How Bureau of Reclamation is Reframing Reservoir Sedimentation

Presented by

Tim Randle, PhD, PE, D.WRE.

Jennifer Bountry, MS, PE

Bureau of Reclamation

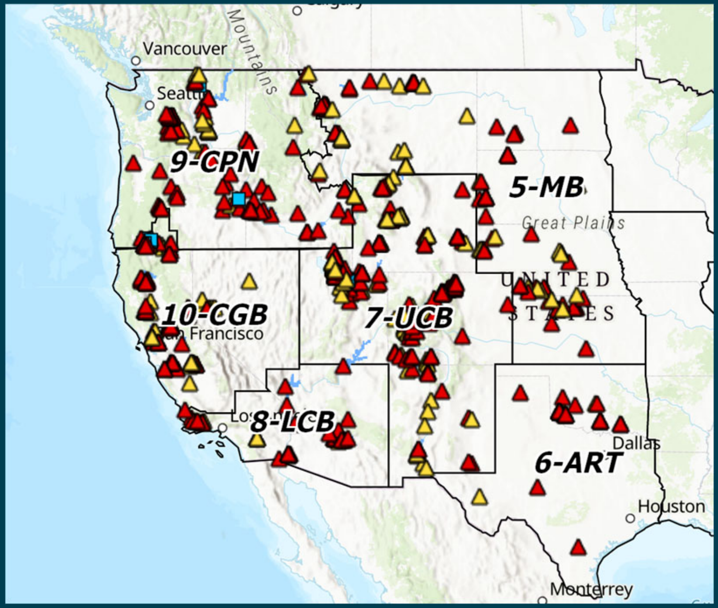
Presentation Overview

- How Reclamation is working on communication of reservoir sediment management issues and solutions
- Detection and monitoring strategies
- New research and numerical modeling
- Reservoir sediment management strategies
- Reservoir sedimentation challenges at Reclamation
- Using a prize competition to crowd source ideas

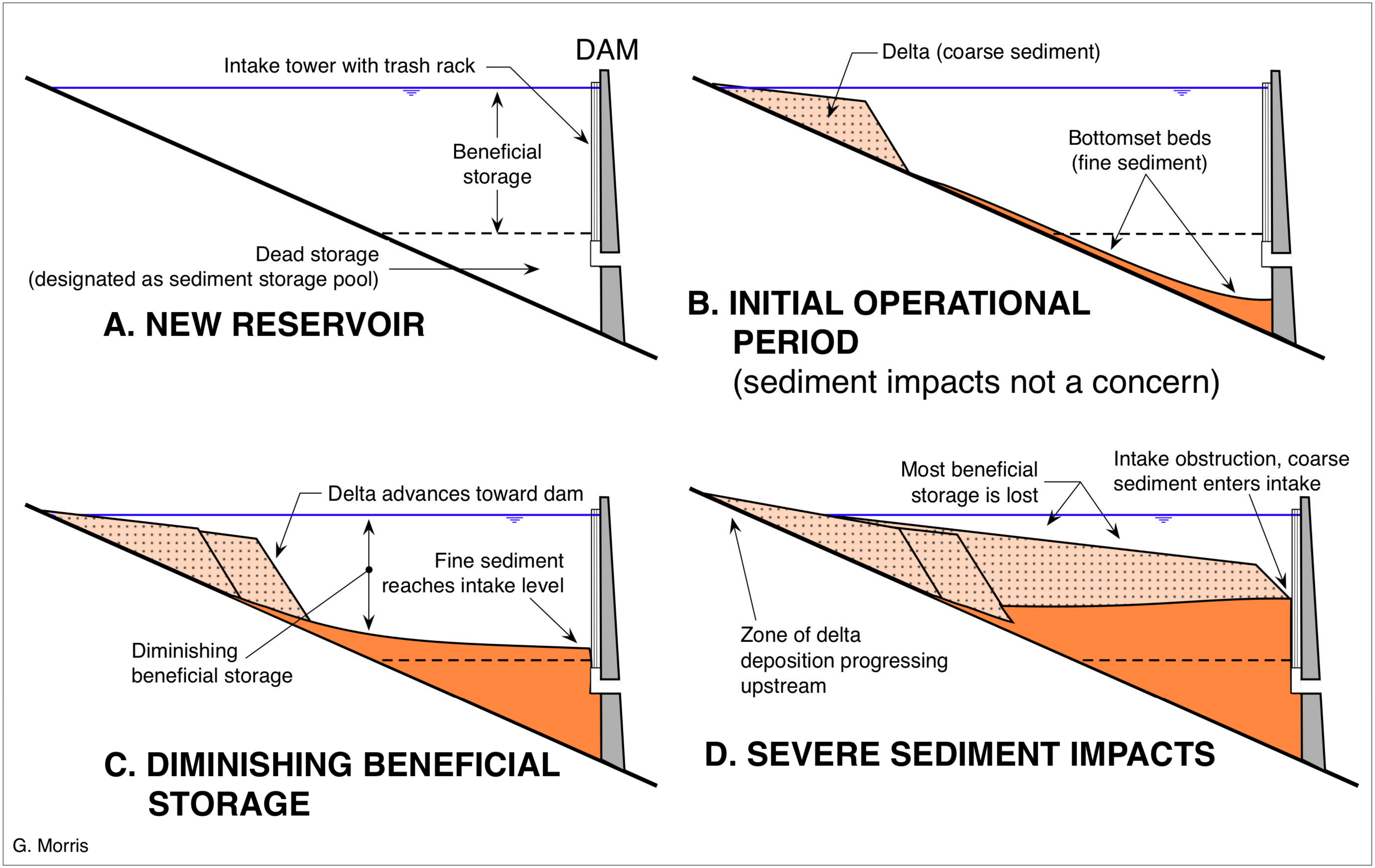
Paonia Reservoir, CO

Introduction

- Reclamation has 294 reservoirs with 141 million acre-feet of storage capacity
- These reservoirs are considered assets that need to be managed over the long term, but dam outlets were originally designed to function until the dead storage was full of sediment



Introduction



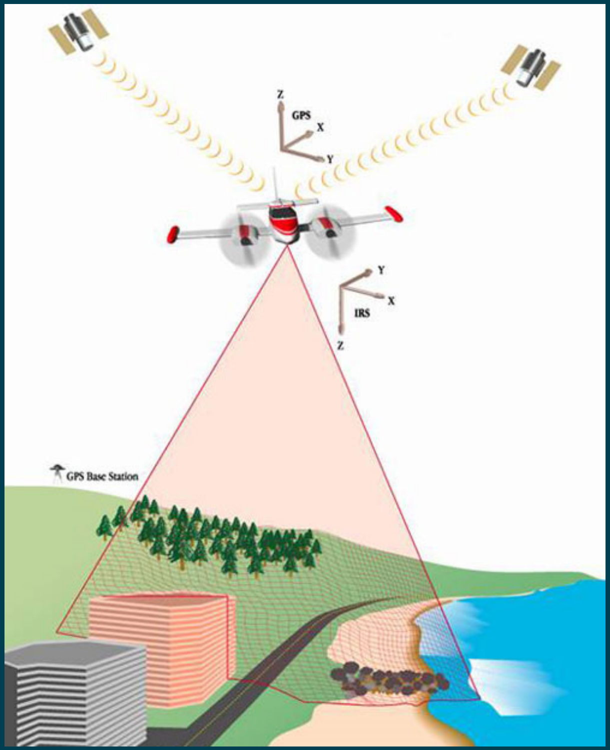
Introduction

- Sedimentation is reducing storage capacity over time and may eventually impair dam and reservoir facilities
  - Sedimentation impacts occur long before the reservoir completely fills with sediment
  - Severe droughts will lower the reservoir pools, allow sediment to move closer to the dam, stress vegetation in the upstream watershed, and increase future sediment yields

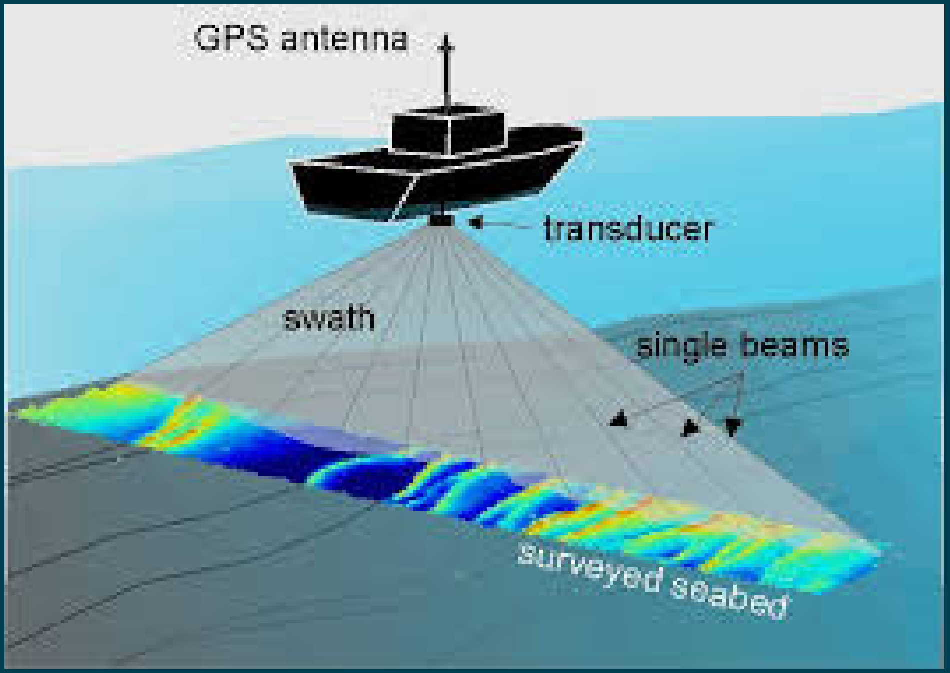
Introduction

- Reclamation is implementing a reservoir sedimentation monitoring policy to better track sedimentation impacts

Aerial surveys by LiDAR



Bathymetric surveys boat, GPS, multibeam depth sounder

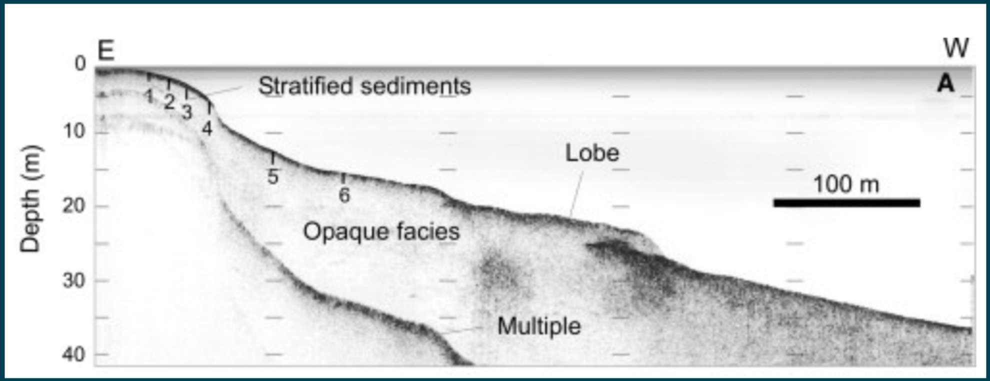


Communicating the Reservoir Sedimentation Paradigm

- White papers
  - Reservoir Sediment Management: Building a Legacy of Sustainable Water Storage Reservoirs (Randle, et al., 2019)
- International workshops
  - April 2018
  - August 2021
- Journal articles
  - Sustaining United States reservoir storage capacity: Need for a new paradigm (Randle, et al., 2021)
  - Sediment Mismanagement Puts Reservoirs and Ecosystems at Risk (Tullos, et al., 2021)
- Webinars (7 recorded webinars 2018-2019)

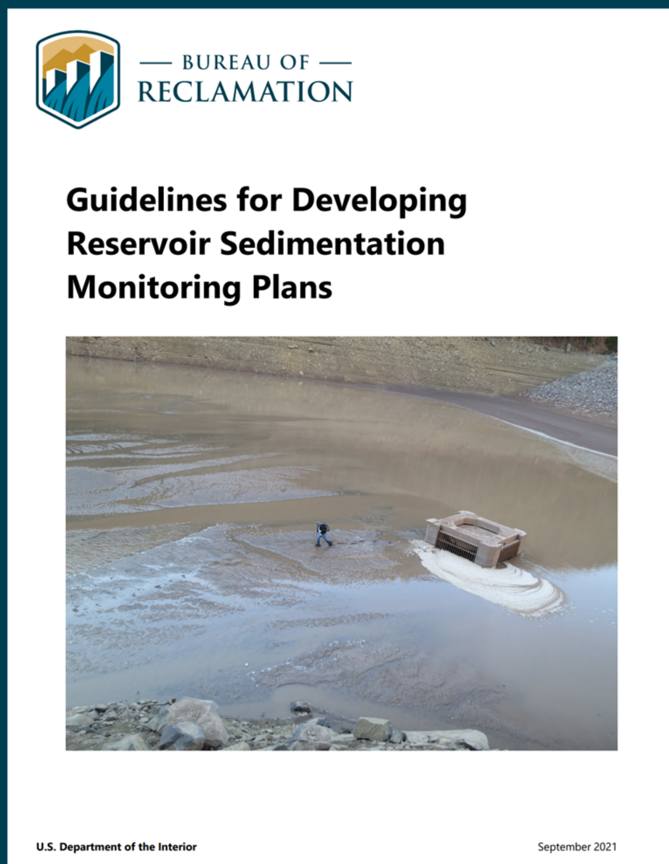
Detection and Monitoring

- Proposal to form agency-wide reservoir survey team
- Use of advance technology
  - Survey grade GPS, multi-beam depth sounders
  - Data processing software
  - Compressed High Intensity Radar Pulse (CHIRP) Sonar



Detection and Monitoring

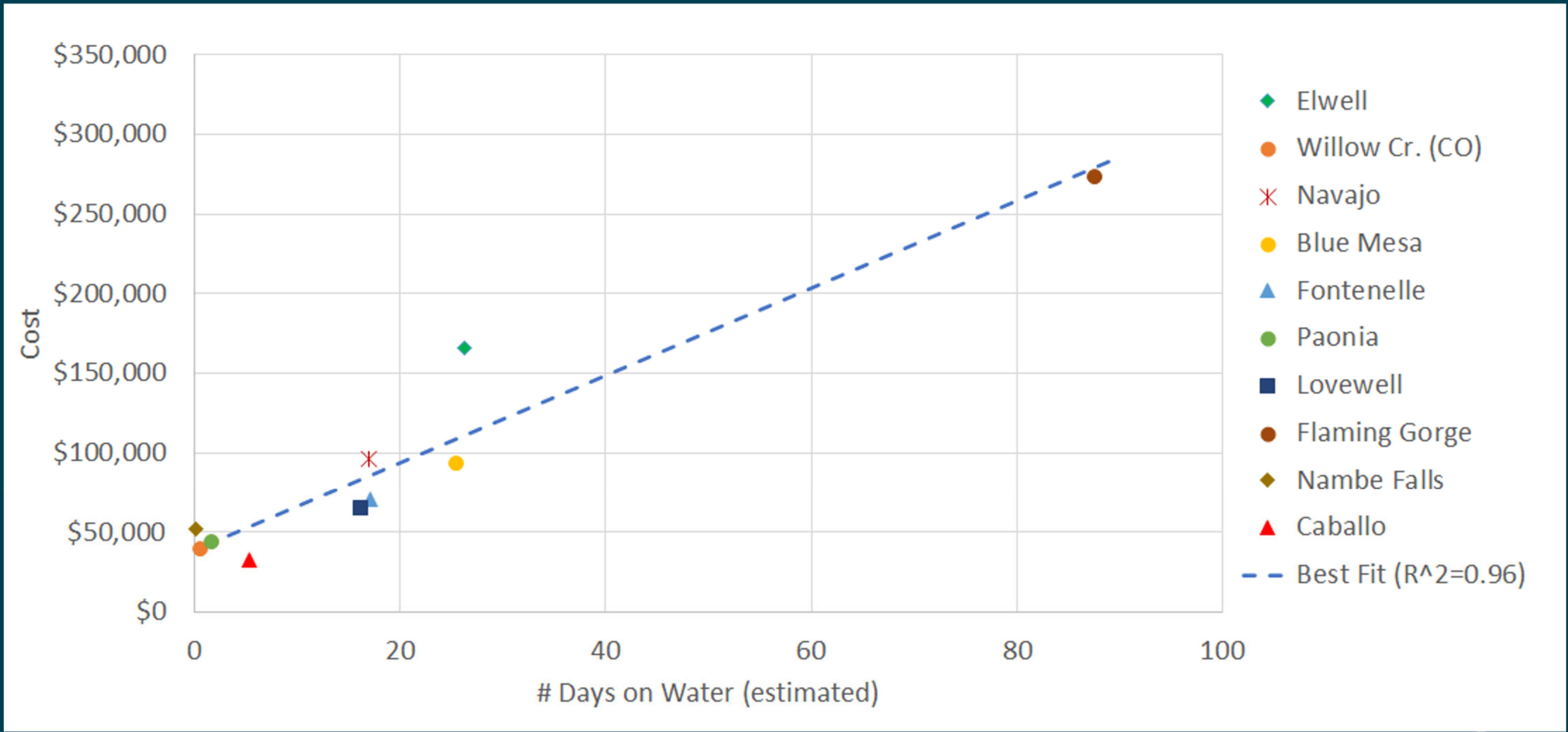
- New Guidelines for Developing Reservoir Sedimentation Monitoring Plans, September 2021) Sonar



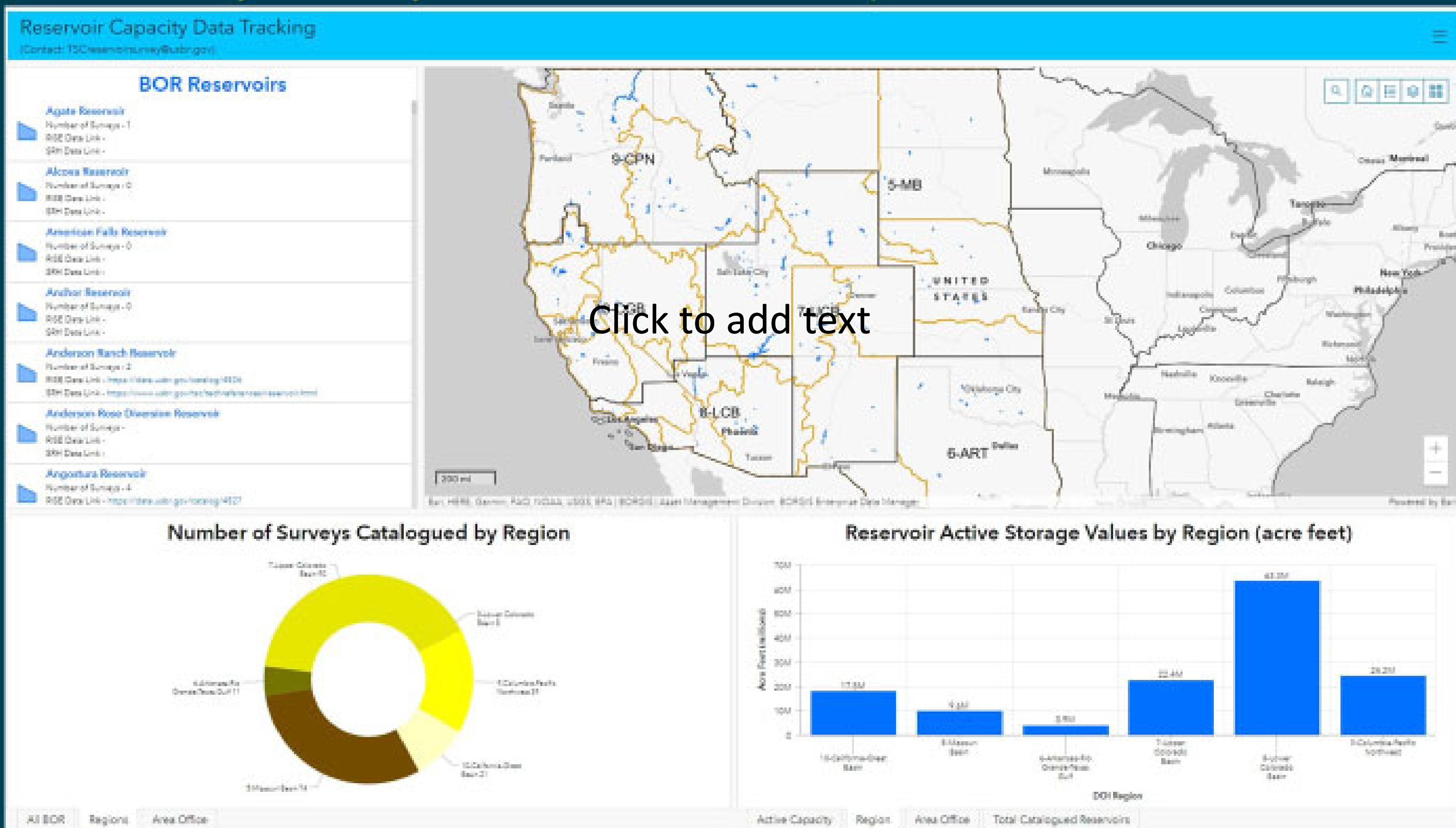
https://www.usbr.gov/tsc/techreferences/reservoir/GuidesForDevReservoirSedimentationMonitoringPlans_09-2021_508.pdf

Detection and Monitoring

- Developing reservoir survey cost estimating guidelines



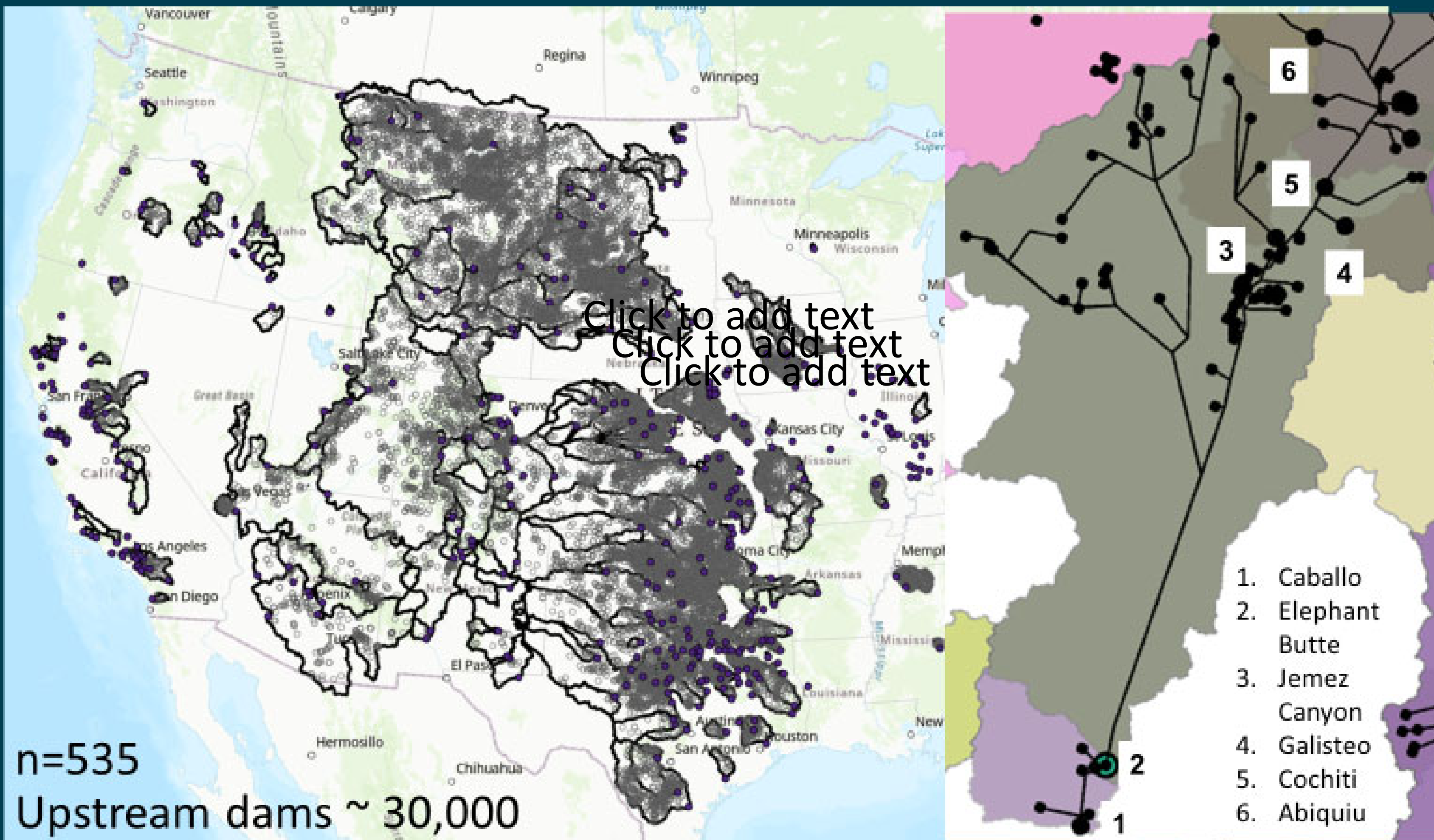
Detection and Monitoring:
Reservoir survey inventory



Click to add text

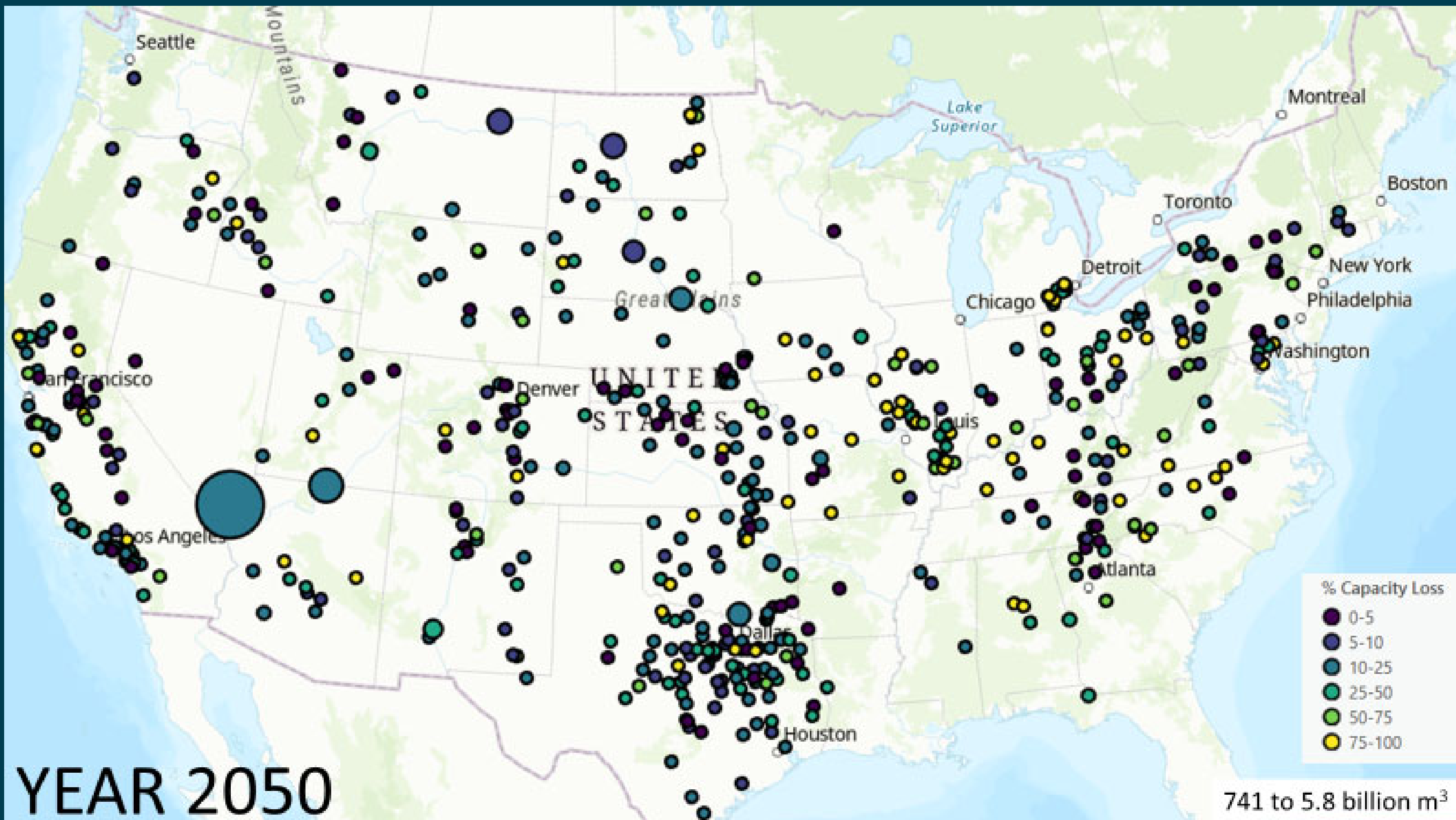
Foster et al., in prep

Detection and Monitoring:
Sediment contributing drainage areas



Foster et al., in prep

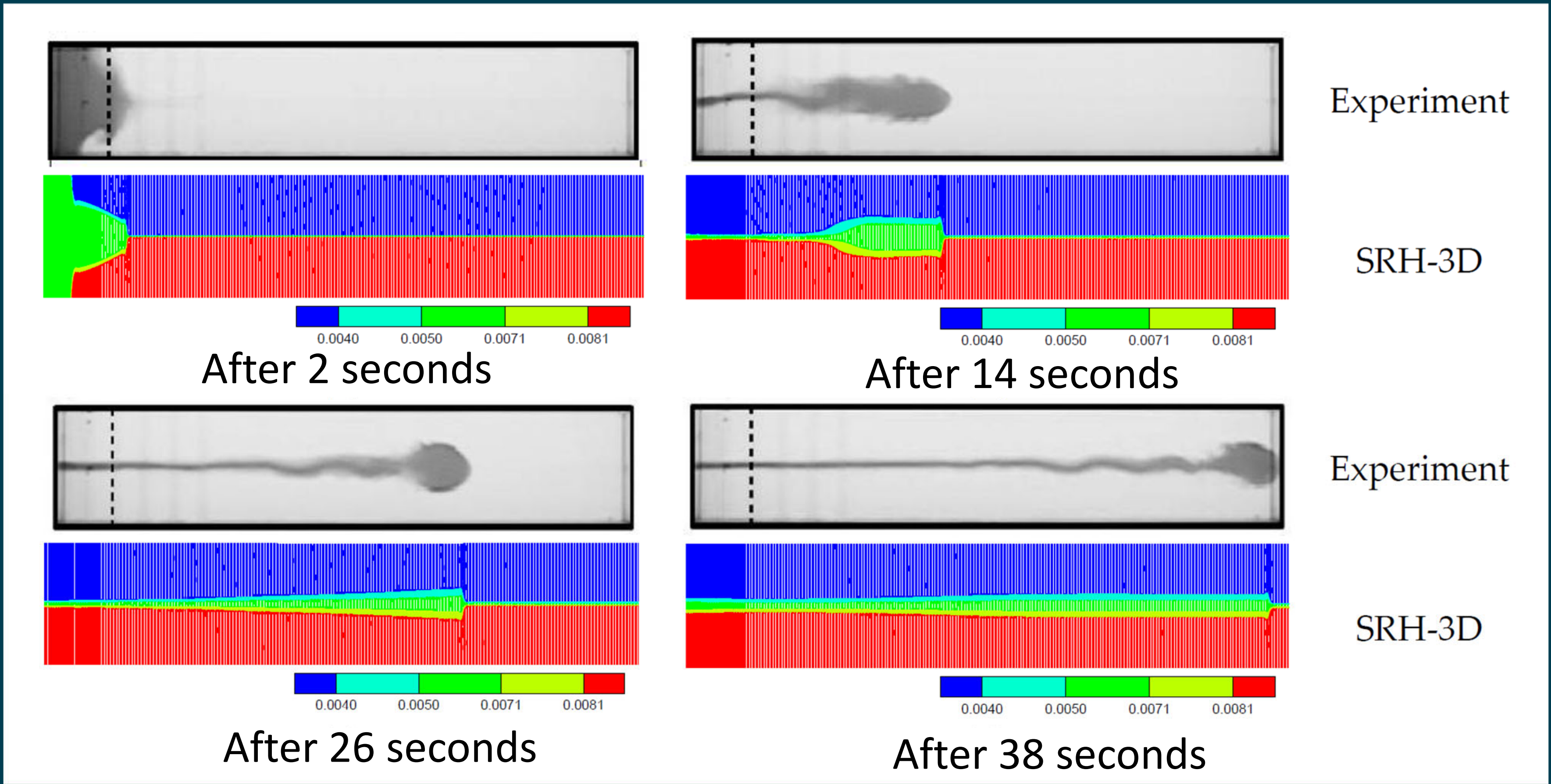
Detection and Monitoring:
Projected sedimentation storage loss



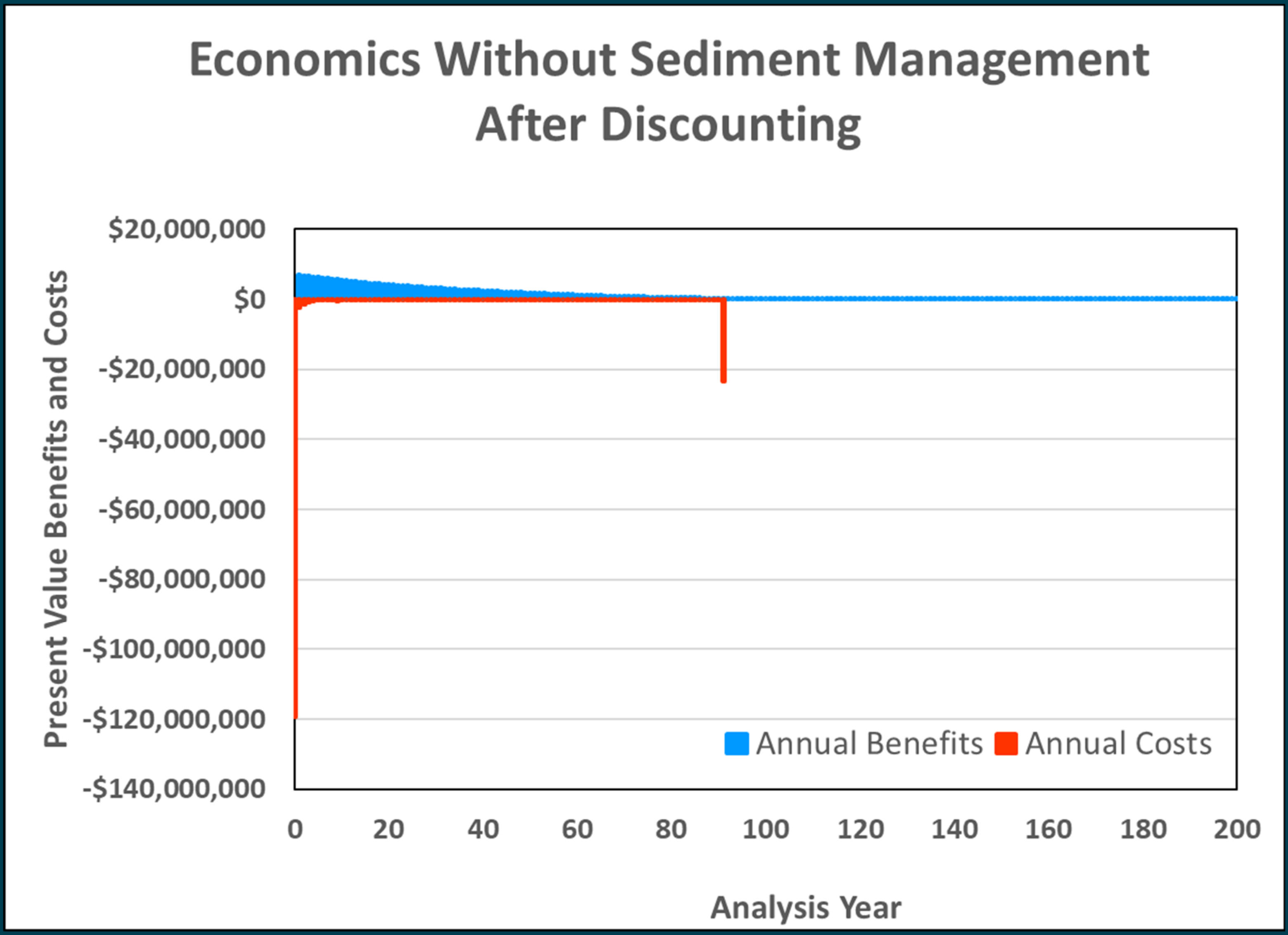
Foster et al., in prep

Research and Numerical Modeling

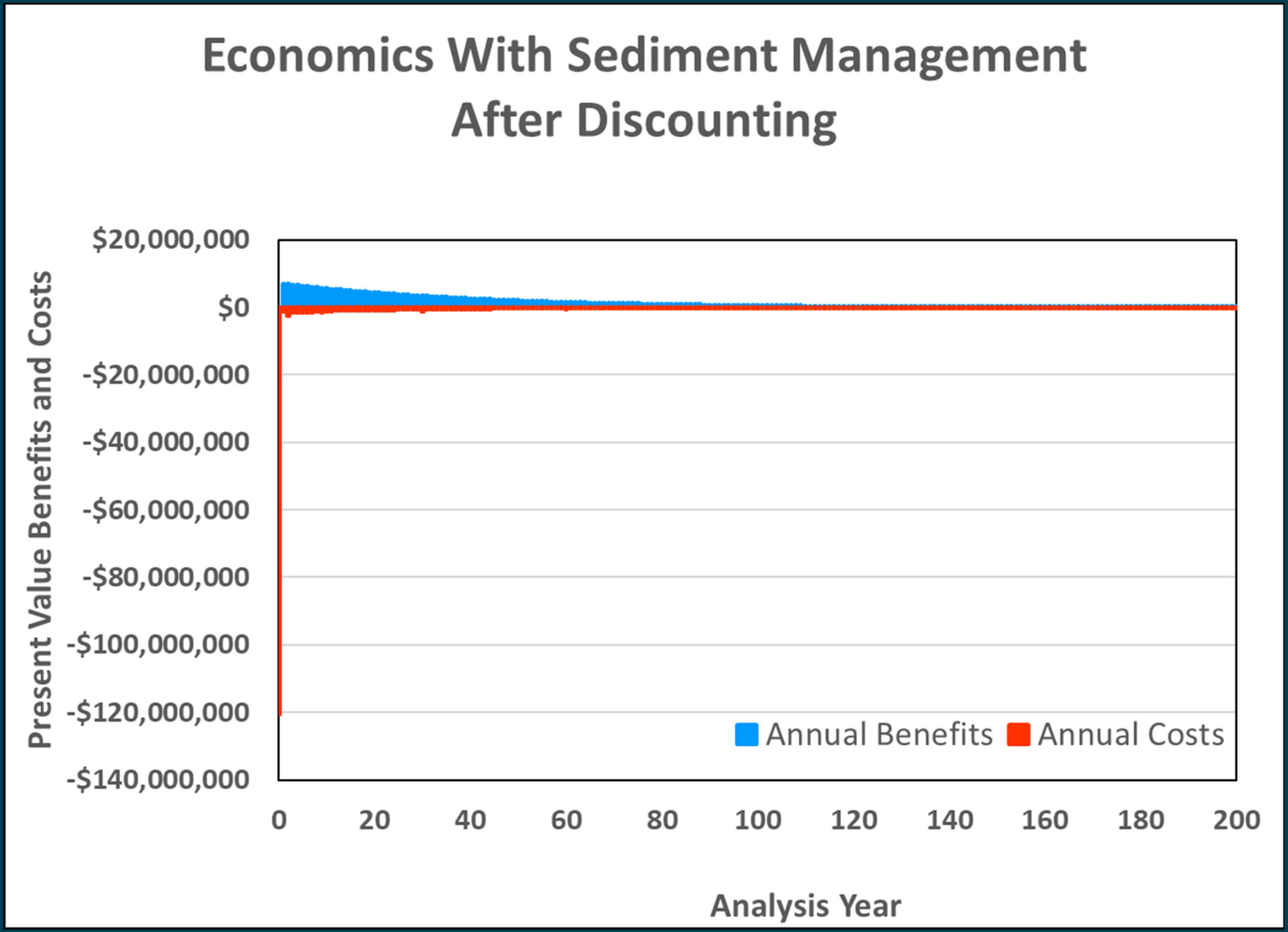
- SRH-3D model developed to simulate sediment turbidity currents through a Taiwan reservoir



Research and Numerical Modeling



Research and Numerical Modeling



Research and Numerical Modeling

- Economics comprehensively considers all benefits and costs to society and how they change over time
- Benefits and costs change with reservoir sedimentation
- Over time, sedimentation leads to
  - Diminished reservoir storage and recreation benefits
  - Upstream impacts to lands, infrastructure, and habitat
  - Downstream costs to lands, infrastructure, and habitat
  - Eventual dam decommissioning

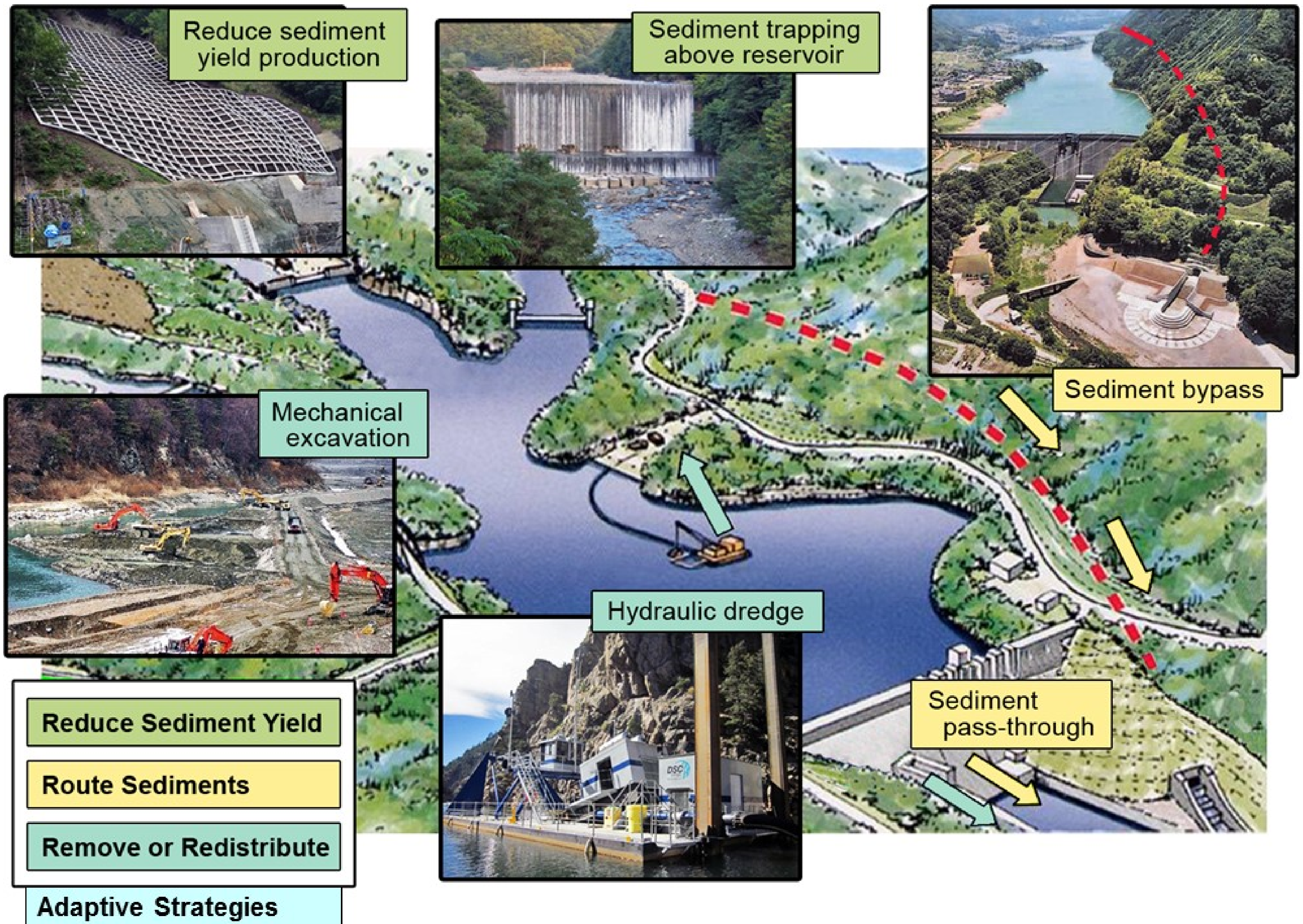
Research and Numerical Modeling

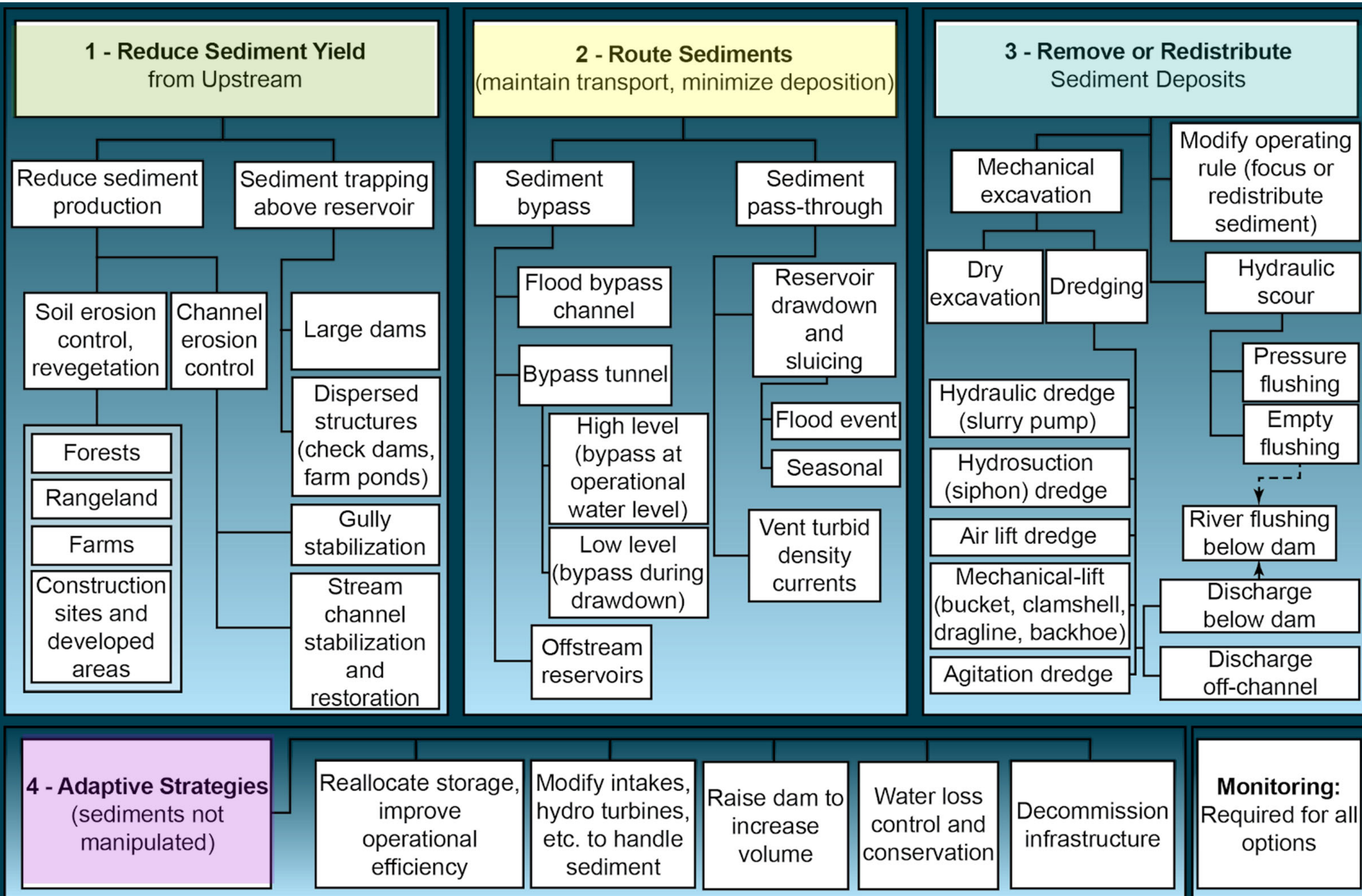
- Economics comprehensively considers all benefits and costs to society and how they change over time
- Benefits and costs change with reservoir sedimentation
- Over time, sedimentation leads to
  - Diminished reservoir storage and recreation benefits
  - Upstream impacts to lands, infrastructure, and habitat
  - Downstream costs to lands, infrastructure, and habitat
  - Eventual dam decommissioning

Research and Numerical Modeling

- Predicting Reservoir Drawdown Flushing to Improve Reservoir Sustainability
- Quantifying the development & dynamics of reservoir delta riparian habitats
- Investigating physical processes impacting fish passage on reservoir deltas and potential solutions

Sediment Management Strategies




1 - Reduce Sediment Yield from Upstream
2 - Route Sediments (maintain transport, minimize deposition)
3 - Remove or Redistribute Sediment Deposits
Reduce sediment production
Sediment trapping above reservoir
Soil erosion control, revegetation
Channel erosion control
Large dams
Dispersed structures (check dams, farm ponds)
Forests
Rangeland
Farms
Construction sites and developed areas
Gully stabilization
Stream channel stabilization and restoration
Sediment bypass
Sediment pass-through
Flood bypass channel
Bypass tunnel
High level (bypass at operational water level)
Low level (bypass during drawdown)
Offstream reservoirs
Reservoir drawdown and sluicing
Flood event
Seasonal
Vent turbid density currents
Mechanical excavation
Modify operating rule (focus or redistribute sediment)
Dry excavation
Dredging
Hydraulic scour
Hydraulic dredge (slurry pump)
Hydrosuction (siphon) dredge
Air lift dredge
Mechanical-lift (bucket, clamshell, dragline, backhoe)
Agitation dredge
Pressure flushing
Empty flushing
River flushing below dam
Discharge below dam
Discharge off-channel
4 - Adaptive Strategies (sediments not manipulated)
Reallocate storage, improve operational efficiency
Modify intakes, hydro turbines, etc. to handle sediment
Raise dam to increase volume
Water loss control and conservation
Decommission infrastructure
Monitoring: Required for all options

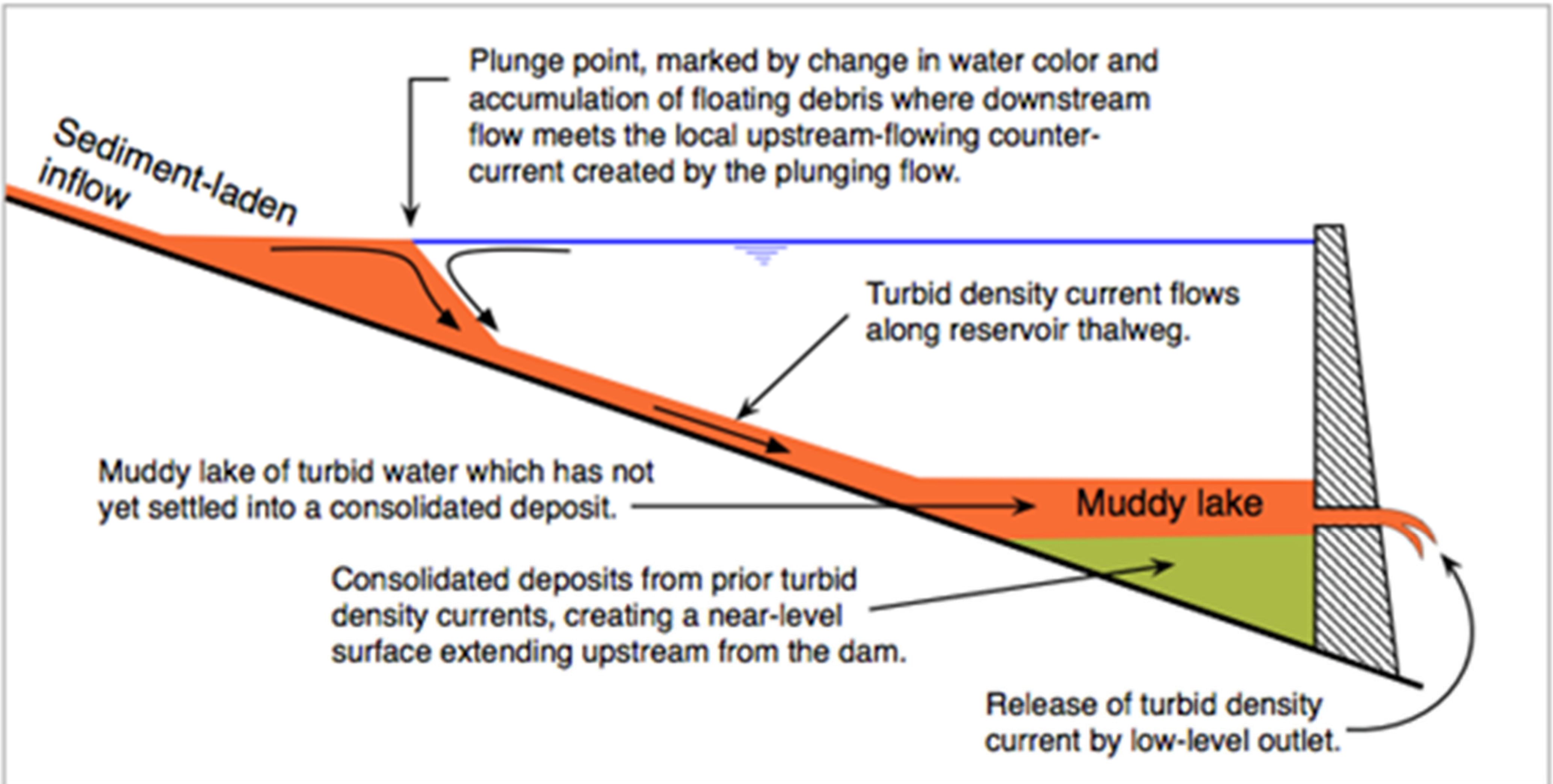
Morris, 2015

Reservoir Sediment Routing

- Tunnel bypass

Tunnel bypass at Miwa Dam, Japan

Turbid Density Currents in Reservoirs



Morris, 2019

Remove or Redistribute Sediments

- Pressure flushing of sediments near the dam outlet

Opening of Cherry Creek Dam Outlets

Downstream Monitoring

Remove or Redistribute Sediments

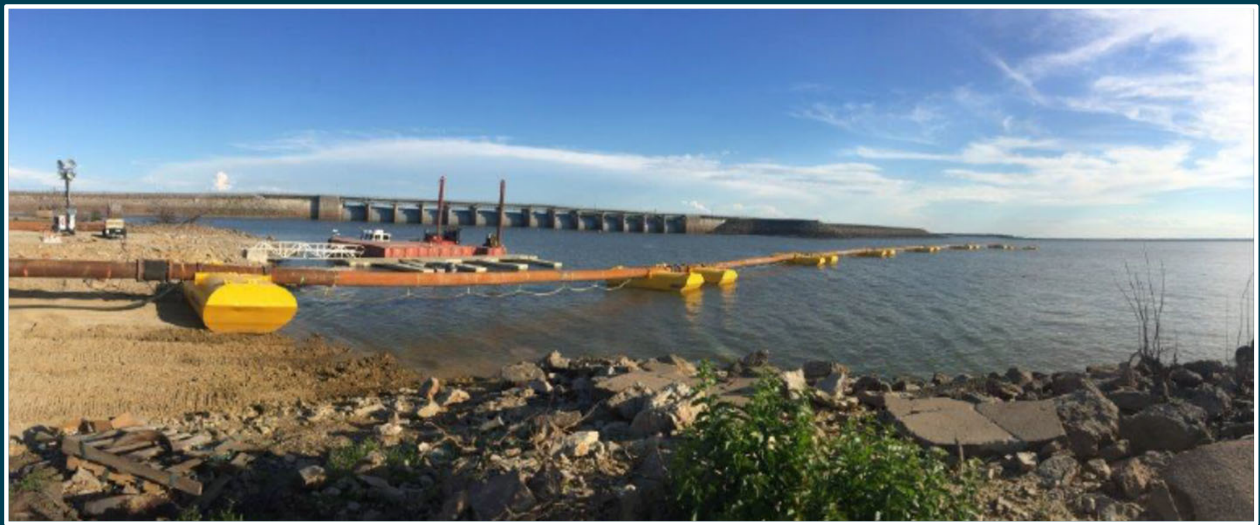
- Drawdown flushing for river erosion

Headcut Erosion in Spenser Reservoir

Sediment Flush below Spenser Dam

Remove or Redistribute Sediments

- Mechanical or hydraulic dredging or dry excavation
  - Transport by slurry pipeline, truck, or conveyor belt for discharge to the downstream river channel, other beneficial use, or disposal site

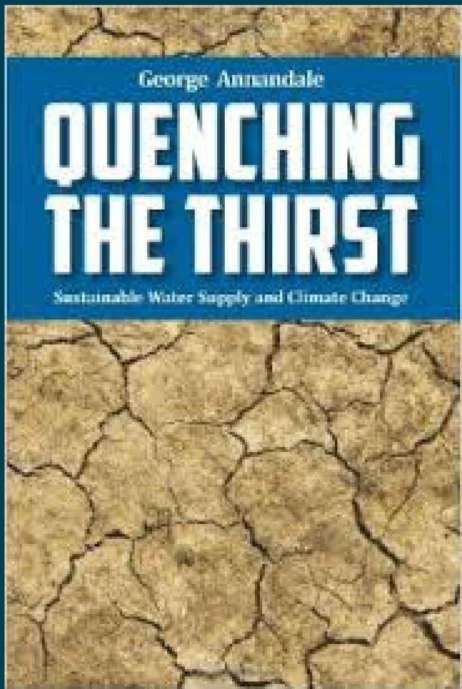


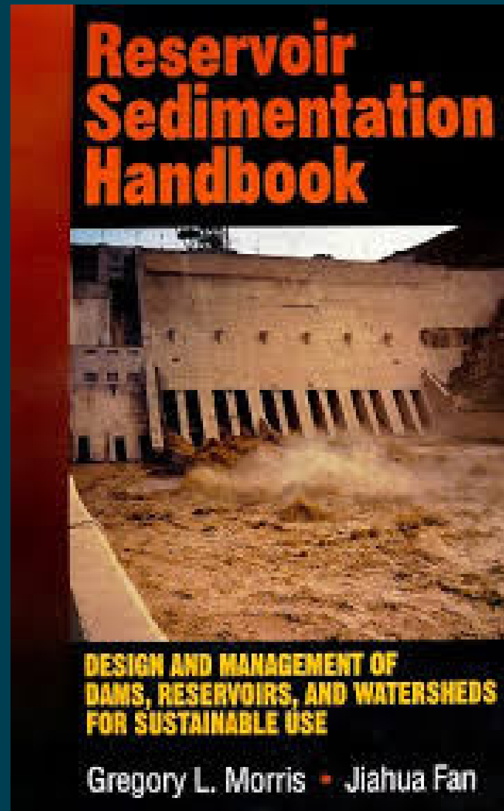
Beneficial Uses

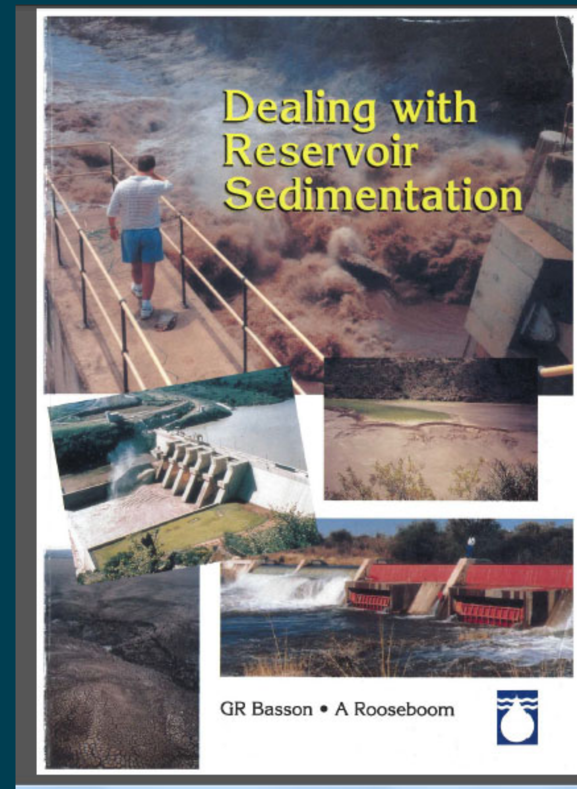
- Soil augmentation for agriculture
- Land development
- Construction fill
- Concrete aggregate


- Wetland and other shallow water habitat creation
- Shoreline beach development or augmentation
- Offset downstream channel incision







AGU PUBLICATIONS

Earth's Future

RESEARCH ARTICLE

10.1002/2013EF000184

Key Points:
- Reservoirs trap sediment, losing storage capacity
- Downstream reaches can become sediment starved
- Many dams can be designed/operated to pass sediment

Corresponding author:
G. M. Kondolf, kondolf@berkeley.edu

Citation:
Kondolf, G. M. et al. (2014), Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents, *Earth's Future*, *2*, 256–280, doi:10.1002/2013EF000184.

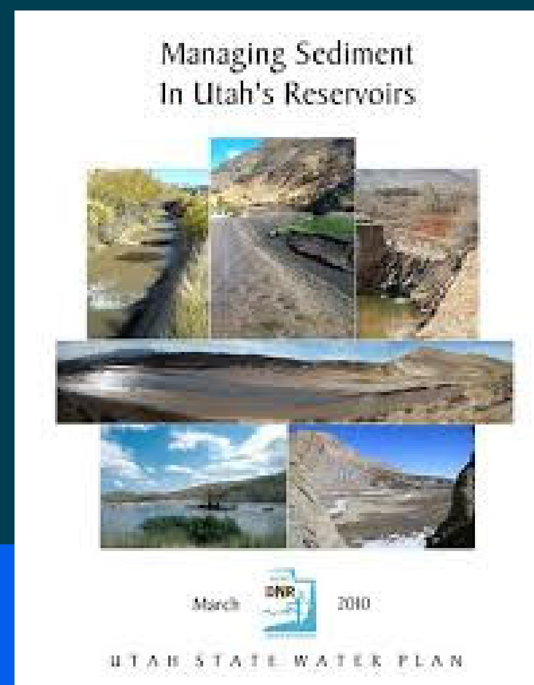
Received 30 SEP 2013

Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents

G. Mathias Kondolf[1], Yongxuan Gao[2], George W. Annandale[3], Gregory L. Morris[4], Enhui Jiang[5], Junhua Zhang[5], Yongtao Cao[5], Paul Carling[6], Kaidao Fu[7], Qingchao Guo[8], Rollin Hotchkiss[9], Christophe Peteuil[10], Tetsuya Sumi[11], Hsiao-Wen Wang[12], Zhongmei Wang[5], Zhilin Wei[13], Baosheng Wu[14], Caiping Wu[5], and Chih Ted Yang[15]

[1]University of California, Berkeley, California, USA, [2]Natural Heritage Institute, San Francisco, California, USA, [3]Golder Associates, Lakewood, Colorado, USA, [4]GLM Engineering COOP, San Juan, Puerto Rico, USA, [5]Yellow River Institute of Hydraulic Research, Zhengzhou, Henan, China, [6]University of Southampton, Southampton, UK, [7]Yunnan University, Kunming, Yunnan, China, [8]Institute of Water Resources and Hydropower Research, Beijing, China, [9]Brigham Young University, Provo, Utah, USA, [10]Compagnie Nationale du Rhone, Lyon, France, [11]Kyoto University, Gokasho, Kyoto, Japan, [12]National Cheng Kung University, Tainan, Taiwan, [13]Wuhan University, Wuhan, Hubei, China, [14]Tsinghua University, Beijing, China, [15]Colorado State University, Fort Collins, Colorado, USA

Abstract By trapping sediment in reservoirs, dams interrupt the continuity of sediment transport through rivers, resulting in loss of reservoir storage and reduced usable life, and depriving downstream reaches of sediments essential for channel form and aquatic habitats. With the acceleration of new dam construction globally, these impacts are increasingly widespread. There are proven techniques to pass



Case Studies: McPhee Reservoir, CO dredging

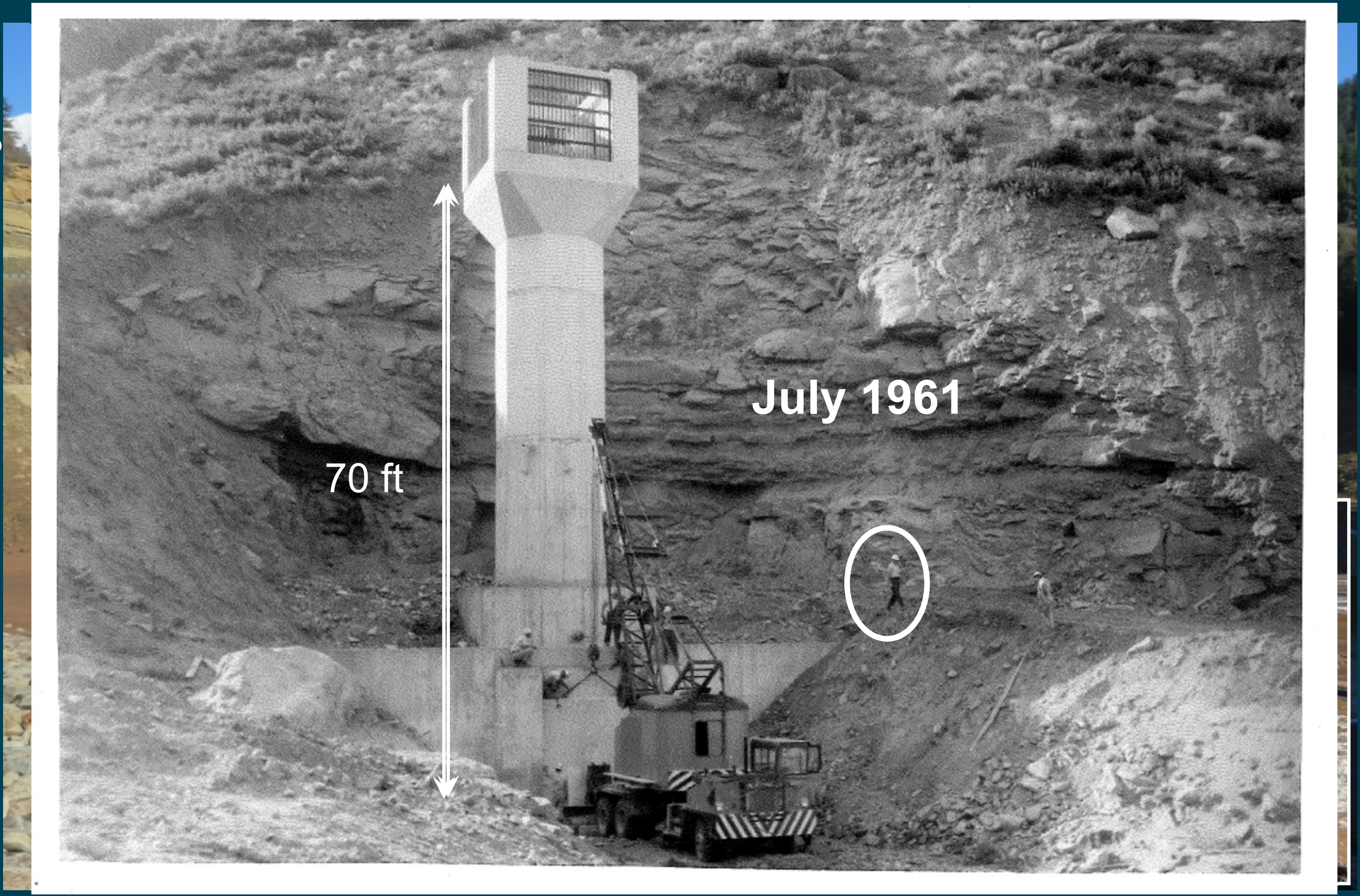
- Located on the Dolores River 10 miles north of Cortez, CO
- Drought triggered reservoir dredging to remove sediment that blocked delivery of water to irrigation canals during the reservoir's lowest level.

4,470 surface acres
13,000 yd^3 dredged

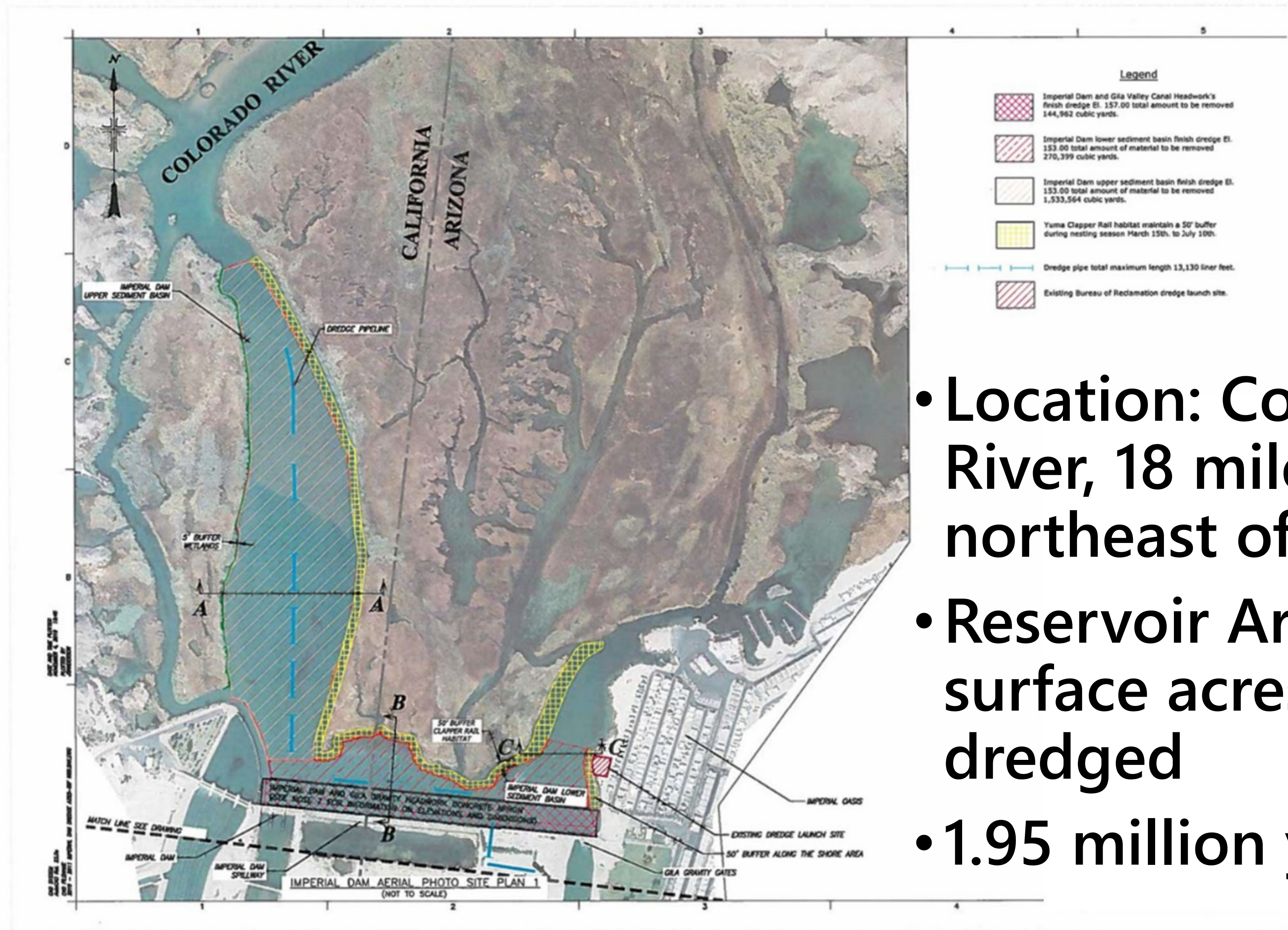
Paonia Reservoir, CO

- Location: Muddy Creek, a tributary of the North Fork of Gunnison River in western Colorado
- Reservoir Area: Approximately 315 surface acres at full pool
- 8.75 million yd^3
- Large wood at intake
- Spring sluicing

Case Studies: Paonia Dam and Reservoir, CO



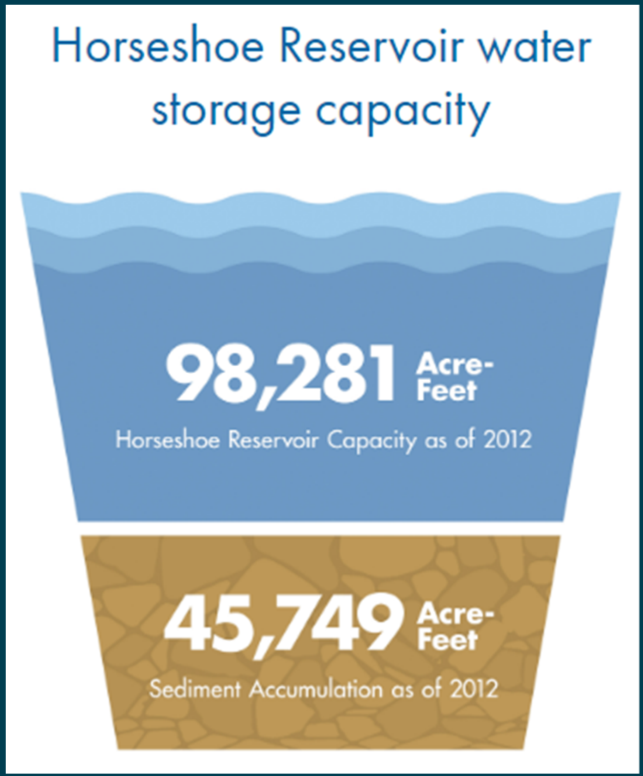
Case Study: Imperial Reservoir, AZ/CA



- Location: Colorado River, 18 miles northeast of Yuma
- Reservoir Area: 69 surface acres are dredged
- 1.95 million yd^3

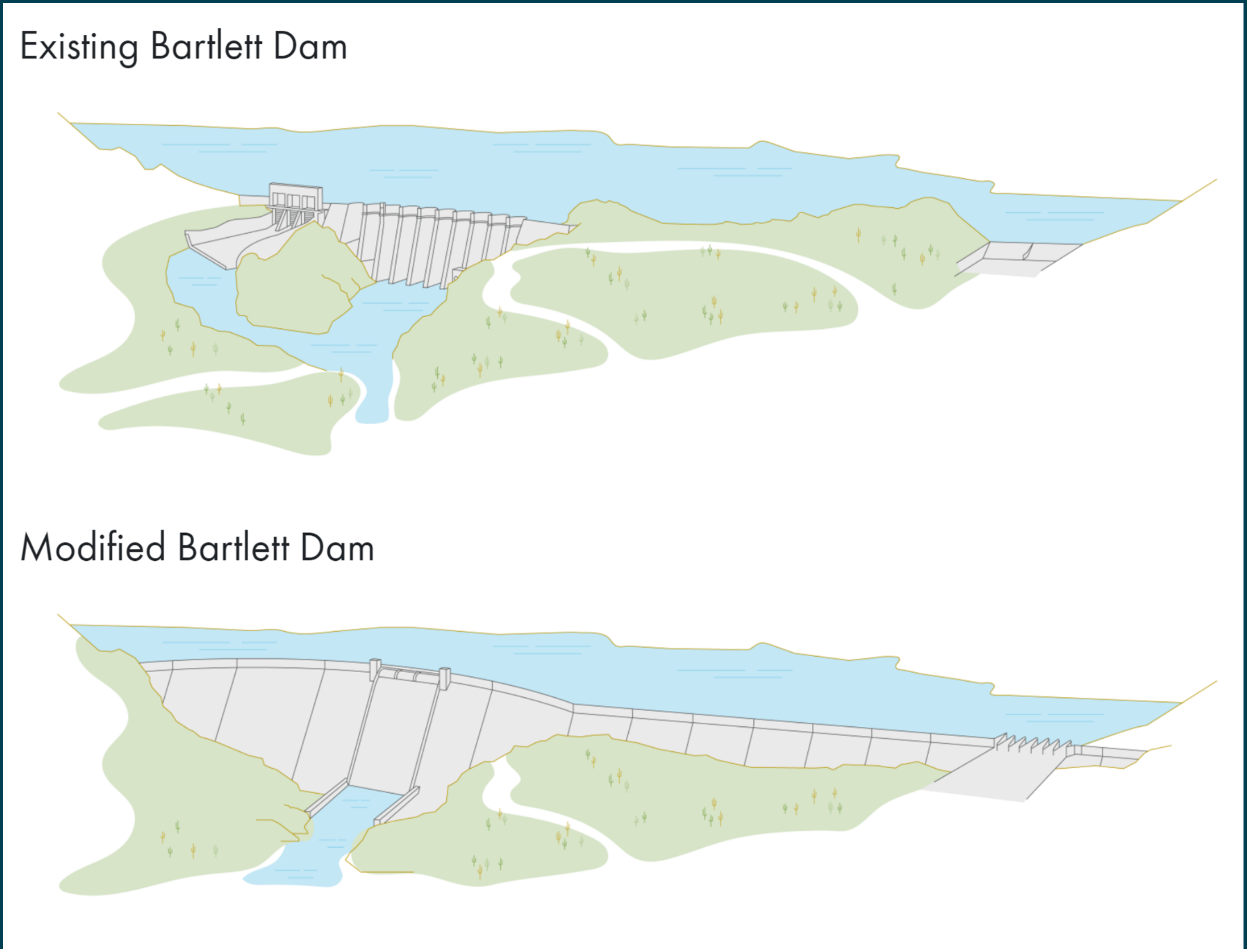
Horseshoe Reservoir, AZ

- Location: Verde River
- Reservoir Area: 2722 surface acres
- 74 million yd^3
- Considering enlarging downstream Bartlett Dam



https://www.srpnet.com/water/dams/horseshoe-sediment.aspx

Case Study: Enlarged Barlett Dam to replace Horseshoe Dam



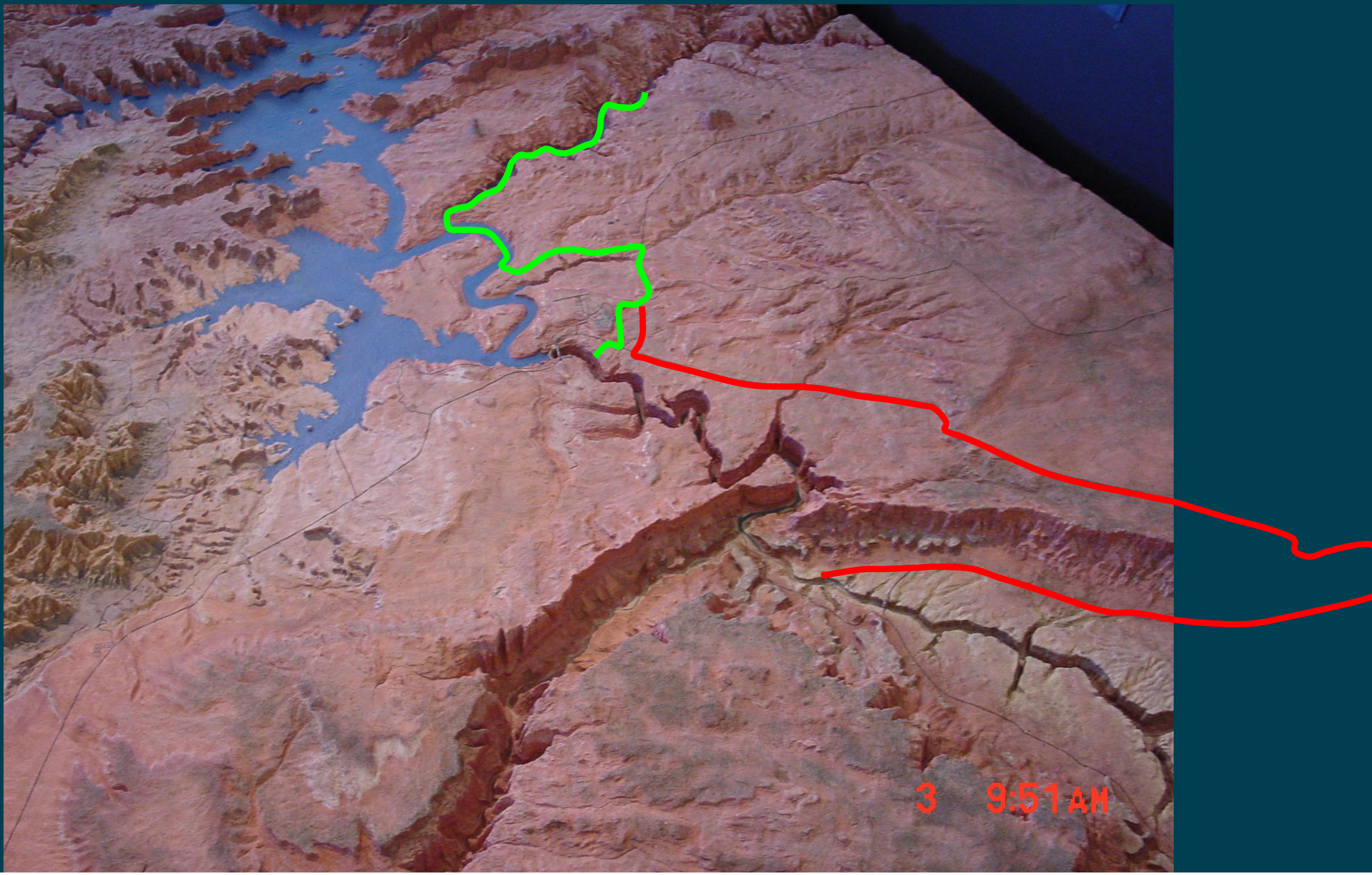
Case Study: Grand Canyon Sediment Augmentation Study

- Seasonally increase turbidity to provide cover for native fish.
- Annually increase sand supply to build larger sandbars, in conjunction with beach-building flows.

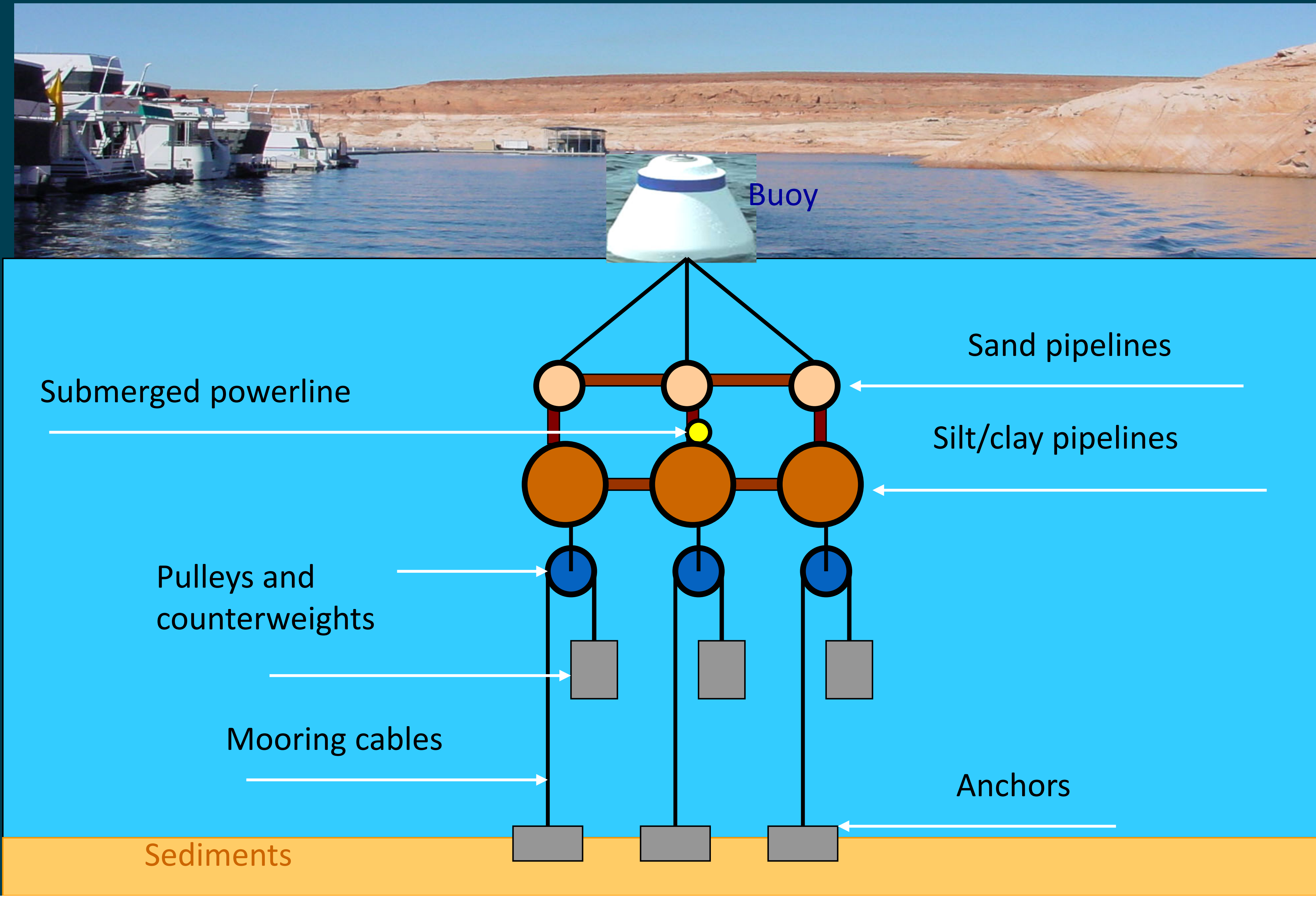

Endangered Humpback Chub

Grand Canyon sandbar

Proposed Lake Powell sediment slurry pipeline alignment



Concept for submerged slurry pipelines



Guardians of the Reservoir Prize Challenge

For More Information:
https://www.herox.com/GuardiansoftheReservoir

Sponsors:

Bureau of Reclamation

US Army Corps of Engineers ®

Contractors:

NASA Tournament Lab

herox

FEDTECH

Challenge Goal

- Develop and demonstrate innovative approaches that may have additional capabilities or efficiencies over existing sediment removal solutions.
- Looking for technologies that will annually move sediment downstream.

Limitations of Current Methods

Expense

- Dredging can cost more than $\$20/yd^3$

Durability and reliability

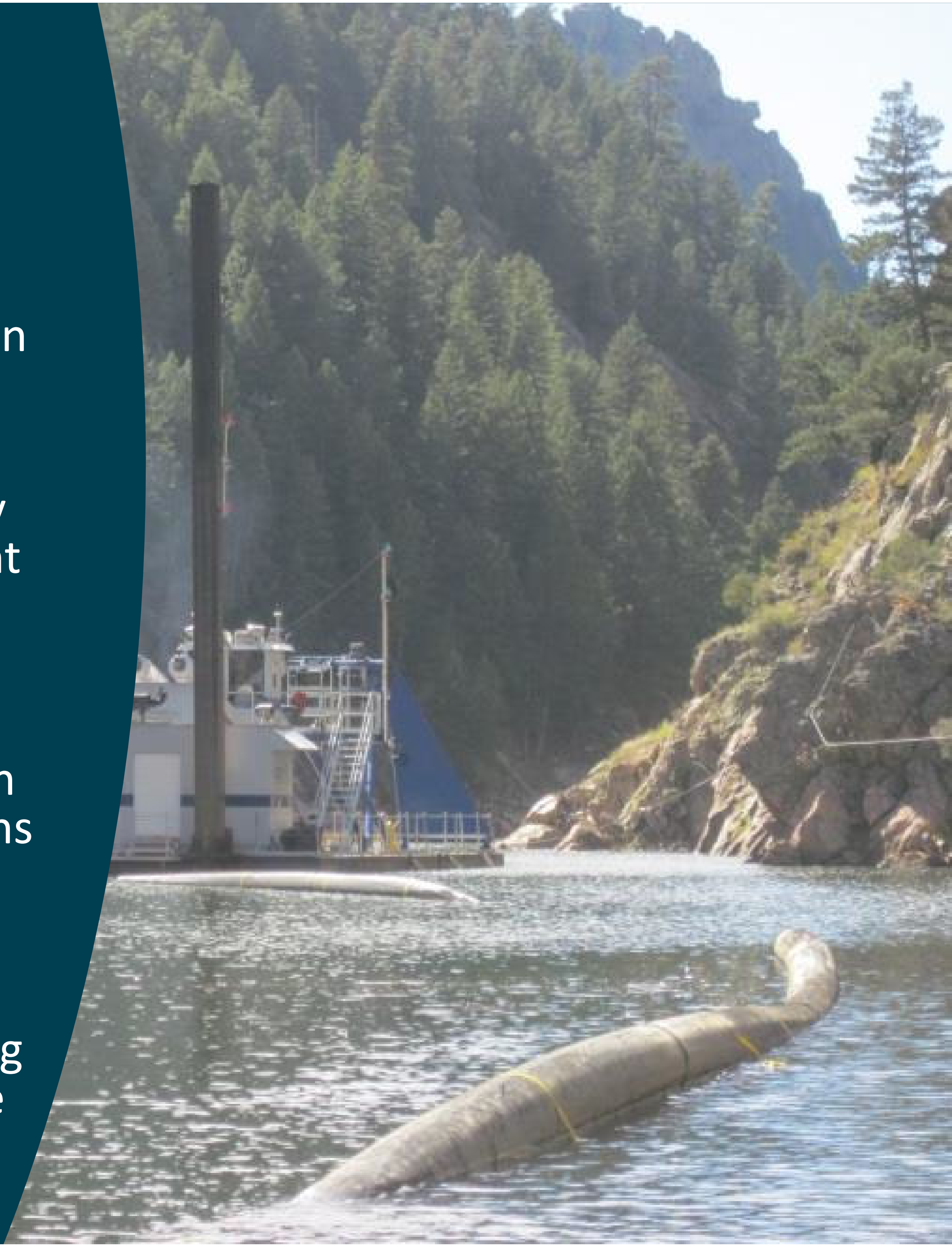
- Sand and gravel can be very abrasive, causing equipment failure and downtime

Versatility

- Reservoirs have different shapes, sizes, fluctuations in stage, and many have depths greater than 50 ft and long lengths

Water loss

- Reservoir flushing or sluicing uses valuable water storage



Solution Constraints

- Must not cause significant reservoir drawdown.
- Must be able to coexist with recreational activities, without limiting access to large areas of the reservoir or endangering visitors.
- Should not release harmful materials into the water or the air and should not endanger wildlife.

Challenge Summary

- Phase 1: Proposals
  - Five teams won $75,000 each to further develop their proposed solution and compete in Phase 2
- Phase 2: Lab-scale demonstration
  - Teams received technical support, mentoring, and business plan development guidance to further advance their idea
  - 3 teams won $25,000 and advanced to Phase 3
- Phase 3: Lab or field-scale demonstration

  We are here
  - The top three teams have 13 weeks to complete a lab or field scale demonstration to be judged in August 2022
  - Top team wins $100,000!

3D DREDGER™

- Nicholas LaBry and Kenneth LaBry of Prometheus Innovations, LLC., and Bartolomeo Mongiardino of Hydro Maintenance Service, Louisiana, Complete Sediment Management
- Developing a fully autonomous dredging system designed to handle sediment and larger debris using three dredging attachments.
- System designed for deployment in any environment, without impacting operation or recreation.

D-Sediment

- Dr. Michael Detering Laura Backes, and Joana Kueppers, Germany, Sediment Continuity and Restoration
- Developed the SediMover technology as an autonomous vessel for efficient 24/7 sediment transfer from reservoirs.
- Patented and scalable, modular technology can be used for downstream river sediment continuity or sediment land processing.
- Generally no limits in control, transfer range, and scope. The transfer is measured constantly onboard and is documented.

Mazdak International

- Baha Abulnaga, Washington, High Volume Deep Dredging for Low Water De-silting
- Developing a new technology based on 3 steps: (1) a deep dredging slurry piston pump engine, (2) dewatering sediments in settling ponds, and (3) hydraulic capsule pipelines to transport dewatered sediments in dry or semi-dry form (NSF grant).
- Technology is based on minimizing water and power consumption and reducing abrasion in pumps and pipelines.

Questions and discussion