
Ecological Implications of Post-Dam Removal Sediment Processes

ASCE 2005 Watershed Management Conference



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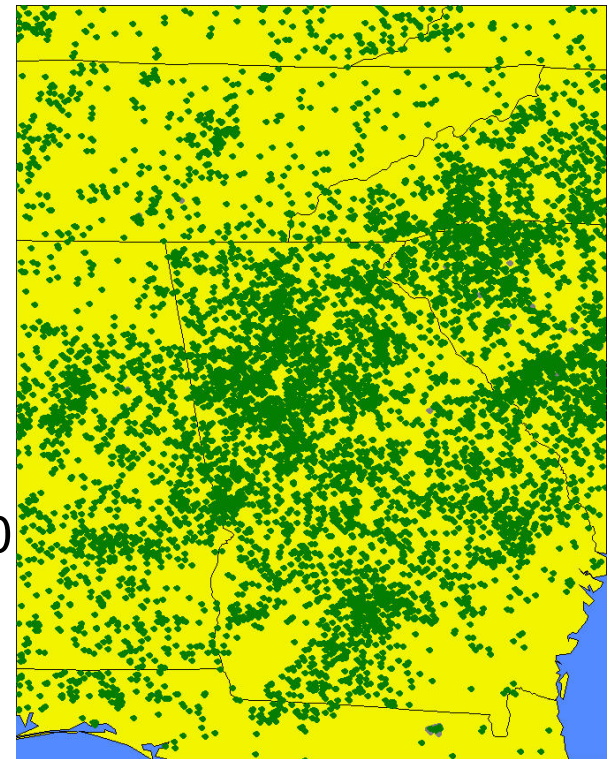


Outline

- Overview and problem scope
- Dams, ecosystems, and society
- Dam removal—ecological contexts
- Dam decision metrics
- Conclusions and needs

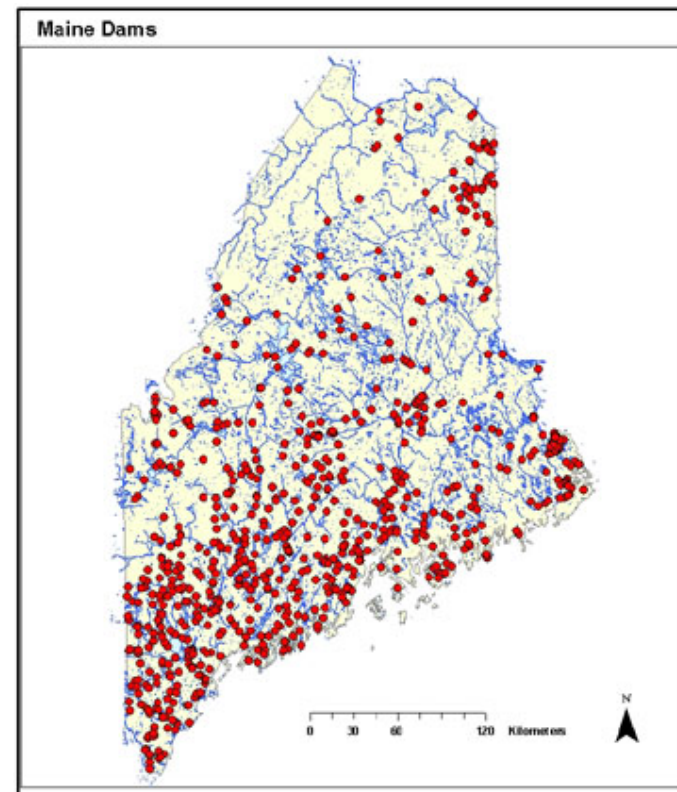
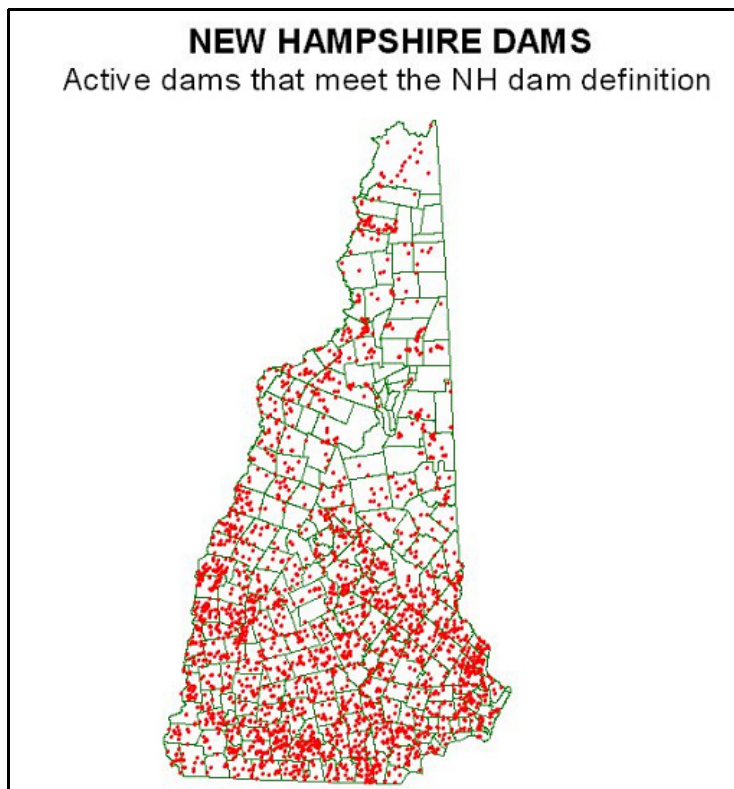
Overview and problem scope

- ~77,000 large dams in the US, ~2.5 million total (National Academy of Sciences)
- Impounded water 5x volume of flowing water
- Sediments are leading cause of impairment in US. 6-12% of these are contaminated to Tier 1 or 2.
- Structural and economic obsolescence have condemned many smaller dams; that is less true of large structures, but 85% of large dams will have reached their design lifespan by 2020
- Dams and their removal are emotionally charged subjects in which science and reasoned discourse have played minor roles.



Overview and problem scope

- Unobstructed river reaches have been reduced 91% in the North Atlantic region



Benefits and costs of dams

Benefits

- Water quality and delivery for domestic, agricultural, and industrial uses
- Hydropower
- Navigation, including canals
- Control of flooding and ice regime
- Control of invasive populations
- Flatwater recreation
- Waste or sediment disposal and trapping
- Archeological and aesthetic values

Costs

- Ecosystem impacts
- Water quality impacts
- Recreation dependent with unregulated hydrography and ecological integrity
- Impacts on T&E populations
- Legal and financial liability
- Safety
- Maintenance requirements for structure, headpond, associated erosion
- Archaeological and aesthetic impacts



St. Francis Dam failure, CA, 1928



Teton Dam failure, ID, 1976



Chase Brook
Bridge collapse
caused by
private dam
failure, NY,
1996.



Rockfish
Creek
dam
failure,
NC,
2003

Dams and ecosystems

- Altered sediment, hydrologic, woody debris, and ice regimes
- Habitat fragmentation
- Nutrient cycling and flow impacts
- Water quality and thermal regimes
- Major impacts on T&E, anadromous, catadromous, and adfluvial populations
- Mix of lentic and lotic habitats alters predation regimes and other life history processes
- Dams encourage floodplain development and discourage spatial and temporal dynamism

Nutrient flows and cycling

- The Columbia River system once received about 200,000 tons of nutrients annually from salmon runs.
- ~60% of the carbon structuring the bodies of juvenile salmon and other species is marine in origin in anadromous rivers.
- As much as 18% of nutrients supporting riparian vegetation in salmon rivers is ocean-derived.
- Salmonid fry double their growth rate post-spawning in rivers with active runs, as opposed to control rivers.
- Hydrologic flux and woody debris budget changes
- Reservoirs can act beneficially as nutrient sinks in agricultural watersheds.

Cited reasons for removals

- Environmental--43%
- Safety--30%
- Economics--18%
- Failure--6%
- Unauthorized structure--4%
- Recreation—2%



(American Rivers et al., 1999)

Public safety and desire to save costs of repair usually drive removal, not restoration goals (Born et al., 1998)

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- ERDC**
Engineer Research and Development Center



Perceptions and social values

- What would it look like? Change is threatening.
- Professionals don't value public opinion.
- Impoundment recreation will be missed.
- Many appreciate the impoundment's aesthetics.
- Fish and wildlife values will be lost.
- It's safer without the dam.
- Fish and wildlife values will improve.
- Maintenance and liability costs need to be eliminated.
- Removal is cheaper.

(From Born et al., 1998)



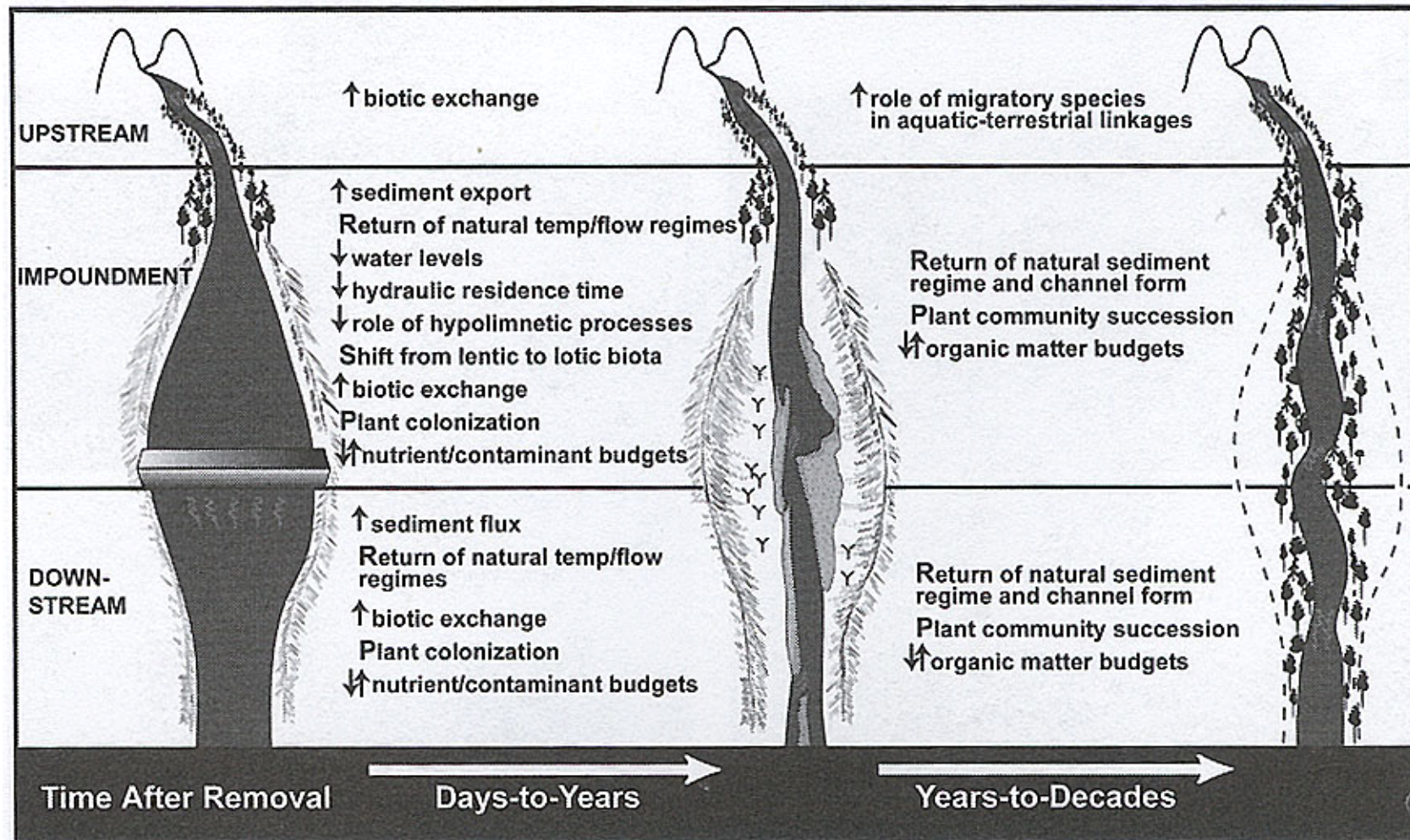
Scientific and advocacy communities must articulate functions, core processes, and values or “services” of naturalized system better than they have.

Dam removal and ecosystems

- New hydrology and hydraulics on sites and reaches that have adjusted, to some degree, to original alteration.
- Sediment pulse (often relatively short lived; “dispersion dominates advection”)
- Morphology and layering of deposition lens influences passive routing and magnitude, duration, and timing of suspended sediment impacts
- Risk of invasive plant communities on exposed substrate
- Risk of invasive aquatic populations (fragmentation, unfortunately, can be beneficial)
- Impacts on T&E populations
- Altered redox boundary



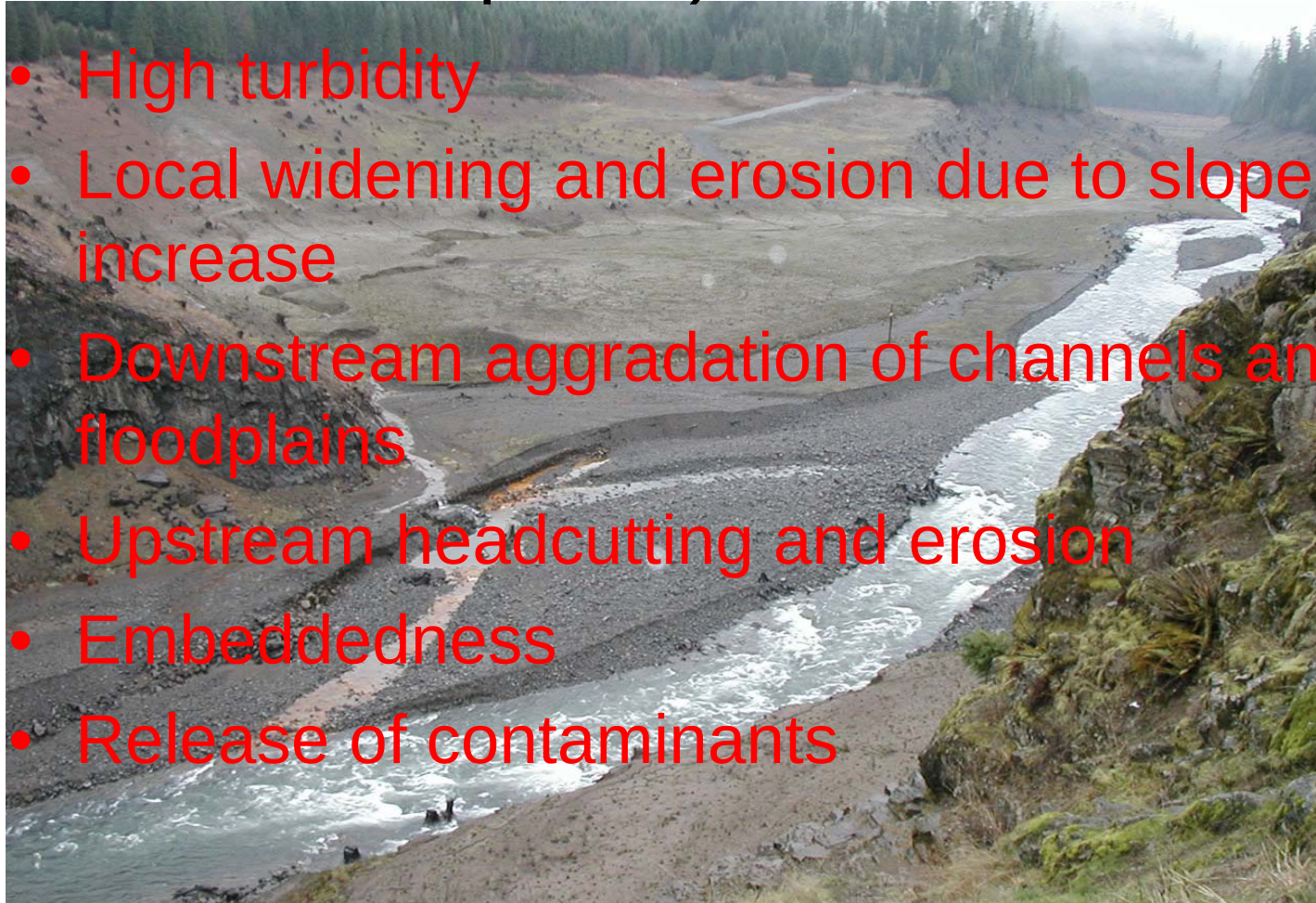
Realistic Expectations for Ecological Response



From Hart, D.D, T.E Johnson, K.L. Bushaw-Newton, R.J. Horwitz, A.T. Bednarek, D.F. Charles, D.A. Kreeger, and D.J. Velinsky (2002) "Dam removal: Challenges and opportunities for ecological research and river restoration." *BioScience*, Vol. 52, No. 8, p. 669-681.

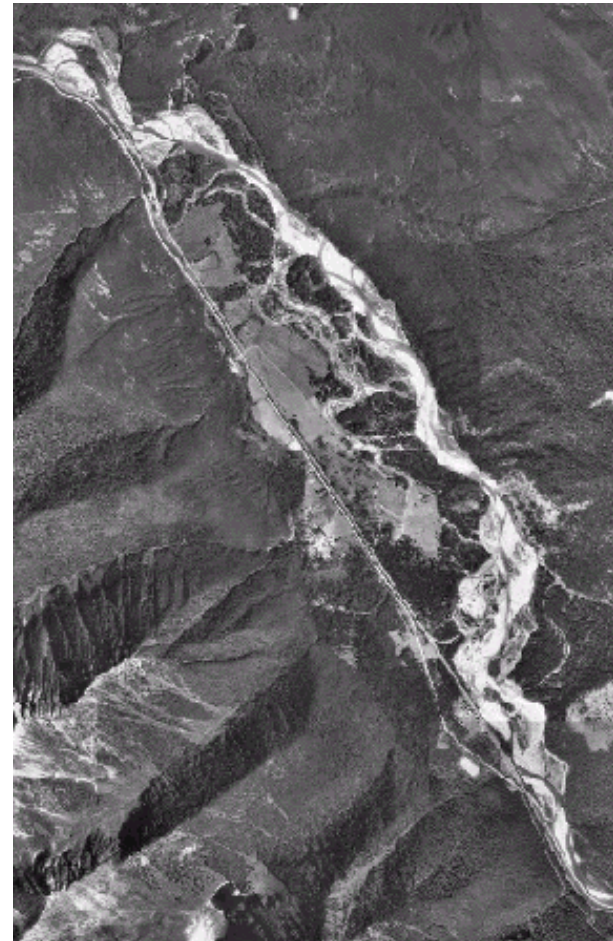
Sediment transport and fate (“It’s the sediment, stupid...”)

- High turbidity
- Local widening and erosion due to slope increase
- Downstream aggradation of channels and floodplains
- Upstream headcutting and erosion
- Embeddedness
- Release of contaminants



Embeddedness and the Channel Margin

- Embeddedness reduces redd success, entombs larvae, limits overwintering, alters chemical and thermal regimes by limiting interaction with hyporrheic zone, but methods are not standardized
(<http://el.erdcl.usace.army.mil/publications.cfm?Topic=technote&Code=emrrp>)
EMRRP-SR-36.



Factors Influencing Impacts

- Sediment types and particle size distribution
- Volume and morphology of deposition
- Nutrient and contaminant concentrations
- Load-local and background
- Timing
- Duration
- Source sites
- Fate—local and system-wide
- Vegetation



Case Study Analyses of Physical Responses

Doyle et al.'s studies:

- Sand-bed, high-transport channels
- Impoundment filled with sediment
- Channel evolution accomplished by **erosion and channel widening**, almost at any size flow

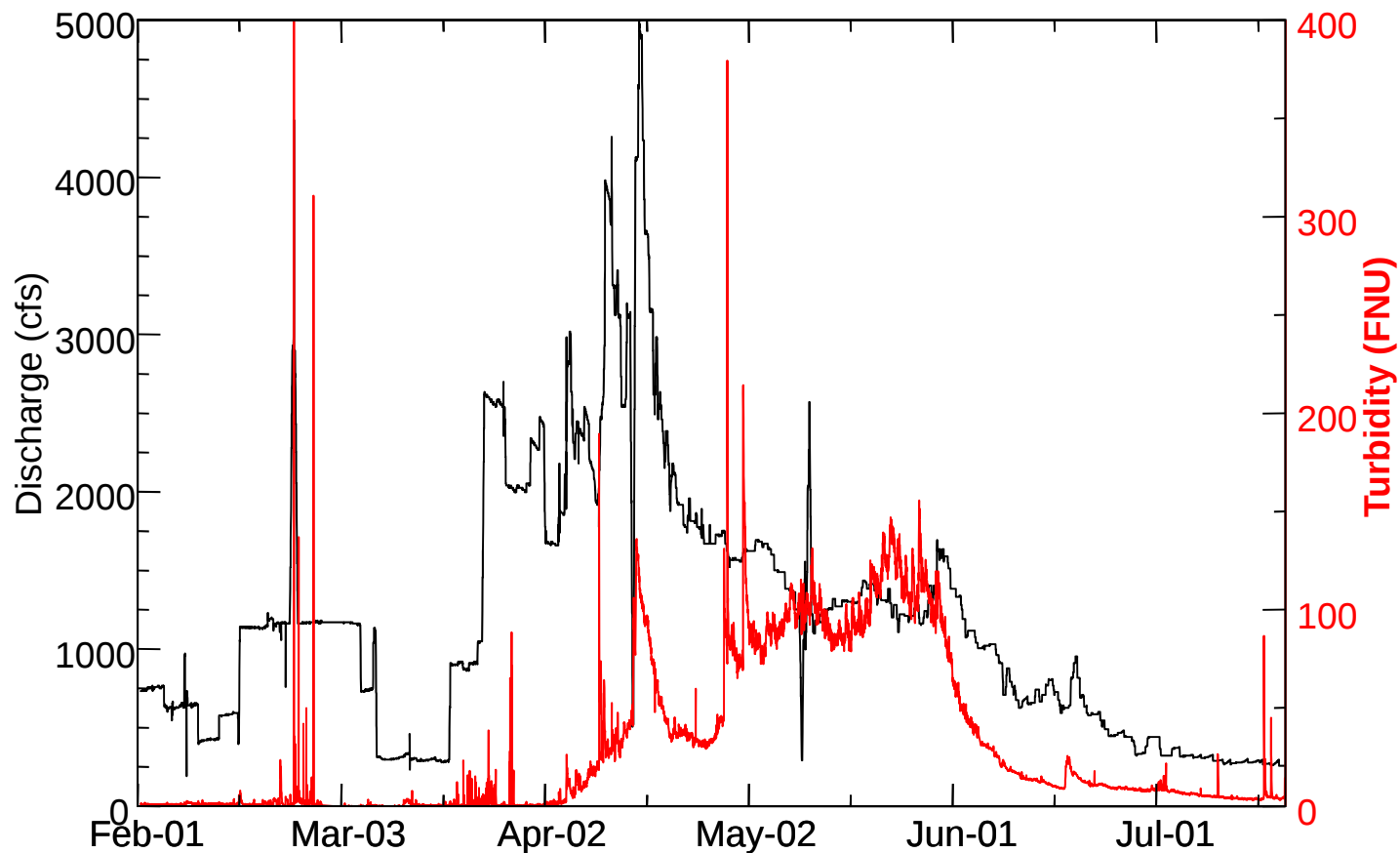
Pizzuto et al.'s study:

- Gravel systems
- Impoundment not filled with sediment
- Channel evolution accomplished by **deposition** of new floodplains and **channel narrowing** during floods

“Blow and Go”



Cougar Dam Drawdown Impacts on South Fork MacKenzie River (provisional data)



Sources of Cougar Modelling Inaccuracies

- Initial submergence of dried lakebed deposits **
- Mass wasting and slope failures caused by rapidly changing pool levels
- Active erosion of predominantly clay banks
- Lateral migration and downcutting of main inflow tributaries. **

**** cause higher levels of turbidity**

Sediment Sources in Cougar Drawdown



Management Options

- No action
- Bypass
- Mechanical removal
- Stabilization (temporary or permanent)
- Controlled release (spatial or temporal increments)
- River erosion
- Combination—remove fines, passively route coarse



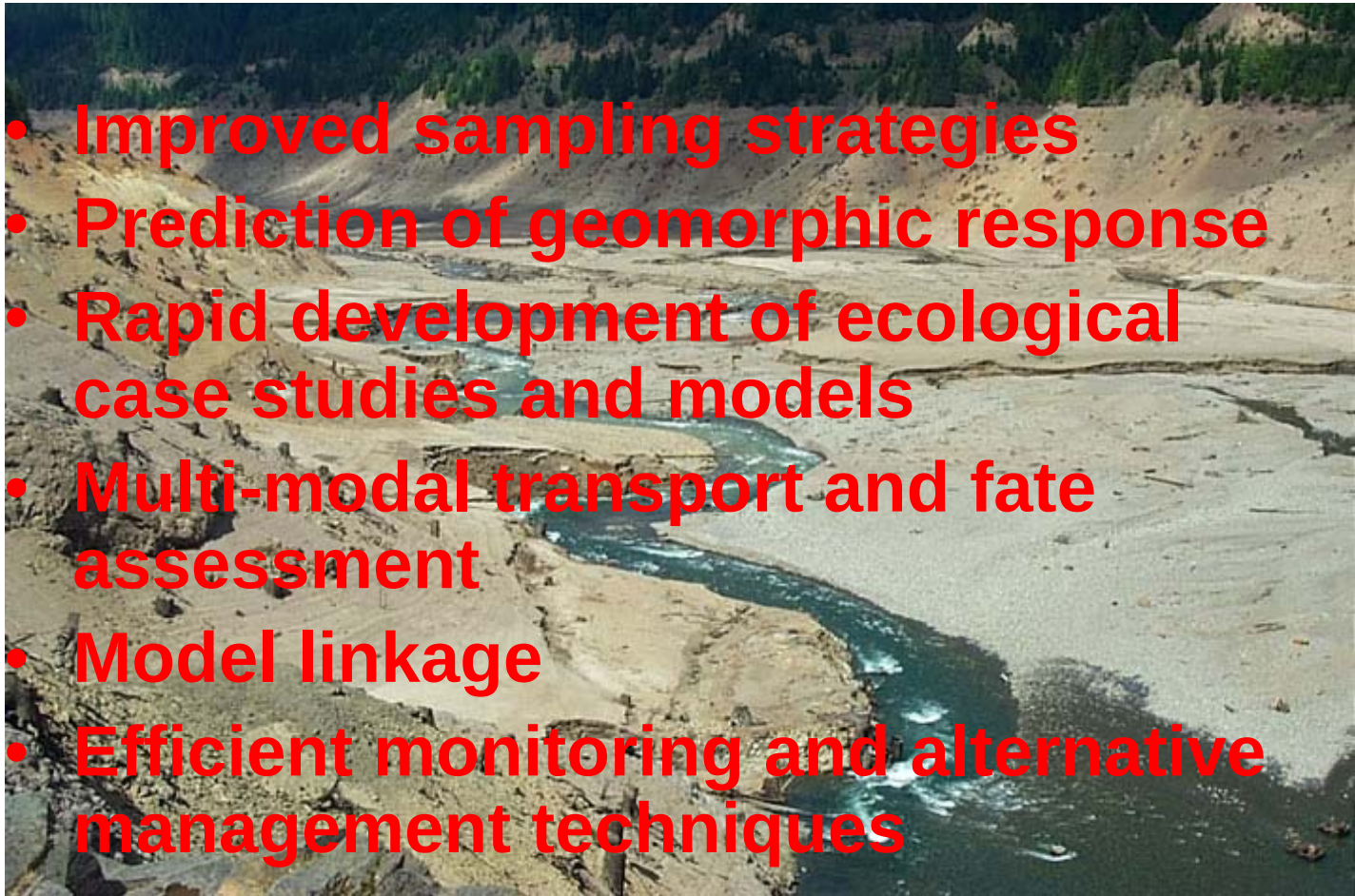
State-of-practice

- “To manage sediment, you need two out of three: time, money, water.” (Greimann)
- No standards
- Size matters. Volume counts.
- Qualitative
- Limited monitoring and adaptation
- Rapid rate of learning from lab and paired sample studies, field scale drawdowns, initial cohort of removals
- Need for some rapid assessment and decision support tools



An aerial photograph of a river system. A large, light-colored, turbid plume of sediment or sand is being discharged from a mountainous area into a river. The river flows from the top left towards the bottom right. The surrounding landscape is rugged and mountainous, with some green vegetation visible on the slopes. The sediment plume is a prominent feature, indicating a significant geomorphic or environmental event.

- Improved sampling strategies
- Prediction of geomorphic response
- Rapid development of ecological case studies and models
- Multi-modal transport and fate assessment
- Model linkage
- Efficient monitoring and alternative management techniques

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- An aerial photograph of a river system. A large, light-colored, turbid plume of sediment or sand is being discharged from a mountainous area into a river. The river flows through a valley, and the surrounding landscape is rugged and forested. The text of the presentation is overlaid on the left side of the image.
- Improved sampling strategies
 - Prediction of geomorphic response
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Conclusions 1

- Dam removal is a requisite tool for managing aging structures and restoring both aquatic and riparian populations.
- Develop more knowledge on the effects of dams and drawdowns to learn about dam removals.
- Analytic and communications requirements are demanding but scale-, goal-, and system-dependent.

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Conclusions 3

- Develop design deposition zones and techniques for downstream reaches.
- Specify acceptable risks and dynamism to reduce hardening where possible and reallocate resources to sediment management, physical restoration, exotics management, and revegetation.
- For existing dams, route sediment as part of ongoing O&M.
- Improve sediment routing design in new structures.