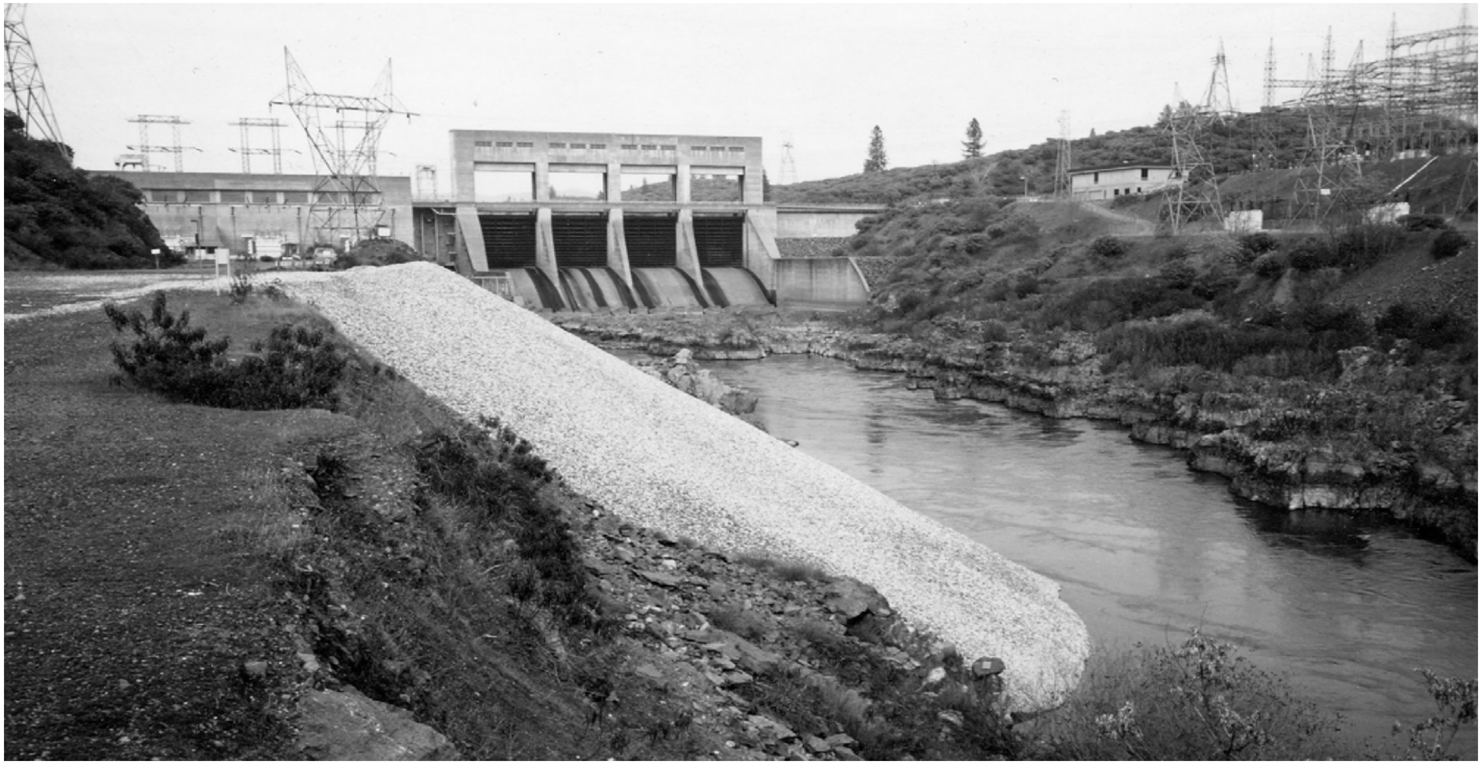
Gravel Augmentation on Rivers:
Geomorphic Perspectives
and Lessons Learned from Some Past Projects
A MULTI-MEDIA EXTRAVAGANZA!



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with thanks to: Toby Minear, Anthony Falzone, Erin Lutrick, Graham Matthews, Scott McBain, Andreas Krause

Objectives of this Presentation

Well, what’s left to say?

Big-picture thoughts on:

- setting objectives, selecting methods
- geomorphic/management issues

Finish Andreas’ talk (Trinity R lessons)

Mystery of the table solved:

Summary of Central Valley gravel projects

Finish Frank’s talk (ie, return to the question:
is it worthwhile? Is it our top priority or just easy?)

How the German engineers do it

Rivers, rocks, and resto taken *seriously* in Denmark

Setting Objectives – consequent methods

"Let the punishment fit the crime!"

Goals Broadly:

salmonid habitat enhancement,
protect infrastructure from incision,
restore coarse sediment load

Methods Broadly:

inject gravel (coarse sediment)
build riffles

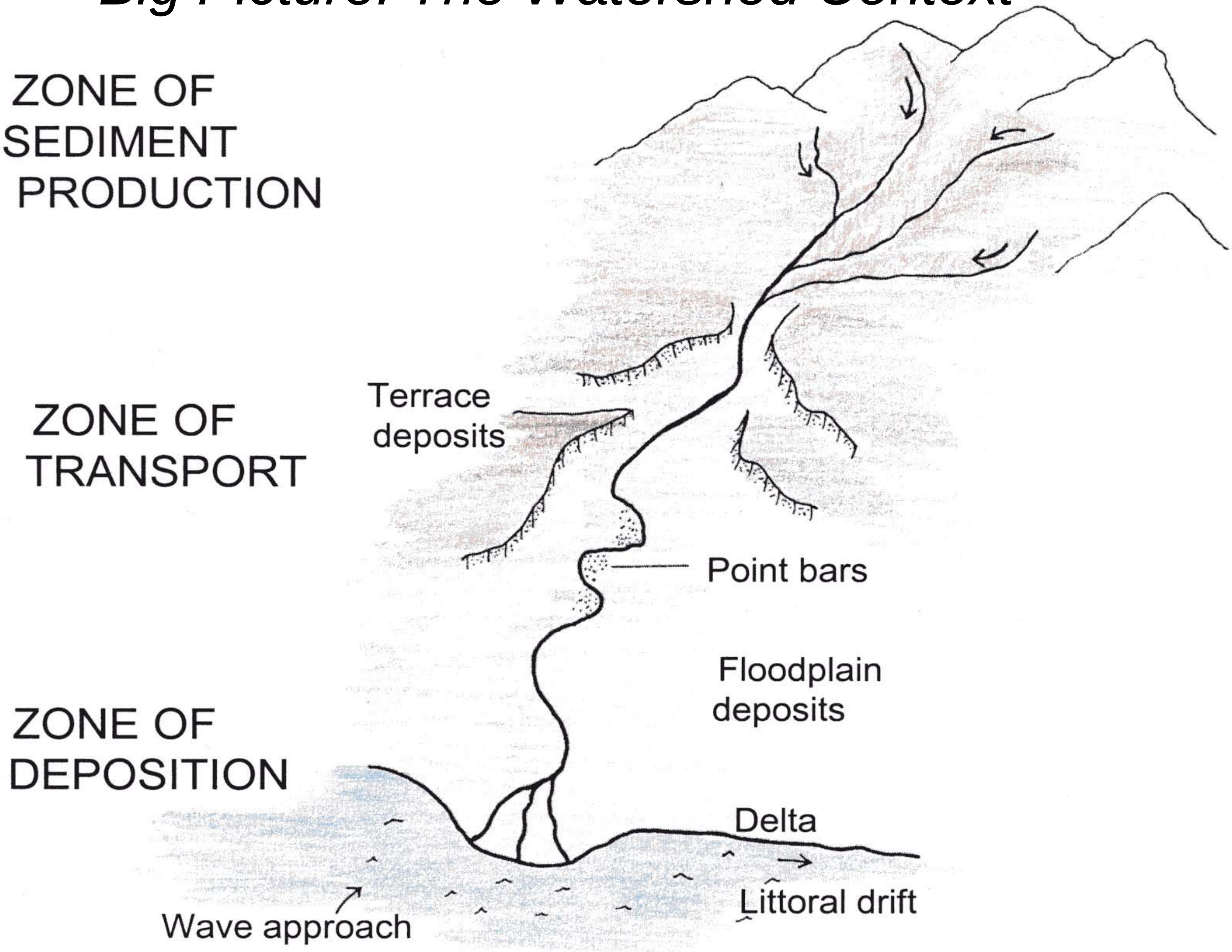
Coarse Sediment Augmentation General Goals/Objectives

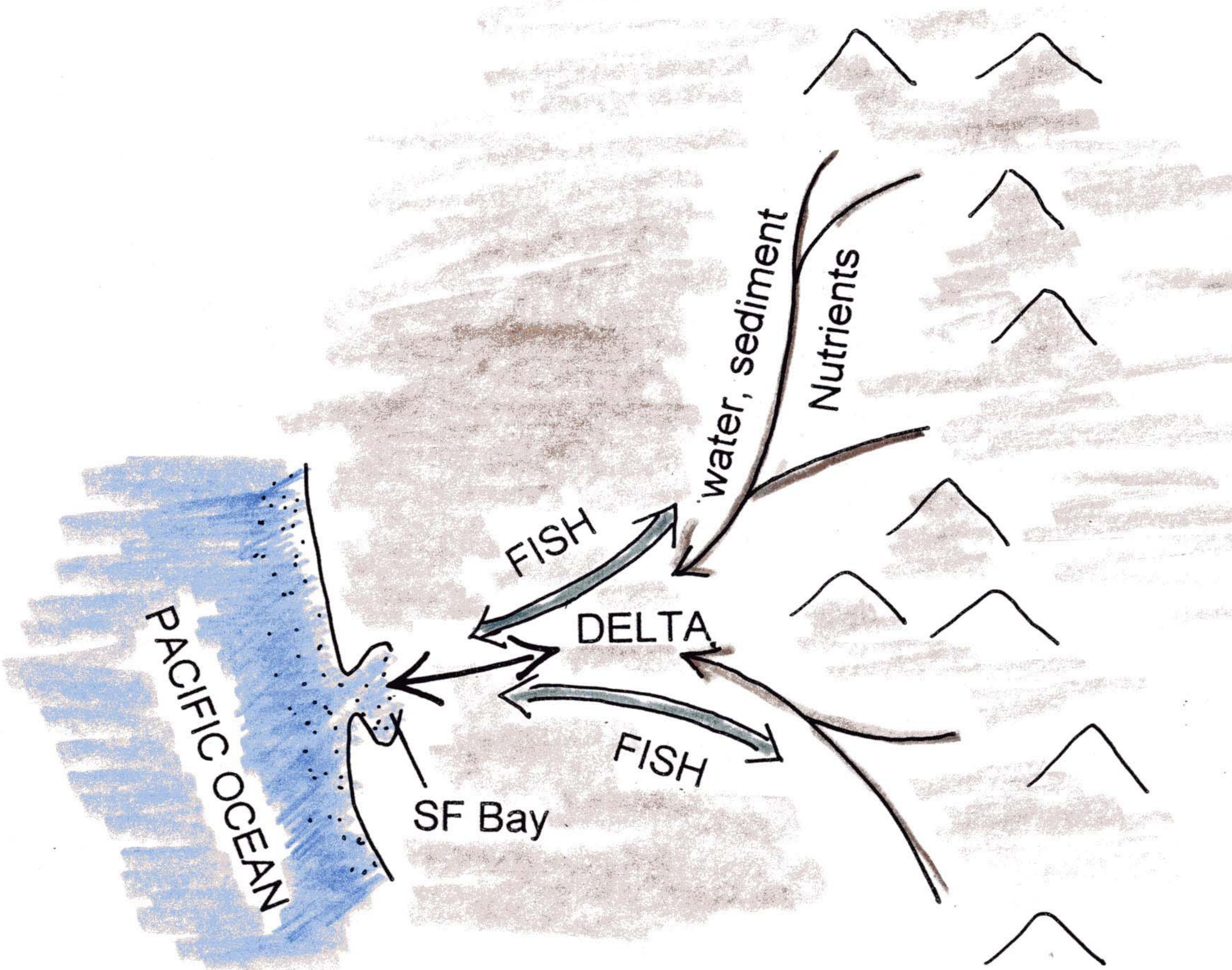
Societal Goals	*Geomorphic objectives*
Prevent/reverse incision, infrastructure damage	Eliminate deficit through adding sufficient gravel to meet current sed xport capacity (Rhine R)
Restore spawning habitat	Increase gravel supply by injection of gravel (gravel to move) *and/or* Construct riffles (gravel to stay)
Restore dynamic channel processes	Increase coarse sed supply, increase dynamic flow regime - match xport capacity?

Need clearly-defined goals to:

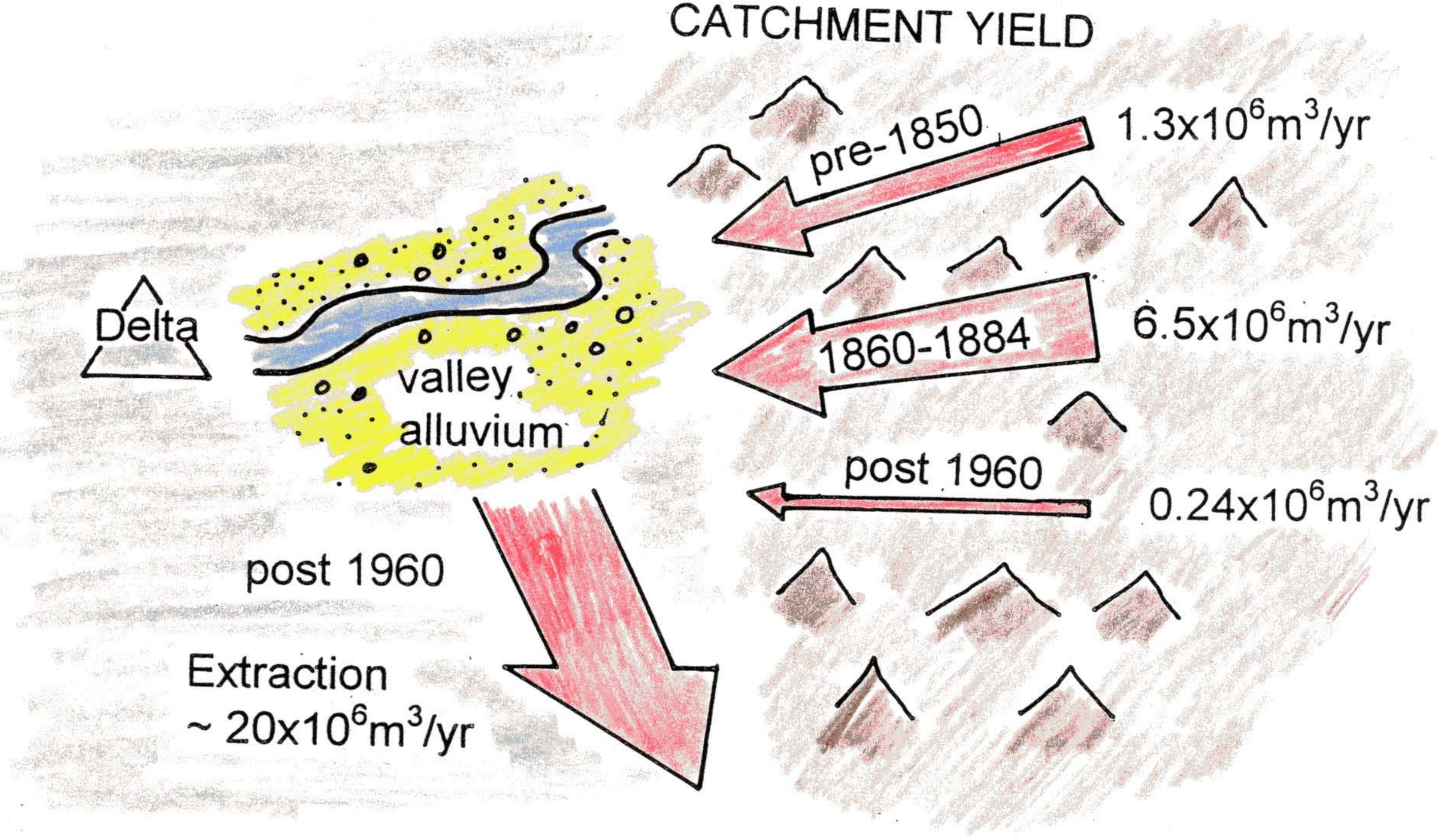
- Assess whether goals are realistic
  eg, add sufficient sediment to match current transport capacity
- Select appropriate implementation method
- Evaluate performance success
- 'Learning success'

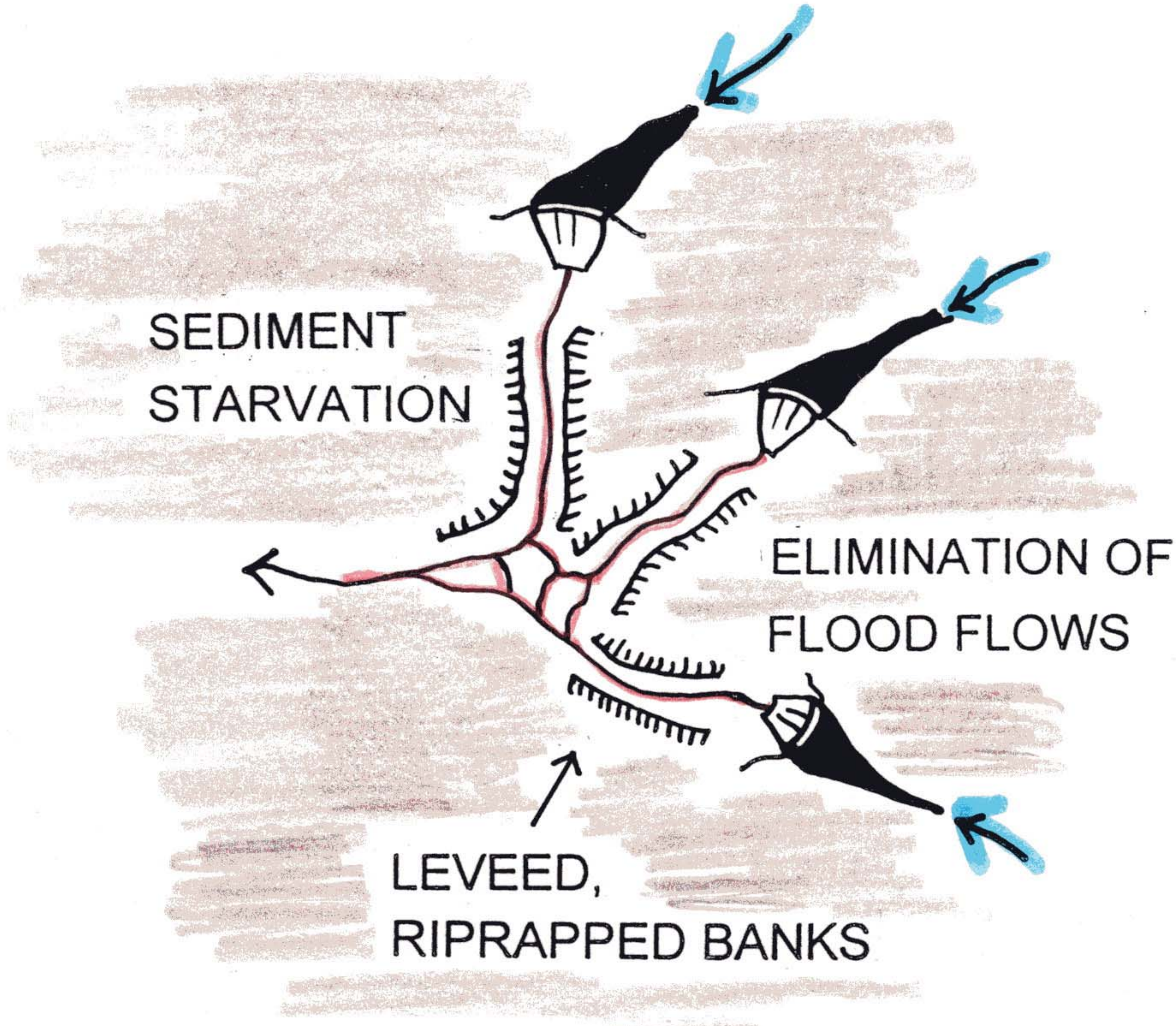
Big Picture: The Watershed Context





water, sediment
Nutrients
FISH
DELTA
FISH
PACIFIC OCEAN
SF Bay


CATCHMENT YIELD
pre-1850
$1.3x10^6 m^3/yr$
1860-1884
$6.5x10^6 m^3/yr$
post 1960
$0.24x10^6 m^3/yr$
Delta
valley alluvium
post 1960
Extraction
$\sim 20x10^6 m^3/yr$


SEDIMENT STARVATION
ELIMINATION OF FLOOD FLOWS
LEVEED, RIPRAPPED BANKS

Consider Catchment Context

Reduced sediment supply – “Hungry Water”

Some catchments have naturally low gravel yields

Dams cut off all bedload, some susp

Gravel mining – gravel sinks

Bank protection

Channelization/dredging legacy effects

Tributary inputs!

Changed sediment transport capacity

Increased xport capacity from land use (urban)

Decreased xport capacity below dams

Relative impact of reservoirs varies, rough indicator:

IR = res capacity/mean annl runoff

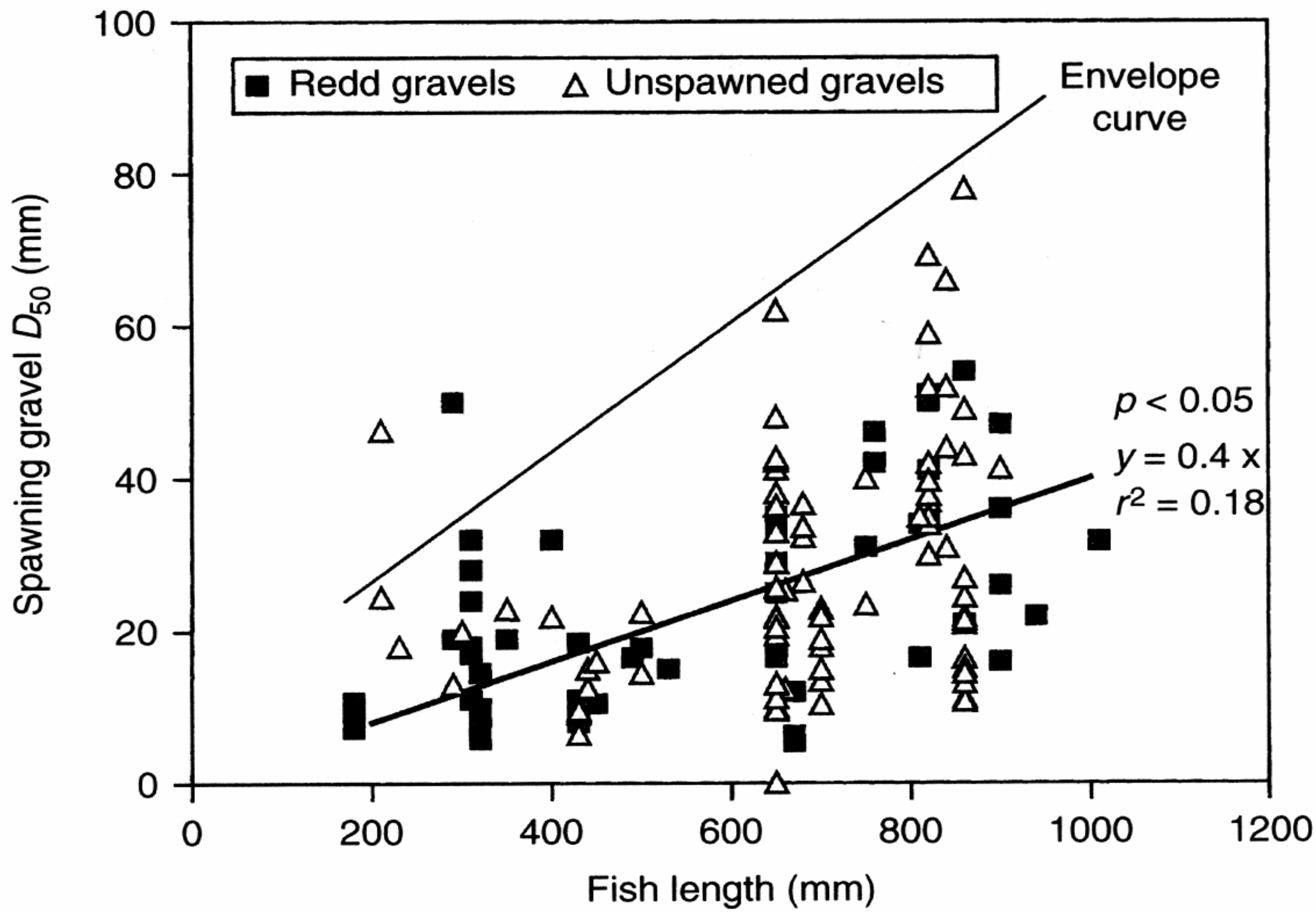
Counteracting: narrower channel, higher shear?

Uncertainty in bedload xprt predictions, must manage adaptively,
- gravel augmentation projects as experiments, data sources

Bedload rating curves will change as gravel is added due to increased supply and changed grain size

Amount added below dams should account for tributary inputs downstream
(ie if you add transport capacity at dam, too much downstream of trib?)

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



SPAWNING BED — Ron Osborne (left) and Tom Cronin, both supervisors for Marin Municipal Water District, show off a spawning bed which volunteers have created below Kent Reservoir for steelhead and salmon. (Light photo by Linda Berlin)

Fishers restore spawning bed

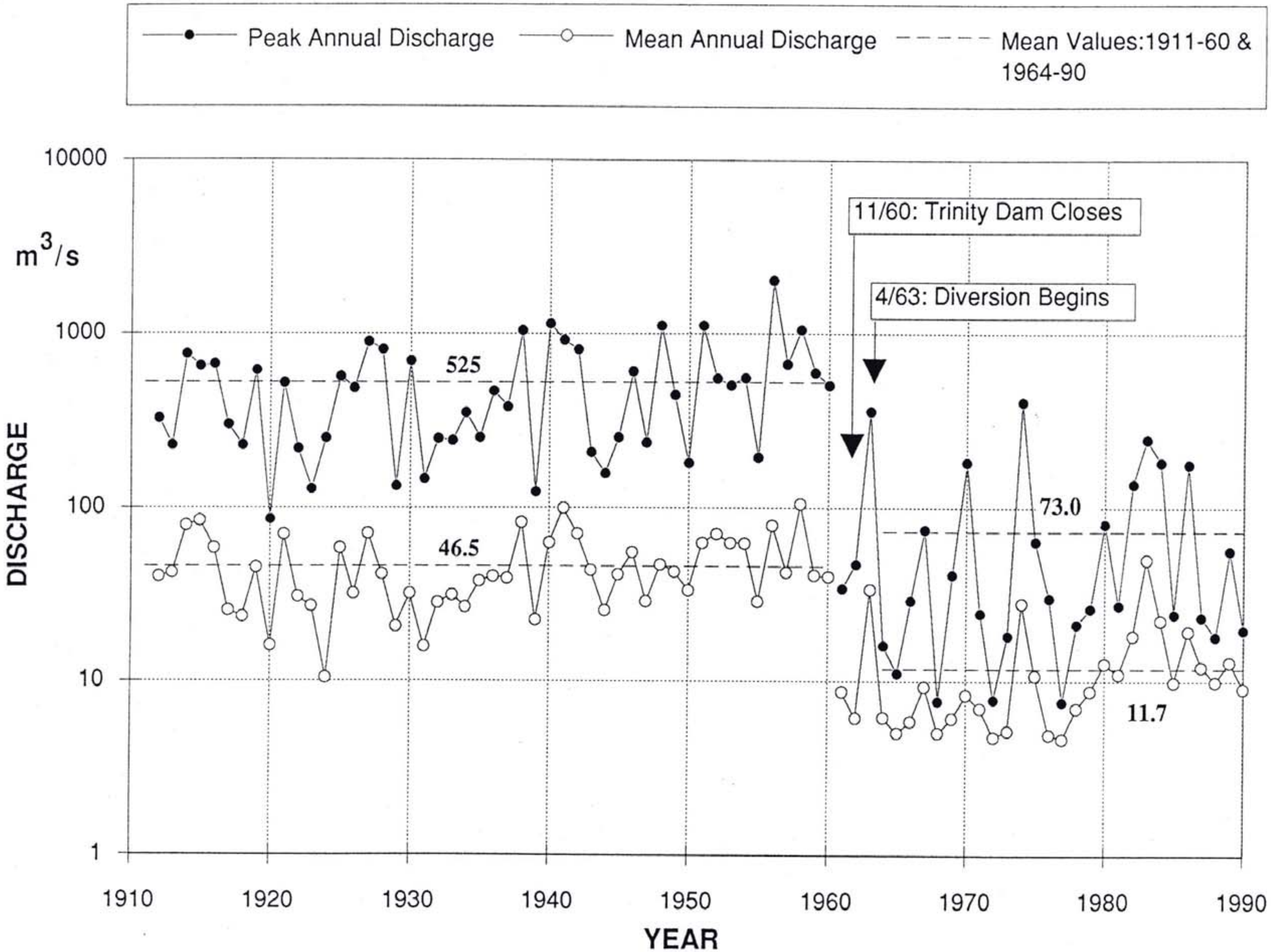
(continued from page 1)

final product of a two-week effort.

"There is no [natural] spawning gravel left in the creek," said Cronin, the son of MMWD Director Leo Cronin, "so we have supplemented [the riverbed's rock] with

which are now at 30 acre-feet per day – more than four times as much as befor[e] Oct. 15, said Cronin.

Trinity River background: stream power greatly reduced



And channel narrowing

1960 predam

1977 postdam

History of Gravel Augmentation on the Trinity

Past projects envisioned as spawning gravel

- construction of riffles to be stable
- increase gravel bedload supply

Current goal to increase coarse sediment supply

First projects were riffle constructions by USBR in 1976 and 1977, from dam RM 111.9 to RM 104.1

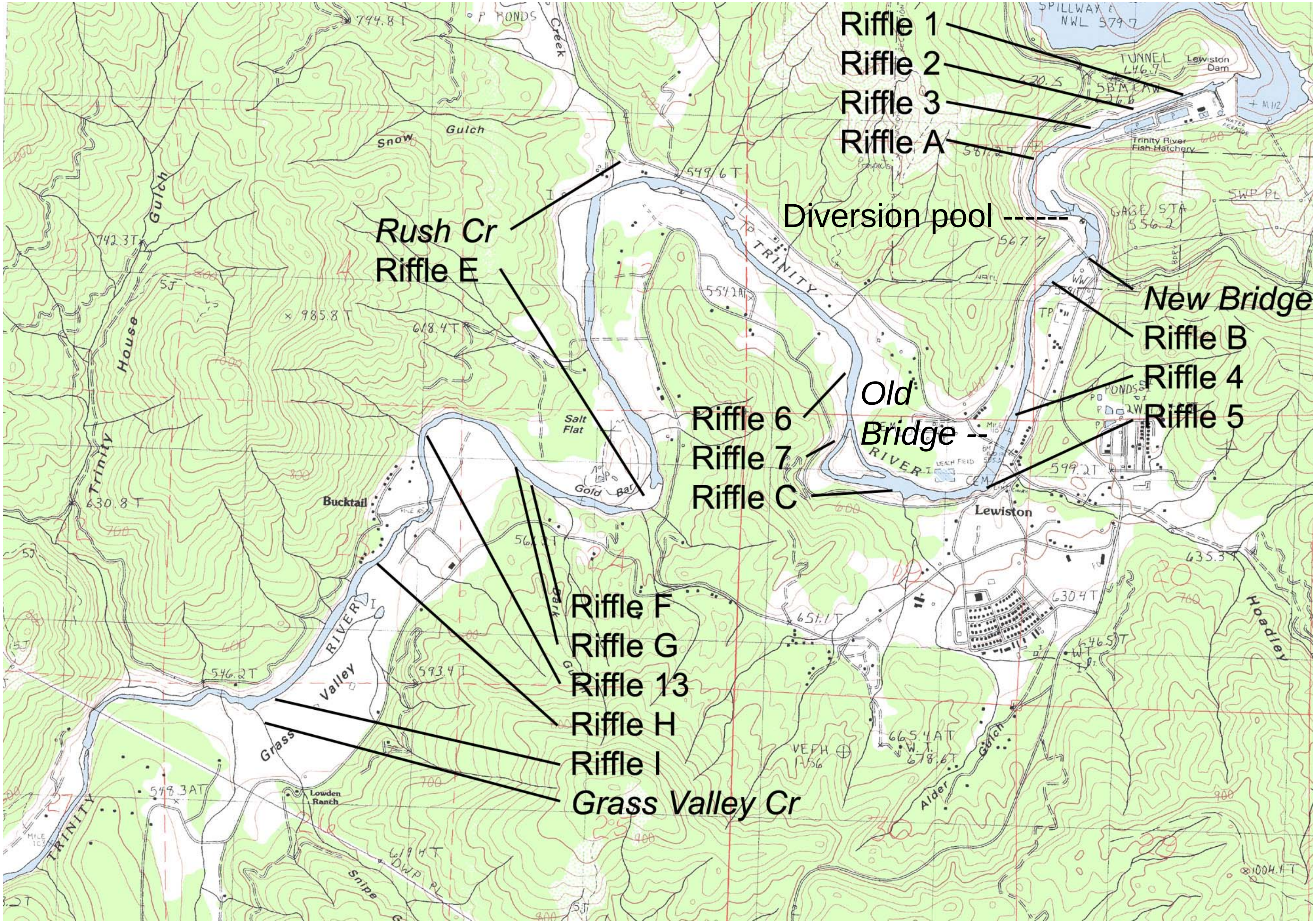
- 14 riffles, total volume added 22,800 yd3
- largest such effort to date
- 1976 Riffles 1,2,3 etc, 1977 Riffles A,B,C etc

Trinity History (cont)

DWR riffle repairs 1983, 1984

Subsequent riffle repairs, coarse sed injections (various agencies)

Total augmentation 1976-2003 = 35,800 yd3



Riffle 1
Riffle 2
Riffle 3
Riffle A
Diversion pool ------
New Bridge
Riffle B
Riffle 4
Riffle 5
Rush Cr
Riffle E
Riffle 6
Old Bridge --
Riffle 7
Riffle C
Riffle F
Riffle G
Riffle 13
Riffle H
Riffle I
Grass Valley Cr
Lewiston Dam
Trinity River Fish Hatchery
Lewiston
Bucktail
Salt Flat
Gold Bar
Lowden Ranch

1976 Phase I riffle construction projects (USBR):
Boulder weirs constructed 400-500 ft apart,
Spawning gravel filled in between
(designated Riffles 1,2,3 etc)

Riffle 1 (RM 111.8), just downstream Lewiston Dam

Riffle 1, view upper boulder line from left bank
Partly smeared out, repaired, mostly intact
Gravels mostly scoured from riffle, some along right side

Trinity History (cont)

DWR Riffle repairs in 1983-1984
Following loss of gravel in high flows 1983, 1984

Concerns that fish not using constructed riffles

Experimental addition of boulders to Riffles 1 and 3
to provide more complex habitat in 1986

HSU MS thesis study by Mary Kay Buck (1988)
- found that spawning concentrated near boulders

View downstream to USFS 1998 injection site, RM 111.3

Mid-channel bar developed downstream of upper weir of Riffle 3, Estimated volume 1200 yd3 (<10% of gravel added upstream)

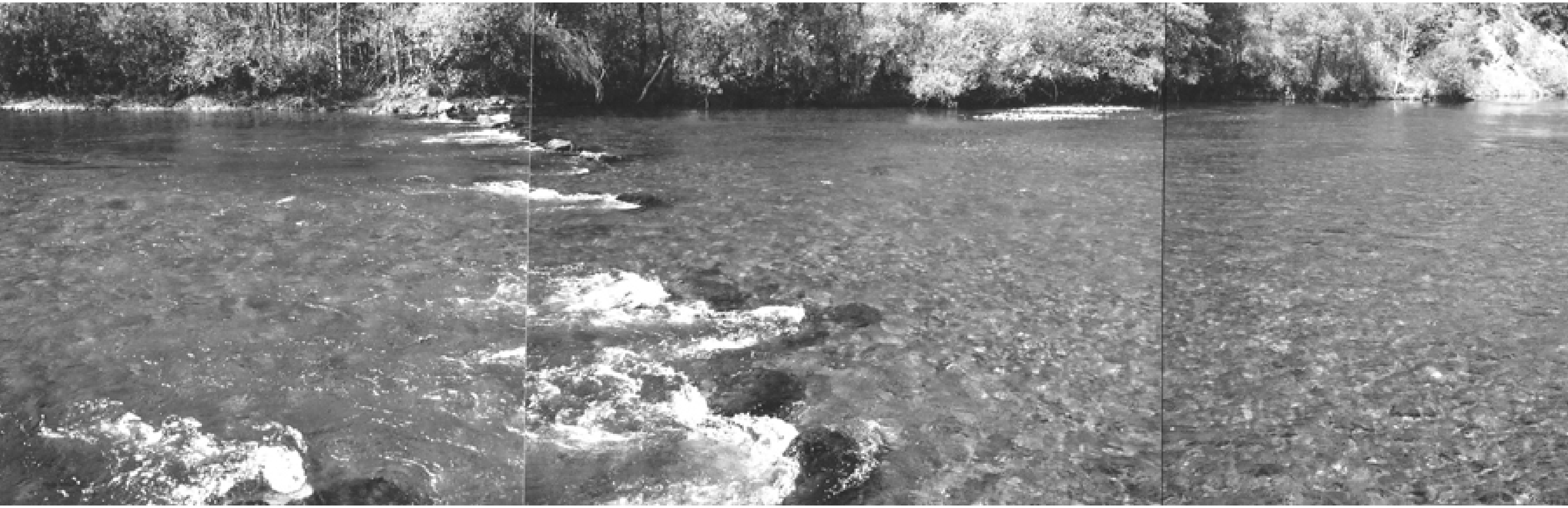
Upper boulder weir, Riffle A – left half washed out

View upstream to diversion pool and gauge
Site of 1998, 1999, and 2000 gravel injections,
And proposed site for future large injections

View downstream from hatchery road to right bank below of diversion, 2000 gravel along right bank

Deposits of gravel mobilized from the 2000 USBR coarse sed augmentation at the diversion pool.

Negative public reaction to "gravel in the trees", delayed next project

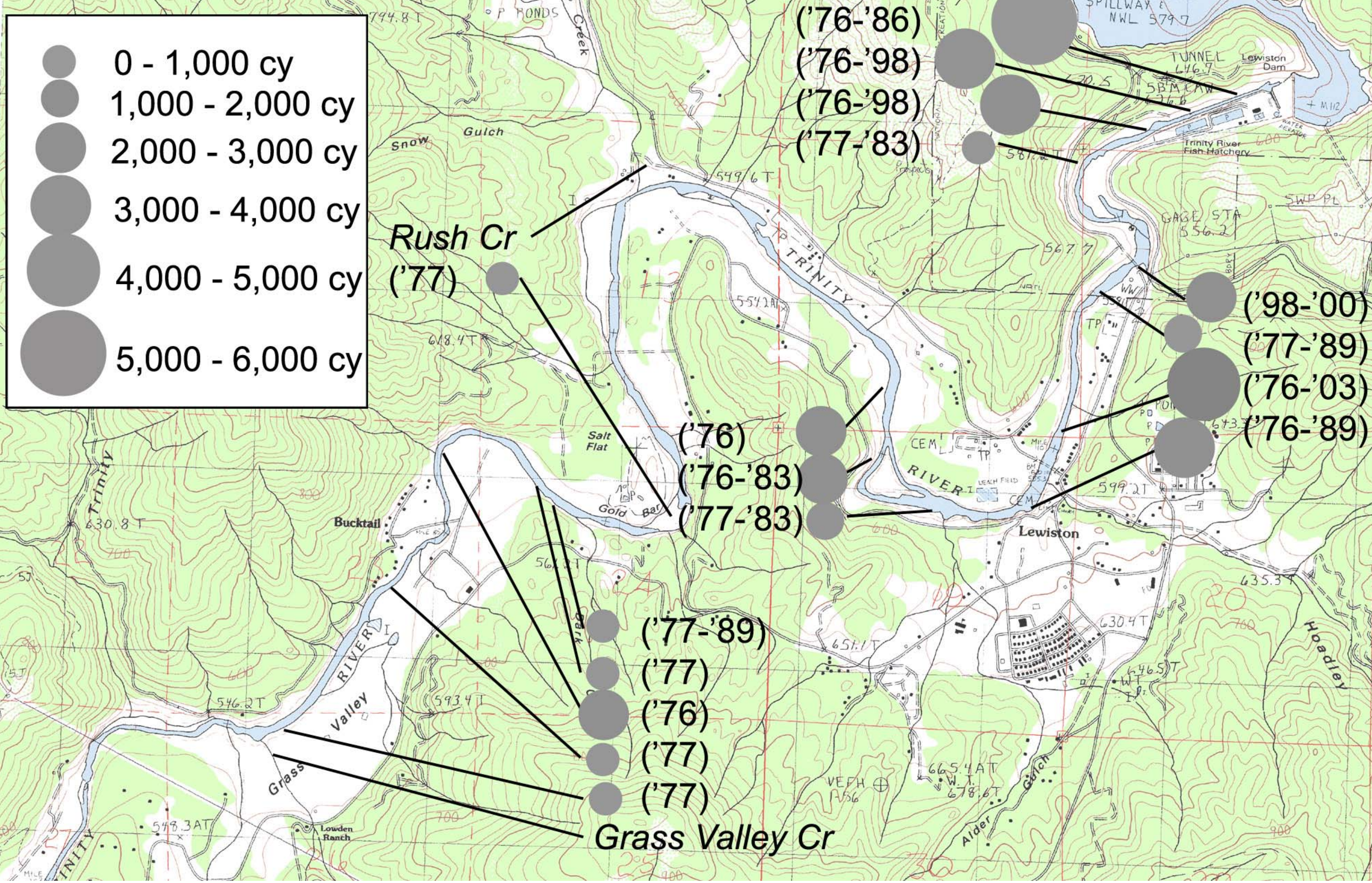


Riffle 4 (Rm 100.2) View of upper boulder weir. Weirs in good condition. Excellent spawning-sized gravels up and downstream of weir

Summary of Conditions of Artificially Constructed Weirs, Trinity River

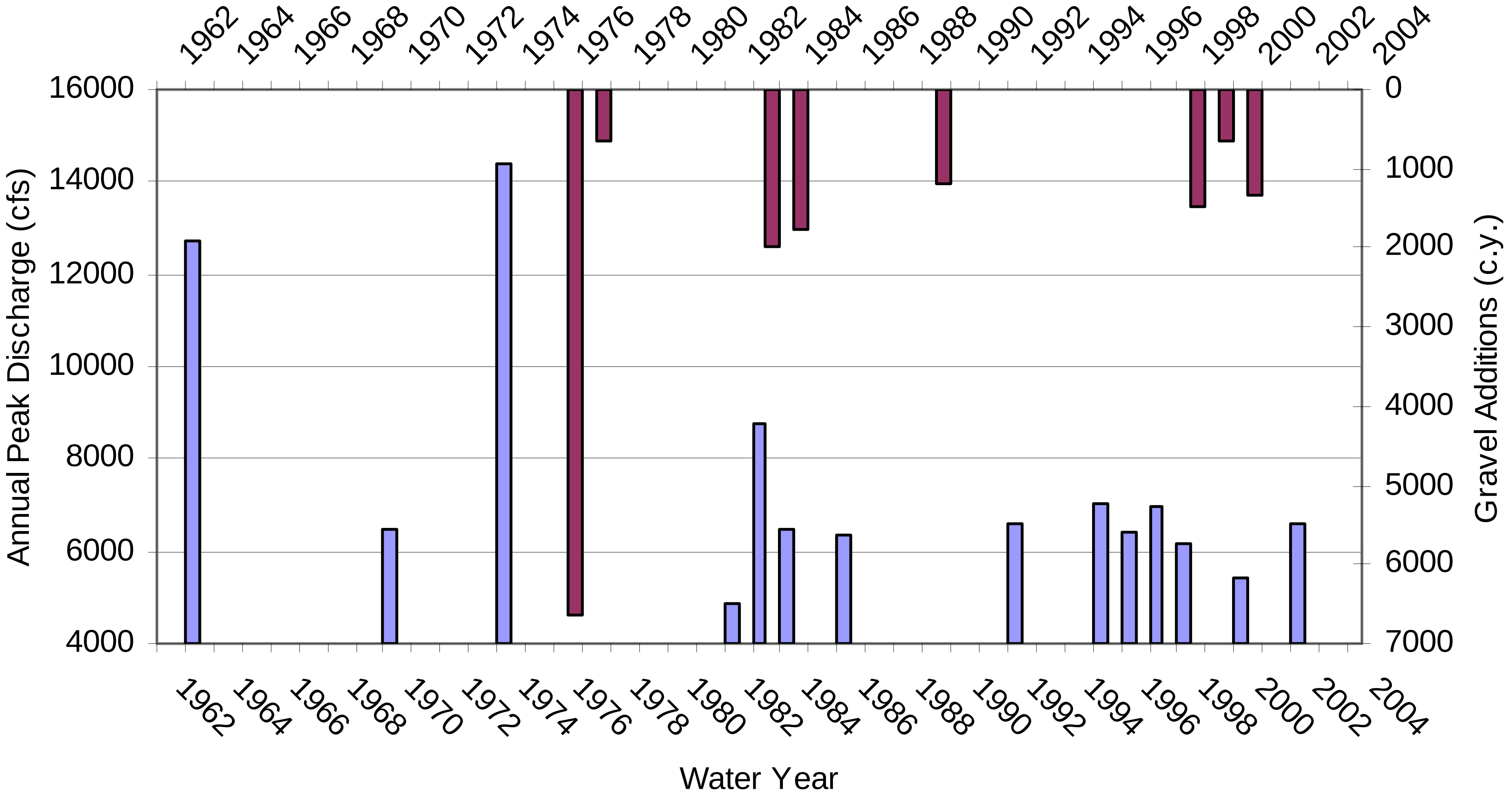
RM	*Riffle*	*Weir type*	*Weir Condition*	*Gravel Condition*	*Weir controlling gravel?*
111.8	*1*	*b*	*mostly intact*	*mostly scoured*	*no*
111.5	*2*	*b*	*mostly intact*	*scoured*	*no*
111.3	*3*	*b*	*partly intact, partly buried?*	*excellent in side channel*	*no*
111.2	*A*	*b*	*upper weir failed*	*scoured*	*no*
110.7	*B*	*?*	*no weirs observed*		
110.2	*4*	*b*	*intact*	*excellent*	*no*
110.1	*5*	*?*	*no weirs observed*		
109.3	*C*	*g*	*upstr weir OK, downstr failing*	*good upstream*	*no*
109.1	*7*	*b*	*upstr weir smeared out*	*excellent upstream*	*unclear*
108.8	*6*	*b*	*partly smeared out*	*excellent upstream*	*unclear*
106.2	*E*	*?*	*no weirs observed*		
105.7	*F*	*b*	*partly smeared*	*excellent grave in riffle*	*yes*
105.6	*G*	*g*	*only 1 weir found, intact*	*poor*	*no*

Notes: b = boulder, g = gabion basket.



Most augmentation has been above Old Lewiston Bridge

Gravel additions above New Lewiston Bridge on the Trinity River against annual peak discharge



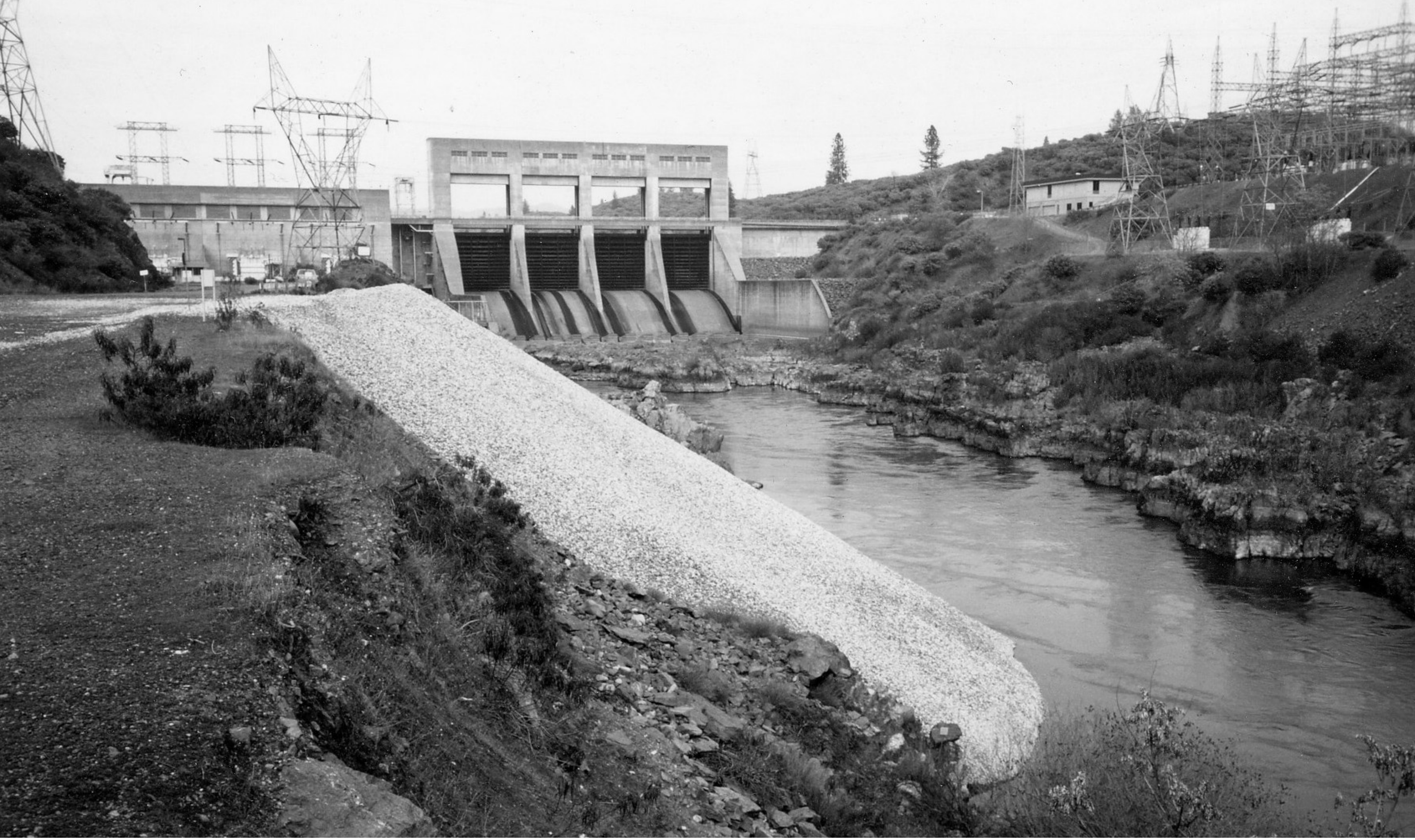
Gravel Augmentation Experience, Central Valley

Gravel added below dams
on 19 rivers Sac-SJ

Over 400,000 yd3 from
1978-2003 (>$8m)

Mixture of injection,
riffle construction,
side-channel construction

Sacramento River
below Keswick Dam



Gravel injection below Keswick Dam

Gravel Augmentation Projects Below Dams Central Valley (includes Trinity)

River (Regulating Dam)	Years	Number of Projects	Volume (yd^3)	Total Cost
Hat Creek (Crystal Lake)	1968-71	1	na	na
Trinity (Lewiston Dam)	1972-2000	12	36,407	$347,765
Middle Creek	1998	1	185	$3,835
Clear Creek (Whiskeytown)	1996-2000	7	23,704	$500,000
Sacramento (Keswick)	1978-1999	13	268,396	$3,905,000
Battle Creek	1993	1	513	Na
Payne's Creek	1986-1987	2	1,481	Na
Mill Ck (Clough Dam)	1988-1991	2	1,396	$64,561
Feather (Oroville Res.)	1982-1987	2	5,045	Na
Hamilton Branch (Almanor)	2000	1	30	Na
Granite Creek	future	1	na	Na
Opapee Creek	future	1	na	Na
American (Nimbus)	1991-1999	2	5,445	$530,000
Dry Creek	1999	1	up to 200	$12,250
Mokelumne (Camanche)	1990-1999	8	14,545	$299,575
Stanislaus (Goodwin)	1994-1999	6	33,107	$1,420,240
Tuolumne (La Grange)	1993-1999	2	17,750	$440,975
Merced (Crocker-Hoffman)	1986-1999	8	4,760	$620,773
Helms Creek (Courtwright)	1985	1	7	$12,000
Total: 19 Rivers		**82**	**412,970**	**$8,156,974**

Some lessons learned from gravel projects in Sacto-San Joaquin system

On Merced, Tuolumne, Stanislaus:

-Early projects constructed riffles to be stable:
 excavated 2-ft deep, replaced with smaller gravel
 built boulder weirs to hold gravel in place

- Hydraulic analysis only for spawning season flows
- Imported gravels mobile,some at post-dam Q1.5

-Sufficiently high flows to mobilize

-Later projects account for mobility

Contrast w/ Trinity – post-dam flows much reduced, so constructed riffles have survived better than elsewhere

Side channels on Sacto and Feather, fine sed issues, less scour but still scour at high flows

Lessons and Future Thoughts (continued)

Gravel cleanliness issue:

High flow injections to avoid cost of washing?

With increased flows on Trinity, will now-stable riffles mobilize?

Most striking:

Can’t learn from past projects due to lack of baseline data and monitoring

Monitoring needed in reaches that may receive gravel, not just augmentation sites

How to evaluate project performance? Spawning use? building bars and other complex habitat features?

Finishing Frank's talk (sort of):

Is gravel enhancement worth doing?

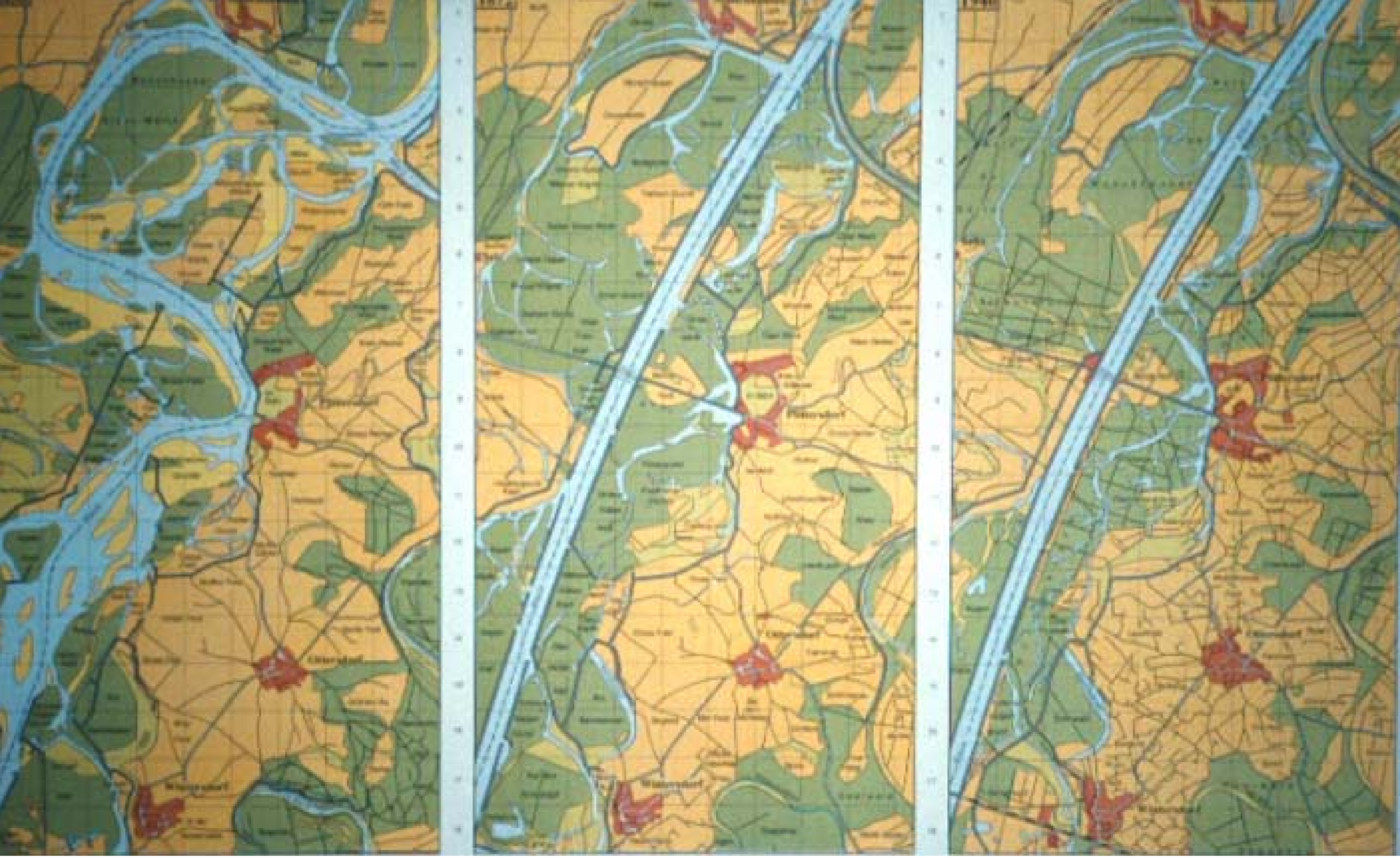
Put another way: Should we be doing this or something else?

Is spawning habitat limiting?
Today's reading from WRC Rept 90

Other benefits – but need to be better articulated

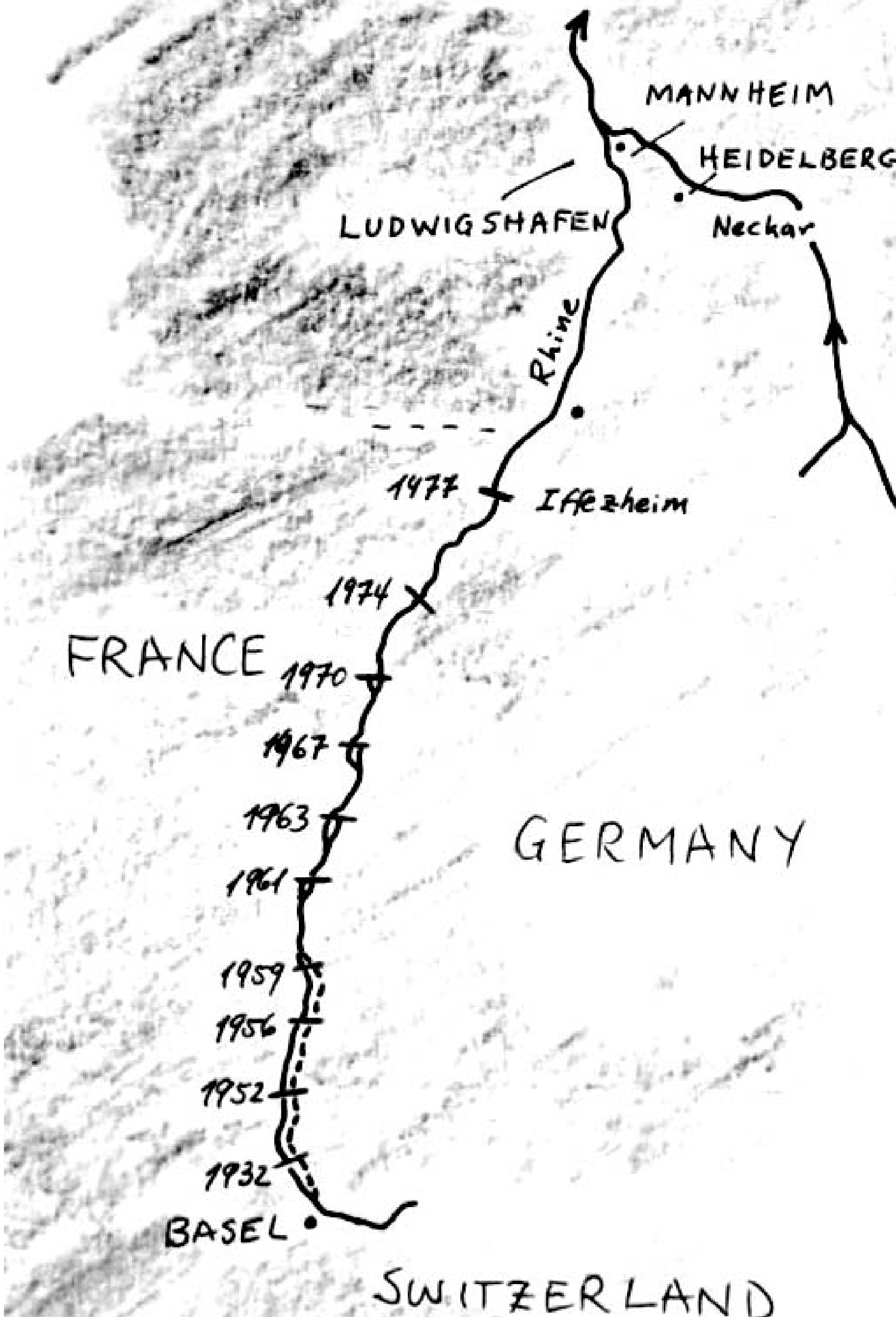
Let's acknowledge that gravel projects are easy.
Are gravel enhancement projects "bus shelters"?

How the German Engineers Do It (on the Rhine)



19thC channel rectification by Tulla

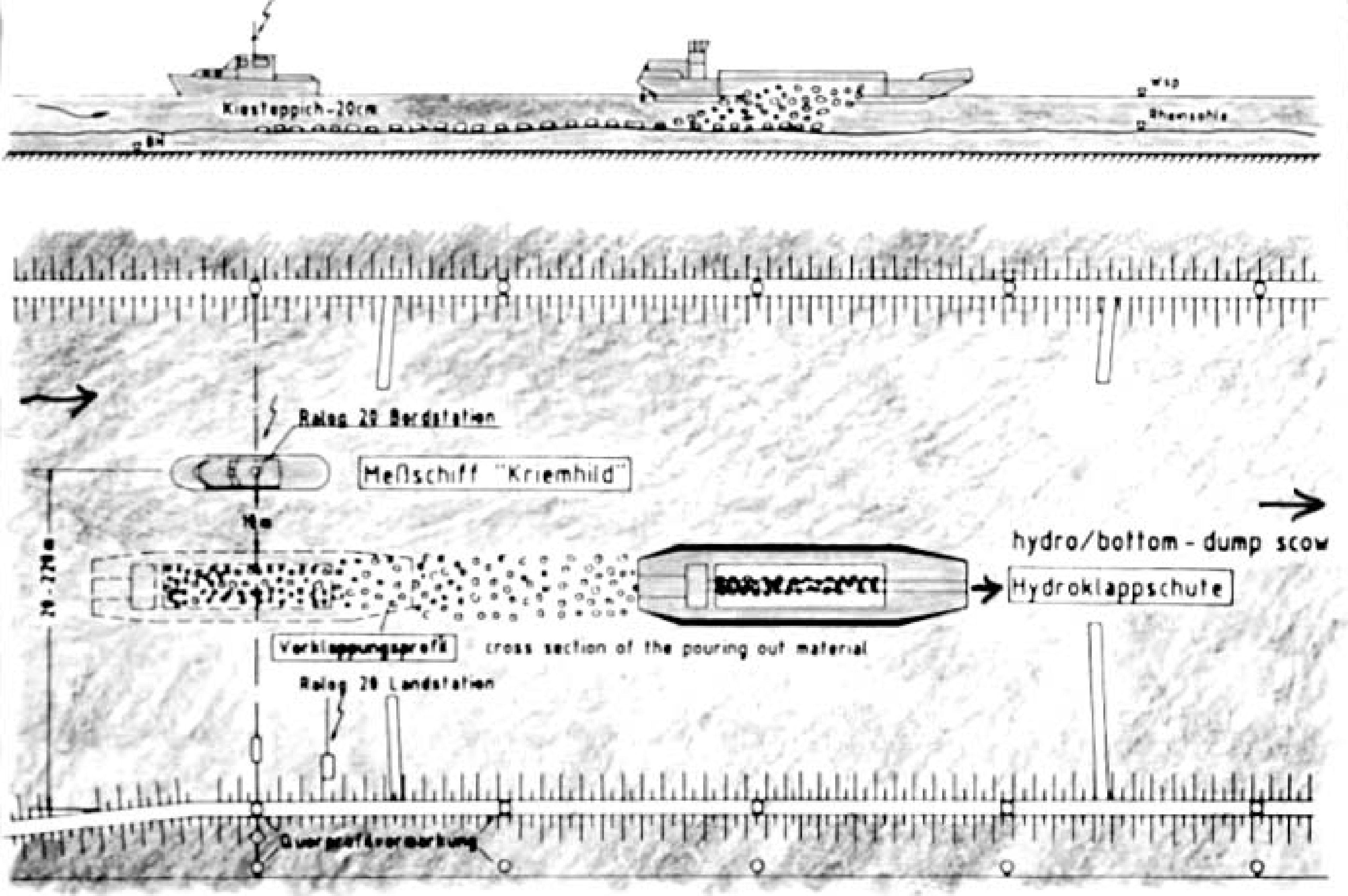
Today: a navigation canal, series of hydro dams



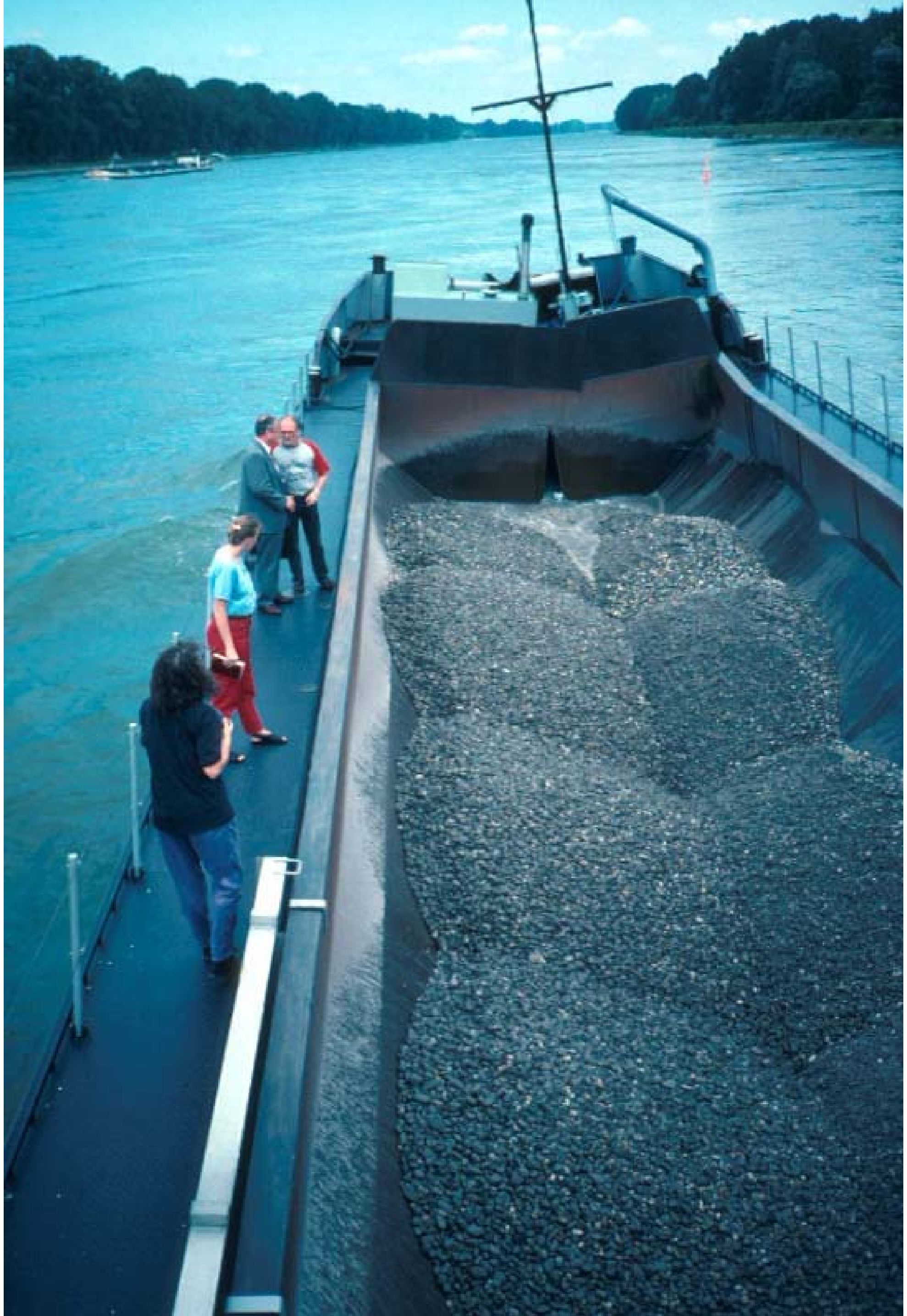
The French-German Rhine

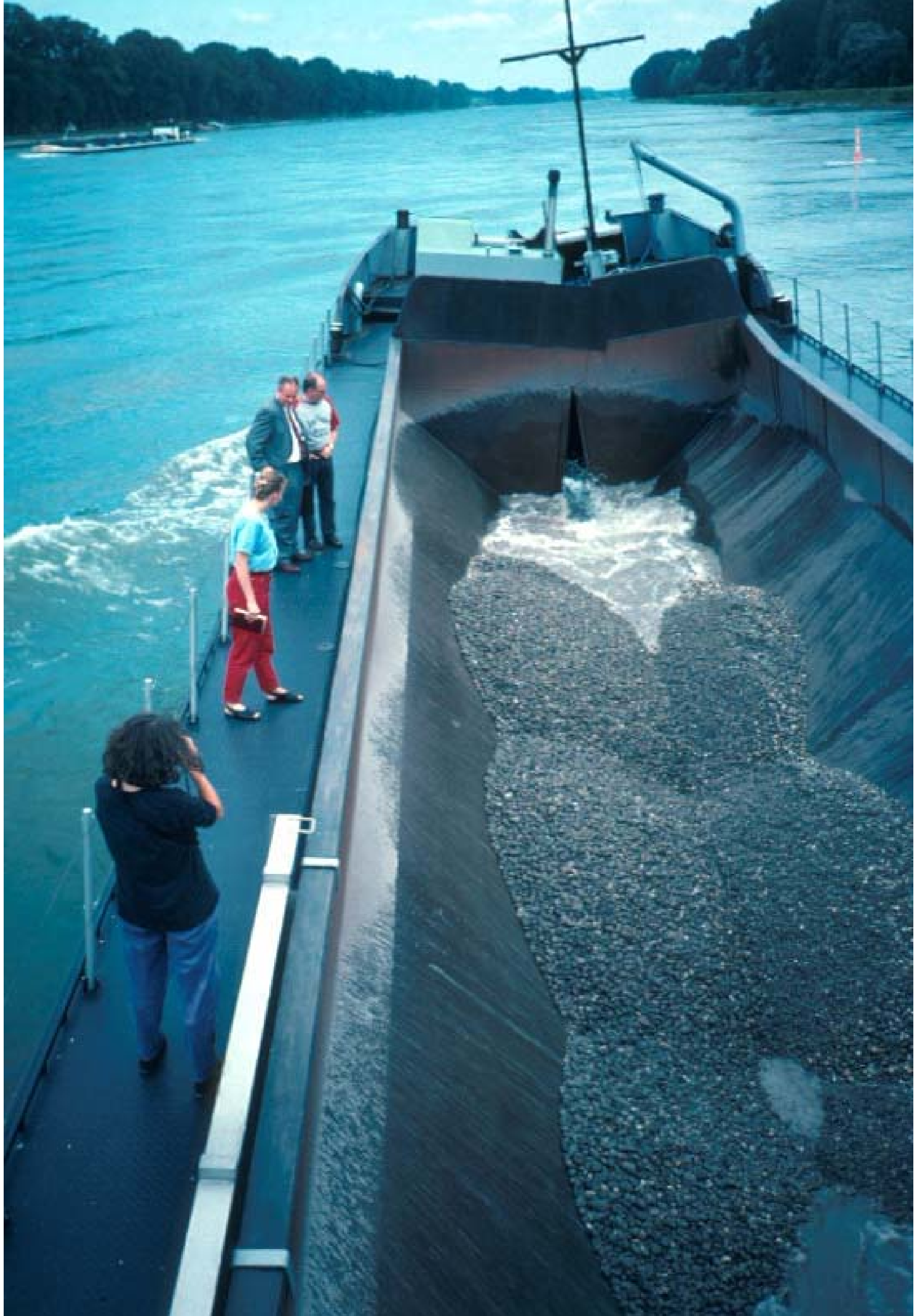
Series of hydroelectric dams built progressing downstream

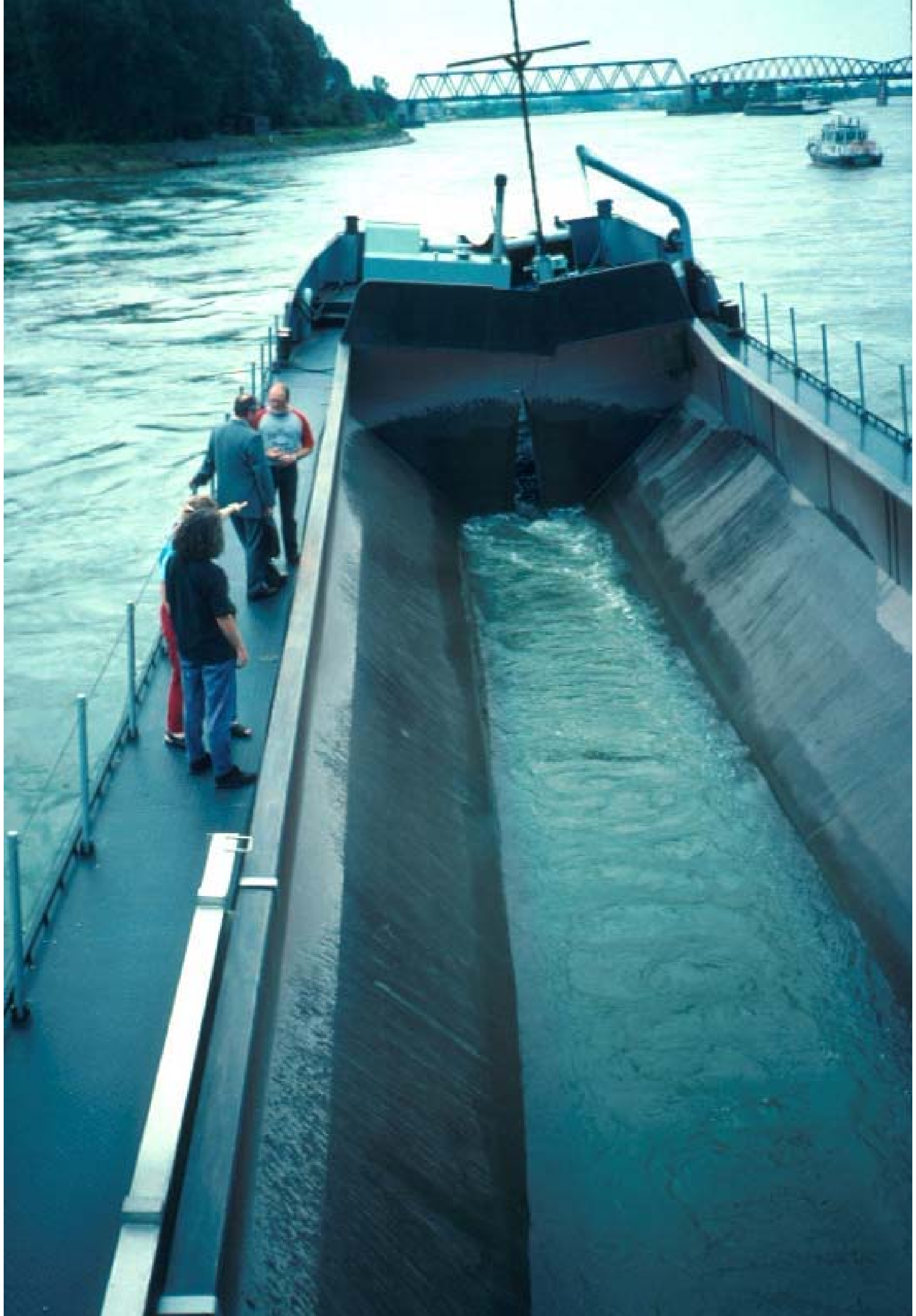
Iffezheim: the downstream-most dam



Process of pouring out







To close:

They take it seriously in Denmark!

excerpt from video “Freedom Regained”
by BM Madsen
of the European Centre River Restoration,
Silkeborg, Denmark