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