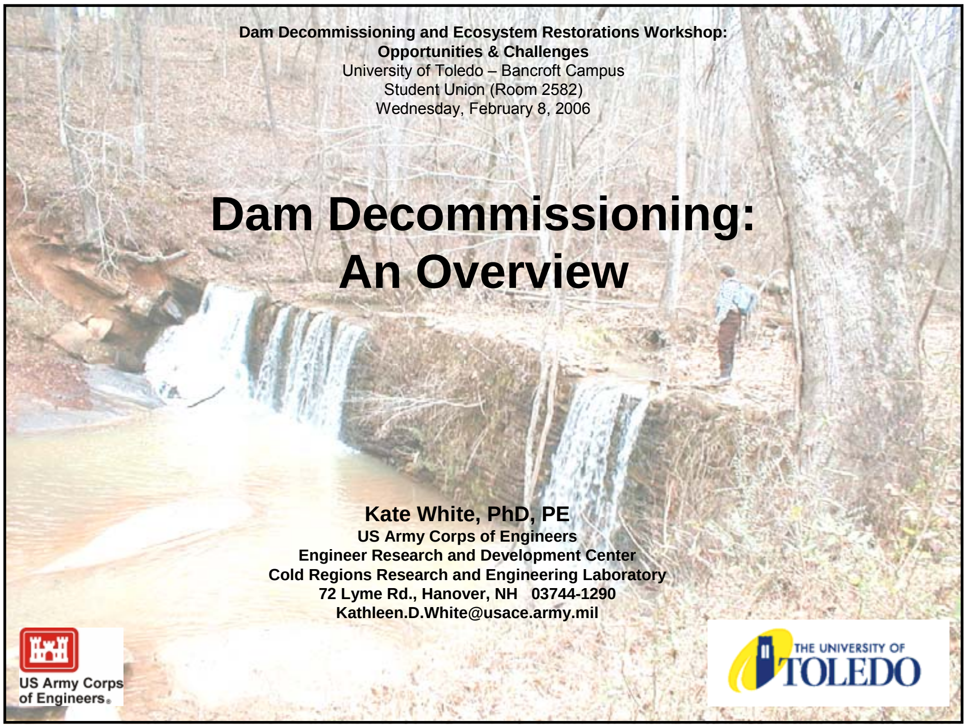

Dam Decommissioning and Ecosystem Restorations Workshop:
Opportunities & Challenges
University of Toledo – Bancroft Campus
Student Union (Room 2582)
Wednesday, February 8, 2006

Dam Decommissioning: An Overview

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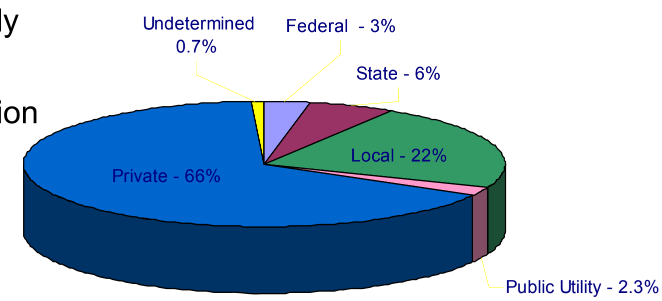
Background

- Dam building associated with early colonization
  - Water supply
  - Agriculture
  - Transportation
  - Industry



- NRC estimates 2.5 million dams in 1990
- Corps lists 75,000 dams in National Inventory of Dams (NID)

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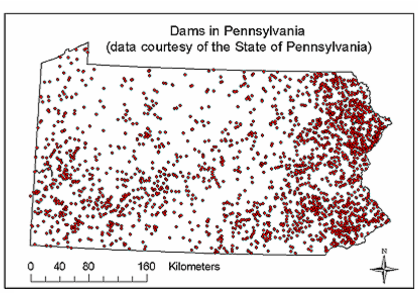
Relevant Parties and Agencies

- Affected landowners
- Taxpayers
- State dam safety personnel
- State regulatory and wildlife management agencies
- Federal Agencies
  - USACE, Reclamation, FERC, USFWS, NOAA, NRCS, BLM, National Park Service, USGS
- NGOs
  - The Nature Conservancy, Trout Unlimited, American Rivers

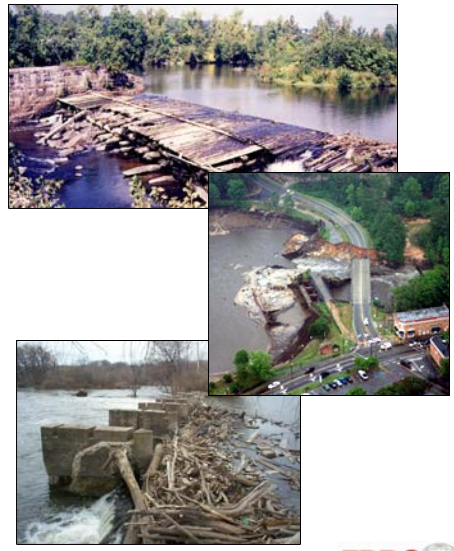
Overview and Problem Scope

- 58,000 (85% of NID) large dams will exceed their design lifespan by 2020 (FEMA)
- 2000-2001: 61 dam failures and 520 incidents, 2100 structures classified as unsafe (ASCE)
- Failure of efforts to date to restore T&E or economically and ecologically significant species



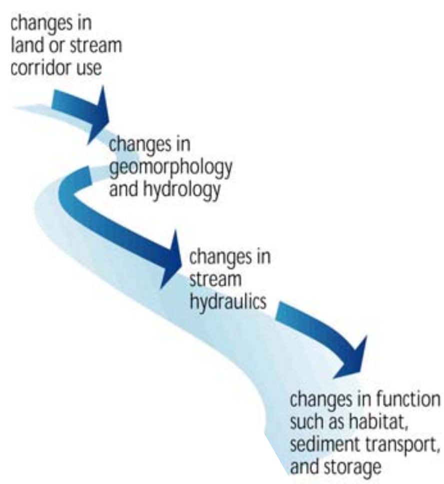
Impetus for Dam Decommissioning

- Public Safety: Aging dams often need costly repair
- Recreation
- Ecological Impact Mitigation: Alternatives to dams may now be available
- Socioeconomic: Community contexts and values have changed
- American Rivers identified 467 removals in 1900's (92 in 1980's, 177 in 1990's)



Dam Decommissioning is a Nontrivial Issue

- Cumulative impacts of natural events and human activities combined with watershed changes associated with urbanization and deforestation has significantly disrupted the dynamic equilibrium of rivers
- Watersheds reach some equilibrium after dam construction
- Further adjustments due to disturbances associated with dam decommissioning must be considered



Decision-Making Considerations

- Acceptable Risk and Uncertainty
- Degree of Potential Impact
- Recovery Potential
- Physical Constraints
- Public Perception
- Available Data
- Costs
- Benefits

- Dam construction impacts provide a useful analog, even though removal is not the opposite of dam construction:
  - some processes are reversible, others are not

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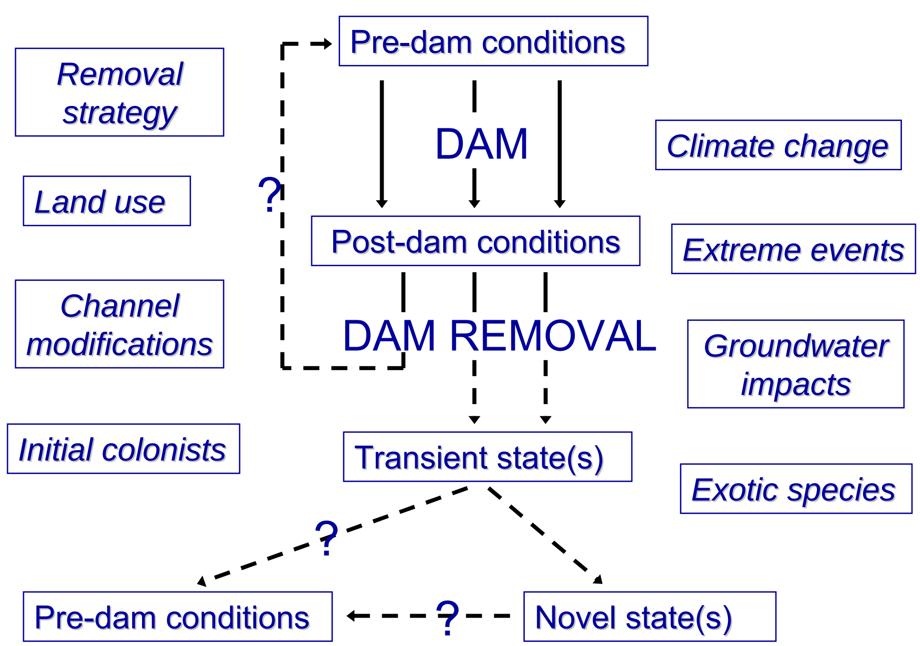
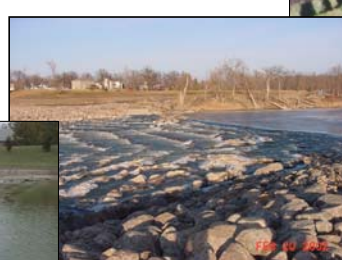


Decision-Making for Dam Decommissioning

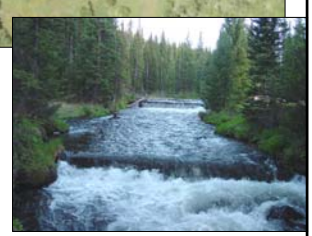
- Define desired end state(s) and goals (e.g., safety, fish and wildlife, aesthetics, recreational use)
- Define existing regime
  - Understand relationship between aquatic resources and H&H (riparian, reservoir, wetlands)
  - Identify water uses (e.g., hydropower, water supply, recreation, flood damage reduction)
  - Describe hydraulics (e.g., diurnal, seasonal, flood, low-flow, surface, groundwater)
- Quantify all benefits and costs of existing regime
- Identify alternative methods to reach desired end state
  - Address modification; partial or full removal; removal sequenced over time; sequential grade control for head pond maintenance, organism passage, or channel stability; reoperations
  - Explicitly characterize transition processes (e.g., sediment management plan, stream bank stabilization, channel restoration)
  - Assign values to individual components
- Quantify all benefits and costs of end state(s)
- Select optimum plan

Decommissioning Alternatives

- Nature-like fishways bypass dam
- Rock arch ramps
- Boulder vanes
- Dam reoperations
- Removal
- Do nothing



Grand Forks Riverside $4.8M



Rio Blanco, CO $30K/mi

Fargo Midtown $260K

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Dam Reoperations

- Restore Natural Flow Regime
  - Restore historic flood disturbance patterns
  - Can target key species which require specific flow magnitude/duration/ season
  - Release sediment to downstream ecosystems
- Problems:
  - Usually highest magnitude flows aren't possible
  - Doesn't release sediment

http://nature.org/success/dams.html

Dam Removals to Date (>500)

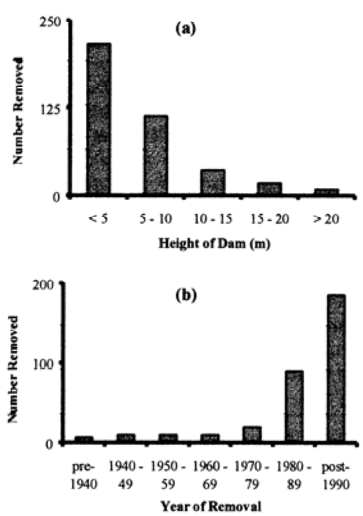


Figure 1. Number of dams removed as a function of (a) dam height, and (b) year of removal (adapted from American Rivers et al., 1999).

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

Impacts of Dams

Upstream → *Impoundment* → *Downstream*

Upstream

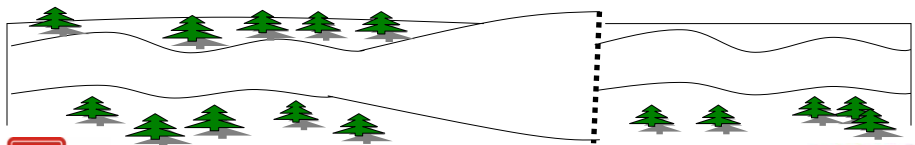
- **Reduced marine derived nutrients from migratory fish**
- **Aggradation**
- **Groundwater**
- **Riparian Structure**

Impoundment

- **Inundate riparian zone**
- **Store water, sediments, seeds, and particulates**
- **Altered thermal regime**
- **Altered gas conditions**
- **Nutrient conversion & storage**
- **Flood attenuation**

Downstream

- **Altered hydrology**
- **Reduce sediment, CPOM, & seed supply**
- **Channel instability**
- **Decreased heterogeneity**
- **Anthropogenic disturbance**



Impacts of Dams

- Barrier Effects
- Hydrologic Alteration
- Water Quality
- Sediment/Particulate Transport
- Morphology
- Direct/Indirect Biological Impacts
- Social/Cultural
- Recreation

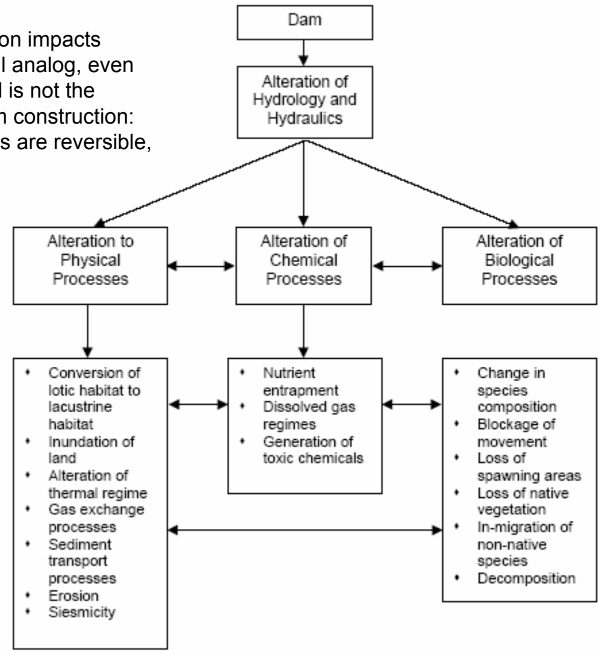
Barrier Effects

- Fish movement
- Coarse particulate organic matter (CPOM, ~ > 1 mm) storage
- Sediments
- Invertebrates
- Invasive Species
- Ice retention

Hydrologic Impacts

- Reduced average annual runoff
- Reduced seasonal variability
- Altered timing of extremes
- Reduced flood magnitude
- Sediment deposition, erosion, transport

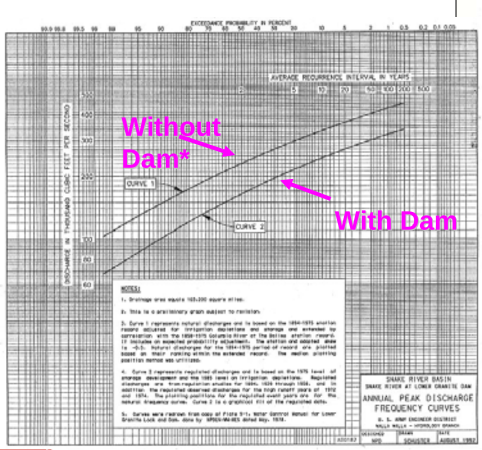
Dam construction impacts provide a useful analog, even though removal is not the opposite of dam construction: some processes are reversible, others are not

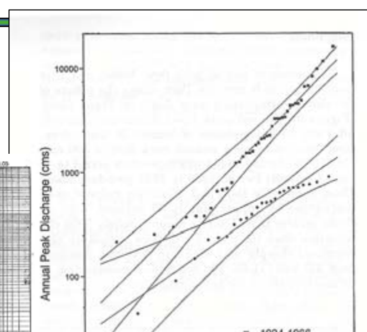


From Bizer, J.R. (2000) "International Mechanisms for Avoiding, Mitigating and Compensating the Impacts of Large Dams on Aquatic and Related Ecosystems and Species."IN Berkamp, G., McCartney, M., Dugan, P., McNeely, J., Acreman, M. (2000) Dams, ecosystem functions and environmental restoration, Thematic Review II.1 prepared as an input to the World Commission on Dams, Cape Town, South Africa: http://www.dams.org

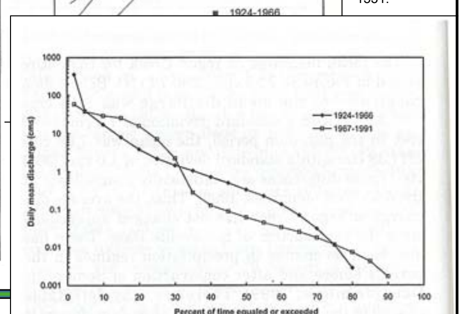
Basic Hydrological Effects of Dam Construction

- Flood frequency
- Flow duration



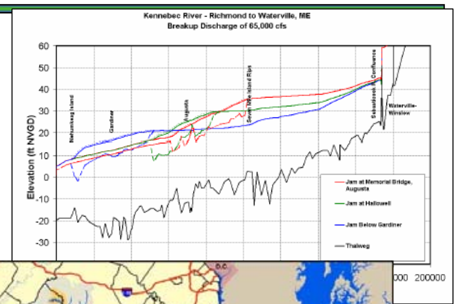


From Chin et al (2002) "Adjustment of stream channel capacity following dam closure, Yegua Creek, Texas." J. A.W.R.A Vol. 38, No. 6, p. 1521-1531.

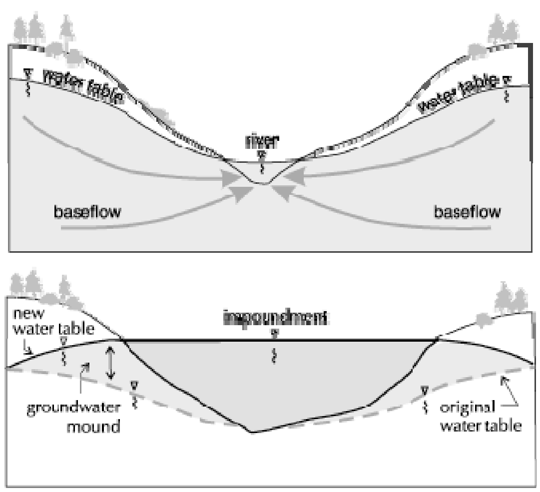


Heinz Center 2002 Workshop on Dam Removal Research

- Hydrologic and hydraulic modeling techniques well-established
  - Need better integration with geomorphologic and biological models
  - Spatially and temporally varying models
- Small dam (<25 ft, run-of-river) removal impacts fairly well-known on site-specific basis
  - Generalization is next step
  - Landscape-scale studies of watershed impact necessary
  - Large dam impacts not well-documented
- General direction of changes predictable, but not magnitude
  - Except for hydrology for small run-of-river dams or where basin hydrology is well-understood



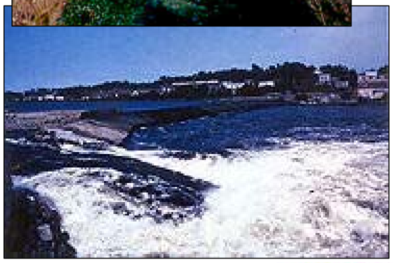
Groundwater



From: University of Wisconsin Water Resources Management Practicum (2000) Dam Repair or Removal: A Decision-Making Guide. http://www.ies.wisc.edu/research/wrm00/index.htm.

Water Quality

- Temperature
- Dissolved oxygen
- Nutrients
  - ~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
- Plankton



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Sediment/Particulate Transport

- Sediment storage in reservoir
- Reduced sediment yield downstream
- Increased plankton downstream
- Altered ice regime
- Woody debris
- Contaminated sediments

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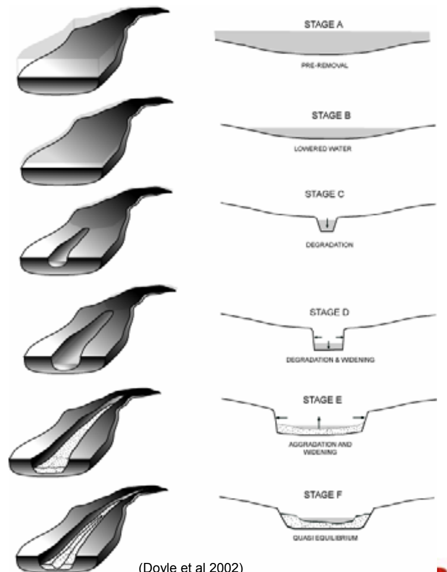
Morphologic Impacts

- Upstream aggradation
- Downstream aggradation or degradation
- Bank stability
- Headcutting
- ƒ (Q, ds, Qs, Teff)



(Doyle et al 2002)

Direct & Indirect Biological Impacts

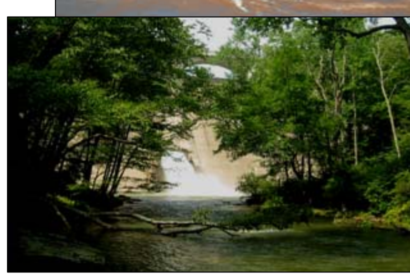
- Altered sediment, hydrologic, woody debris, and ice regimes
- Habitat fragmentation
- Nutrient cycling and flow impacts
- Water quality and thermal regimes
- Major impacts on T&E, anadromous, catadromous, and adfluvial populations
- Mix of lentic and lotic habitats alters predation regimes and other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

Effects of Dams on Vegetation

- Impoundment
  - Reduced propagule transport
  - Altered flood regime
  - Riverine to littoral
  - Inundates vegetation
  - New shoreline veg.
  - Aquatic vegetation may thrive due to reduced turbidity, thermal & flood reg.
- Downstream
  - Altered hydrodynamics
  - Groundwater impacts
  - Disturbance
    - propagule transport
    - floodplain wetting
    - vegetation stability
    - patch diversity
    - species diversity

Effects of Dams on Vegetation

- More exotics below small dams
  - Minimal alteration of the flood regime
  - Exotic species potentially washed downstream from the disturbed area near dam site
- Fewer exotics below large dams
  - Reduced propagule transport
  - Altered flood regime

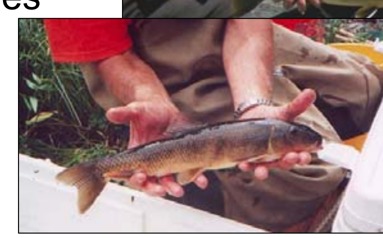


Macroinvertebrates

- Barrier Effects
- Reduced Diversity
- Increased Biomass
- Community Shifts
- *ƒ* (Q, ds, D, V, Stab)
- T&E Species

Fish

- Barrier Impacts
- Lotic to Lentic Shift
- Tailwaters
- Thermal Impacts
- Gas Supersaturation
- Invasive Species
- T&E Species



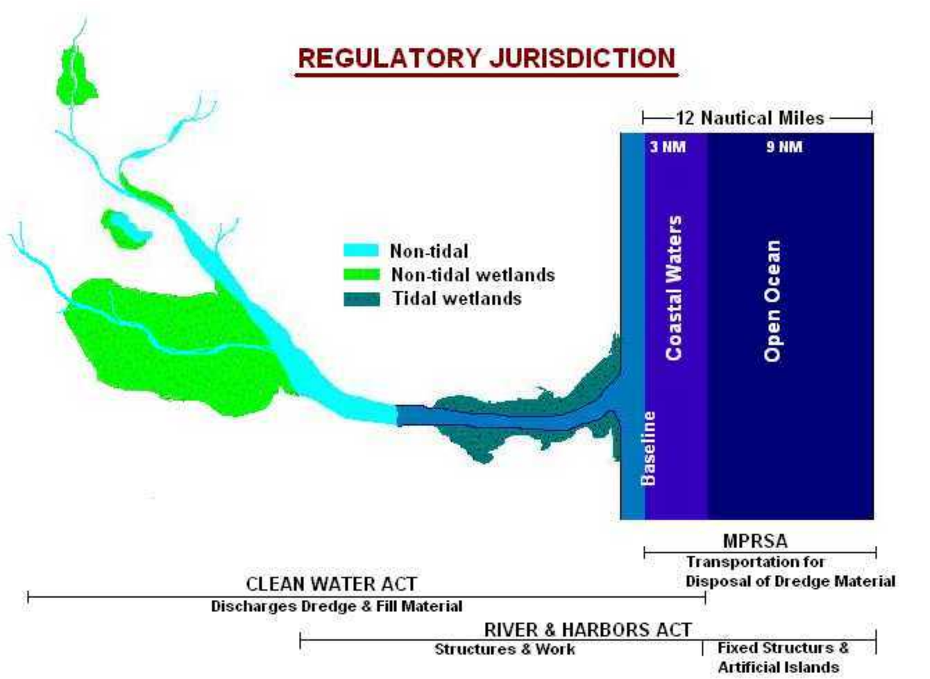
Social Benefits and Costs of Dams

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 disposal and trapping
- Archeological and aesthetic values

Costs

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



Is Removal Beneficial?

Cited reasons for removals

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

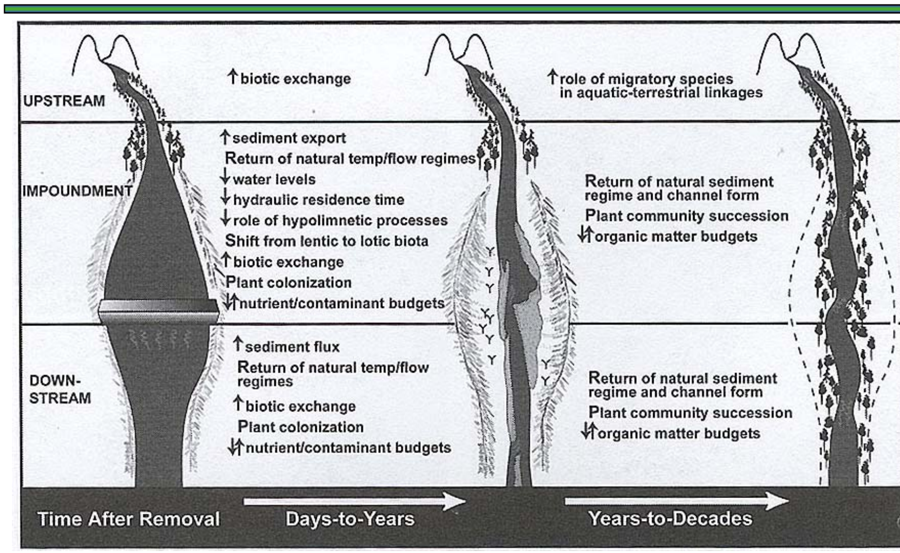
(American Rivers et al., 1999)

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

Potential Adverse Impacts From Removal

- High Turbidity
- Downstream Aggradation
- Upstream Headcutting and Erosion
- Release of Contaminants or Nutrients
- Exotic Species Exploitation
- Vegetation Impacts
- T&E Species Stress
- Altered Ice Regime

Realistic Expectations for 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.

Dam Decision Metrics

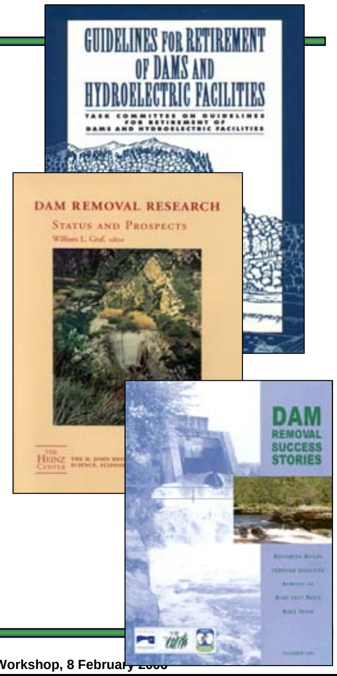
- Physical
  - Hydrology and hydraulics
  - Sediment budget, storage, and properties
  - Channel and valley morphology
  - Headpond capacity
- Chemical
  - WQ and temperature
  - Sediment contamination
- Biological
  - Aquatic and riparian ecosystems' processes and functions
  - Recovery of T&E populations
  - 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

Conclusions and Future Directions

- From the standpoints of public safety, management of aging infrastructure, ecosystem restoration, and management of T&E populations, dam decommissioning is a powerful new tool.
- The lessons learned in removal of smaller structures will be critical to efficient and technically sound removals of the looming cohort of large dam removals - better documentation is required.
- In most cases dam removal has significant restoration costs that are not considered
- Cost-benefit and alternatives analyses are demanding and central to decision making process.

Resources

- **ASCE (1997)** *"Guidelines for Retirement of Dams and Hydroelectric Facilities"* American Society of Civil Engineers: Washington, DC.
  - http://www.asce.org/bookstore/book.cfm?book=3118
- **Graf, W.L. (ed.) (2003**) *"Dam Removal Research: Status and Prospects."* The Heinz Center: Washington, DC.
  - http://www.heinzctr.org/NEW_WEB/PDF/Dam_Research_Full%20Report.pdf
- **American Rivers, Friends of the Earth, and Trout Unlimited (1999)** *"Dam Removal Success Stories."* American Rivers: Washington, DC.
  - http://www.amrivers.org/index.php?module=HyperContent&func=display&cid=1743



Resources

- **Muskegon River Watershed Assembly**: MRWA Data Repository, General Watershed Data - Hydrology
  - http://www.mrwa.org/repository/repository-general-hydrology.htm
- *BioScience* - Special Issue on Dam Removal and River Restoration, Vol. 52, No. 8, August 2002
- **EWRI dam removal series**: http://www.ewrinstitute.org/damremoval04/
- **Conyngham, Fischenich, and White, 2004.** *Engineering and Ecological Aspects of Dam Removal—An Overview*. http://www.wes.army.mil/el/emrrp/tnotes.html
- **White, K.D., 2001.** *Considerations for dam removal in ice-affected rivers*. http://www.crrel.usace.army.mil/ierd/tectran/27InDesign.pdf
- **Aspen Institute, 2002.** *Dam Removal: A New Option For a New Century*. http://www.aspeninstitute.org → Bookstore