Dam Removal Webinar Series

Oct 27 **Part 1: Overview of Dam Removal**

Nov 3 **Part 2: Sediment Management**

Nov 10 **Part 3: Assessment Methods**

Nov 19 **Part 4: Modeling Techniques**

This webinar series is provided through the USACE - Ecosystem Management and Restoration Research Program.

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Dam Removal Webinar Series

Part 3A:
Dam Removal Assessment Methods: Overview of Tools and Techniques

November 10, 2020

Dr. Tahirih Lackey
(ERDC Coastal and Hydraulics Laboratory)

Me!

Dam removal workshop
Aug 23-24, 2017

What have we discussed so far?

- Motivation:
  - Dam removal is one of many tools in the asset management toolbox.
  - The number of dam removals is increasing in response to many motivating factors (e.g., aging infrastructure, environmental reasons, flood hazard,…).
  - The body of knowledge is growing rapidly relative to the geomorphic and ecological consequences of dam removals.
- How much sediment is stored behind a dam?
- What are the geomorphic effects of removal?
- What is the quality of the sediment?
- How do these (and other) factors influence permitting decisions?

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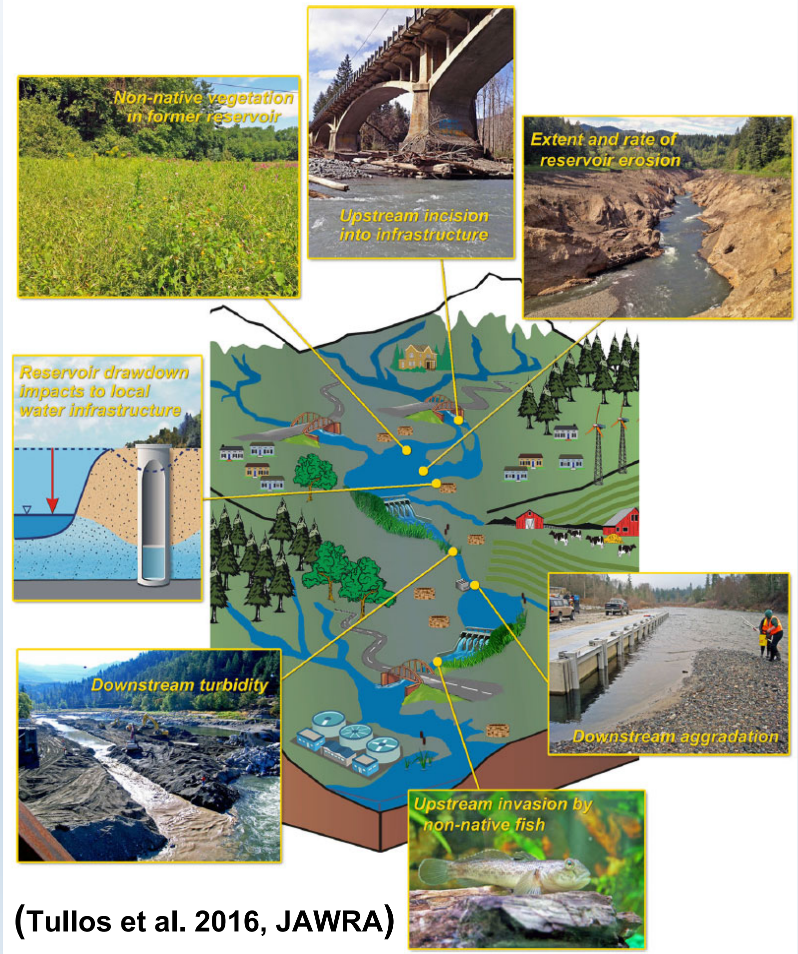
- What are the geomorphic effects of removal?
- What is the quality of the sediment?
- How do these (and other) factors influence permitting decisions?
- How do we better understand and predict the impact (risk) of sediment released due to dam removal?
  - https://www.sedhyd.org/2019/openconf/modules/request.php?module=oc_proceedings&action=summary.php&id=103&a=Accept

Common management concerns for dam removal directly related to sediment

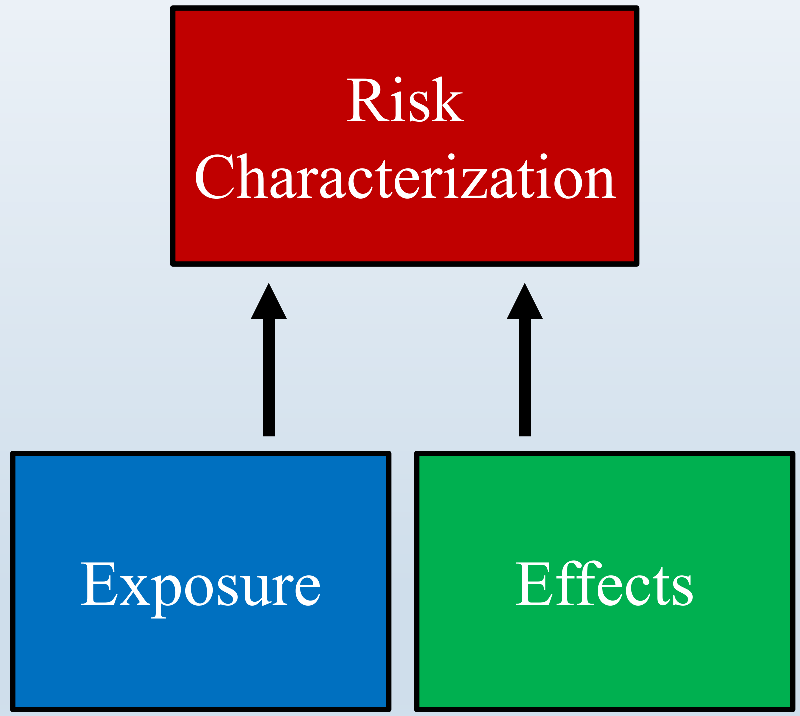
- Degree and rate of reservoir sediment erosion
  - How much reservoir sediment will erode and how quickly will it be transported?
- Excessive channel incision upstream of reservoirs
  - Will upstream infrastructure be affected ?
- Downstream sediment aggradation
  - Will bedforms be affected?
  - Will flood levels increase?
  - Will downstream water bodies be impacted?
- Elevated turbidity
  - Will suspended sediment exceed critical thresholds?
  - Will turbidity influence human uses of the river ?



(Tullos et al. 2016, JAWRA)

What Is Risk And How Do We Characterize It?

- Risk (as defined for this purpose) is a quantified understanding of exposure and effects.
- Exposure: How much sediment is moving downstream? Where is it in the water column? When does it arrive at a specific location of interest and how long does it last at that strength?
- Effects: What are critical environmental receptors? Habitat, migration, etc. What levels of exposure will negatively impact critical environmental receptors? (Acute stressors vs prolonged stressors)



Predictive and Explorative Tools/Models

We can use predictive sediment transport models and tools to address some of those questions and concerns.

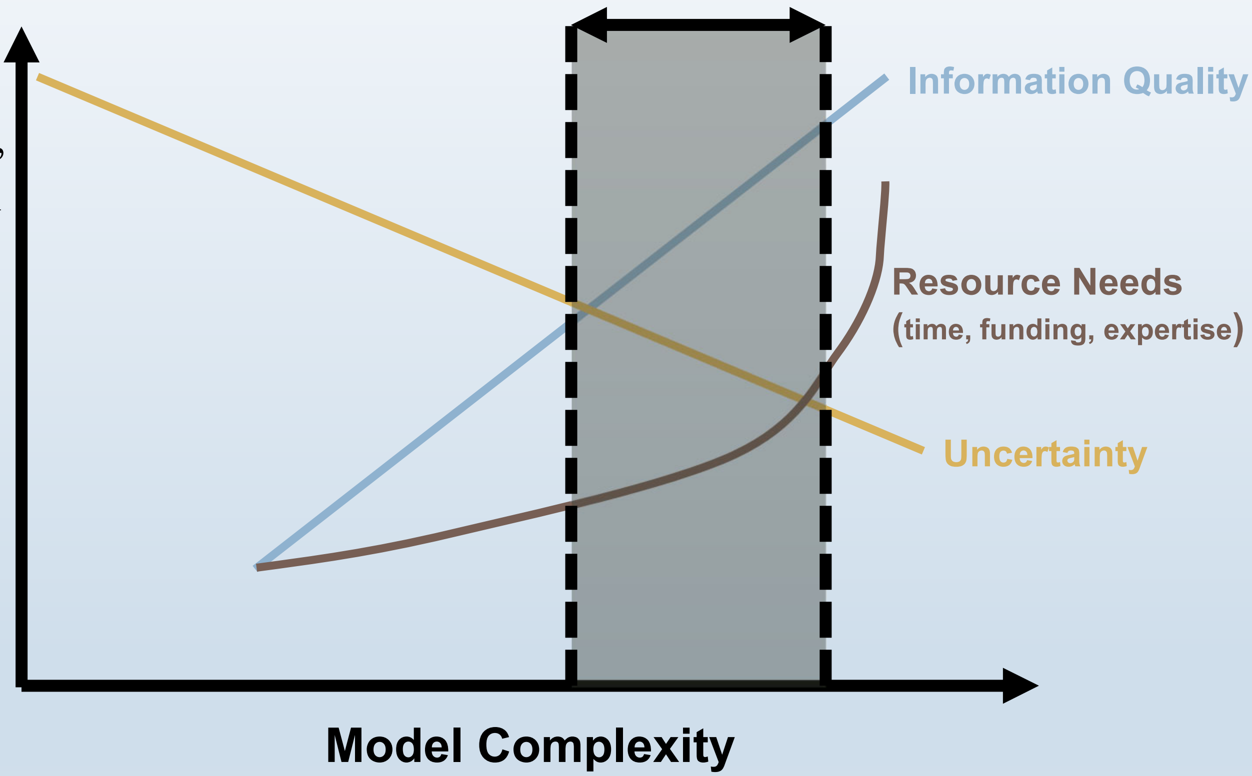
Important questions before we begin:

- Do we even need a model? (Dam Removal Analysis Guidelines)
- Which models are appropriate for which assessment?
  - How much data do I need? / How much data do I have?
  - What level of assessment is "good enough"?
  - How much time do I have?
  - How much money do I have?

Is it Worth it?

"Geomorphic tools should be selected in line with the project objectives, risks, data availability, and analysis time for a given dam removal; furthermore, multiple tools can be applied to a single site as an analysis proceeds from preliminary screening to permit application"

(Randle and Bountry 2017)



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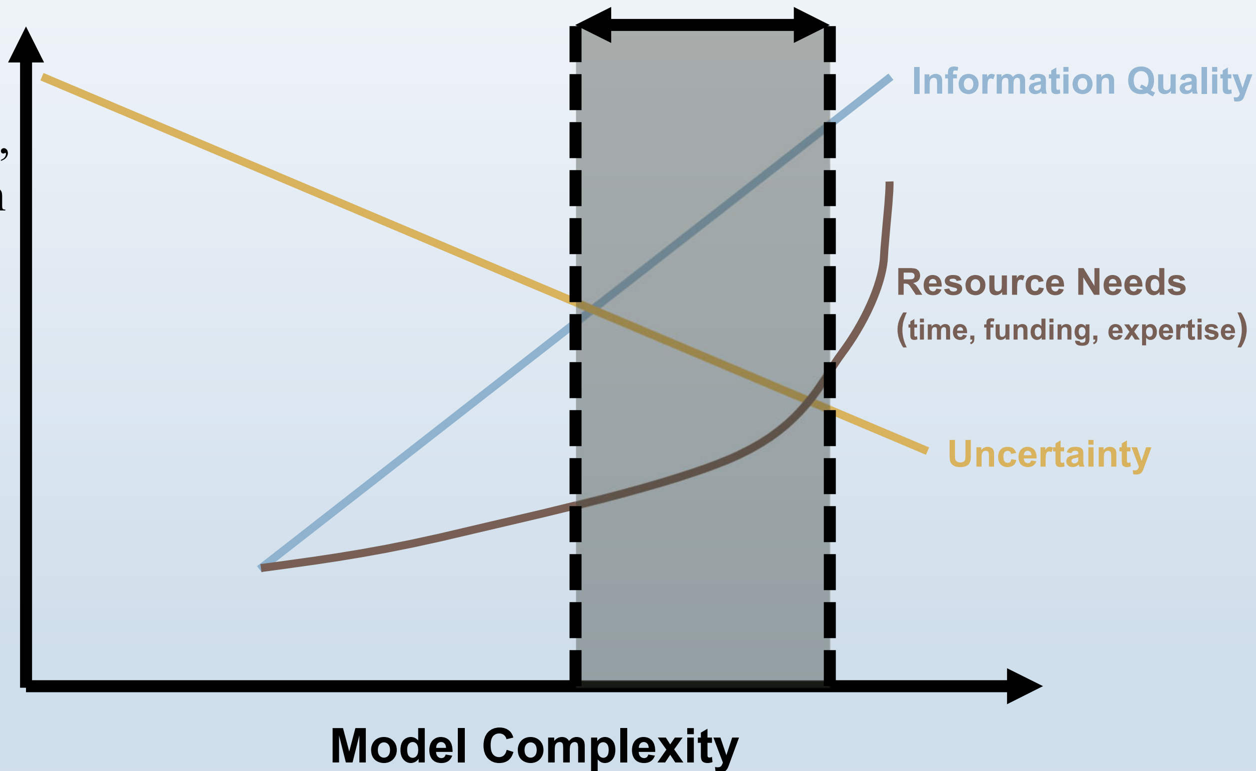

"Not everything is Milltown" (K. Mckay)

Methods/tools used to quantify the geomorphic implications of dam removal

General increase in complexity ↓

General List of Tools/Methods
Conceptual model
Generalized rule
Geomorphic analysis
Preliminary sediment analysis
1-D Sediment transport modeling
2-D Sediment transport modeling
Lagrangian transport modeling
3-D Sediment transport modeling

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Methods/tools: Conceptual Models

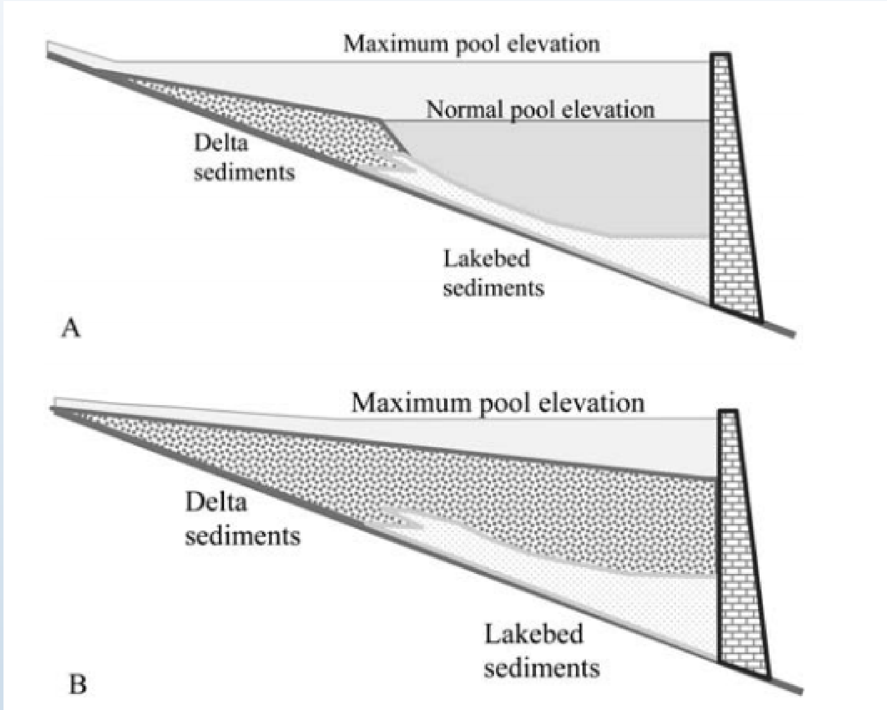
Description: Describes generally what will happen to the reservoir sediment and upstream sediment load as a result of a dam removal project. Conceptual models are developed based on existing knowledge of hydraulic and sediment processes.

Some Questions Answered:

Will the system be impacted greatly due to dam removal?

How will the channel evolve due to dam removal?

Do we need more modeling?



Conceptual model for reservoir sediment erosion during dam removal published by Doyle et al (2003) in Sediment Dynamics upon Dam Removal (Papanicolaou and Barkdoll, 2011)

Methods/tools: Generalized rules

Description: Empirical rules for system response to dams can indicate the sensitivity to sediment release

- Example: Major et al 2017 "In general, rivers converged toward stability conditions within a few years when both V∗ and E∗ had values of ≤20" after analysis of approximately 20 well-studied removals.

V* is ratio of impounded sediment volume to background sediment flux and E* is ratio of sediment volume eroded within 1 year of removal to background sediment flux.

Some Questions Answered:

Varies based on analysis and focus…Stability, channel evolution etc.

Methods/tools: Geomorphic Analysis

Description:

Qualitative insight (e.g., pre-dam topography, sediment volume, grain size) may be gained from historical aerial photographs, soil maps, historical accounts, and field reconnaissance (Tonitto and Riha 2016, Randle and Bountry 2017). The historical data and general site specific information, provides the basis for a narrative explanation of the channel system's sensitivity and thus how it may respond to the proposed dam removal.

Some Questions Answered:

Is there potential for significant risk due to dam removal?

What will the channel evolution look like generally following the dam removal?

Methods/tools

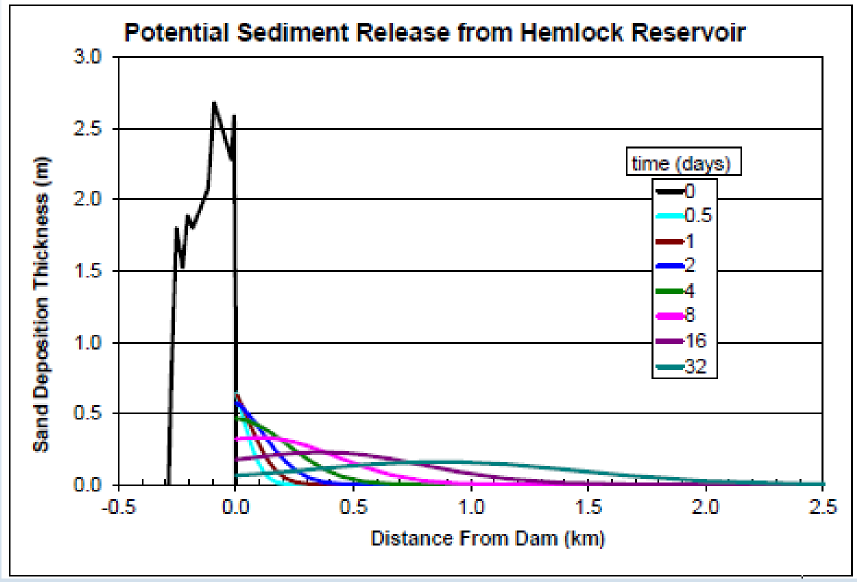
- Required Input: Varies and specific to question
- Benefits: Field data collection requirements are minimum. General results can be easily focused to the concern even with lack of site specific data.
- Limitations: Low resolution information. Cannot provide specific information, primarily trends.

Methods/tools: Preliminary sediment analysis

Description: A variety of simple desktop tools to answer a range of questions.

Examples:

- Sediment budgets (Warrick et al. 2015, Collins et al. 2017)
- Sediment wave models (Doyle et al. 2002, Pace et al. 2016)



Example sediment wave model results for the removal of Hemlock Dam on Trout Creek in southwest Washington State. From Greimann et al (2006) in (Randle and Bountry 2017)

Methods/tools: Preliminary sediment analysis

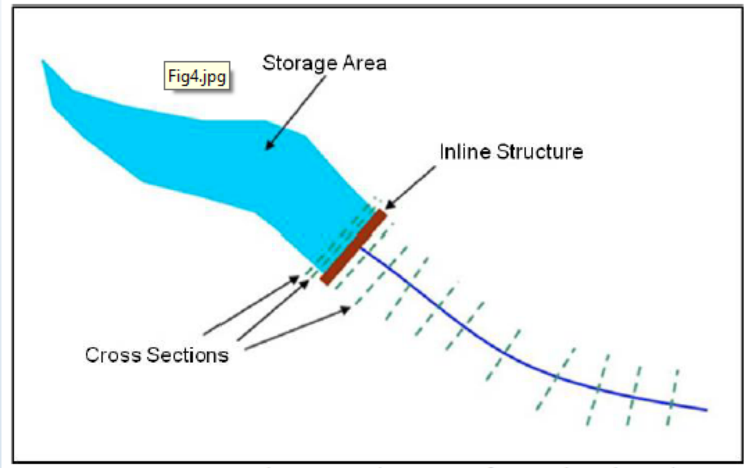
Required Input: Depends on the analysis.

Benefit: Simple analysis requires less site specific data. Results can be bracketed. Great for screening level assessment.

Limitation: Generally box models, basic information to a series of equations, resulting in a single solution that does not change with time or have an extremely simplified perspective of a complex system.

Methods/tools: 1-D sediment transport modeling

Description: Reach-averaged hydraulic tools provide a mechanism for assessing longitudinal change, but the data needs and outcomes can be widely variable. Focus is on total volume transported and reach-averaged response.



Example of Storage Area and Cross Section Layout for HEC-RAS Dam Break study (USACE 2014)

Some Questions Answered:

- How does a cross section of the channel change with dam removal?
- Volume changes?
- When does the sediment arrive downstream?

DREAM 1& 2	FLUVIAL12
HEC-RAS	SEDMOD

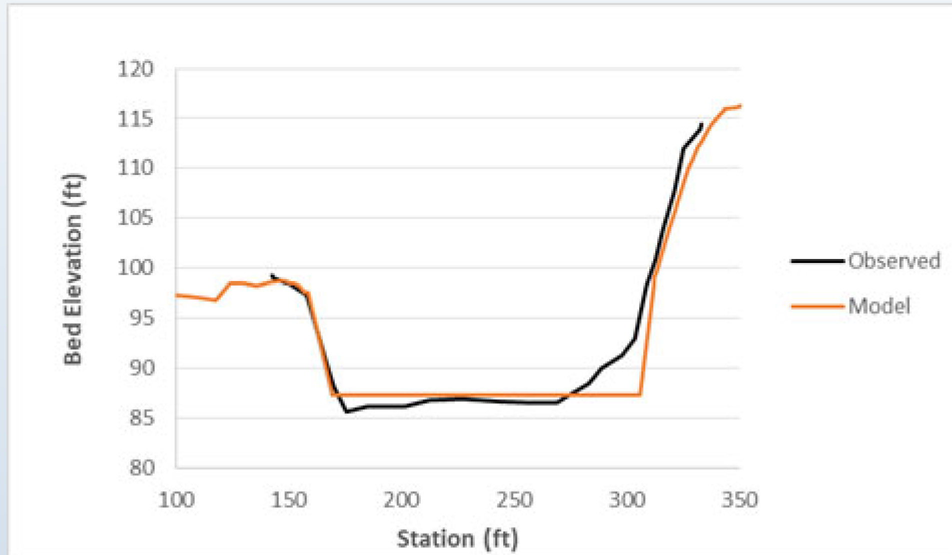
Methods/tools: 1-D sediment transport modeling

Required Input (HEC-RAS)

- bathymetry data (cross sections),
- hydrograph (time series of the flowrate entering the system),
- grainsize distribution at the bed (at every cross section)
- Sediment rating curve: Sediment load vs flow Upstream Boundary condition
- Additional parameters : roughness parameters

Benefits: Amount of input data can be reduced. Begin to get results that can be validated.

Limitations: In some models, cross sections are simplified to one bed elevation. It should be mentioned that all 1D models are not the same. Each model may have further limitations.



Cross section example comparing HEC-RAS model results with observed data.

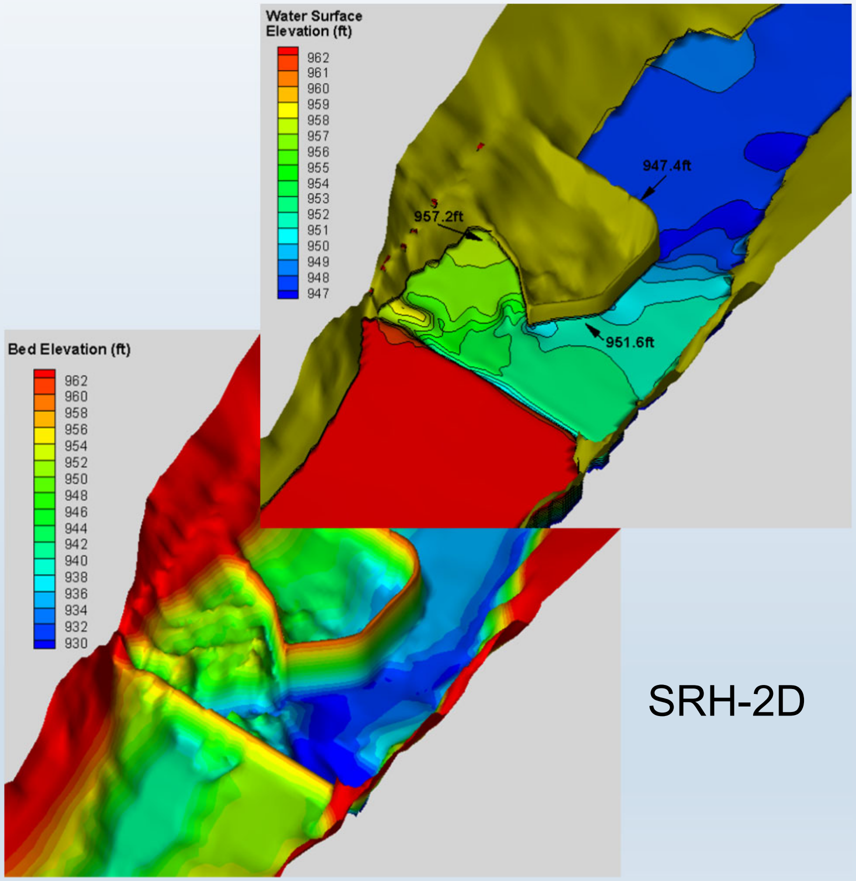
DREAM 1& 2	FLUVIAL12
HEC-RAS	SEDMOD

Methods/tools: 2-D Sediment transport modeling

Description: Lateral movement of channels and cross-sectionally distributed outcomes. Models of this type begin to allow for better assessment of sediment characterization addressing the issue of bed composition transition.

Some Questions Answered: What are the morphology changes (cross-sectionally) downstream? Suspended sediment concentration?

River2D, R2DM	MIKE-21C
SRH-2D	ADH



SRH-2D

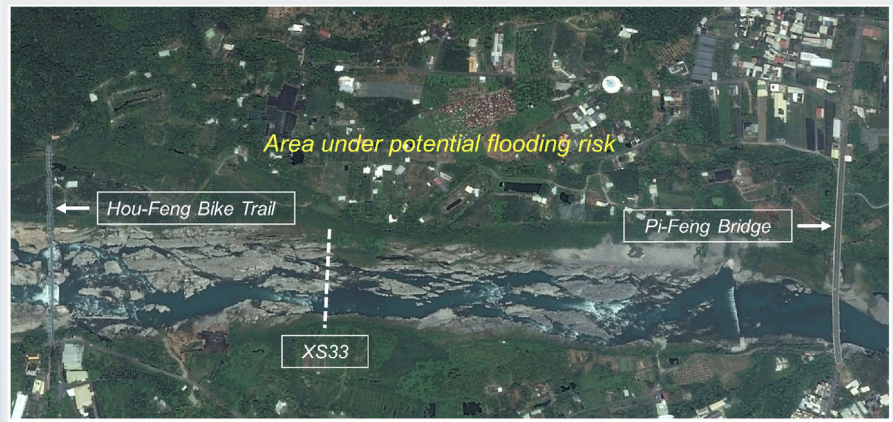
Savage Rapids Dam Removal Study (not sediment)

Methods/tools: 2-D Sediment transport modeling

Required Model Input: Sediment distribution over the entire area of interest. Time series of wse, velocity, and/or flowrate series as boundary conditions for hydrodynamics. Bedload or suspended load for sediment boundary conditions.

Benefits: Provides spatially and temporally varying results of deposition and erosion. Spatial resolution is increased from the 1D cross sections and equations can more realistically predict details in flow complex regimes.

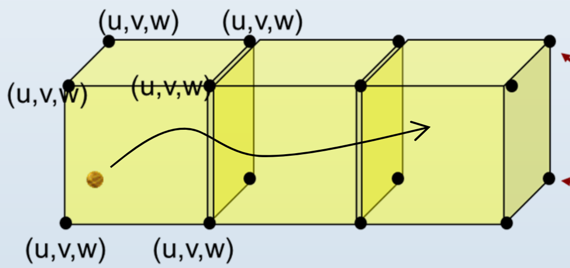
Limitations: Hydrodynamic assumptions are generally depth averaged. Assumptions that salinity is unchanged in the vertical. Data requirements increased.

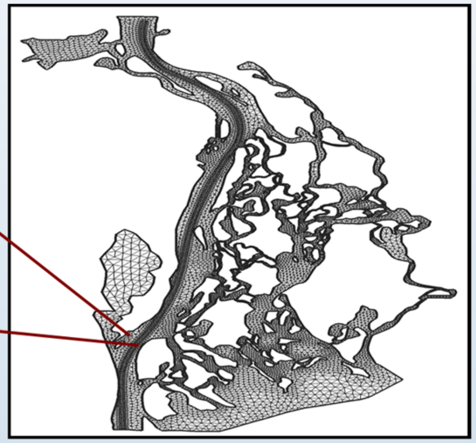


Downstream of Shihgang Dam on the Dajia River (Taiwan), Wang and You 2016 , SRH-2D

Methods/tools: Lagrangian sediment transport modeling

Description: Lagrangian particle transport focuses on specific user defined sources and determines their ultimate fate. The model may not be coupled with the hydrodynamic model which makes it extremely efficient.





- ❑ Computational grid
- ❑ Hydrodynamic solution

Questions Answered:

What is the potential fate of sediment introduced due to dam removal?

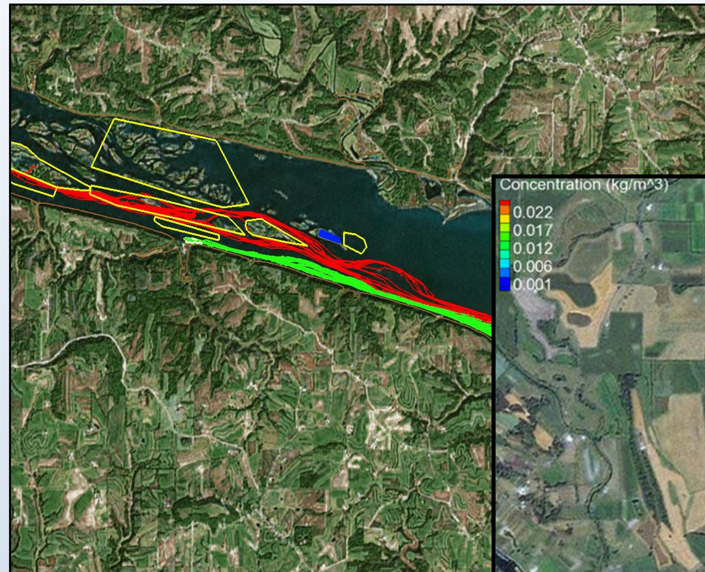
Does material expose critical environmental receptors to increased levels of suspended sediment?

Methods/tools: Lagrangian sediment transport modeling

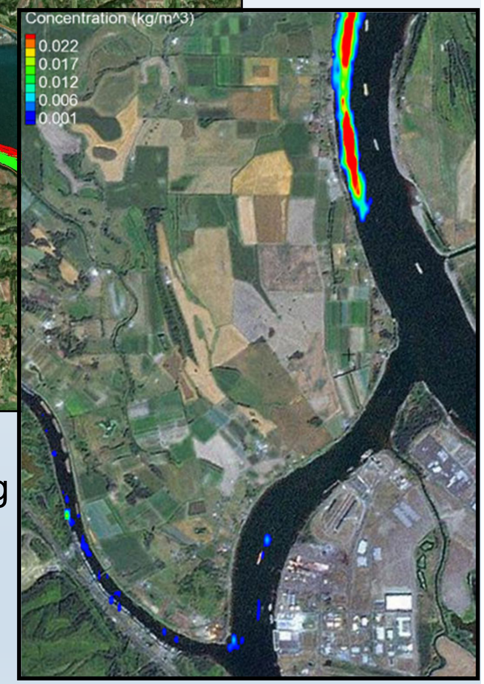
Data Input Requirement: Sediment characterization: including sediment distribution, settling rates, and critical shear stresses. Hydrodynamic modeling output.

Benefits: Potentially an exciting tool. Can use both 2D and 3D hydrodynamics as input. Can identify particle pathways to critical environmental receptors. For quantitative results, SSC concentration, deposition rate, accumulation can be calculated. For one hydrodynamic solution, can run multiple scenarios

Limitations: To date, has not been used in Dam Removal. For quantitative results, best used for fine sediment that will remain in water column. Sediment cannot impact hydrodynamics because they are not coupled. Does NOT determine morphology or channel evolution.



Particle Pathline results from the Particle Tracking Model



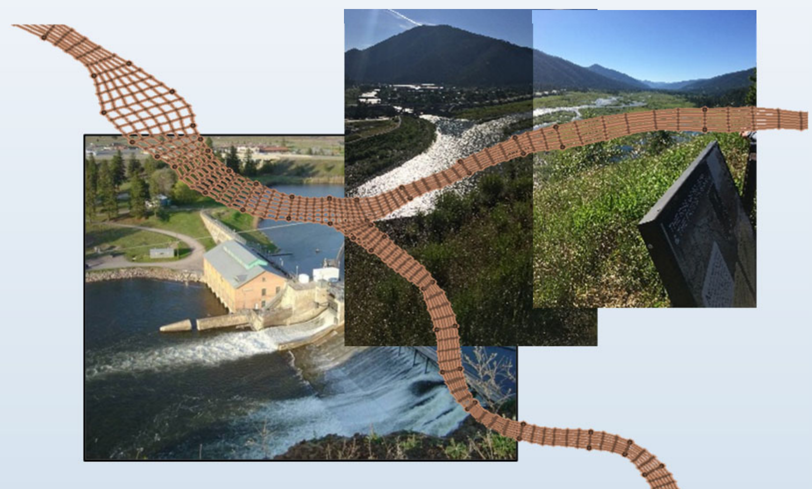
SSC from the Particle Tracking Model

Methods/tools: 3-D sediment transport modeling

Description: Modeling in 3D (generally unsteady) conditions, sediment transport.

Some Questions Answered:

- What is the TSS or Deposition at a specific location at a specific time (temporal range days - years)?
- What is the morphology change over time (everywhere in the system)?



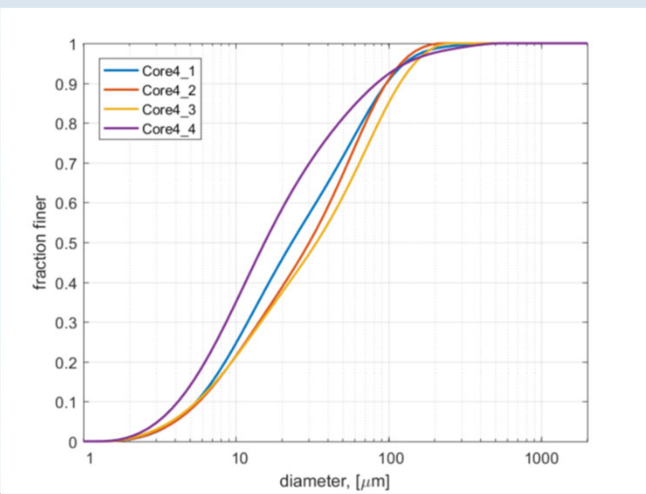
Milltown Dam, MT on the confluence of Clark Fork and Blackfoot rivers.

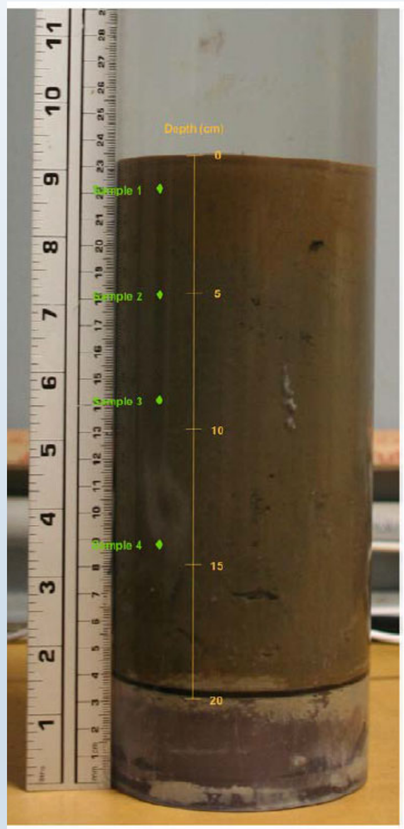
Milltown Dam
- 28-ft dam removed 2008
- Superfund site – heavy metals
- 2.2 mcy (of 6.6) fine-grained sediment removed

Methods/tools: 3-D sediment transport modeling

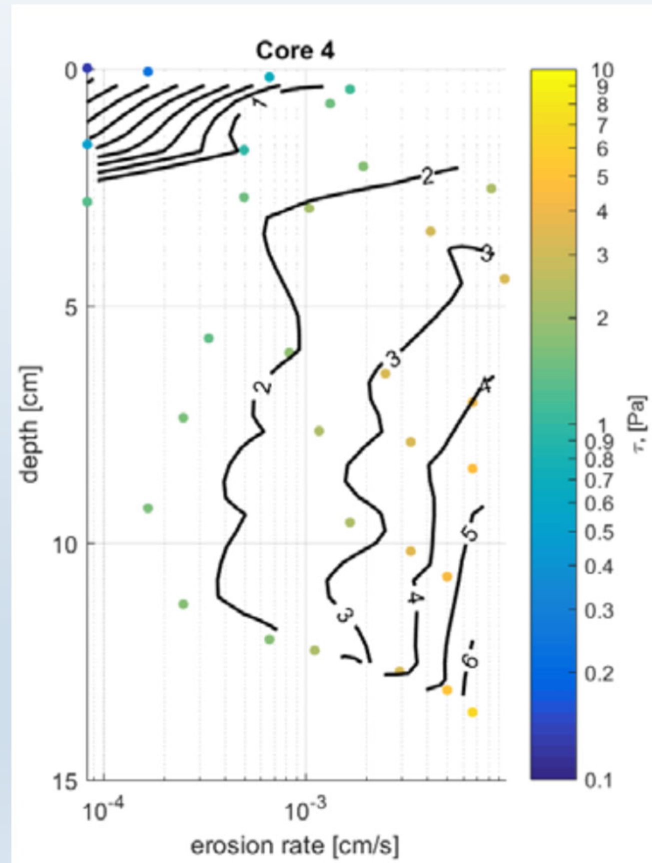
Model Input Requirements:

- Sediment characterization
  - cores (sediment grainsize, density, and critical shear stress described vertically within bed)
  - Sediment settling rates
- Sediment load data for boundaries
- Hydrodynamic boundary conditions (WSE, flowrate, velocities)





Example: Sediment Core

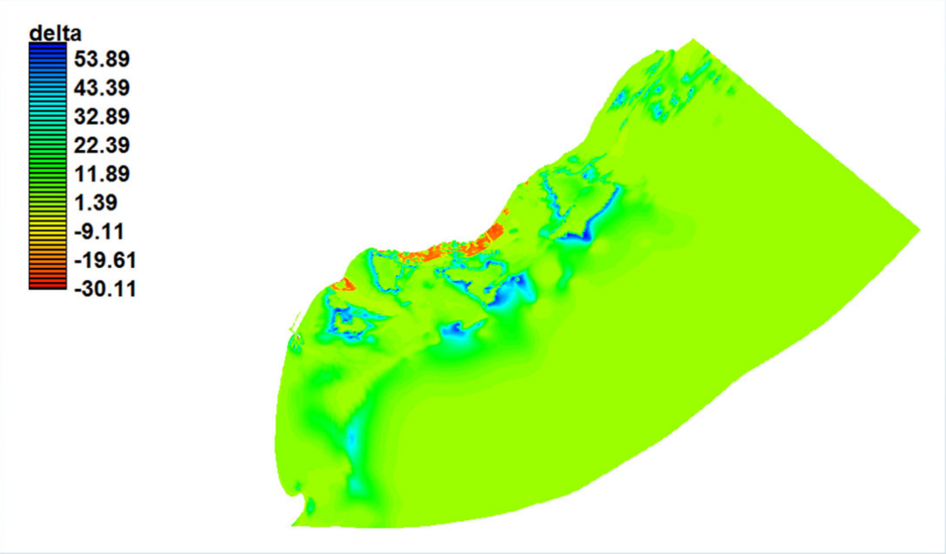


Methods/tools: 3-D sediment transport modeling

Benefits: At minimum the hydrodynamics of the model will be validated for pre-dam removal conditions.

- Allows users to better understand detailed and site specific issues:
  - water quality near habitat
  - bed morphology changes at specific locations of importance

Results should be more spatially resolved



Example of GSMB morphology change results

Limitations:

Have not (to our knowledge) been applied in dam removal predictions (computationally expensive)

Require extensive site specific input data to be effective

Summary

- We can use predictive sediment transport models and tools to address some of concerns regarding sediment transport due to dam removal:
  - Morphology
  - Risk
- We looked at a wide range of methods and technologies to help categorize and understand appropriate model usage.
- Determining which tool to use is dependent on resources and the specifics of the question/concern. We need to understand:
  - Data requirements
  - Benefits
  - Limitations/Assumptions

What's next?

Case Studies with increasing levels of complexity:

- Case Study 1: Moodna Creek
- Case Study 2: 1D Modeling Techniques - Simkins
- Case Study 3: 3D Modeling Techniques - Milltown