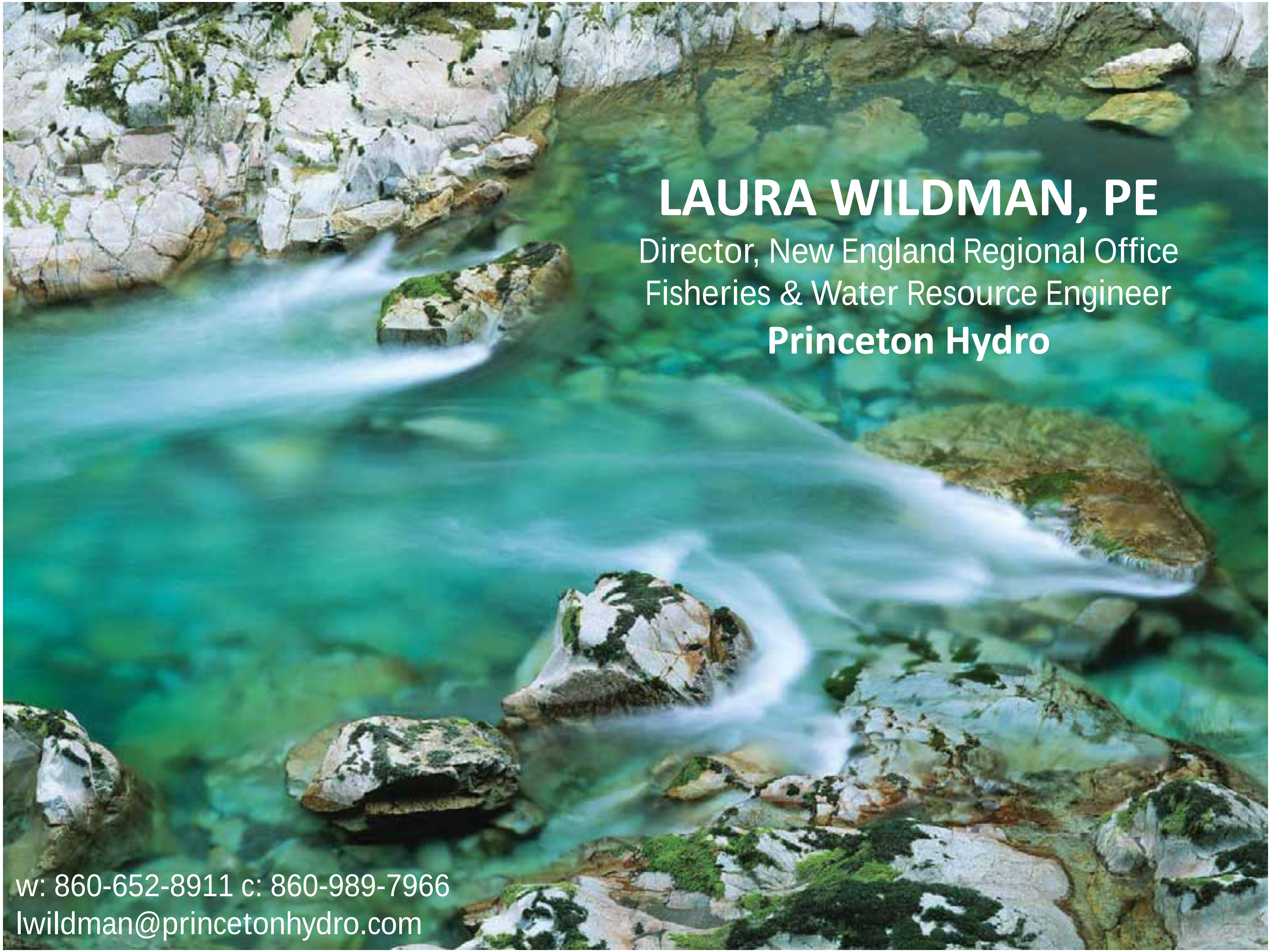

LAURA WILDMAN, PE

Director, New England Regional Office
Fisheries & Water Resource Engineer
Princeton Hydro

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lwildman@princetonhydro.com

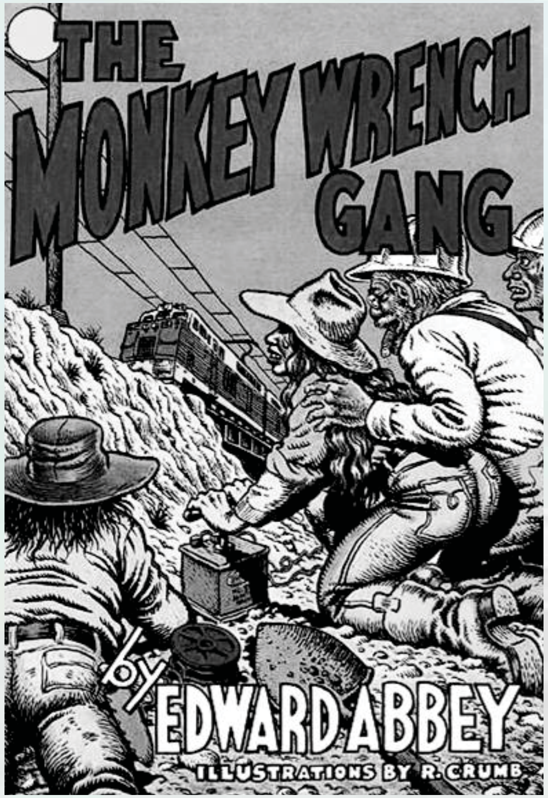
DAM REMOVAL

DAMNED *(BY SOME)*
IF YOU DO
DAMMED
IF YOU DON'T

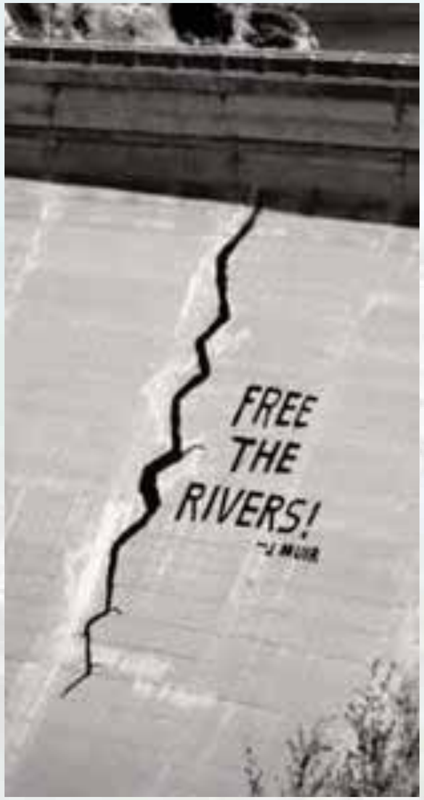
- Why Remove Dams?
- How We Analyze Dams for Removal
- What We are Learning Through a Wide Diversity of Case Studies
- Potential Differences Between Dam Removal in the USA and Europe

WHY REMOVE DAMS?

IS DAM REMOVAL JUST "CRAZY TALK" FROM HOPELESS ENVIRONMENTAL DREAMERS?



Edward Abby's infamous 1975 fiction on environmental vigilantes



John Muir's quote placed on the O'Shaughnessy Dam in 1987

Henry David Thoreau "A Week on the Concord and Merrimack Rivers" 1849 (1839 paddle)

Poor shad! Where is thy redress? When Nature gave thee instinct, gave she thee the heart to bear thy fate? Still wandering the sea in thy scaly armor to inquire humbly at the mouths of rivers if man has perchance left them free for thee to enter...armed only with innocence and a just cause...I for one am with thee, and who knows what may avail a crow-bar against that Billerica Dam?

IS DAM REMOVAL JUST "CRAZY TALK"

You do what for a living? Why would you want to remove a dam, they are so pretty?

Princeton Hydro

pH

Laura AS Wildman, P.E.

~~Fisheries & Water Resource Engineer~~

Remover of Waterfalls

931 Main Street
South Glastonbury, CT 06073

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Rainbow Removal and Unicorn Extermination at no extra charge

THE PUBLIC DOESN’T HAVE THE SAME ATTITUDE WHEN IT COMES TO REMOVING ABANDONED BUILDINGS AND BRIDGES

Lower Case Pond Dam, CT

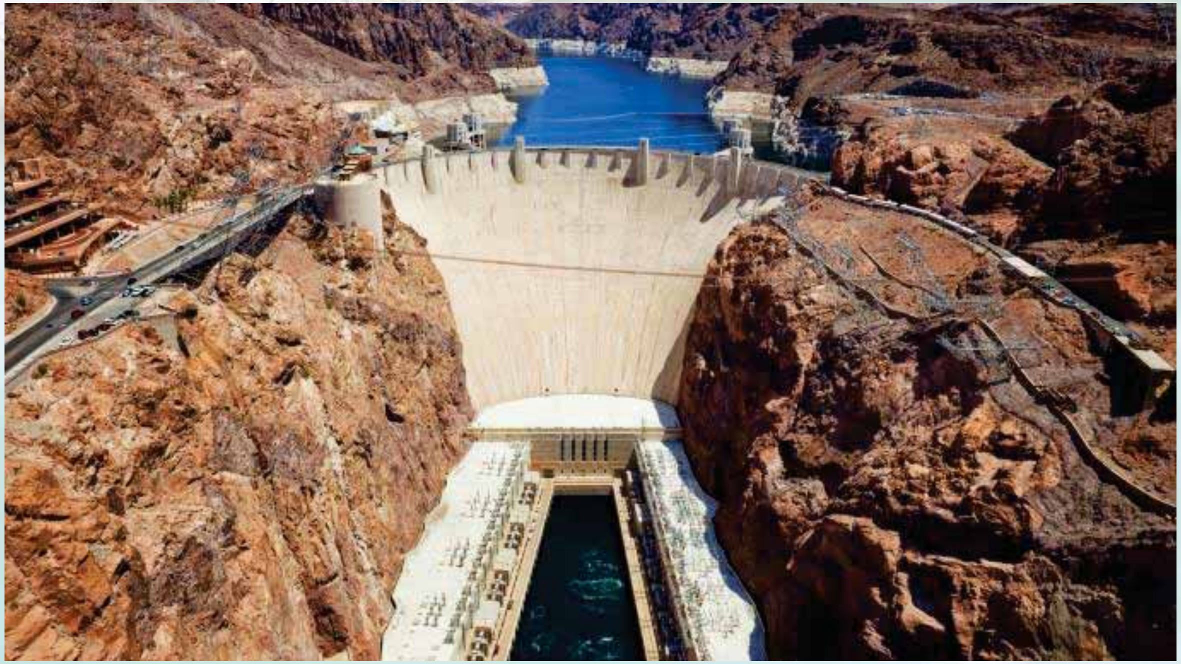
NO

We are NOT trying to remove this historic dam at the head of a waterfall

We DID remove this breached industrial dam that was actively undermining a sewer line

YES

Anaconda Dam, CT



Hoover Dam

NO

We are NOT trying to remove Hoover Dam

(well maintained, iconic, multiple purposes)

We ARE trying to remove this abandoned, sediment filled dam

YES

Rindge Dam, CA

We are NOT trying to remove this recreational dam with multiple lakeside homes, even though it has significant safety hazards

NO

Lake Wyola Dam, MA

We ARE trying to remove this environmentally damaging dam with no economic purpose

YES

Wonoosquatucket River Dam, RI

And not just because my grandfather built it

NO

We are NOT trying to remove active water supply dams
(or flood control dams)

Bartlett Water Supply Dam, AZ

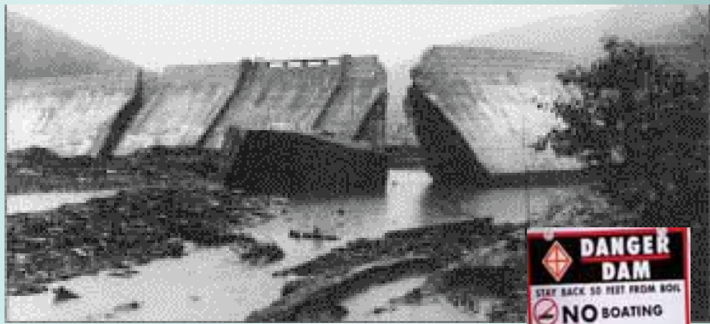
We DID remove this environmentally damaging dam and built a new water intake for the factory

YES

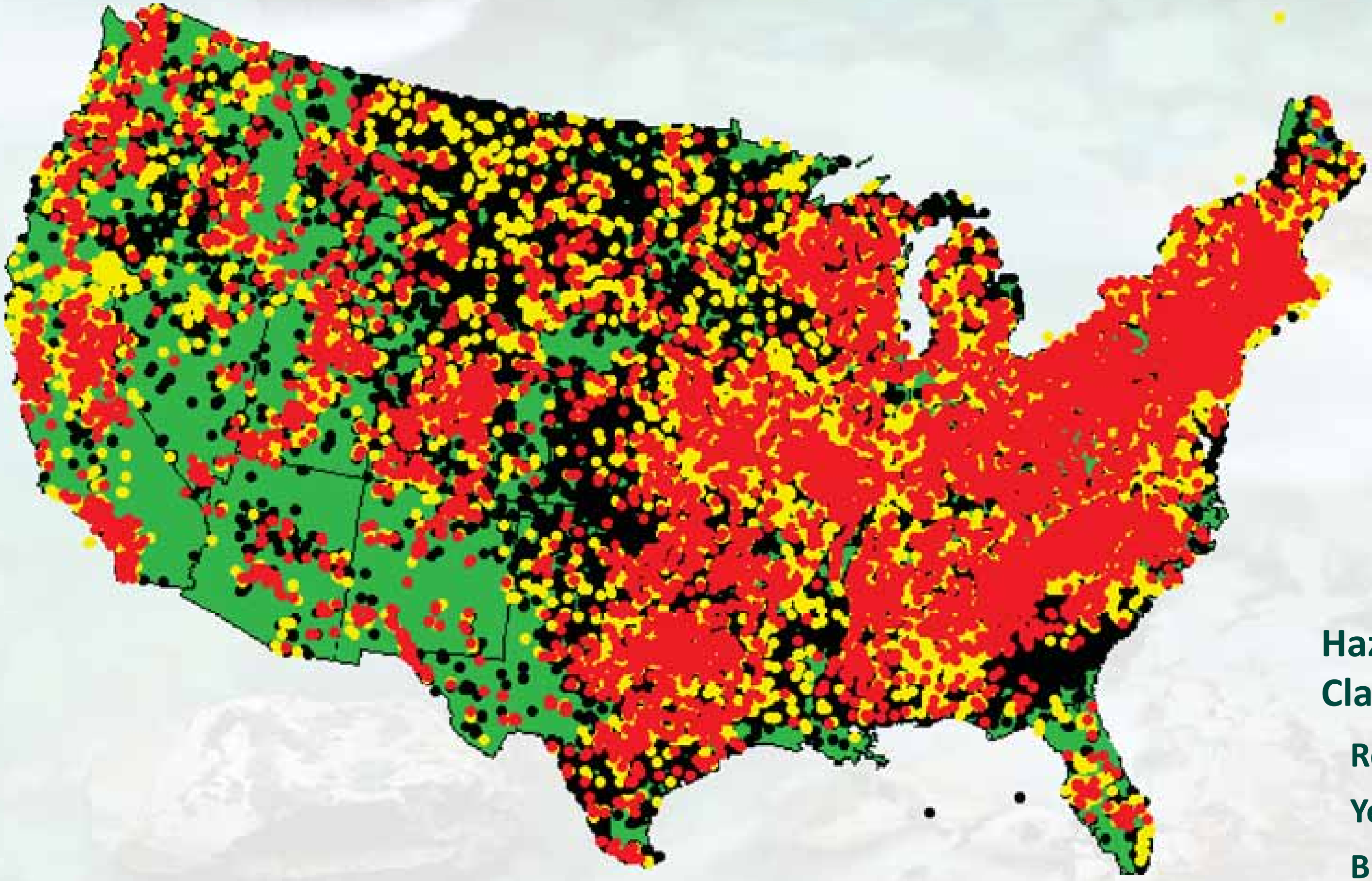
Great Works Dam, ME

Why Remove Dams?

1. Economic
   - Loss of original purpose
   - Maintenance (i.e. dam safety regulations)
   - No longer economically justified
2. Dam Safety
   - Aging dam structure
   - Reservoir sedimentation
   - Dam failure
   - Attractive nuisance
   - Liability
3. Environment
   - Environmental impact is too great
   - Proactive restoration (river, fish, WQ, sediment, etc.)



WE HAVE A LOT OF DAMS IN THE U.S.A.



Hazard Classifications

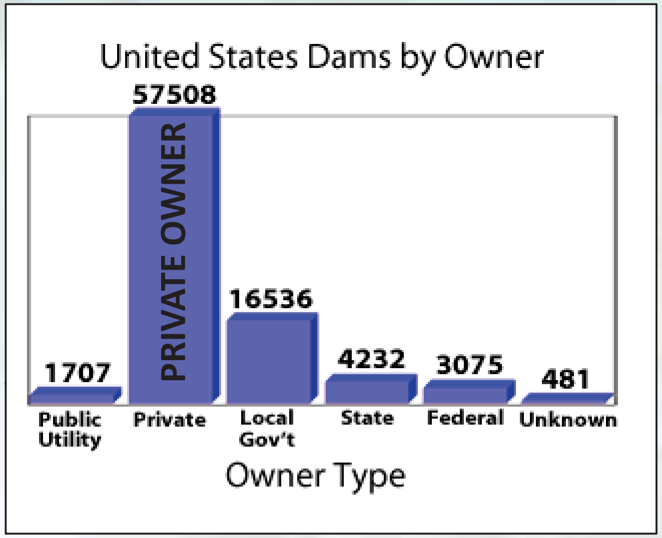
Red: High

Yellow: Significant

Black: Low

- **National Inventory of Dams >87,000 Dams** (>25 ft w/ 15ac-ft capacity or >6ft w/ 50ac-ft capacity)
- **~99,000 Dams regulated by states & in the USFWS Barrier Database**
- **Potentially Several Million Dams** Status Report on the Nation's Floodplain Management Activity, 1989

DAMS ARE AGING & MAINTENANCE COSTS ARE RISING



Source: National Inventory of Dams

- The vast majority of dams in the US are privately owned
- US Dam Safety Regulations require that most dams be maintained
- # of deficient dams in the US is increasing faster than repairs
- $57 billion needed to repair dams (2013 Dam Report Card ASDSO)

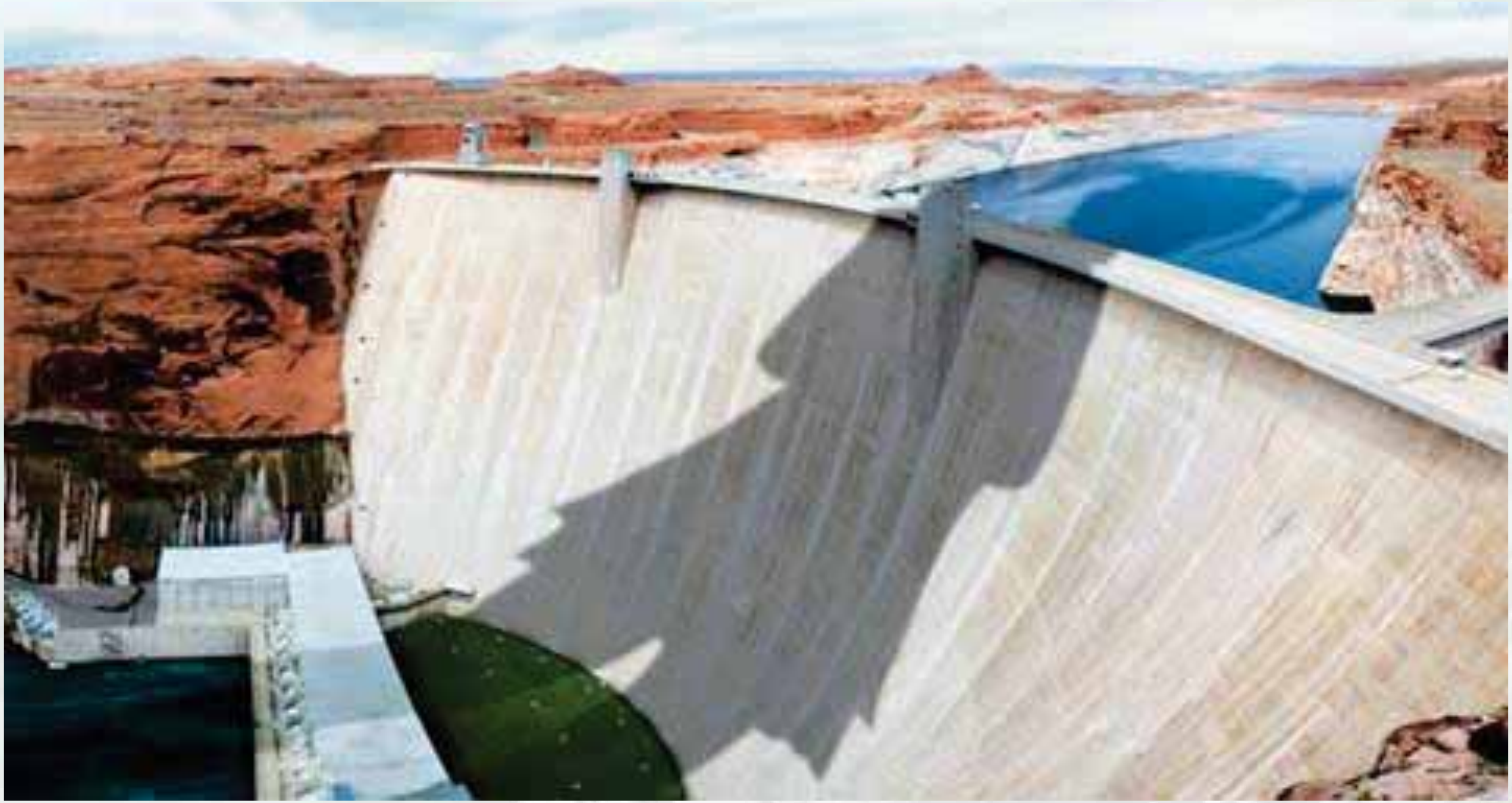
Source: Association of State Dam Safety Officials from The Cost of Rehabilitating Our Nation's Dams: A Methodology, Estimate, and Proposed Funding Mechanism and http://www.infrastructurereportcard.org/dams/

MAINTAINING DAMS IS NOT AS FUN AS BUILDING OR REMOVING THEM

"Infrastructure is like Legos, building is fun, destroying is fun, but a Lego maintenance set would be the most boring #$%^@! toy in the world.

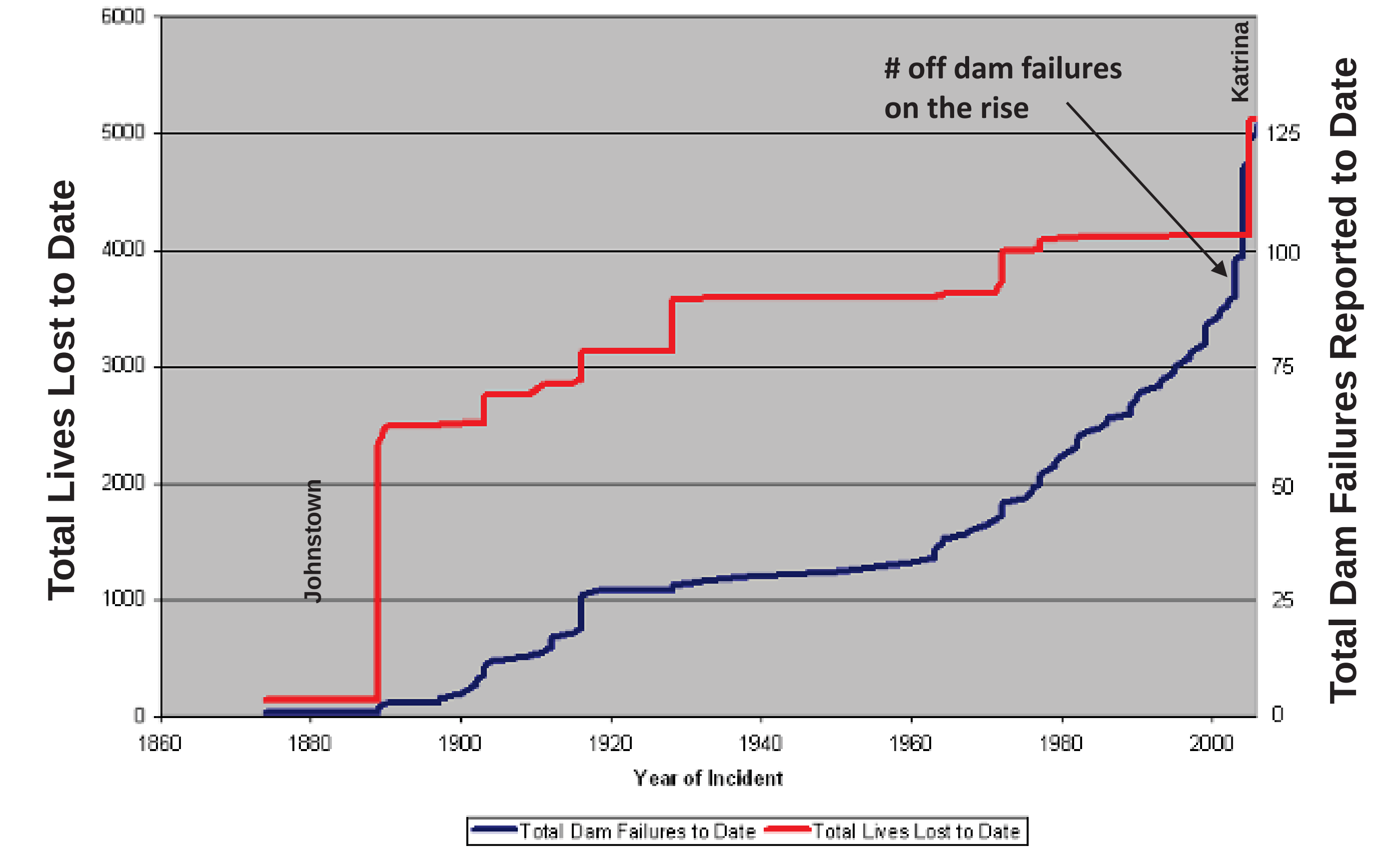
It comes built and then you maintain it, and if you do it right nothing happens and eventually you die." *John Oliver, Last Week Tonight*

BUT UNFORTUNATELY WE DON'T HAVE A GIANT BORED CHILD WATCHING OVER ALL OF OUR DAMS



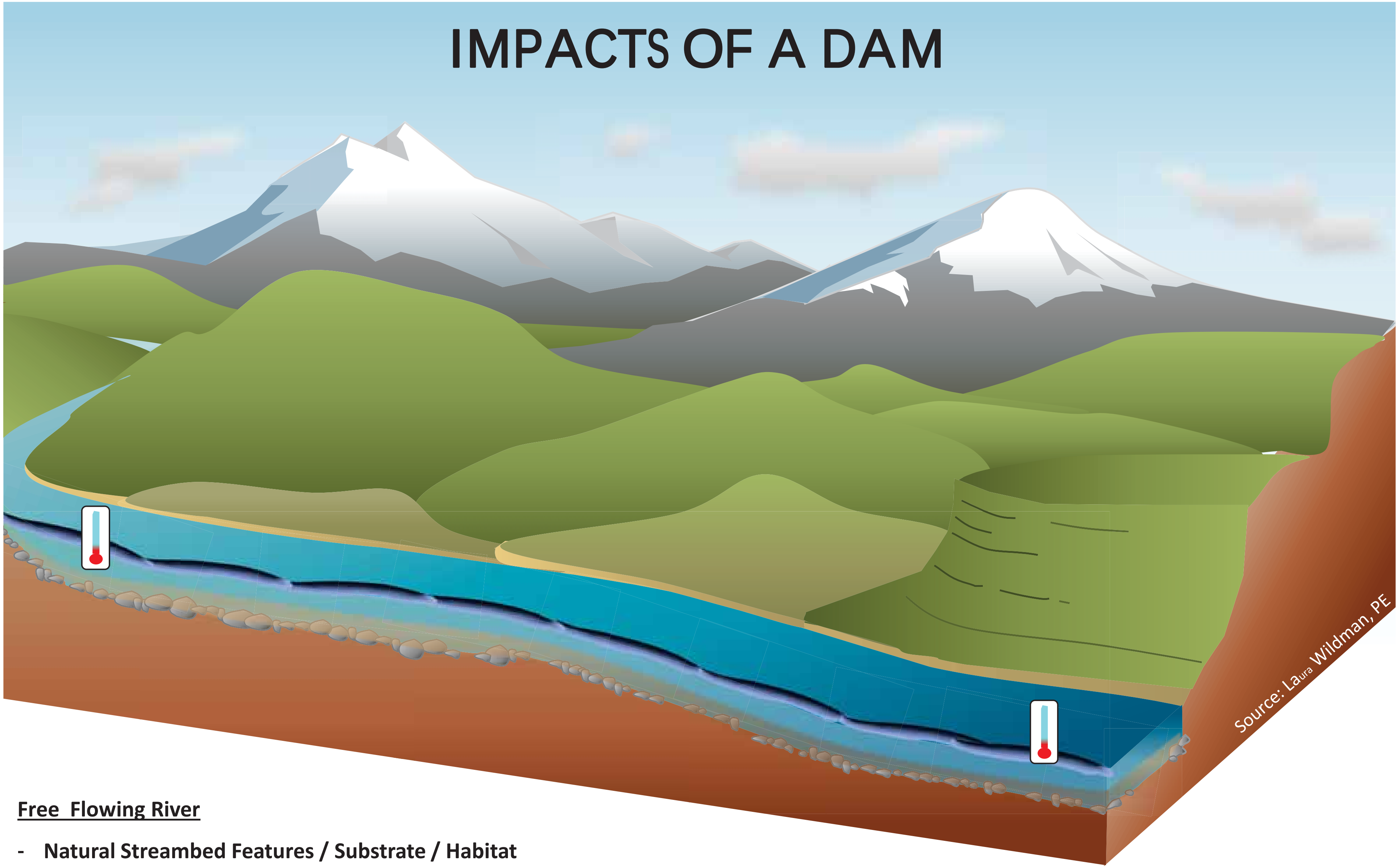
Source: Lego

DAMS FAILURES ARE ON THE RISE IN THE U.S.A.



Update: 2005-2013, 173 dam failures and 587 "incidents" reported

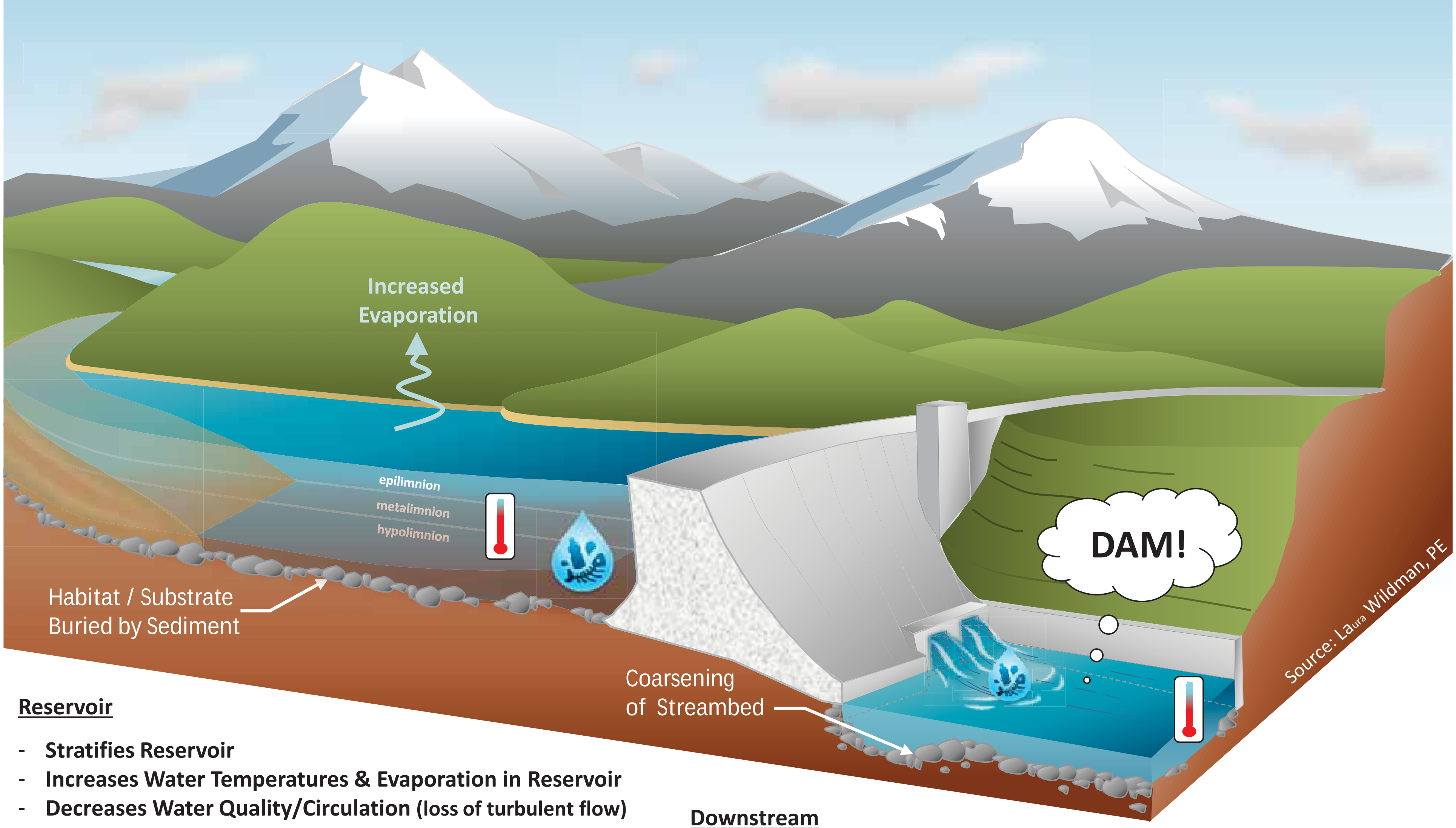
Source: ASDSO



Free Flowing River

- Natural Streambed Features / Substrate / Habitat
- Turbulent Flow Patterns
- Natural Temperature & Flow Regime
- Natural Transport of Sediments (suspended and bed load)
- Natural Transport of Debris & Nutrients
- Fish / Aquatic Organism Passage

IMPACTS OF A DAM



Reservoir

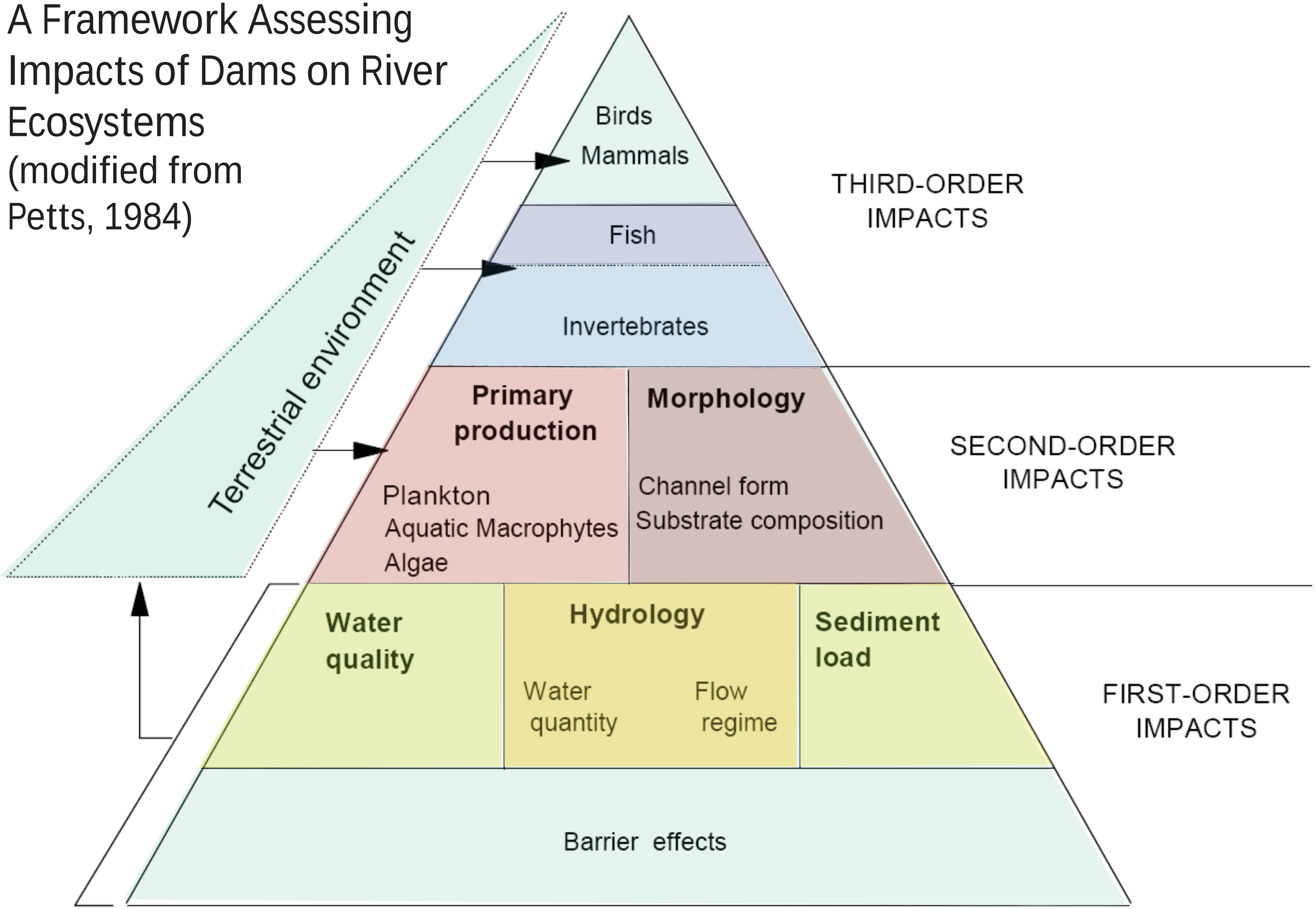
- Stratifies Reservoir
- Increases Water Temperatures & Evaporation in Reservoir
- Decreases Water Quality/Circulation (loss of turbulent flow)
- Depletes Oxygen Levels (may become anoxic)
- Creates Algae Blooms
- Blocks Nutrient & Debris Transport
- Traps Sediment
- Pollutants Accumulate in Sediment
- Blocks Fish Passage

Downstream

- Modifies Water Temperatures
- Decreased Water Quality
- Creates Nutrient Starved Conditions Downstream
- Alters Downstream Flow Regime
- Creates Sediment Starved Conditions Downstream / Riverbed Degrades

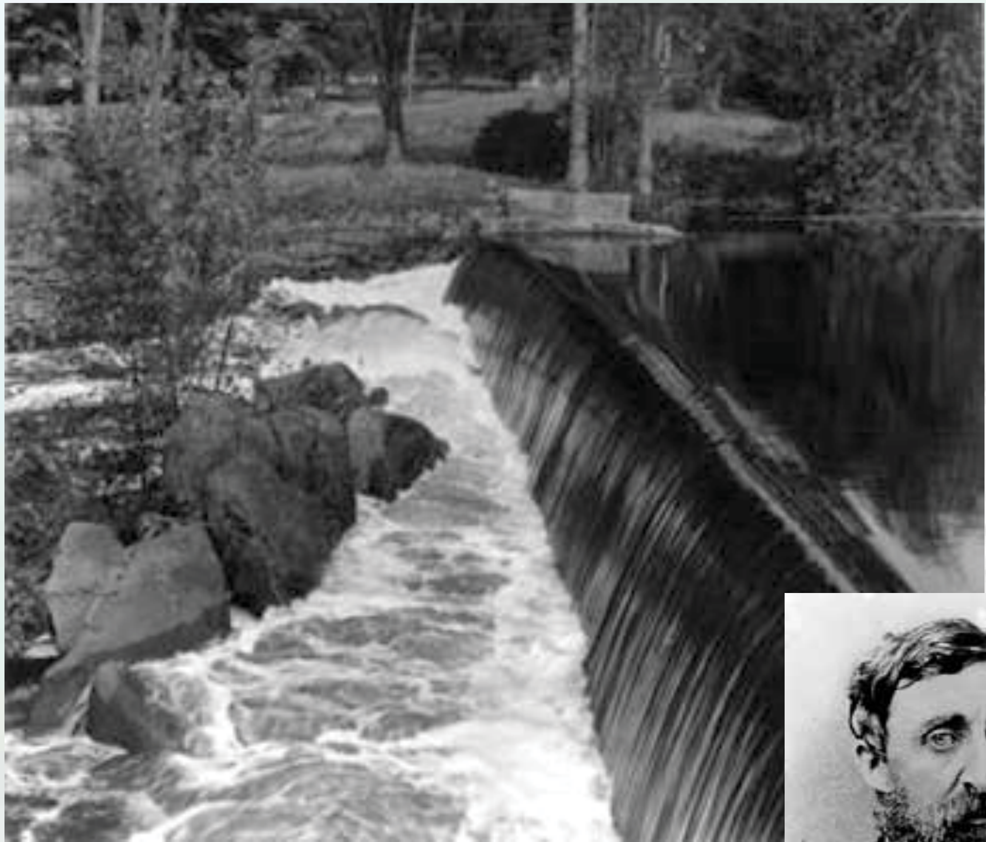
CASCADING ENVIRONMENTAL IMPACTS OF DAMS

A Framework Assessing Impacts of Dams on River Ecosystems (modified from Petts, 1984)



BUT WITH DAM REMOVAL, COMES CONTROVERSY

Billerica Dam, Concord River, MA



Henry David Thoreau was the surveyor for the farmers battling to remove the dam in 1861.

Henry French pleads with the Massachusetts Legislature, 1861:

"For generations, a painful and expensive controversy has existed in relation to [the Billerica Dam], and if [not removed now], **the children and children's children of these parties will be cursed with strife and contention"**

DAMN IF YOU DO, DAMMED IF YOU DON'T

As Predicted the Children and Children's Children Are Certainly Cursed with Strife and Contention

Winnemem Wintu Tribe war dance to protest Shasta Dam

"But not all of my job is about getting yelled at in public meetings"

ANALYZING DAMS FOR REMOVAL

Issues Assessed

ENGINEERING

DATA COLLECTION
TYPE & CONDITION OF DAM (dam safety)
SCALE OF PROJECT
SITE LIMITATIONS (Topo., Encroachment, etc.)
UPSTREAM & DOWNSTREAM IMPACTS
UTILITIES/INFRASTRUCTURE
SCOUR ASSESSMENT
PROJECT PERMITTING
ALTERNATIVES ANALYSIS
FIELD WORK AND CONDITIONS (survey, probes, photographs, resource delineation, etc.)
ENGINEERING COST ESTIMATES

HYDROLOGIC

WATERSHED HYDROLOGY
FLOODWATER STORAGE / ATTENUATION
IMPOUNDMENT DRAWDOWN/DEWATERING
WELL IMPACTS
GAUGING

HYDRAULIC

CHANNEL HYDRAULICS (& safety)
FLOODPLAIN HYDRAULICS
FLOODING IMPACTS
ICE JAMS
WATER INTAKES & DIVERSIONS
FLOOD MAPPING REVISIONS

FLUVIAL GEOMORPHIC

TESTING (probes, borings, samples)
SEDIMENT QUANTITY & QUALITY
SEDIMENT STABILITY/TRANSPORT
SEDIMENT MANAGEMENT
SEDIMENT DISPOSAL
CHANNEL MORPHOLOGY/DESIGN (equilibrium slope, form, function, process, materials, geomorphic assessment)
GEOLOGY/BEDROCK/GRADE CONTROLS
TRIBUTARY IMPACTS
REFERENCE REACHES
SITE RESTORATION

SOCIOECONOMIC

WHY REMOVE A DAM?
OWNERSHIP (Water Rights; Easements) & BUY-IN
ABUTTERS & OTHER USERS
CURRENT USES & ALT. USES (hydro., navigation, flood control, water supply, recreation, etc.)
AESTHETICS (mud flats, water fall, fear of unknown)
RECREATION
LIABILITY & PUBLIC SAFETY
ECONOMIC ISSUES & ANALYSIS
FUNDING
ARCHEOLOGICAL/HISTORICAL
SENTIMENTAL VALUE
PRESS & POLITICS

ECOLOGICAL

FISH: DIADROMOUS/RESIDENT/PASSAGE
AQUATIC HABITAT
HABITAT CONNECTIVITY
ECOLOGICAL STUDIES & INTERCONNECTIONS
VEGETATION / PLANTING PLANS
REGULATED RESOURCES (i.e. wetlands, wildlife invasives, etc.)
SPECIES OF SPECIAL CONCERN

WATER QUALITY

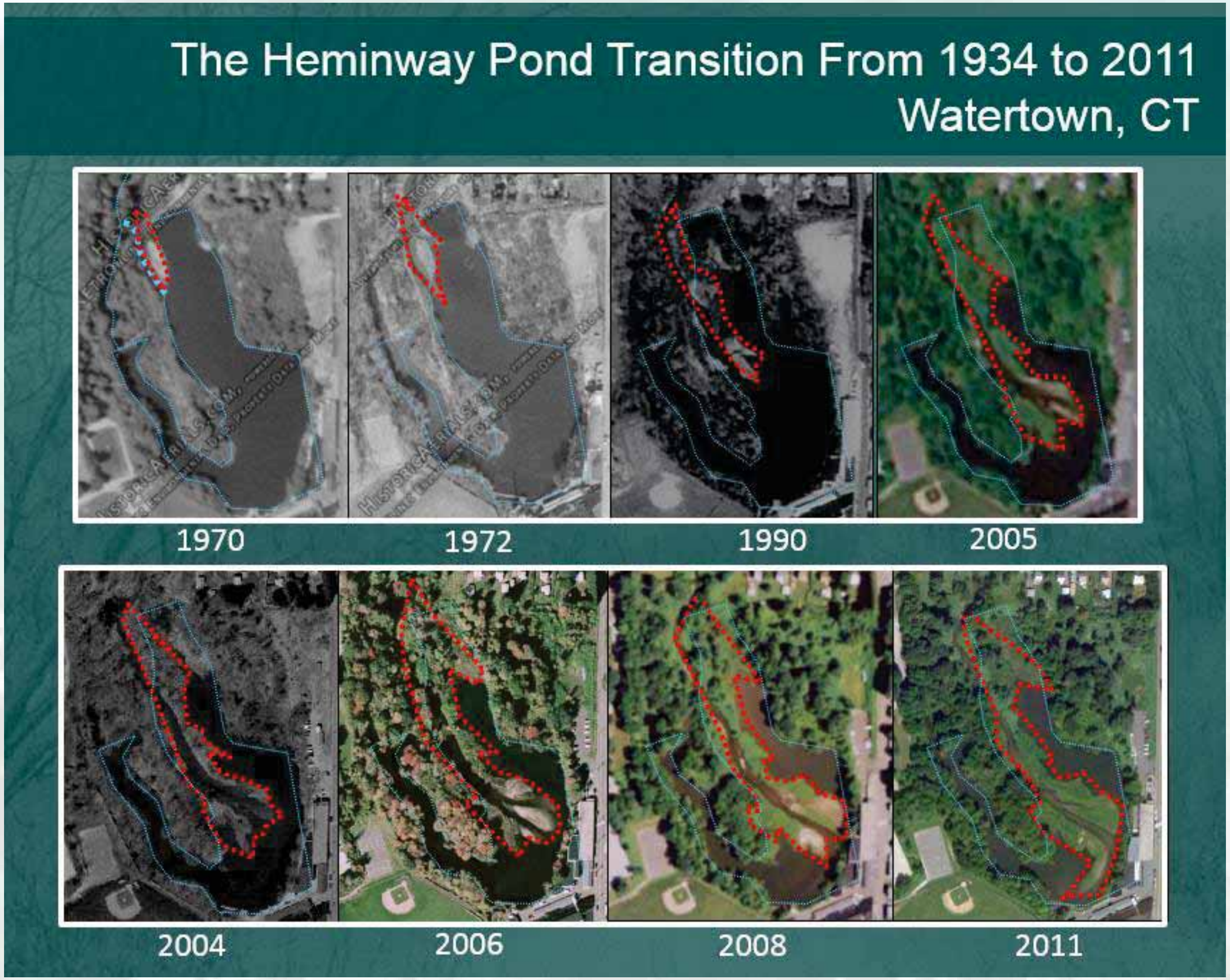
CHEMICAL PROPERTIES
PHYSICAL PROPERTIES (i.e. temperature, turbidity)
PUBLIC HEALTH
REGULATORY TRIGGERS, i.e. TOTAL DAILEY MAXIMUM LOADS (TMDLs)

CONSTRUCTION

SEASONAL CONSTRUCTION LIMITS/WEATHER
CONSTRUCTION ACCESS
CONSTRUCTION SEQUENCE
WATER CONTROL
CONSTRUCTABILITY
EROSION & SEDIMENT CONTROL
WORKING IN WET VS DRY
CONSTRUCTION COST
PROTECTING UTILITIES
BONDING
INSPECTION & OVERSIGHT
PRESS & THE PUBLIC
UNKNOWNS

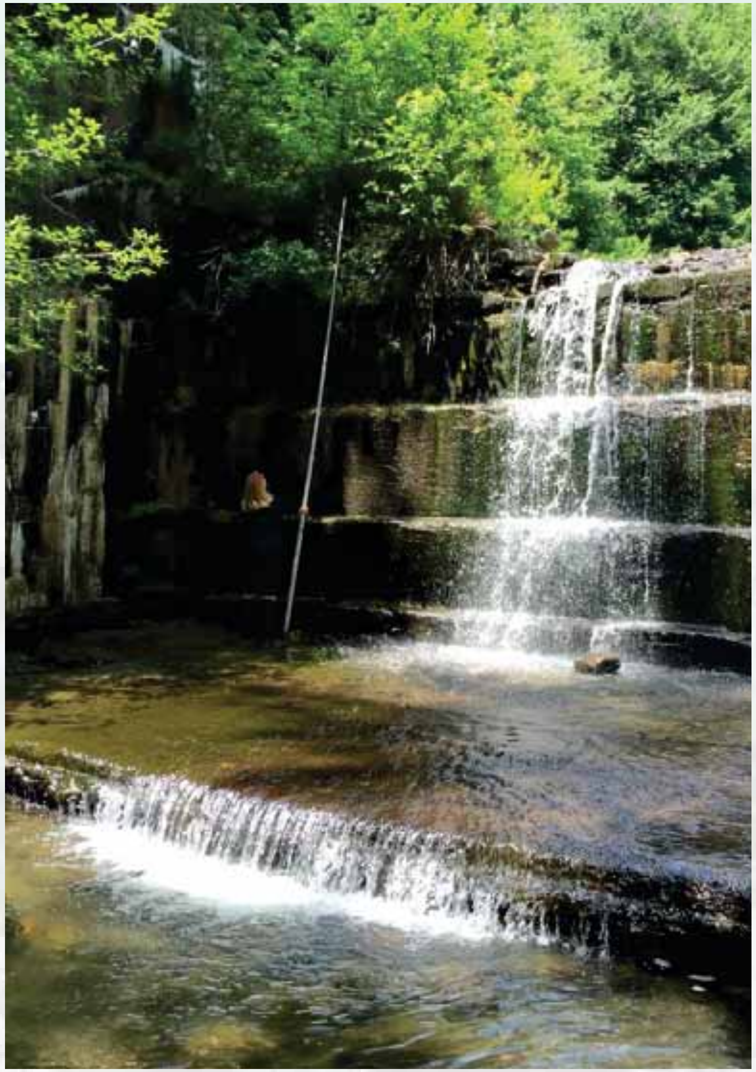
AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Identify project **goals** (i.e. fish passage, dam safety, water quality, etc.)
- Review/**discuss all potential project issues** (to determine what the key issues are)
- Determine **ownership** (dam, land & water rights)
- Investigate **available site data**



AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Conduct a **field investigation**

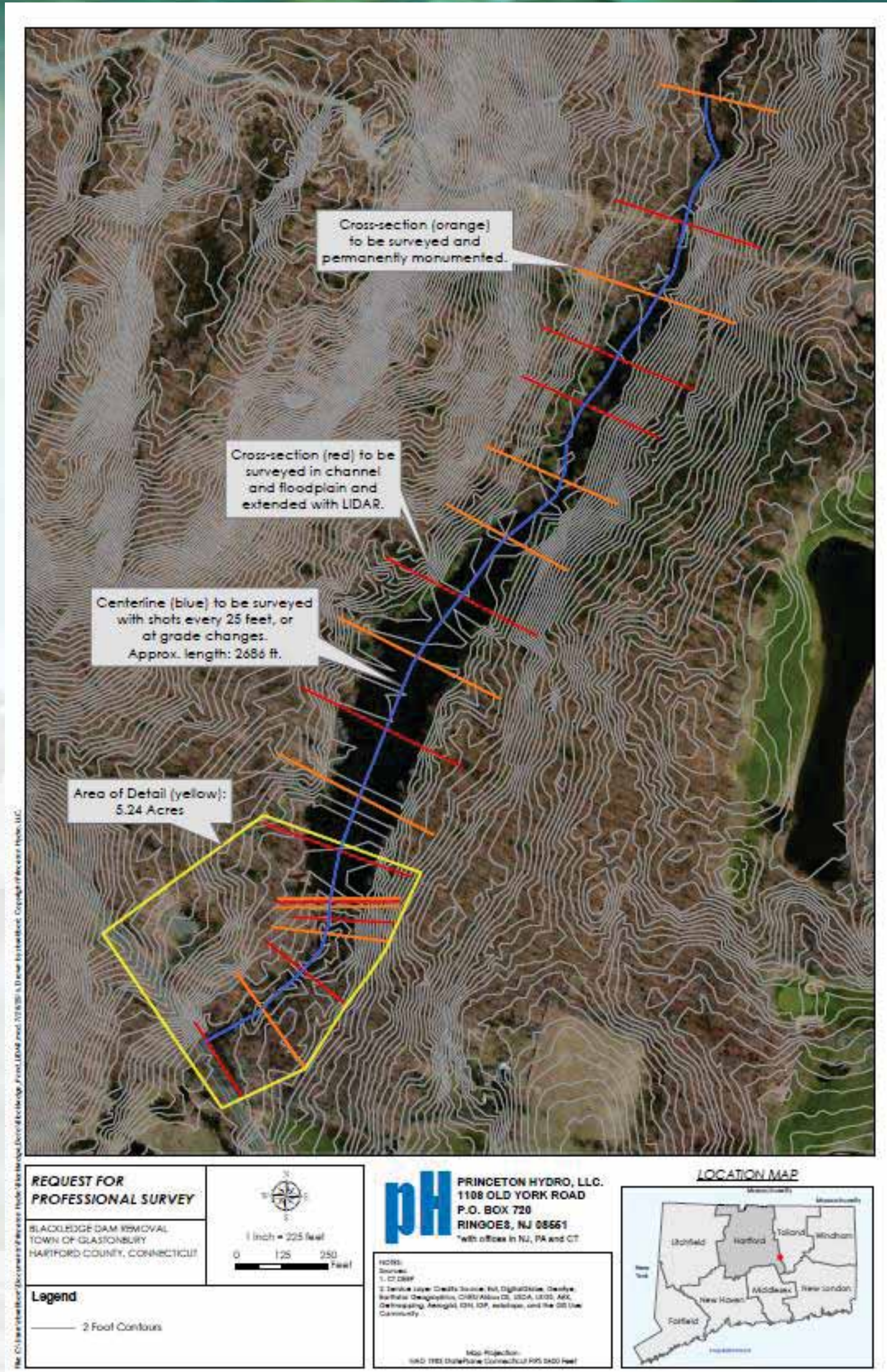


AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Identify **infrastructure/utilities** that could be impacted

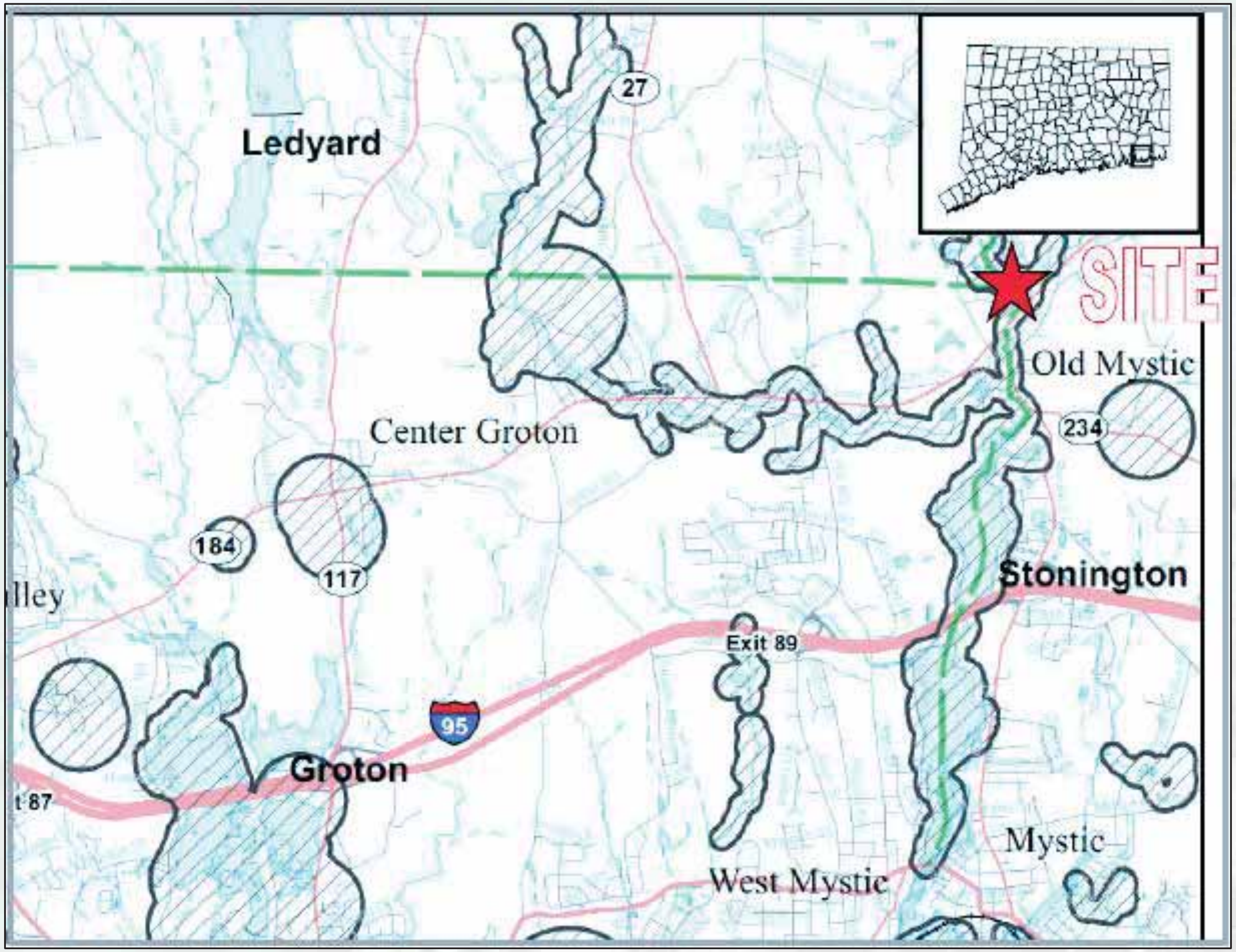
AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Conduct topographic, bathymetric and cross sectional **surveys** (often with monumenting)
- Delineate **regulated resources** (i.e. wetlands)
- Create **base mapping**



AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Determine if any **threatened or endangered species** could be impacted

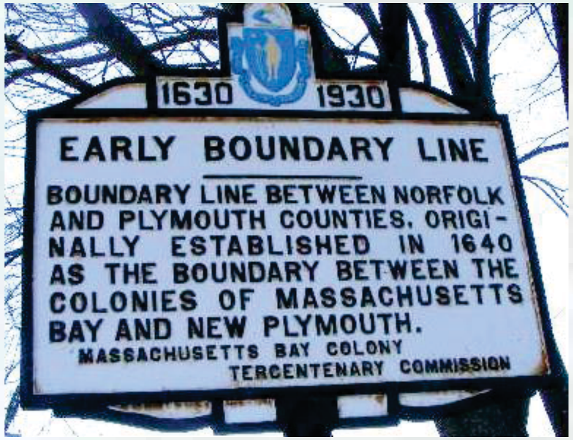


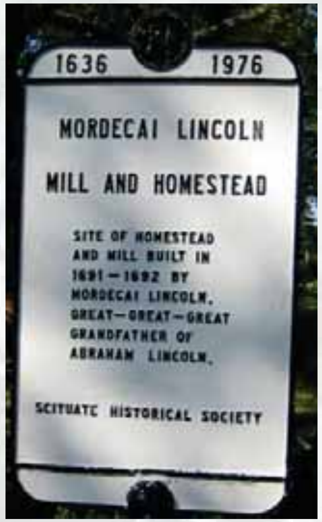
AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Conduct **sediment probes and testing** (chemical and physical)
- Develop a **sediment management plan**

AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

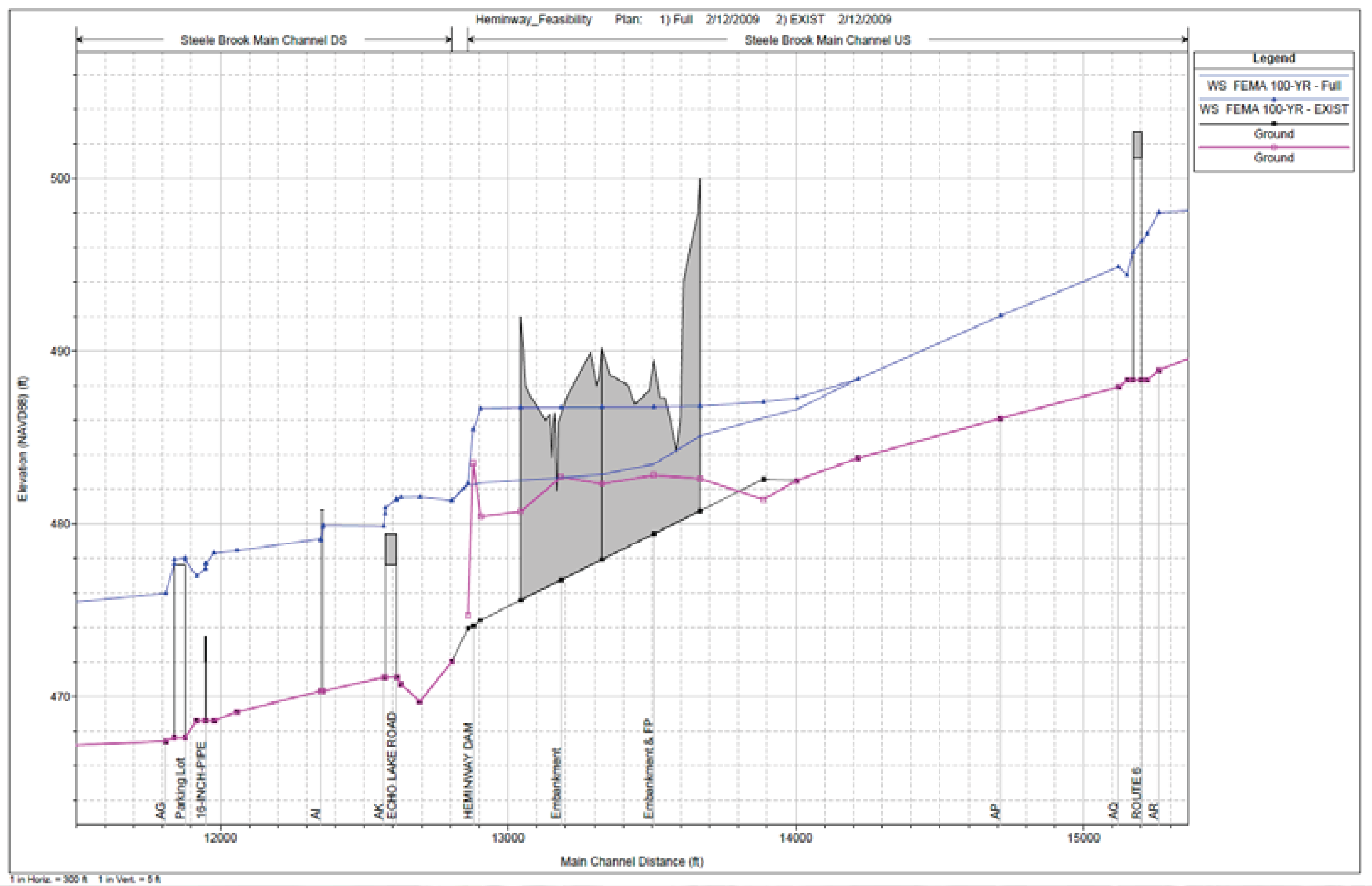
- Conduct a **historical/archeological** review





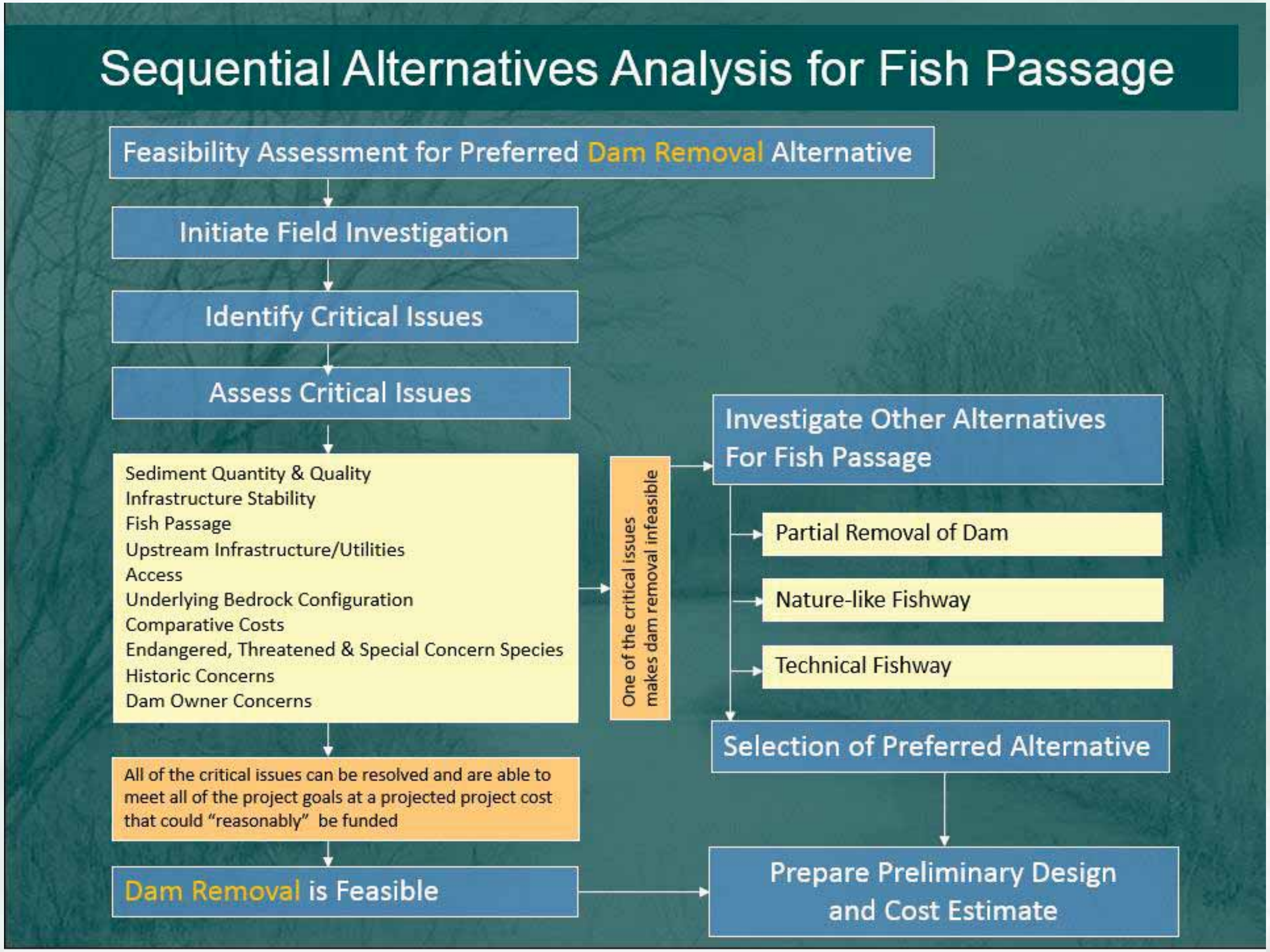
AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Analyze **hydrologic and hydraulic** conditions and develop a **water surface profile model** (existing and proposed conditions)



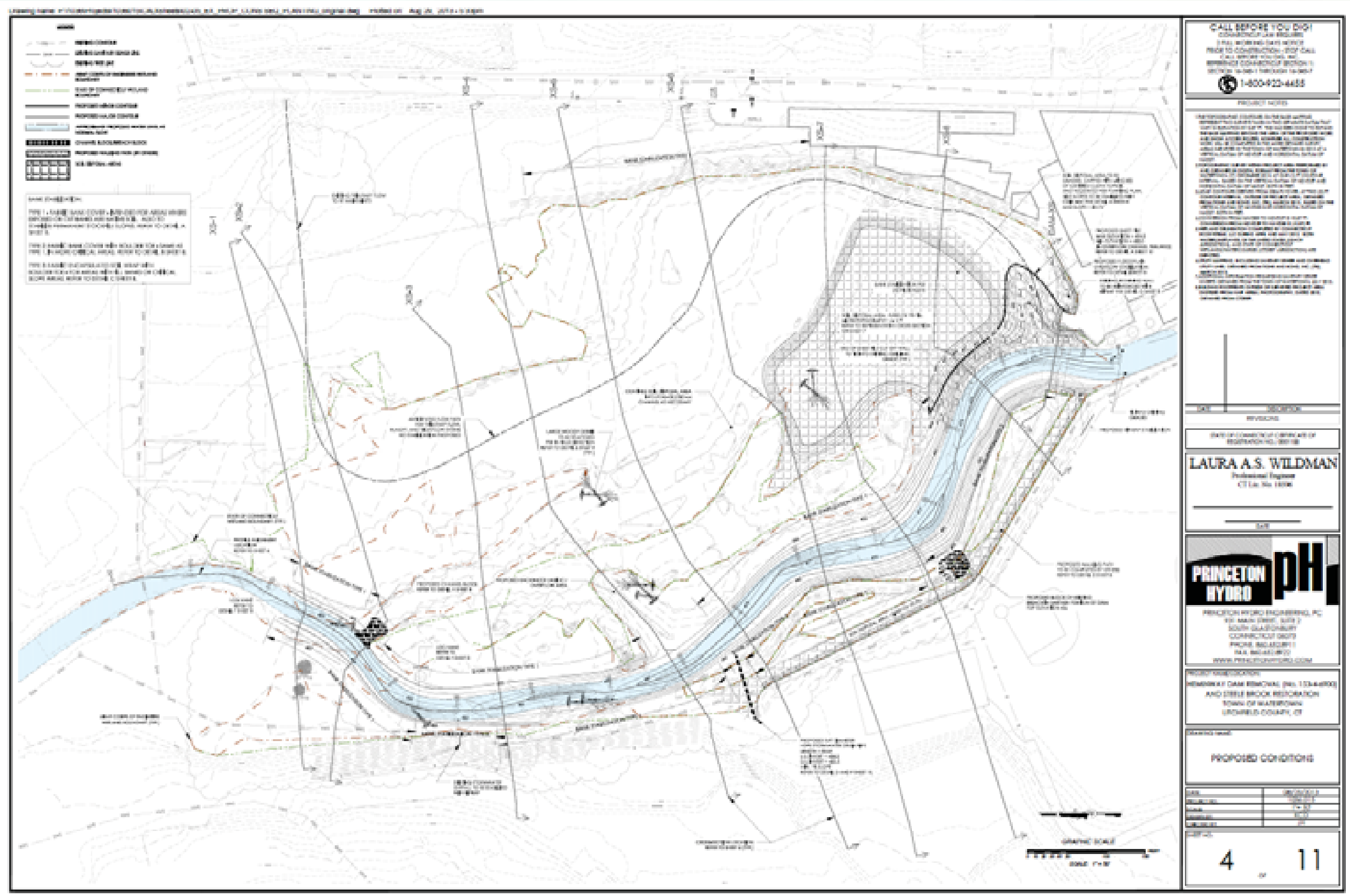
AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Assess **alternatives**



AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Prepare a **design report**
- Develop engineering **design plans**
- Develop a **construction cost estimate** (and technical specifications of going to bid)



AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Conducts **public outreach/meetings**
- Obtain regulatory **permits**

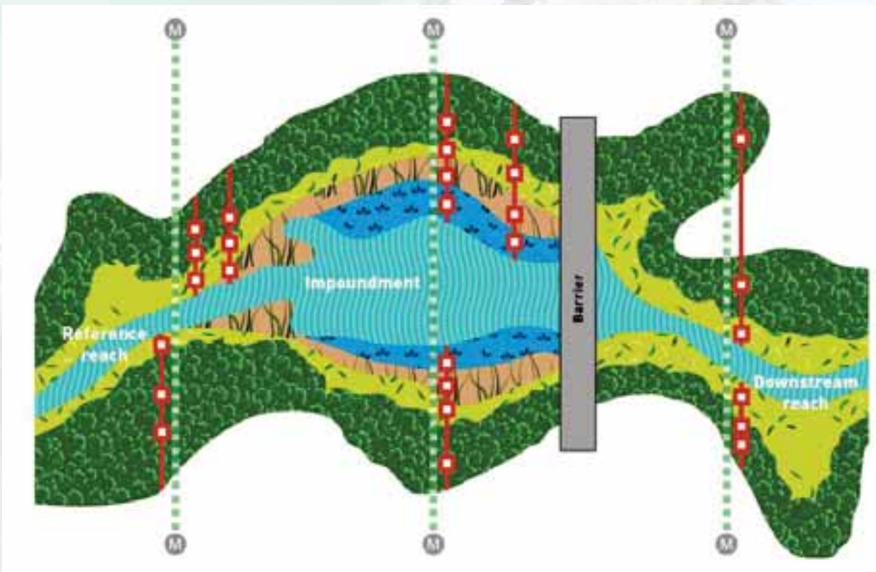
AT A MINIMUM, FOR ALL DAM REMOVAL PROJECTS, WE:

- Conduct Construction **Oversight**

THIS DATA CAN THEN BE USED AS THE PRE-REMOVAL DATA SETTING US UP FOR POST-REMOVAL MONITORING

DETAILED: When funds are available

RESOURCE MANAGEMENT FOCUSED: When funds are not available



http://www.gulfofmaine.org/streambarrierremoval/

8 CRITICAL PARAMETERS

A set of common monitoring parameters viewed by workshop participants as necessary to <u>adequately assess the physical, chemical, and biological response</u> of a stream reach to a barrier removal project.

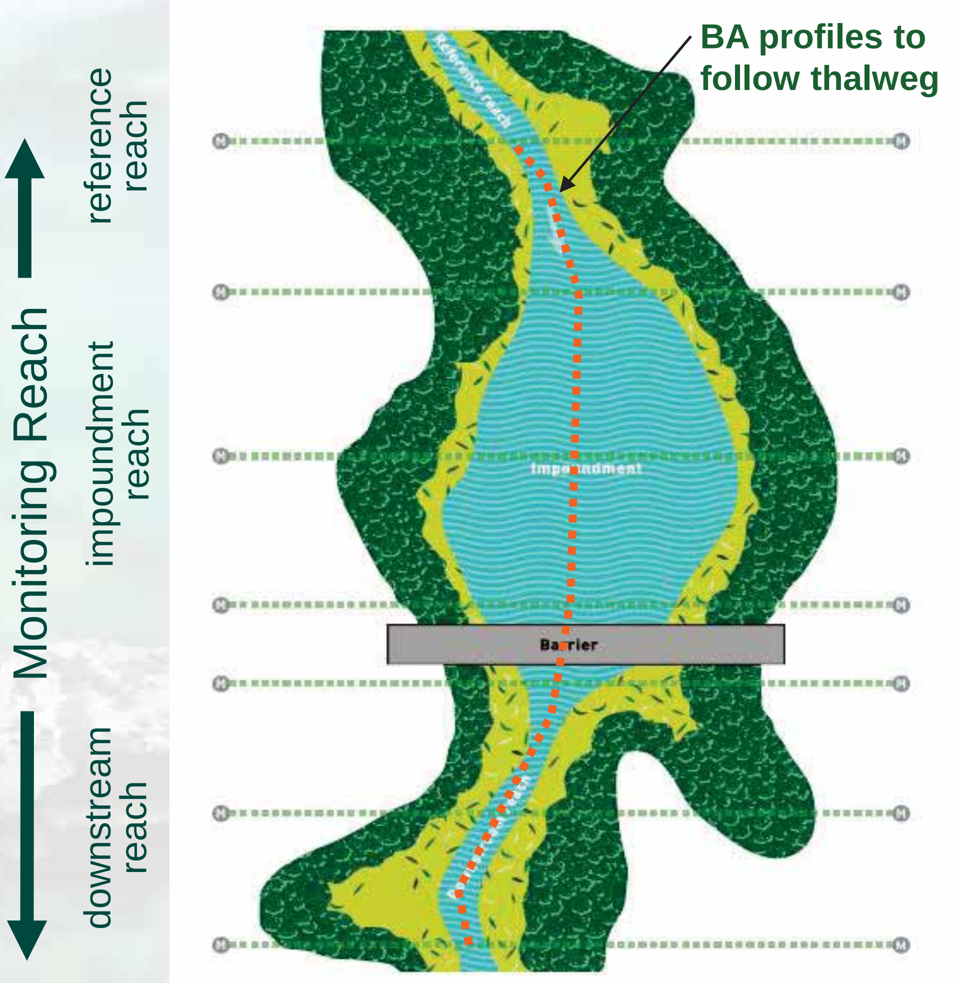
- Monumented cross-sections
- Longitudinal profile
- Grain size distribution
- Photo stations
- Water quality
- Riparian plant community structure
- Macroinvertibrates
- Fish passage assessment

Parameters have wide applicability

Process is generic and transferable to other regions

http://www.gulfofmaine.org/streambarrierremoval/

Monumented Cross-section as the "skeleton"



For:

- Longitudinal profile
- Grain size distribution
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- Riparian plant community structure

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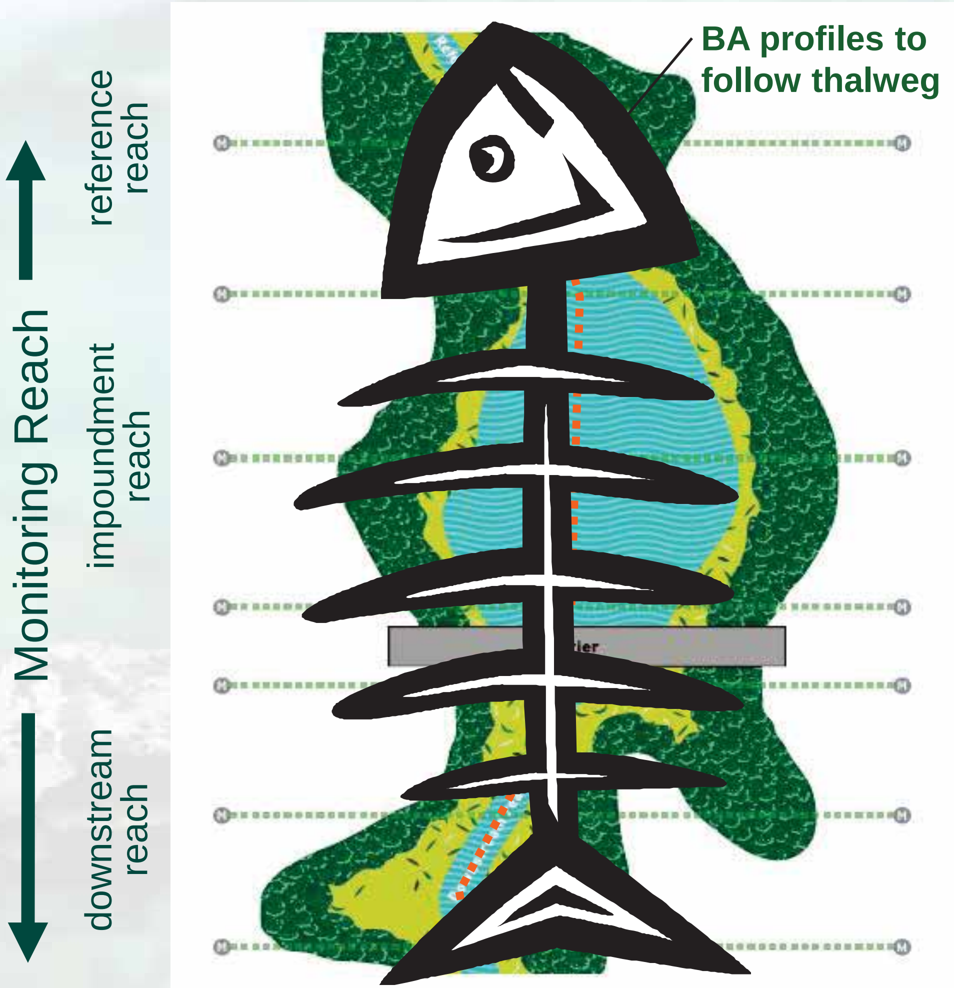

For:

- Longitudinal profile
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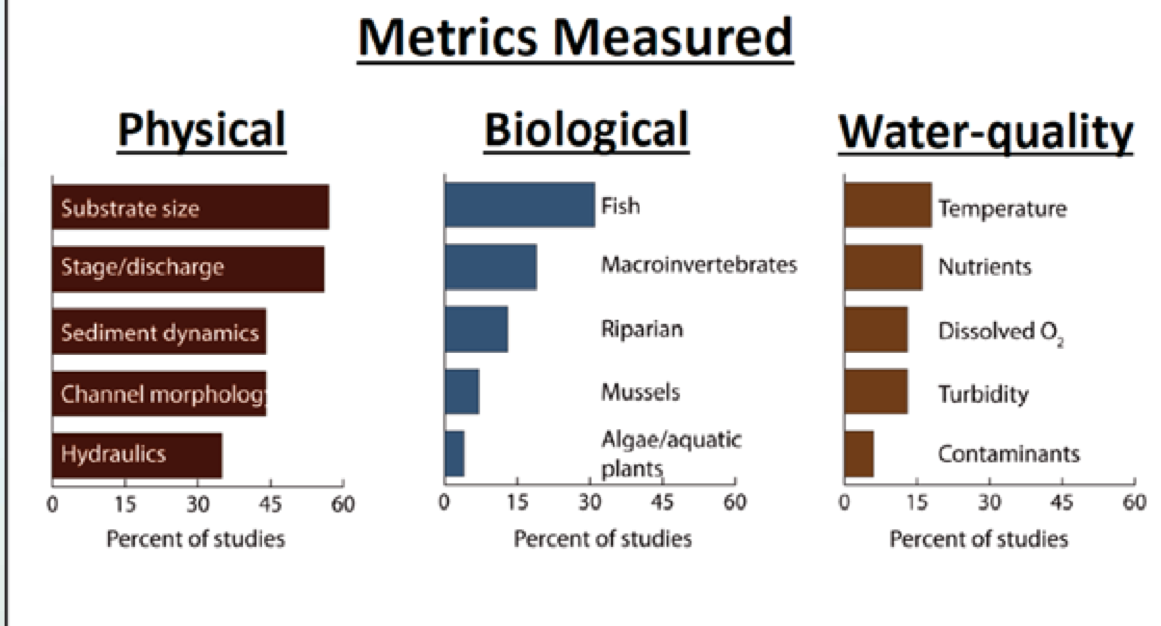
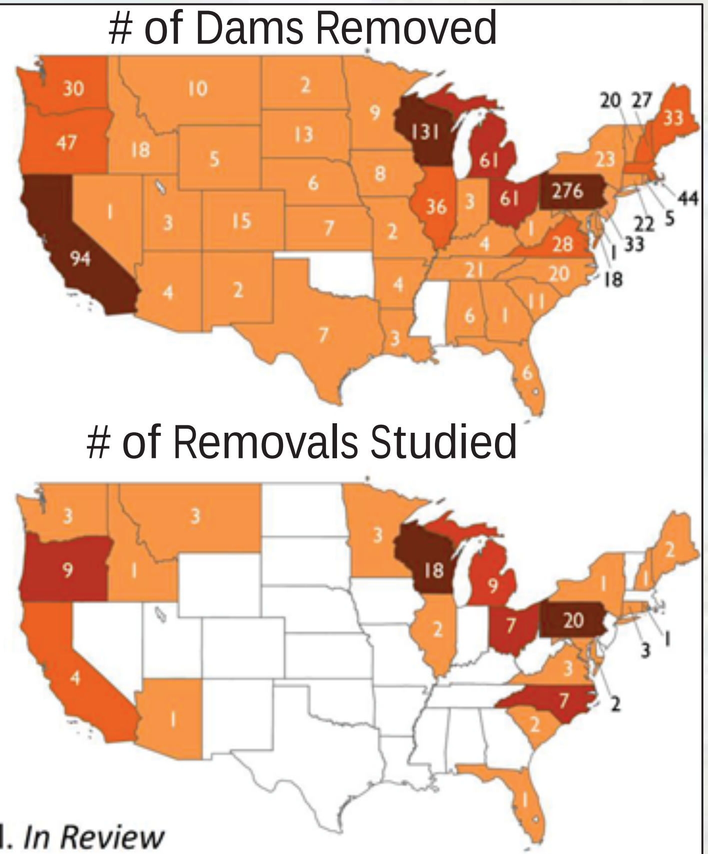
USGS Powell Center: Review and Synthesis of Dam Removal Research in the US

Gathered 600 dam removal studies – Analyzed 139 US studies with empirical data



Bellmore et al. *In Review*



Bellmore et al. *In Review*

- **This metadata was incorporated into a relational database, and published as a USGS data series**
  - Bellmore JR, Vittum KM, Duda JJ, and Greene SL. 2015. USGS Dam Removal Science Database. US Geological Survey. http://doi.org/10.5066/F7K935KT.
- **Can be accessed and downloaded on the web at: http://doi.org/10.5066/F7K935KT**
  - **Search for "USGS Dam Removal Science Database"**

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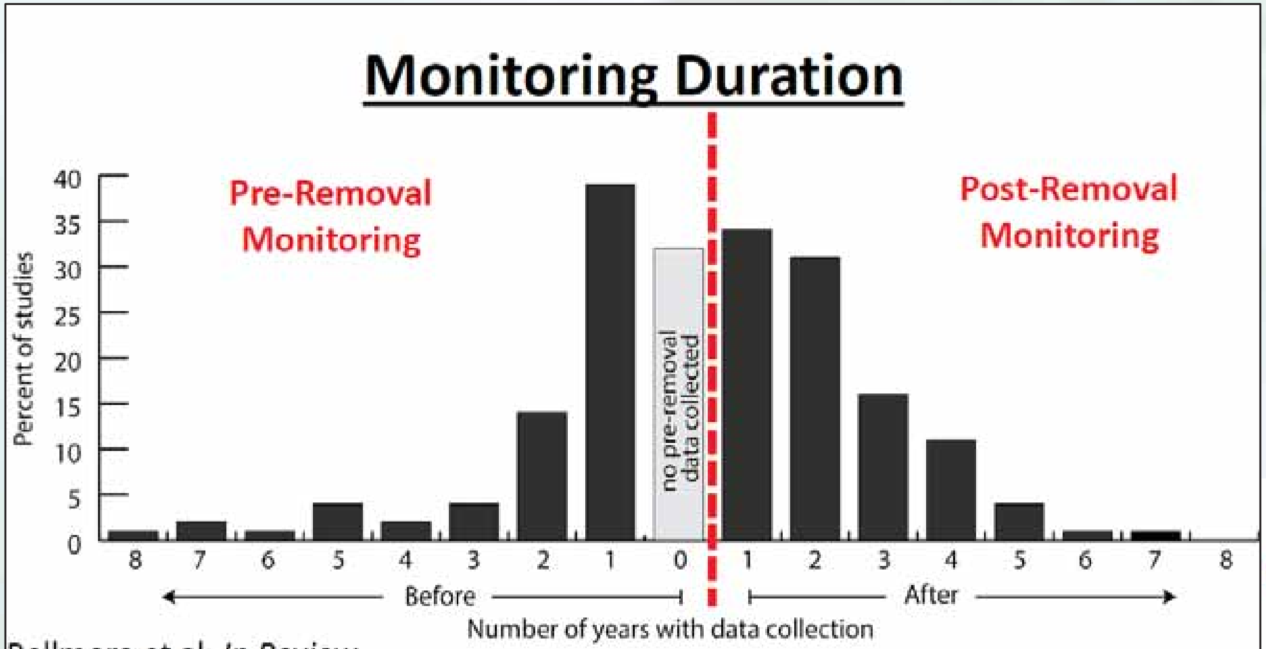
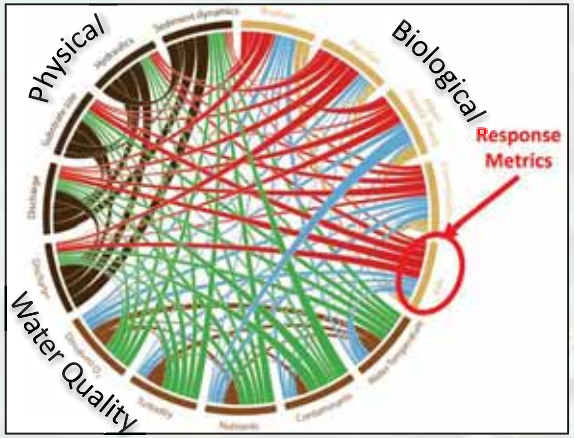
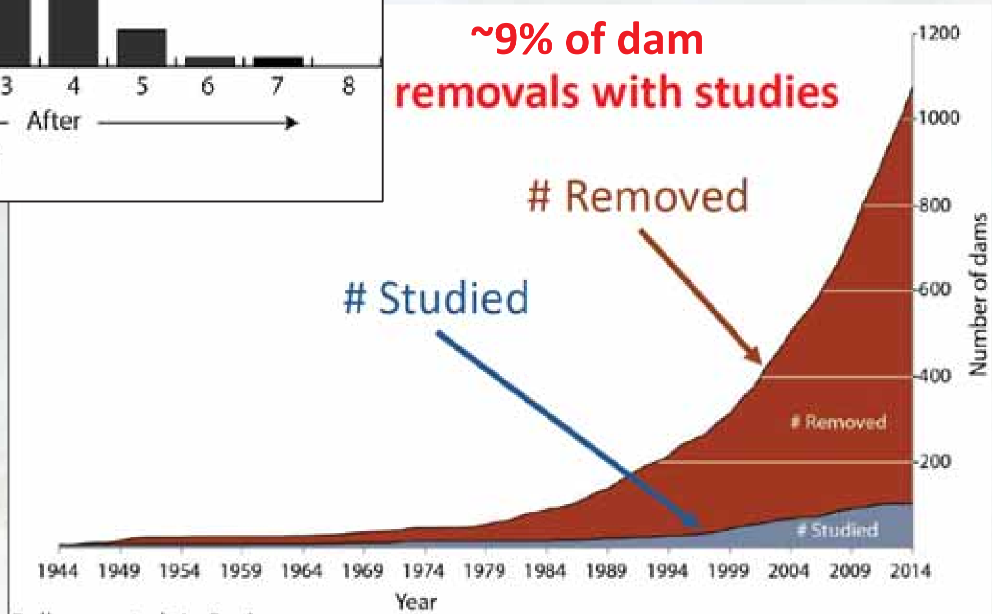


Bellmore et al. *In Review*





Bellmore et al. *In Review*

New England Sustainability Consortium - The Future of Dams (NEST)

For Information Contact: David Hart, Director, Mitchel Center for Sustainable Solutions

- $6 million grant from the National Science Foundation
- 4-year study examining the future of dams in New England.

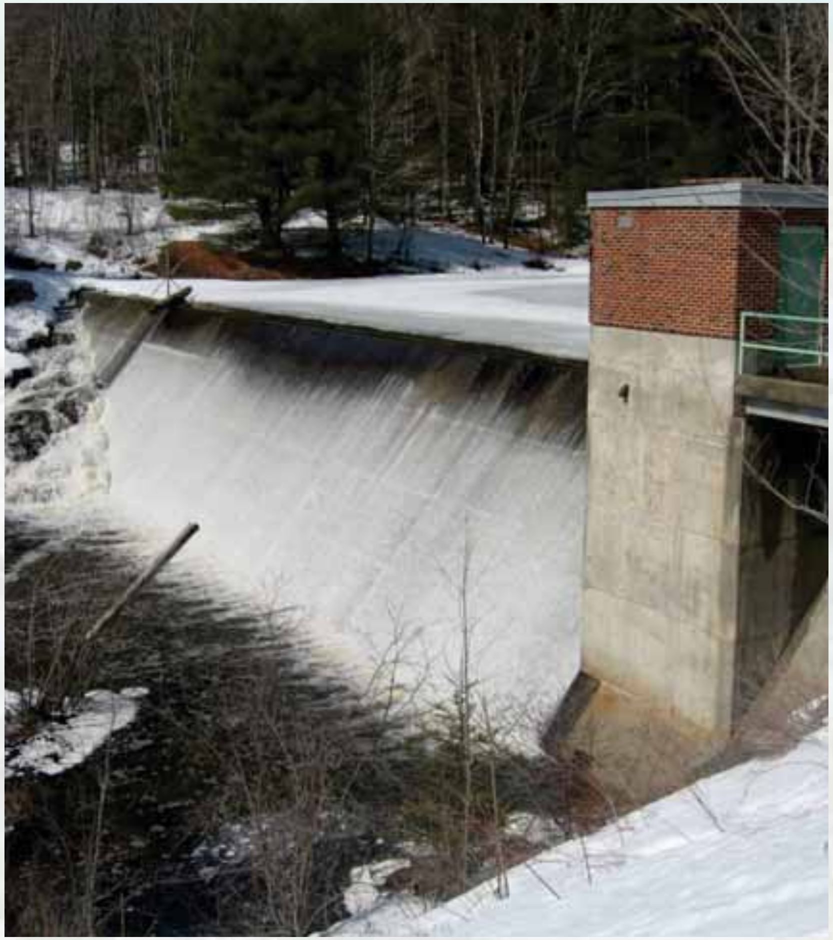
Looks at potential dam options:

- maintaining existing hydropower dams,
- expanding hydropower capacity,
- removing aging dams to restore fisheries or reduce safety risks

By examining:

- economic,
- environmental, and
- social tradeoffs

To help make better decisions about dams



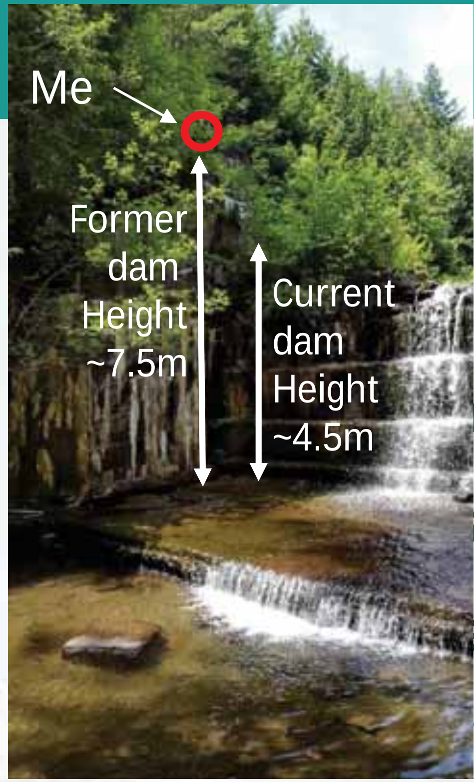
http://umaine.edu/mitchellcenter/road-to-solutions/new-england-sustainability-consortium/the-future-of-dams-nest/

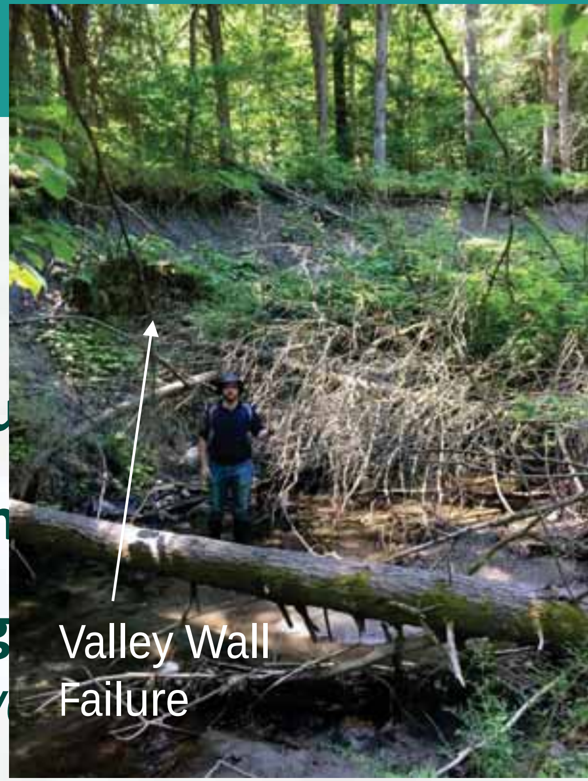
LEARNING THROUGH A WIDE DIVERSITY OF CASE STUDIES

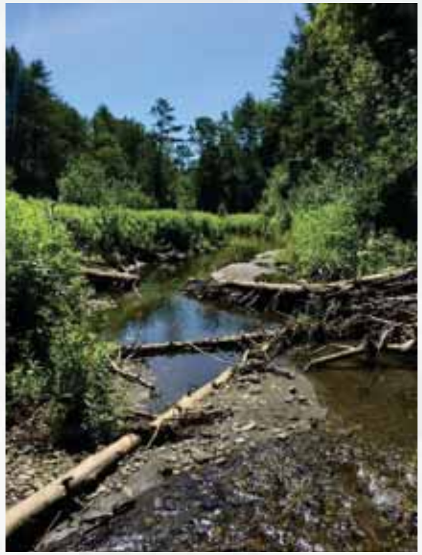
NO TWO DAM REMOVALS ARE THE SAME

Type of Dam	Use	Site Specific Issues	Issues Associated with Impacts
Earth	Water Supply	Wide/Narrow Reservoir	System Sensitivity
Gravity	Navigation	Urban or Rural	Sensitive Species
Stone Masonry	Water Level Control	Highly Managed	Entrenched
Timber Crib	Flood Control	Delta Deposited	Water Quality
Arch	Fire Suppression	Quantity of Sediment	Transport Capacity
Stop Log	Recreational	Historic Operation	Social Perception
Concrete	Hydro Electric	Legacy Thalweg	Scale
Reinforced or Not	Irrigation	Quality of Sediment	Historic
Slab and Buttress	Tailings	Layered Deposit	Cost/Funding
Inflatable Rubber	Grade Stabilization	Legacy Dam	
Other	Fish & Wildlife	Coarse or Fine Grained	
	No Use	Bedrock or Vegetation	
	Other	Infrastructure Impacted	

Norwich Dam, VT

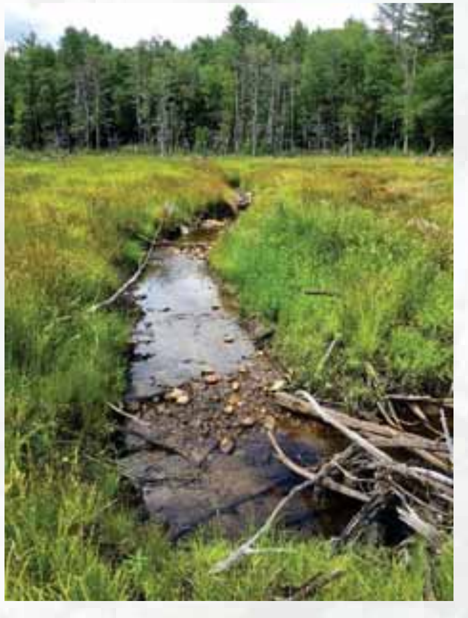






Tannery Brook Dam, New Hampshire

- 8.5m earthen dam
- Wide impoundment
- Little impounded sediment
- Passive channel treatment



5 Dams on the Naugatuck River, Connecticut

Chase Brass

Concrete Dam
height = 2m   length = 53m

Platts Mill

Stone Rubble / Timber Crib
height = 3n   length = 77m

Anaconda

Timber crib / Sheetpile Dam
height = 4m   length = 109m

Union City

Timber Crib Dam
height = 2.5m length = 63m

Freight Street

Concrete / Sheetpile Dam
height = 1m   length = 53m

- 5 Dams Removed
- 70% of Watershed now free flowing
- Revival of an industrial river

5 Dams on the Naugatuck River, Connecticut

- **Revival of an industrial river**

Pizzini Dam, Connecticut

- 1m high stone masonry dam
- No sediment
- Threatened mussel species downstream
- 3 years to permit
- 10 min to remove

Lamprey & mussel relocation post removal

9:00AM

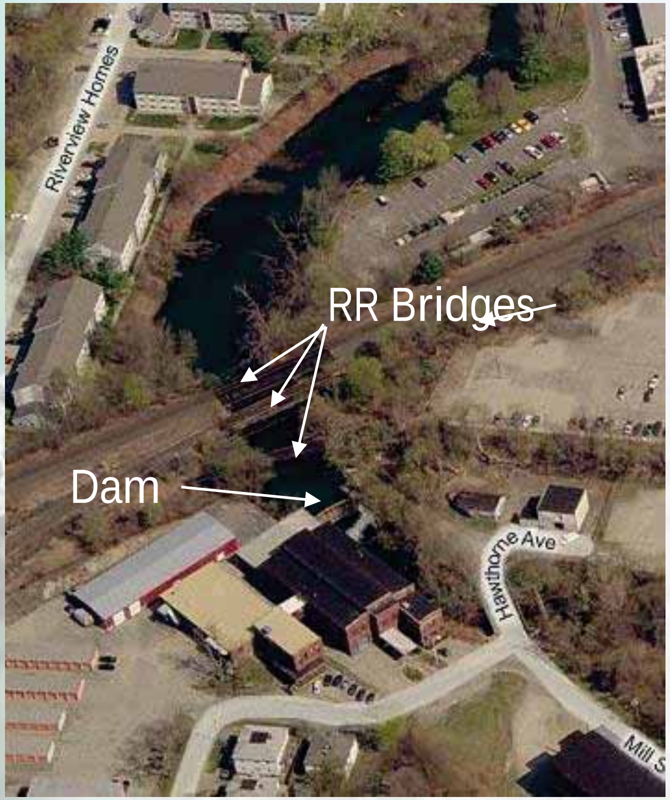
9:15AM

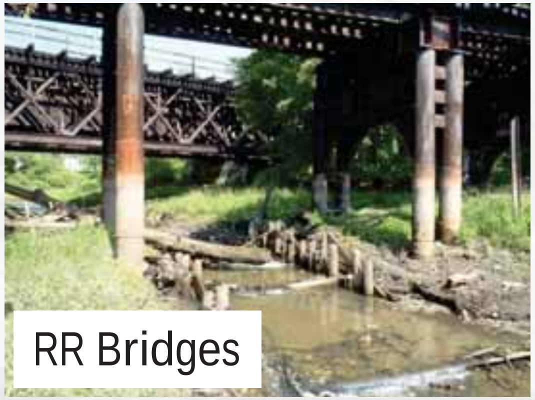
9:30AM

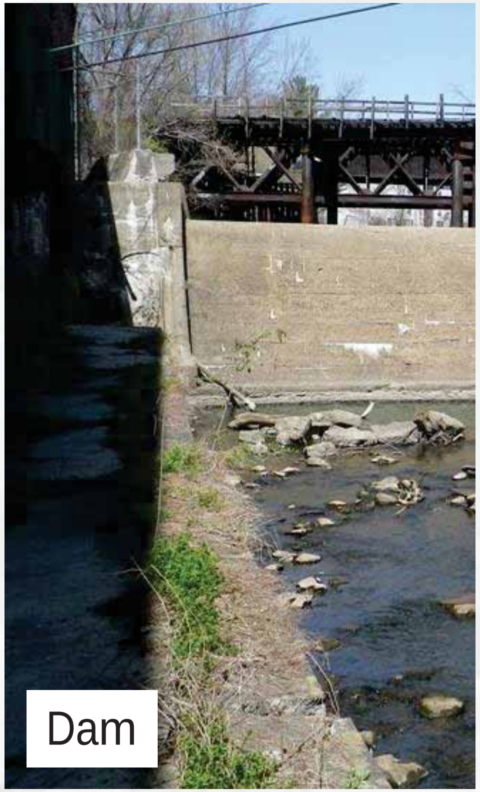
10:00AM

Tel-Electric Dam, Massachusetts

- 5m concrete capped stone masonry dam
- Significant infrastructure: 2 active railroad bridges; 1 abandoned railroad bridge to be removed, factories, retaining walls, etc.
- Contaminated sediments throughout river
- 1 recent death

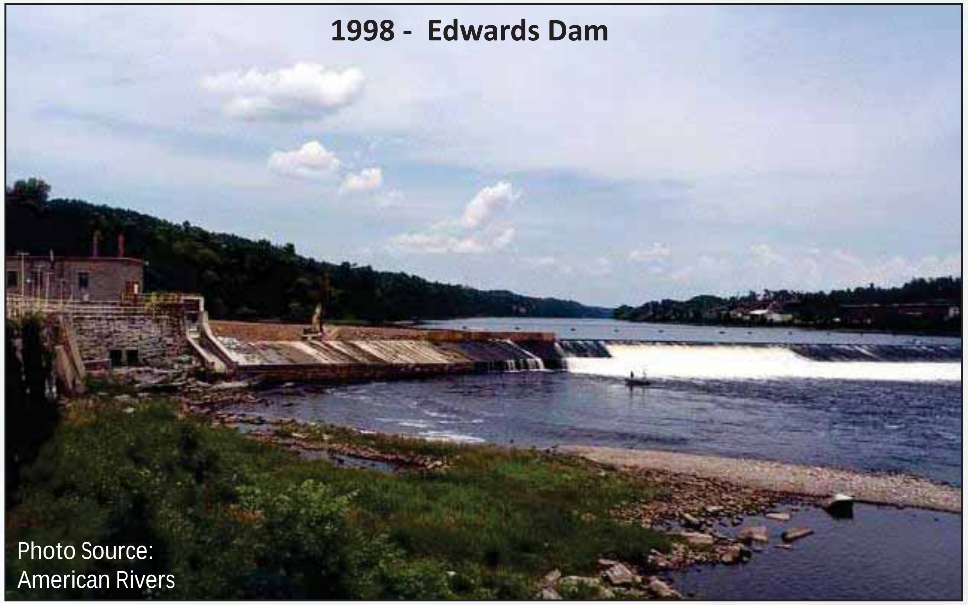


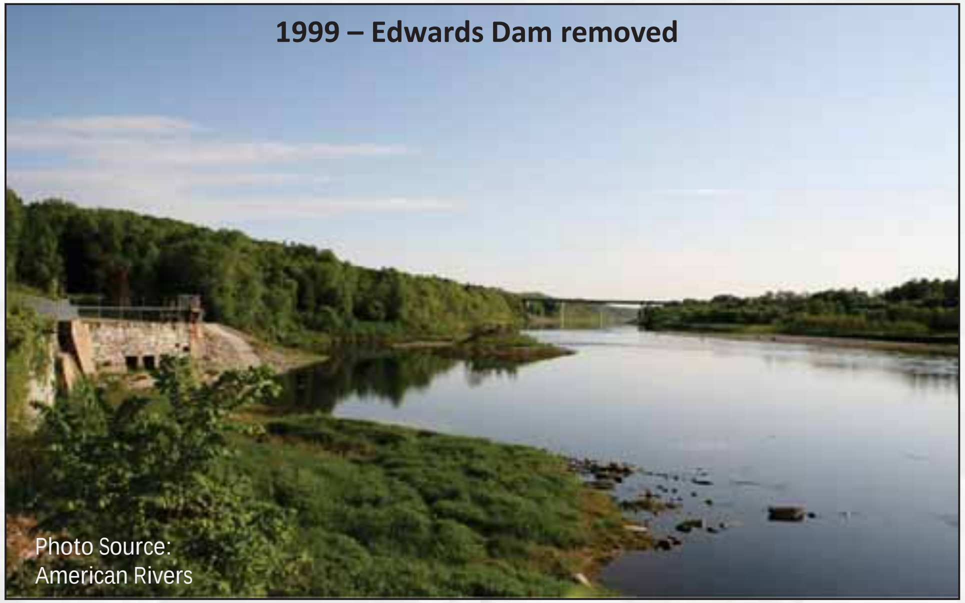




Edwards Dam, Maine

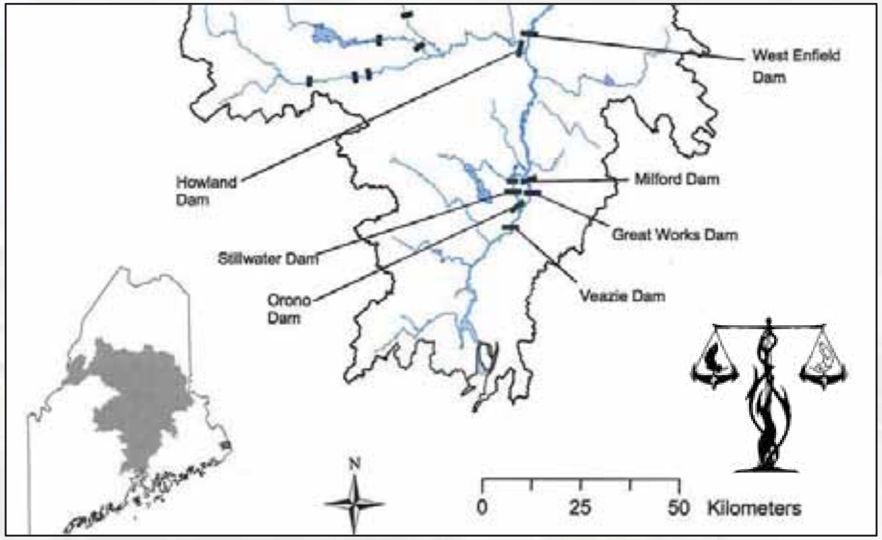
- **7.3m high hydropower dam**
- **1997:** Edwards Dam marked the first time that FERC had ever denied an application for relicensing and set a precedent for FERC's authority to remove dams that pose greater harm than good. One year after removal in 1999 alewife returned by the millions for the first time in 160 years.





Penobscot River Dams, Maine

- FERC Settlement
- Hydro & Environmental Balancing: removed 2 dams increased power on two others



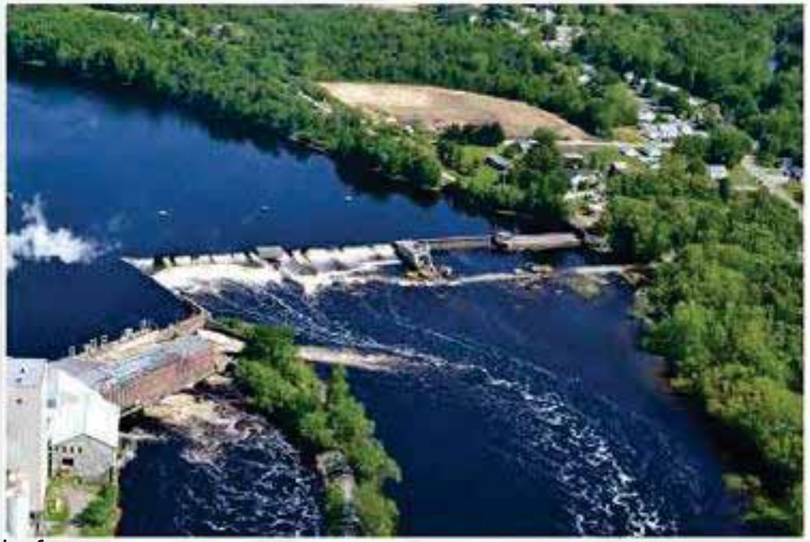
Penobscot River Dams, Maine

before

Veazie Dam Removal

after

Great Works Dam Removal

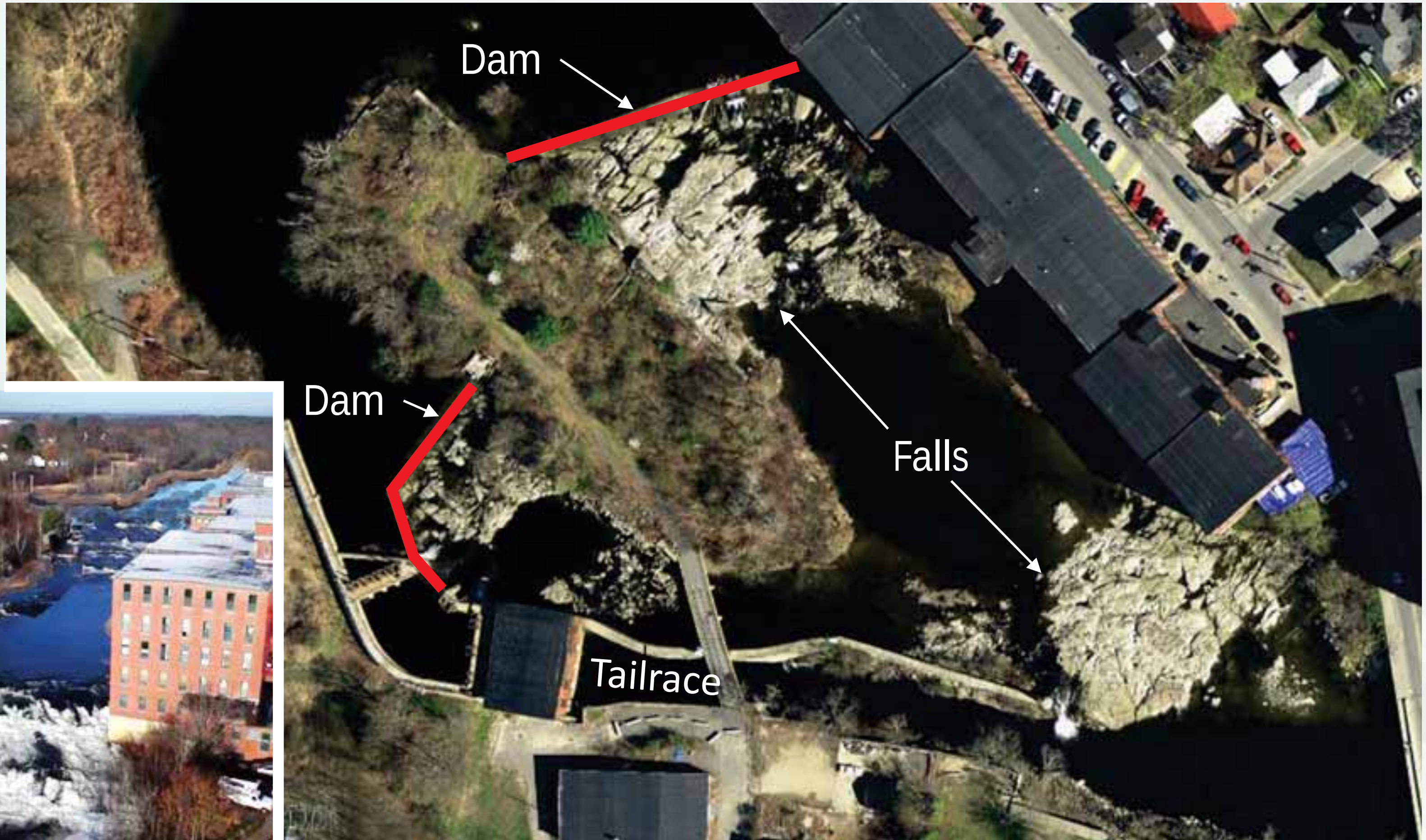


before

after

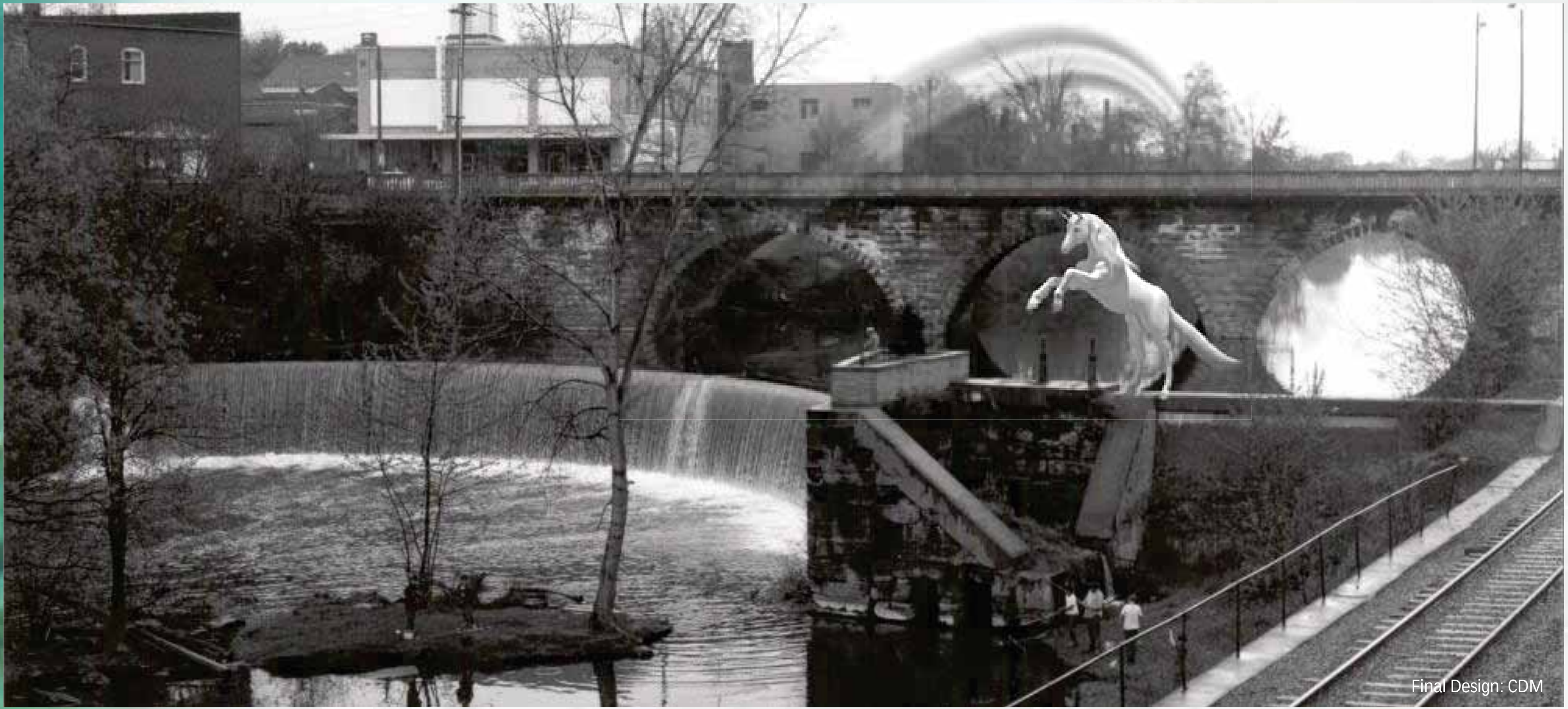
Saccarappa Dam, Maine

- Active hydro-electric; economically infeasible w/ fish passage prescription
- 2 concrete spillways with bedrock excavated tailrace; 2 bedrock falls; significant site modification
- Removal ≠ Fish Passage



Kent Dam, Ohio

- **Historic Site**
- **Creative solution: portion of dam retained to create falling water aesthetic**

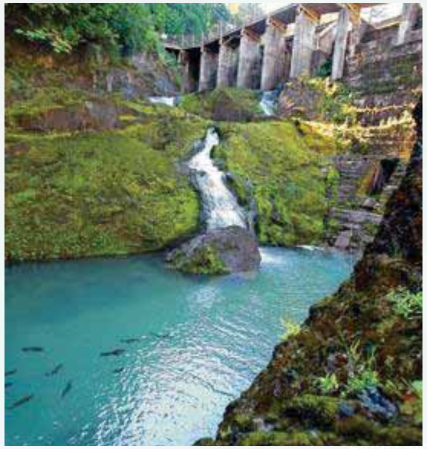


Kent Dam, Ohio

- **Historic Site**
- **Creative solution: portion of dam retained to create falling water aesthetic**

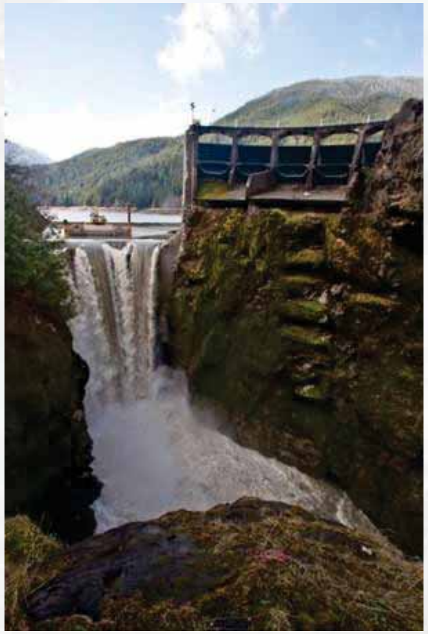
Elwha River Dams, Washington

- Tribal rights
- Passage Critical: Listed salmon species
- Active hydropower
- ~21 million m^3 of impounded sediment allowed to transport downstream
- Significant infrastructure improvements needed



Final Design: URS

Elwha Dam, WA (~37m high)



Glines Canyon Dam, WA (~62m high)

Final Design: URS

Milltown Dam, Montana

- 10m high timber crib and concrete, hydroelectric dam
- Superfund site
- 5 million m^3 of contaminated sediment
- Much of the sediment relocated on site and capped in place

Heminway Dam, Connecticut

- Originally dredged impoundment
- Sediment filled impoundment now considered wetland
- Difficult permitting sediment relocation within former impoundment

San Clemente Dam, California

- Hydropower Dam: economically infeasibly to repair seismic and hydrologic deficiencies
- Unique bypass alternative to deal with sediment

Post Removal

San Clemente Dam, California

- Hydropower Dam: economically infeasibly to repair seismic and hydrologic deficiencies
- Unique bypass alternative to deal with sediment

Post Removal

Cumberland Dam, Maryland

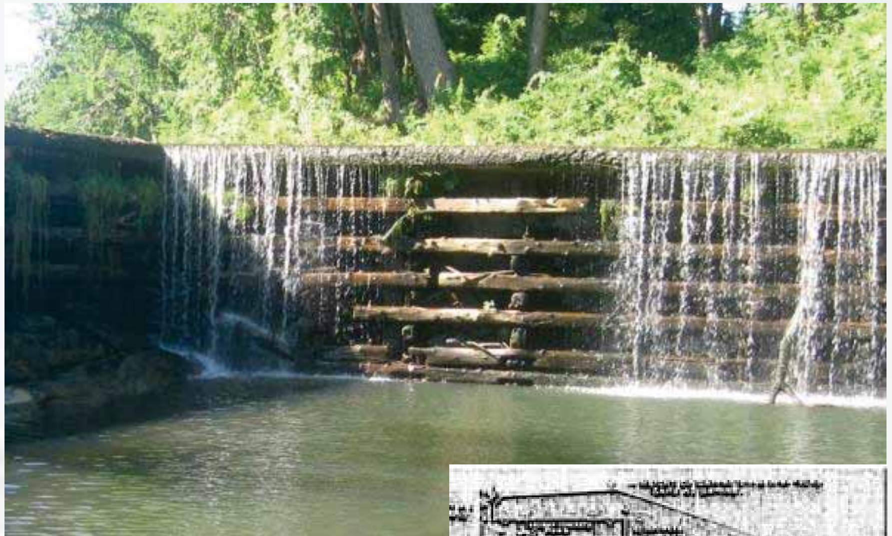
- Historic bridge & canal
- Need to modify 5.2 MGD water intake for historic canal ($200-$500K)
- Dioxins in sediment

Green River Dams, Massachusetts

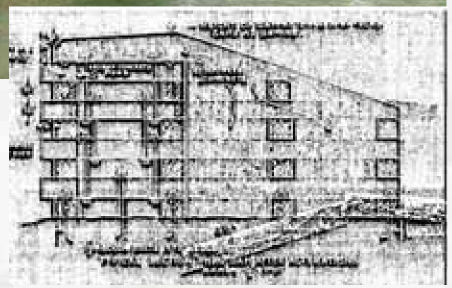
- **Cascading infrastructure impacts due to geomorphic instabilities**
- **Timber crib dam, not what it appeared to be**
- **Submerged knickpoint due to river avulsion per-dam construction**

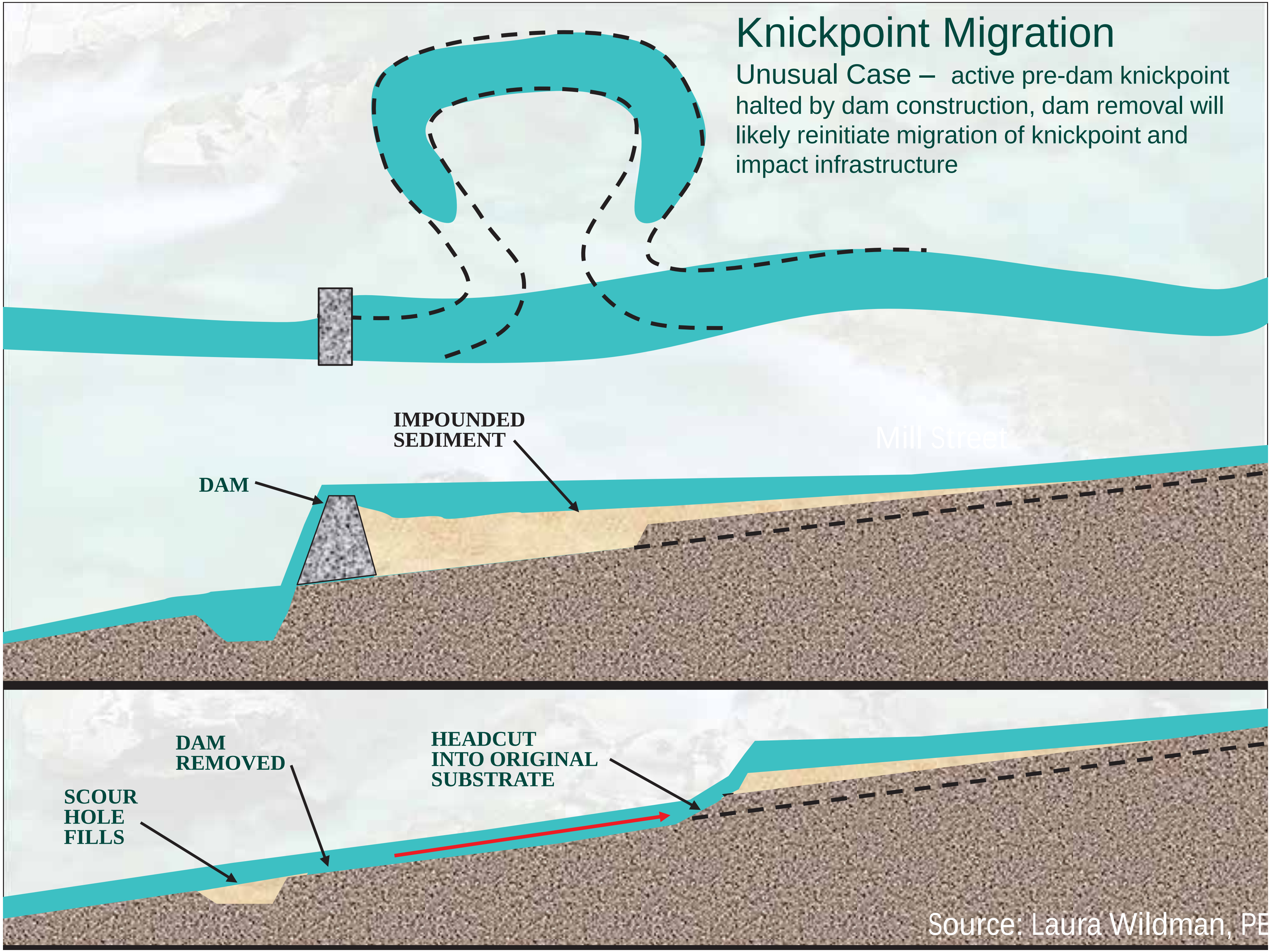
Mill Street

Mill Street Dam



Winchell Smith Dam





Knickpoint Migration
Unusual Case – active pre-dam knickpoint halted by dam construction, dam removal will likely reinitiate migration of knickpoint and impact infrastructure
IMPOUNDED SEDIMENT
Mill Street
DAM
DAM REMOVED
HEADCUT INTO ORIGINAL SUBSTRATE
SCOUR HOLE FILLS
Source: Laura Wildman, PE

Cuddebackville Dam, New York

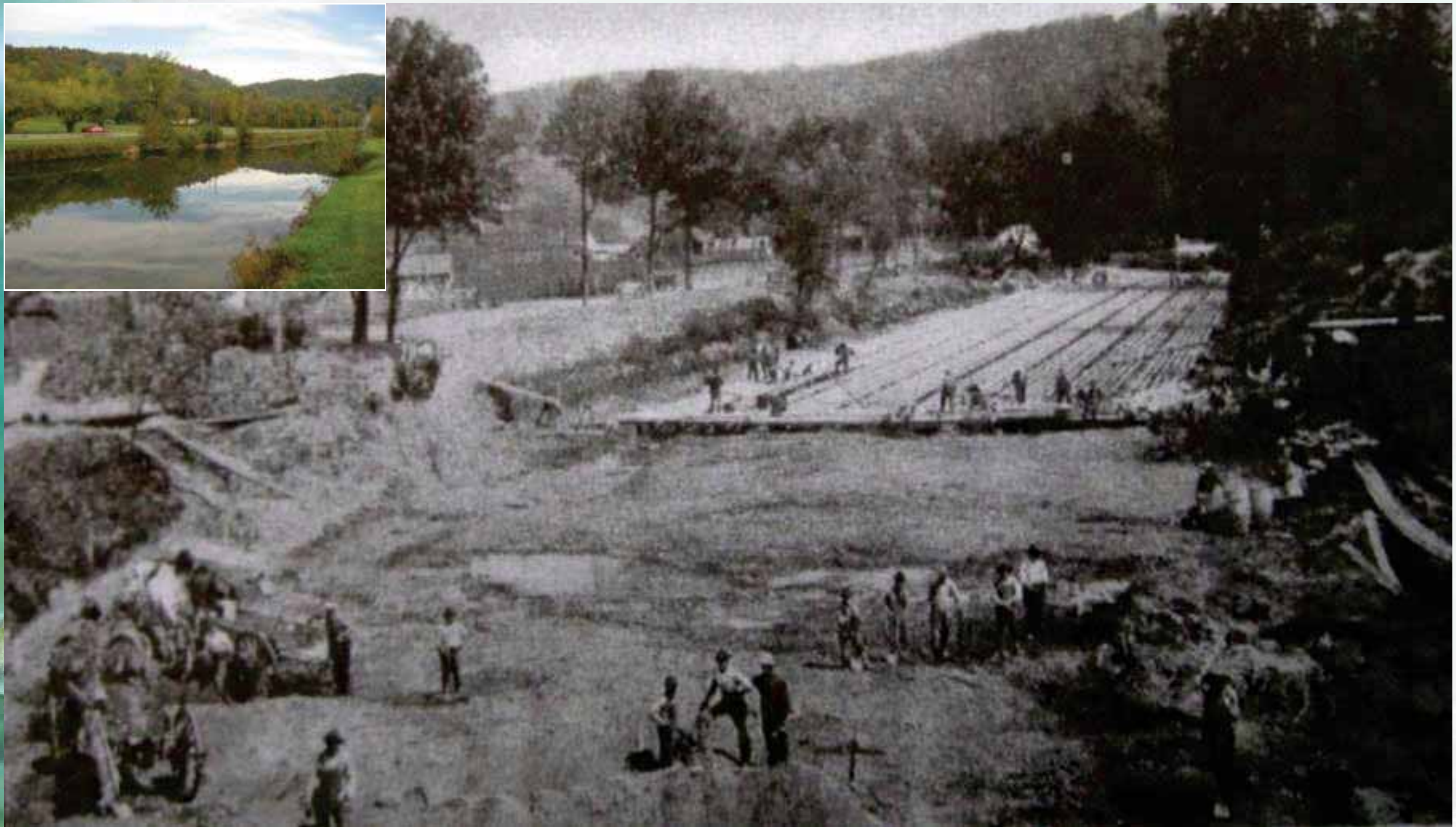
- **Threatened Dwarf Wedge mussel species, needed to be identified, tagged, relocated**

Brave Dam, Pennsylvania

A typical impoundment?

Brave Dam, Pennsylvania

~~A typical impoundment?~~ No, the worlds largest radiator!

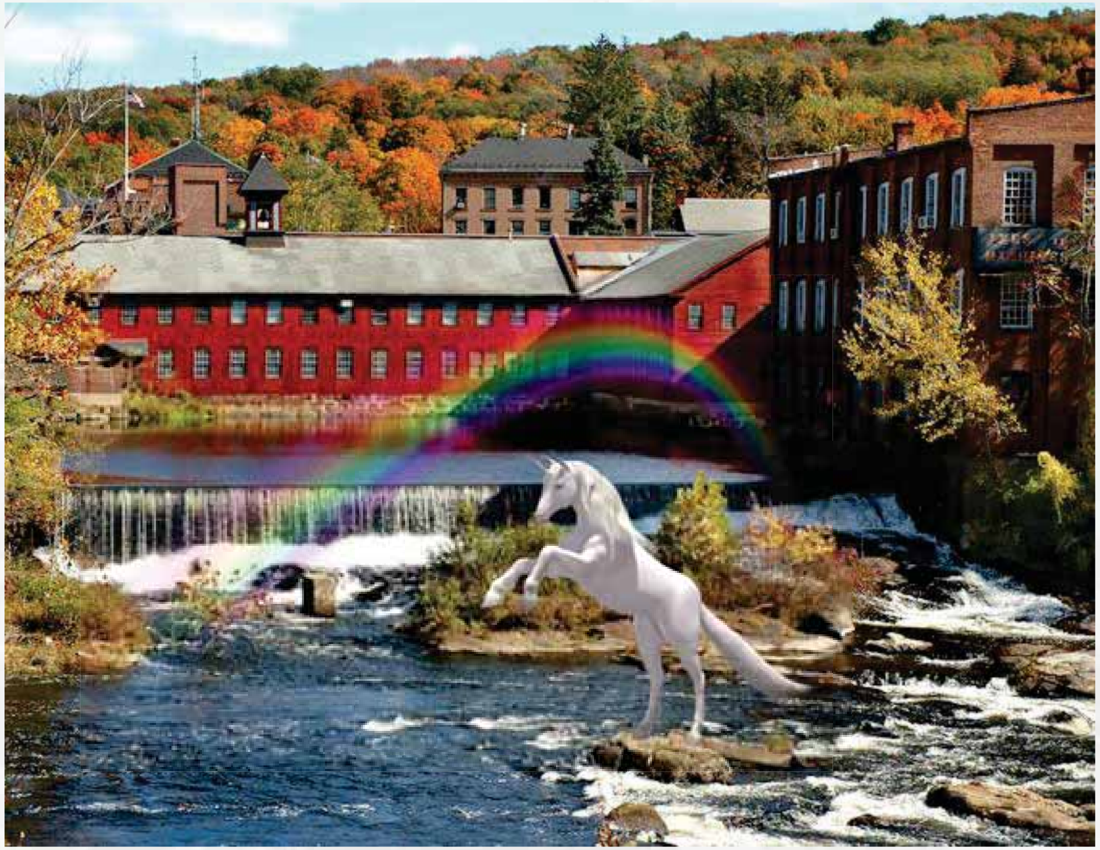


Dunkard Creek Dam, PA - Turn of the century cooling systems for a gas pumping station

Canton Dam, Connecticut

- Dam removal blocked due to future desire to develop small hydro – decades into process
- Is there potential to look into other micro-hydro options?

In-Conduit Turbines



POTENTIAL DIFFERENCES BETWEEN USA AND EUROPE

HOW KEY ISSUES MAY DIFFER IN EUROPE

- Multiple countries in Europe vs. multiple states in U.S.
- Different regulations that will define different "key" issues (i.e. wetlands may not be as big of a regulatory issue, but historic or water rights may play a larger role)
- Stakeholders are at a different stage in the evolution of the concept of restoring river connectivity through dam removal
- Engrained "vision" of a tamed or controlled landscape with dams

HOW KEY ISSUES MAY DIFFER IN EUROPE

- Small dams are often referred to as weirs, not dams
- Highly manipulated and "managed" systems
- Harder to obtain a "natural" approach
- Indicators such as an equilibrium slope may be less relevant
- Many small dams may be acting as grade controls (potentially in series)
- Long history of infrastructure that could now be impacted with removal
- Different invasive species and water chemistry issues

BEWARE: EUROPE HAS A HIGHER PERCENTAGE OF UNICORN HABITAT

Photo taken from a website entitled: The Most Beautiful Waterfalls in Sweden


THANK YOU
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