Frequently Asked Questions in Dam Decommissioning: Guidance for Data Collection, Analytic Needs, and Project Implementation

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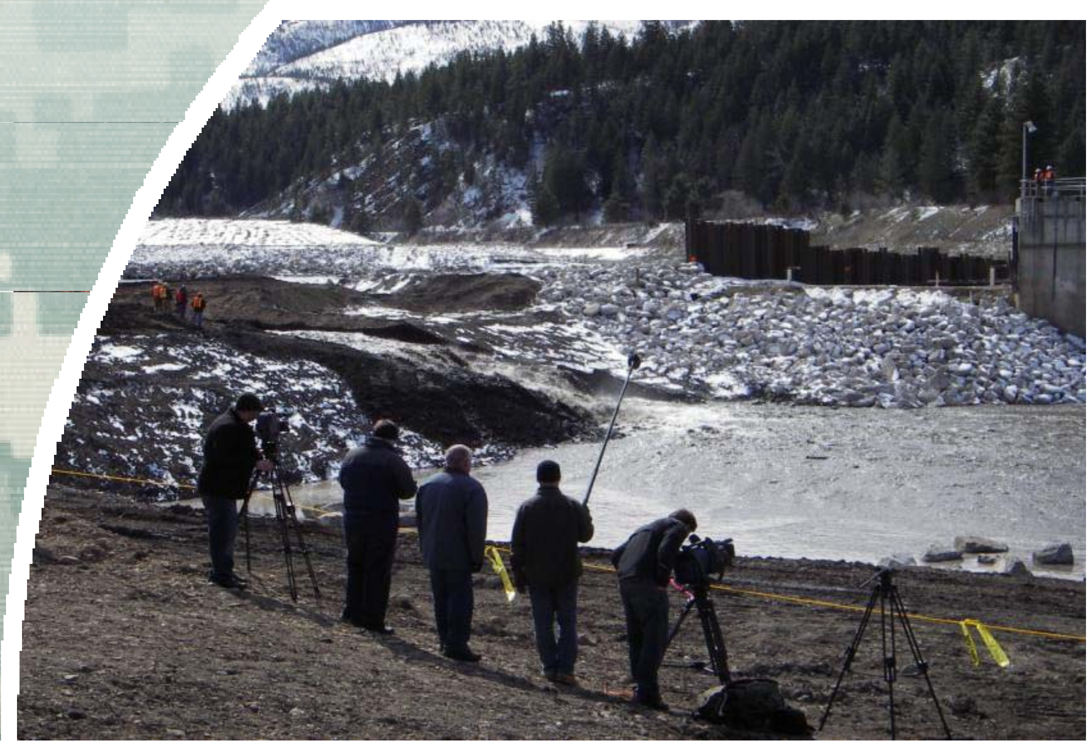

Ecosystem Management and Restoration Research Program

US Army Corps of Engineers

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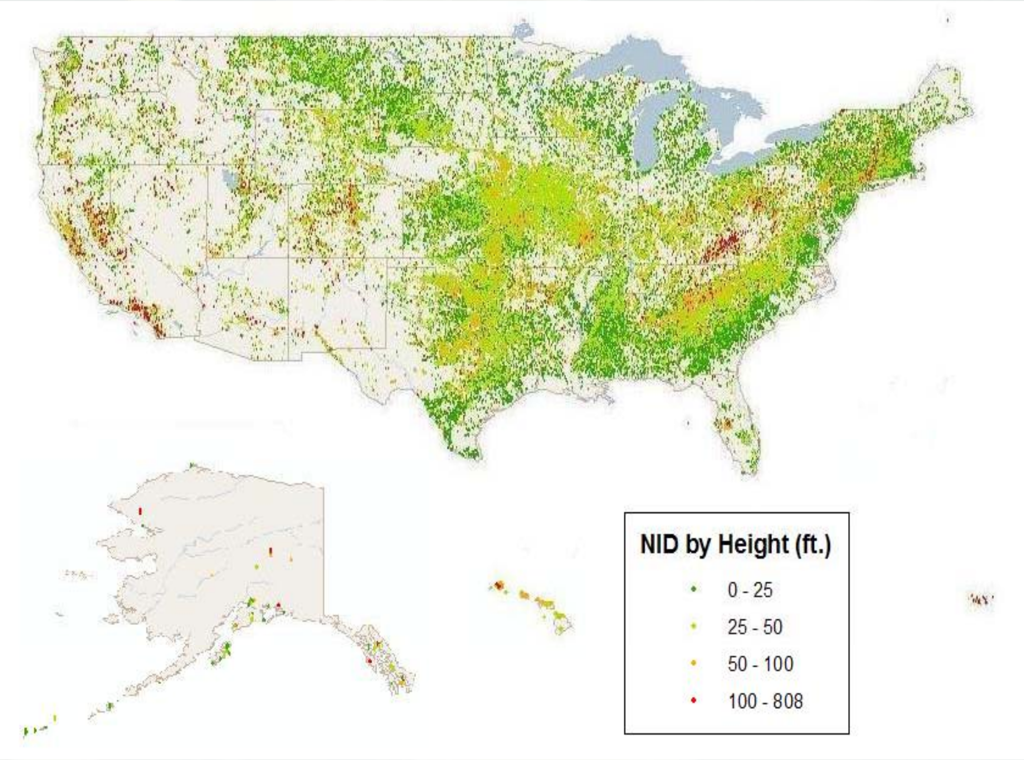
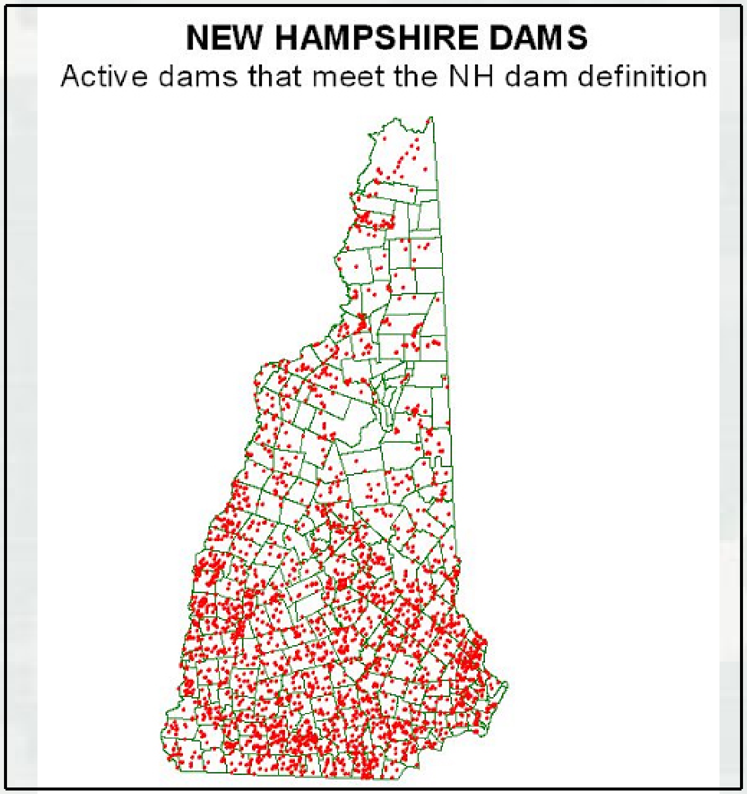
Overview and Problem Scope

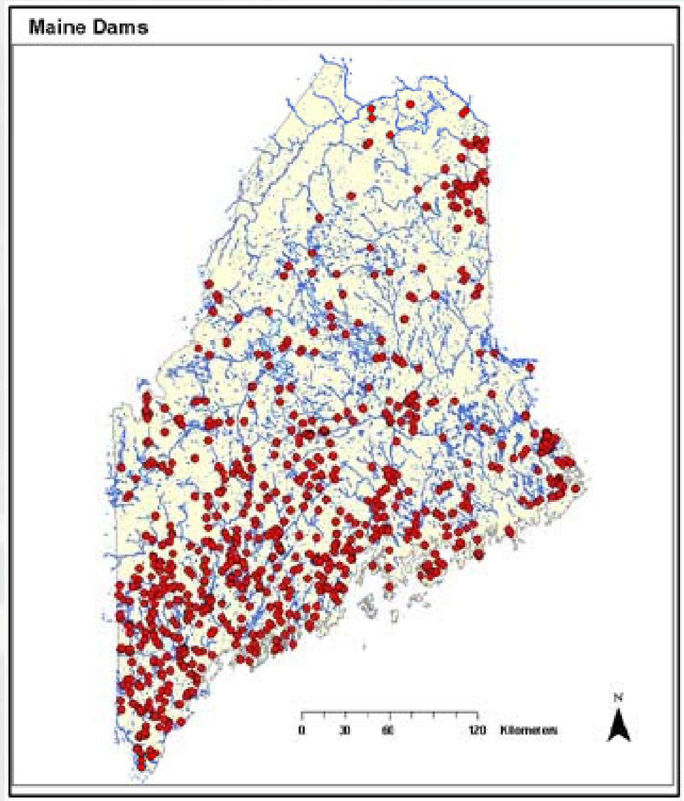
- 82,642 large dams (NID), ~2.5 million total (NAS)
- 3% of US land inundated
- Impounded water 76% (25-380%) of mean annual runoff
- Every non-AK river over 750 sq.mi. drainage fragmented



Overview and Problem Scope

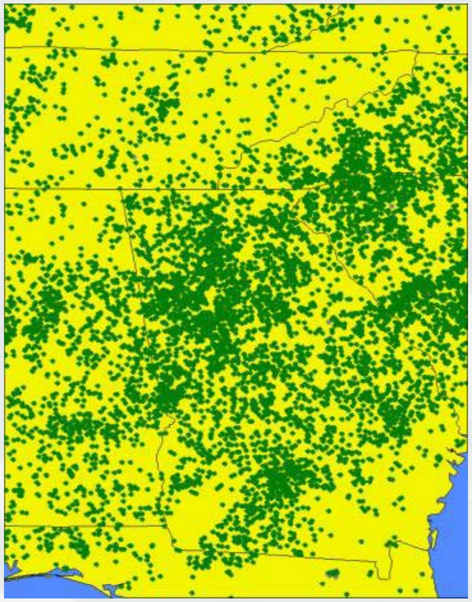
- Unobstructed river reaches have been reduced 91% in the North Atlantic region





Overview and Problem Scope

- 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 (FEMA, 2001).
- Dams and their removal are emotionally charged subjects in which science and reasoned discourse have played minor roles.

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SEDIMENT CONTROL
DIVERSION
IRRIGATION

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, nutrient, or sediment 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

Dam Life Concepts

- Engineering, design life spans
- Usable life (for original or altered purposes)
- Economic life (present value exceeds costs)
- Geomorphic life
- Overall value balance (including ecosystem effects, liability, and risk of catastrophic failure)

St. Francis Dam failure, CA, 1928

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

Teton Dam failure, ID, 1976

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 and supports exotics
- Dams encourage floodplain development and discourage spatial and temporal dynamism

Nutrient flows and cycling

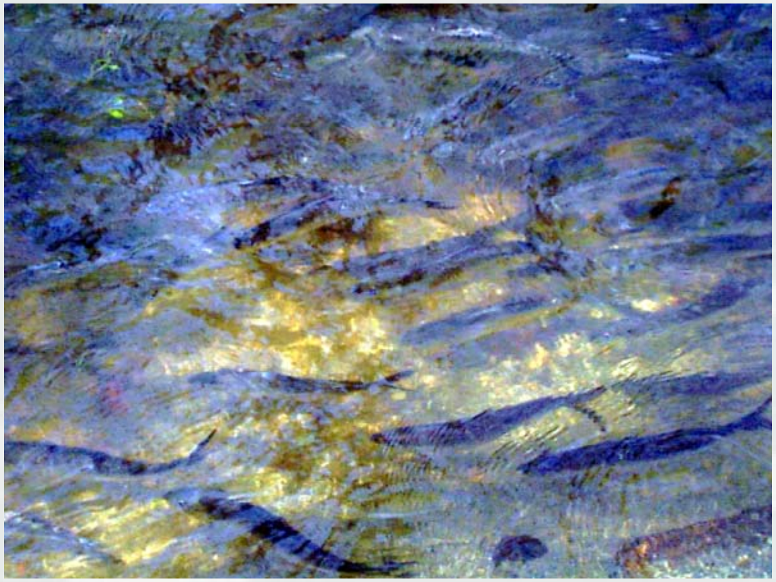
- The Columbia River system once received about 200,000 tons of nutrients annually from salmon runs.
- ~60% of the carbon structuring the bodies of juvenile salmon and other species is marine in origin in anadromous rivers.
- As much as 18% of nutrients supporting riparian vegetation in salmon rivers 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.

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)
- 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

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)

Dam removal to date (>500)

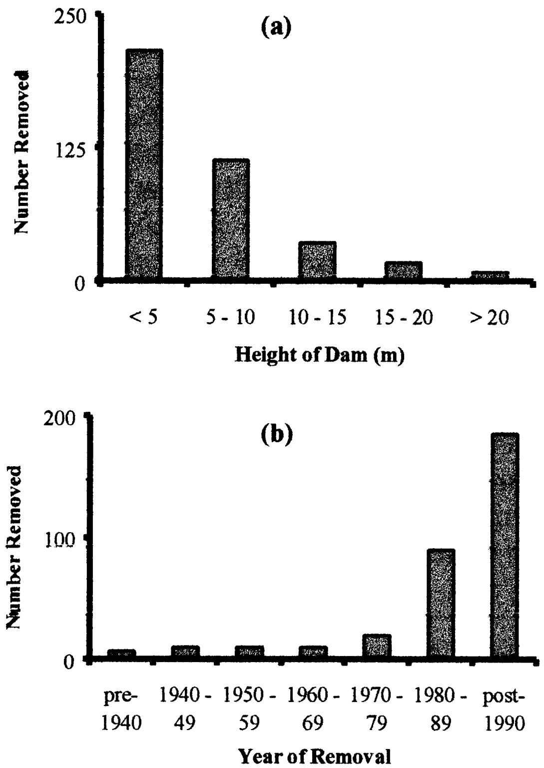


Figure 1. Number of dams removed as a function of (a) dam height, and (b) year of removal (adapted from American Rivers et al., 1999).

Table 1. Number of dams removed per state (American Rivers et al., 1999). States with less than 5 dams removed are not listed.

State	Number of dams removed
WI	73
CA	47
OH	39
PA	38
TN	26
WA	19
IL	17
CT	16
ID	13
TX	12
SD	11
KS	10
CO	9
ME	9
MI	9
MN	9
VA	9
NJ	9
VT	8
WY	8
MD	7
MT	7
NE	6
OR	5
SC	5

From Doyle et al., 2000

Data and analytic needs—key issues

- Financial and legal contexts
- Original and current purpose(s)-flood control?
- Size relative to watercourse and effects on sediment storage and reach hydrology
- Presence, distribution, and nature of contaminants
- Invasive or T&E species
- Archaeological values
- Public perceptions, opinions, and goals
- Physical constraints
- Costs

Dam decision metrics and data needs

- Physical
  - Hydrology and hydraulics
  - Sediment budget, storage, and properties
  - Channel and valley morphology
  - Headpond capacity
- Chemical
  - WQ, gases, temperature
  - Sediment contamination
- Ecological
  - Aquatic and riparian ecosystems' processes and functions
  - Recovery of T&E populations
  - Keystone population needs
- Economic values
  - Site, reach, and system values w/dam and w/o dam(s)
  - Regional economies
  - Flood risk
  - Relevant infrastructure
- Social and legal
  - Ownership
  - Tribal rights
  - Safety and liability
  - Aesthetics and cultural

Factors in Data Collection and Analytic Intensity

- Size of project
- Public profile of project
- Consequences for project success or failure
  - Legal and financial mandates
  - Listed species
  - Affected infrastructure
- Complexity of project and ecosystem

Sediment Transport and Fate Impacts (“It’s the sediment, stupid…”—E. Stanley)

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

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**, at almost any 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

Sediment 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 component
- Design deposition
- “To manage sediment, you need 2 out of these three: time, money, and water.” (Greimann)

Applied needs: a fate determination, sediment dynamics, and management FAQ

- Where is dam in life cycle
- Effects on ssc/discharge over time
- Sediment volume vs. transport capacity
- Background vs. local load
- Morphology, sizing, sorting, and contaminant characteristics
- Where are likely depositional zones for fines and ungraded sediments? Over time?
- Effects on flooding
- Effects of temporary stabilization or induced deposition techniques
- Maximum lateral and vertical dynamism, infrastructure risks
- Are vertical or longitudinal sorting present and significant?
- T&E implications, invasives risks?

Analytical Techniques

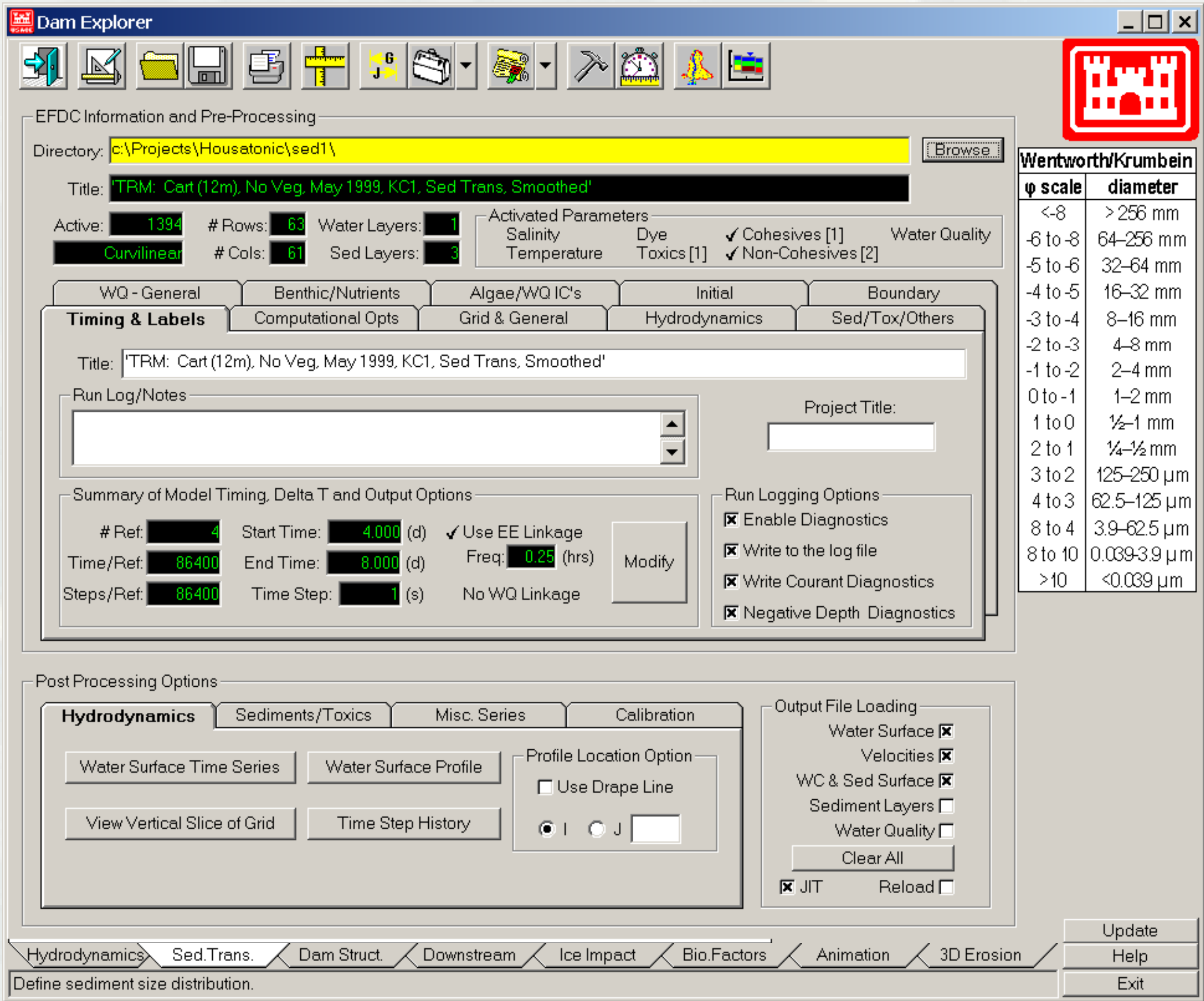
- Sediment Budgets
- Geomorphic Assessment
- Transport Analyses
- Coupled Modeling
  - ► HEC 6T ->HEC-RAS
  - ► GSTAR-1D
  - ► DREAM
  - ► CONCEPTS

Don't get invested in one.

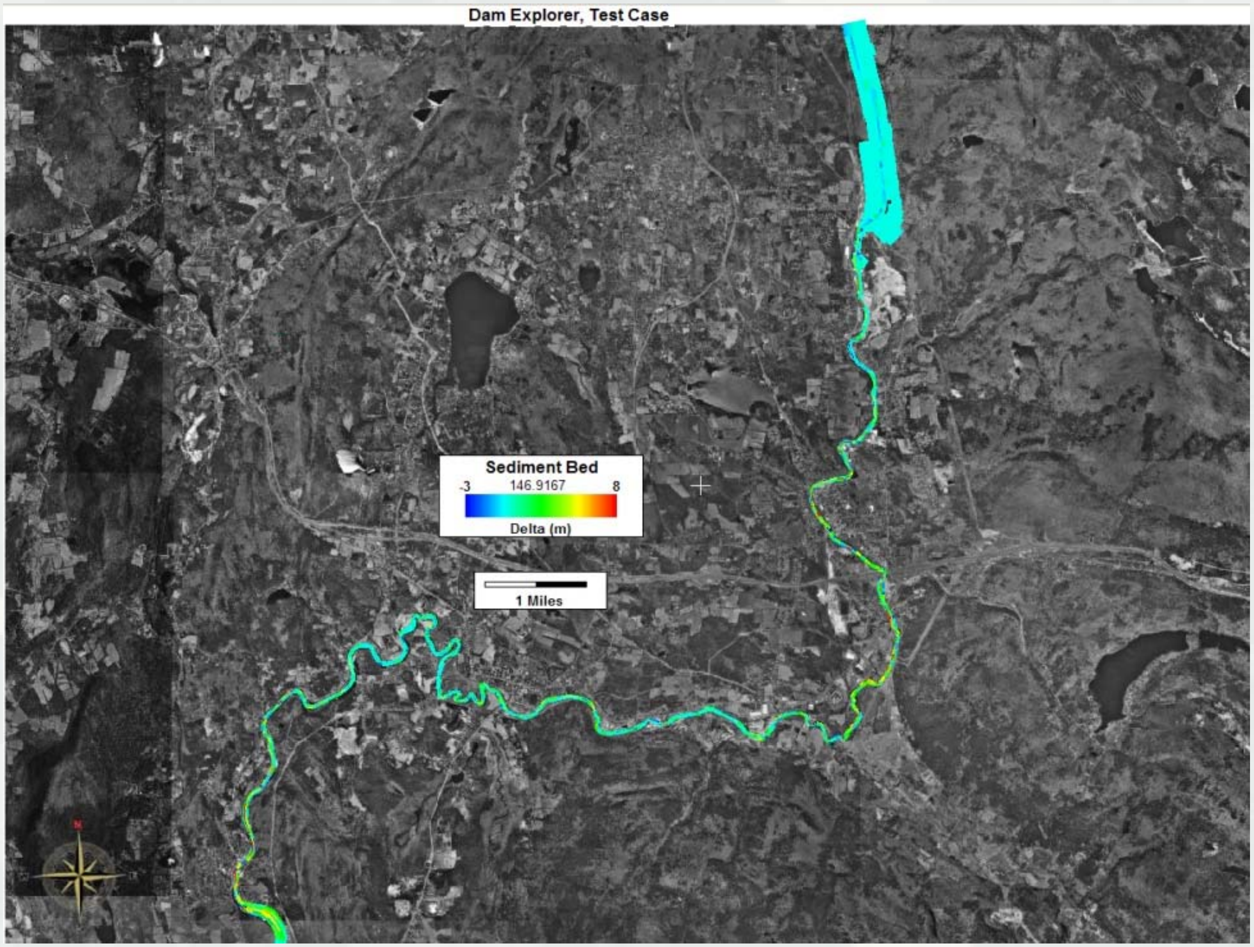
Why don't even the 1-D models always work?

- Unpredictable hydrology
- Vertical layering and longitudinal sorting
- Non-alluvial mechanisms of transport initiation
- Erosion widths unknown
- Most models don't handle silts and clays well
- Models don't include many geomorphic phenomena, e.g. sinuosity, secondary hydraulics, and channel position

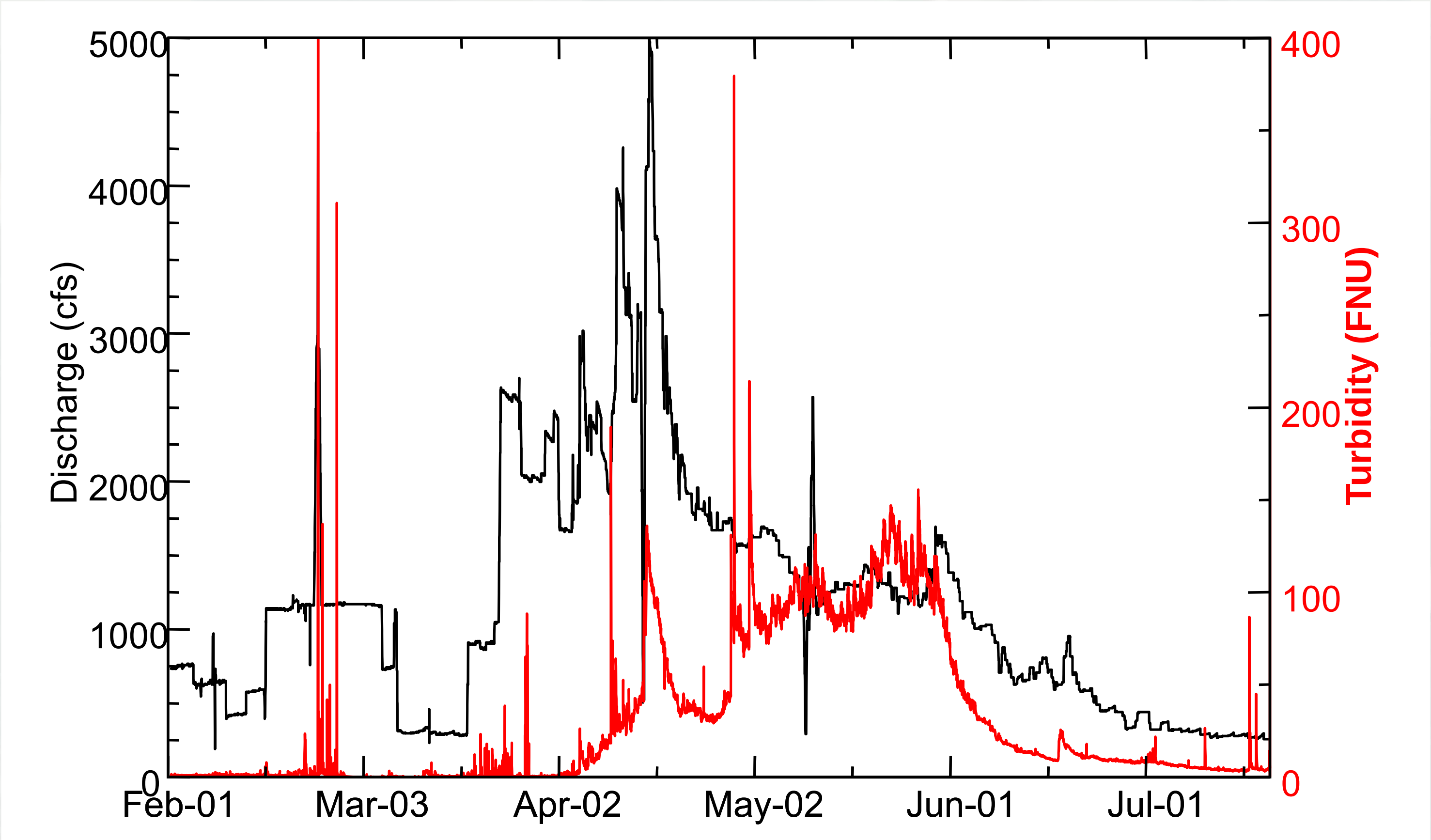
Dam_Explorer



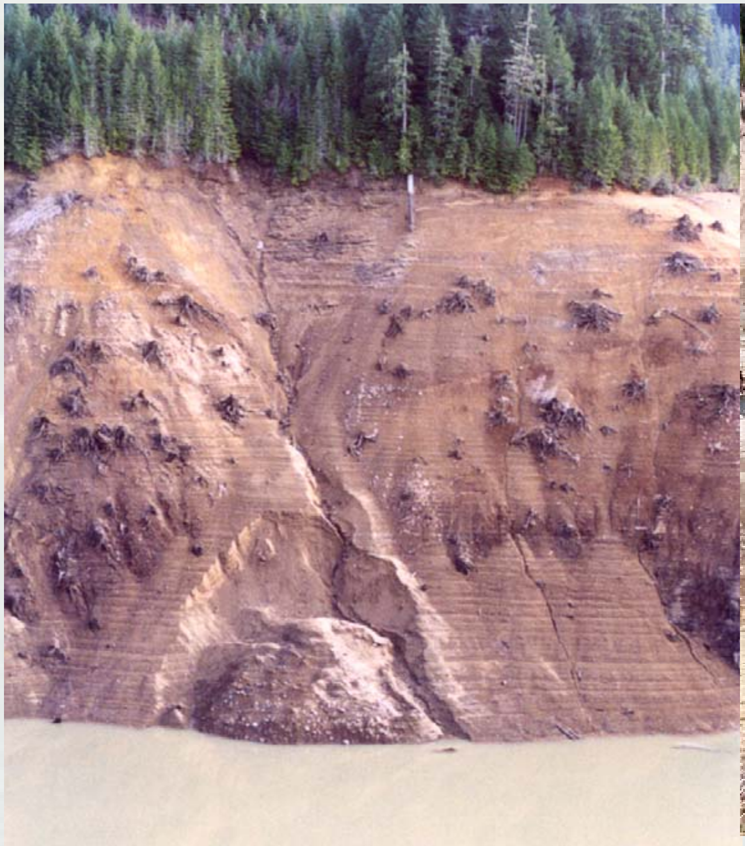
Dam_Explorer Scenario Testing—Scour and deposition 82 days after breach, with storm events



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



Sediment Sources in Cougar Drawdown



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

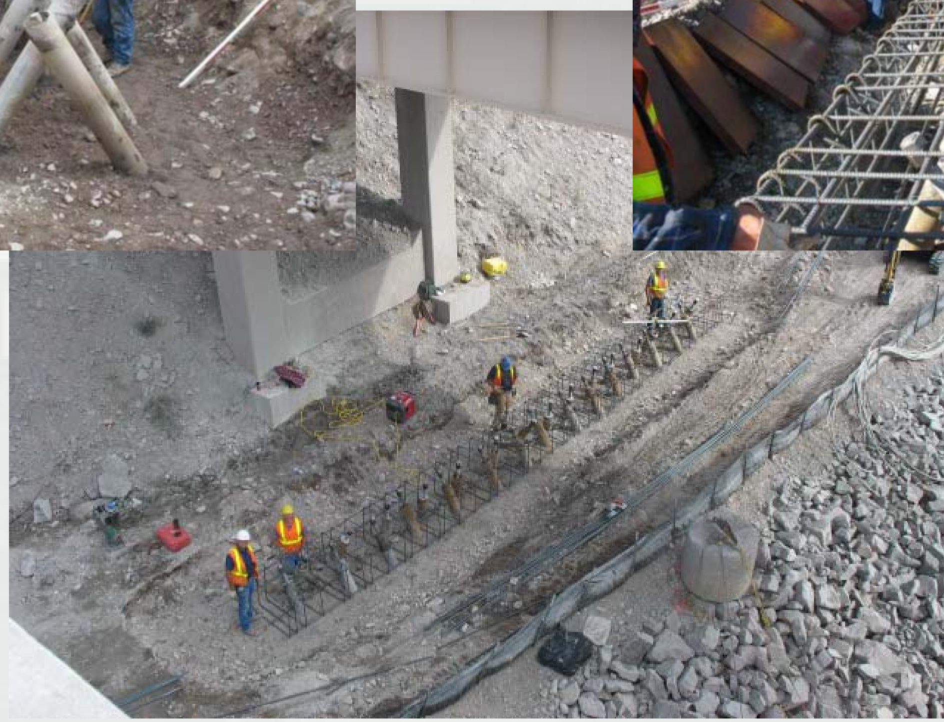
•Lateral migration and downcutting of main inflow tributaries. **

** cause higher levels of turbidity

Milltown Dam Removal Issues

Clark Fork Channel Widening, 2008

Micropile Installation



Blackfoot River channel constraint

Conclusions and Needs 1

- **Dam removal is a requisite tool for managing aging structures and restoring both aquatic and riparian populations and processes.**
- **We need to continue to continue the currently rapid growth in empirical knowledge on the effects of dams and drawdowns to learn about dam removals and lend perspective to use of models.**
- **Analytic and communications requirements are demanding but scale-, goal-, and system-dependent.**

Conclusions and Needs 2

- **Projects can be difficult and expensive; prioritization and effective planning and implementation are sorely needed.**
- **Improved models, model application, and case study documentation are needed, particularly for ecosystem responses. Physical and ecological models need linkage and dynamic capacity for temporal and spatial scaling. Physical responses, their consequences, and their attenuation can be rapid.**

Conclusions and Needs 3

Needs:

- **Specify acceptable risks and dynamism to reduce hardening where possible and reallocate resources to sediment management, physical restoration, exotics management, and revegetation.**
- **Communicate realistic expectations regarding sources, domains and parameters of uncertainty**
- **For existing dams, route, harvest, and reduce inflow of sediment as part of ongoing O&M.**
- **Improve sediment routing design in new structures.**

Communications & Feedback

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Environmental Benefits Analysis Research Program Website
http://cw-environment.usace.army.mil/eba/

Current Publications (http://el.erdc.usace.army.mil/emrrp/techtran.html)

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Questions?