal wetlands, floodplain forests remain.
How to "restore"?
How to allocate resources?

But no big dam downstream,
Tributaries wired in parallel,
Thus can restore salmon in one river whilst writing off its neighbor

Need catchment/system-scale perspective



Five Principles for River Restoration

1. Approach restoration in context of historical changes

-What is “restoration”?

2.Riverine species depend on connectivity/dynamics

-Restore (preserve) process, not form

3.River restoration still largely experimental

-Learn by post-project appraisal, adaptive management

4.Approach larger spatial and temporal scale

-Understand processes and historical changes at basin scale

-Prioritize actions in larger context

5.Set goals in context of constraints/opportunities

-Urban-wilderness continuum