The Importance of Floodplains to Riverine Ecosystems and Flood Management

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Overview of Presentation

1. Floodplains – so what?
2. What have we done to our floodplains?
3. What methods are available to identify what we should do with our floodplains?
4. Examples of what we are trying to do and what we have done (success?)
5. What about the future?

Photo: Roman Loranc

FLOODPLAINS…

SO WHAT?

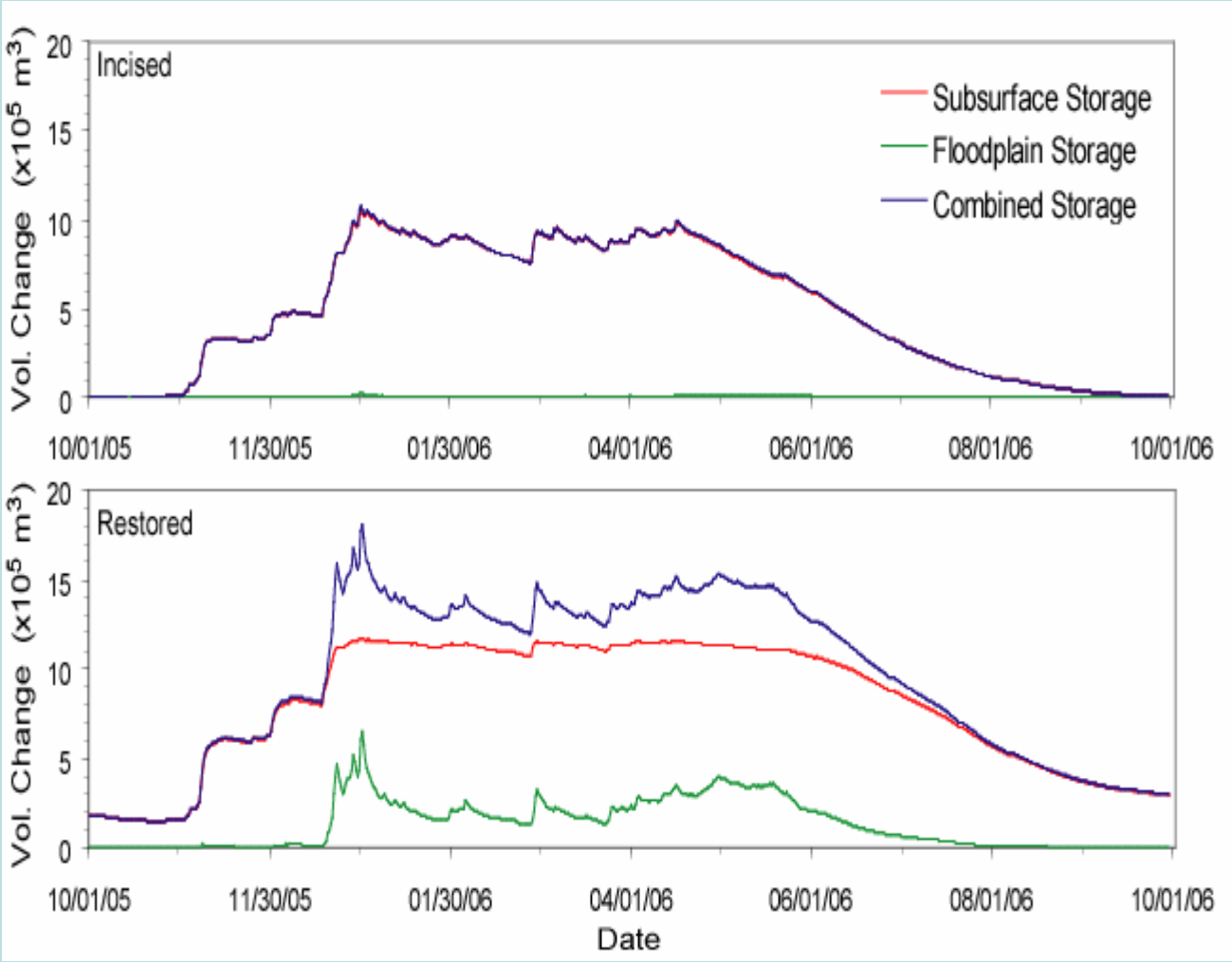
Floodplains – so what?

CHRIS BOWLES, 2006

- Floodplains are the sponges of our ecosystems.

Floodplains – so what?

- Floodplains are the sponges of our ecosystems.



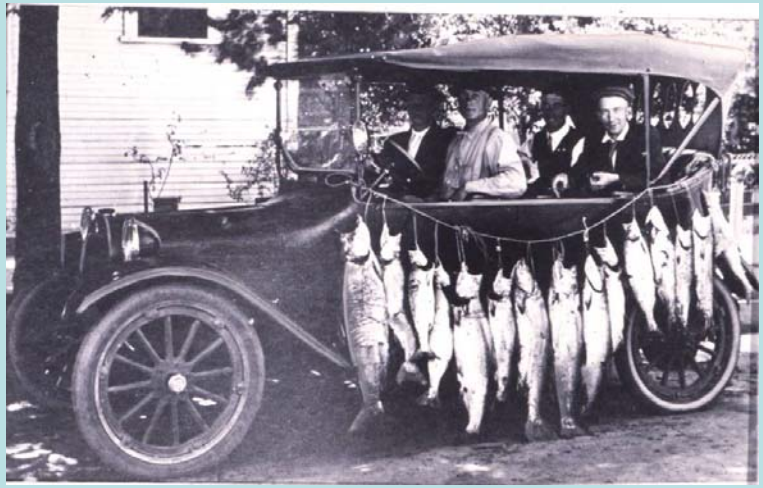
Bear Creek, California

Hammersmark et al. 2007

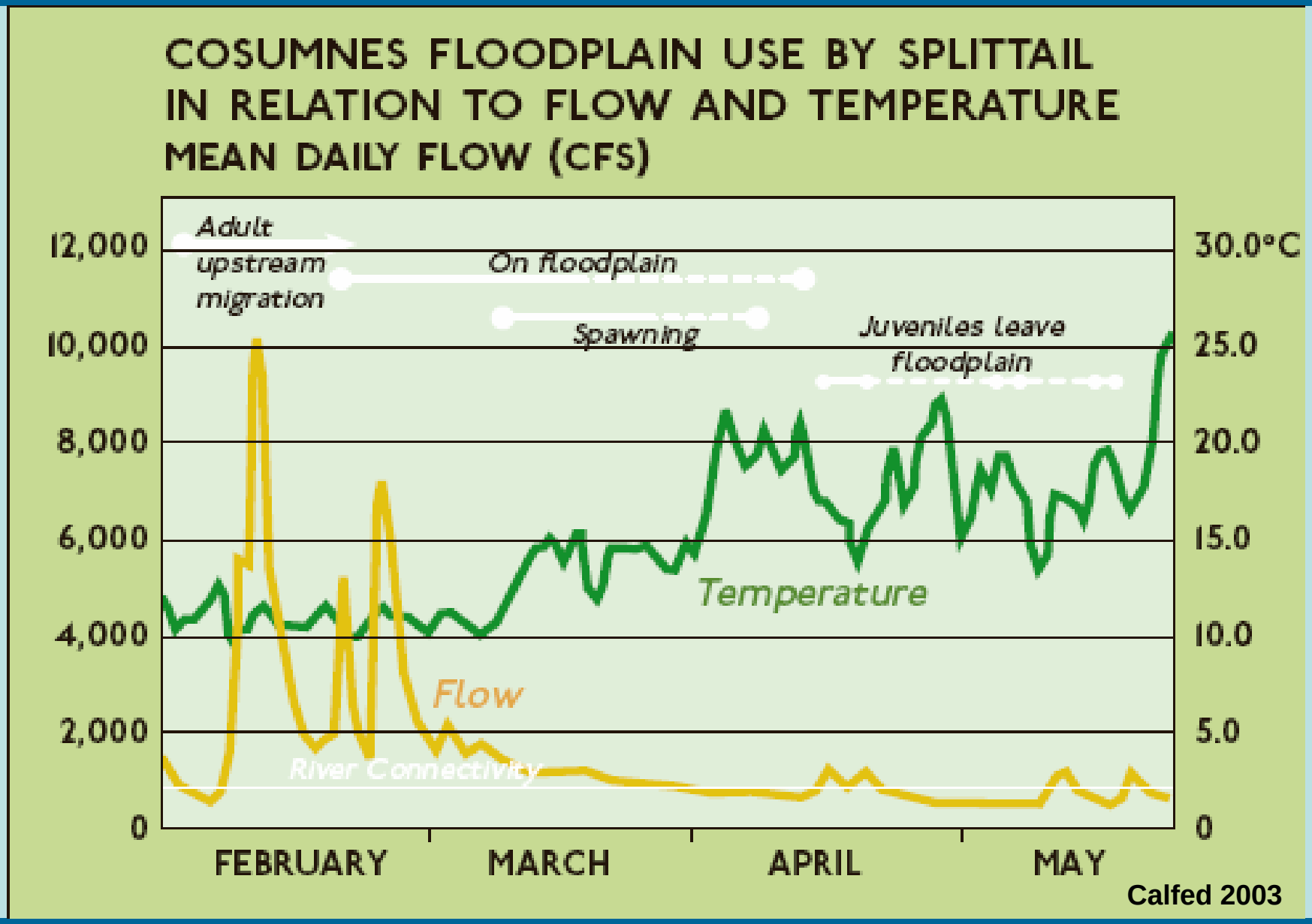
Floodplains – so what?

Floodplains – so what?

- Floodplains reduce the impacts of flooding for our urban areas.
- Floodplains are essential for ecosystem health
  - Floodplain foraging, spawning habitat, rearing habitat, refugia.
  - Flood-pulse concept (Junk et al. 1989) – lateral inputs of organic material are more important than longitudinal inputs for large streams and rivers.



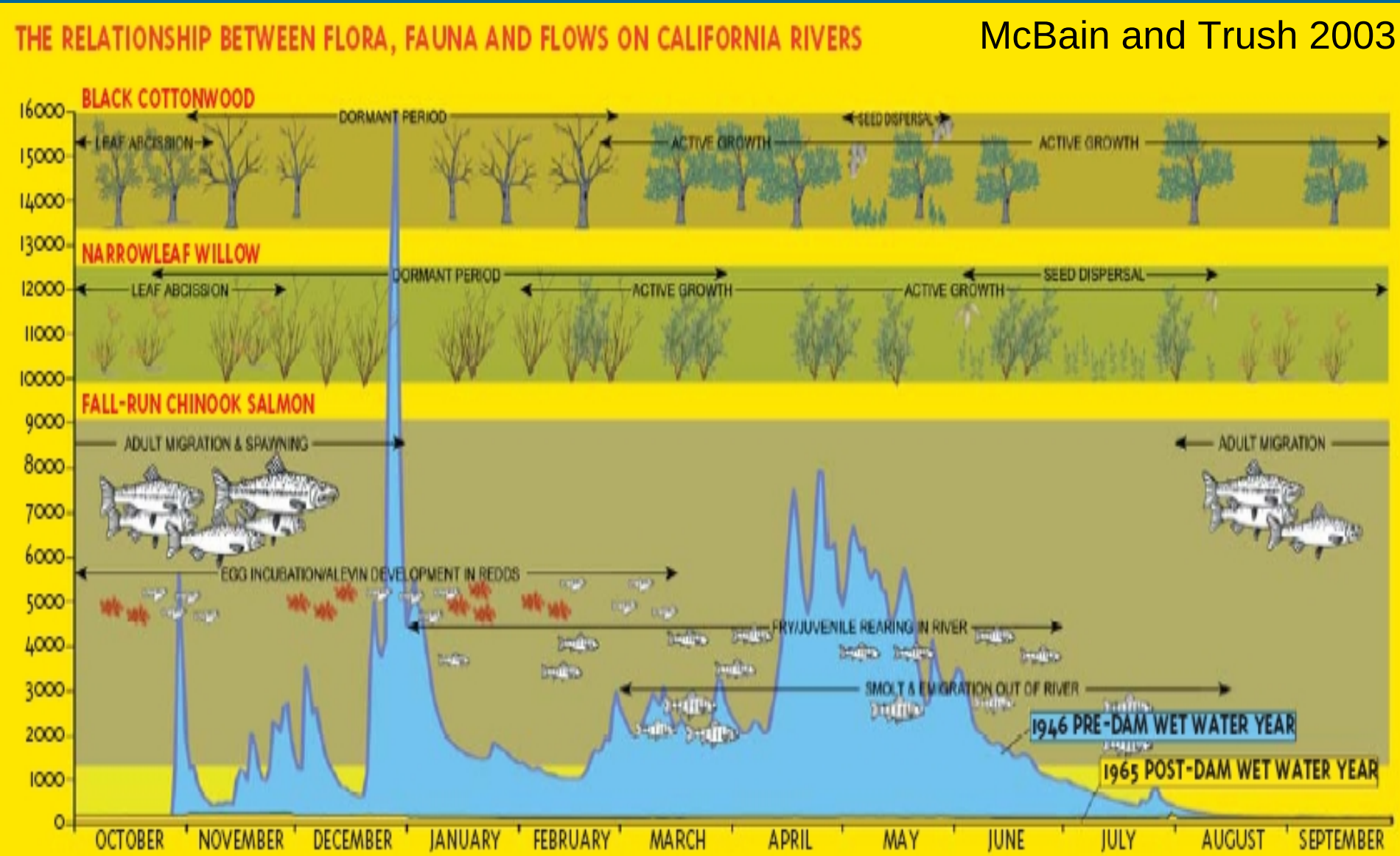
Lowland River Floodplain Habitat for Fish



Calfed 2003

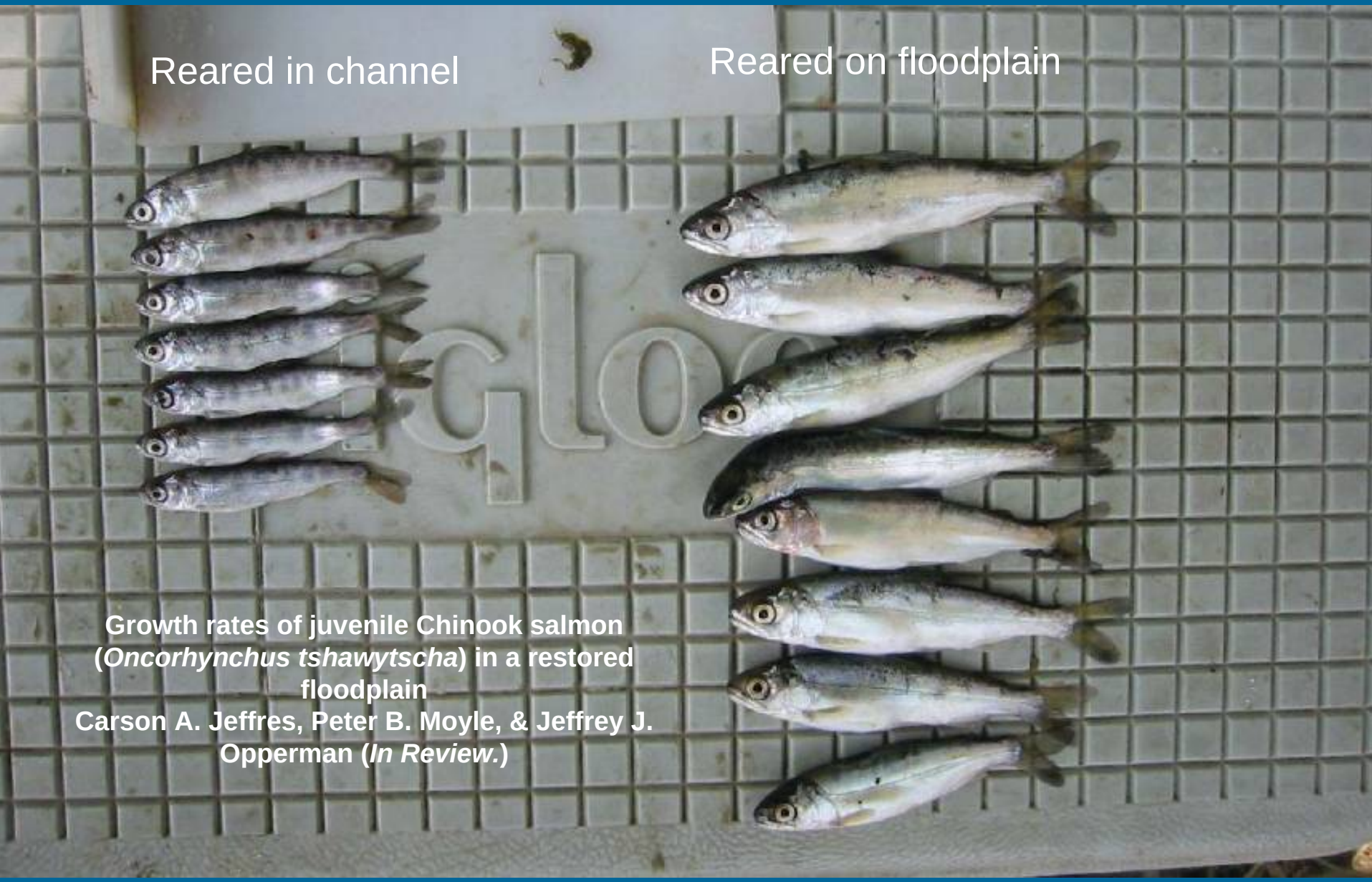
Defining Functional Floodplains: A Continuum of Processes

McBain and Trush 2003



PWA

Floodplains Grow Native Fish



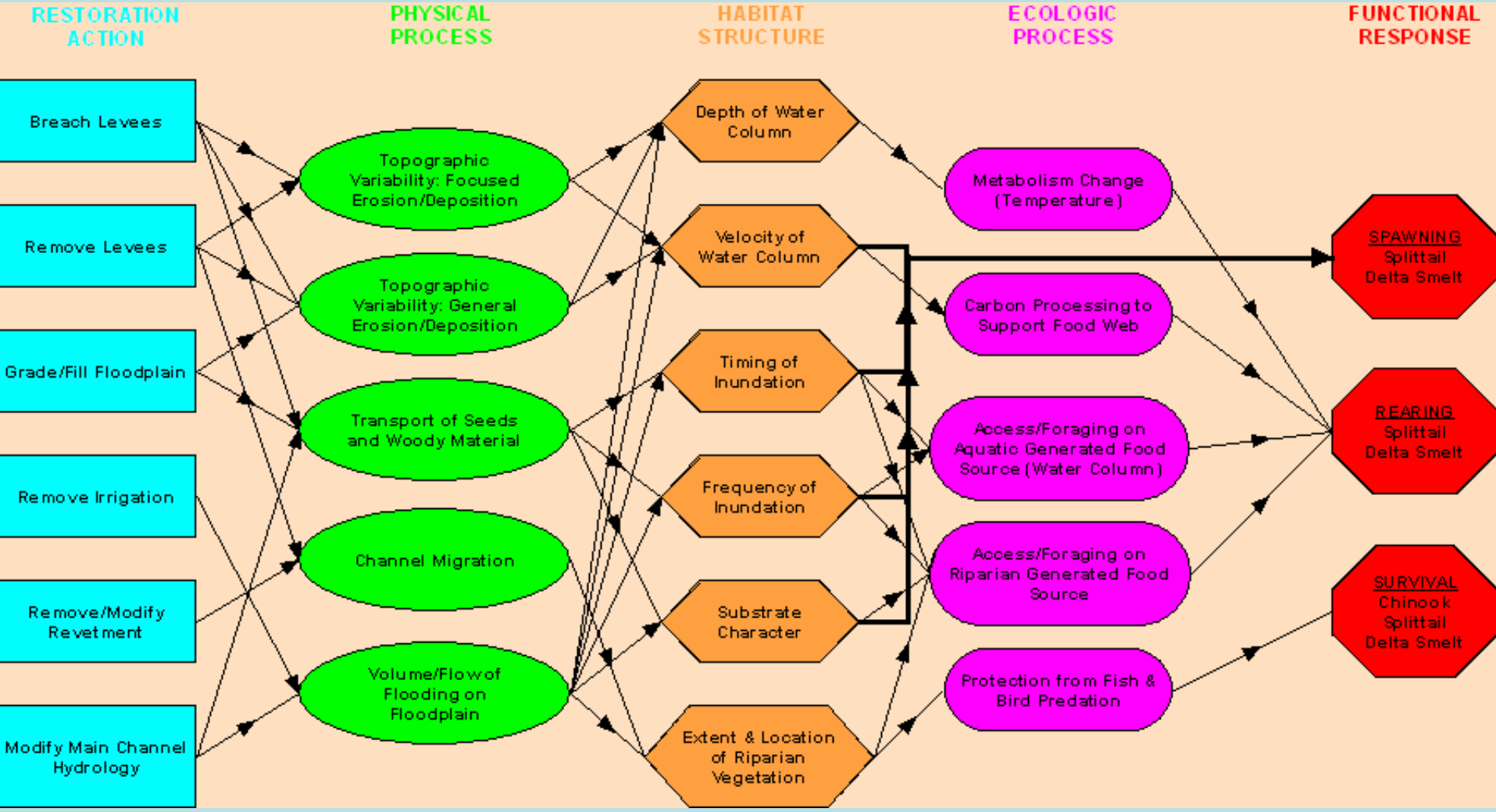
Growth rates of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in a restored floodplain

Carson A. Jeffres, Peter B. Moyle, & Jeffrey J. Opperman (*In Review.*)

Lateral Input of Organic Material!

Photo: Josh Viers, UC Davis

Conceptual Models



Bowles, 2004

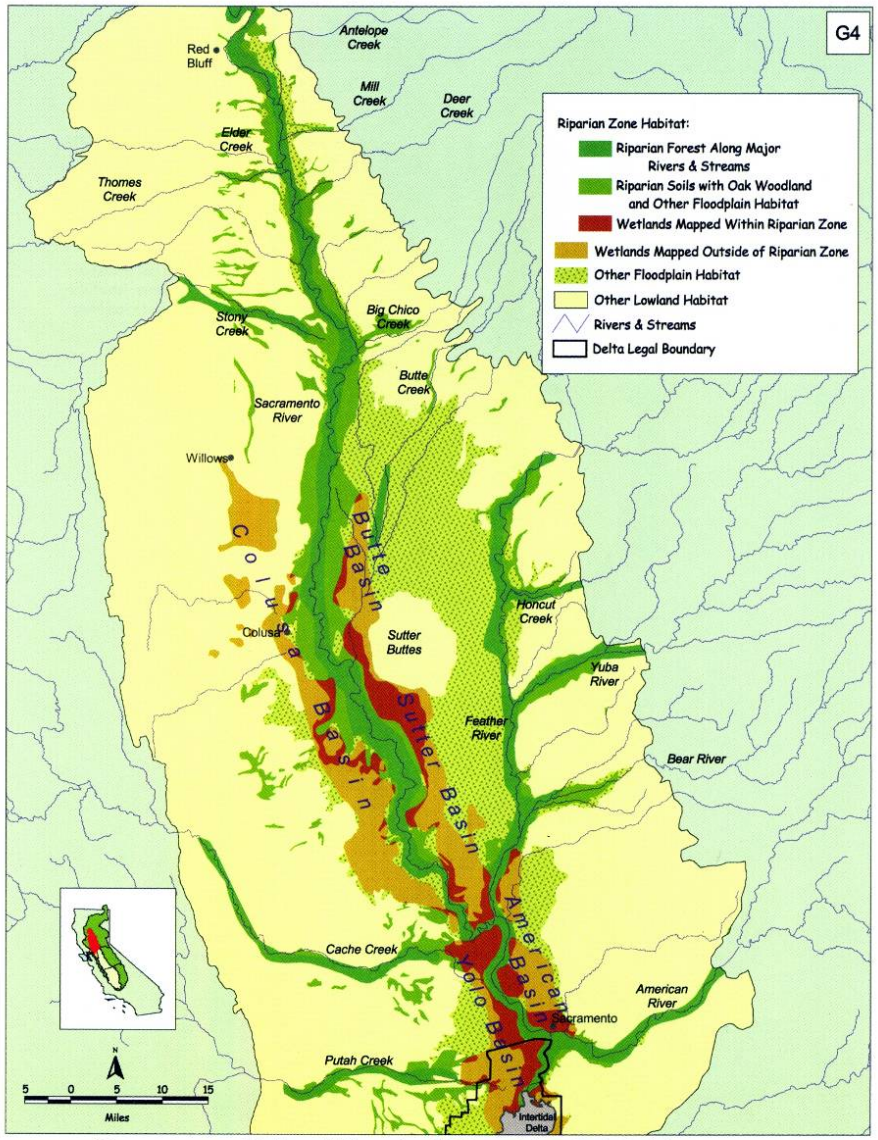
WHAT HAVE WE DONE TO OUR FLOODPLAINS?

What have we done to our floodplains?

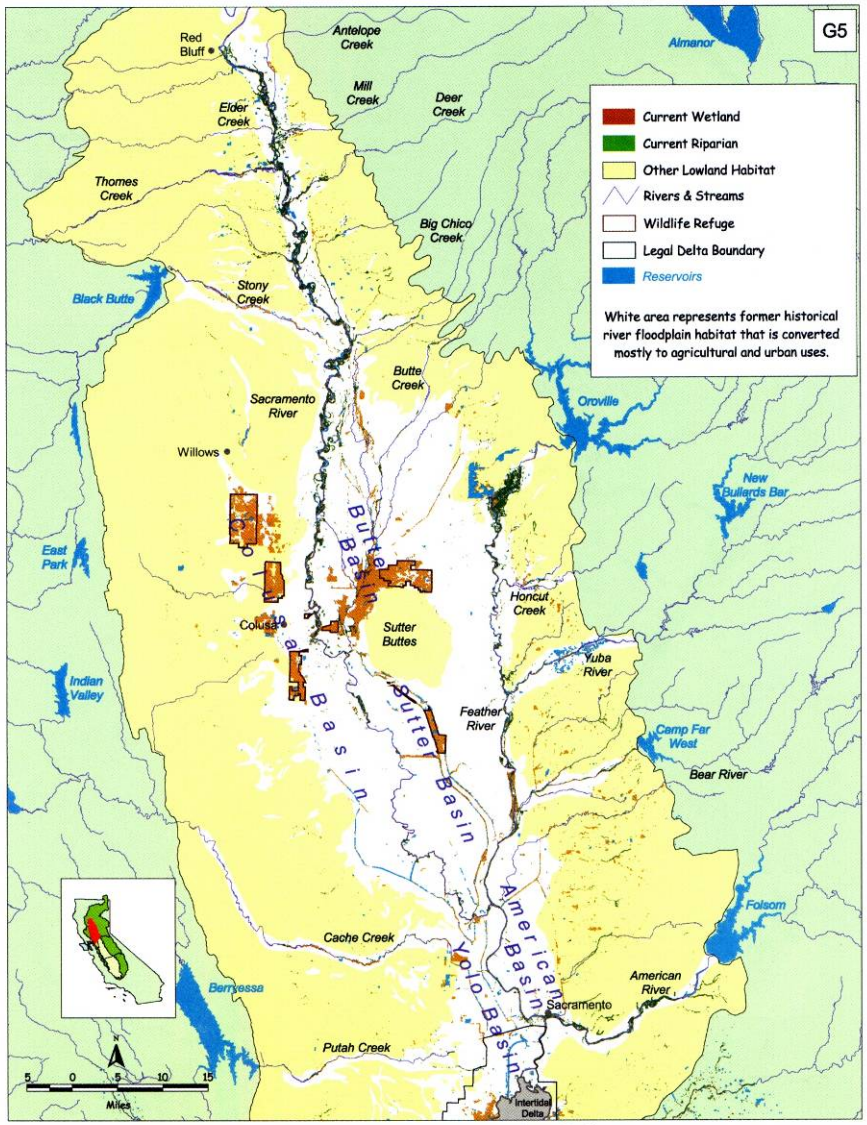
Remnant Floodplains of the Sacramento Valley

The Sacramento Valley Floodplain Now

The Sacramento River's Wetlands, Then and Now



Sacramento Valley Historical River Floodplain Ecosystem

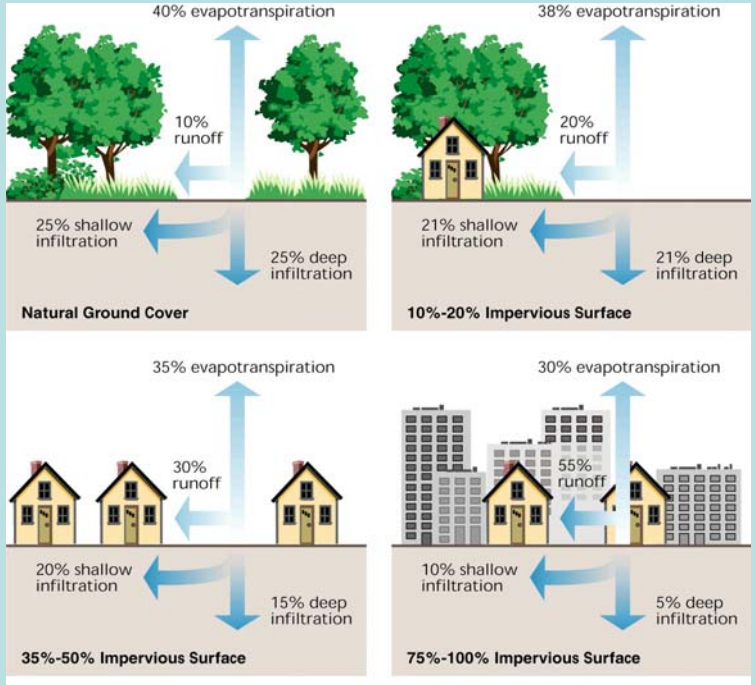


Sacramento Valley Current River Floodplain Ecosystem

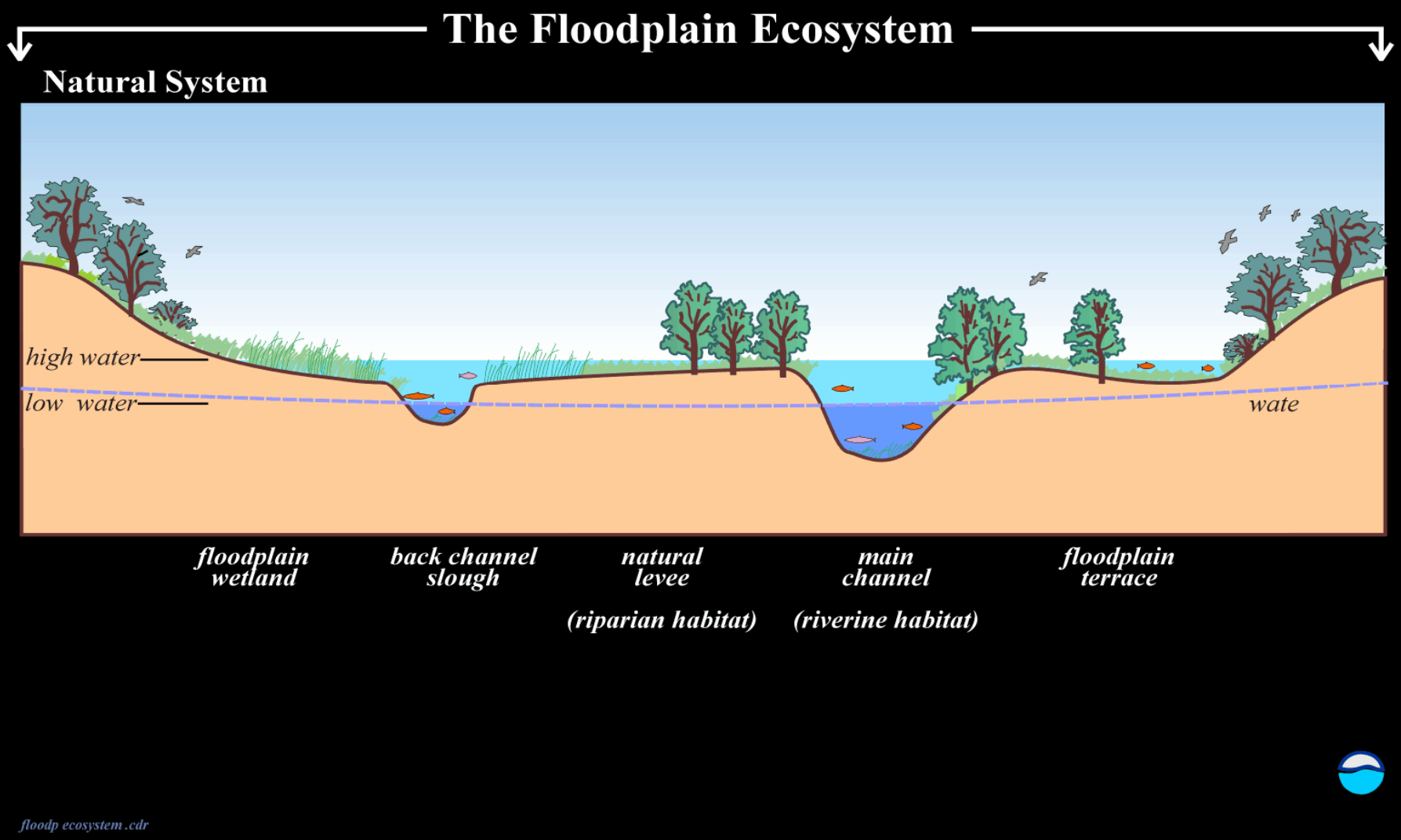
PWA

How Floodplains Have Been Disconnected from the River

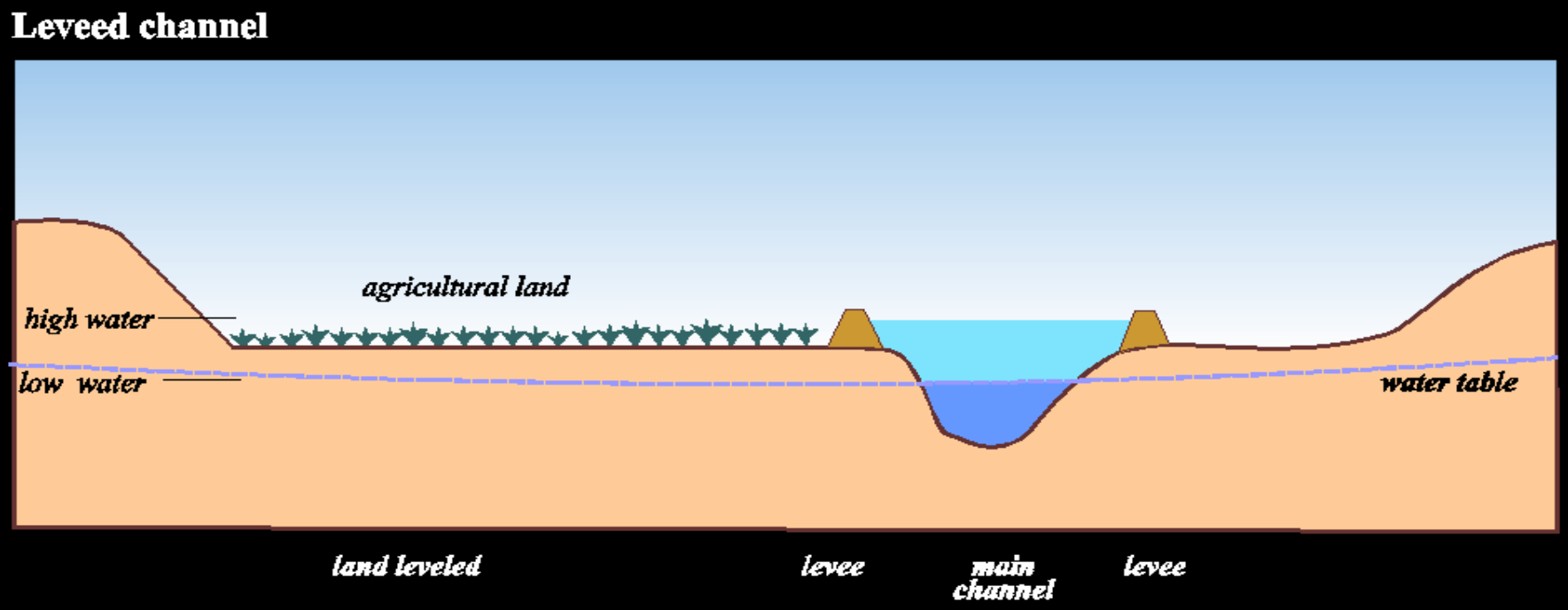
- Landscape modifications
  - Levee construction
- Hydrologic changes:
  - Upstream reservoir ‘flatlining’ flood flows
  - Diversions and watershed changes upstream
  - Climate change
- Geomorphic changes:
  - Channel degradation:
    - Reservoir bed load capture
    - Gravel and sand mining
  - Floodplain aggradation
- Hydraulic changes
  - Channelization
  - Riparian vegetation removal



A Functional Frequently Activated Floodplain

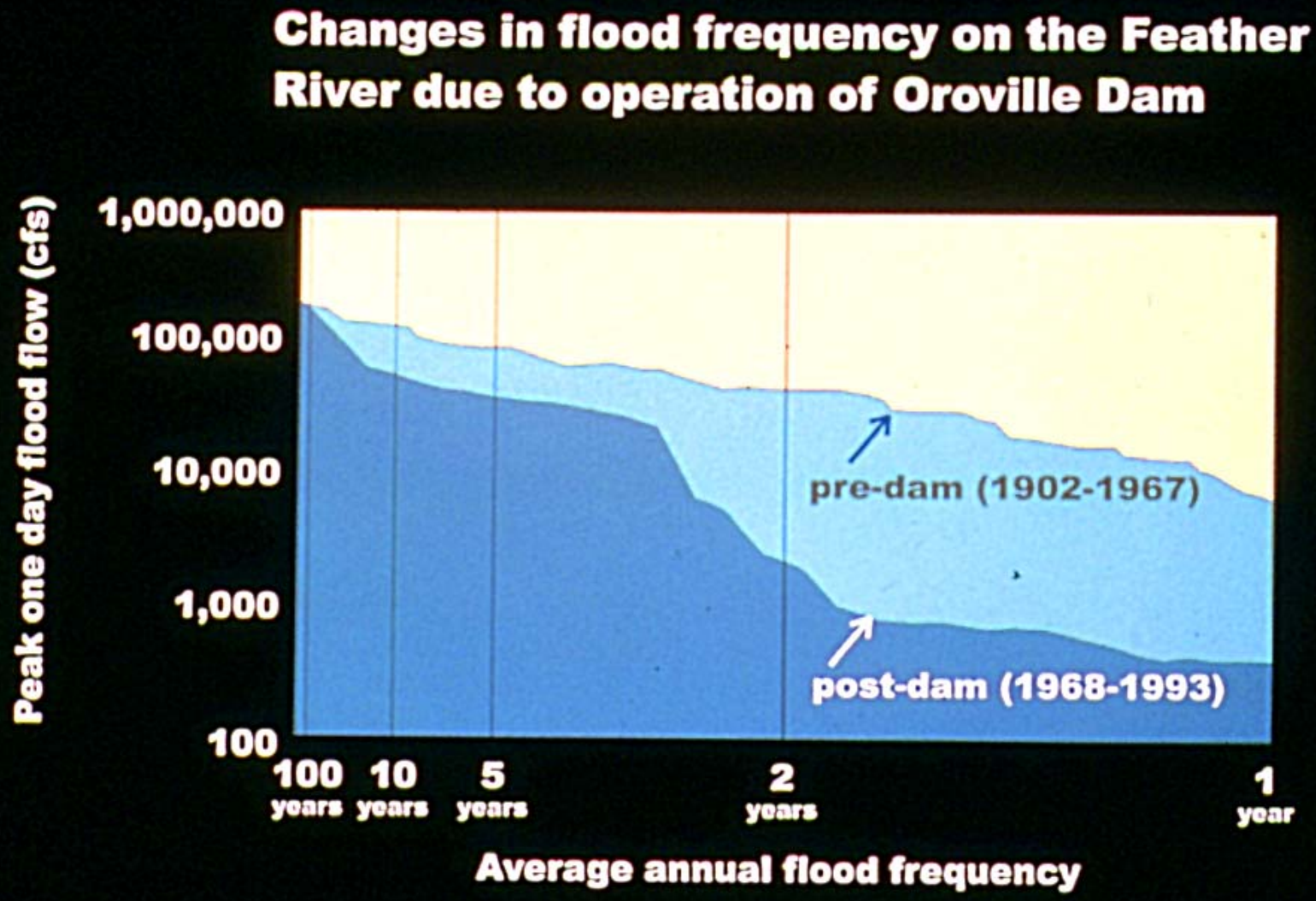


Isolated Floodplains 1: Levees



floodp ecosystem 3.cdr

Isolated Floodplains 2: Reservoirs Eliminate Floods



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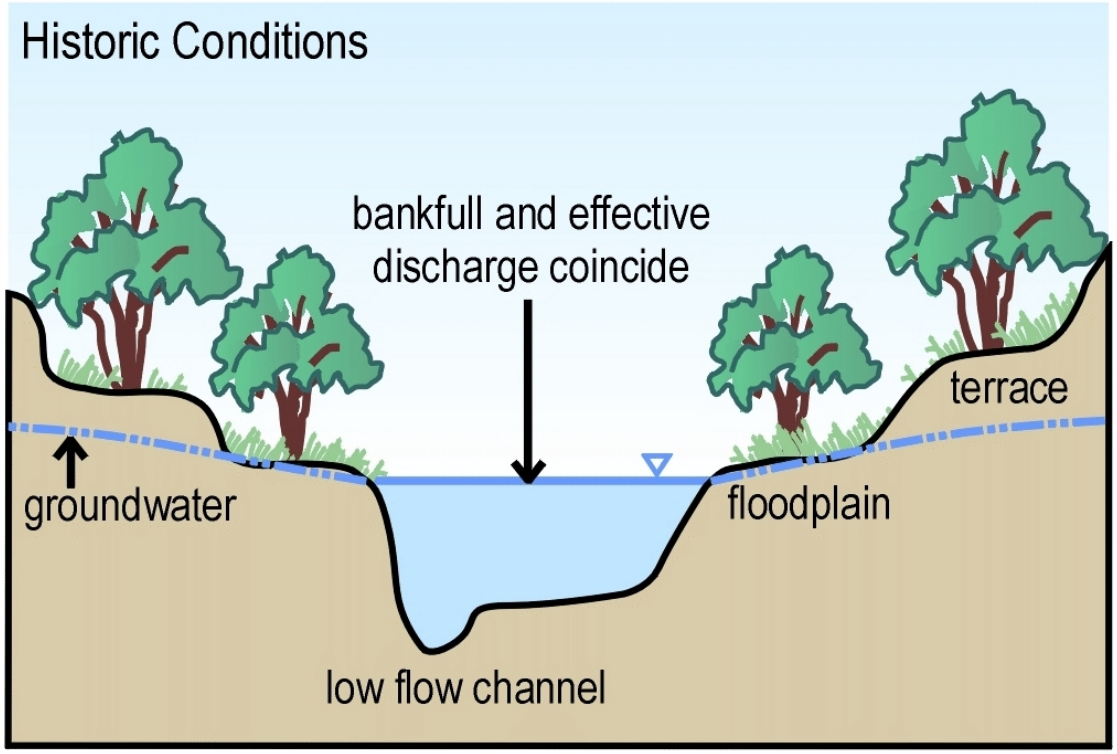
Isolated Floodplains 3: Channel Degradation

PWA, 2006

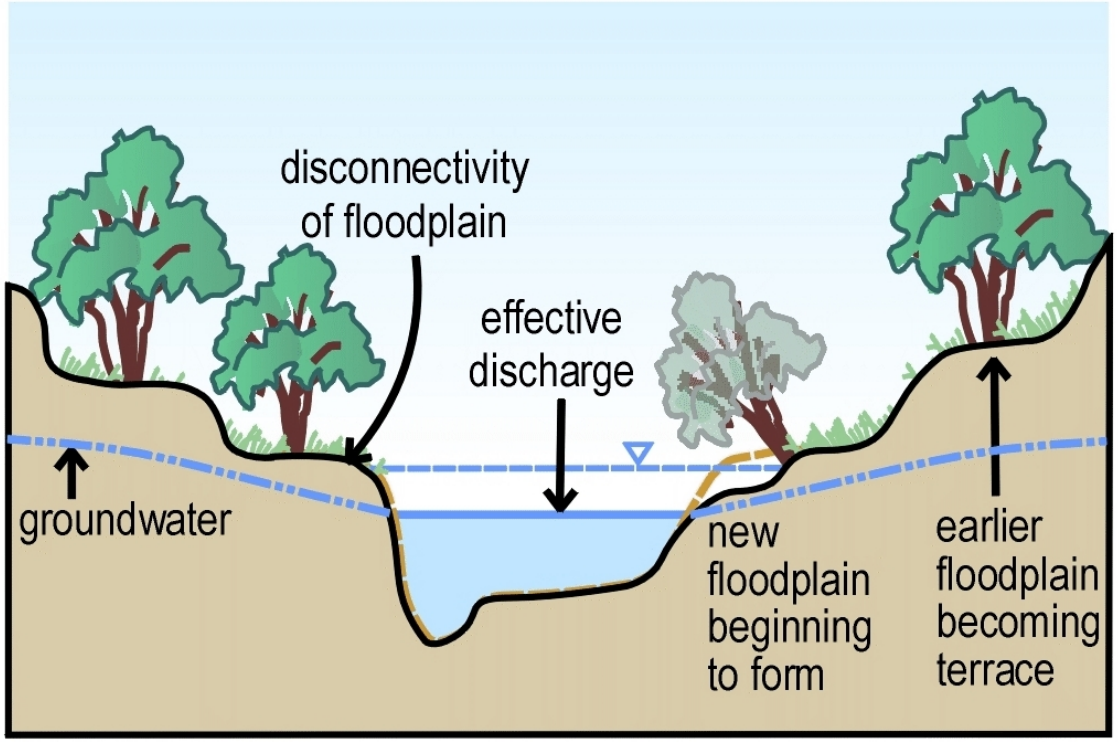
(A)



River Response

PWA, 2006

(B)

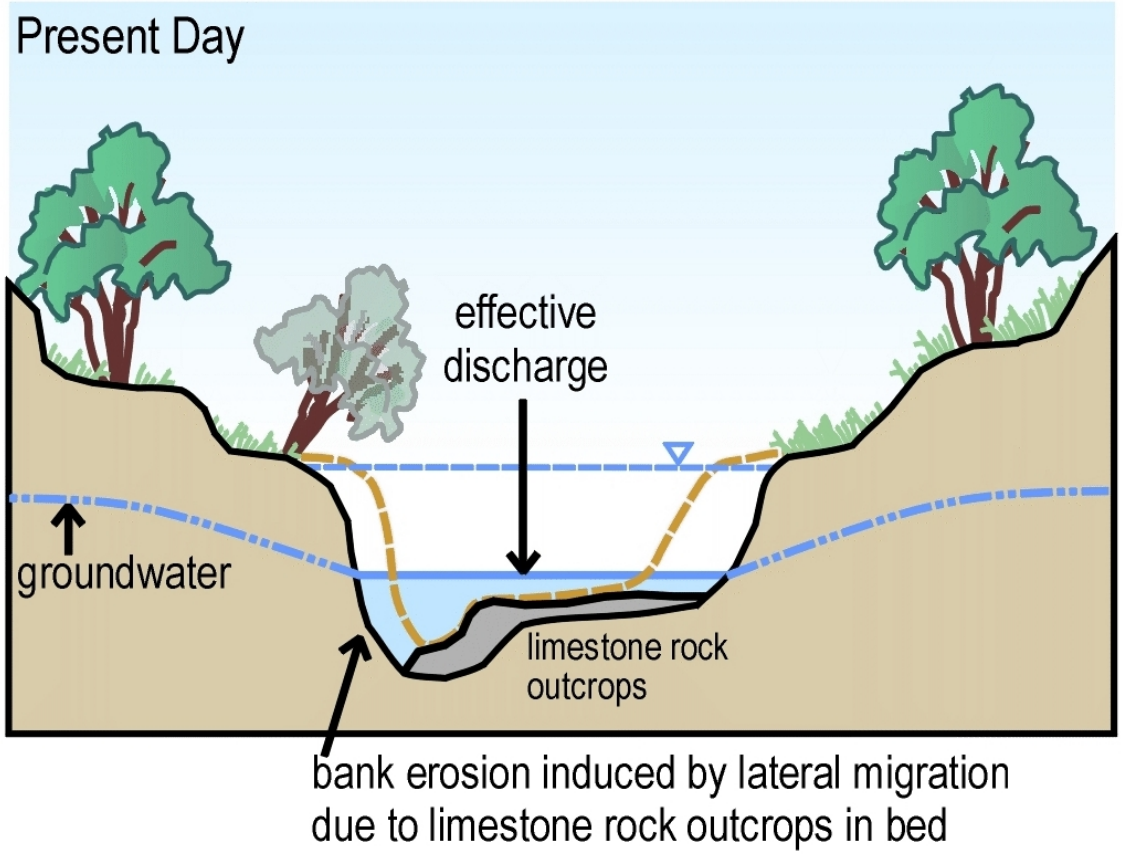


Vertical channel degradation due to impacts of dams and navigation dredging

River Response

PWA, 2006

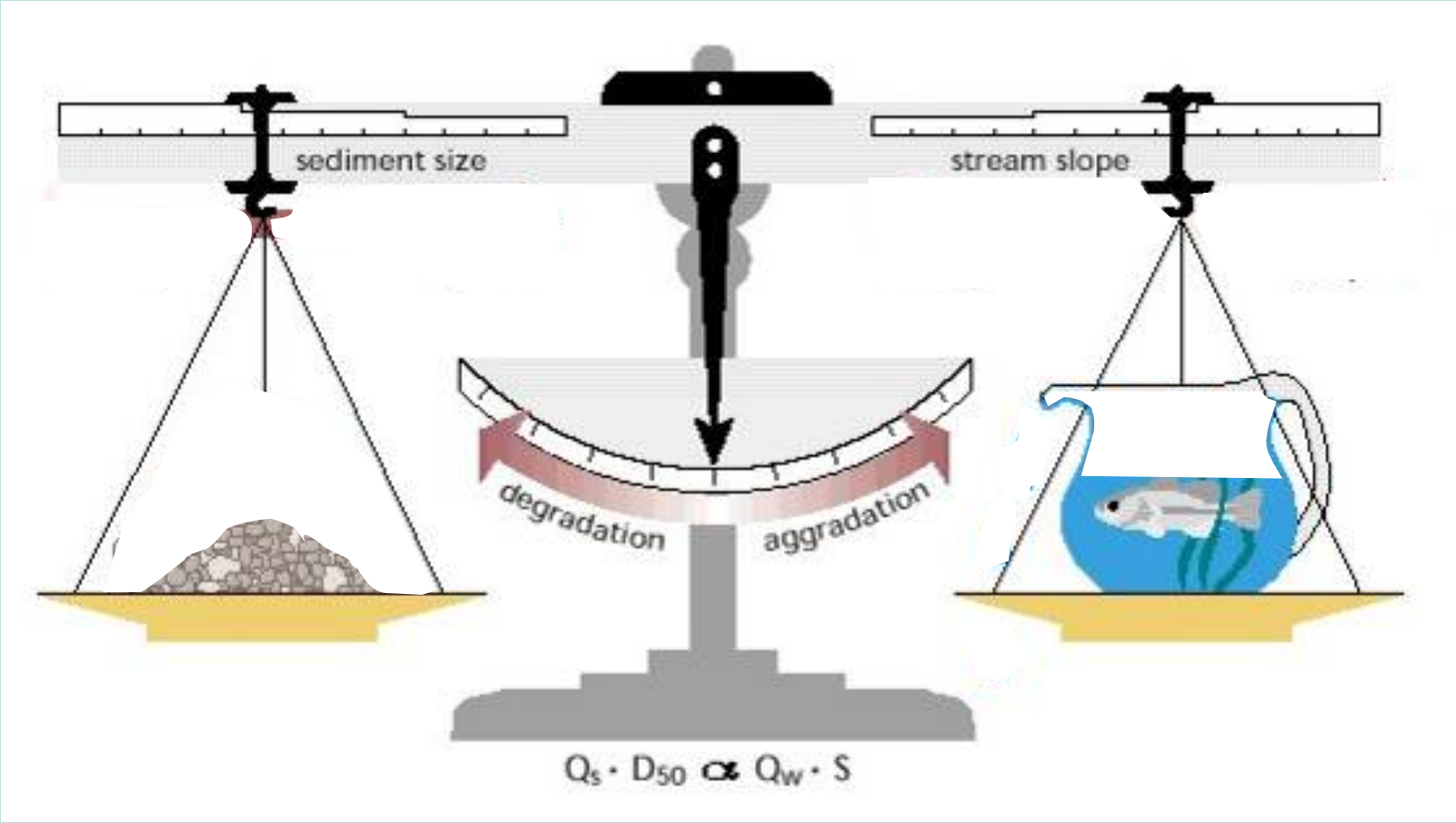
(C)



Lateral channel widening due to arrest of vertical degradation

Channel geomorphology 101

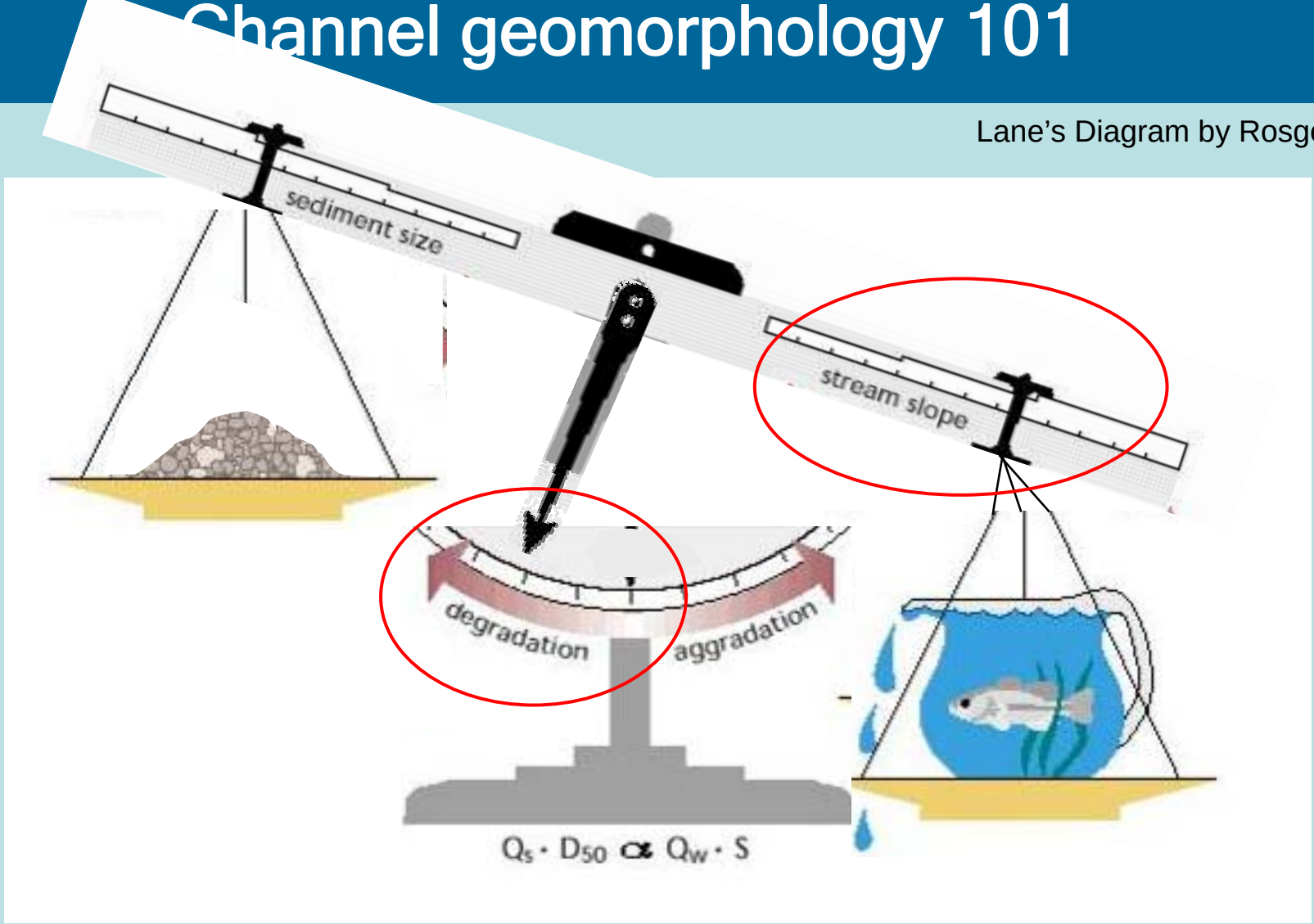
Lane's Diagram by Rosgen, 1996



Over time channel geometry (width, depth, gradient) adjusts to be in equilibrium with water and sediment load

Channel geomorphology 101

Lane's Diagram by Rosgen, 1996

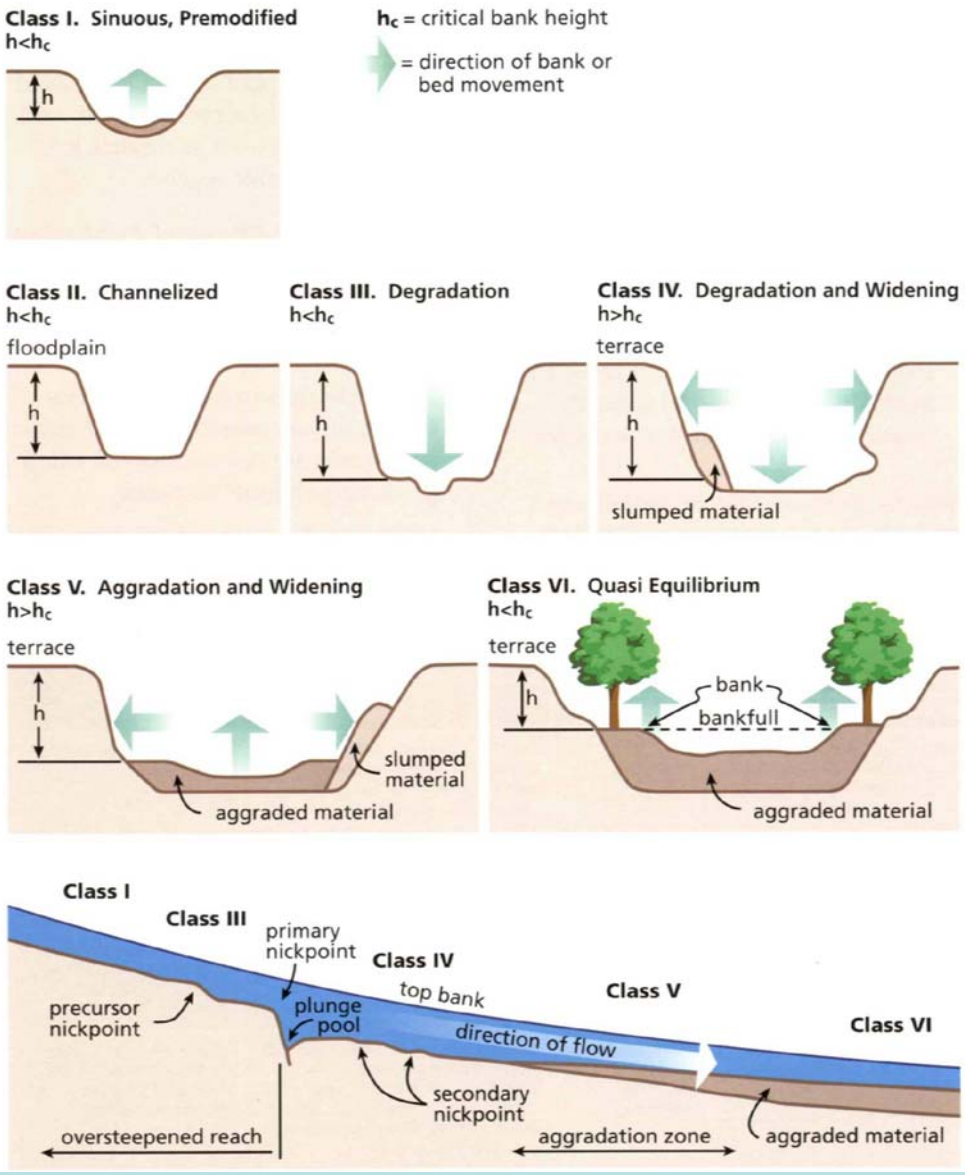


HydroMod increases peak flow and reduces sediment load

-Result is channel incision, expansion and slope flattening

-The question is – how much?

IMPACTS TO RIVERS AND CREEKS



Simon, 1989
Schumm, 1977

WHAT METHODS ARE AVAILABLE TO IDENTIFY WHAT WE SHOULD DO WITH OUR FLOODPLAINS?

Methods and Techniques Available.

- Breach levees
- Setback levees
- Inset floodplains (or raise the bed
- Modification to flow releases

Photo: Chris Bowles

1. Floodway width (McBain, 2007).
2. Streamway concept (Ward et al. 2006)
3. Floodplain Activation Flow (PWA & UCD, 2007).

Photo: Chris Bowles

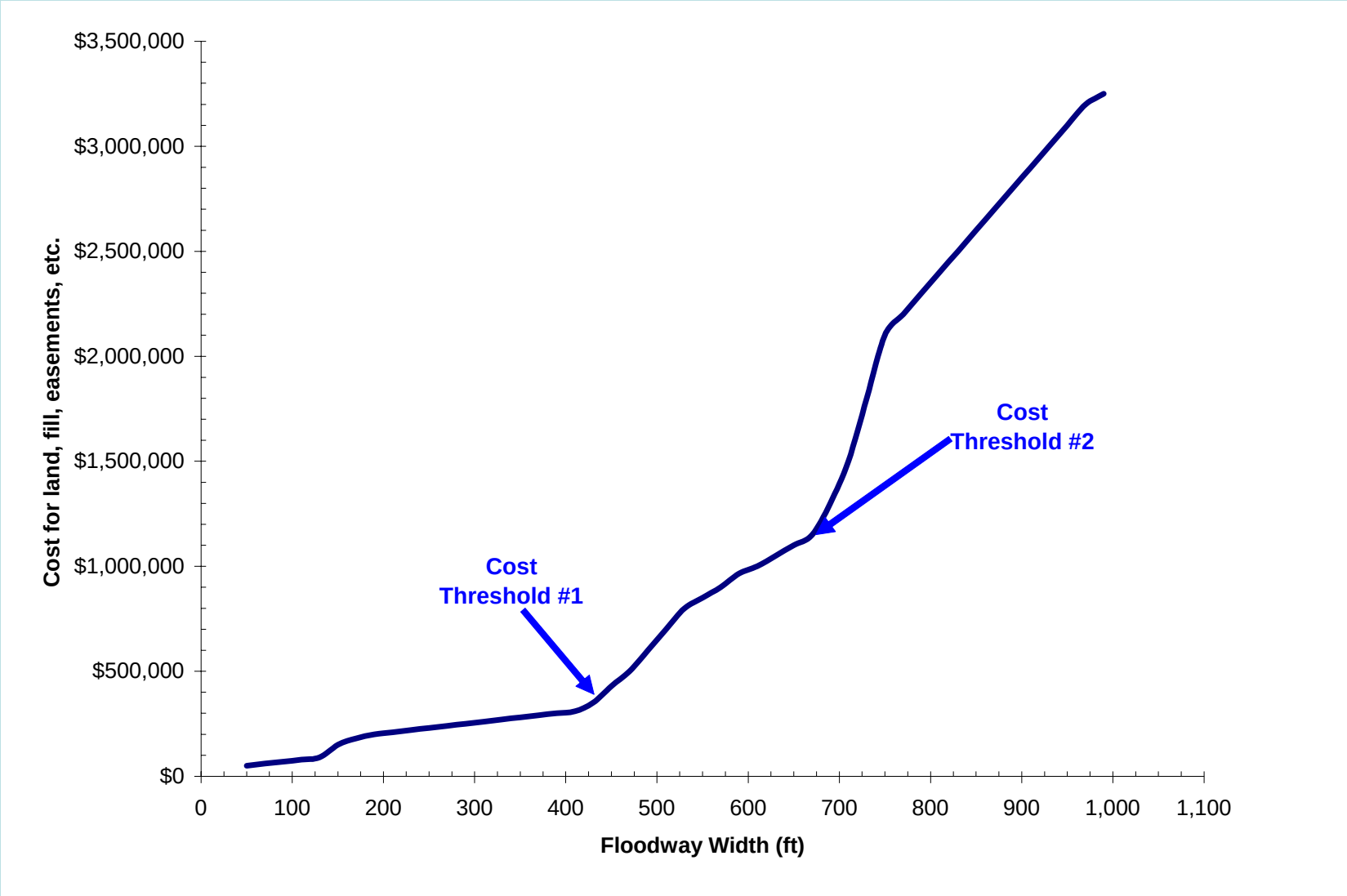
Stream Buffer Sizing

- Streamway concept – Ward et al., 2002.
- Site potential tree – Kondolf et al., 1996.
- Species specific method – Raymond et al., 2003.
- Riparian Habitat Joint Venture – Collins, J., Stein, E., et al., 2006.

Photo: Chris Bowles

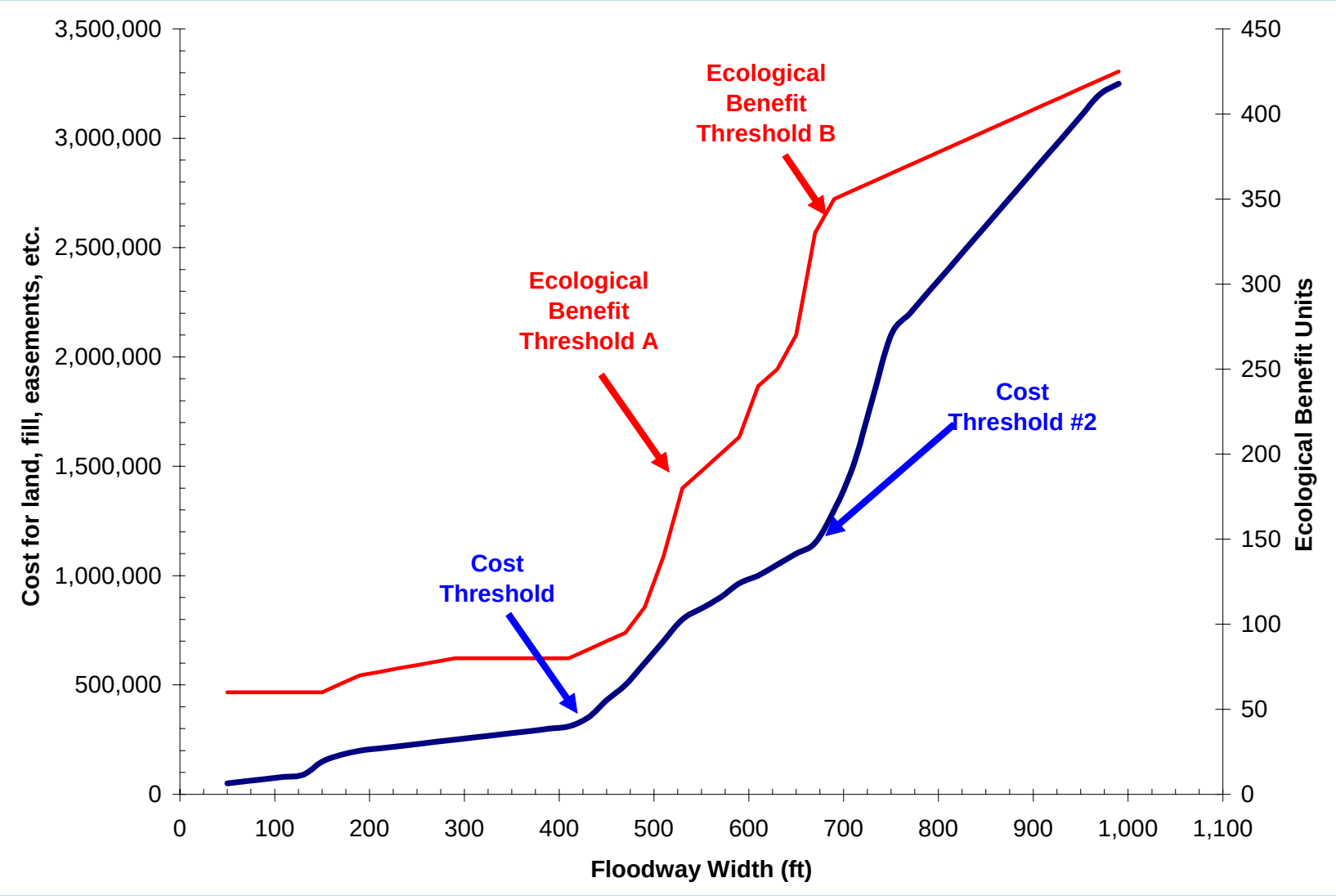
Photo: Roman Loranc

McBain and Trush, Inc. 2007



Often driven by funding boundaries or inflections in project cost

McBain and Trush, Inc. 2007



But we need to provide ecological benefit information too!

Hydraulic/geomorphic criteria

- Patch hole in levee
- Flood conveyance (no floodplains, maximum velocity)
- Flood conveyance (small floodplains, moderate velocity)
- Flood conveyance (moderate floodplains, low floodplain velocity)
- Meander belt (moderate floodplains, allow some lateral channel adjustment)
- Migration zone (larger floodplains, allow lateral channel migration and avulsion)

SCALE

Triage

Enhancement

Restoration

Potential riparian habitat criteria

- One continuous canopy width (hey, its green!)
- Two continuous canopy width (begin to affect understory microclimate)
- <2.5 acre willow patches (willow flycatcher, yellow warbler)
- <12 acre willow patches (yellow-breasted chat)
- Larger patch site, less edge (reduce cowbird parasitism)
- >100 ft wide, >25 acres (yellow-billed cuckoo)
- Wide enough for oxbow formation (western pond turtle, yellow-billed cuckoo)

SCALE

Enhancement

Restoration

Potential salmonid habitat criteria for floodway width

- Floodplain velocities for Q1.5 < 1 ft/sec
- Minimum width for geomorphic stability
  - No channel incision
  - Straight alternate bar formation (maintain bar storage)
  - Meandering alternate bar formation (maintain bar storage)
  - Side channel formation
  - High flow scour channel formation
  - Meander belt formation
  - Migration zone formation
- Remove floodway width perturbations to avoid catastrophic scour/deposition

SCALE

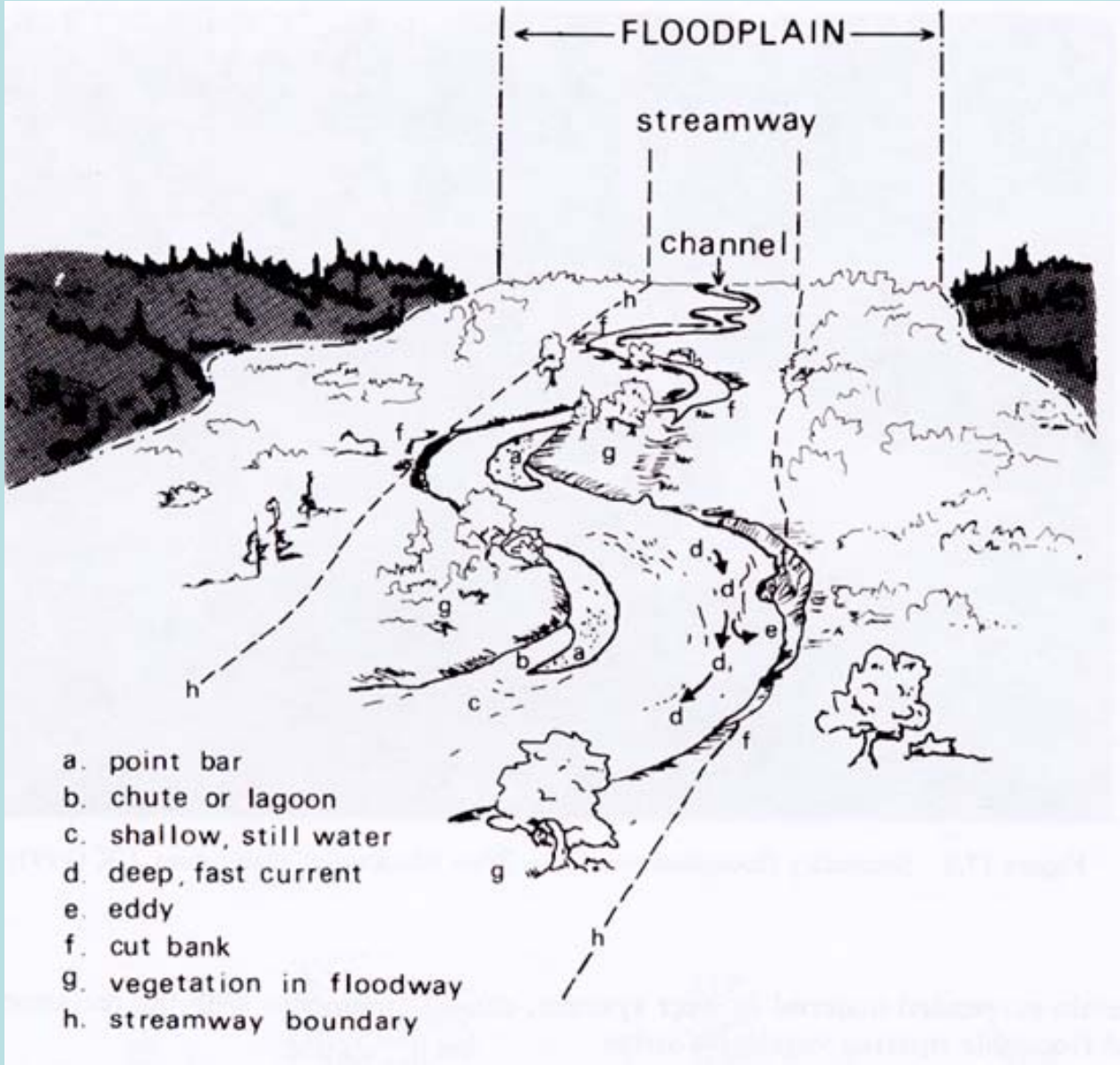
Enhancement

Restoration

Streamway Concept (Ward et al. 2007)

1. Streamway is defined as the historical area where a stream's meander pattern is confined
2. Meander patterns fluctuate over time due to flood events, infrastructure in these areas can be damaged
3. If a channel does not have access to a floodplain, it will downcut or widen, requiring larger and larger flows to achieve bankfull, this scenario will result in stream failure
4. The application of defining a stream way width for a system will reduce the amount of initial engineering and focus on holistically developing a self-sustain system

Streamway Concept (Ward et al. 2007)



Streamway Concept (Ward et al. 2007)

1. Ward et al. (2002) developed research by Williams (1986) for Eastern US relating meander beltwidth (B) and bankfull width (W)

$$B = 4.0 * W^{1.12}$$

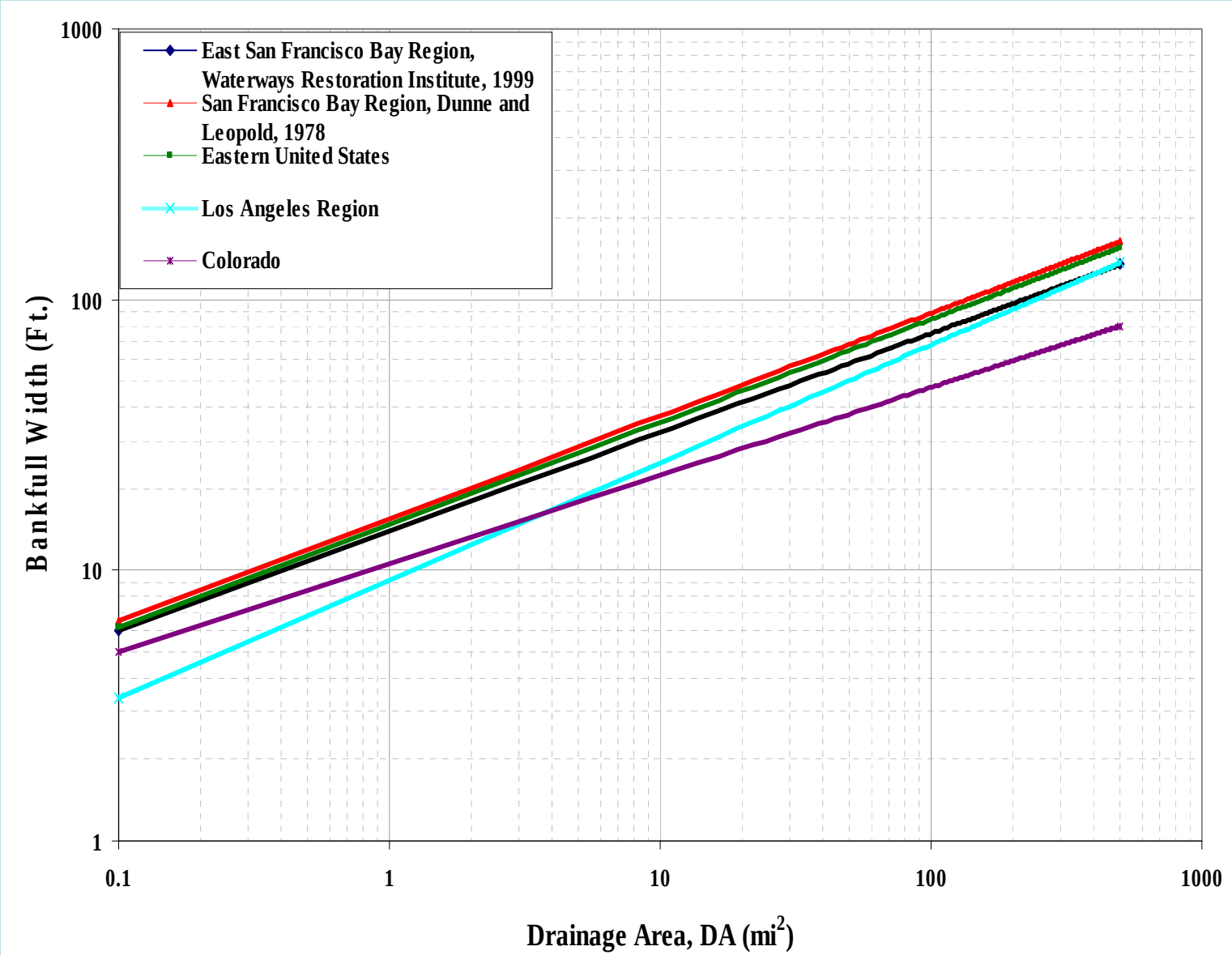
2. Ward et al. found through validation that this equation under-predicted the beltwidth in some instances and over-predicted in other instances. Based on this analysis the streamway width equation was modified to:

$$Sw = 6.0 * W^{1.12}$$

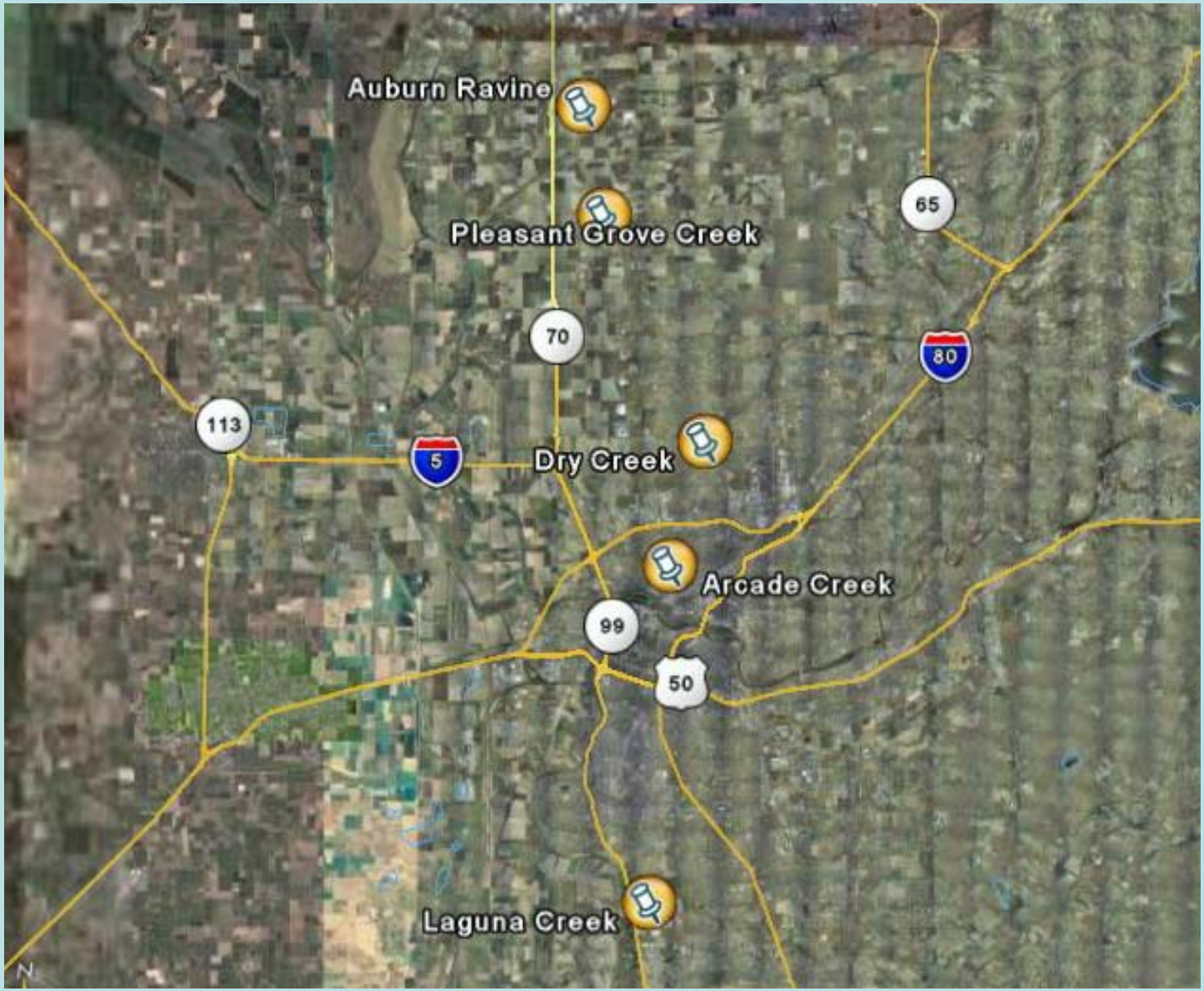
3. This equation was coupled with a regression equation from a regional curve to develop a streamway width for a particular watershed:

$$Sw = 120 * DA^{0.43}$$ (for streams in the Eastern US)

Streamway Analysis of Central Valley Streams



Streamway Analysis of Central Valley Streams



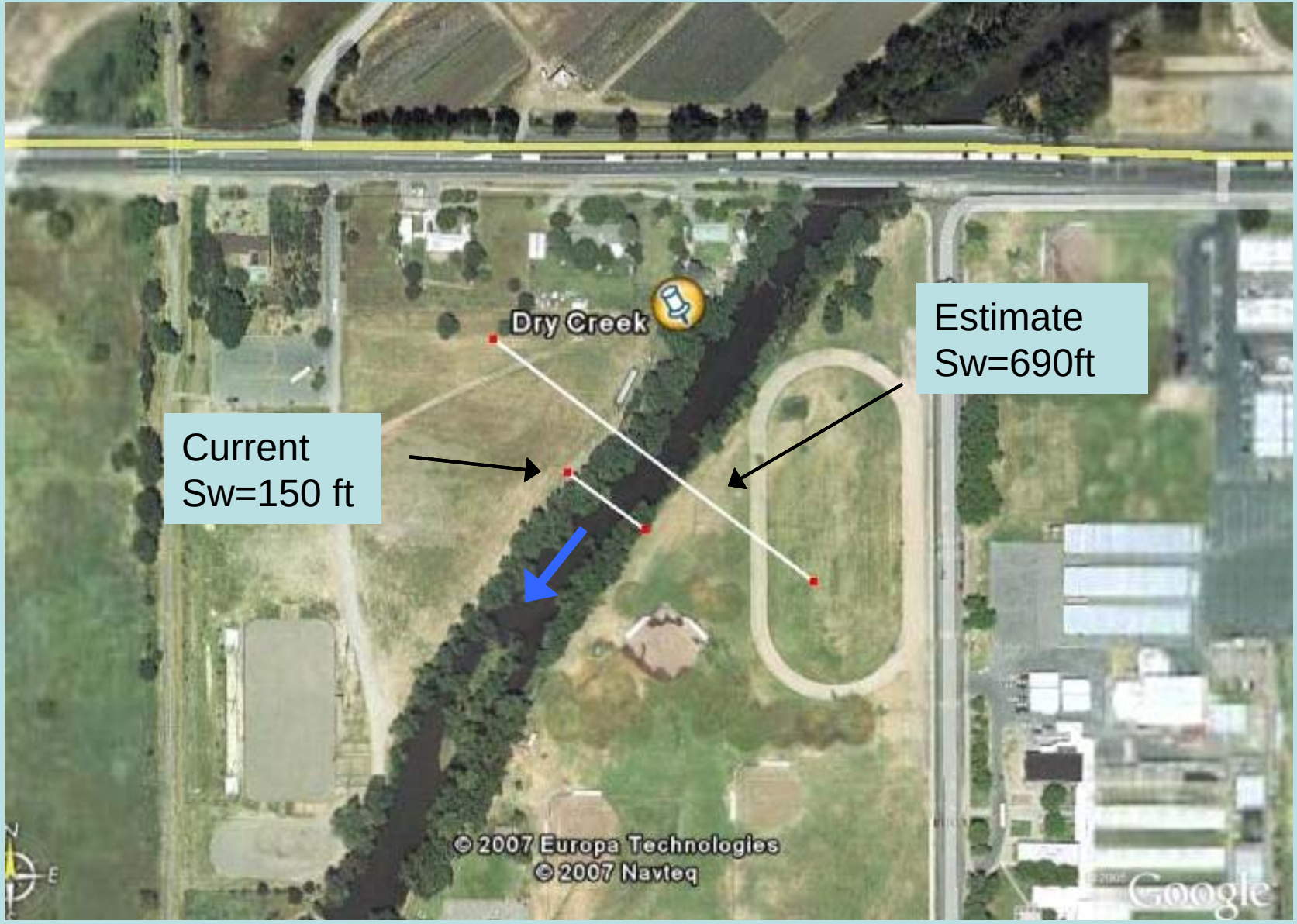
Streamway Analysis of Central Valley Streams

Stream	Current Streamway Width (ft)	Estimate Streamway Width (SF East Bay/SF West Bay) ft	Estimate Difference
Arcade Creek	350	514/614	100
Auburn Ravine	200	686/829	143
Dry Creek	150	690/839	146
Laguna Creek	220	569/683	114
Pleasant Grove	90	693/770	77

Streamway Analysis of Central Valley Streams

PWA

Streamway Analysis of Central Valley Streams



Streamway Analysis of Central Valley Streams

Streamway Analysis of Central Valley Streams

Defining Functional Floodplains: It's the Stage, Not the Flow

Different Floodplain Mapping Criteria

- Flood hazard criteria: 100 Year flood maps
- Physical features: soils and terraces
- Biotic indicators: wetland delineation
- Floodplain function:
  - 2 Year peak flood stage inundation area
  - Floodplain Activation Flood [FAF] inundated area

Defining Functional Floodplains

Strategy:

Restore connectivity and food-web processes

For the Sacramento lowland river a **Floodplain Activation Flood [FAF]** can be defined as:

"*Floodplain inundation for at least 7 days, during the period March 15th to May 15th , in at least 2 out of 3 years*"

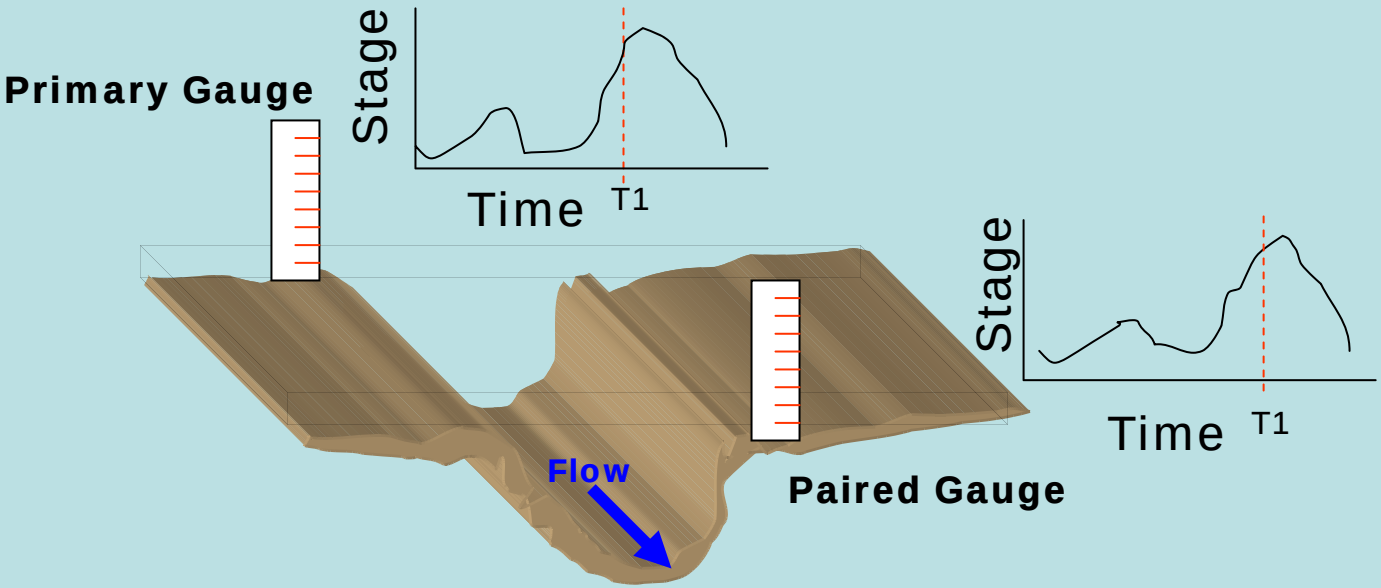
The extent of '**activated floodplain**' is the area inundated by the FAF and connected to the river channel.

Quantifying the Active Floodplain

Need to define:

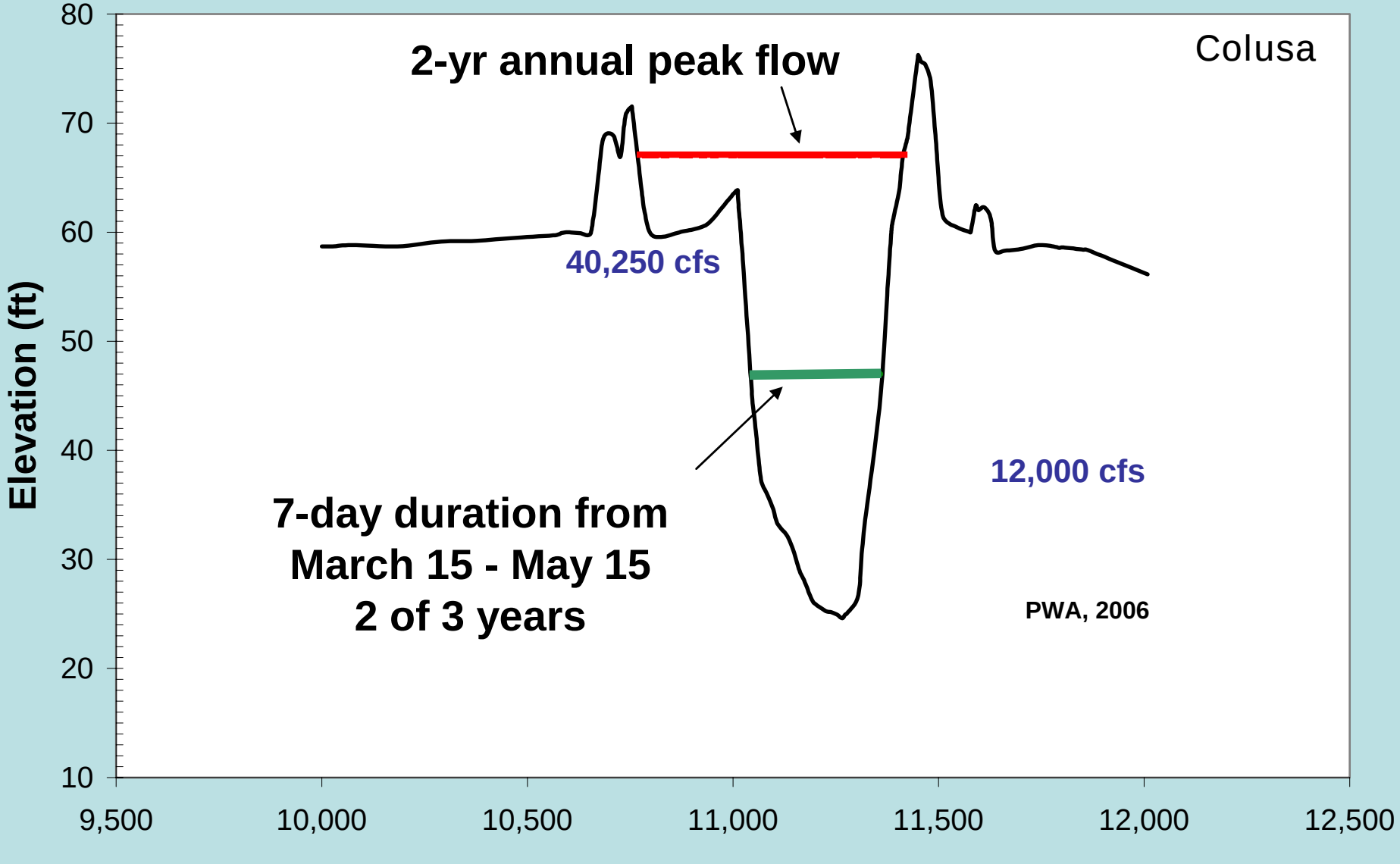
1. Hydrology : actual reservoir operation
2. Hydraulics : calibrated hydrodynamic model; or actual gage data.
3. Floodplain topography: detailed mapping at fine enough resolution to define connectivity to river channel

Methodology

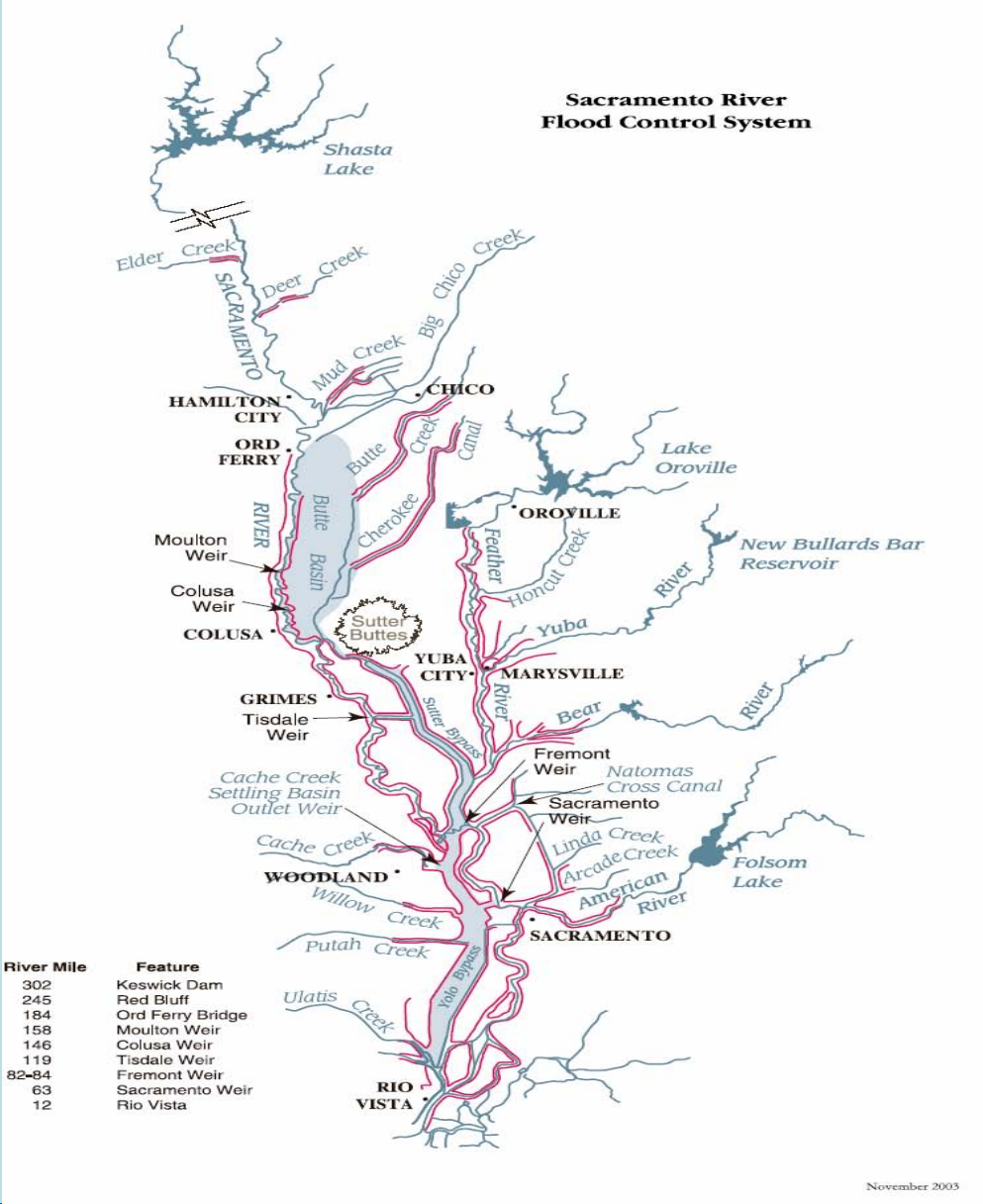


-Use stage/flow rating curves to define water surface plane of FAF
-Superimpose plane on floodplain topography

Results: FAF Stage Below Floodplain

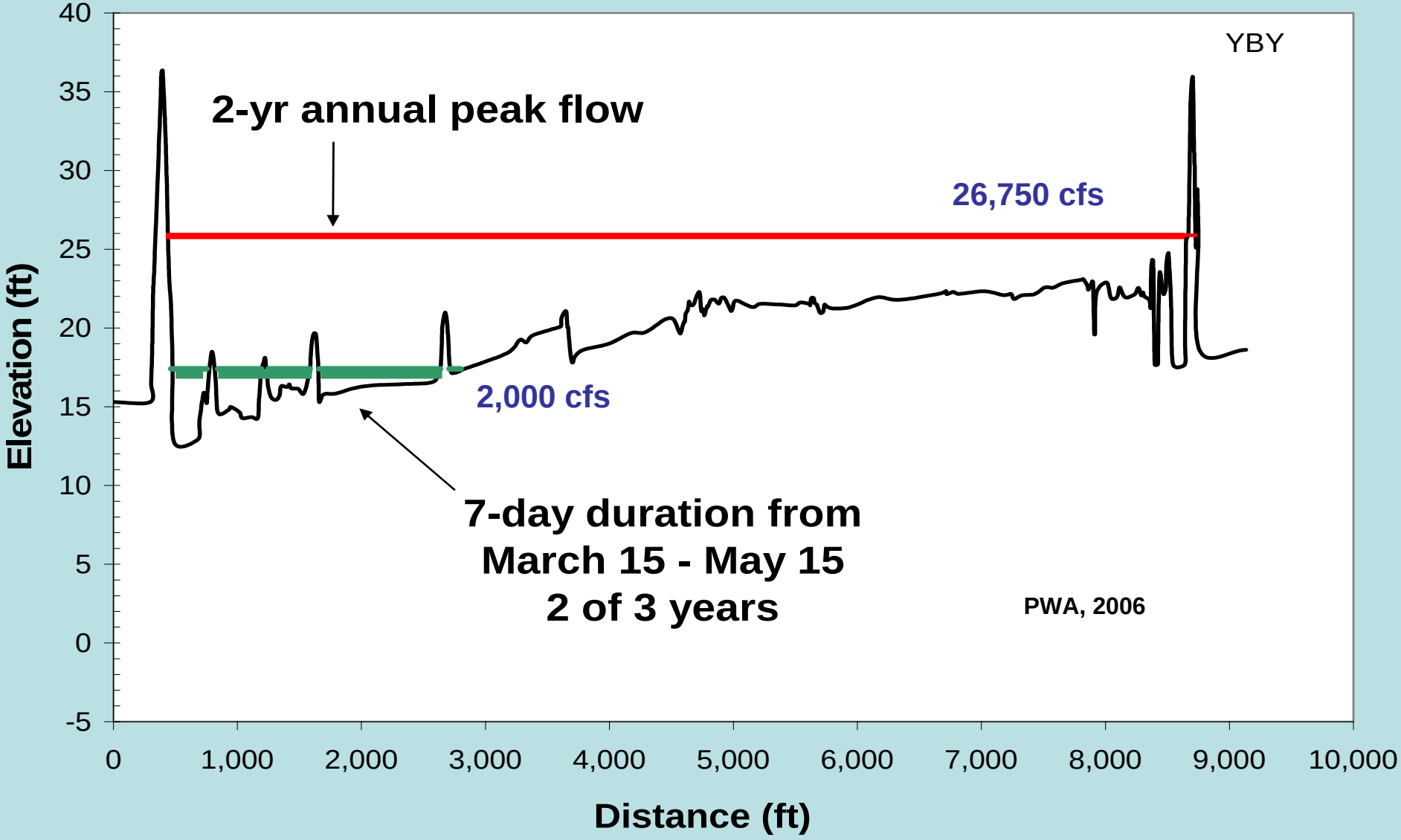


Sacramento Valley Flood Bypasses



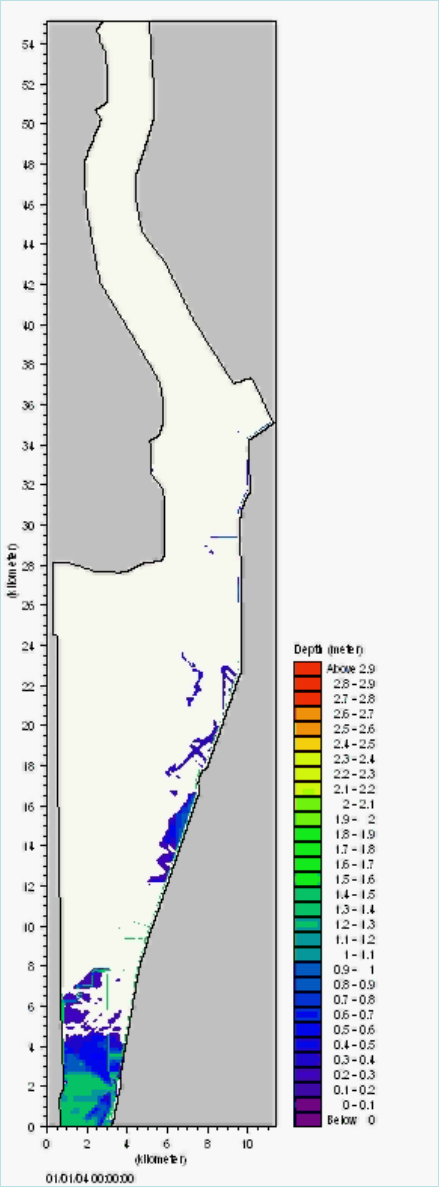
River Mile	Feature
302	Keswick Dam
245	Red Bluff
184	Ord Ferry Bridge
158	Moulton Weir
146	Colusa Weir
119	Tisdale Weir
82-84	Fremont Weir
63	Sacramento Weir
12	Rio Vista

Results: FAF Inundates Significant Areas in Yolo Bypass



Yolo Bypass

PWA, 2005



FAF as Restoration Design Tool

To increase FAF area in a lowland river system, we can:

- Increase frequency of small flood reservoir releases: *Hydrology*
- Raise flood stage: *Hydraulics*
- Lower floodplain terrace: *Topography, elevation*
- Set-back levees: *Topography, planform*

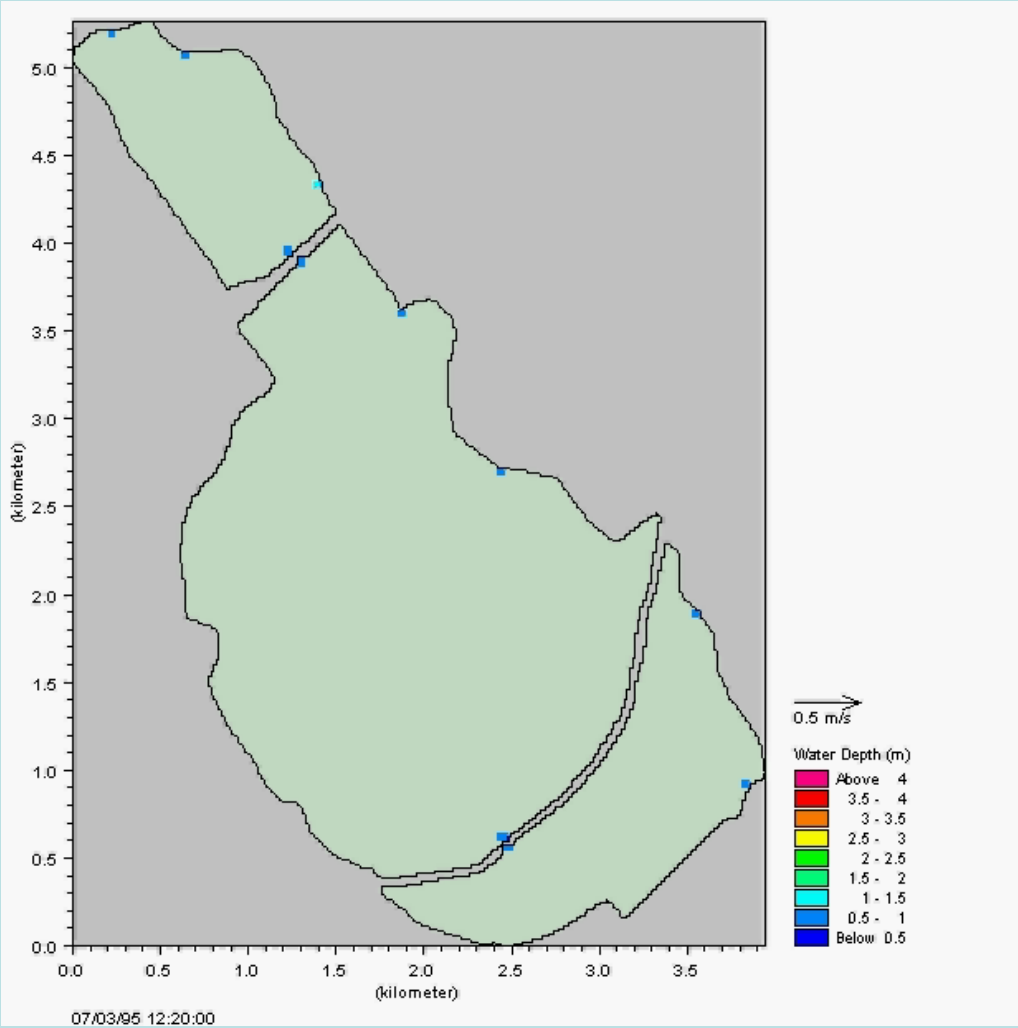
FAF as a Management Tool

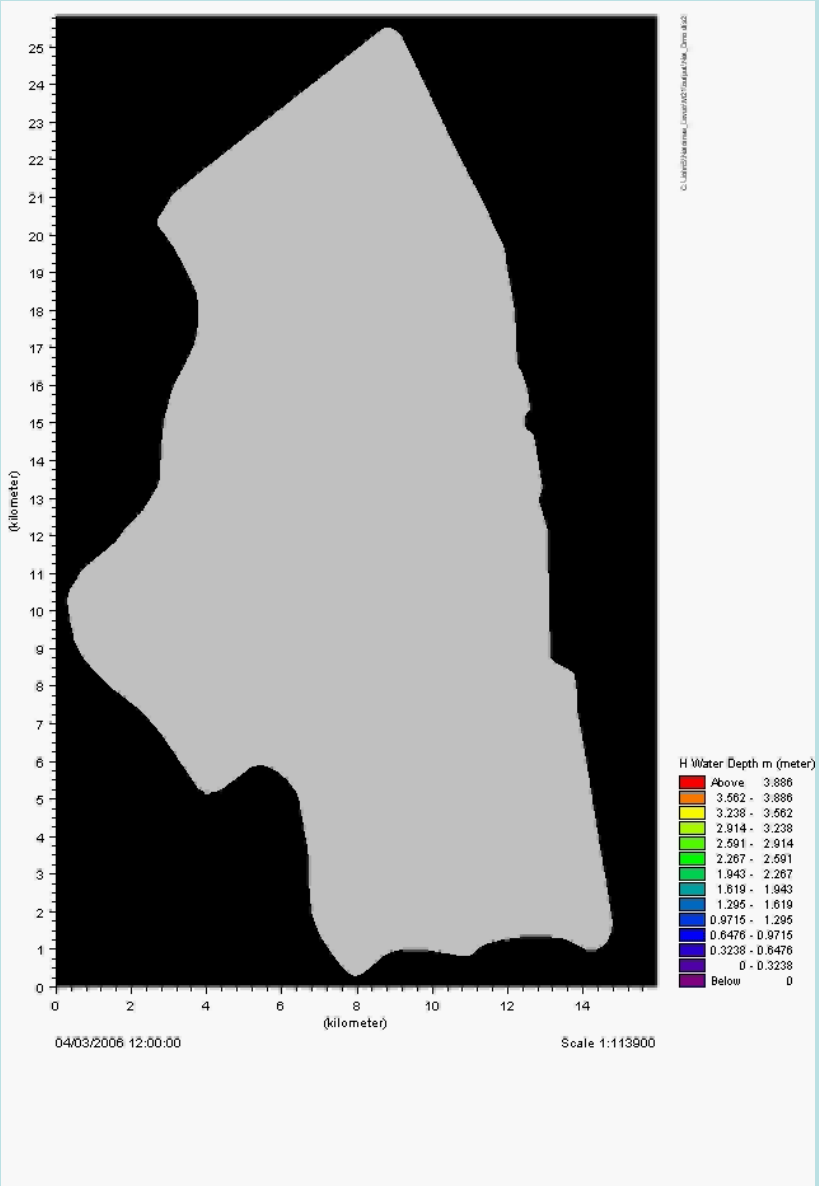
- Goal setting: allows for hindcasting at the landscape scale
- Planning: allows forecasting at the landscape scale
- Design: establishes reservoir operation or grading criteria
- Monitoring: easy and transparent, use in adaptive management

EXAMPLES OF SUCCESS?

Examples of Success or Not… (Breached Levees)

PWA, 2005 AND 2006





Examples of Success - Bear River: Grading and Re-connecting the Floodplain

Bear River Levee Setback

Bear River Levee Setback

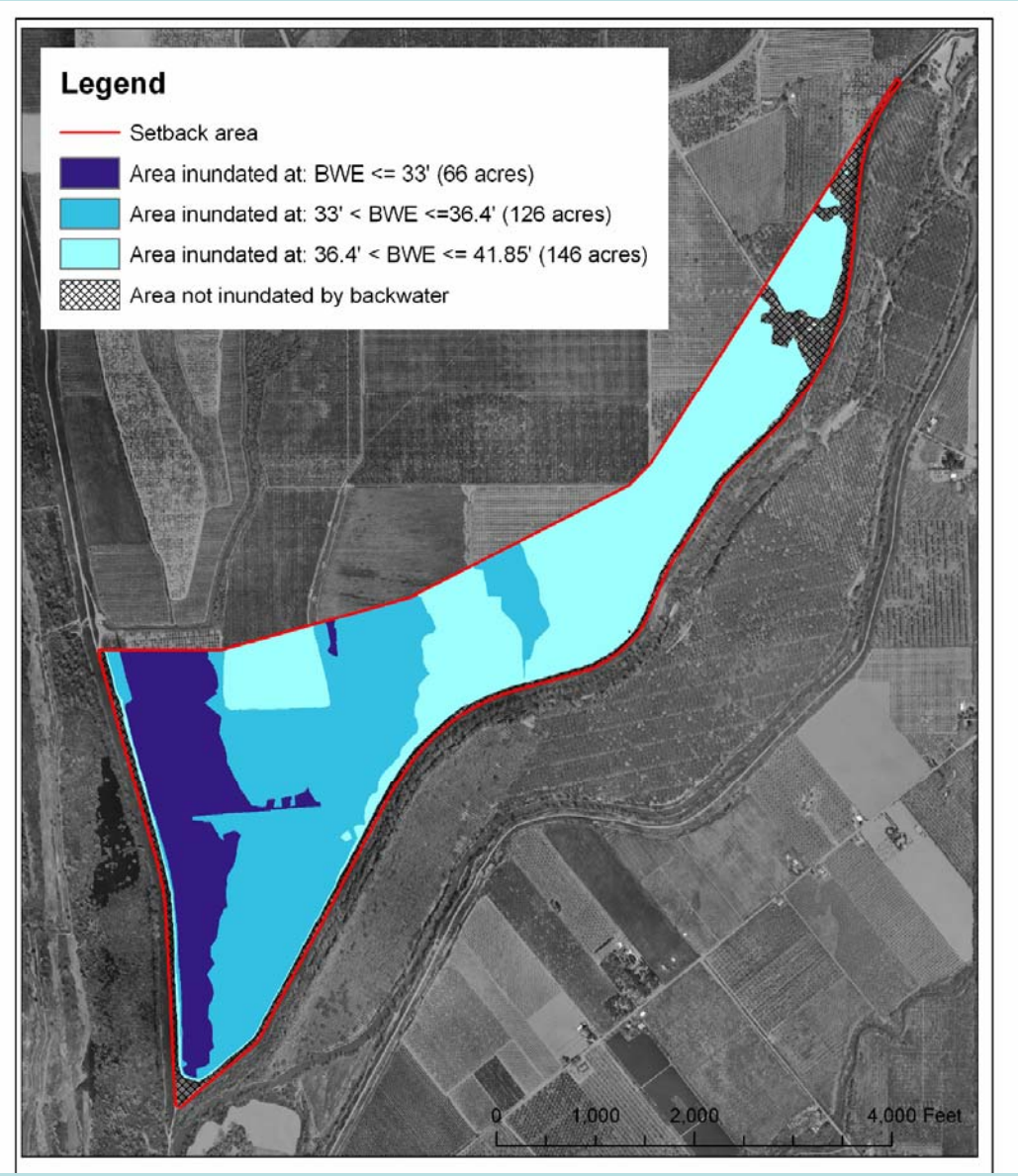


PHOTO: CHRIS BOWLES, 2006

PHOTO: GEI, 2006

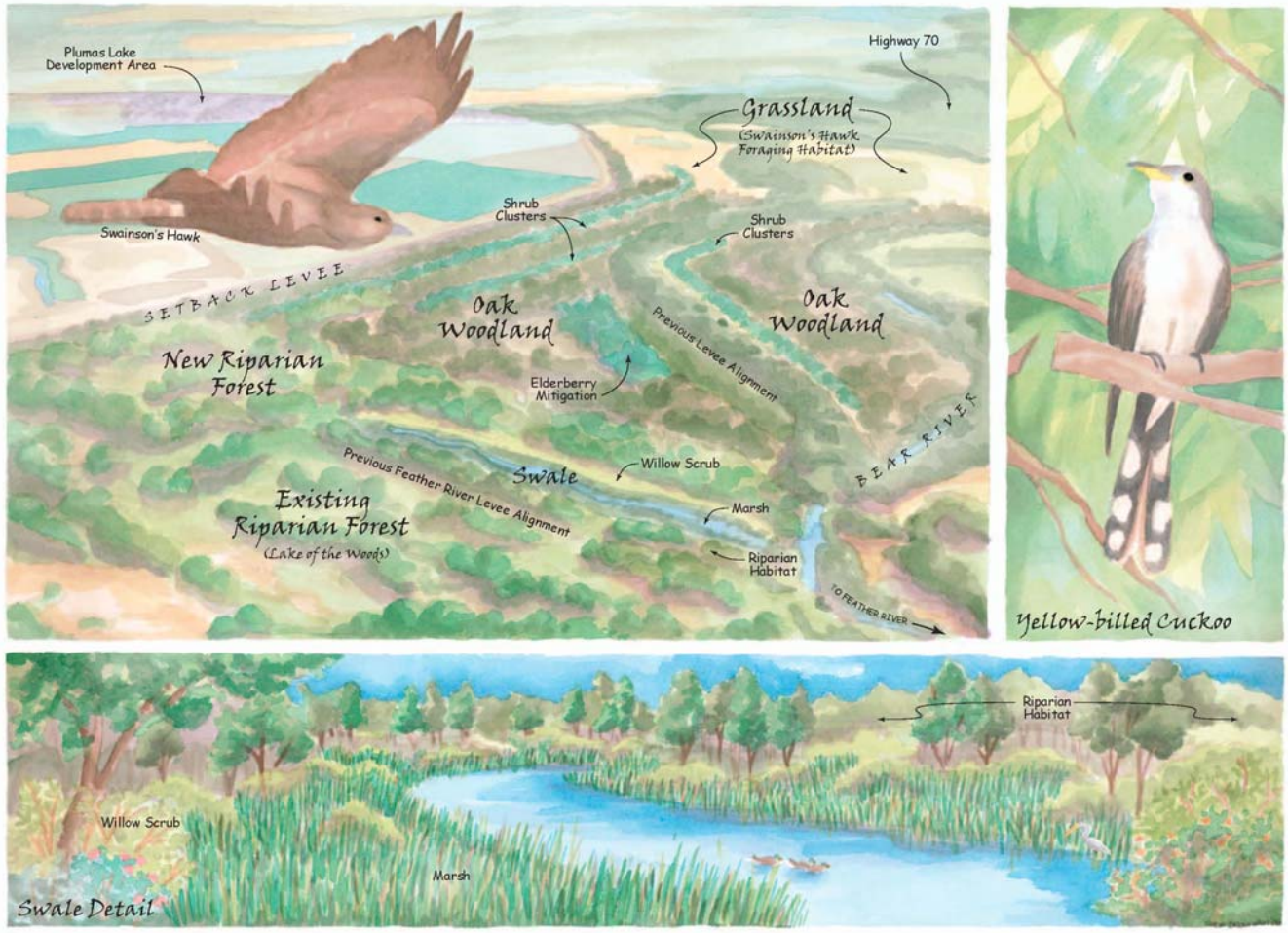
Bear River Levee Setback

PLAY VIDEO

Bear River Levee Setback

PHTOS: CHRIS BOWLES, 2006 AND 2007

Bear River Levee Setback

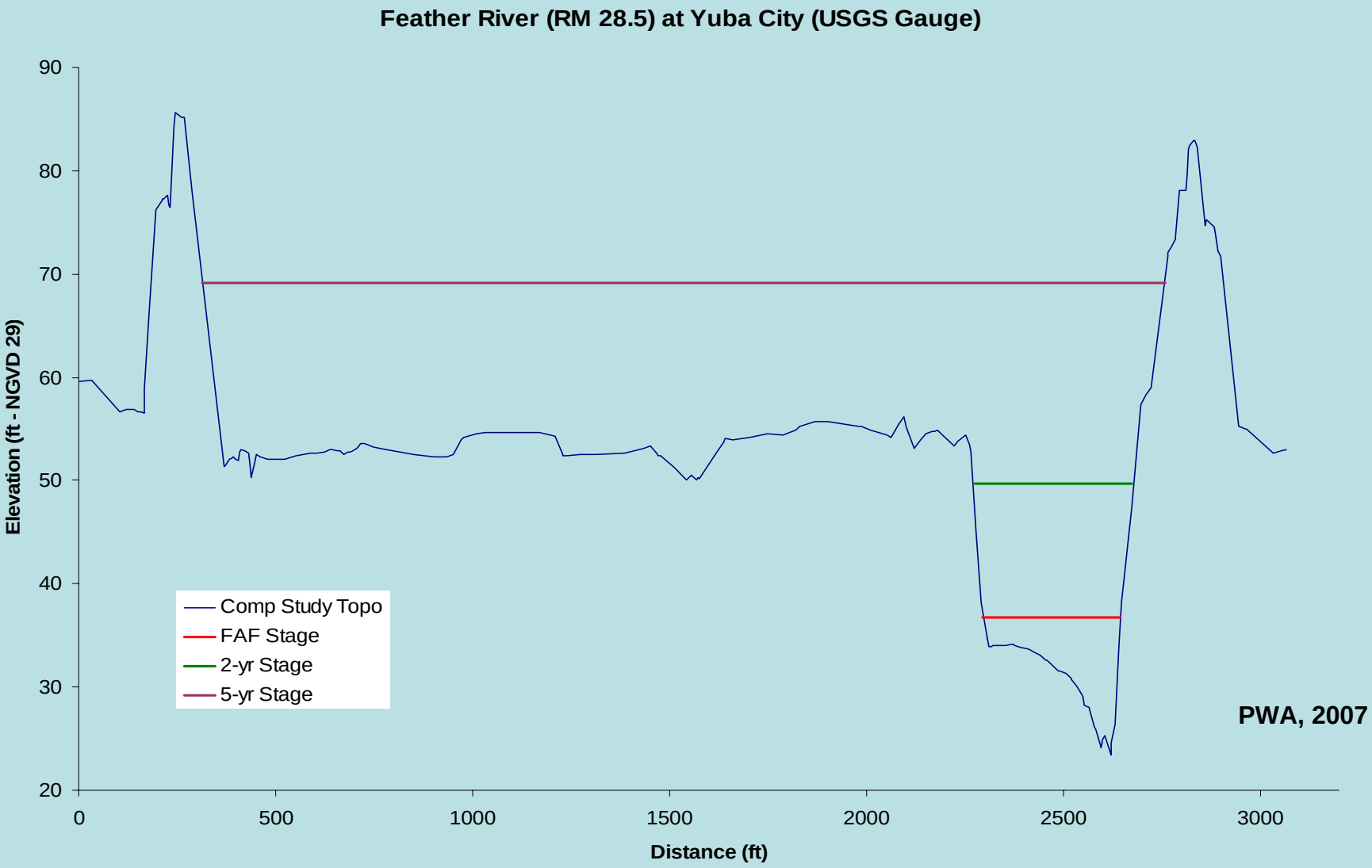


TRLIA, 2006

Feather River at Olivehurst 1997 flood

Feather River Floodplain Restoration: Levee Setback

Preliminary Feather River Flood Stages



Lowering the Floodplain or Raising the Bed

Photos: Pasternack, UC Davis

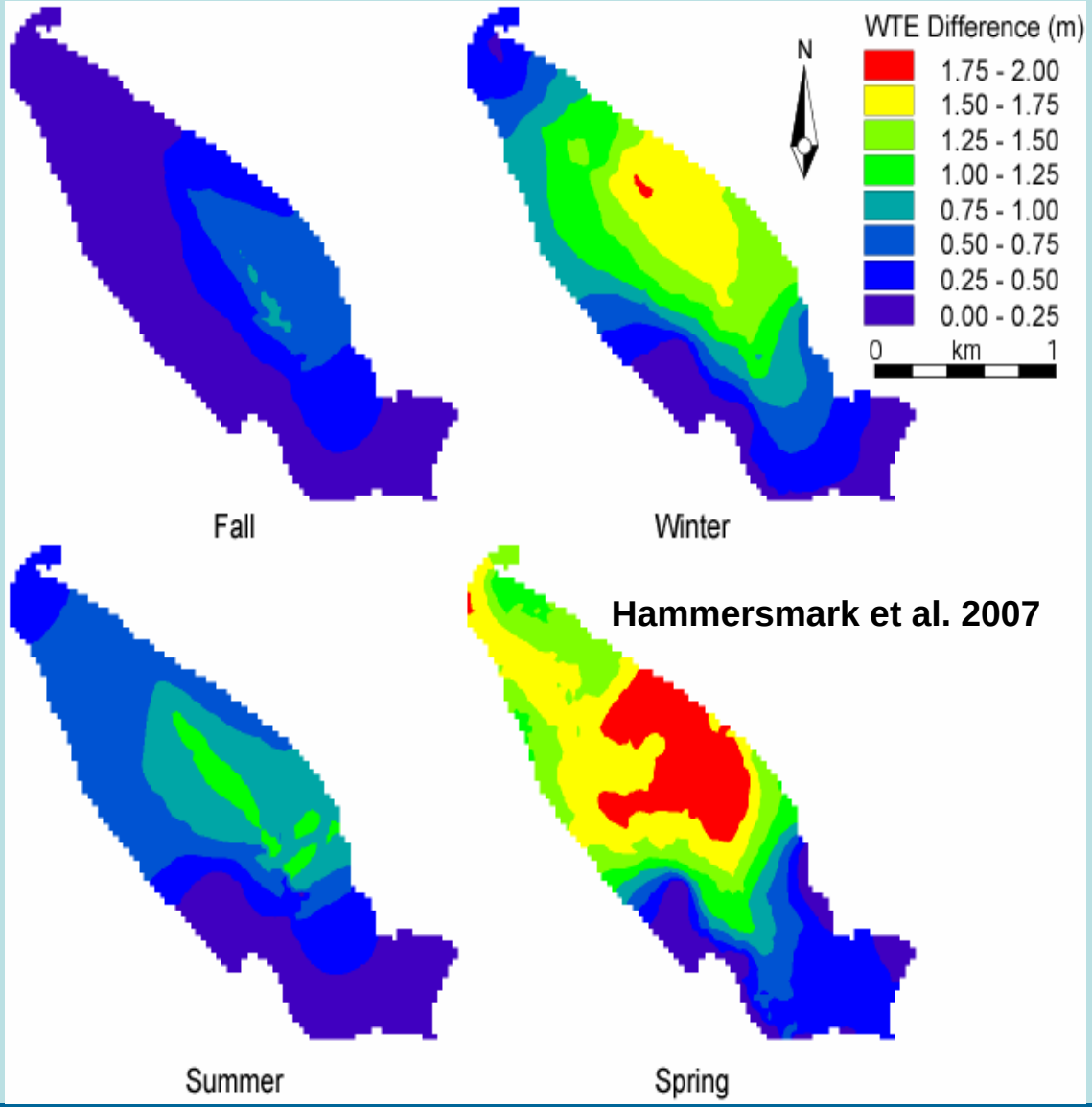
Inset Floodplain (raising bed) – Bear Creek

Hammersmark et al. 2007

- Groundwater
  - Groundwater levels raised
  - Subsurface storage increased
- Surface water
  - Increased frequency and duration of floodplain inundation
  - Increased surface storage
  - Decreased flood peak magnitude
  - Decreased duration of baseflow
  - Decreased total annual runoff
- Atmospheric exchange
  - ET increased

Groundwater

- Groundwater levels raised
- Largest difference in winter and spring
- Complex response due to channel realignment
- Larger maximum and residual volume stored

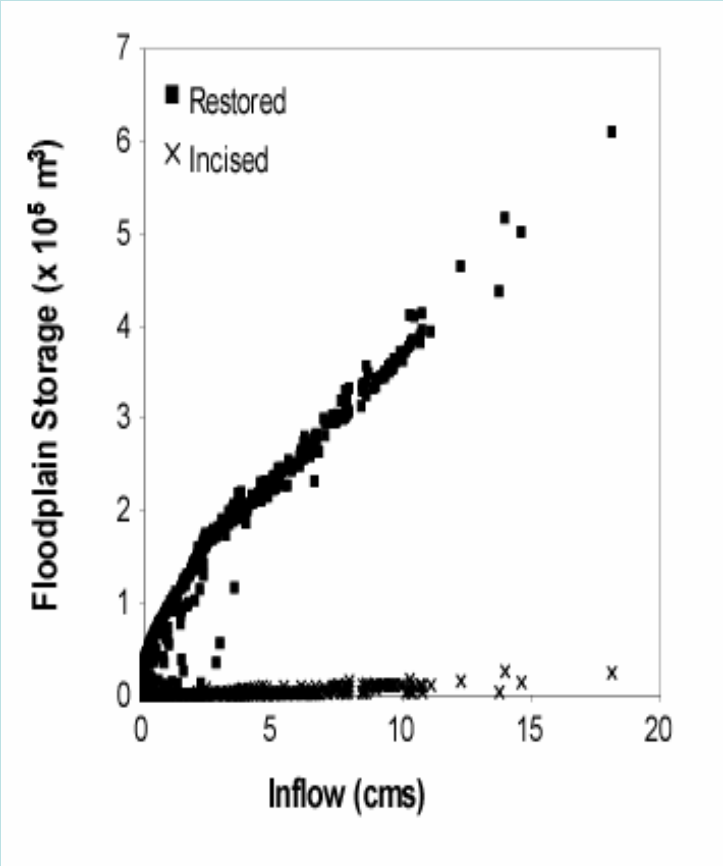


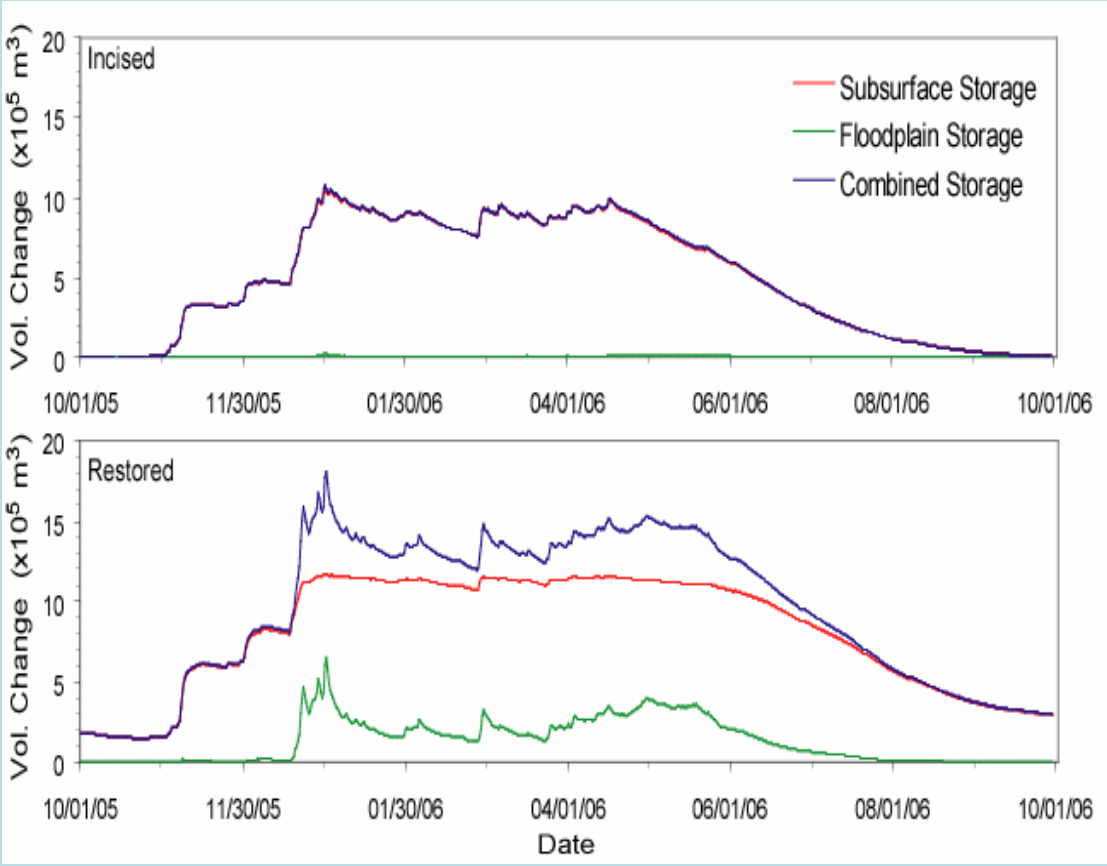
Hammersmark et al. 2007

Surface Storage

Hammersmark et al. 2007

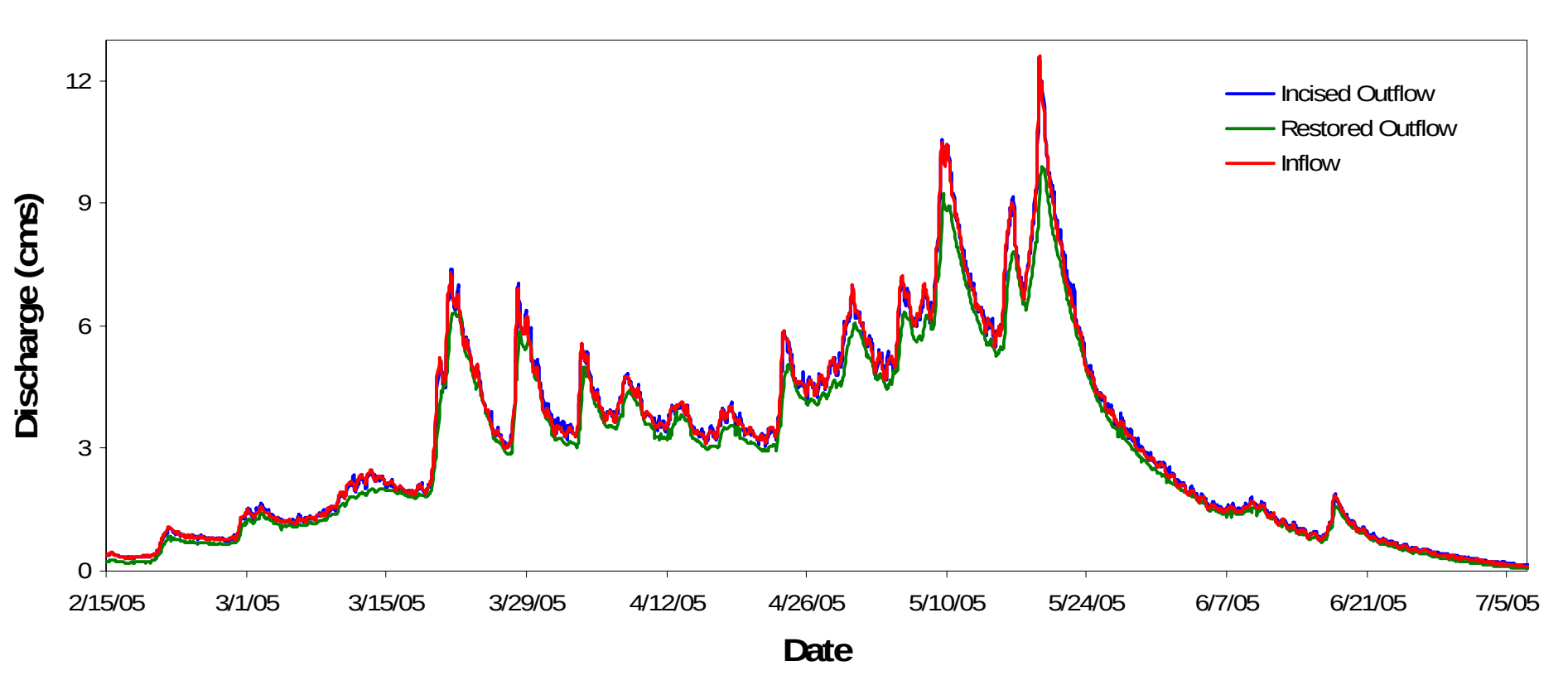
- Increased channel-floodplain connectivity
- Increased floodplain inundation frequency and duration
- Increased volume of surface storage





Flood Peak Reduction

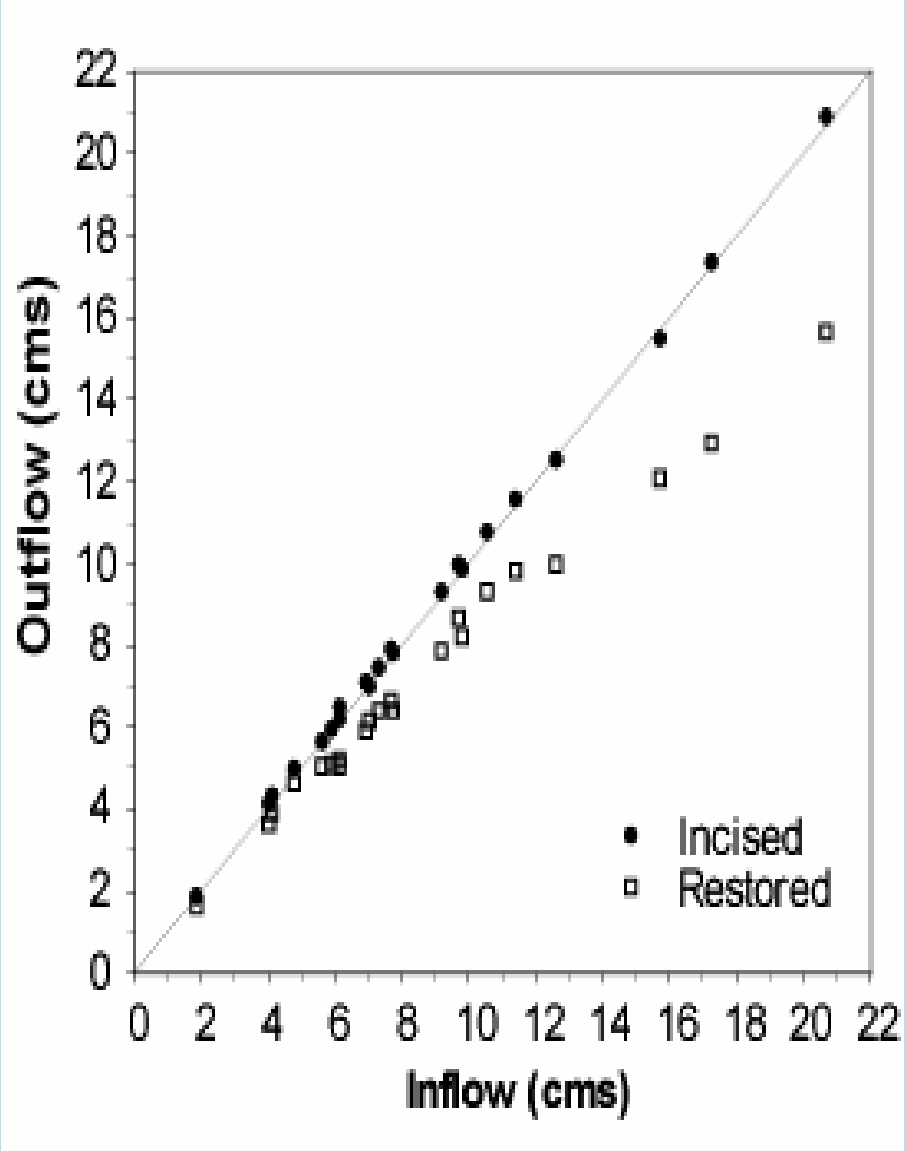
Hammersmark et al. 2007



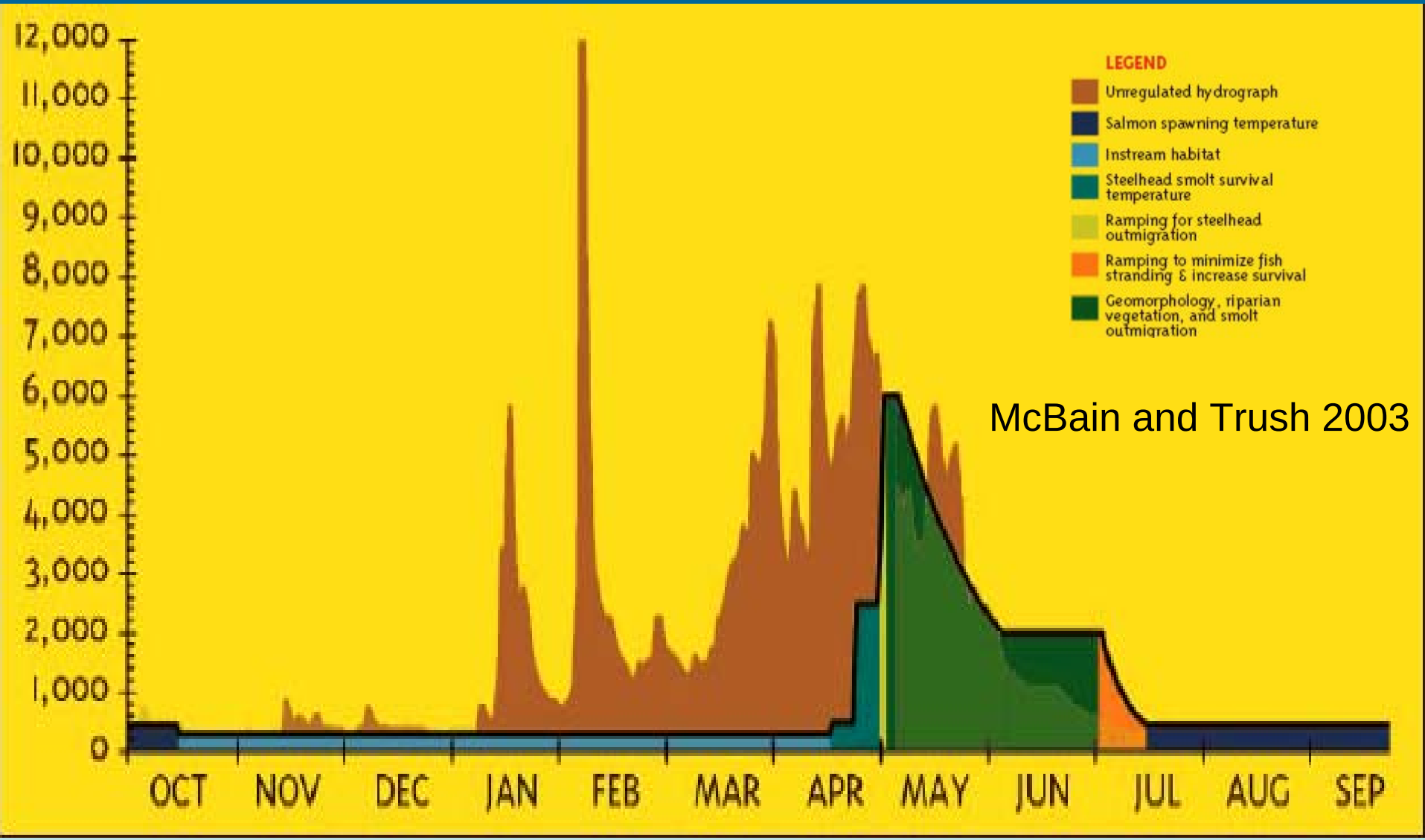
Flood Peak Reduction

- Incised outflow nearly identical
- Restored peaks reduced by 12-25%

Hammersmark et al. 2007



Examples of Success – Modification to Flow Releases



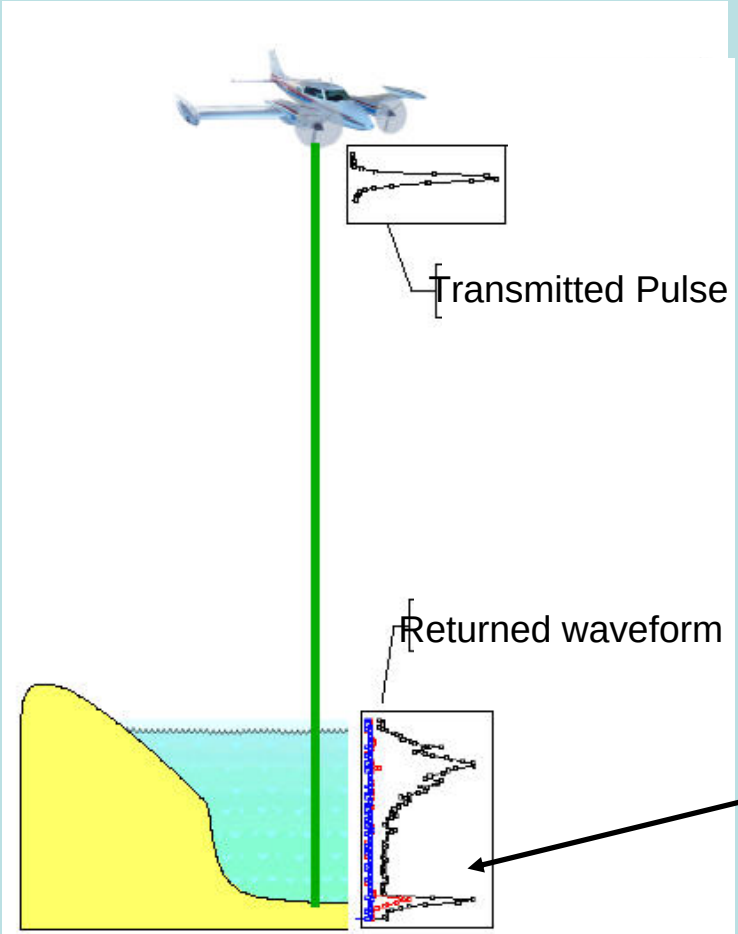
Prescribed Flood Releases on the Trinity River

WHAT ABOUT THE FUTURE?

Emerging technologies and the World!

NASA Experimental Advanced Airborne Research Lidar (EAARL)

Jim McKean, U.S. Forest Service
Wayne Wright, NASA



Three channels –
90%, 9% and 0.9%
of the reflected photons

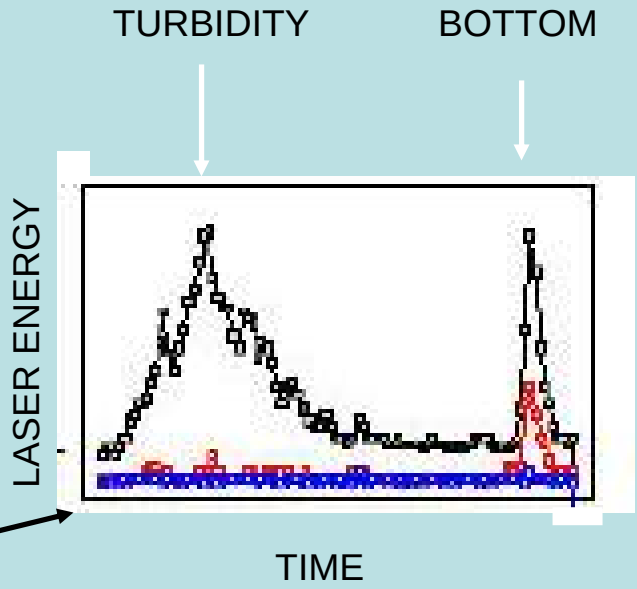
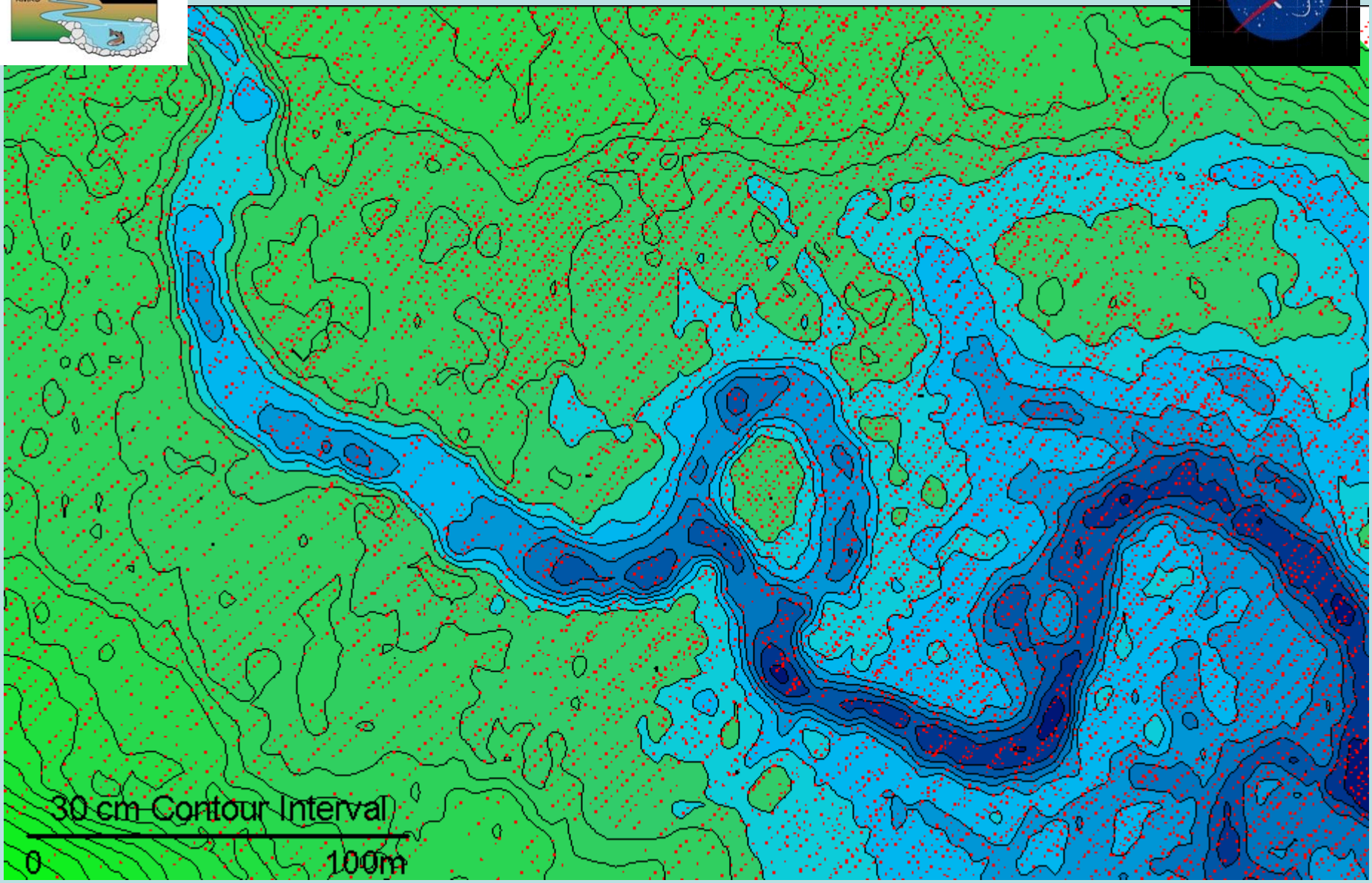
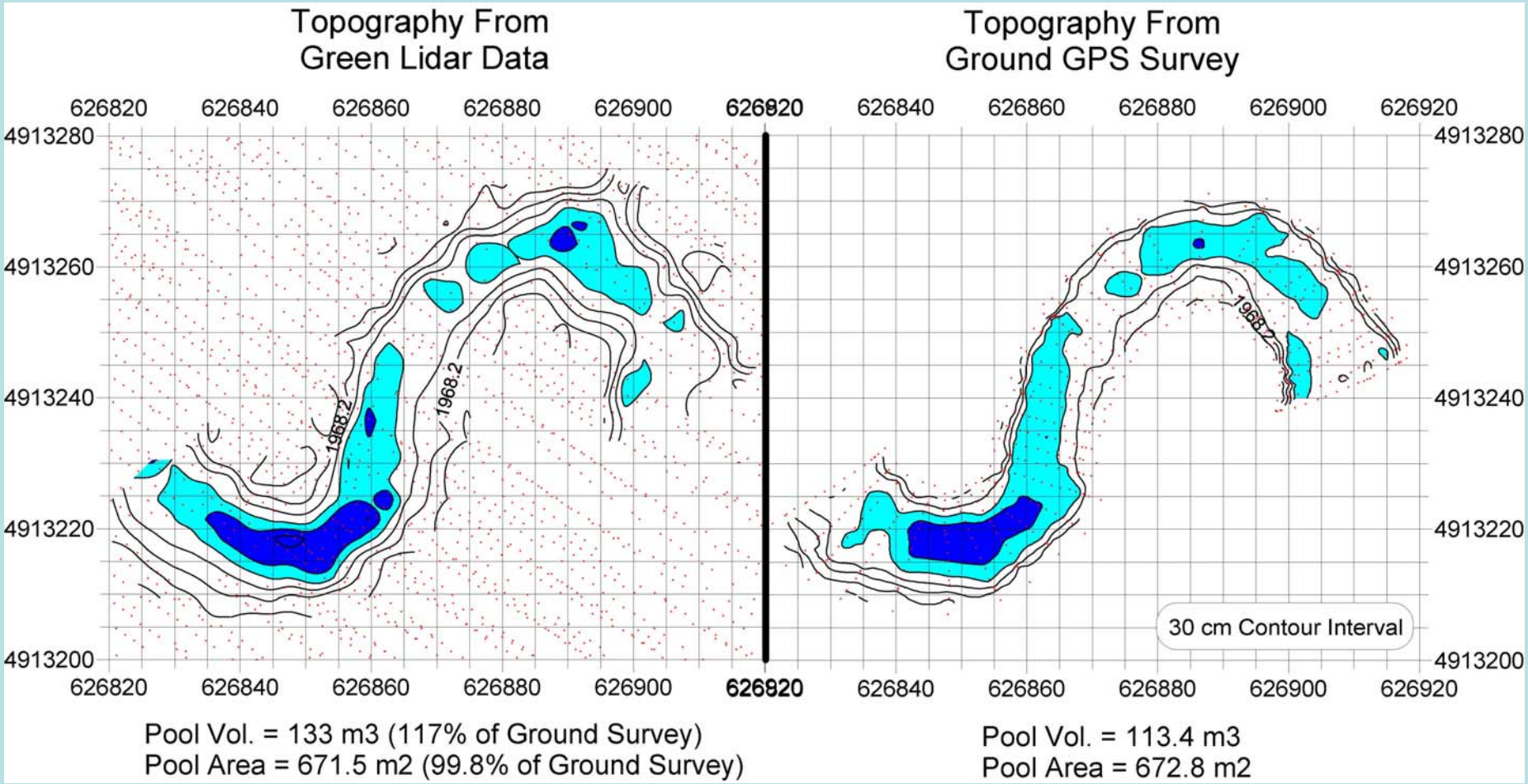


Figure modified from Wright and Brock, 2002.
EAARL was developed by Wayne Wright,
NASA Wallops Flight Facility.

jmckean@fs.fed.us



jmckean@fs.fed.us



What's going on elsewhere - UK

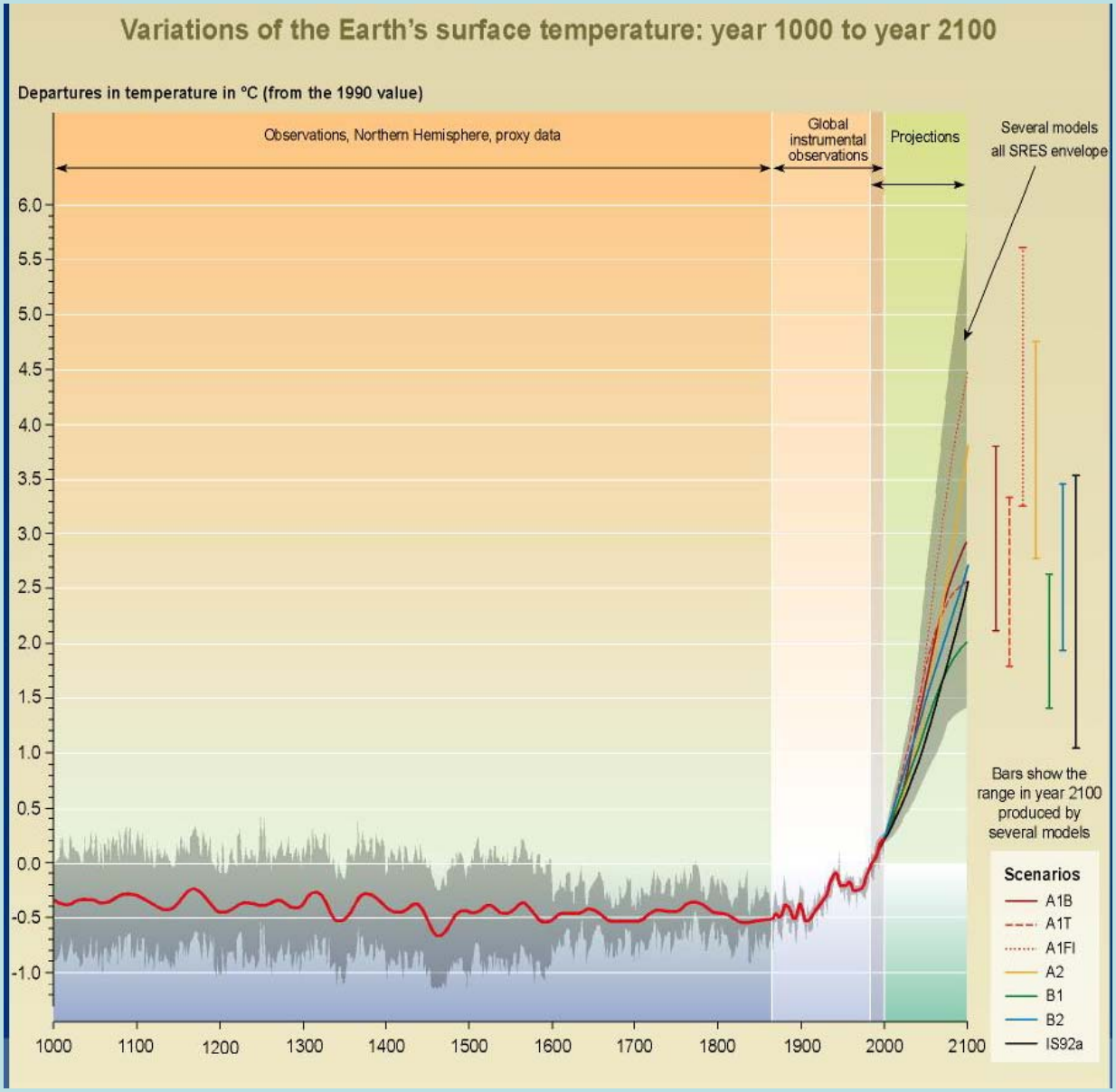
Wise Use crucial in face of:

- Flooding
- Climate change
- Water Framework Directive
- Threats to biodiversity

Wise Use of Floodplains
EU LIFE-ENVIRONMENT PROJECT

PWA

And to Exacerbate Our Concerns…



IPCC, 2007

Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990

Photo: Eric Ginney

Acknowledgements

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