A Research Paper by

HEADWATERS ECONOMICS

Dam Removal:

Case Studies on the Fiscal, Economic, Social, and Environmental Benefits of Dam Removal

October 2016

Dam Removal:

Case Studies on the Fiscal, Economic, Social, and Environmental Benefits of Dam Removal

October 2016

PUBLISHED ONLINE:
http://headwaterseconomics.org/economic-development/local-studies/dam-removal-case-studies

ABOUT HEADWATERS ECONOMICS

Headwaters Economics is an independent, nonprofit research group whose mission is to improve community development and land management decisions in the West.

CONTACT INFORMATION

Megan Lawson, Ph.D.| megan@headwaterseconomics.org | 406-570-7475

P.O. Box 7059
Bozeman, MT 59771
http://headwaterseconomics.org

Cover Photo: Whittenton Pond Dam, Mill River, Massachusetts. American Rivers.

TABLE OF CONTENTS

INTRODUCTION

Since the 18th century, dams have been built across the United States to power mills, provide downstream flood control, facilitate transportation, provide irrigation water, and generate hydroelectricity. Presently there are more than two million dams across the country (William 1993), and a federal inventory has identified more than 87,000 dams across the United States that are more than six feet tall (CorpsMaps National Inventory of Dams 2013).

Over time these dams have aged. By 2020, 70 percent of dams in the United States will be more than 50 years old (2013 report card…2013). The Association of State Dam Safety Officials—a national non-profit serving state dam safety programs—estimates it could cost $51.5 billion to rehabilitate the nation's non-federally owned dams (Association of State Dam Safety Officials 2009).

At the same time, economies and energy needs have shifted, and ecological research has advanced. Regulations like the Clean Water Act (CWA) and Endangered Species Act (ESA), state water and fisheries regulations, and tribal rights claims have elevated water quality, fish, and tribal claims where dams are concerned.

While some dams continue to serve useful purposes, others have outlived their original function. For these obsolete dams, the benefits to the public of removing them outweighs the costs. In light of aging infrastructure, it is appropriate to evaluate individual dams to determine whether their ongoing costs and effects on rivers and people justifies the services they provide.

Agencies like the U.S. Army Corps of Engineers (USACE) and the Federal Energy Regulatory Commission (FERC) have established processes to evaluate benefits and costs as a part of various agency programs.

Licensing decisions at FERC, for example, consider multiple management scenarios when evaluating whether to issue new or renew existing dam licenses. The management scenarios may require dam owners to allow greater water flow through the dam, install infrastructure to allow migratory fish to pass upstream, or make safety upgrades. Often the options include a dam removal scenario. These evaluations also include impact assessments that evaluate the benefits and costs to the many parties affected by each management alternative.

The USACE undertakes similar analyses when it evaluates its dams and other river restoration programs. Some dam owners have found that removing a dam is more appropriate than leaving it in place after comparing benefits and costs of addressing the needs of concerned parties and meeting state and federal regulatory requirements.

Since 1912, more than 1,300 dams have been removed across the U.S., and 62 dams were removed in 2015 alone (American Rivers 2016).

This report describes the methods used to measure the benefits of dam removal when comparing costs to benefits, including five case studies and a summary of small dams. The case studies illustrate the range of benefits and costs that can be considered, multiple methodological approaches, and a range of locations.

The case studies range from small former mill sites to large western hydropower dams, including:

- Whittenton Pond Dam on the Mill River in Massachusetts;
- Elwha and Glines Canyon Dams on the Elwha River in Washington;
- Edwards Dam on the Kennebec River in Maine;
- Condit Dam on the White Salmon River in Washington;

- Great Works and Veazie Dams on the Penobscot River in Maine; and
- Three small dam removals including Hyde Pond Dam on Whitford Brook in Connecticut, Bartlett Pond Dam on Wekepeke Brook in Massachusetts, and White Rock Dam on Pawcatuck River in Connecticut and Rhode Island.

MEASURING THE BENEFITS OF DAM REMOVAL

The circumstances for individual dam removal projects are wide-ranging and depend on unique combinations of environmental, historic, and economic factors. The following sections describe the most common reasons for removing dams and how those factors have been quantified. Examples of some benefit-cost comparisons are described in detail in the Case Studies.

In addition, at the end of this section and the Conclusion, Table 1 summarizes benefits by each case study, including the estimated costs of dam removal, the types of benefits, and the alternatives to dam removal that were considered.

Throughout this report, all dollar values have been converted to 2016 dollars.

Cost-Effectiveness of Maintenance Versus Removal

Dams require ongoing maintenance to remove accumulating sediment, make small repairs, and upgrade safety systems. Particularly when older dams are no longer used for their original purpose, dam owners may defer maintenance to the point where the dams pose a threat to public safety (see Whittenton Pond Mill Dam case study). In these cases, it is appropriate for dam owners to work with state and federal experts to figure out how to protect communities. In some cases, it is less expensive to remove the dam than to make the necessary repairs (see Small Dams case study).

Many dam removal decisions have been made after the costs of maintenance or upgrades have been compared with costs of removal.

Vulnerable Species and Other Ecological Benefits

Dams interfere with the life cycle of migratory fish by blocking the migration of adults to upstream spawning grounds, as well as limiting the passage of sediment and large woody debris necessary to maintain suitable spawning areas downstream (Brenkman et al. 2012). Fish passage devices at dams allow some fish to move upstream, but the success rate varies depending on the dam height and the species (Brown et al. 2013).

Dams can be significant impediments to the recovery of vulnerable fish species, including those listed as threatened or endangered under the Endangered Species Act. Removing one dam can open hundreds of miles of upstream spawning habitat in a river's main stem and tributaries, such as the Great Works and Veazie Dams in Maine.

In several cases, the Endangered Species Act has been the catalyst for dam removal due to mandated changes to river management to increase populations of endangered species. In cases such as the Glines Canyon Dam on the Elwha River, which was too high for fish ladders, fish passage facilities are insufficient to restore fish populations. In cases such as the Condit Dam on the White Salmon River, retrofitting the dam to allow fish passage would have been more expensive than removing the dam.

Follow-up population studies after dam removal have found that species quickly return to upstream spawning habitat, even when the river has been blocked for 100 years (Penobscot River Restoration Trust et al., NPS 2014).

Researchers have measured a cascade of ecological improvements associated with dam removal, including: more robust plant and animal health in upper watersheds due to ocean-derived nutrients transported upstream by migrating fish (Tonra et al. 2015); improved health of plants and animals in estuaries and river mouths due to more abundant sediment (Baurick 2015); and improved water quality (Bednarek 2001).

Cultural Values

In addition to subsistence and commercial fish harvests, many Native American tribes have deep cultural, spiritual, and historical connections to specific free flowing rivers, features along those rivers, and the animal and plant species they support. Dams often severely harmed those resources, and were installed with little or no consideration of nearby tribes and their rights (Guarino 2013).

Tribes continue to play significant roles in demonstrating the importance of removing dams. The Edwards Dam in Maine and Elwha and Glines Canyon Dams in Washington are examples of dam removal efforts where a local tribe provided much of the initial impetus for removing dams, and were among the greatest beneficiaries of their removal.

Recreational and Commercial Fisheries

Removing dams also can increase the abundance of commercially and recreationally targeted fish species.

Benefits to commercial fisheries are measured in terms of increased revenue from improved catch rates (Meyer et al. 1995). Benefits to recreational anglers are measured in terms of improved experiences due to increased catch rates and species diversity, discussed in the Non-Market Values section. Benefits from improved recreational fishing also are measured in terms of additional jobs and income supported by more visiting anglers (Meyer et al. 1995).

River Recreation and Other Tourism

Removing dams and returning rivers to a free-flowing state can provide new boating opportunities, particularly for whitewater rafting, canoeing, and kayaking. This provides increased enjoyment for the paddlers, which can be measured by the increased number of boaters and the quality of their experience (Loomis 1999).

Neighboring communities benefit from increased whitewater recreation and other river-related tourism when visitors spend money with local guides, outfitters, restaurants, and other businesses, bringing new money to oftentimes remote communities (Meyer et al.1995).

Non-Market Values

People value seemingly unquantifiable outdoor amenities like free-flowing rivers, endangered species, and recreational opportunities. Researchers are able to apply statistical methods to measure how much people value selected environmental qualities and then translate that value into dollars. These "non-market values" can then be incorporated into cost-benefit analyses.

Non-market values often are used to weigh pros and cons when a federal project will result in large environmental impacts. Since the 1970s the Federal Energy Regulatory Commission (FERC) has considered non-market values in relicensing decisions, due in large part to the passage of the Endangered Species Act and methodological refinements for measuring non-market values (Duffield 2011).

Researchers have found that people place substantial value on the following environmental changes associated with removing dams:

- The existence of a free-flowing river that individuals can see now or in the future, or will be available for their children to visit (Loomis 1996, Loomis 2002, Sanders 1990);
- Knowledge that endangered species are present in a river and their population is recovering (Mansfield et al. 2012, Bell et al. 2003, Berrens et al. 2000, Ekstrand and Loomis 1998);
- Improved catch rates for recreational anglers (Kotchen et al. 2006, Layton et al. 1999, Boyle et al. 1991, Olsen et al 1991, Bishop et al. 1987); and
- Improved experiences for whitewater boaters (Loomis 1999, Gloss et al. 2005).

The Elwha and Glines Canyon Dams case study, for example, describes research that found the American public would be willing to pay approximately $5.3 billion per year to remove the dams and restore the river (Loomis 1996).

Non-market benefits are distinct from the additional spending that anglers and tourists bring to an area. Because the benefits are experienced by people close to the dam as well as those who live far away, total non-market benefits can be quite large and therefore influential in FERC relicensing decisions.

Cost-Effectiveness of Energy Production

Many older hydroelectric dams were built to support nearby mills, factories, and communities, and have relatively small generating capacity. As the U.S. power grid has shifted to more regional rather than local production, power produced by smaller dams can be more expensive than power from regional sources (see Edwards Dam case study) or may no longer be needed if the nearby industrial user has closed (see Elwha Dams case study).

In these cases, the end users are able to secure sufficient electricity generating capacity from less expensive sources, eliminating the original need for the dam.

Economic Impact of Removal Projects

Dam removal and associated river restoration can be substantial, multi-year projects, employing local residents, providing personal income, and contributing to the local economy. Jobs associated with these removal projects often are relatively short-term, but nonetheless valuable particularly in smaller communities.

A 2012 study found that every $1 million spent on Massachusetts Division of Ecological Restoration projects resulted in 10 to 13 jobs created or maintained (Industrial Economics Inc. 2012). A 2010 study in Oregon finds that every $1 million spent on forest and watershed restoration results in 15-23 new jobs and $2.1-2.3 million in economic activity (Nielsen-Pincus and Moseley 2010).

Property Values

Researchers have found that some dams, particularly small dams with small upstream impoundments, can create an unpleasant feature that drives down property values due to lower water quality or flooding risk.

On the Kennebec River in Maine, researchers found that before the Edwards Dam was removed, homes closer to the river had significantly lower property values than similar homes farther from the river. After the dam was removed, there was no longer a price penalty to living closer to the river (Lewis et al. 2008).

A study on numerous small dams in Wisconsin found a similar pattern (Provencher et al. 2008).

CONCLUSION

Dam removal decisions are complex, requiring owners and regulators to weigh a dam's current value in accomplishing its original purpose—such as flood control, agriculture, recreation, and power generation—against the dam's ongoing effects on public safety, water quality, fish and other species, recreation, and cultural values. These considerations also must be evaluated in the context of long-term maintenance costs and costs of removal.

As the thousands of dams in the United States have aged, the upkeep expenses and the need for significant repairs have risen for many dams. At the same time, scientific research has improved our understanding of river systems and the effects dams have on a region's environmental health. Advances in economic methods also have improved our understanding of the economic benefits to nearby communities, river users, and the broader public from free-flowing rivers.

Together, the higher ongoing costs of operating dams and an improved awareness of the economic and social benefits of removing them has shifted the balance sheet for some dams. For these dams, removal often provides greater rewards to taxpayers, local economies, and the surrounding environment. Additionally, funding for removal projects often can be gathered from several sources as different agencies, organizations, and communities better understand how they can benefit from dam removal.

The case studies that follow, summarized in Table 1 below, highlight the many factors that contribute to dam removal decisions, how these factors have been weighed, and the process that led to a dam's removal. This review demonstrates that in many cases the economic, environmental, and social benefits of dam removal outweigh the costs of keeping a dam in place.

Table 1: Case Studies, Benefits of Dam Removal, and Alternatives Considered

Location	Estimated cost of removal (2016$)	Estimated benefits of removal (2016$)	Alternatives to dam removal
Whittenton Pond Dam, Mill River, Massachusetts	$447,000: 99 percent paid by state and federal partners, non-profits	• $1.5 million for avoided emergency response • Increased numbers of two vulnerable species: American eel and river herring • Property values projected to increase due to lower flooding risk	Rebuilding was necessary due to disrepair and safety hazard, cost estimated at $1.9 million
Elwha and Glines Canyon Dams, Elwha River, Washington	$324.7 million	• $5.3 million annually from increased commercial fishing • Cultural and public safety benefits to the Lower Elwha Klallam Tribe, downstream from the dams • $33 million in personal income and 760 new jobs associated with dam removal • $43.8 million and 446 new jobs from 500,000 more visitor days annually • $5.3 billion worth of improved well-being for the American public	Not available
Edwards Dam, Kennebec River, Maine	$10.9 million	• $2.5-$38.2 million for improved recreational fishing quality • $397,000-$2.7 million for improved river recreation quality • Property values closest to the former dam site increased • Electricity produced by Edwards Dam cost 4-5 times the market rate • Water quality prior to dam removal did not meet minimum standards; afterward it could support all native fish • Alewife population increased 60-fold, and they now are used commercially for bait • Quality of life in Augusta has improved due to new connection to the river	$14.9 million to install fish passages and conduct environmental mediation

Location	Estimated cost of removal (2016$)	Estimated benefits of removal (2016$)	Alternatives to dam removal
Condit Dam, White Salmon River, Washington	$24.8 million	• Cultural benefits for the Yakama Nation from returned salmon and lamprey, including sustenance fishing • Expanded spawning grounds for recreationally and commercially important fish: 12 miles for salmon and 33 miles for steelhead • Increased populations of five fish species listed under the Endangered Species Act • 30,000 additional whitewater boaters annually	$52.4 million for fish passages, plus $3.9 million annually in higher electricity costs
Great Works and Veazie Dams, Penobscot River, Maine	$65 million	• 76 jobs and $3.6 million in economic impact from dam removal • Access re-opened for 1,000 miles of habitat for 11 depleted historic fisheries • Cultural and sustenance fishing benefits for the Penobscot Indian Nation • New area spending by whitewater boaters, including several events.	Fish passage facilities were insufficient to restore fisheries
Small Dams: Hyde Pond Dam, Whitford Brook, Connecticut	$1.1 million	• Avoided public safety hazards from catastrophic failure and upstream flooding • Four miles of stream habitat opened to fish species including American eel, a vulnerable species	Dam would have to be rebuilt to meet safety standards. Dam owner would have been responsible for full cost of rebuilding dam
Small Dams: Bartlett Pond Dam, Wekepeke Brook, Massachusetts	$325,000	• Avoided public safety and infrastructure hazards from catastrophic failure and upstream flooding • Eighteen miles of stream habitat opened for brook trout and other species	$671,000 for repairs
White Rock Dam, Pawcatuck River, Connecticut and Rhode Island	$800,000	• Avoided public safety and infrastructure hazards from catastrophic failure and upstream flooding • Twenty-five miles of river habitat opened to fish species	Dam would have to be rebuilt to meet safety standards. Dam owner would have been responsible for full cost of rebuilding dam

References

2013 report card for America's infrastructure - Dams: condition & capacity. 2013. Reston (VA): American Society of Civil Engineers; [accessed 2016 September 20]. http://www.infrastructurereportcard.org/a/ - p/dams/conditions-and-capacity.

American Rivers. 2016. 62 dams removed to restore rivers in 2015. [accessed 2016 September 19]. https://s3.amazonaws.com/american-rivers-website/wp-content/uploads/2016/02/02122410/DamsRemoved_1999-2015.pdf

Association of State Dam Safety Officials. 2009. The cost of rehabilitating our nation's dams. Lexington (KY): Assoc. of State Dam Safety Officials; [accessed 2016 September 19]. http://www.damsafety.org/media/Documents/DownloadableDocuments/RehabilitationCosts2009.pdf.

Baurick T. 2015. Threatened fish makes a comeback in restored Elwha. Kitsap Sun. [accessed 2015 February]. http://www.kitsapsun.com/news/local/threatened-fish-makes-a-comeback-in-restored-elwha-ep-951933878-354896431.html.

Bednarek AT. 2001. Undamming rivers: A review of the ecological impacts of dam removal. Environ Manag. 27(6):803-814.

Bell KP, Huppert D, Johnson RL. 2003. Willingness to pay for local Coho salmon enhancement in coastal communities. Mar Resour Econ. 18(1):15-32.

Berrens RP, Bohara AK, Silva CL, Brookshire D, and McKee M. 2000. Contingent values for New Mexico instream flows: With tests of scope, group-size reminder and temporal reliability. J Environ Manag. 58:73–90.

Bishop RC, Boyle KJ, Welsh MP, Baumgartner RM, and Rathbun PC. 1987. Glen Canyon Dam releases and down stream recreation: An analysis of user preferences and economic values. Springfield (VA): U.S. Department of Commerce National Technical Information Service Pub PB88-183546.

Boyle KJ, Teisel MF, Moring JR, Reiling SD. 1991. Economic benefits accruing to sport fisheries on the Lower Kennebec River from the provision of fish passage at Edwards Dam or from the removal of Edwards Dam. Chelsea (ME): Maine Department of Marine Resources.

Brenkman SJ, Duda JJ, Torgersen CE, Welty E, Pess GR, Peters R, McHenry ML. 2012. A riverscape perspective of Pacific salmonids and aquatic habitats prior to large-scale dam removal in the Elwha River, Washington, USA. Fisheries Manag Ecol. 19(1):36-53.

Brown JJ, Limburg KE, Waldman JR, Stephenson K, Glenn EP, Juanes F, Jordaan A. 2013. Fish and hydropower on the U.S. Atlantic coast: failed fisheries policies from half-way technologies. Conserv Letters. 6:280–286.

CorpsMap National Inventory of Dams. 2013. Washington (DC): U.S. Army Corps of Engineers; [accessed 2016 September 6]. http://nid.usace.army.mil/cm_apex/f?p=838:1:0::NO.

Duffield JW. 2011. The Political Economy of Hydropower and Fish in the Western U.S. In: Johansson P-O, Kristrom B, editors. Modern cost-benefit analysis of hydropower conflicts. Cheltenham, UK: Edward Elgar Publishing.

Ekstrand ER, Loomis JB. 1998. Incorporating respondent uncertainty when estimating willingness to pay for protecting critical habitat for threatened and endangered fish. Water Resour Res. 34(11):3149.

Gloss SP, Lovich JE, Melis TS, eds. 2005. The state of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282. Reston (VA): U.S. Geological Survey; [accessed 2016 September 22]. http://pubs.usgs.gov/circ/1282/c1282.pdf.

Guarino J. 2013. Tribal advocacy and the art of dam removal: The Lower Elwha Klallam and the Elwha dams. Am Indian Law J. 2(1):114-145.

Industrial Economics Inc. 2012. The economic impacts of ecological restoration in Massachusetts. Boston (MA): Massachusetts Division of Ecological Restoration; [accessed 2016-09-22]. http://www.mass.gov/eea/docs/dfg/der/pdf/economic-impacts-ma-der.pdf.

Kotchen MJ, Moore MR, Lupi F, Rutherford ES. 2006. Environmental constraints on hydropower: An ex post benefit-cost analysis of dam relicensing in Michigan. Land Econ. 82(3):384.

Layton DF, Brown GM, Plummer ML. 1999. Valuing multiple programs to improve fish populations. Discussion Papers in Economics at the University of Washington, Department of Economics at the University of Washington.

Lewis LY, Bohlen C, Wilson S. 2008. Dams, dam removal, and river restoration: A hedonic property value analysis. Contemp Econ Policy. 26(2):175-186.

Loomis J. 1996. Measuring the economic benefits of removing dams and restoring the Elwha River: Results of a contingent valuation survey. Water Resour Res. 32(2):441-447.

Loomis J. 1999. Recreation and passive use values from removing the dams on the Lower Snake River to increase salmon. Walla Walla (WA): U.S. Army Corps of Engineers.

Loomis J. 2002. Quantifying recreation use values from removing dams and restoring free flowing rivers: A contingent behavior travel cost demand model for the Lower Snake River. Water Resour Res. 38(6):2.1-2.8.

Mansfield C, Van Houtven G, Hendershott A, Chen P, Porter J, Nourani V, Kilambi V. 2012. Klamath River Basin restoration nonuse value survey: Final report. Research Triangle Park (NC): RTI International.

Meyer PA, Lichtkoppler R, Hamilton RB, Borda CL, Harpman DA, Engel PM. 1995. Elwha River restoration project: Economic analysis. Final technical report. Davis (CA): US Bureau of Reclamation, National Park Service, Lower Elwha S'Klallam Tribe; [accessed 2016 September 22]. https://www.nps.gov/olym/learn/nature/upload/Economic analysis.pdf.

National Park Service (NPS). 2014. Three Chinook salmon spotted above Glines Canyon; First salmon return to the Upper Elwha in 102 years. Port Angeles (WA): Olympic National Park; [accessed 2016 August 31]. https://www.nps.gov/olym/learn/news/three-chinook-spotted-above-glines-canyon.htm.

Nielsen-Pincus M, Moseley C. 2010. Economic and employment impacts of forest and watershed restoration in Oregon. Eugene (OR): Ecosystem Workforce Program, Institute for a Sustainable Environment, University of Oregon; [accessed 2016-09-22]. https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/10776/WP24.pdf?sequence=1.

Olsen D, Richards J, Scott RD. 1991. Existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. Rivers. 2(1):44-56.

Penobscot River Restoration Trust, University of Maine, NOAA. 2015 November 15. After more than a century, endangered shortnose sturgeon find historic habitat post dam removal. [accessed 2016 August 5]. http://www.penobscotriver.org/assets/JtPressReleaseSturgeonDamRemoval_FINAL.pdf.

Provencher B, Sarakinos H, Meyer T. 2008. Does small dam removal affect local property values? An empirical analysis. Contemp Econ Policy. 26(2):187-197.

Sanders LD, Walsh RG, Loomis JB. 1990. Toward empirical estimation of the total value of protecting rivers. Water Resour Res. 26(7):1345-1357.

Tonra CM, Sager-Fradkin K, Morley SA, Duda JJ, Marra PP. 2015. The rapid return of marine-derived nutrients to a freshwater food web following dam removal. Biol Conserv. 192:130-134.

William G. 1993. Landscapes, Commodities, and Ecosystems: The relationship between policy and science for American rivers. Sustaining our water resources. Tempe (AZ). Arizona State University. [accessed 2016 October 7]. https://www.nap.edu/read/2217/chapter/4

WHITTENTON POND DAM, MILL RIVER, MASSACHUSETTS

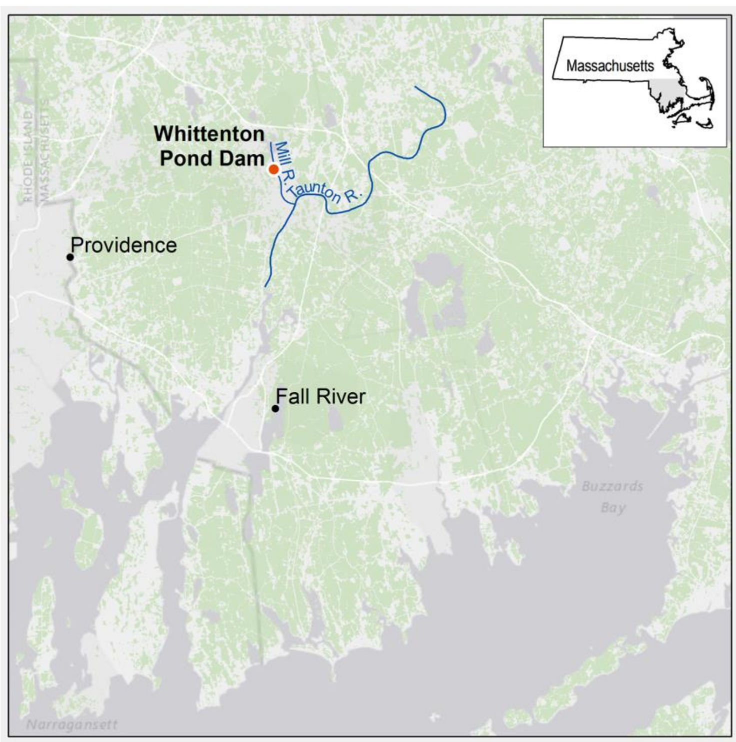
Overview

The Whittenton Pond Dam in Taunton, Massachusetts was in disrepair and the potential for a catastrophic breach was a significant risk to downstream communities. Removing the dam was less expensive than repairing it, and its removal in 2013 opened 30 miles of river habitat to vulnerable fish species.

Dam Removal Process

The Whittenton Pond Dam was a privately-owned dam located in Taunton, Massachusetts on the Mill River. The 10-foot- high and 120-foot-wide wood and concrete structure originally was built in 1832 to power a textile mill. When the mill closed, the dam was no longer maintained.

Heavy rains in 2005 brought the threat of a catstrophic breach and flooding of downtown Tauton, which was evacuated for a week as the dam appeared on the verge of failure (MDFG 2015). Around this time, the dam owner also decided it would be prudent "to remove the dam in order to reduce liability and avoid the cost of rebuilding the dam" (MDFG 2015).



Primary Benefits

Cost Effectiveness: Removing the dam cost less than one-quarter of the cost of necessary repairs.

Avoided Emergency Response Cost: Without the threat of a catastrophic dam breach, taxpayers avoid emergency response costs of more than $1.5 million.

Vulnerable Species: Dam removal opened access to historical habitat for a number of species, including vulnerable American eel and river herring.

Property Values: Due to reduced flooding risk, dam removal is expected to increase values for properties upstream and downstream of the dam site.

Benefits of Dam Removal

Removing the Whittenton Pond Dam is associated with four main types of benefits: cost effectiveness compared to other management alternatives, avoided emergency response cost, protection of vulnerable species, and increased property values.

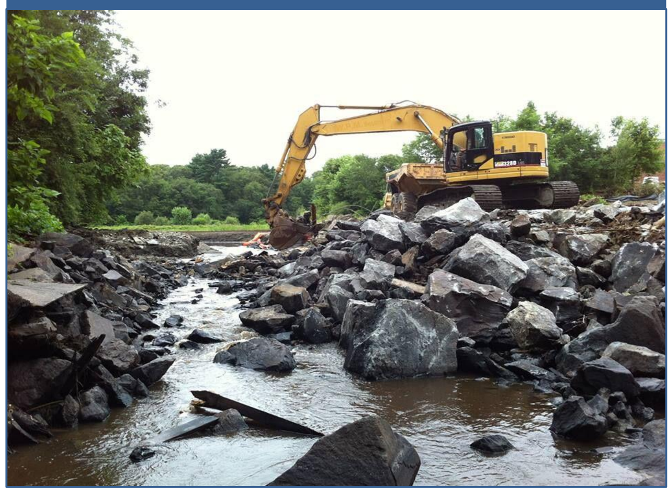
Cost Effectiveness

In 2008, Massachusetts Division of Ecological Restoration (DER) and the Southeastern Regional Planning and Economic Development District commissioned a feasability assessment of removing the dam, including no-action, dam removal, and fish passage alternatives.

Improvements to the dam were necessary to protect public safety. Due to the age and disrepair of the dam, these improvements essentially required rebuilding the dam, dramatically increasing the cost of the "no-action" alternative.

Dam removal cost $447,000 compared to $1.9 million estimated to rebuild the dam (MDFG 2015). Repair options with a fish ladder or a fish bypass channel would have cost even more than rebuilding. Due to the public safety and ecological importance of this dam removal project, together the National Oceanic and Atmospheric Administration (NOAA), American Rivers, The Nature Conservancy, and Coastal America Foundation paid for 99.5 percent of the removal costs. The dam was removed in 2013 as part of a larger effort that removed two dams on the Mill River, with a third to be removed in the next year.

BEFORE



AFTER

Photo credits: American Rivers

Avoided Emergency Response Cost

Removing the dam represented a significant avoided cost for emergency response to a catastrophic breach, that would have been borne by state and local taxpayers. The 2015 MDFG study estimated the 2005 costs of emergency reponses were in excess of $1.5 million; a catastrophic breach likely would have cost even more.

Vulnerable Species

Removing this dam and two other Mill River dams opened more than 30 river miles of additional river habitat, benefitting two vulnerable fish species: the American eel, being evaluated for listing as threatened under the Endangered Species Act, and river herring, listed as a Species of Concern by the National Marine Fisheries Service.

Although no studies of fish recovery yet have been conducted at this dam site, just downstream of the Whittenton Pond Dam, the Hopewell Mill Dam was removed in 2012. The following year, the Massachusetts Division of Marine Fisheries (DMF) found river herring above the dam for the first time in more than 200 years (Larocque 2013). Furthermore, a 2015 news article reported that American eel had returned and are again "fairly plentiful" in the Mill River (Winokoor 2015).

Property Values

Research on other dam sites in Maine and Wisconsin found that removing dams, and thereby eliminating associated small impoundments and flooding risk, results in small but consistently higher property values nearby (Provencher et al. 2008, Lewis et al. 2008). The Massachusetts Department of Fish and Game (MDFG 2015) expects to see a similar boost to local property values near the Whittenton Pond Dam site.

References

Larocque M. 2013. Alewife fish run through former site of Hopewell Mills Dam in Taunton. Tauton Daily Gazette, Apr 28, 2013. [accessed 2016 September]. http://www.tauntongazette.com/x2062758468/Alewife-fish-run-through-former-site-of-Hopewell-Mills-Dam-in-Taunton.

Lewis LY, Bohlen C, Wilson S. 2008. Dams, dam removal, and river restoration: A hedonic property value analysis. Contemp Econ Policy. 26(2):175-186.

Massachusetts Department of Fish and Game (MDFG). 2015. Economic & Community Benefits from Stream Barrier Removal Projects in Massachusetts. Boston (MA): Massachusetts Department of Fish and Game; [accessed 2016 September]. http://www.mass.gov/eea/docs/dfg/der/pdf/phase-iii-benefits-from-stream-barrier-removal-projects.pdf.

Winokoor C. 2015. Going with the flow, 10 years after Taunton's dam crisis. Tauton Daily Gazette, October 18, 2015. [accessed 2016 September]. http://www.tauntongazette.com/article/20151018/NEWS/151016326.

Provencher B, Sarakinos H, Meyer T. 2008. Does small dam removal affect local property values? An empirical analysis. Contemp Econ Policy. 26(2):187-197.

ELWHA AND GLINES CANYON DAMS, ELWHA RIVER, WASHINGTON

Overview

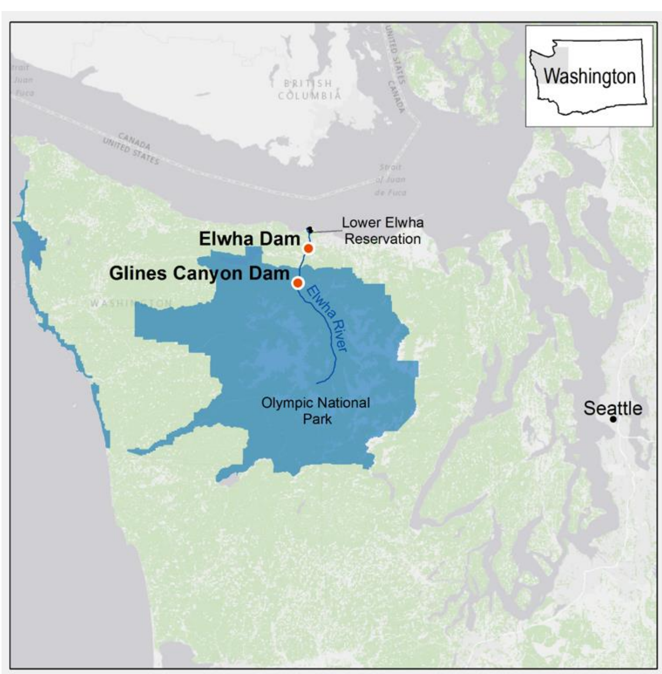
Removal of the Elwha and Glines Canyon Dams from the Elwha River in Washington in 2012 was the largest dam removal and river restoration project in the United States to date. Before these dams were built, the river supported ten runs of salmon and trout, including all five Pacific salmon species.

Removing these two dams was the only way to restore these fish runs. This project was a unique opportunity for fishery restoration because the upper section of its watershed lies entirely in Olympic National Park, increasing the chances of successful recovery.

The cost of removing two dams and restoring the river, as well as lost power generation, were outweighed by the benefits to the Lower Elwha Klallam Tribe, nearby communities, and American public.

Dam Removal Process

Completed in 1913, the Elwha Dam was located five miles upstream from where the Elwha River empties into the Strait of Juan de Fuca. It was 105 feet high and had a 14.8 MW generation capacity.



Primary Benefits

Recreational and Commercial Fisheries: Total increased catch is expected to value approximately $5.3 million per year.

Cultural Values: Dam removal restored the river, historical fishing grounds, and cultural sites important to the Lower Elwha S'Klallam Tribe.

Dam Removal Economic Impact: The dam removal and river restoration processes are expected to add 760 new jobs and $33 million in personal income.

Tourism: The newly restored river is expected to bring 500,000 additional visitor days per year, generating $43.8 million in new spending.

Non-Market Values: The American public is willing to pay approximately $5.3 billion per year to support dam removal and river restoration on the Elwha River.

Ecological Benefits: Dam removal opened access for 40 miles of historical habitat for ten runs of salmon and trout, including ESA-listed Chinook salmon and bull trout.

The Glines Canyon Dam was completed in 1927 and was 13 miles from the Strait of Juan de Fuca. It was 210 feet high and had 13.3 MW generation capacity. Both dams were used to generate hydroelectric power for nearby paper and lumber mills.

The Crown Zellerbach Corporation (now James River Corporation) submitted an application for a FERC license in 1973. A failed safety inspection in 1978, followed by modeling of flood hazard should the dam fail, highlighted potential harm to the Lower Elwha Klallam Tribe.

The licensing process was proceeding when Congress passed the Elwha River Ecosystem and Fisheries Restoration Act in 1992, which a) removed FERC's authority to license the Elwha Project; b) required federal studies to research alternatives for full restoration of the Elwha River ecosystem and migratory fisheries; and c) authorized the Secretary of Interior to purchase and acquire both the Elwha and Glines Canyon Dams for a fixed price and then implement necessary actions to meet full restoration objectives (U.S. Congress 1992).

The Department of Interior purchased the two dams from James River Corporation in 2000 for $29.5 million. Two environmental impact statements (EIS) concluded that neither leaving the dams intact nor installing fish passages would be sufficient to restore the fisheries. As a result, the Elwha and Glines Canyon Dams were removed in 2012. The total cost of purchasing and removing the dams and hydropower facilities, and conducting river restoration activities, was $324.7 million (National Park Service 2016).

Benefits of Dam Removal

Removing the dams and restoring the river and its historic fish runs have generated wide ranging benefits for local residents and visitors, including: cultural benefits for the Lower Elwha Klallam Tribe; improved catch rates for commercial and recreational anglers; additional jobs and income from dam removal and river restoration activities; additional jobs and income from new tourism; benefits to the American public from restoring a notable river; and a suite of ecological benefits from restoring the salmon runs.

Because 83 percent of the Elwha River's watershed is located within Olympic National Park, this river represented a unique restoration opportunity.

Twenty years passed between when the Elwha River Ecosystem and Fisheries Restoration Act was passed and when the dams were removed. The research describing the benefits of dam removal therefore spans decades as well.

Recreational and Commercial Fishing

Removing the Elwha and Glines Canyon Dams provided access to an additional 40 miles of mainstem river habitat as well as tributaries. A few months after dam removal, the mainstem and its tributaries were being used by wild and hatchery salmon. In the first season after the Elwha Dam was removed, more than 4,000 spawning Chinook were counted (Mapes 2016). Scientists also observed increased sockeye salmon populations, with 400 sockeye counted in 2012 after the Elwha Dam was removed. Those counts increased to 800 and then 1,100 in 2013 and 2014 (Witze 2014).

These increased fish populations are expected to bring approximately $5.3 million dollars per year from increased total catch from tribal and non-tribal commercial fishing and recreational fishing (Meyer et al. 1995). Larger catches will likely add income and employment in the local fishing sector, but these changes have not been quantified.

Cultural Benefits

The benefits of dam removal to the Lower Elwha S'Klallam Tribe, who was a key partner in the process which ultimately led to dam removal, are immeasurable. The Tribe has lived in the area since before the beginning of recorded history, and the Elwha River and its fishery had served as the basis for the culture, economy and sustenance of the tribe, all of which were severely impacted by installation of the dams.

BEFORE

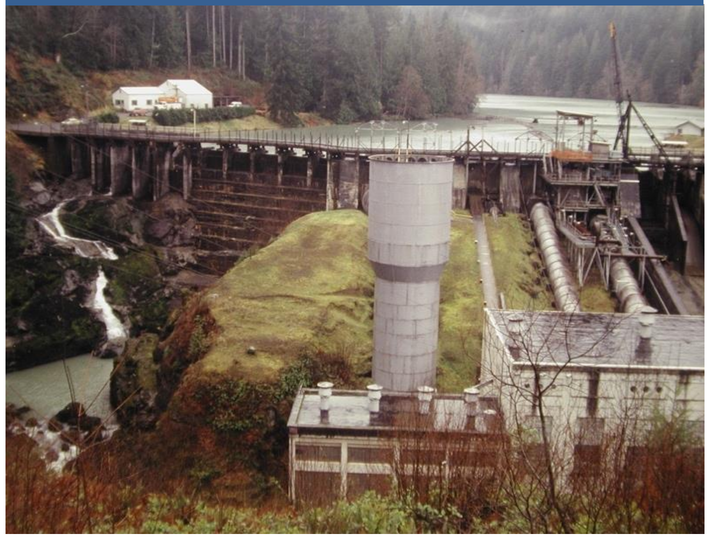


Photo credit: Thomas O'Keefe

Dam Removal Economic Impact

The processes of dam removal and river restoration were forecasted to add at least 760 new jobs and $33 million in new personal income to the area (Meyer et al. 1995). Data on the actual change in local jobs and income is not yet available.

AFTER

Photo credit: Richard Probst

Tourism

Loomis (1996) estimates dam removal and full restoration of the river would result in 500,000 more visitor days to the area per year from U.S. residents alone, with associated expenditures of $43.8 million per year. These expenditures were expected to support 446 additional jobs in the county.

Non-Market Values

Using a survey technique called contingent valuation, Loomis (1996) estimated the American public would be willing to pay approximately $5.3 billion per year to remove the dams and restore the Elwha River. This number is orders of magnitude greater than other monetary benefits, such as from tourism or increased fishing, but it is not unusual for environmental considerations of national importance. For example, a contingent valuation study of the Exxon-Valdez oil spill in Alaska estimated the American public would be willing to spend $4.8 billion to avoid another oil spill like Exxon-Valdez (Carson et al. 1992).

This technique, commonly used by federal agencies to measure the benefits of projects with substantial environmental impact, involves asking survey respondents to vote yes or no to dam removal if dam removal meant the respondent had to pay higher taxes. By aggregating responses from respondents around the United States, Loomis was able to estimate the American public's value for removing these dams.

References

Carson RT, Mitchell RC, Hanemann WM, Kopp RJ, Presser S, Ruud PA. 1992. A Contingent Valuation Study of Lost Passive Use Values Resulting from the Exxon Valdez Oil Spill: A Report to the Attorney General of the State of Alaska. [accessed 2016 September 16]. http://www.evostc.state.ak.us/static/PDFs/econ5.pdf

Federal Energy Regulatory Commission (FERC). 1997. Final Environmental Impact Statement: Kennebec River Basin, Maine. Washington DC.

Le P. 2014. As dams fall, Elwha River makes stunning recovery. The Spokesman-Review, July 7, 2014. [accessed 2016 September 16]. http://www.spokesman.com/stories/2014/jul/07/as-dams-fall-elwha-river-makes-stunning-recovery/.

Loomis J. 1996. Measuring the economic benefits of removing dams and restoring the Elwha River: Results of a contingent valuation survey. Water Resour Res. 32(2):441-447.

Mapes LV. 2016. Elwha: Roaring back to life. The Seattle Times, February 13, 2016. [accessed 2016 August 25]. http://projects.seattletimes.com/2016/elwha/.

Meyer PA, Lichtkoppler R, Hamilton RB, Borda CL, Harpman DA, Engel PM. 1995. Elwha River restoration project: Economic analysis. Final technical report. Davis (CA): US Bureau of Reclamation, National Park Service, Lower Elwha S'Klallam Tribe; [accessed 2016 September 22]. https://www.nps.gov/olym/learn/nature/upload/Economic analysis.pdf.

National Park Service. 2016. Elwha Frequently Asked Questions. [accessed 2016 September 28]; https://www.nps.gov/olym/learn/nature/elwha-faq.htm.

Nijhuis M. 2014. World's largest dam removal unleashes U.S. river after century of electric production. National Geographic, Aug. 27, 2014. [accessed 2016 August 25]; http://news.nationalgeographic.com/news/2014/08/140826-elwha-river-dam-removal-salmon-science-olympic/.

U.S. Congress. 1992. H.R. 4844 - Elwha River Ecosystem and Fisheries Restoration Act. Washington (DC): 102nd Congress of the United States of America.

Witze A. 2014. Dam demolition lets the Elwha River run free. Science News, December 30, 2014. [accessed 2016 August 25]. https://www.sciencenews.org/article/dam-demolition-lets-elwha-river-run-free.

EDWARDS DAM, KENNEBEC RIVER, MAINE

Overview

The Edwards Dam, removed from the Kennebec River in 1999, resulted in significant benefits for recreational fisheries and boating, improved water quality and wetland habitat, and enhanced quality of life for nearby communities. Due to the potential for large ecological benefits and cost savings compared to installing fish passage, this dam removal was the first instance when FERC overrode the relicensing request of a dam owner.

Dam Removal Process

The Edwards Dam, originally built in 1837, was a 917-foot-long, 24-foot-high hydroelectric facility with a relatively small generating capacity of 3.5 MW. The reservoir behind it covered 1,000 acres and extended more than 15 miles up the Kennebec River (FERC 1997, Lewis et al. 2008).

As a hydroelectric project, the Edwards Dam operated under a FERC license, which, along with eight other dams on the Kennebec River, was set to expire in 1993. In their relicensing application, the Edwards Manufacturing Company proposed to expand the generating capacity of the facility from 3.5 MW to 11 MW (FERC 1997).

After an extended regulatory battle, during which FERC overruled the dam owner's preferences to keep the dam in place, the agency ordered the dam to be removed.

Primary Benefits

Recreational Fisheries: Dam removal benefitted recreational anglers through improved catch rates.

River Recreation: Removing the dam opened a new stretch of river, projected to attract many new boaters, while generating $397,000 to $2.7 million in new income.

Property Values: The river is less prone to flooding and water quality is higher, making the river more appealing and increasing property values for those living closest to the river.

Cost Effectiveness: Removing the dam was less expensive than installing fish passages.

Water Quality: Eliminating the dam increased the river's water quality within two months from Class C to Class B.

Commercial Fisheries: Dam removal opened access to more than 17 miles of historical habitat for multiple Kennebec River fisheries.

Quality of Life: The free flowing river created a new amenity for the city of Augusta, the state's capital, with a large new park, and access to new river recreation opportunities.

The dam cost $10.9 million to remove, compared to the $14.9 million needed to build fish passages and perform other environmental remediation (FERC 1997).

Benefits of Dam Removal

Removing the Edwards Dam generated benefits related to recreational angling, boating, property values, cost effectiveness, water quality, commercial fisheries, and quality of life for nearby residents.

Recreational Fisheries

Boyle et al. (1991) estimated recreational anglers' willingness-to-pay (WTP) to restore Kennebec River migratory fisheries and the subsequent improved catch rates. The study estimated recreational anglers would be willing to pay $2.5 million per year for improved fisheries.

Using alternative methods, Freeman (1996) estimated that dam removal would bring a minimum of $2.7 million in annual benefits to recreational anglers. Freeman's findings, and methodological insights highlighting the need to consider benefits other than those related to hydroelectric power, ultimately influenced FERC's decision to deny the dam owner's relicensing application.

Research conducted after the dam was removed used a travel cost model to estimate benefits of dam removal to recreational anglers. Based on average fishing licenses sold in Maine, Robbins (2006) estimated total annual economic benefits of more than $38.2 million between freshwater ($11 million) and tidal water ($27.2 million) sections of the Kennebec.

River Recreation

The U.S. Fish and Wildlife service commissioned Industrial Economics to estimate the benefits from improved boating on the Kennebec River as a case study for its handbook on methods for conducting economic analyses of hydropower project relicensing. This study estimated annual benefits of between $397,000 and $2.7 million, amounting to benefits totaling $4.9 to $61.2 million over 30 years. The wide range in benefits is due to different underlying assumptions about predicted changes in the number of new boaters. At the time of this study, as a point of comparison, the estimated cost of removing the Edwards Dam was $4 million (Black R et al. 1998).

Property Values

After the dam was removed, Lewis et al. (2008) estimated the economic impact of dam removal on property values, the first study of its kind. The report found that properties closer to the Kennebec River had lower property values than properties farther away, potentially due to lower water quality or flooding risk. After dam removal, however, the "penalty" decreased significantly from $2,889 to $194, showing that dam removal has had a small but consistently positive impact on nearby property values.

Cost Effectiveness

In addition to the monetized benefits of dam removal, FERC determined that dam removal would be the least expensive management alternative. Regulators deemed that fish passage was necessary, but installing these structures would make the relicensing option approximately 1.4 times more expensive than dam removal (FERC 1997).

Additionally, electricity produced by the Edwards Dam, under both the 3.5 MW and 11 MW scenarios, cost four to five times the average market rate (FERC 1997, American Rivers et al. 1999).

BEFORE

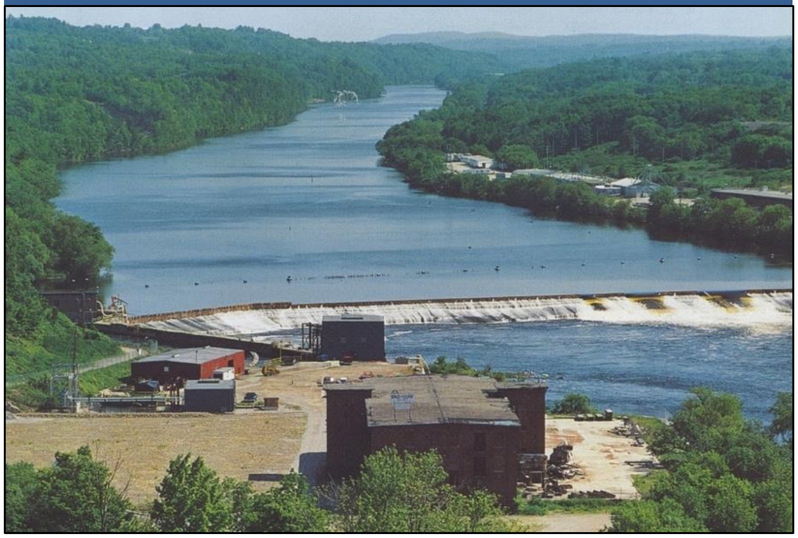


Photo credit: American Rivers

AFTER

Photo credit : American Rivers

Water Quality

Water quality improved quickly and measurably after the dam was removed. Before removal, water in the impoundment behind Edwards Dam failed to meet the minimum water quality standard for Maine (Class C, the lowest standard that supports all native fish). Two months after removal, water quality had improved enough to meet Maine's Class B standard, which indicates the habitat for native fish is unimpaired (Kennebec Coalition 2000).

Commercial Fisheries

In combination with other restoration efforts, removal of the Edwards Dam opened 17 miles of habitat, leading to substantial gains for some of the Kennebec River migratory fish. According to the Natural Resources Council of Maine, the largest runs of alewives and river herring on the eastern seaboard are found in the Kennebec River (Edwards 2014). In 2016, an article in the Portland Press Herald reported that an estimated 3 million alewives now travel up the river annually as compared to a decade ago when fewer than 50,000 did. The species is now being used for commercial fishery bait and has also supported a substantial increase in bald eagles in the area—as the species' annual run coincides with breeding season for the bald eagles (McGuire 2016).

Quality of Life

The City of Augusta, which initially opposed removal due to the losses in revenue and property taxes associated with dam removal, is benefitting from its new connection to the free flowing river, including a 17-acre park where the dam was once located. Mayor Roger Katz noted: "The breaching of the dam is leading to so many wonderful consequences for our community. From the Mill Park with its canoe and kayak launch and new pavilion to the looming Arsenal project, to our expected development of the old paper mill site, we are finally returning our focus to the river" (Fahlund 2016).

References

American Rivers, Friends of the Earth, Trout Unlimited. 1999. Dam removal success stories: Restoring rivers through selective removal of dams that don't make sense. [accessed 2016 September 16]; https://www.michigan.gov/documents/dnr/damsuccess_513764_7.pdf.

Black R, McKenney B, Unsworth R. 1998. Economic analysis for hydropower project relicensing: Guidance and alternative methods. Cambridge (MA): Industrial Economics, Inc. Report prepared for U.S. Fish & Wildlife Service, Division of Economics. (See Chapter 7 - Case Studies.)

Boyle KJ, Teisel MF, Moring JR, Reiling SD. 1991. Economic benefits accruing to sport fisheries on the Lower Kennebec River from the provision of fish passage at Edwards Dam or from the removal of Edwards Dam. Report prepared for the Maine Department of Marine Resources.

Edwards K. 2014. Without Edwards Dam, fish and birds thrive on the Kennebec. centralmaine.com, June 30, 2014. [accessed 2016 August 11]; http://www.centralmaine.com/2014/06/30/without-edwards-dam-fish-and-birds-thrive-on-the-kennebec/.

Fahlund A. 2016. River rebirth: Removing Edwards Dam on Maine's Kennebec River. National Geographic. [accessed 2016 August 11]; http://environment.nationalgeographic.com/environment/freshwater/lessons-from-the-field-edwards-dam-removal-maine/.

Federal Energy Regulatory Commission (FERC). 1997. Final Environmental Impact Statement: Kennebec River Basin, Maine. Washington (DC): Federal Energy Regulatory Commission.

Freeman AM. 1995. The economic benefits of removing Edwards Dam. Unpublished paper, Bowdoin College, Brunswick ME.

Freeman AM. 1996. Review and critique of FERC's benefit-cost analysis for the Edwards Dam project: Report to the Federal Energy Regulatory Commission. Bowdoin College, Brunswick, ME.

Kennebec Coalition. 2000. FERC stands by Edwards Dam removal decision. Trout Unlimited, May 31, 2000. [accessed 2016 August 11]; http://www.tu.org/press_releases/2000/ferc-stands-by-edwards-dam-removal-decision.

Lewis LY, Bohlen C, Wilson S. 2008. Dams, dam removal, and river restoration: A hedonic property value analysis. Contemp Econ Policy. 26(2):175-186.

McGuire P. 2016. The eagles have landed on alewife migration in Maine. Portland Press Herald, April 10, 2016. [accessed 2016 August 11]; http://www.pressherald.com/2016/04/10/the-eagles-have-landed-on-the-alewife-migration/.

Robbins JL. 2006. The economic benefits of the Kennebec River fishery post-Edwards Dam removal [thesis]. Lewiston (ME): Bates College.

CONDIT DAM, WHITE SALMON RIVER, WASHINGTON

Overview

The Condit Dam, removed from the White Salmon River in Washington in 2012, used to block 12 miles of spawning ground for salmon and 33 miles of spawning grounds for steelhead, including several populations listed under the Endangered Species Act. Removing the dam was the most effective and least expensive means of achieving fish management goals.

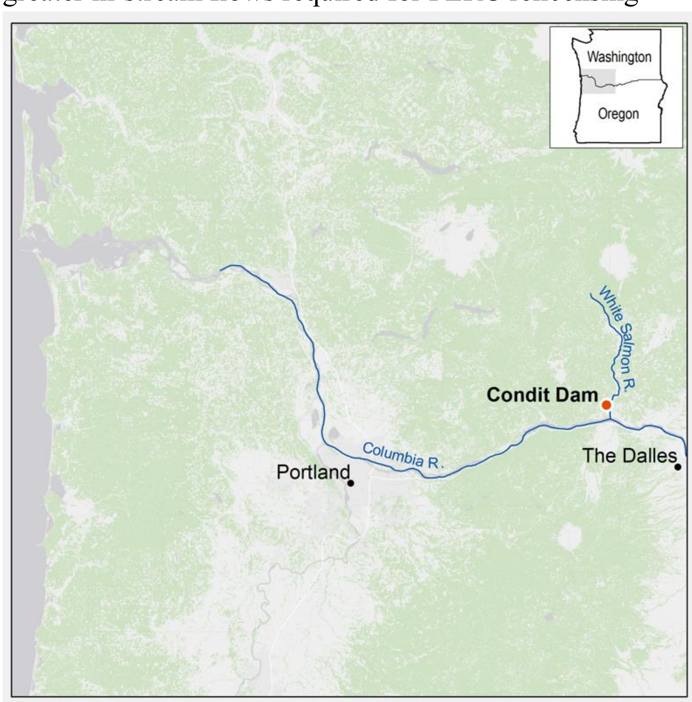
Dam Removal Process

The Condit Dam was a 125-foot-high and 471-foot-long concrete structure located on the White Salmon River in south-central Washington approximately 3.3 miles upstream of the White Salmon's confluence with the Columbia River. A few miles above the dam, the White Salmon is part of the National Wild and Scenic Rivers system. Below the former dam site the river is part of the Columbia River Gorge National Scenic Area (Allen at al. 2016).

The Northwestern Electric Company (now PacifiCorp) originally installed this 14.7 MW hydroelectric facility in 1968 to supply electricity to the Crown Willamette Paper Company in Camas, Washington and support increasing demand from local municipalities (PacifiCorp 2011).

The Condit Dam had no fish passage facilities, creating a barrier limiting migratory fish spawning grounds to the short stretch of river below the dam. To rectify this problem, FERC presented a series of recommendations and an analysis of dam removal benefits and alternatives in a Final Environmental Impact Statement (FEIS) in 2002 (FERC 2002).

PacifiCorp removed the Condit Dam after determining that the modifications to accommodate fish passage and greater in-stream flows required for FERC relicensing



Primary Benefits

Cost effectiveness: Removing the dam was less expensive than installing fish passages.

Cultural: The free-flowing river restored the river and historical fishing grounds important to the Yakama Nation.

Recreational and Commercial Fishing: Without the dam, salmon and steelhead now have access to historical habitat.

Vulnerable Species: Dam removal opened the river to five threatened species including steelhead, Chinook salmon, and Coho salmon.

River Recreation: The river now has five additional miles of boatable whitewater.

would have reduced the dam's energy production, increased production costs, and made continued dam operations uneconomical (FERC 2002).

FERC accepted the dam removal agreement in 2010, the dam was breached in 2011, and dam removal was completed in 2012.

Benefits of Dam Removal

Researchers identified four primary categories of benefits from removing the Condit Dam: cost-effectiveness, endangered species, river recreation, and cultural values. While researchers did not estimate dollar values other than those associated with cost-effectiveness, their importance factored significantly into the decision to remove the dam.

Cost Effectiveness

The primary economic evidence supporting dam removal was the relative cost of removing the dam according to the dam removal agreement ($24.8 million) versus installing the recommended modifications ($52.4 million). Additionally, the reduced generation capacity would have raised generation costs by $48 per megawatt hour, resulting in $3.9 million additional costs for ratepayers (FERC 2002).

Cultural Values

Dam removal has had "profound spiritual and cultural significant for the Yakama Nation" (USFWS 2016). In addition to being a large part of their oral traditions, the White Salmon River and its fish (particularly salmon and lamprey) provided sustenance for tribal members. While much of the post-removal research has focused on salmon, in 2016 Pacific lamprey were found for the first time in more than 100 years in the river upstream from the dam site (Pesanti 2016).

Recreational and Commercial Fisheries

Removing the dam was expected to increase and improve migratory fish habitat, subsequently increasing fish populations and benefitting recreational and commercial fisheries.

Historically, the White Salmon River served as spawning grounds for a variety of salmon and steelhead species. However, without any provision for fish passage the dam blocked access to 12 miles of spawning grounds for salmon and 33 miles of spawning grounds for steelhead (Gimblett et al. 2015). This essentially limited these migratory species to 3.3 river miles below the dam. In addition to removing this major barrier to fish passage, dam removal improved spawning habitat, water quality and instream flow above and below the dam (FERC 2002).

Researchers have studied the river and its fisheries since removal of the dam and have found that the expected increases in fish populations that researchers anticipated are occurring. Fish are creating new spawning grounds, with salmonids using spawning grounds both downstream and upstream of the dam site; some species' spawning counts are increasing and other species are spawning in new locations (see Allen et al. 2016, Hardiman and Allen 2015, Gimblett at al. 2015, Hatten et al. 2015).

Additionally, the FEIS noted, "removal of the Condit dam would provide substantial long-term benefits to the scenic area and scenic river management objectives of the area" (FERC 2002), consistent with its National Scenic Area and Wild and Scenic River designations.

Vulnerable Species

The Condit Dam removal project also was expected to support the populations of five fish populations listed under the Endangered Species Act, including sockeye salmon, Chinook salmon, Coho salmon, Chum salmon, steelhead, and bull trout (Hardiman and Allen 2015).

One year after the dam was removed, researchers found redds (places where salmon and steelhead lay their eggs) from both Chinook runs and steelhead above and below the dam (Engle et al. 2013).

Pacific lamprey, a federal Species of Concern, have been found upstream of the dam site for the first time in more than 100 years (Pesanti 2016).

BEFORE

Photo credit: Thomas O'Keefe

AFTER

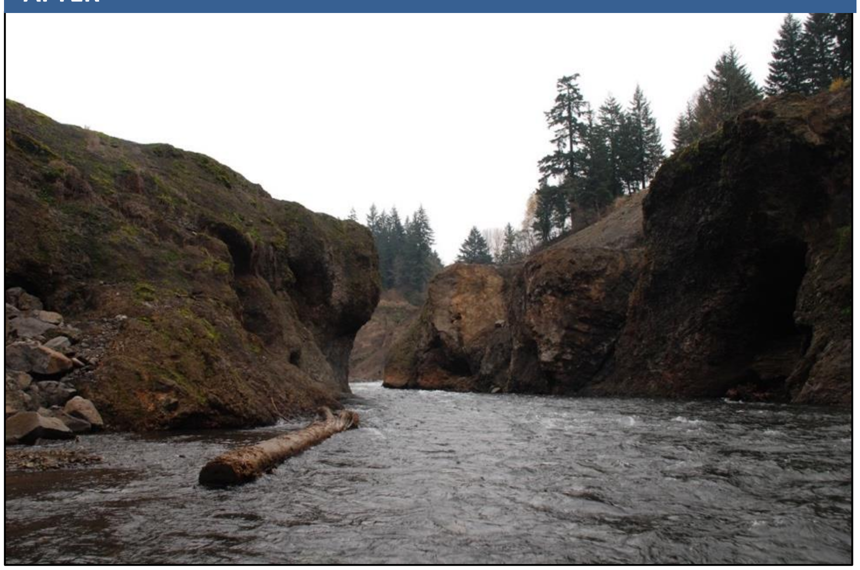


Photo credit: Thomas O'Keefe

River Recreation

Without the dam, whitewater recreationalists now have access to an additional five miles of river in an area that was already a whitewater destination and important economic driver (FERC 2002, Gimblett et al. 2015). The FEIS also projected that dam removal would result in increased recreational spending in the area as a result of both improved fishing and whitewater rafting/kayaking opportunities (FERC 2002). Research has estimated a low estimate of 30,000 whitewater recreationalists using the White Salmon River during the four summer months of 2014 (Gimblett et al. 2015). The author describes this as "high levels of use" as compared to estimates on other popular rivers. These benefits were not monetized.

References

Allen MB, Engle RO, Zendt JS, Shrier FC, Wilson JT, Connolly PJ. 2016. Salmon and steelhead in the White Salmon River after the removal of Condit Dam–Planning efforts and recolonization results. Fisheries. 41(4):190-203.

Engle R, Skalicky J, Poirier J. 2013. Translocation of Lower Columbia River fall Chinook salmon (*Oncorhynchus tshawytscha*) in the year of Condit Dam removal and Year One post-removal assessments: 2011 and 2012 report. Vancouver (WA): U.S. Fish and Wildlife Service. [accessed 15 September 2016]; https://www.fws.gov/columbiariver/publications/WhiteSalmonRiverReportMarch2013.pdf.

Federal Energy Regulatory Commission (FERC). 2002. Final Environmental Impact Statement: Condit Hydroelectric Project, FERC Project No. 2342. Washington (DC): Federal Energy Regulatory Commission.

Gimblett R, Scott C, Hamersley M. 2015. Freeing the White Salmon River: Dam removal, climate change, fish, and rafting. Tucson (AZ): University of Arizona. [accessed 2016 September 16]; http://cals.arizona.edu/~gimblett/White_Salmon_Final_Report.pdf.

Hardiman JM, Allen MB. 2015. Salmon habitat assessment for conservation planning in the lower White Salmon River, Washington. Reston (VA): U.S. Geological Survey. [accessed 2016 September]; https://pubs.usgs.gov/of/2015/1100/pdf/ofr2015-1100.pdf.

Hatten JR, Batt TR, Skalicky JJ, Engle R, Barton GJ, Fosness RL, Warren J. 2015. Effects of dam removal on Tule Fall Chinook salmon spawning habitat in the White Salmon River, Washington. River Res. Applic. 32(7):1481-1492.

PacifiCorp. 2011. Condit - Project Overview; [accessed 2016 August 4]. http://www.pacificorp.com/condit.

Pesanti D. 2016. Pacific lamprey return to White Salmon River. The Columbian, March 30, 2016. [accessed 2016 September]. http://www.columbian.com/news/2016/mar/30/pacific-lamprey-return-to-white-salmon-river/.

U.S. Fish and Wildlife Service (USFWS). 2016. The free-flowing White Salmon River returns. Portland (OR): U.S. Fish and Wildlife Service, Pacific Region. [accessed 2016 August 4]. https://www.fws.gov/columbiariver/publications/White_Salmon_River_Fact_Sheet.pdf.

GREAT WORKS AND VEAZIE DAMS, PENOBSCOT RIVER, MAINE

Overview

Removing the Great Works and Veazie Dams from the Penobscot River in Maine in 2012 and 2013, respectively, restored access to nearly 1,000 miles of historic habitat for eleven severely depleted migratory fisheries, including endangered species and culturally and recreationally significant species. This dam removal project, which also included installation of fish passages at the Howland Dam, was the first of its kind to balance the interests of river restoration with hydropower generation, allowing the dam owner to maintain its overall hydropower generating capacity in the region by increasing permitted capacity at other facilities.

Dam Removal Process

The Veazie Dam was a run-of-river hydroelectric facility on the Penobscot River in Maine. It was 32 feet high, 830 feet wide, and had 8.4 MW generating capacity. It was located approximately 25 miles upstream of where the river meets the Atlantic Ocean and was the lowermost impoundment on the river. The Great Works Dam, eight miles upstream of the Veazie Dam, was 20 feet high, 1,426 feet wide, and had 7.9 MW generating capacity.

The dams were removed because research demonstrated that fish passages would not be sufficient to restore the fisheries (Kleinschmidt Associates, 2008).

In 2004 a variety of state and federal agencies, private organizations, and the Penobscot Indian Nation signed a multi-party settlement agreement with PPL Corporation, the owner of the Veazie Dam. The purpose of the agreement was two-fold: 1) to restore access to almost 1,000 miles of historic habitat for "severely depleted" sea-

Primary Benefits

Dam Removal Economic Impact: The dam removal project generated $3.6 million from 76 temporary jobs associated with the project, plus ongoing jobs associated with river recreation and canoe or kayak racing.

Vulnerable Species: Removing the dam opened access to 1,000 miles of historical habitat for 11 sea-run species, including ESA-listed species like Atlantic sturgeon and Atlantic salmon.

Cultural Values: Dam removal restored the river and historical fishing grounds important to the Penobscot Indian Nation.

River Recreation: Since the dams were removed, this section of river has become a boating destination.

run fisheries; and 2) to allow PPL to increase hydropower generation at other approved facilities in Maine to maintain a similar level of total output.

To ensure that PPL Corporation's net power generation goals were met, negotiations to remove the Veazie Dam were done concurrently with negotiations to remove the Great Works Dam, install a fish bypass at the Howland Dam, and increase generation at other Penobscot River facilities. Because PPL increased its generation capacity at other dams, the removal avoided costs to the company or consumers associated with decreased production (Kleinschmidt Associates 2008).

The total cost of buying and removing the dams was estimated to be approximately $65 million (Carpenter 2012). Individual costs to remove each dam ranged from $5.1 to $6.2 million (FERC 2010).

Benefits of Dam Removal

Researchers identified four main types of benefits associated with removing these dams: additional jobs, endangered species, cultural values, and river recreation. Because fish passages were deemed insufficient to restore the fisheries, costs of installing fish passages at the Veazie and Great Works Dams were not considered.

Dam Removal Economic Impact

Research prior to dam removal estimated that removal of the Veazie Dam would create 76 temporary jobs in the area, with a total direct economic benefit of $3.6 million (FERC 2010).

Vulnerable Species

Removal of the Veazie Dam, along with removal of the Great Works Dam and the addition of fish passage around Howland Dam, opened access to 1,000 miles of habitat for eleven "severely depleted historic sea-run fisheries in the Penobscot River system" (Harvey 2014). According to NOAA (2016), these changes provided access to 100 percent of historic habitat for four species—two federally listed under the Endangered Species Act (ESA) (Atlantic and shortnose sturgeon) and two "important recreational species" (Atlantic tomcod and striped bass). Among the other species expected to benefit were the Atlantic salmon (also ESA listed), alewife and blueback herring (both Species of Concern), American shad, rainbow smelt, sea lamprey, and American eel (Kleinschmidt Associates 2008).

Since dam removal researchers have measured the following changes in fish populations:

- Sea lampreys increased from 2,330 in 2012 to 8,333 in 2016 (Holyoke 2012, Maine DMR 2016);
- Alewives and river herring increased from approximately 13,000 in 2013 to 590,000 in 2015 (Miller 2015, Maine DMR 2016);
- American shad increased from an estimated 20 prior to dam removal to 1,800 in 2015 and 7,846 in 2016 (Miller 2015, Maine DMR 2016); and
- The ESA-listed shortnose sturgeon was also sighted for the first time in more than 100 years in the area above the former site of the Veazie Dam (NOAA 2016).

Cultural Values

The cultural benefits of dam removal to the Penobscot Indian Nation, who have lived in the area for more than 10,000 years, are significant. The river and its fish are at the heart of their culture, and their oral history tells of river salmon and other fish being transformed into first Penobscot people (Toensing 2013). The tribe historically relied on the river for sustenance fishing but had been unable to exercise those rights for more than 100 years. At the breaching of the Veazie Dam, Penobscot Chief Kirk Francis stated: “This river is simply who we are. It’s the very core of our identity as a people and it’s simply the most important thing in the Penobscot Nation’s life” (Toensing 2013).

River Recreation

Since the Veazie and Great Works Dams have been removed, this section of the Penobscot River has been used for a variety of boating events, including the Penobscot River Whitewater Nationals Regatta held by the American Canoe Association in 2015, 2016, and to be held there again in 2017 (Miller 2015). These events bring valuable tourism dollars to the nearby communities. In 2014, the Penobscot Indian Nation also hosted the inaugural Bashabez Run Canoe and Kayak Race, which is now in its third year. The economic impact of these additional visitors has not yet been measured.

BEFORE

Photo credit: Steve Shepard, U.S. Fish and Wildlife Service

AFTER

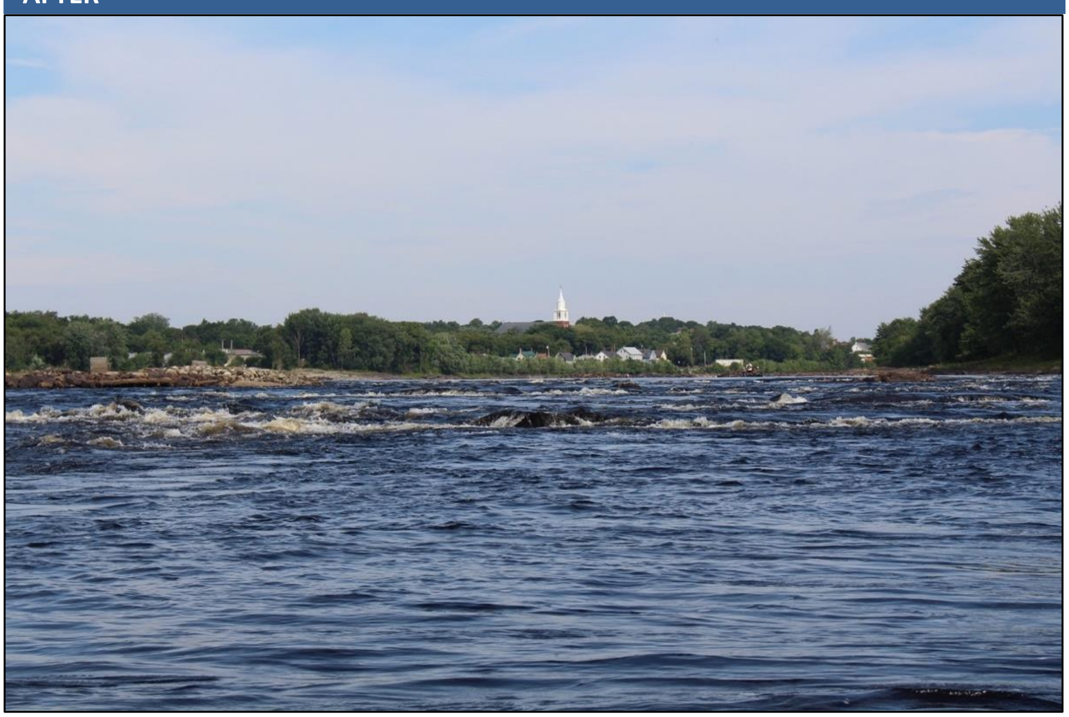


Photo credit: Penobscot River Restoration Trust

References

Carpenter M. 2012. Dam removal to help restore spawning grounds. The New York Times, June 1, 2012. [accessed 2016 September 30]; http://www.nytimes.com/2012/06/12/us/maine-dam-removal-a-start-to-restoring-spawning-grounds.html?_r=0.

Federal Energy Regulatory Commission (FERC). 2010. Final Environmental Assessment, Application for Surrender of License, Veazie, Great Works, and Howland Projects. FERC Project Nos. 2403-056, 2312-09, 2721-020. Washington (DC): Federal Energy Regulatory Commission.

Harvey BG. 2014. Maine Historic Engineering Record (MHER): Former City Mills Dam. MHER No. 44. [accessed on 2016 August 9]. http://bgharvey.com/wp-content/uploads/2014/02/Veazie-MHER-Narrative-Final.pdf.

Holyoke J. 2012. Penobscot salmon total hits 168, lampreys thriving. Bangor Daily News, May 24, 2012. [accessed 2016 August 10]; http://outthere.bangordailynews.com/2012/05/24/fishing/salmon-total-reaches-168-lampreys-thriving/.

Kleinschmidt Associates. 2008. Multi-project environmental analysis – Veazie Project, FERC No. 2403; Great Works Project, FERC No. 2312; Howland Project, FERC No. 2721. Prepared for Penobscot River Restoration Trust.

Maine Department of Marine Resources. 2016. Trap count statistics. [accessed 2016 August 10]; http://www.maine.gov/dmr/science-research/searun/programs/trapcounts.html.

Miller K. 2015. Two years after dams' removal, Penobscot River flourishes. Portland Press Herald, September 27, 2015. [accessed 2016 August 10]. http://www.pressherald.com/2015/09/27/a-river-revived-the-penobscot-river-two-years-after-dams-removal/.

NOAA Fisheries. 2016. Veazie dam removal. [accessed on 2016 August 5]; https://www.greateratlantic.fisheries.noaa.gov/stories/2013/veazieDamRemoval.html.

Toensing GC. 2013. Ceremony – and eagles – mark beginning of Veazie Dam removal. Indian Country Today Media Network, July 23, 2013. [accessed 2016 August 10]; http://indiancountrytodaymedianetwork.com/2013/07/23/ceremony-and-eagles-mark-beginning-veazie-dam-removal-150543.

SMALL DAMS CASE STUDIES

Overview

This case study describes the removal of three small dams with similar characteristics. All three privately owned structures were originally built to power small mills, but were no longer used for that purpose at the time of their removal and had fallen into disrepair over time. They also posed substantial public safety risks primarily associated with elevated water levels and flooding, and the potential for breaching or catastrophic failure. All three dams were high enough to prevent fish from moving upstream and none had acceptable fish passage facilities.

Hyde Pond Dam, Whitford Brook, Connecticut

The Hyde Pond Dam on Whitford Brook near Mystic, Connecticut, was a privately owned structure in Connecticut. Originally built in the early 1800s for hydropower, the dam had not been operation for some time before removal in 2015.

Hyde Pond Dam was structurally obsolete and posed a significant public safety risk. Removing the dam opened four miles of stream to important migratory and resident fish species, including alewife, blueback herring, and American eel, candidate species under the Endangered Species Act.

A 2015 Environmental Assessment conducted by the USFWS considered various project alternatives, with a focus on dam removal, the primary purpose of which was to “mitigate flooding and possible dam failure” (USFWS 2015). Removal was funded by USFWS using a $1.1 million grant from federal Hurricane Sandy recovery funding (Federal Grants 2016).

The “no-action” alternative reviewed by the USFWS (2015) stated that the Hyde Pond Dam was in poor condition and was not maintained to regulatory standards, making dam

Primary Benefits

Public Safety: The three dams posed a threat to public safety from upstream flooding and risk of catastrophic failure due to disrepair.

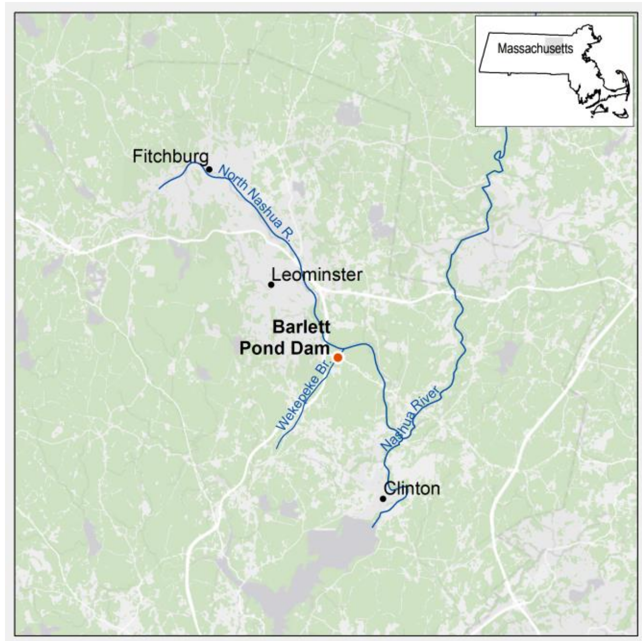
Cost Effectiveness: All three dams would have been much more expensive to repair than to remove. Funding was available from federal and other sources to support dam removal, but dam repair would have been borne by the owner alone.

Vulnerable Species: Removing these dams extended the habitat of migratory and resident fish by numerous miles, including several fish that are candidates for Endangered Species Act listing, including alewife, blueback herring, and American eel.

repair essentially the same as the "no-action" alternative. While funds were available for removal, the owner would be responsible for repairs and future maintenance as well as legal liability in case of dam failure.

Removing the Hyde Pond Dam provided local benefits in the form of increased public safety and restored riverine habitat. It also provided broader regional benefits by mitigating potential flood hazards and supporting coastal resiliency.

Bartlett Pond Dam, Wekepeke Brook, Massachusetts



The Bartlett Pond Dam on Wekepeke Brook in Lancaster, Massachusetts was in poor condition and classified as a "significant hazard," meaning "dam failure could result in loss of life and considerable damage to property or infrastructure" (MDFG 2015). The 2014 removal of the dam also opened 18 miles of river habitat for brook trout and other species.

Bartlett Pond Dam was built in 1814 to provide hydropower for a local chair factory. After the factory burned, the dam was no longer used for power nor maintained. The Town of Lancaster assumed ownership of the dam at some point and incorporated the impoundment behind the dam into a conservation area.

In recent years, obstruction of water flows by the dam had led to multiple floods. In 2008, after a required inspection of the dam, the Town of Lancaster was issued a notice of failure by the Massachusetts Office of Dam Safety. In Massachusetts the law requires that "dams be repaired or removed to meet dam safety standards," meaning that in this case, the no-action alternative was the same as dam repair (MDFG 2015).

The estimated cost of removing the Bartlett Pond Dam was $325,000 compared to $671,000 for repair.

In addition to the cost savings seen by the dam owner, the primary benefits of removing the Bartlett Pond Dam were avoided costs associated with decreased risk of flooding including avoided infrastructure damage, lost business revenue and travel delays.

White Rock Dam, Pawcatuck River, Connecticut and Rhode Island

Before removal in 2015, the White Rock Dam spanned the Pawcatuck River between Stonington, Connecticut and Westerly, Rhode Island. It was structurally and functionally obsolete and posed a risk to public safety. The removal also opened 25 miles of river habitat to key aquatic species, including some ESA candidate species, as only approximately 15 percent of fish were able to navigate successfully the sluice around the dam (Kuffner 2015).

The last version of the White Rock Dam was constructed in 1940 to provide power to a local mill, although dams had been in that location since 1770. At the time of removal, the privately owned dam had not been used for hydropower in decades. In addition to safety concerns, the dam also contributed to elevated water levels and local flooding and was the first impediment to fish moving up the Pawcatuck River.

USFWS conducted an environmental assessment of the dam in 2015 with a recommendation for removal. Federal funding was available for dam removal, but not for repair or maintenance. As such, the private owner would have been responsible for continued maintenance of the structure as well as any cost associated with breaching or failure of the dam.

Removal was funded by USFWS using federal Hurricane Sandy recovery funding and cost an estimated $800,000. This removal was part of a larger $2.3 million restoration effort on the Pawcatuck (USFWS 2014).

In addition to providing cost savings to the owner, removal of the White Rock Dam helped restore access to river habitat for American shad, alewife, and American eel; improved river connectivity; reduced flood risk; and eliminated risk of dam failure.

Bartlett Pond Dam

BEFORE

Photo credit: Massachusetts Division of Ecological Restoration

AFTER

Photo credit: Pare Corporation. For additional details: *http://blog.parecorp.com/?p=1124* .

References

Kuffner A. 2015. Dam removal will be watershed moment for R.I.'s Pawcatuck River. Providence Journal, September 4, 2015. [accessed 2016 August 24]; http://www.providencejournal.com/article/20150904/NEWS/150909561.

Federal Grants. 2016. Hyde Pond and Pond Lilly Dam Removal, CT -- Hurricane Sandy Disaster Relief. federalgrants.com. [accessed 2016 September 30]. http://www.federalgrants.com/Hyde-Pond-and-Pond-Lilly-Dam-Removal-CT-Hurricane-Sandy-Disaster-Relief-45108.html.

Massachusetts Department of Fish and Game (MDFG). 2015. Economic & Community Benefits from Stream Barrier Removal Projects in Massachusetts. Boston (MA): Massachusetts Department of Fish and Game; [accessed 2016 September]. http://www.mass.gov/eea/docs/dfg/der/pdf/phase-iii-benefits-from-stream-barrier-removal-projects.pdf.

U.S. Fish and Wildlife Service (USFWS). 2014. Hurricane Sandy Mitigation/Resilience Projects: Overview and Specific Project Examples. [accessed 2016 September 16]. https://www.fws.gov/hurricane/sandy/pdf/FundedSandyResiliencyProjectSummaries032714.pdf

U.S. Fish and Wildlife Service (USFWS). 2015. Environmental assessment – Aquatic connectivity and coastal resiliency project: Hyde Pond Dam and Whitford Brook, Stonington and Groton, Connecticut. Charlestown (RI): U.S. Fish and Wildlife Service, Rhode Island Field Office.

HEADWATERS ECONOMICS

Executive Summary: Dam Removal

Case Studies on the Fiscal, Economic, Social, and Environmental Benefits of Dam Removal

Headwaters Economics | October 2016

This is an executive summary of a **larger report** that highlights the many factors that contribute to dam removal decisions, how these factors have been weighed, and the process that led to their removal. This review demonstrates that in many cases the economic, environmental, and social benefits of dam removal outweigh the costs of keeping a dam in place.

Summary Findings

- The U.S. has more than 87,000 dams greater than six feet high (and two million overall). While many dams continue to provide benefits such as flood control, irrigation, and water supply. For other dams the cost of maintenance or the negative effects on communities, fish, and tribes justifies their removal.

- Dam owners and regulators decide whether to remove a dam by weighing many factors: including the cost of removal and the ability to replace any lost power generation against avoided long-term maintenance, safety concerns, benefits to endangered fish populations, increased recreational and commercial fishing, and restoration of cultural values of nearby tribes.

- By 2020, roughly 70 percent of dams will be more than 50 years old, inviting us to reconsider the value to the public of long-term investments in this infrastructure.

Introduction

Since the 18th century, dams have been built across the United States to power mills, provide downstream flood control, facilitate transportation, provide irrigation water, and generate hydroelectricity. Presently there are more than two million dams across the country (William 1993), and a federal inventory has identified more than 87,000 dams across the United States that are more than six feet tall (CorpsMaps National Inventory of Dams 2013).

Over time these dams have aged. By 2020, 70 percent of dams in the United States will be more than 50 years old (2013 report card…2013). The Association of State Dam Safety Officials—a national non-profit serving state dam safety programs—estimates it could cost $51.5 billion to rehabilitate the nation's non-federally owned dams (Association of State Dam Safety Officials 2009).

At the same time, economies and energy needs have shifted, and ecological research has advanced. Regulations like the Clean Water Act (CWA) and Endangered Species Act (ESA), state water and fisheries regulations, and tribal rights claims have elevated water quality, fish, and tribal claims where dams are concerned.

While some dams continue to serve useful purposes, others have outlived their original function. For these obsolete dams, the benefits to the public of removing them outweighs the costs. In light of aging infrastructure, it is appropriate to evaluate individual dams to determine whether their ongoing costs and effects on rivers and people justifies the services they provide.

Agencies like the U.S. Army Corps of Engineers (USACE) and the Federal Energy Regulatory Commission (FERC) have established processes to evaluate benefits and costs as a part of various agency programs.

Licensing decisions at FERC, for example, consider multiple management scenarios when evaluating whether to issue new or renew existing dam licenses. The management scenarios may require dam owners to allow greater water flow through the dam, install infrastructure to allow migratory fish to pass upstream, or make safety upgrades. Often the options include a dam removal scenario. These evaluations also include impact assessments that evaluate the benefits and costs to the many parties affected by each management alternative.

The USACE undertakes similar analyses when it evaluates its dams and other river restoration programs. Some dam owners have found that removing a dam is more appropriate than leaving it in place after comparing benefits and costs of addressing the needs of concerned parties and meeting state and federal regulatory requirements.

Since 1912, more than 1,300 dams have been removed across the U.S., and 62 dams were removed in 2015 alone (American Rivers 2016).

This report describes the methods used to measure the benefits of dam removal when comparing costs to benefits, including five case studies and a summary of small dams. The case studies illustrate the range of benefits and costs that can be considered, multiple methodological approaches, and a range of locations.

The case studies range from small former mill sites to large western hydropower dams, including:

- Whittenton Pond Dam on the Mill River in Massachusetts;
- Elwha and Glines Canyon Dams on the Elwha River in Washington;
- Edwards Dam on the Kennebec River in Maine;
- Condit Dam on the White Salmon River in Washington;
- Great Works and Veazie Dams on the Penobscot River in Maine; and
- Three small dam removals including Hyde Pond Dam on Whitford Brook in Connecticut, Bartlett Pond Dam on Wekepeke Brook in Massachusetts, and White Rock Dam on Pawcatuck River in Connecticut and Rhode Island.

Measuring the Benefits of Dam Removal

The circumstances for individual dam removal projects are wide-ranging and depend on unique combinations of environmental, historic, and economic factors. The following sections describe the most common reasons for removing dams and how those factors have been quantified. Examples of some benefit-cost comparisons are described in detail in the case studies.

In addition, at the end of this section and the Conclusion, Table 1 summarizes benefits by each case study, including the estimated costs of dam removal, the types of benefits, and the alternatives to dam removal that were considered.

Throughout this report, all dollar values have been converted to 2016 dollars.

Cost-Effectiveness of Maintenance Versus Removal

Dams require ongoing maintenance to remove accumulating sediment, make small repairs, and upgrade safety systems. Particularly when older dams are no longer used for their original purpose, dam owners may defer maintenance to the point where the dams pose a threat to public safety (see Whittenton Pond Mill Dam case study). In these cases, it is appropriate for dam owners to work with state and federal experts to figure out how to protect communities. In some cases, it is less expensive to remove the dam than to make the necessary repairs (see Small Dams case study).

Many dam removal decisions have been made after the costs of maintenance or upgrades have been compared with costs of removal.

Vulnerable Species and Other Environmental Benefits

Dams interfere with the life cycle of migratory fish by blocking the migration of adults to upstream spawning grounds, as well as limiting the passage of sediment and large woody debris necessary to maintain suitable spawning areas downstream (Brenkman et al. 2012). Fish passage devices at dams allow some fish to move upstream, but the success rate varies depending on the dam height and the species (Brown et al. 2013).

Dams can be significant impediments to the recovery of vulnerable fish species, including those listed as threatened or endangered under the Endangered Species Act. Removing one dam can open hundreds of miles of upstream spawning habitat in a river's main stem and tributaries, such as the Great Works and Veazie Dams in Maine.

In several cases, the Endangered Species Act has been the catalyst for dam removal due to mandated changes to river management to increase populations of endangered species. In cases such as the Glines Canyon Dam on the Elwha River, which was too high for fish ladders, fish passage facilities are insufficient to restore fish populations. In cases such as the Condit Dam on the White Salmon River, retrofitting the dam to allow fish passage would have been more expensive than removing the dam.

Follow-up population studies after dam removal have found that species quickly return to upstream spawning habitat, even when the river has been blocked for 100 years (Penobscot River Restoration Trust et al. 2015, NPS 2014).

Researchers have measured a cascade of ecological improvements associated with dam removal, including: more robust plant and animal health in upper watersheds due to ocean-derived nutrients transported upstream by migrating fish (Tonra et al. 2015); improved health of plants and animals in estuaries and river mouths due to more abundant sediment (Baurick 2015); and improved water quality (Bednarek 2001).

Cultural Values

In addition to subsistence and commercial fish harvests, many Native American tribes have deep cultural, spiritual, and historical connections to specific free flowing rivers, features along those rivers, and the animal and plant species they support. Dams often severely harmed those resources, and were installed with little or no consideration of nearby tribes and their rights (Guarino 2013).

Tribes continue to play significant roles in demonstrating the importance of removing dams. The Edwards Dam in Maine and Elwha and Glines Canyon Dams in Washington are examples of dam removal efforts where a local tribe provided much of the initial impetus for removing dams, and were among the greatest beneficiaries of their removal.

Recreational and Commercial Fisheries

Removing dams also can increase the abundance of commercially and recreationally targeted fish species.

Benefits to commercial fisheries are measured in terms of increased revenue from improved catch rates (Meyer et al. 1995). Benefits to recreational anglers are measured in terms of improved experiences due to increased catch rates and species diversity, discussed in the Non-Market Values section. Benefits from improved recreational fishing also are measured in terms of additional jobs and income supported by more visiting anglers (Meyer et al. 1995).

River Recreation and Other Tourism

Removing dams and returning rivers to a free-flowing state can provide new boating opportunities, particularly for whitewater rafting, canoeing, and kayaking. This provides increased enjoyment for the paddlers, which can be measured by the increased number of boaters and the quality of their experience (Loomis 1999).

Neighboring communities benefit from increased whitewater recreation and other river-related tourism when visitors spend money with local guides, outfitters, restaurants, and other businesses, bringing new money to oftentimes remote communities (Meyer et al.1995).

Non-Market Values

People value seemingly unquantifiable outdoor amenities like free-flowing rivers, endangered species, and recreational opportunities. Researchers are able to apply statistical methods to measure how much people value selected environmental qualities and then translate that value into dollars. These "non-market values" can then be incorporated into cost-benefit analyses.

Non-market values often are used to weigh pros and cons when a federal project will result in large environmental impacts. Since the 1970s the Federal Energy Regulatory Commission (FERC) has considered non-market values in relicensing decisions, due in large part to the passage of the Endangered Species Act and methodological refinements for measuring non-market values (Duffield 2011).

Researchers have found that people place substantial value on the following environmental changes associated with removing dams:

- The existence of a free-flowing river that individuals can see now or in the future, or will be available for their children to visit (Loomis 1996, Loomis 2002, Sanders 1990);
- Knowledge that endangered species are present in a river and their population is recovering (Mansfield et al. 2012, Bell et al. 2003, Berrens et al. 2000, Ekstrand and Loomis 1998);
- Improved catch rates for recreational anglers (Kotchen et al. 2006, Layton et al. 1999, Boyle et al. 1991, Olsen et al 1991, Bishop et al. 1987); and
- Improved experiences for whitewater boaters (Loomis 1999, Gloss et al. 2005).

The Elwha and Glines Canyon Dams case study, for example, describes research that found the American public would be willing to pay approximately $5.3 billion per year to remove the dams and restore the river (Loomis 1996).

Non-market benefits are distinct from the additional spending that anglers and tourists bring to an area. Because the benefits are experienced by people close to the dam as well as those who live far away, total non-market benefits can be quite large and therefore influential in FERC relicensing decisions.

Cost-Effectiveness of Energy Production

Many older hydroelectric dams were built to support nearby mills, factories, and communities, and have relatively small generating capacity. As the U.S. power grid has shifted to more regional rather than local production, power produced by smaller dams can be more expensive than power from regional sources (see Edwards Dam case study) or may no longer be needed if the nearby industrial user has closed (see Elwha Dams case study).

In these cases, the end users are able to secure sufficient electricity generating capacity from less expensive sources, eliminating the original need for the dam.

Economic Impact of Removal Projects

Dam removal and associated river restoration can be substantial, multi-year projects, employing local residents, providing personal income, and contributing to the local economy. Jobs associated with these removal projects often are relatively short-term, but nonetheless valuable particularly in smaller communities.

A 2012 study found that every $1 million spent on Massachusetts Division of Ecological Restoration projects resulted in 10 to 13 jobs created or maintained (Industrial Economics Inc. 2012). A 2010 study in Oregon finds that every $1 million spent on forest and watershed restoration results in 15-23 new jobs and $2.1-2.3 million in economic activity (Nielsen-Pincus and Moseley 2010).

Property Values

Researchers have found that some dams, particularly small dams with small upstream impoundments, can create an unpleasant feature that drives down property values due to lower water quality or flooding risk.

On the Kennebec River in Maine, researchers found that before the Edwards Dam was removed, homes closer to the river had significantly lower property values than similar homes farther from the river. After the dam was removed, there was no longer a price penalty to living closer to the river (Lewis et al. 2008).

A study on numerous small dams in Wisconsin found a similar pattern (Provencher 2008).

Conclusion

Dam removal decisions are complex, requiring owners and regulators to weigh a dam's current value in accomplishing its original purpose—such as flood control, agriculture, recreation, and power generation—against the dam's ongoing effects on public safety, water quality, fish and other species, recreation, and cultural values. These considerations also must be evaluated in the context of long-term maintenance costs and costs of removal.

As the thousands of dams in the U.S. have aged, the upkeep expenses and the need for significant repairs has risen for many dams. At the same time, scientific research has improved our understanding of river systems and the effects dams have on a region's environmental health. Advances in economic methods also have improved our understanding of the economic benefits to nearby communities, river users, and the broader public from free-flowing rivers.

Together, the higher ongoing costs of operating dams and an improved awareness of the economic and social benefits of removing them has shifted the balance sheet for some dams. For these dams, removal often provides greater rewards to taxpayers, local economies, and the surrounding environment. Additionally, funding for removal projects often can be gathered from several sources as different agencies, organizations, and communities better understand how they can benefit from dam removal.

The case studies that follow, summarized in Table 1 below, highlight the many factors that contribute to dam removal decisions, how these factors have been weighed, and the process that led to a dam's removal. This review demonstrates that in many cases the economic, environmental, and social benefits of dam removal outweigh the costs of keeping a dam in place.

Table 1: Case Studies, Benefits of Dam Removal, and Alternatives Considered

Location	Estimated cost of removal (2016$)	Estimated benefits of removal (2016$)	Alternatives to dam removal
Whittenton Pond Dam, Mill River, Massachusetts	$447,000: 99 percent paid by state and federal partners, non-profits	• $1.5 million for avoided emergency response • Increased numbers of two vulnerable species: American eel and river herring • Property values projected to increase due to lower flooding risk	Rebuilding was necessary due to disrepair and safety hazard, cost estimated at $1.9 million
Elwha and Glines Canyon Dams, Elwha River, Washington	$324.7 million	• $5.3 million annually from increased commercial fishing • Cultural and public safety benefits to the Lower Elwha Klallam Tribe, downstream from the dams • $33 million in personal income and 760 new jobs associated with dam removal • $43.8 million and 446 new jobs from 500,000 more visitor days annually • $5.3 billion worth of improved well-being for the American public	Not available
Edwards Dam, Kennebec River, Maine	$10.9 million	• $2.5-$38.2 million for improved recreational fishing quality • $397,000-$2.7 million for improved river recreation quality • Property values closest to the former dam site increased • Electricity produced by Edwards Dam cost 4-5 times the market rate • Water quality prior to dam removal did not meet minimum standards; afterward it could support all native fish • Alewife population increased 60-fold, and they now are used commercially for bait • Quality of life in Augusta has improved due to new connection to the river	$14.9 million to install fish passages and conduct environmental mediation

Location	Estimated cost of removal (2016$)	Estimated benefits of removal (2016$)	Alternatives to dam removal
Condit Dam, White Salmon River, Washington	$24.8 million	• Cultural benefits for the Yakama Nation from returned salmon and lamprey, including sustenance fishing • Expanded spawning grounds for recreationally and commercially important fish: 12 miles for salmon and 33 miles for steelhead • Increased populations of five fish species listed under the Endangered Species Act • 30,000 additional whitewater boaters annually	$52.4 million for fish passages, plus $3.9 million annually in higher electricity costs
Great Works and Veazie Dams, Penobscot River, Maine	$65 million	• 76 jobs and $3.6 million in economic impact from dam removal • Access re-opened for 1,000 miles of habitat for 11 depleted historic fisheries • Cultural and sustenance fishing benefits for the Penobscot Indian Nation • New area spending by whitewater boaters, including several events.	Fish passage facilities were insufficient to restore fisheries
Small Dams: Hyde Pond Dam, Whitford Brook, Connecticut	$1.1 million	• Avoided public safety hazards from catastrophic failure and upstream flooding • Four miles of stream habitat opened to fish species including American eel, a vulnerable species	Dam would have to be rebuilt to meet safety standards. Dam owner would have been responsible for full cost of rebuilding dam
Small Dams: Bartlett Pond Dam, Wekepeke Brook, Massachusetts	$325,000	• Avoided public safety and infrastructure hazards from catastrophic failure and upstream flooding • Eighteen miles of stream habitat opened for brook trout and other species	$671,000 for repairs
White Rock Dam, Pawcatuck River, Connecticut and Rhode Island	$800,000	• Avoided public safety and infrastructure hazards from catastrophic failure and upstream flooding • Twenty-five miles of river habitat opened to fish species	Dam would have to be rebuilt to meet safety standards. Dam owner would have been responsible for full cost of rebuilding dam

Contact

Megan Lawson, Ph.D., 406-570-7457, megan@headwaterseconomics.org

About Headwaters Economics

Headwaters Economics is an independent, nonprofit research group that works to improve land management and community development decisions in the West, http://headwaterseconomics.org/.

References

2013 report card for America's infrastructure - Dams: condition & capacity. 2013. Reston (VA): American Society of Civil Engineers; [accessed 2016 September 20]. http://www.infrastructurereportcard.org/a/ - p/dams/conditions-and-capacity.

American Rivers. 2016. 62 dams removed to restore rivers in 2015. [accessed 2016 September 19]. https://s3.amazonaws.com/american-rivers-website/wp-content/uploads/2016/02/02122410/DamsRemoved_1999-2015.pdf

Association of State Dam Safety Officials. 2009. The cost of rehabilitating our nation's dams. Lexington (KY): Assoc. of State Dam Safety Officials; [accessed 2016 September 19]. http://www.damsafety.org/media/Documents/DownloadableDocuments/RehabilitationCosts2009.pdf.

Baurick T. 2015. Threatened fish makes a comeback in restored Elwha. Kitsap Sun. [accessed 2015 February]. http://www.kitsapsun.com/news/local/threatened-fish-makes-a-comeback-in-restored-elwha-ep-951933878-354896431.html.

Bednarek AT. 2001. Undamming rivers: A review of the ecological impacts of dam removal. Environ Manag. 27(6):803-814.

Bell KP, Huppert D, Johnson RL. 2003. Willingness to pay for local coho salmon enhancement in coastal communities. Mar Resour Econ. 18(1):15-32.

Berrens RP, Bohara AK, Silva CL, Brookshire D, and McKee M. 2000. Contingent values for New Mexico instream flows: With tests of scope, group-size reminder and temporal reliability. J Environ Manag. 58:73–90.

Bishop RC, Boyle KJ, Welsh MP, Baumgartner RM, and Rathbun PC. 1987. Glen Canyon Dam releases and down stream recreation: An analysis of user preferences and economic values. Springfield (VA): U.S. Department of Commerce National Technical Information Service Pub PB88-183546.

Boyle KJ, Teisel MF, Moring JR, Reiling SD. 1991. Economic benefits accruing to sport fisheries on the Lower Kennebec River from the provision of fish passage at Edwards Dam or from the removal of Edwards Dam. Chelsea (ME): Maine Department of Marine Resources.

Brenkman SJ, Duda JJ, Torgersen CE, Welty E, Pess GR, Peters R, McHenry ML. 2012. A riverscape perspective of Pacific salmonids and aquatic habitats prior to large-scale dam removal in the Elwha River, Washington, USA. Fisheries Manag Ecol. 19(1):36-53.

Brown JJ, Limburg KE, Waldman JR, Stephenson K, Glenn EP, Juanes F, Jordaan A. 2013. Fish and hydropower on the U.S. Atlantic coast: failed fisheries policies from half-way technologies. Conserv Letters. 6:280–286.

CorpsMap National Inventory of Dams. 2013. Washington (DC): U.S. Army Corps of Engineers; [accessed 2016 September 6]. http://nid.usace.army.mil/cm_apex/f?p=838:1:0::NO.

Duffield JW. 2011. The Political Economy of Hydropower and Fish in the Western U.S. In: Johansson P-O, Kristrom B, editors. Modern cost-benefit analysis of hydropower conflicts. Cheltenham, UK: Edward Elgar Publishing.

Ekstrand ER, Loomis JB. 1998. Incorporating respondent uncertainty when estimating willingness to pay for protecting critical habitat for threatened and endangered fish. Water Resour Res. 34(11):3149.

Gloss SP, Lovich JE, Melis TS, eds. 2005. The state of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282. Reston (VA): U.S. Geological Survey; [accessed 2016 September 22]. http://pubs.usgs.gov/circ/1282/c1282.pdf.

Guarino J. 2013. Tribal advocacy and the art of dam removal: The Lower Elwha Klallam and the Elwha dams. Am Indian Law J. 2(1):114-145.

Industrial Economics Inc. 2012. The economic impacts of ecological restoration in Massachusetts. Boston (MA): Massachusetts Division of Ecological Restoration; [accessed 2016-09-22]. http://www.mass.gov/eea/docs/dfg/der/pdf/economic-impacts-ma-der.pdf.

Kotchen MJ, Moore MR, Lupi F, Rutherford ES. 2006. Environmental constraints on hydropower: An ex post benefit-cost analysis of dam relicensing in Michigan. Land Econ. 82(3):384.

Layton DF, Brown GM, Plummer ML. 1999. Valuing multiple programs to improve fish populations. Discussion Papers in Economics at the University of Washington, Department of Economics at the University of Washington.

Lewis LY, Bohlen C, Wilson S. 2008. Dams, dam removal, and river restoration: A hedonic property value analysis. Contemp Econ Policy. 26(2):175-186.

Loomis J. 1996. Measuring the economic benefits of removing dams and restoring the Elwha River: Results of a contingent valuation survey. Water Resour Res. 32(2):441-447.

Loomis J. 1999. Recreation and passive use values from removing the dams on the Lower Snake River to increase salmon. Walla Walla (WA): U.S. Army Corps of Engineers.

Loomis J. 2002. Quantifying recreation use values from removing dams and restoring free flowing rivers: A contingent behavior travel cost demand model for the Lower Snake River. Water Resour Res. 38(6):2.1-2.8.

Mansfield C, Van Houtven G, Hendershott A, Chen P, Porter J, Nourani V, Kilambi V. 2012. Klamath River Basin restoration nonuse value survey: Final report. Research Triangle Park (NC): RTI International.

Meyer PA, Lichtkoppler R, Hamilton RB, Borda CL, Harpman DA, Engel PM. 1995. Elwha River restoration project: Economic analysis. Final technical report. Davis (CA): US Bureau of Reclamation, National Park Service, Lower Elwha S'Klallam Tribe; [accessed 2016 September 22]. https://www.nps.gov/olym/learn/nature/upload/Economic analysis.pdf.

National Park Service (NPS). 2014. Three chinook salmon spotted above Glines Canyon; First salmon return to the Upper Elwha in 102 years. Port Angeles (WA): Olympic National Park; [accessed 2016 August 31]. https://www.nps.gov/olym/learn/news/three-chinook-spotted-above-glines-canyon.htm.

Nielsen-Pincus M, Moseley C. 2010. Economic and employment impacts of forest and watershed restoration in Oregon. Eugene (OR): Ecosystem Workforce Program, Institute for a Sustainable Environment, University of Oregon; [accessed 2016-09-22]. https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/10776/WP24.pdf?sequence=1.

Olsen D, Richards J, Scott RD. 1991. Existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. Rivers. 2(1):44-56.

Penobscot River Restoration Trust, University of Maine, NOAA. 2015 November 15. After more than a century, endangered shortnose sturgeon find historic habitat post dam removal. [accessed 2016 August 5]. http://www.penobscotriver.org/assets/JtPressReleaseSturgeonDamRemoval_FINAL.pdf.

Provencher B, Sarakinos H, Meyer T. 2008. Does small dam removal affect local property values? An empirical analysis. Contemp Econ Policy. 26(2):187-197.

Sanders LD, Walsh RG, Loomis JB. 1990. Toward empirical estimation of the total value of protecting rivers. Water Resour Res. 26(7):1345-1357.

Tonra CM, Sager-Fradkin K, Morley SA, Duda JJ, Marra PP. 2015. The rapid return of marine-derived nutrients to a freshwater food web following dam removal. Biol Conserv. 192:130-134.

William G. 1993. Landscapes, Commodities, and Ecosystems: The relationship between policy and science for American rivers. Sustaining our water resources. Tempe (AZ). Arizona State University. [accessed 2016 October 7]. https://www.nap.edu/read/2217/chapter/4.

HEADWATERS
ECONOMICS