A Summary of Existing Research on Low-Head Dam Removal Projects

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on the Environment

Prepared by:

ICF Consulting
33 Hayden Ave.
Lexington, MA 02421 USA
781/676-4000

In association with Woodlot Alternatives, Inc.

September, 2005

The information contained in this report was prepared as part of NCHRP Project 25-25, Task 14, National Cooperative Highway Research Program, Transportation Research Board.

Acknowledgements

This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of the National Cooperative Highway Research Program (NCHRP) Project 25-25. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 25-25 is intended to fund quick response studies on behalf of the AASHTO Standing Committee on the Environment. The report was prepared by a research team led by Francisco Silva of ICF Consulting. The work was guided by a task group chaired by Gary McVoy which included Jock Conyngham, Timothy Granata, Elizabeth Maclin, Stephen Radzyminski, and Matthew Raymond. The project was managed by Christopher Hedges, NCHRP Senior Program Officer.

Disclaimer

EXECUTIVE SUMMARY

During the past decade, dam removal has emerged as a major environmental management issue. Recently, several state transportation agencies have been negotiating with federal and state regulatory agencies regarding the use of low-head dam removal projects as a method of stream restoration to receive stream mitigation credit. Removal of unneeded dams is often promoted under the assumption that dam removal will be inherently beneficial because the dam presence is detrimental to aquatic ecosystems. While dam removal can benefit many components of local ecosystems, removing a dam may also result in detrimental impacts. For example, sediment released following a dam removal may be harmful to many downstream flora and fauna. Whether such detrimental impacts will be temporary phenomena, or whether they will be significant perturbations to already highly altered ecosystems is an issue deserving of increased attention and consideration among researchers, practitioners and regulators. Therefore, one must consider that dam removal might "fail" (i.e., be contrary or inefficient with regard to particular goals, such as environmental restoration).

Because of the potential for both beneficial and detrimental effects of low-head dam removal, the appropriateness of using low-head dam removal projects as a mitigation technique requires evaluation. Dam removal has intuitive appeal as an environmental mitigation technique for lineal projects, such as many transportation projects. Instead of a restoration project extending over many miles along a stream alignment, the removal of a relatively short structure spanning the stream channel could have beneficial impacts, possibly extending for miles upstream and downstream of the dam location.

Although many dams have been removed in the United States, very few published environmental impact studies accompanied the removals. The lack of studies documenting the actual impacts of dam removal makes it necessary to produce a document that outlines and summarizes the benefits and impacts associated with dam removal, including its effects on water quality, aquatic biology, and physical stream characteristics. Therefore, the National Cooperative Highway Research Program initiated this research project with the objective of producing a document to provide transportation departments, regulatory agencies, resource agencies, and the public with a tool to help assess the value of low-head dam removal projects as a stream restoration and mitigation option.

This study focuses on removal of low-head or small run-of-river dams, which are defined as follows:

Low-head dam: A constructed barrier in a river with a hydraulic height (head water to tail water) not exceeding 25 feet. This definition encompasses run-of-river dams as well as other small dams but not industrial dams that do not create an impoundment in a river.

Run-of-river dam: A constructed barrier in a river where the river inflow normally overflows from behind the dam from one side of the waterway to the other. A run-of-river dam has limited short-term storage capacity.

Small dam: A constructed barrier in a river with a structural height not exceeding 50 feet. This definition does not attempt to encompass industrial dams not built to create an impoundment in a river.

A brief review of the available data on dam removal projects shows that the existing databases do not include all the dams removed in the United States and, for the dams included in the existing databases, only limited information is included for each dam removal project. To bridge these data gaps, a survey was conducted for this study. We sent the survey to 169 individuals at different agencies and received 50 responses (a 30% response rate after sending two "tickler messages"). Among the respondents, 21 (42%) provided new data and 29 (48%) provided no new information. Appendix B presents the survey results and final list of dam removal projects we collected. Analyses of the survey results and the final dam removal project database lead to the following conclusions:

1. Dam removal appears to have been relatively uncommon before the 1980s but has escalated significantly in the 21st century. The recent acceleration of dam removals reflects problems associated with aging structures, growing interest in restoring rivers and fish passage, new funding opportunities to support dam removal, and national policies aimed at improving the safety of aging structures and mitigating the environmental impacts of these structures.
2. The three most common reasons for dam removals are, in order of frequency, ecology, economics, and safety.
3. Most of the dams removed have a structural height smaller than 20 feet. This is in agreement with Heinz Center's (2002) conclusion that "almost all of the dams removed thus far have been small ones."
4. Most of the dams (79%) were totally removed, and only 21% were breached or partially removed.
5. The deconstruction cost is about half (52%) the total removal cost.

Removal of low-head dams has different impacts, both beneficial and adverse, including physical and chemical, ecological, social, and economic. Chapter 3 discusses these impacts in detail. Removing dams can have distinct economic benefits, such as cost savings over repairing and maintaining the dam, potential for community riverfront revitalization, increased income to local fishing and boating industries, and decreased costs related to water quality improvements and fisheries management. However, these dam removal benefits may also come at a price, due to the loss of economic benefits from the dam. To determine the economic consequences of a dam removal, one has to consider different costs and benefits including those to the dam owner, society, recreation, and the environment. Chapter 4 discusses the various costs and benefits associated with dam removal and the challenges for economic analysis of dam removals.

Different legal and regulatory requirements exist for dam removal projects. Chapter 5 describes these requirements and illustrates the general permitting process for dam removal projects. This chapter also discusses primary and secondary criteria for determining mitigation credit for dam removal.

Partial dam removal and/or diversion/bypass structures have also been used for stream restoration, although complete removal of dams may not always be the best option for a river system. Chapter 6 presents examples of partial dam removal projects and discusses the specific issues related to partial dam removal.

Monitoring is necessary to measure the performance of dam removal projects. Chapter 7 discusses the importance of monitoring and describes who should do the monitoring and what should be monitored. It also presents applicable monitoring techniques for low-head dam removal projects.

Chapter 8 briefly reviews and evaluates existing guidance documents on decision-making related to dam removal. These existing documents, produced by different state and federal agencies, are presented in different formats. Some documents provide detailed coverage of activities before, during, and after dam removal while others cover only information used to decide whether a dam should be removed. All the documents cover the issues of safety, cost, ecology, technology, etc. However, none describe the issues related to mitigation credits for transportation projects. Our review and evaluation of the information available led to a simple method for ranking and identifying dams that can be removed so that stream remediation credits can be obtained for transportation projects. This method consists of four progressive evaluation steps: preliminary, basic, detailed, and mitigation-credit evaluation.

Scientific research on the effects of dam removal is still in its initial stages, and elaborate theories and practices on the subject are not yet developed. Although more than 600 dams have been removed in the United States in the past decades, very few removals are documented in published investigations. Chapter 9 lists the topics (environmental, economic, social, etc.) associated with low-head dam removal and needing additional research and study.

The following individuals from ICF Consulting and Woodlot Alternatives participated in the investigation and preparation for this report:

ICF Consulting
Phyllis Nissen
Francisco Silva
Lianyang Zhang

Woodlot Alternatives
Michael Chelminski
Stephanie Lindloff

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 BACKGROUND

The purpose of a dam is to impound (store) water, wastewater or liquid borne materials for various reasons (e.g., flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, navigation, recreation, or pollution control [ASDSO, 2005]). Over the past 200 years, thousands of dams were built in the United States to fulfill one or more of the above functions (see Figure 1.1). Dams are a vital part of the national infrastructure, providing a life-sustaining resource to people in all regions of the United States. As part of the national infrastructure, dams are equal in importance to bridges, roads, airports, or other major elements of the infrastructure (ASDSO, 2005). However, the planned life expectancy of many dams is commonly around 50 years (Trout Unlimited, 2001), and many existing dams can no longer serve their intended purpose because of poor condition or changes in societal needs since their construction. Although many dams are no longer in use, they continue to exist in rivers and creeks and may block the movement of fish and other aquatic species, degrade water quality, and alter the flow of sediment and nutrients critical for stream health. Dams in a state of disrepair can also create safety hazards to downstream communities if they fail and to boaters and canoeists who sometimes go over them and get caught in dangerous currents. The deterioration of some aging dams, coupled with safety and environmental concerns, has led to the removal of many of them (American Rivers, 2002).

During the past decade, dam removal has emerged as a major environmental management issue. Recently, several state transportation agencies have been negotiating with federal and state regulatory agencies regarding the use of low-head dam removal projects as a method of stream restoration to receive stream mitigation credit. Removal of unneeded dams is often promoted under the assumption that dam removal will be inherently beneficial because the dam presence is detrimental to aquatic ecosystems. For example, Bednarek’s (2001) examination of the ecological impacts of dam removal was based primarily on a review of the ecological impacts of dams, extrapolated to generate predictions of how dam removal would reverse these effects.

While dam removal can benefit many components of local ecosystems, removing a dam may also cause detrimental impacts. For example, sediment released following a dam removal may be harmful to many downstream flora and fauna. Whether such detrimental impacts will be temporary phenomena, or whether they will be significant perturbations to already highly altered ecosystems is an issue deserving of increased attention and consideration among researchers, practitioners and regulators. Therefore, one must consider that dam removal might “fail,” i.e., be contrary or inefficient with regard to particular goals, such as environmental restoration.

Although many dams have been removed in the United States, very few published environmental impact studies accompanied the removals. The lack of studies documenting the actual impacts of dam removal makes it necessary to produce a document that outlines and summarizes the benefits and impacts associated with dam removal, including the effects on water quality, aquatic biology, and physical stream characteristics.

The removal of some dams can be straightforward and inexpensive. But for many dams, it is difficult and time-consuming to evaluate and implement the removal option because removing a dam can result in different economic, ecological, and societal impacts, both beneficial and adverse. Although several guidance documents on decision-making related to dam removal are available, they were produced by different agencies for their specific goals, and none are directly related to stream restoration and mitigation credits relevant to transportation agencies.

The current research project, “A Study of Existing Research on Low-Head Dam Removal Projects,” culminated in this document, which provides transportation departments, regulatory agencies, resource agencies, and the public a tool to help assess the value of low-head dam removal projects as a stream restoration and mitigation option. The research relies on a multitude of outreach activities (e.g., literature reviews and surveys) to obtain needed information on dam removal projects; and employs experts in ecological, environmental, geotechnical, and hydraulic engineering to ensure that critical issues, diverse perspectives, and innovative responses are identified to result in a technically robust final document.

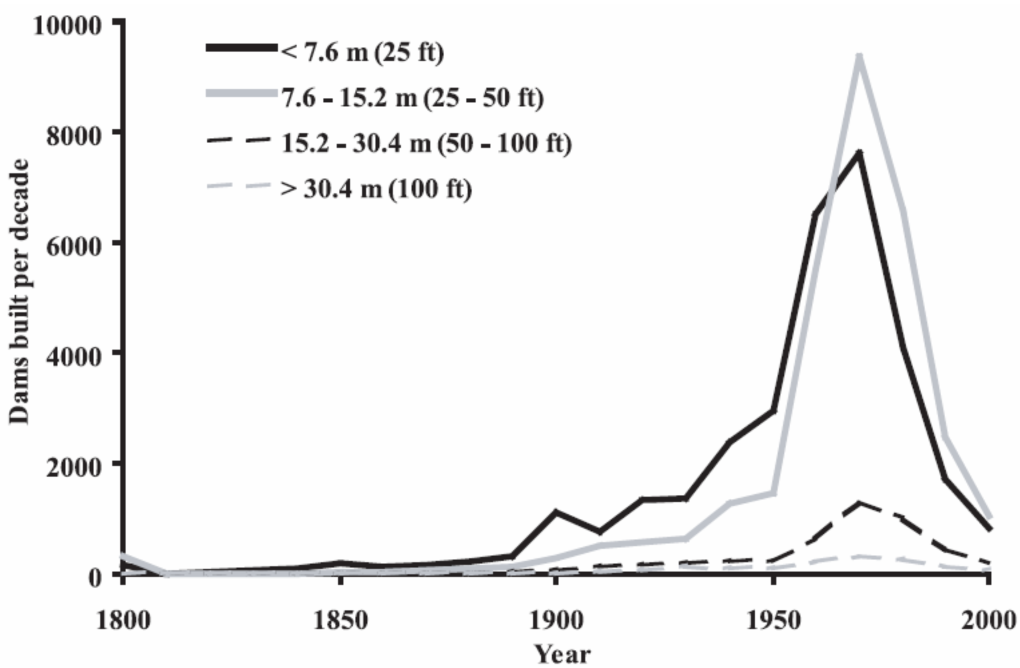


Figure 1.1 Number of dams constructed over the past 200 years by decade and by National Inventory of Dams height class (FEMA, 1999). The most active period of dam building occurred between 1950 and 1970, and has been called "the golden age of dam building."

1.2 LOW-HEAD, SMALL AND RUN-OF-RIVER DAMS

A universal specification defining low-head, small, or run-of-river dams does not exist. Table 1.1 lists different definitions of low-head, small, or run-of-river dams. For this study, the following definitions are adopted:

Low-head dam: A constructed barrier in a river with a hydraulic height (head water to tail water) not exceeding 25 feet. This definition encompasses run-of-river dams as well as other small dams but not industrial dams not built to create an impoundment in a river.

Run-of-river dam: A constructed barrier in a river where the river inflow normally overflows from behind the dam from one side of the waterway to the other. A run-of-river dam has limited short-term storage capacity.

Small dam: A constructed barrier in a river with a structural height not exceeding 50 feet. This definition does not attempt to encompass industrial dams not built to create an impoundment in a river.

The vast majority of removals to date have been of small, privately-owned structures (Heinz Center, 2002). Large dams store a disproportionately large amount of water and sediment and often have profound effects on riverine ecosystems at both local and watershed scales; but in most cases, they still serve their original, or at least modified, purposes. The time and cost to remove a large dam are substantial (Wik, 1995), and removal may cause unanticipated environmental damage with uncertain long-term benefits. In contrast to their larger counterparts, smaller dams are typically older, frequently no longer serve their original purpose, have deteriorated, and may have impoundments filled with sediment. Although they store only small volumes of water and sediment, they may impose other ecological impacts on rivers, including blocking migration routes and impounding unique habitats. Removal of these structures is often a cost-effective alternative to repair and maintenance; recent studies show removals of small dams can have limited negative environmental impacts while restoring riverine functions (Kanehl et al., 1997; Stanley et al., 2002). Most dams removed to date in the United States have been small, and this trend is likely to continue. Issues surrounding small dam removals are thus the most critical focus for new science and policy.

This study will focus on removal of low-head or small run-of-river dams.

1.3 REPORT CONTENTS

This report contains ten chapters and two appendices starting with this initial Chapter 1 that provides a brief introduction to the background of this research project, defines the low-head and small run-of-rivers dams considered, and describes the various topics covered in this report.

Chapter 2 presents a brief review of the available data on dam removal projects, the survey conducted for this study in order to bridge the data gaps, and the analysis of the survey results and the final dam removal project database constructed for this project. A case study is also presented to show the benefits of a dam removal and how a state Department of Transportation (DOT) obtained remediation credits by sponsoring the dam removal.

Removal of low-head dams has different impacts, both beneficial and adverse, including physical, chemical, ecological, social, and economical impacts. These impacts are discussed in Chapter 3.

Chapter 4 discusses the various costs and benefits associated with dam removal, which include the costs and benefits to the dam owner, and the societal, recreational, and environmental costs and benefits. The challenges for economic analysis of dam removals are also briefly discussed.

In Chapter 5, the legal and regulatory requirements of dam removal projects are described. This chapter also discusses the primary and secondary criteria for determining the mitigation credit for dam removal.

Partial dam removal and/or diversion/bypass structures have also been used for stream restoration, recognizing that complete removal of dams may not always be the best option for a river system. Chapter 6 presents examples of partial dam removal projects and discusses the specific issues related to partial dam removal.

Monitoring is necessary to measure the performance of dam removal projects. Chapter 7 discusses the importance of monitoring and describes who should do the monitoring and what should be monitored. The applicable monitoring techniques for low-head dam removal projects are also presented.

Chapter 8 briefly reviews and evaluates the existing guidance documents on decision-making related to dam removal. Based on the review and evaluation, a simple method is proposed for ranking and identifying the candidates of dams that can be removed so that stream remediation credits can be obtained for transportation projects.

The scientific research on the effects of dam removal is still in its initial stages, and elaborate theories and practices on the subject are not yet developed. Although more than 600 dams have been removed in the United States in the past decades, very few published investigations accompanied the removals. Chapter 9 lists the topics (environmental, economical, social, etc.) associated with low-head dam removal that are in need of additional research and study.

Finally, the conclusions of this research project are presented in Chapter 10.

Table 1.1 Different definitions of low-head, small and run-of-river dams.

Term	Definition	Reference
Low-head dam	**A constructed barrier in a river with a hydraulic height (head water to tail water) not exceeding 25 feet.** This definition encompasses run-of-river dams as well as other small dams but not industrial dams not built to create an impoundment in a river.	**Adopted for this study**
Low-head dam	A low-head dam is a dam of low height, usually less than 15 feet, made of timber, stone, concrete, and other structural material, or some combination thereof, that extends from bank to bank across a stream channel. A low-head dam may also be referred to as a channel dam.	Ohio Department of Natural Resources http://www.dnr.state.oh.us/water/dsafety/lowhead_dams/what_are_lh_dams.htm
Low-head dam	A dam at which the water in the impoundment is not high above the turbine units.	StreamNet, 205 SE Spokane Street, Suite 100, Portland, OR 97202 http://www.streamnet.org/pub-ed/ff/Glossary/glossarydam.html
Low-head dam	Low-head dams are run-of-the-river overflow weir or spillway structures, normally producing vertical water surface drops from one to 15 feet, and constructed across rivers and canals for the purpose of raising the water level to improve industrial and municipal water supplies, divert irrigation water, protect utility crossings, and enhance recreational opportunities.	B.A. Tschantz, Public Hazards at Low–head Dams: Can We Make Them Safer? *National Dam Safety Conference Proceedings*, 2003 Dam Safety Conference, Minneapolis, September 2003.
Low-head dam	A typical low head dam may be built with a drop of 2 to 12 feet, and some are built at angles between 45 degrees and 75 degrees.	Fire Chief magazine http://firechief.com/mag/firefighting_insurance
Low-head dam	A low head dam is a dam where the water pours over the top of a river–wide wall. These dams are almost always designed to be straight as a ruler, which results in a perfectly uniform hydraulic, with the water on the surface flowing back upstream all along the width of the dam.	http://www.eecs.tufts.edu/~gowen/White_Water_Paddling_FAQ.txt
Low-head dam	A low head dam is a manmade barrier in the river that causes the river to drop several feet in a very small distance.	The South Batavia Dam Project, Kane County Forest Preserve District http://www.southbataviadam.com/typ__dam_section.htm
Low-head dam	<25 feet in height	Illinois Department of Natural Resources http://bataviansforahealthyriver.org/dam_fact.htm
Low-head dam	Low-head dams are characterized for this paper as having a vertical drop of less than 3 meters.	Wright, Kenneth R; Keliy, Jonathan M.; Houghtalen, Robert J.; Bonner, Mark R.; Emergency Rescues At Low-Head Dams *Proceedings. Dam Safety 1995*

Table 1.1 *(Continued)*

Term	Definition	Reference
Run-of-river dam	**A constructed barrier in a river where the river inflow normally overflows from behind the dam from one side of the waterway to the other.** A run-of-river dam has limited short-term storage capacity.	**Adopted for this study**
Run-of-the-river dam	Manmade structure which: 1. is regulated or permitted by the Department of Environmental Protection (DEP) pursuant to the act of November 26,1978 (P.L.1375, No.325), known as the Dam Safety and Encroachments Act; 2. is built across a river or stream for the purposes of impounding water where the impoundment at normal flow levels is completely within the banks and all flow passes directly over the entire dam structure within the banks, excluding abutments, to a natural channel downstream; and 3. DEP determines to have hydraulic characteristics such that at certain flows persons entering the area immediately below the dam may be caught in the backwash.	Pennsylvania Department of Environmental Protection http://sites.state.pa.us/PA_Exec/Fish_Boat/rrdam.htm
Run-of-the-river dam	Run-of-the-river dams are where the overflow from behind the dam stretches from one side of the waterway to the other. Low–head dams are where there is a difference in elevation above and below the dam. Some have permanent lakes behind them.	Pennsylvania Dept. of Environmental Protection http://www.dep.state.pa.us/dep/deputate/polycom m/pressrel/novak/cn0619.htm
Run-of-river dam	A dam with limited storage capacity, such as Bonneville Dam. Hydroelectric generating plants at these dams (run-of-river plants) operate based only on available stream flow and some short-term storage (hourly, daily, or weekly).	The Bonneville Power Administration http://www.bpa.gov/corporate/pubs/definitions/d.cfm#dam
Run-of-river dam	Hydroelectric generating plants that operate based only on available inflow and a limited amount of short-term storage (daily/weekly pondage).	StreamNet, 205 SE Spokane Street, Suite 100, Portland, OR 97202 http://www.streamnet.org/pub-ed/ff/Glossary/glossarydam.html

Table 1.1 *(Continued)*

Term	Definition	Reference
Small dam	**A constructed barrier in a river with a structural height not exceeding 50 feet.** This definition does not attempt to encompass industrial dams not built to create an impoundment in a river.	**Adopted for this study**
Small dam	storing 1 – 100 acre–feet of water (pp. xii) storing less than 100 acre–feet of water (pp. 1)	The Heinz Center (The H. John Heinz Center for Science, Economics and the Environment),2002, Dam Removal: Science and Decision Making
Small dam	25 feet high with an impoundment of at least 15 acre–feet, or 6 feet high with an impoundment of at least 50 acre–feet	National Inventory of Dams http://crunch.tec.army.mil/nid/webpages/nid.cfm
Small dam	heights ranging up to 50 feet	California Division of Safety of Dams, Guidelines For The Design and Construction of Small Embankment Dam, 1993 Reprint http://damsafety.water.ca.gov/guidelines/introduction.htm
Small dam (Class IV)	A Class IV Dam must meet the following: • Drainage area must be less than 150 acres. • Dam Height must be less than 15 feet. • Dam must not have the potential to impound more than 15 acre–feet of water. • Dam must pose Low Hazard potential. • Spillway capacity must safely pass the 24–hour 100–year frequency Type III storm plus 50 percent	New Jersey Department of Environmental Protection, Dam Safety and Flood Control, Dam Safety Standards, N.J.A.C. 7:20 http://www.state.nj.us/dep/nhr/engineering/damsafety/faq.htm http://www.state.nj.us/dep/nhr/engineering/damsafety/standard.pdf
Small dam	Height of dam less than 40 feet. Storage at normal water surface less than 1000 acre–feet (Size classification determined by either storage or height, whichever gives the larger size category)	New York State Department of Environmental Conservation, Guidelines for Design of Dams, revised January 1989 http://www.dec.state.ny.us/website/dow/bfp/ds/damguideli.pdf
Small dam	Height less than 15 feet	Washington State Department of Ecology, Chapter 173–175 WAC, Dam Safety http://www.ecy.wa.gov/pubs/wac173175.pdf

Table 1.1 *(Continued)*

Term	Definition	Reference
Small dam	Less than 15 feet high and creates an impoundment of 100 surface acres or less of water. Height is measured as the hydraulic height. Surface acres are measured at normal pool.	Wisconsin Department of Natural Resources, Chapter NR 336, Small and Abandoned Dam Removal Grant Program, Register, October 2003, No. 574 http://www.legis.state.wi.us/rsb/code/nr/nr335.pdf
Small dam	< 25 feet high	Wisconsin Department of Natural Resources (WDNR), May 10, 2000, reported in Dam Removal Research, Status and Prospects, Proceedings of the Heinz Center's Dam Removal Workshop, William L. Graf, editor, The H. John Heinz III Center for Science, Economics and the Environment, October 23 – 24, 2002, p. 41
Small dam	Those whose fate can be discussed and determined by local communities and local government agencies.	Brian Graber (2002), Potential Economic Benefits of Small Dam Removal, Dam Removal Research, Status and Prospects, Proceedings of the Heinz Center's Dam Removal Workshop, William L. Graf, editor, The H. John Heinz III Center for Science, Economics and the Environment, October 23 – 24, p. 56
Small dam	Those structures with heights above streambeds not exceeding 50 feet, except for concrete dams on pervious foundations. For the latter structures, the maximum height is further limited to dams whose maximum net heads (headwater to tail water) do not exceed 20 feet.	United States Department of Interior, Bureau of Reclamation, Design of Small Dams, A Water Resources Technical Publication, Third Edition, 1987

2 SUMMARY OF DAM REMOVAL PROJECTS

To obtain the information on dam removal practices, a database containing dam removal projects has been developed. The following describes the process for developing the database and the results of the data analysis.

2.1 AVAILABLE DATA

American Rivers, Inc. (1999) produced a database containing dam removal projects up to 1999, which served as the starting point for developing the database used in this investigation. The American Rivers database, however, contains only very brief information and has several limitations including:

- No distinction between dams that were completely removed and those breached;
- No information on the cost of dam removal;
- No information on the type of dams removed; and
- Dam removal projects are only up to 1999.

In order to construct a more comprehensive and more detailed dam removal database, we expanded the American Rivers database by

- adding other dams removed up to 1999 but not included in the American Rivers database;
- adding new dams removed after 1999; and
- including more information available for each dam removal project.

We obtained the new information on dam removals by conducting a literature review, including web searches. We also received existing dam removal project databases from Ms. Elizabeth Maclin of American Rivers, Inc. and Professor Molly Pohl-Costello of San Diego State University.

We listed the dam removal projects that we could find in a Microsoft Excel table. For each project, we listed the available data as well as unavailable information that we would like to obtain. Table 2.1 shows the first several rows of this table. Because much important information is missing, we conducted a survey in order to bridge the data gaps. The details of the survey are presented in the next section.

2.2 SURVEY FOR THIS STUDY

The purposes of the survey are:

- To identify additional dam removal projects;
- To bridge data gaps for known dam removal projects; and
- To learn about the current dam removal practices from different agencies.

In order to maximize the response rate and receive useful information, it is important to define simple and clear survey questions and determine the right agencies to which the questions would be sent. After finishing the literature review, we conducted a brain-storming meeting to discuss the survey questions and the agencies to which the questions would be sent.

Besides filling the data gaps for each dam removal project (as shown in Table 2.1), we also prepared survey questions specifically related to this research project as shown in Table 2.2. The answers to these questions would provide state-of-the-art information on current dam removal practices.

We prepared a list of contacts, including more than 100 individual from different agencies such as:

- State DOTs
- Association of State Dam Safety Officials
- State Departments of Environment and Natural Resources
- State Department of Water Resources
- State Environmental Protection Agencies (EPA)
- U.S. Environmental Protection Agency (USEPA) – Regional offices
- U. S. Army Corps of Engineers (USACE) – District offices

These agencies provide a representative sample of the organizations involved in dam removals. The preparation of the recipient list proved to be a major effort since most organizations did not have updated lists of individuals in the target positions (e.g., state CWA 401 and 404 representatives).

To make it convenient for the person contacted to fill the data gaps for each dam project and answer the survey questions, we decided to send out the survey via email. The email cover letter and a list of entities that were contacted are included in Appendix A.

In total we sent the survey to 169 individuals and received 50 responses (a 30% response rate, after sending two "tickler messages"). Among the respondents, 21 (42%) provided new data and 29 (48%) provided no new information.

Table 2.1 First several rows of the table containing the dam removal projects and related information

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (**deconstruction** cost only)	How was removal funded?	Indicate whether dam was **removed** (total removal) or **breached** (partial removal)	Dam Maximum **Structural Height** (ft)	Dam **Hydraulic Height** (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	**Run–of–river dam**? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
AK	Unnamed Dam	Allison Creek	2004					6		30			1970	Gravel				Stream Gauging	
AK	Davidson Ditch Diversion Dam	Chatanika River	2002										1920s	Concrete butress					
AK	Switzer One Dam	Switzer Creek (trib.)	1988					15											
AK	Switzer Two Dam	Switzer Creek (trib.)	1988					15											

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	**Stream Mitigation Credit** assigned? (Yes or No)	**Study** after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
		No longer in service; Block fish passage		Restore creek's ecological integrity by restoring free movement of fish and other aquatic organisms				Meagan Boltwood, Anchorage Waterways Council, (907) 743-1052, Meagan@awcgroup.org.	
		Severely damaged		Open upstream habitat to fisheries; Increase recreational opportunities				Mike Roy, U.S. Fish and Wildlife Service, (907) 786-3825, Michael_Roy@fws.gov	

This page is intentionally left blank.

Table 2.2 Survey questions sent to different agencies.

#	Survey Questions	Responses
1	The worksheet "*Database for Your Input*" lists the dam removal projects we have collected. However, we were unable to find much information. If you have information to bridge these knowledge gaps, please fill in as many blank or partially completed cells as possible, particularly for those projects with your name in column "AC." For ease of navigation, the projects have been sorted by state.	Please write your responses on the work sheet "*Database for Your Input.*" **If you do not have documentation for numerical answers but can estimate the magnitude, please follow your estimate with an asterisk (*).**
2	If you can, please **add any other dam removal projects** not listed on the sheet. Even partial information that could help us track down the information will help.	
3	What federal, state and local **permits/approvals** are required to conduct the dam removals which you have participated in? Please provide citations for applicable laws, statutes, regulations and/or codes, where possible.	
4	Have you used or do you know any **regulatory guidelines specifically applicable to dam removal projects**? If so, please cite.	
5	How do you or your organization define **low-head** dams?	Your organization's definition: Your own personal definition:
6	Do you know of any dam removal projects that have qualified for **stream mitigation credits** to transportation agencies? If so, please provide project name and contact information. (Note: **Stream Mitigation Credit** refers to credits assigned to project owners to compensate for adverse impacts to the stream due to new construction.)	
7	Does your organization have **technical guidance documents** regarding which dams are good candidates for removal? If so, please provide reference(s).	
8	How does your organization handle the issue of land ownership for previously inundated lands that become accessible after the removal of the reservoir? Please provide references to any guidance documents.	

Notes: The worksheet "*Database for Your Input*" is in the format of Table 2.1 and contains the dam removal projects we could found before sending the survey.

2.3 DATA ANALYSIS

The answers to the survey questions and the final list of dam removal projects including those added by the survey respondents are presented in Appendix B. The following paragraphs present the analyses and discussion of the survey responses and the database in the order of the questions listed in Table 2.2.

Survey Question #1: The worksheet "*Database for Your Input*" lists all the dam removal projects we have collected. However, we were unable to find much information. If you have information to bridge these knowledge gaps, please fill in as many blank or partially completed cells as possible, particularly for those projects with your name in column "AC." For ease of navigation, the projects have been sorted by state.

Survey Question #2: If you can, please **add any other dam removal projects** not listed on the sheet. Even partial information that could help us track down the information will help.

Twenty respondents added new dam removal projects and/or provided the missing information for the dam removal projects we had collected. The final list of removed low-head dams (hydraulic head not exceeding 25 feet) and/or removal small dams (structural height not exceeding 50 feet) is presented in Table B.2 in Appendix B. Figure 2.1 shows the number of removed low-head dams and/or small dams in different decades. Dam removal appears to have

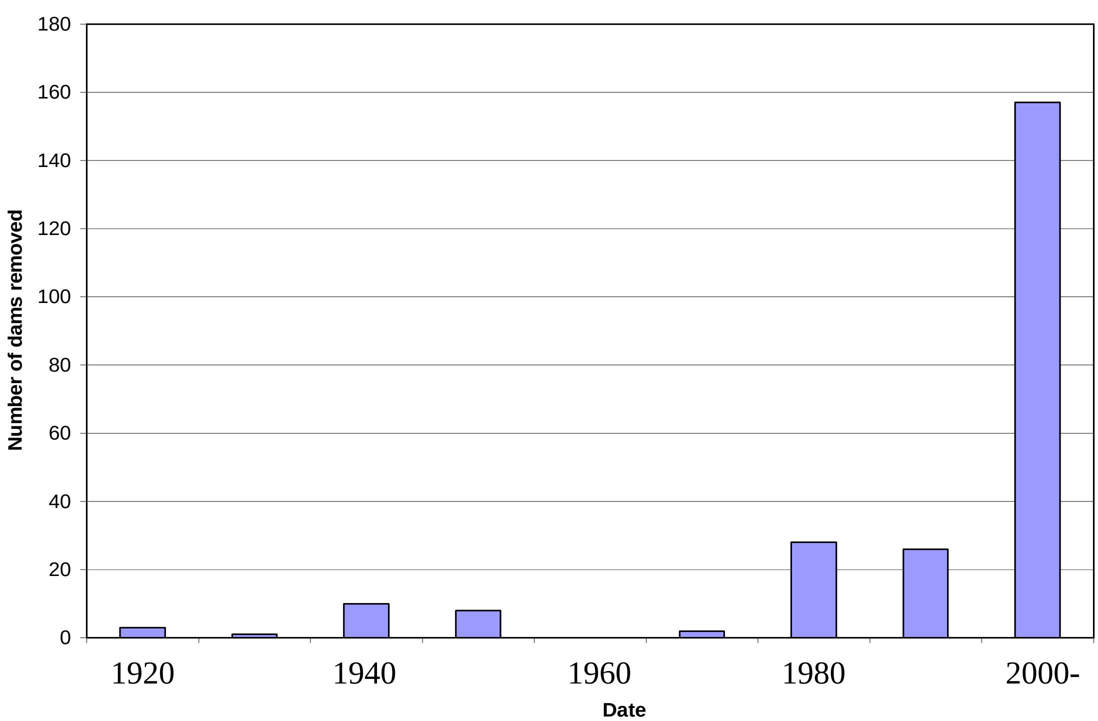


Figure 2.1 Number of low head dams or small dams removed in different decades.

been relatively uncommon before the 1980s, but has escalated significantly in the 21st century. Poor record keeping may account in part for the infrequent dam removals cited before 1980s. However, the data may also simply reflect the fact that dams were newer and thus were less likely to have age-related safety problems and more likely to meet economic and social needs. The recent acceleration of dam removals reflects problems associated with aging structures, growing interest in restoring rivers and fish passage, new funding opportunities to support dam removal, and national policies aimed at improving the safety of aging structures and mitigating the environmental impacts of these structures (Pohl, 2002).

There are different reasons for dam removals. American Rivers et al. (1999) classified the reasons for dam removals into six categories: ecology, economics, failure, recreation, safety, and unauthorized dam. We adopted these category terms but added other specific reasons not covered by American Rivers et al. into some of the categories. Specifically, these six categories are defined as follows:

- **Ecology**: dam was removed to restore fish and wildlife habitat; to provide fish passage; to improve water quality; to remediate environment; and to provide environmental mitigation credits.
- **Economics**: maintenance of dam was too costly; removal was cheaper than repair; dam was no longer used; and dam was in poor or deteriorating condition.
- **Failure**: dam failed; or dam was damaged in flooding.
- **Recreation**: dam was removed to increase recreational opportunities.
- **Safety**: dam was deemed unsafe; and owner no longer wanted liability.
- **Unauthorized dam**: dam was built without a needed permit; dam was built improperly; or dam was abandoned.

As American Rivers et al. (1999) noted, some categories overlap, and many dams are removed for more than one reason. Figure 2.2 shows the number of low-head or small dams removed due to different reasons. The three most common reasons for dam removals are ecology, economics, and safety, in that order.

Figure 2.3 shows the number of removed low-head or small dams of different structural heights. Most of the dams removed have a structural height smaller than 20 feet. This is in agreement with the Heinz Center's (2002) conclusion that "almost all of the dams removed thus far have been small ones."

Records for 105 dams contain information on whether the dam was totally removed or partially breached. Of the 105 dams, 83 dams (79%) were totally removed and 22 dams (21%) were breached or partially removed.

Records for 131 removed dams contain information on removal cost. Of these 131 dams, 7 dams (5%) have a total removal cost over 1 million U.S. dollars and one dam (0.8%) has a deconstruction cost exceeding 1 million U.S. dollars (see Table 2.3). These dams have high removal costs due to additional work related to the dam removal, such as riparian tree plantings and erosion control with native grasses.

Dams with removal costs over 1 million U.S. dollars are very few, and the removal costs themselves are significantly higher than the value of most removed dams; therefore, these dams are not included in the analysis of the relation between the removal cost and structural height. This omission will delete the bias of these significantly high values on the general relation between the removal cost and structural height. Figure 2.4 shows the removal cost versus the structural height. In general, both the total removal cost and the destruction cost increases with the structural height. The fitting analysis of the data gives the following relations between the removal cost and the structural height:

$$\text{Total Removal Cost (US\$)} = 9{,}287.6 \times H_s \tag{2.1}$$

$$\text{Deconstruction Cost (US\$)} = 4{,}846.8 \times H_s \tag{2.2}$$

in which, H_s is the structural height of the removed dams, in feet. The deconstruction cost is about half (52%) of the total removal cost.

In a review of a number of case examples, Pansic et al. (1998) determined the following cost breakdown for a typical dam removal project:

Infrastructure removal or deconstruction costs - 30%
Environmental engineering or enhancement - 22%
Sediment management - 48%

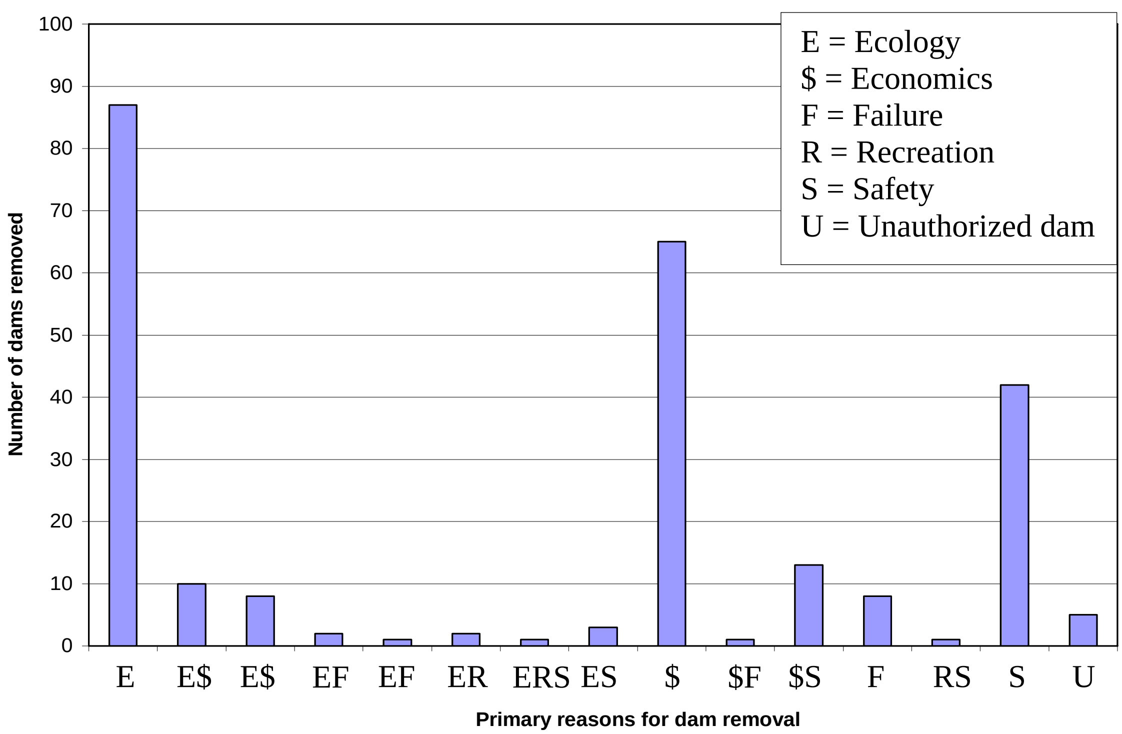


Figure 2.2 Number of low head dams or small dams removed due to different reasons.

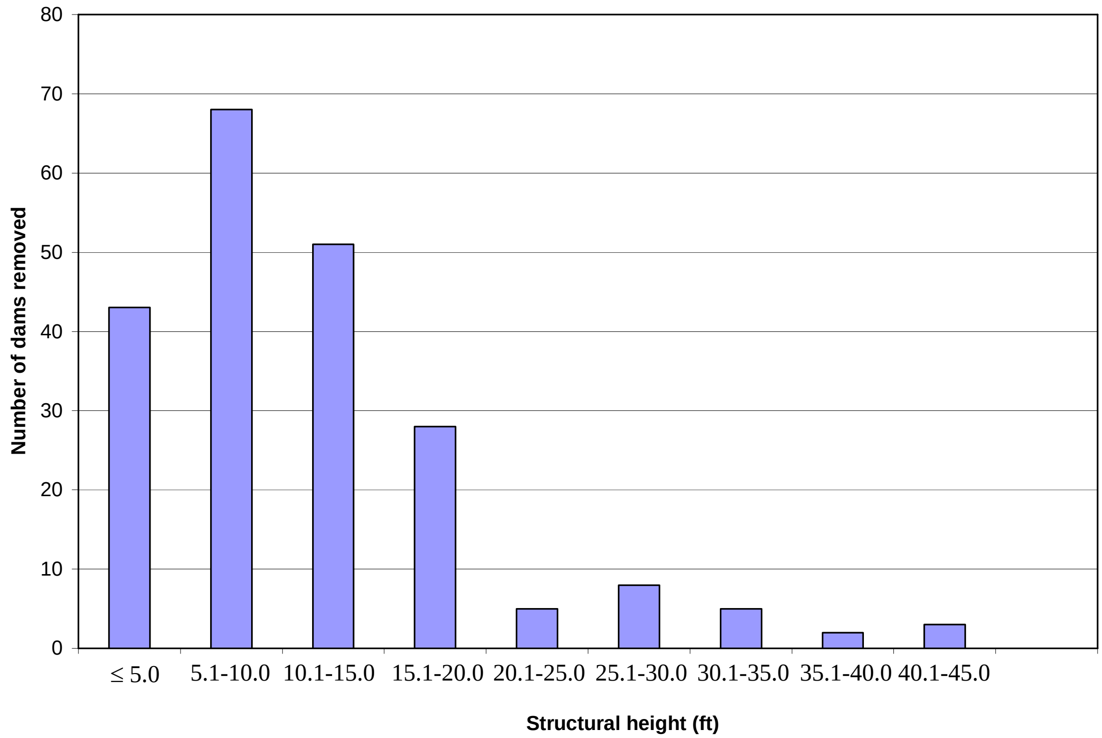


Figure 2.3 Number of removed low head dams or small dams of different structural heights.

Table 2.3 Removed dams with removal cost over U.S. $1,000,000.

State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)
CA	McPherrin Dam	Butte Creek	1998	9,500,000	
ME	Smelt Hill	Presumpscot River	2002	1,017,000	311,000
ME	Edwards Dam	Kennebec River	1999	2,100,000	
MI	Newaygo Dam	Muskegon River	1969	1,300,000	
NY	Cuddebackville Dam	Neversink River	2004	2,200,000	1,400,000
OR	Jackson Street Dam	Bear Creek	1998	1,200,000	
WA	Goldsborough Creek Dam	Goldsborough Creek	2001	4,800,000	

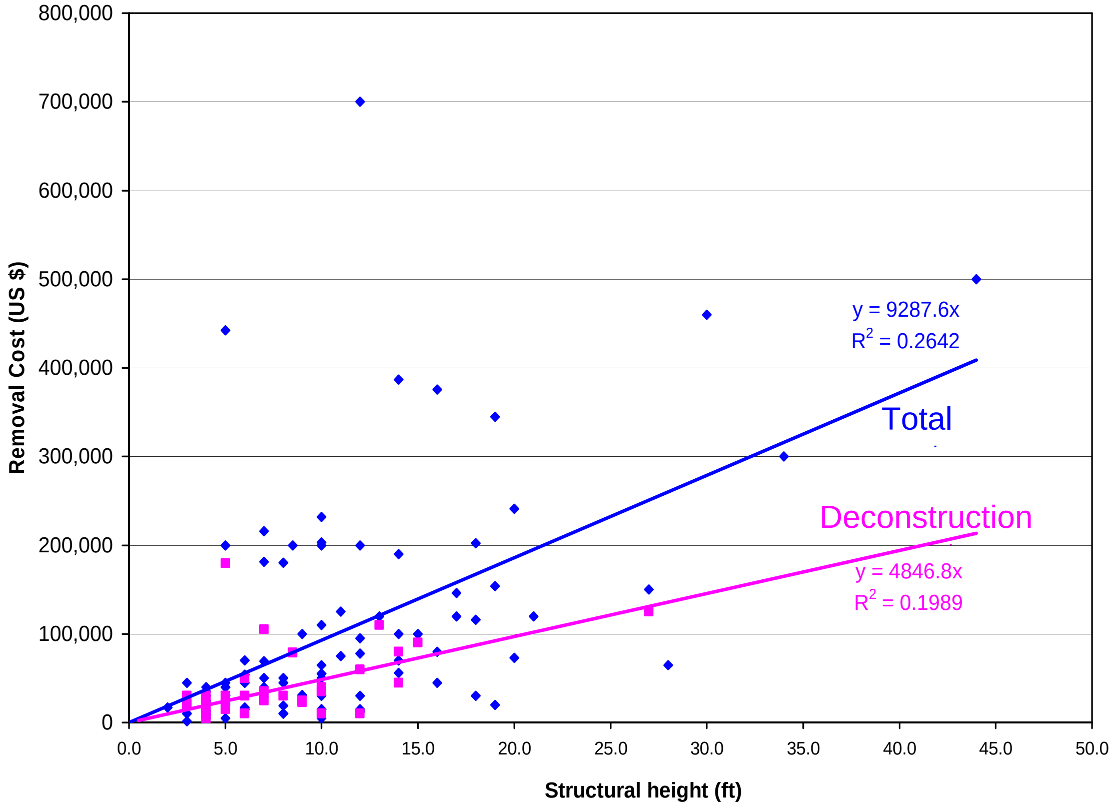


Figure 2.4 Removal cost of low head dams or small dams of different structural heights.

Records for 86 dams contain information on the fund resources for the dam removal. Figure 2.5 shows the number of removed dams with different fund resources. It can be seen that most of the dam removal funds come from state and federal sources.

Figure 2.6 shows the condition of the dams prior to removal. As expected, most of the dams were in poor or failed condition prior to removal.

A geographical assessment of the dam removal data shows that the states with the most dam removals are Wisconsin, Pennsylvania, California, and Ohio. These state governments are committed to providing administrative support for the dam removal activity (Heinz Center, 2002). Wisconsin has a long history of fostering sport fishing, and in many cases the removal of obsolete and unsafe dams advances the state's general interest in improving aquatic habitat and supporting recreational fishing. In some cases, Wisconsin has also reconstructed channels in previously inundated reservoir areas. Pennsylvania has an interest in reconnecting the Susquehanna River system, which drains into Chesapeake Bay. Because the state is part of a regional compact to enhance the bay's environmental quality, dam removal fits within a more general state policy goal. The critical need for connected river segments for the health of the bay provides an environmental incentive. California has environmental policies that stimulate the dam removal process. Ohio DOT has negotiated with the Ohio EPA and the USACE for the use of dam removals (St. John's Dam, Lover's Lane Dam and North River Road Dam) for stream mitigation credit. New Hampshire is one of the few states that has established a program within a state agency to provide support for dam removal activities.

Survey Question #3: What federal, state, and local permits/approvals are required to conduct the dam removals which you have participated in? Please provide citations for applicable laws, statutes, regulations and/or codes, where possible.

The respondents' answers to this question are variable, from no permits/approvals requirement to different federal, state and local permits/approvals required (see Table B.1 in Appendix B). The most frequent requirements are the Clean Water Act (CWA) 404 permit and the CWA 401 State Water Quality Certification Other permit/approval requirements are mainly related to safety and ecology issues. (see Chapter 5 for a detailed discussion of the legal and regulatory requirements for dam removal projects).

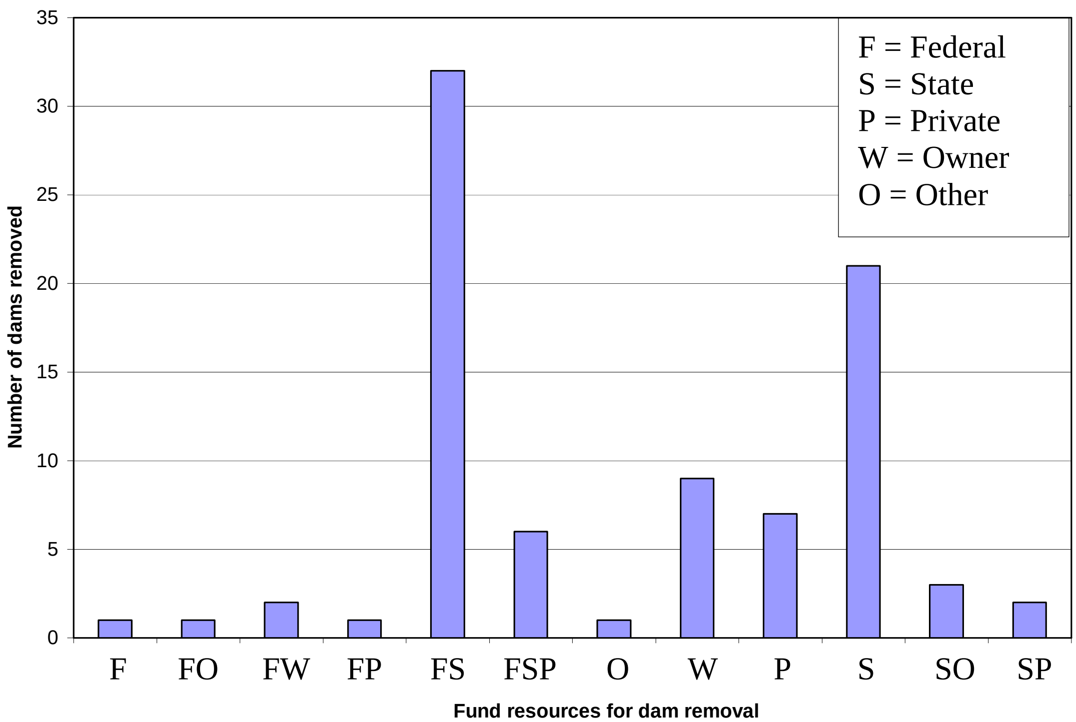


Figure 2.5 Number of removed low head dams or small dams with different fund resources.

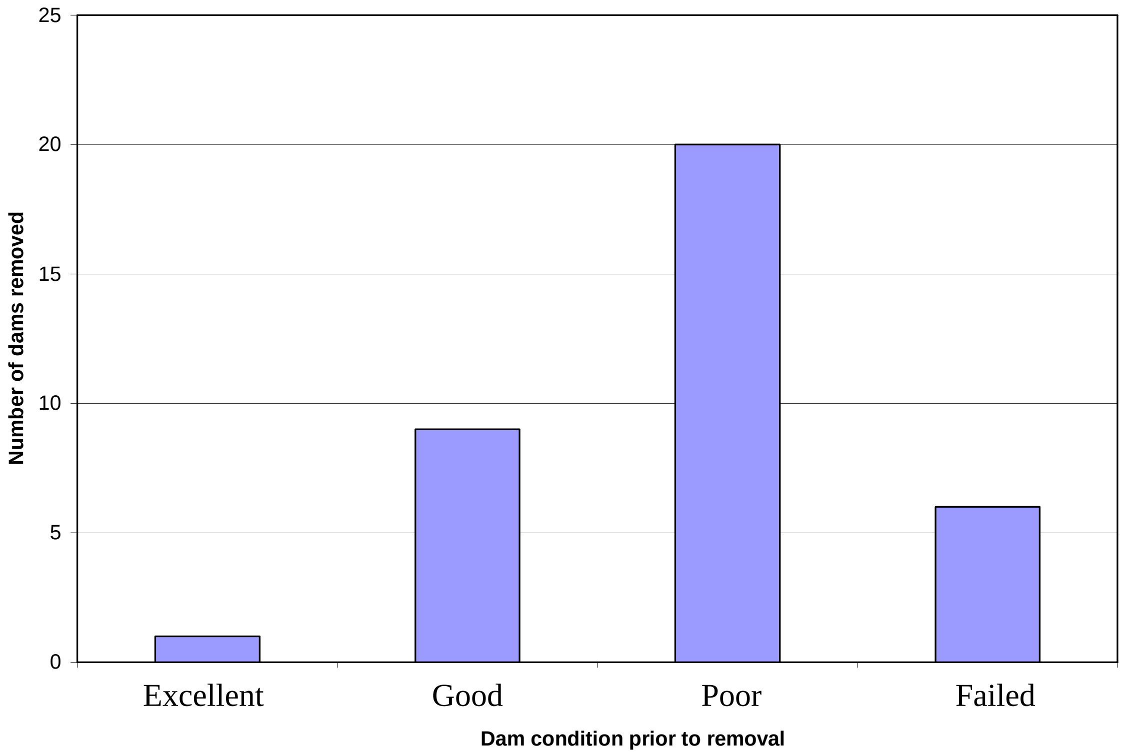


Figure 2.6 Number of removed low head dams or small dams at different conditions prior to removal.

Survey Question #4: Have you used or do you know any regulatory guidelines specifically applicable to dam removal projects? If so, please cite.

Again, the respondents' answers to this question are variable, from no specific regulatory guidelines to different regulatory guidelines applicable to dam removal projects (see Table B.1 in Appendix B):

- NC: Dept of Environment and Natural Resources - NCGS 143-215 and NCAC 15A-2K.
- NH: Department of Environmental Services–"Guidelines to the Regulatory Requirements for Dam Removal Projects in New Hampshire" (see Section 8.1.1 for additional information).
- NJ: New Jersey Dam Safety Standards, N.J.A.C. 7:20 contains guidelines relative to removal of dams
- OH: Ohio DOT – Ohio EPA's Draft "Compensatory Mitigation for Stream Impacts"

Survey Question #5: How do you or your organization define low-head dams?

Many of the respondents' organizations do not define low-head dams. As expected, the respondents' definitions or classifications of low-head dams are variable and are within the range covered in Table 1.1.

Survey Question #6: Do you know of any dam removal projects that have qualified for stream mitigation credits to transportation agencies? If so, please provide project name and contact information. (Note: Stream Mitigation Credit refers to credits assigned to project owners to compensate for adverse impacts to the stream due to new construction.)

Only the two respondents from NH and OH provided the information on dam removal projects in planning or that have been conducted for stream mitigation credits:

- NH: Two dam removal projects, currently in the planning process, may be conducted to offset impacts associated with the filling wetlands for an airport expansion.

- OH: Ohio DOT has negotiated with the Ohio EPA and USACE for the use of dam removals for stream mitigation credit. They are the St. John's Dam (see Case Study in Section 5.4.3), Lover's Lane Dam, and North River Road Dam.

While not indicated in their survey response, additional contact was initiated with a NC agency based on prior knowledge of potential mitigation projects. Three dam removal projects for the purpose of obtaining stream mitigation credit are currently under review; however, the feasibility of the projects has not been finalized.

Survey Question #7: Does your organization have technical guidance documents regarding which dams are good candidates for removal? If so, please provide reference(s).

Most of the respondents' organizations do not have technical guidance documents for making removal decisions. However, the respondents of NH, OH, and PA provided information on their technical guidance documents:

- NH Department of Environmental Services - "Guidelines for Prioritizing Dam Removal Projects in New Hampshire" was developed in response to numerous requests for agency assistance in planning and conducting dam removal projects. These guidelines are completely distinct from the regulatory permit review process. The document provides a method for agencies to determine which proposed dam removal projects represent the most effective use of limited agency resources (see Section 8.1.1 for additional information).

- Ohio DOT – The Ohio DOT works closely with the OH Department of Natural Resources (ODNR) to establish those dams that should be removed.

- Pennsylvania Fish And Boat Commission - Project Selection Protocol and Guidelines for Pennsylvania Fish And Boat Commission Consultation and Grant Program for Fish Passage and Habitat Restoration

Survey Question #8: How does your organization handle the issue of land ownership for previously inundated lands that become accessible after the removal of the reservoir? Please provide references to any guidance documents.

Many of the respondents have not yet addressed or fully considered this issue. However, the ownership of land exposed through dam removal typically requires site-specific investigation. In addition, a variety of state-specific laws may apply to determining ownership of lands exposed through dam removal. Land ownership questions can typically be answered by referring to the deeds for the specific dam property and the adjacent properties. The dam's deed might include all of the land that was flooded and the exposed land would revert to the dam owner. Some dam owners have donated these lands to land trusts or quit-claim deeded them to adjacent land owners or municipalities. In other cases, the land currently underwater may be publicly owned, or it may simply revert to the property owners bordering the restored river (NHDES, 2005).

2.4 PROBLEMS WITH CURRENT DAM REMOVAL DATA

It is noted that the information on most of the removed dams is incomplete. Although Table B.2 contains information on more than 600 dams, most of the entries lack one or more types of information. The incomplete information may be due to the following reasons (Pohl, 2002):

- No one organization or agency has formal responsibility for collecting and compiling these data at the national level. Much of the information on dam removals is found piecemeal through various local, state, and federal agencies and organizations that have responsibility for (or interest in) dams, water, and environmental quality. These agencies or organizations may just report dam removal information limited to their own interest.
- In past decades, dam removal was not a major issue, and the investigations, if conducted, are not readily available.

3 DAM REMOVAL IMPACTS

3.1 PHYSICAL AND CHEMICAL IMPACTS

Potential impacts of low-head dam removal on river morphology, flooding, sedimentation and sediment transport, and erosion are discussed. Although low-head dams typically function as run-of-river systems with commensurate, minimal effects on the riverine hydrologic regime, their presence and subsequent removal can affect a variety of other riverine processes. These potential effects should therefore be evaluated when planning and implementing the removal of a low-head dam.

3.1.1 River Hydrology

Hydrologic effects of low-head dam removal will depend on factors including the size of the upstream impoundment, the impoundment's effect on groundwater recharge to the formally-impounded area, and the geometry and operational regime of outlet appurtenances. Where low-head dams function as run-of-river systems, dam removal should have minimal effects on the riverine hydrologic regime except for the restoration of riverine conditions in formally-impounded and backwatered areas.

Where low-level outlet appurtenances in a low-head dam provide for gradual drawing-down of an impoundment during periods of low flow, removal may affect downstream flows. This condition is quantifiable, however, and may be evaluated in planning for dam removal.

Impacts to groundwater recharge may result from the increased hydraulic gradient (i.e., slope) following dam removal and drawdown of the formally-impounded areas. Potential changes in groundwater recharge will be site-specific and dependent on factors including the magnitude of the drawdown and substrate conditions.

3.1.2 River Morphology

Effects of dam removal on river morphology will vary depending on site-specific parameters, including the quantity and composition of impounded sediments and the rate of sediment erosion and transport. Specific parameters associated with river morphology include stream channel hydrogeometry and slope, hydrology, and the duration of time in which the dam impounded water and sediments. Changes associated with these parameters can be correlated to the effect of the dam on 1) changes in the downstream hydrologic regime and 2) trapping of sediments in the impoundment and changes in the delivery of sediments to the river downstream of the dam. By definition, low-head dams have minimal effects on downstream hydrologic regimes, and therefore hydrologic effects of low-head dam removal on river morphology will not be discussed.

A fundamental problem in the evaluation of potential geomorphic effects resulting from dam removal is that most of the available information on fluvial response is based on the regime concept. This concept implies that a river channel system is in a state of dynamic, or "quasi", equilibrium (Chang, 1998). Potential morphological effects resulting from dam removal may occur over transient time scales characteristic, however, thereby violating the dynamic equilibrium basis of regime concepts such as Lane's relationship or the process-response relationships developed by Schumm (Chang, 1998). Due to the lack of information on transient responses, the following discussion is based on regime concepts, and the reader must therefore consider the applicability of this information on a project-specific basis.

Morphologic effects associated with the construction of a dam, and therefore also associated with the removal of dam, can be discrete by location such as 1) the reach of river upstream of an impoundment, 2) within an impoundment, and 3) downstream of a dam. A potential morphological effect associated with the construction of a dam is streambed aggradation upstream of the impoundment (Morris and Fann, 1998). Removal of a downstream dam can reverse this process but may not necessarily result in the river reestablishing itself within the original channel. Possible remedial actions in this case may include mechanized restoration of the original stream channel, including the removal or redistribution of sediment deposit.

Morphological effects within the impoundment as a result of dam removal may be similar to morphological effects upstream of the impoundment (Morris and Fann, 1998). To a large extent, this is dependent on the quantity, composition, and distribution of the deposited materials, particularly in relation to the river channel that is reestablished post-dam removal. If sedimentation within an impoundment is minimal, morphological change resulting from dam removal is likely to be similarly minimal. If a large volume of sediment is present, however, there is the potential for increased morphological change, and, depending on the composition of the native substrates relative to the sediments, the possibility that the channel could reestablish in a location other than the preexisting stream channel. For this case, reconstruction of the preexisting river channel within the formally impounded area may be desirable.

Morphological changes can occur downstream of a dam (Chang, 1998), and the removal of a dam and restoration of sediment continuity may therefore also effect the downstream morphology. The time scale associated with the presence of the dam may be an important characteristic affecting potential downstream changes in river morphology following dam removal. As previously discussed, a transient (i.e., short and non-equilibrium) response may require judgment in the application of regime concepts. In cases where there has not been substantial sedimentation upstream of a dam, affects on river morphology may be minimal, as it can be assumed that dynamic equilibrium of the riverine system was not affected. Over longer time scales and/or in cases where large amounts of sediment have been and continue to be trapped upstream of a dam, the lack of sediment replenishment downstream of the dam may result in channel degradation and incising, as well as erosion and slumping of stream banks. While removal of the dam in this case could replenish the sediment deficit downstream, rapid erosion of previously-impounded sediments could result in changes to channel morphology. In cases where an impoundment has experienced substantial sedimentation and sediment continuity to the downstream channel has been restored through dam removal, the potential exists for increased effects on river morphology (Morris and Fann, 1998), as the downstream channel may not have sufficient sediment transport capacity. For this case, removal of sediments within the impounded area should be considered as a means to control downstream morphological effects associated with dam removal.

3.1.3 Flooding

Effects on flooding associated with the removal of a low-head dam include direct effects associated with changes in riverine hydrology and indirect effects related to potential changes in river morphology. Because low-head dams typically function as run-of-river systems and therefore do not provide a flood control function, deleterious effects of low-head dam removal on flooding will likely be minimal, with potential benefits achieved through the reduction in flood elevations upstream of the dam. In cases where a dam is in disrepair, the removal of the dam can eliminate the risk of uncontrolled releases of water and sediment resulting from a dam failure event.

Indirect effects of low-head dam removal associated with changes in river morphology can result in increased flood elevations, and should be considered in the determination of appropriate sediment management options when considering dam removal. Within a formally impounded area, removal of a low-head dam will typically result in reduced flooding due to the loss of backwater effects associated with the presence of the dam. Increased flooding could occur downstream of a dam following removal if the volume of released sediment exceeds the river channel's conveyance capacity resulting in aggradation of downstream channel (Morris and Fann, 1998). The potential for this condition should therefore be evaluated when substantial sedimentation has occurred upstream of a dam being considered for removal.

3.1.4 Sediment Transport

The effect of dam removal on sediment transport can be correlated to the changes in sediment transport associated with the presence of a given dam. In cases where minimal sedimentation upstream of a dam has occurred, removal of the dam should have a similarly minimal impact on sediment transport. This condition might occur where a dam has been in place for only a short period of time and/or when sediment transport through the impoundment has not been significantly altered by the presence of a dam. Conversely, dam removal may have increased effects on sediment transport where substantial sedimentation has occurred upstream of a dam, particularly if sedimentation has substantially changed the pre-dam hydrogeometry within the impounded area.

Sedimentation upstream of a dam typically results from decreased capacity for sediment transport due to backwater effects and decreased flow velocities, causing sediment to drop out of the water column. Factors affecting the quantity of material that may accumulate in an impoundment include the sediment delivery into the impounded area, the period over which sediments were impounded, sediment composition (i.e., grain size), and the hydrogeometry of the impounded area. Removal of a dam can restore the pre-dam hydraulic gradient and sediment transport capacity upstream of the dam.

Depending on the volume and composition of the sediment, spatially uniform remobilization of sediment may occur, as the river channel gradually reestablishes itself through the formally impounded area. If the volume of sediment is sufficient, however, removal of the dam may not immediately restore the upstream hydraulic gradient. In this case, remobilization of sediments may occur through head-cutting, with the cut progressing upstream. The period of time required for a head cut to reach equilibrium is determined by several factors including, but not limited to, sediment composition, channel-forming flow events, high-flow events, physical characteristics of the channel (e.g., ledge), presence of infrastructure (e.g., pipeline), and whether river channel aggradation has occurred upstream of the impoundment.

Potential impacts associated with quantity and quality of impounded sediment should be considered as part of the planning and implementation of a dam removal project. This is particularly important when there is a history of industrial or agricultural use in the watershed upstream of the impoundment. Mitigation of deleterious impacts resulting from the remobilization or previously-impounded sediments may be required. Potential remedial measures may include full or partial removal of impounded materials, staged removal of a dam to control sediment remobilization, and/or stabilizing sediment exposed through dam removal.

A critical component in the evaluation of sediment management strategies for dam removal planning and implementation is sediment quality (Morris and Fann, 1998). This evaluation should extend to both "clean" and contaminated sediments. Clean sediments are considered natural and indigenous materials, including organic detritus and inorganic materials (e.g., sand). In some cases, such as with organic materials, the release of these materials can adversely affect downstream water quality. Contaminated sediments are assumed to include compounds such as industrial wastes. While the release of contaminated sediments from an impoundment would not necessarily increase their overall quantity within the riverine system, it can increase their bioavailability and result in more diffuse concentrations, confounding the future feasibility of remediation, if necessary.

The proper assessment of sediment quality is impoundment-specific. For impoundments with sediment deposits that are shallow, surficial or "grab" sampling of sediment may be appropriate. Where sediment deposits are relatively deep and there are historic or current upstream contaminant sources, sampling of sediment depths to point of refusal (e.g., core sampling) may be required. Target contaminants should be assessed based on state and federal requirements, along with local and historical knowledge of potential upstream contaminant sources.

3.1.5 Erosion

The affect of dam removal on erosion is closely related to sedimentation and sediment transport capacity. As previously discussed, removal of a dam can result in remobilization of previously impounded sediments. Erosion of "native" materials can also occur following dam removal due to 1) increased flow speeds in the formally backwatered area, 2) realignment of the upstream river channel and 3) changes in the flow patterns immediately downstream of a former dam.

Potential means to control erosion during and after dam removal include controlling upstream flow speeds, installing grade control structures/systems, reconstructing the upstream channel to be stable and self-maintaining, and stabilizing areas where erosion may occur. These methods may be applied in a complementary manner, with features such as grade control structures (including partial breaching of a dam) and realigning the river channel to reduce reach-length slopes and flow speeds. A gradual drawdown of the impounded area can be used to foster the growth of stabilizing vegetation before a return to full riverine conditions and minimize sloughing of sediments associated with rapid dewatering.

Sediment stabilization can be accomplished using a variety of methods, including traditional, engineering-based methods, such as riprap armoring, as well as the installation of riparian vegetation and/or bio-engineering systems. Applicable methods are typically determined on a project-specific basis due to factors associated with the risk of soil and sediment erosion. At sites where contaminated soils or sediments may be left in place following dam removal, for instance, applied methods should have well documented performance capabilities.

3.1.6 Wetlands

Impacts to wetlands can occur upstream and downstream of dam removal. Because low-head dams typically function as run-of-river systems and do not substantially alter the downstream surface water hydrology, this assessment assumes no hydrologic impact to downstream wetlands resulting from a dam removal project.

Dewatering of an impoundment upstream of a dam following its removal may affect wetlands due to changes in surface water and groundwater hydrology. These effects may occur on a seasonal and/or long-term basis, depending on factors including changes in flood stage associated with dam removal and changes in groundwater elevations resulting from the loss of the impoundment.

Dam removal can impact downstream wetlands due to factors including the restoration of sediment continuity within the riverine system, and in specific cases, changes in groundwater hydrology adjacent to a dam. If a dam removal results in downstream sediment deposition, colonization by wetland plants may result in the creation of wetlands. Where an impoundment has resulted in increased groundwater levels, lateral seepage around a dam can provide hydrology sufficient for the formation of wetlands in the vicinity of a dam. A drawdown in groundwater levels resulting from the removal of a dam in this case could result in the loss of sufficient hydrology for maintaining the wetland.

Dam removal can cause a variety of impacts to wetlands that are adjacent to impounded rivers as well as those occurring downstream of the dam. The type and magnitude of impact is largely site specific.

Vegetation at the interface between a water body and surrounding uplands is primarily structured by the hydrologic gradient (Shafroth et al, 2002). The duration, frequency, and timing of inundation are variable along this gradient. Species tolerances and requirements produce zonation and patterns along the hydrologic gradient (Shafroth et al., 2002). The removal of a dam may alter the hydrological regime and therefore affect the hydrologic gradient within a former impoundment.

Depending on site conditions, dam removal may expose land that was previously under water, resulting in a commensurate shift in the groundwater gradient towards the developing stream channel. This change in hydrology could result in mortality of vegetation along the margin of the former impoundment, especially if it is sensitive to water table declines associated with the drawdown (Shafroth et al., 2002). The new location of the hydrologic gradient will depend on the topography and stage-discharge relations that develop within the former impoundment.

These impacts commonly result from the change in the hydrologic gradient in the former impoundment and the transport of sediment to downstream riparian wetlands.

Studies to remove the Rodman Dam in Florida stressed the need to restore natural flows, which serve to inundate terrestrial areas, such as riverine floodplains. The studies found that if the Rodman Dam is removed, riparian areas would likely flood more frequently, promoting riparian plant growth, revitalizing inland wetlands, and creating small ephemeral ponds that serve as nurseries for aquatic species (American Rivers, 2002; Kaufman, 1992).

In some dam removal cases, the diversity of certain organisms that prefer deeper water wetlands may decline. Wet meadow grasses replaced species of cattail and sedge when the Fulton Dam on the Yahara River was removed in Wisconsin. Consequently, the duck and muskrat populations that relied upon cattail and sedge for habitat were negatively impacted by the dam's removal.

3.1.7 Water Quality

Dams modify the hydrologic regime of a river. A result of this modification is increased retention time of carbon, nutrients (e.g., nitrogen, phosphorus), and sediments within the impounded area (Bushaw-Newton et al., 2002). As water and sediment moves through an impounded reach of river, a variety of biogeochemical reactions take place. These reactions often result in changed water quality conditions within the impounded area, and subsequently downstream of the dam, in comparison to water quality conditions found upstream of the impoundment (Bushaw-Newton, et al, 2002; Newbold, 1987; Mullholand, 1996; Martin et al. 2001). These reactions affect a variety of water quality parameters including, but not limited to, dissolved oxygen, dissolved nutrients, temperature, dissolved organic carbon, total suspended solids, biological oxygen demand, conductivity, and pH. Two of the key factors in determining these processes are the hydraulic residence time (volume/discharge) and the aerobic/anaerobic sediment/water interface (Hannon, 1979; Naiman and Melillo, 1984; Naiman et al., 1988; St Louis et al., 2000; Wetzel, 2001).

The removal of a dam and subsequent return to lotic conditions decreases the hydraulic residence time. The extent of this decrease is specific to the physical characteristics of a particular site. The removal of similarly-sized dams can have different effects on water quality because of differences in their hydraulic residence time (Poff and Hart, 2002). Depending on the rates of various biological reactions (e.g., plant uptake, nitrification, denitrification) dam removal can cause a change in water quality conditions so that the upstream, former impoundment area and downstream areas are more similar (Bushaw-Newton et al. 2002).

The lotic physical conditions that are re-established following removal of a dam can also affect water quality. For instance, emergence of vegetation in the riparian zone of the former impoundment may shade the stream channel, resulting in decreased water temperatures that experience minimal diurnal fluctuation. Another example is the re-emergence of formerly impounded riffles or cascades that serve to aerate the water and increase dissolved oxygen concentrations.

As described in published studies, the effect of dam removal on water quality varies due to physical characteristics of different river systems (Hart et al, 2002). For instance, a study of the Manatawny Creek Dam in Pennsylvania found that water quality did not change markedly following dam removal. Researchers conclude this is likely because the impoundment had a hydraulic residence time of less than two hours at base flow and infrequent temperature stratification (Bushaw-Newton et al. 2002). There was also no substantial accumulation of fine-grained, organically-rich sediment within the impoundment, which would contribute to many biological reactions.

In contrast, Stanley and Doyle (2002) studied the effects of removing the Rockdale Dam on Koshkonong Creek in Wisconsin. This impoundment was dominated by fine-grained sediment. After removal there was a net export of phosphorus-rich sediment to downstream reaches (Stanley and Doyle, 2001) contributing to biological reactions that could adversely affect several water quality parameters.

Relatively few scientific investigations have been completed and published on the effects of dam removal, highlighting the importance of gleaning information from other sources. State water quality assessments and resulting water body classifications can provide pertinent information about the impacts of dam removal. Before the Edwards Dam was removed from the Kennebec River in Maine, the impoundment behind the dam did not meet the minimum state water quality standards (i.e., class C). Following the removal of the dam, water quality notably improved, enough to reclassify the river segment as meeting the higher water quality standard of class B.

A Total Maximum Daily Load (TMDL) study on the Cuyahoga River was conducted in 1999 by the Ohio EPA. The TMDL identified impaired water quality conditions in the impoundment of the Kent Dam. These impairments impeded the attainment of the water body's state designation of warm water habitat. It was determined that if the City of Kent did not reduce or eliminate the impoundment, Ohio EPA would impose stringent effluent discharge limits on the municipal waste water treatment plant. The dam's removal was completed in 2004. It features an innovative design that has transformed the dam into an aesthetic component of a new park while allowing the river to flow freely through the former lock structure (Oakland and Bolender, 2003). The free-flowing river in the former impoundment area has since been evaluated by the Ohio EPA and is now in compliance with state water quality standards (City of Kent, 2004).

3.2 ECOLOGICAL IMPACTS

3.2.1 Aquatic Habitats

Ecological impacts of dam removal to natural communities can be correlated with physical changes in habitat. Such changes may affect dependent flora and fauna due to changes or loss of habitat-specific functions and values. Specific impacts may affect physical and water quality parameters and occur over both short and long-term time scales. Changes in physical parameters affecting aquatic habitats may include the restoration of riverine continuity through formally lotic habitat within the impounded reach of river. Changes in water quality parameters may include increased turbidity resulting from the mobilization of previously deposited sediments and changes in chemical interactions related to the loss of the upstream impoundment. Short-term impacts include the dewatering of the upstream impoundment immediately following dam removal. Long-term impacts may include succession of vegetation in terrestrial vegetation, mobilization of upstream sediments, and increased recruitment of migratory fish.

Dam removal will likely alter the areal extent and composition of aquatic habitats. Changes in the extents of aquatic habitats can be quantified based on post-removal water levels. In some cases, the loss of aquatic habitat may be offset by the restoration of riverine continuity, particularly where opportunities for fish passage are limited or not present prior to dam removal. Changes in the composition of specific aquatic habitat types may result from dam removal, resulting in the partial or complete loss of specific habitats and connection of previously fragmented communities. However, the loss of lentic habitat that is absent elsewhere in the riverine system could include both species and ecological impacts to a variety of life stages.

Sediment dynamics may affect the quantity and type of aquatic habitats upstream and downstream of a dam following removal. While a relatively rapid reversion from lotic to lentic habitat will typically occur following dewatering of an impoundment, ongoing mobilization of sediments can alter habitat parameters including substrate composition over longer time scales. Note that changes in substrate composition can occur upstream of an impoundment following dam removal. The former condition may occur where sediments have aggraded due to backwater effects and remobilize due to the diminished backwater effects. The latter condition may occur where a dam has restricted downstream sediment transport and dam removal has restored sediment continuity into the downstream reach.

Ecological impacts resulting from changes in water quality following dam removal may result from factors including the reversion from lacustrine to riverine conditions and the mobilization of impoundment substrates. Riverine conditions may be less favorable to chemical processes, such as the decomposition of organic detritus under lacustrine conditions, affecting chemical processes though the water column and into underlying sediments. Ecological impacts associated with these changes will be dependent on the nature and extent of specific changes and ecological dependence of specific organisms. The restoration of riverine conditions can result in increased dissolved oxygen, particularly where hypoxia or anoxia occurs within an impoundment. The removal of a dam and elimination of conditions resulting in low dissolved oxygen can directly improve water quality and aquatic communities downstream of a dam, particularly if dam operations have resulted in the release of poor quality water.

The duration of water quality impacts resulting from the reversion of lacustrine to riverine conditions will vary. Chemical processes associated with lacustrine conditions may no longer occur following dewatering of an impoundment. Increased turbidity resulting from the mobilization of impounded detritus and sediments will be dependent on the quantity of available material, and will likely diminish over time.

3.2.2 Vegetation

Low head dam removal can affect both aquatic and terrestrial vegetation. Potential affects can largely be correlated with changes in surface water and groundwater hydrology, particularly changes resulting from the loss of the hydraulic backwater following dam removal and exposure of previously inundated areas. In general, low head dam removal can result in increased habitat for terrestrial vegetation through the exposure of sediments within the former impoundment. The extent and type of terrestrial vegetation colonization and succession will depend on factors including hydrology, sediment composition, and the topography of exposed areas. Changes in hydrology can result in succession of palustrine forested and shrub/shrub wetland habitat to upland habitat. The extent of aquatic vegetation will typically decrease following dam removal due to decreased water surface elevations and, therefore, a decreased area of inundation. Depending upon flow characteristics, such as velocity and depth, restoration of riverine (i.e., lotic) habitat in previously backwatered areas typified by lacustrine habitat may occur following dam removal.

Changes in surface water and groundwater hydrology may affect the type and extent of terrestrial vegetation following dam removal. Palustrine habitat may develop in areas experiencing temporary (i.e., annual) inundation following dam removal, with the establishment of forested wetlands and/or persistent emergent wetlands. This condition can foster revegetation by plant species requiring regular inundation for regeneration, such as cottonwoods (*Populus sp.*). Persistent and non-persistent emergent wetland habitat may form in areas that experience temporary inundation and have hydric soils. Factors affecting the duration and degree of saturation include soil composition and groundwater recharge. Low permeability soils combined with persistent groundwater discharge will typically result in wet conditions favorable to the formation of emergent wetland habitat, while more permeable soils may foster the growth of forested wetlands. A typical example of the latter condition is the establishment of cottonwoods on gravel bars throughout Rocky Mountains riverine systems.

The topography of exposed areas will affect the extent of specific terrestrial vegetation habitats, with flatter areas providing increased opportunity for the formation of relatively homogeneous habitats. Such a condition may occur where sediment deposition has been relatively uniform upstream of a dam. The segregation of deposited sediments may also affect terrestrial revegetation, as coarser materials are more likely to aggrade in the upper reach of an impoundment. Consideration should be given to the likelihood of erosion and redistribution of soils and sediments following dam removal, however, when evaluating terrestrial and aquatic revegetation of sedimented material.

The normal succession of terrestrial revegetation is the growth of herbaceous vegetation with subsequent colonization by shrubs and trees. Succession should be considered following dam removal, particularly where foliar coverage is desirable or vegetation is considered for stabilizing exposed sediments. Although viable natural seed stocks may be present in exposed materials or from existing adjacent vegetation stocks, planting of herbaceous seed and appropriate shrub and trees stock may be advantageous. The application of herbaceous seed and installation of plant stock represents a common approach to stabilizing exposed sediments and are typically components of bioengineering-based stabilization schemes.

The effects of dam removal on aquatic vegetation may include the loss of areas suitable for specific habitat types. Changes in habitat within the formally inundated area may include the alteration or loss of lacustrine, palustrine, or riverine habitats and the restoration of riverine habitat. The extents and types of changes will be highly site specific, and dependent on factors including the geometry of the formally impounded area, post-dam removal hydrology, and substrate composition. In general, existing littoral habitat may be reduced or eliminated following the restoration of riverine conditions.

The control of invasive plants should be considered during planning for dam removal and may be a regulatory requirement for mitigation projects. A practical first step towards controlling colonization by terrestrial invasive plants in exposed areas is to apply herbaceous seed and eradicate adjacent invasive plant stock. Ongoing invasive plant control efforts may be required following initial work. Aquatic vegetation can be planted in inundated area as a means to inhibit colonization by invasive aquatic species, but can be problematic due to possible supply of parent material from stocks upstream of the project area.

3.3 SOCIAL IMPACTS

Dam removal can have different social impacts, both beneficial and adverse. While the ecological impacts of dam removal can be felt far upstream and downstream, the social impacts can range even further. The most directly affected people are often those in the community where the dam is located, including above or below the dam. A much broader community may have a stake in the resources and recreational opportunities associated with the river. This community may be regional, national, or even international (American Rivers and Trout Unlimited, 2002).

Dam removal may have the social benefits of removing known safety hazards and eliminating the safety and liability costs are associated with dam failure, personal injury on or near the structure, or drowning. Dam removal may also lead to free-flowing rivers and provide new recreational and tourism opportunities, such as canoeing, swimming, and fishing. However, recreational opportunities related to the dam impounded may also be lost. For instance, anglers who prefer largemouth bass, sunfish, and other deeper-water species may also lose opportunities with dam removal.

Since most dams that are under consideration for removal were constructed many years ago, they often have historical and cultural value to the local community. Communities that consider a dam to a tangible piece of their history or civic identity may feel a loss with dam removal.

Removing a dam will bring aesthetic value related to the free-flowing river. The exposed land of the original impoundment area can also be transformed to a park and additional aesthetic value can be added. However, removing a dam will result in the loss of the aesthetic value of the impoundment.

Community members that have riverfront property often express the concern that the loss of a dam and its impoundment will automatically reduce their property values. In truth, there is very little factual information available on this issue to point either way. A study done on this issue over a ten-year period following a removal in Wisconsin shows that property values stayed the same following the removal, although there was a slight decline in property values of homes located several blocks from the impoundment because these residents lost their view. Dam removal may create upland for owners who abut the impoundment area, and the exposure of this land will have economic ramifications as well.

3.4 Economic Impacts

The removal of a dam can have a range of economic costs and benefits. The extent of these costs and benefits are highly site specific. Many factors will influence the economic impact of a particular dam's removal. Decision-makers need to assess the operational costs and benefits of a dam. Long-term costs of operating and maintaining a dam and an impoundment (e.g., dredging, weed harvesting) should be compared to the one-time cost of removing the dam and the associated restoration activities.

Removing a dam that provides a viable service, such as hydropower production, water storage, flood control or recreational uses may require replacement of that service, or may make dam removal infeasible. Dam removal can provide for new service opportunities, including improved water quality for water supply needs, river-based recreation, and revitalization of riverfront properties.

Liability associated with public safety hazards and attractive nuisance should be considered when evaluating dam removal. These factors should be considered, particularly those relating to financial and legal responsibilities for risk reduction. Dam removal may also entail liability risk, and proper dam removal planning is critical to prevent or minimize impacts to infrastructure, riverfront properties and the environment.

The environmental effects of dams and dam removal should also be considered in the context of economic impacts. For instance, dam removal may enable improvements to water quality that alleviate the need for costly upgrades to water and wastewater treatment facilities. Programs that focus on stocking of certain fish species may no longer be necessary if natural recruitment is enhanced through dam removal. Maintaining a dam may serve to prevent contaminated sediment from being transported downstream. Likewise, retaining a dam may prevent exotic, diseased or toxic species from accessing upstream aquatic habitats.

Table 3.1 Summary of dam removal impacts.
These impacts may occur on short-, intermediate-, and long-term time scales. The degree to which each potential impact may have an effect is site-specific and therefore should be considered given the unique parameters of a particular project site.

Category of Impact		**Potential Type of Impact**
Physical and Chemical Impacts	Riverine Hydrology	• Changes to downstream hydrologic regime • Changes in groundwater recharge
	River Morphology	• Changes to stream channel hydrogeometry • Changes to stream slope • Changes to retention time of water and sediment • Streambed degradation upstream of impoundment • Relocation of original channel in former impoundment • Change in channel type upstream of impoundment • Streambed aggradation downstream of dam • Re-exposure of natural physical characteristics (e.g., ledge, boulders) • Exposure of manmade physical characteristics (e.g., pipeline) • Transport and deposition of woody debris
	Flooding	• Change in flood elevations upstream of dam • Change in flood elevations downstream of dam
	Sediment Transport	• Change in sediment transport capacity • Change in suspended sediment load • Change in transport of bed-load material • Change in rate and location of sediment deposition • Redistribution and relocation of contaminants • Change in bioavailability of contaminants
	Erosion	• Rate of stream bank sloughing/bank failure • Amount of stream bank sloughing/bank failure • Location of stream bank sloughing/bank failure
	Wetlands	• Surface water and groundwater hydrology • Change in duration, frequency and timing of inundation • Change in location and extent of hydric soils • Change in wetland type(s)

Category of Impact		**Potential Type of Impact**
		• Change in wetland extent • Change in wetland community(ies) • Change in wetland function(s)
	Water Quality	• Change in retention time for carbon and nutrients • Change in rates of biogeochemical reactions (e.g., plant uptake, nitrification, denitrification, anaerobic/aerobic sediment/water interface) • Change to water temperature, turbidity, alkalinity, dissolved oxygen, pH, nutrient loads, etc. upstream and downstream of the dam
Ecological Impacts	Aquatic Habitats	• Change from lentic to lotic conditions • Altered hydrology may affect aquatic habitats and organisms • Altered morphology may affect aquatic habitats and organisms • Altered water quality may affect aquatic habitats and organisms • Altered sediment transport and deposition may affect aquatic habitats and organism • Diurnal and seasonal affects due to altered physical and chemical conditions of aquatic habitat. • Reconnection of stream segments may affect fish movement and fecundity (for both migratory and resident species) • Alterations may affect various life stages of aquatic organisms.
	Vegetation	• Change in areal extent of aquatic and terrestrial vegetative communities upstream of dam • Change in type of aquatic and terrestrial vegetative communities upstream of dam • Change in type of aquatic and terrestrial vegetative communities downstream of dam • Succession of vegetative communities due to hydrologic changes • Alterations in the location of erosion and deposition of sediment may affect vegetative communities • Change in viability of nonnative and/or invasive species
Social Impacts		• Changed aesthetics • Effects to historic and cultural resources • Change in recreational opportunities (lake or pond-based to river-based)

Category of Impact		**Potential Type of Impact**
		• Change in property values • Change in land ownership (e.g., exposed land may revert to riparian landowners) • Conflict due to local attitudes toward the project • Change in social classes residing in or visiting area (e.g., panfishing replaced by trout fishing)
Economic Impacts		• Cost of dam removal (e.g., planning, permitting, construction) • Cost of stream restoration • Cost of infrastructure retrofits (e.g., extending storm sewer outfalls) • Elimination of recurring dam repair costs • Elimination of long-term operating and maintenance costs for dam • Elimination of impoundment management costs (e.g., dredging, weed harvesting) • Elimination of liability risks associated with dam • Cost of replacing dam's benefits (e.g., flood control, hydropower, fire suppression, irrigation, recreation) • Revenue due to new business opportunities (e.g., revitalized waterfront) • Revenue due to new recreational opportunities • Change in property values • Change in cost of water and wastewater treatment

4 COSTS AND BENEFITS ASSOCIATED WITH DAM REMOVALS

Removing dams can have distinct economic benefits such as cost savings over repairing and maintaining the dam, potential for community riverfront revitalization, increased income to local fishing and boating industries, and decreased costs related to water quality improvements and fisheries management. However, these dam removal benefits may come at a price as well, due to the loss of economic benefits from the dam. To determine the economic benefits of a dam removal, we have to consider different costs and benefits including the costs and benefits to the dam owner, the societal costs and benefits, the recreational costs and benefits, and the environmental costs and benefits.

4.1 DIRECT COST COMPARISON: REMOVAL VERSUS REPAIR

Dams are removed for different reasons, but many low-head or small dam removals are triggered by safety concerns. Once a dam no longer conforms to safety standards, a decision has to be made whether to repair or remove the dam by comparing the relative costs and benefits of the two choices.

The direct costs for an actual dam, whether they are repair or removal costs, will be site-specific. The amount of repair needed is proportional to the size and the severity of deterioration the dam has experienced over its life. The goal of any repair activity is to make the appropriate repairs to comply with safety standards. These activities may include repairing the part of the dam that spans the river, fixing abutments on the banks, and many other items. A cost that must commonly be considered when repairing a dam is a fish-passage structure. Although not directly considered in the repair cost, operation and maintenance are important considerations when making a decision. The other associated costs with repairing a dam are the liability costs.

The removal of a dam includes the removal of the dam itself and its appurtenant structures such as concrete wings that reach upstream, spillways, powerhouses, and raceways. Other possible costs are associated with sediment management, grading, vegetation, channel work, etc.

In most cases, the cost of removing a small dam is significantly less than the cost of repairing it (Trout Unlimited, 2001). Born et al. (1998) found that in Wisconsin, small dam removals typically cost \$100,000 to \$1 million, which was 3 times less than the estimated cost of repair. In several cases, the repair cost estimates were more than 10 times removal costs.

Table 4.1 lists the estimated repair costs and actual removal costs for a number of dams. Regression analysis (see Figure 4.1) shows that the average repair cost is about two times the average removal cost, which is in general agreement with the conclusion of Born et al. (1998).

As Trout Unlimited (2001) noted, project costs can vary significantly and should be carefully evaluated when each new case arises. For example, for Somerset Dam on the Apple River in WI, the actual removal cost is higher than the estimated repair cost to make the dam safe.

Table 4.1 List of dams with estimated repair costs and actual removal costs (Modified from Trout Unlimited, 2001).

State	Dam	River	Removal Date	Estimated Repair Cost in U.S. $	Actual Removal Cost in U.S. $
CA	Lake Christopher Dam	Cold Creek	1994	160,000 to 180,000	80,000
ME	Columbia Falls Dam	Pleasant River	1998	80,000	25,000
ME	Grist Mill Dam	Souadabscook Stream	1998	150,000	56,000
MN	Sandstone Dam	Kettle River	1995	1,000,000	208,000
NH	McGoldrick Dam	Ashuelot River	2001	100,000 to 150,000	54,000
NM	Two-Mile Dam	Sante Fe River	1994	4,100,000	3,200,000
NY	Gray Reservoir Dam	Black River	2002	1,500,000	300,000
VT	Newport 11 Dam	Clyde River	1996	783,000	550,000
WA	Rat Lake Dam	Whitestone Creek	1989	261,000	52,000
WI	Greenwood Dam	Black River	1994	500,000	80,000
WI	Young America Dam	Milwaukee River	1994	313,000	74,000
WI	Lemonweir Dam	Lemonweir River	1992	700,000	190,000
WI	Somerset Dam	Apple River	1965	30,000	75,000
WI	Hayman Falls Dam	Embarrass River	1995	455,000 to 800,000	180,000
WI	Manitowoc Rapids Dam	Manitowoc River	1984	30,000 to 250,000	45,000
WI	Waterworks Dam	Baraboo River	1998	694,600 to 1,091,500	213,770
WI	Willow Falls Dam	Willow River	1992	5,000,000 to 6,000,000	450,000
WI	Mounds Dam	Willow River	1998	3,300,000 to 6,000,000	500,000
WI	Fulton Dam	Yahara River	1993	900,000 to 1,000,000	375,000
WI	Ontario Dam	Kickapoo River	1992	100,000 to 200,000	47,000
WI	Prairie Dells Dam	Prairie River	1991	725,000	200,000
WI	Shopiere Dam	Turtle Creek	2000	251,000	100,000
WI	Deerskin Dam	Deerskin River	2001	400,000	15,000
WI	Franklin Dam	Sheboygan River	2001	350,000 to 400,000	190,000
WI	Linen Mill Dam	Baraboo River	2001	100,000 to 150,000	58,000
WI	Ball Park Dam	Maunesha River	2004	750,000	125,000

However, there are many other costs associated with dam repair or dam removal other than just the direct costs. To repair a dam means to keep it, and the true costs should also include the following expenses (Trout Unlimited, 2001):

- General operation and maintenance;
- Future repairs (often multiple over time);
- Maintaining the impoundment and its water quality;
- Liability costs; and
- Environmental costs.

Similarly, in addition to the costs for removing structures, the total dam removal costs should also include the following expenses (Trout Unlimited, 2001):

- Sediment management;
- Associated stream channel work;
- Ongoing restoration and monitoring;
- Replacing the dam's use(s).

These costs are discussed in the following sections.

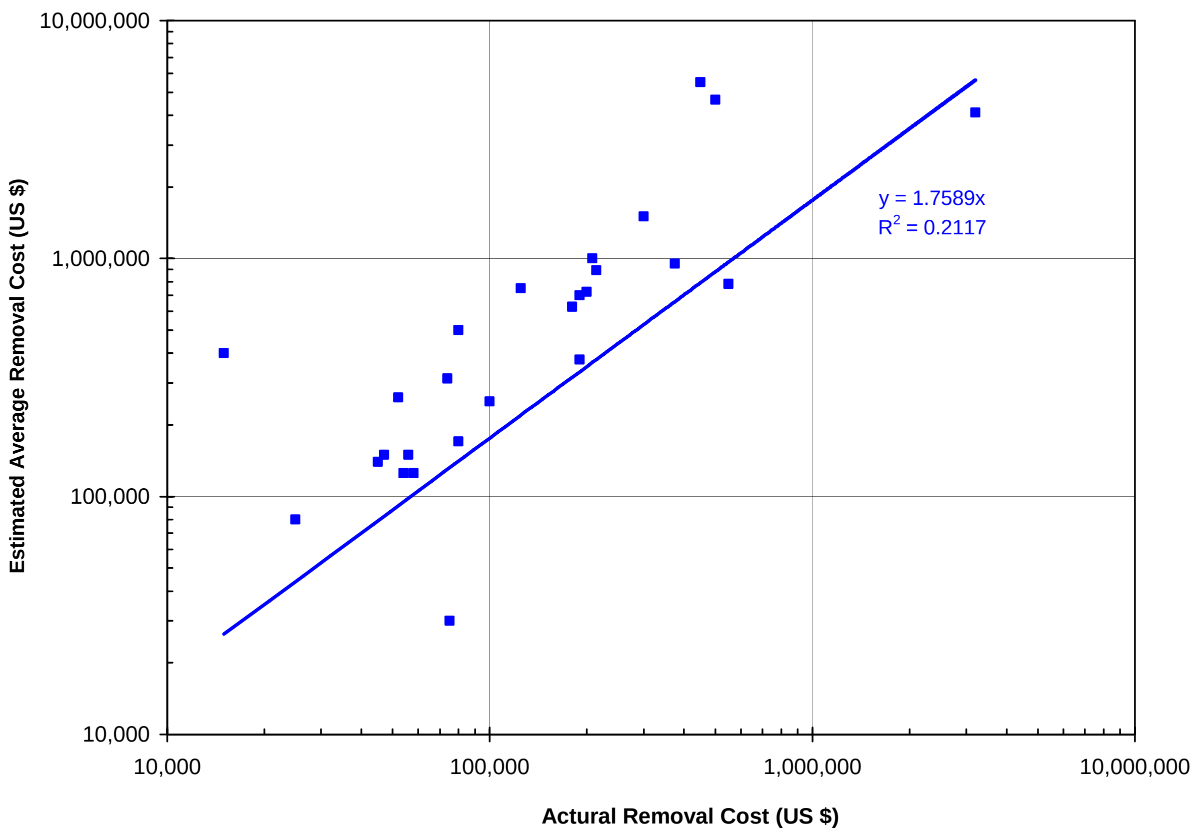


Figure 4.1 Estimated repair costs versus actual removal costs.

4.2 OPERATION AND MAINTENANCE COSTS

Operation and maintenance (O&M) are needed after a dam is repaired. The O&M costs vary greatly depending on the size and condition of the dam. For example, the O&M costs for the Ward Paper Mill Dam, Prairie River, WI is $20,000-$50,000 a year, while the O&M costs for the Waterworks Dam, Baraboo River, WI is about $203,900 a year (WRM, 2000). The O&M covers not only the dam itself but also the impoundment (e.g., dredging of the sediment). Dredging is expensive, with onetime costs ranging from $200,000 to $700,000 for a 30 to100-acre impoundment (Marshall, 1988). Moreover, dredging is not a permanent solution because it does not remove the source of the material filling the impoundment. Consequently, an impoundment that needs to be dredged will likely have to be dredged again.

It should be noted that dam repair may not be a one-time event. To keep a dam operational for its intended uses, future repairs may be required. For example, the 30-foot high Little Falls Dam on Willow River, WI was built in the 1920s and was repaired in 1980, 1990, 1991, and 1996, with repair costs greater than $250,000 each year (Trout Unlimited, 2001). Despite examples like Little Falls Dam, well designed dams are robust structures. Numerous examples exist of dams that perform satisfactorily year after year with only routine maintenance.

Dam removal may eliminate the O&M costs for the dam itself, but operating and maintaining the land of the old impoundment will cost money. The following lists the O&M costs for three parks located on former impoundment beds (WRM, 2000):

- Woolen Mills Dam, Milwaukee River, WI: About $3000 per year
- Colfax Dam, Eighteen Mile Creek, WI: Maximum of $500 per year
- North Avenue Dam, Milwaukee River, WI: Average of $3,000

The costs for operating and maintaining the parks on former impoundment beds are generally much lower than those for operating and maintaining the repaired dams. The operation and maintenance costs of active dams are usually justified based on the service or benefits provided by the structure.

4.3 SAFETY AND LIABILITY COSTS

Repairing a dam will reduce but not eliminate the safety and liability costs. The safety and liability costs are associated with dam failure, personal injury on or near the structure, or drowning. Even small dams can pose significant risks. In 1999, the Federal Emergency Management Agency (FEMA) reported to Congress: “Failure of even a small dam releases sufficient water energy to cause great loss of life, personal injury, and property damage.” A sudden, massive release of water and sediment can also devastate aquatic habitat (Trout Unlimited, 2001).

Dam owners will almost certainly need some type of insurance to protect against the liabilities at the dam site and downstream from the dam. The combined cost of insuring against dam failures and accidents can result in high liability protection costs.

The Waterworks Dam, Baraboo River, WI includes the following safety and liability costs (WRM, 2000):

- Dam Failure Analysis: $16,500
- Emergency Action Plan: $5,500
- Liability insurance: $5,000 per year

Removing the dam will eliminate almost all safety and liability costs associated with the dam itself. However, removing a dam may result in new liabilities such as the release of unknown toxic sediments downstream. The liability can be decreased greatly by rigorous pre-removal investigations of both the impoundment and the previous land-use activities around the impoundment. If the dam is used for flood control purposes, removal may have a negative impact downstream.

4.4 Economic Growth

Since impoundments created by dams and free-flowing rivers provide different economic opportunities, dam removal and dam repair can have different impacts on economic growth. Members of the dam community may favor or oppose dam removal on the basis of the possible changes in economic opportunities.

Community businesses, particularly those at or near large impoundments, may rely directly on the impoundment for income. Many of these are recreation-based businesses, such as fishing and boating businesses. Other nearby businesses, such as restaurants and lodges, may indirectly rely on people who come to use the impoundment. Repairing the dam and restoring the impoundment will promote the existing businesses that have been affected by the deteriorating condition of the dam.

Although dam removal eliminates the economic opportunities related to the impoundment, it will bring different opportunities to stimulate economic growth in communities close to the free-flowing rivers. Free-flowing rivers provide many recreational opportunities, such as canoeing, swimming, and fishing. It is noted that the character of a fishery may change after the dam is removed. The removal of a dam tends to cool the water in the river and may change a warm-water fishery to a cool- or cold-water fishery. The fisheries in rivers may support warm-water fish as well as cool- and cold-water species, depending on the temperature of the river. Some rivers may support all of these types of fisheries along their lengths through the seasonal migration of fish. Because the removal of a dam may change the character of the fishery, it may change the types and abundance of sport fish in the river.

The recreational opportunities of free-flowing rivers provide opportunities for recreation-based businesses. Any existing river-based recreation business will probably enjoy increased trade.

The change of the water resource to a river may also attract new river recreation businesses to the area. Also, recreation businesses that rely on the impoundment can change their business strategy to take advantage of the new recreation opportunities afforded by the river. For example, a boat rental business could change to a canoe rental and shuttle business. Also, a community can use dam removal to spur economic development along the river where it flows through town. Examples of this strategy would include creating a river walk or a waterfront business district (WRM, 2000).

Removing a dam can expose relatively large amounts of previously flooded land. If the exposed lands are publicly owned, they may be dedicated as new open spaces adjacent to the river, such as parks, nature walks, bird watching areas, or other natural areas. For example, more than 37,000 people a year now use a park in downtown West Bend, WI that was developed in the area formerly impounded by the Woolen Mills Dam. The impoundment had previously experienced very little activity. Increased use of the area translates into more activity and exposure for nearby businesses. A local business executive also noted that the improved quality of life associated with the new recreational opportunities and improved aesthetics helps his business to recruit and keep employees (Trout Unlimited, 2001).

Removing dams may also improve a system-wide river habitat and promote economic growth. For example, at a cost of under $1 million, 17 dams have been removed from the Conestoga River in PA since 1996. The removals have allowed the return of American shad to the river, which had been absent for more than 80 years. The rejuvenated fishery is expected to generate $2–3 million a year for local economies (Trout Unlimited, 2001).

4.5 ECOLOGICAL BENEFITS

Repairing dams will essentially provide no ecological changes. Impoundments behind dams often have poor water quality and may not have the quantity and diversity of aquatic species often found in a free-flowing river.

Removing dams, however, will bring different ecological benefits, including restoring free-flowing rivers, enabling unobstructed fish passage, and improving water quality (Scruton et al., 1998; Bednarek, 2001). Bednarek (2001) reviewed the long-term and short-term ecological impacts of dam removal based on 16 dams. She concluded that biotic diversity could increase by removing the dams and that the increased sediment load was a short-term effect. Scruton et al. (1998) showed an 18-fold increase in biomass of juvenile salmon and trout, a result of a 62% habitat increase after removing some dams.

4.6 SOCIAL BENEFITS

Ecological, engineering, and economic factors drive the decision to remove or repair a dam, but public acceptance of change may be the ultimate determining factor (Johnson and Graber, 2002). Furthermore, all the economic issues and virtually all of the biological or technical issues affect humans, and therefore can translate into social issues. Thus, it is important to consider the social perspectives on dam repair and dam removal.

4.6.1 Property Values

Repairing a dam or removing a dam will have different benefits to property values. Repairing a dam will essentially not change the surrounding property values. However, repairing a dam may also mean that the community has to pay for permanent and continuous maintenance of the dam throughout the years to come. These payments may come in the form of higher property taxes that may make property in the area less attractive.

It has been generally observed that property adjacent to a lake or river is more valuable than property farther away from the water. Therefore, if a dam is removed, it is possible that certain properties that were on the impoundment would no longer be near the water and might decline in value as a result. On the other hand, if a stagnant, silted impoundment that holds only a few inches of water is converted into a free-flowing river by removing the dam, nearby properties may well increase in value. Of course, many other factors determine property values, so full investigation is critical to determine the impact of dam removal on property values.

4.6.2 Exposed Land

Repairing dams will essentially provide no exposed land and sometimes may even reduce the exposed land by raising the impounded water level.

Removing a dam will provide exposed land, which can be used as new public space such as parks, nature walks, bird watching areas, or other natural areas. For example, more than 37,000 people a year now use a park in downtown West Bend, WI that was built over the former impoundment of Woolen Mills Dam where there had previously been very little activity (Trout Unlimited, 2001).

4.6.3 Aesthetic Concerns

The aesthetics of a dam impoundment are those qualities that people might find beautiful or attractive. Repairing a dam will essentially keep the aesthetic value of the impoundment. However, because the dam repair may also include a development option, some new aesthetic value may be added to the impoundment development. For instance, after the repair of a dam, dredging the impoundment can increase its depth and improve the water clarity.

Removing a dam will bring aesthetic value related to the free-flowing river. The exposed land of the original impoundment area can also be transformed to a park and additional aesthetic value can be added.

4.7 CHALLENGES FOR ECONOMIC ANALYSIS OF DAM REMOVALS

Formal economic analysis can be very helpful in supporting the decision-making process for dam removal, in setting priorities, and in considering the interests of stakeholders and agencies.

Nevertheless, significant challenges remain for those who would use methods such as benefit-cost analysis for this purpose (Heinz Center, 2002).

Dam removal has a number of beneficial and adverse outcomes, some of which can be easily valued monetarily while others are highly uncertain and difficult or impossible to value.

For example, the cost of removing the structure and disposing the debris can be easily estimated. The evaluation of one category of dam removal outcomes—lost dam services—may be facilitated if there are usable data on some or all of these services in past years. However, the various environmental outcomes of dam removal may be difficult or impossible to evaluate economically. The removal of a dam usually has a profound effect on the stream and its riparian environment. Specifically, the stream flows freely again; there is no longer a distinction between upstream and downstream areas in the reach containing the dam site; land previously inundated is exposed and revegetated; slack water habitats and flat-water recreation areas may be lost; stream habitats may be expanded and reconnected; and some fish habitats are lost and others re-created. However, the restored habitats and biological communities will not necessarily be identical to those that were lost when the dam was constructed. Fish runs may or may not approximate those of historical record and may develop only after some time. Exposed land may revegetate with exotic trees or plants. An assessment of restored environmental functions and related economic benefits, therefore, requires a determination of what is likely to be created and how long it will take. However, predictions of many environmental outcomes are likely to be quite uncertain, as are the predictions of the times at which such outcomes will appear.

As part of an on-going research program at the Ohio State University on the economics of river restoration (Hitzhusen, 2003), Kruse (2005), based on contingent valuation (CV), attempted to create an interdisciplinary framework for estimating the economic benefits of dam removal. The framework was applied to the Ballville Dam located in Sandusky County, in northwest Ohio. A CV survey and several variants were developed to test several methodological considerations.

5 LEGAL AND REGULATORY REQUIREMENTS OF DAM REMOVAL PROJECTS

5.1 FEDERAL, STATE AND MUNICIPAL PERMITTING REQUIREMENTS

5.1.1 Federal Requirements

Permits. The U.S. Army Corps of Engineers (USACE) and the Federal Energy Regulatory Commission (FERC) are the federal entities with permitting and licensing authorities that most directly apply to dam removal actions.

CWA Section 404 Dredge and Fill Permit. The purpose of the CWA is to restore and maintain the physical, chemical, and biological integrity of the nation's waters. CWA Section 404 (33 U.S.C 1344) requires authorization from the USACE for the discharge of dredged or fill material into all waters of the United States, including wetlands. A Section 404 permit is required whether the work is permanent or temporary. There are several components of removing a dam that may require a Section 404 permit, including but not limited to temporary fills for access roadways, cofferdams, storage and work areas and temporary dewatering of dredged material prior to final disposal. Additional detail on the various types of Section 404 permits is found in Section 5.3.1.

Rivers and Harbors Act Permit. In conjunction with a Section 404 permit, the USACE will issue a Rivers and Harbors section 10 permit (33 U.S.C. 403). The USACE will issue the permit if there is no adverse impact on interstate navigability (Bowman, 2002).

FERC License Surrender Order or Non-power License Approval. If the dam to be removed is regulated by FERC, the dam owner will have to apply for surrender of the FERC license or issuance of a non-power license (16 U.S.C. 799, 808[f]). As part of issuing a license surrender or non-power license, FERC can impose conditions on how the dam is removed (Bowman, 2002).

Reviews and Consultations. In accordance with federal statute, federal agencies are subject to various reviews and consultations when permitting, licensing, approving or funding a proposed action. The following reviews and consultations are directly relevant to the removal of a dam.

National Environmental Policy Act (NEPA) review. The permitting, licensing, approval or funding of a project by any federal agency requires the agency or agencies to consider the project's potential to cause environmental and socioeconomic impacts, including direct and indirect impacts, beneficial and adverse impacts and potential cumulative impacts (42 U.S.C. 4321 et seq.). A NEPA document may already have been prepared as part of the permitting, licensing or funding process and, therefore, it may not be necessary to prepare a new NEPA document, or only a supplemental document may be required.

Endangered Species Act consultation. If federally threatened or endangered species are present at or near the project site, the lead federal agency (e.g., USACE, FERC) may need to consult with the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS) regarding the impact of the dam's removal on these species. (16 U.S.C. 1531-1543) (Bowman, 2002).

Fish and Wildlife Coordination Act consultation. Federal agencies that construct, license or permit water resource development projects, including dam removals, are required to consult and coordinate with the USFWS and the applicable state fish and wildlife agency regarding impacts on fish and wildlife resources and measures to mitigate these impacts.

Magnuson-Stevens Act consultation. The lead federal agency may need to consult with the NMFS regarding the impact of the dam's removal on any fishery management plan developed by a regional fishery management council (16 U.S.C. 1855[b][2]). This consultation is carried out to ensure that the dam's removal will not adversely affect any essential fish habitat established in the fishery management plan. (Bowman, 2002)

National Historic Preservation Act consultation. Federal agencies permitting, licensing, approving, or funding a dam removal project are required to assess the impact of the proposed action on historic properties pursuant to Section 106 of the National Historic Preservation Act (16 U.S.C. 470[f]). The lead federal agency for the proposed dam removal must consult with the state historic preservation officer. The two entities must coordinate to (1) determine whether the project has the potential to impact resources of historic significance; (2) identify potentially historic resources and evaluate their historic significance; (3) assess adverse effects of the proposed project to historically significant resources; and (4) resolve adverse effects through avoidance, minimization and/or mitigation.

Wild and Scenic Rivers Act. The USACE must consult with the National Park Service (NPS) regarding any activity that occurs in a segment of a river within the National Wild and Scenic River System, or within 0.25 mile up or downstream of the main stem or tributaries of a designated segment, or that has the potential to alter flows within a designated segment. This condition applies to both designated Wild and Scenic Rivers and rivers officially designated by Congress as study rivers for possible inclusion while such rivers are in official study status. The USACE will consult with the NPS with regard to potential impacts of the proposed work on the resource values of the wild and scenic river.

Certifications. In order for the USACE to issue a Section 404 permit or for FERC to issue a license surrender or non-power license, the state must grant the following certifications.

CWA Section 401 Water Quality Certification. The state must grant water quality certification pursuant to Section 401 of the CWA (33 U.S.C. 1341). This certificate states that the proposed activity will not result in the violation of state water quality standards. As part of this certification, the state may issue conditions related to how the dam is removed (Bowman, 2002). Additional information on the Section 401 Water Quality Certification is found in Section 5.3.2.

Coastal Zone Management Act certification. If the project would take place in a coastal zone, the state must issue a certificate pursuant to the Coastal Zone Management Act (16 U.S.C. 1451 et seq.). This certification states that the proposed activity is consistent with the state's approved coastal zone management program. As part of this certification, the state may issue conditions related to how the dam is removed (Bowman, 2002).

5.1.2 State Requirements

State permit, approval and consultation requirements vary from state to state. The following are the most common requirements for dam removal projects.

Dam Safety Permit or Approval. The state may have regulations that require a permit or approval for any activity that will affect the construction and safety of a dam. Removal of a dam may require such a permit or approval from the state dam safety office.

Floodplain Map Amendments. Most states require review of any activity that may change the 100-year floodplain. The applicant may be required to determine the new elevation for the 100-year floodplain once the dam is removed. This information would be provided to FEMA to update the existing floodplain maps (Bowman, 2002).

Historic Preservation Review. The state may have a state historic preservation act similar to the National Historic Preservation Act. The state act may require that before any state permit, approval or funding is issued to a project the potential impacts to historic and cultural resources must be reviewed and approved by the state historic preservation officer. This may involve additional investigations before the project can be approved, and can usually be done in conjunction with the federal historic preservation review.

Impoundment Drawdown Permit. The state may require operators of dams to obtain a permit or approval to conduct the drawdown of an impoundment. This may be a requirement in addition to the dam safety permit or approval mentioned above. It is often state fish and wildlife agencies that require an impoundment drawdown permit or approval.

Outstanding Resource Review. The state may have statutes or regulations requiring review and approval for activities to be conducted on or near specific rivers or wetlands that have been determined to be of outstanding natural and cultural resource value.

Shoreland Management Review. The state may restrict or prohibit certain activities on lands within a protected buffer area around public water bodies and require that other activities obtain a permit.

Species of Concern Consultation. The state may require consultation with resource agency personnel regarding potential for impacts to rare, threatened or endangered species and habitats.

State Environmental Policy Act Review. The state may have an environmental impact review statute similar to NEPA. A proposed dam removal action may trigger the requirement for consideration of environmental and socioeconomic impacts by the state agency or agencies that are permitting, approving, licensing or funding the proposed project. Appropriate coordination between the relevant federal and state agencies can meet these requirements in a single document or decision-making process.

Waterways Development Permits. The state may have laws that regulate the development of waterways for hydropower, navigation and other purposes. Dam removal may require such a permit (Bowman, 2002).

Wetlands Permit. The state may have a permit for dredge and fill activities in wetlands similar to the CWA Section 404 permit. Wetlands may include rivers, streams and tidal buffer zones. Projects conducted in the state's wetland jurisdictional areas may require avoidance, minimization and/or mitigation of impacts.

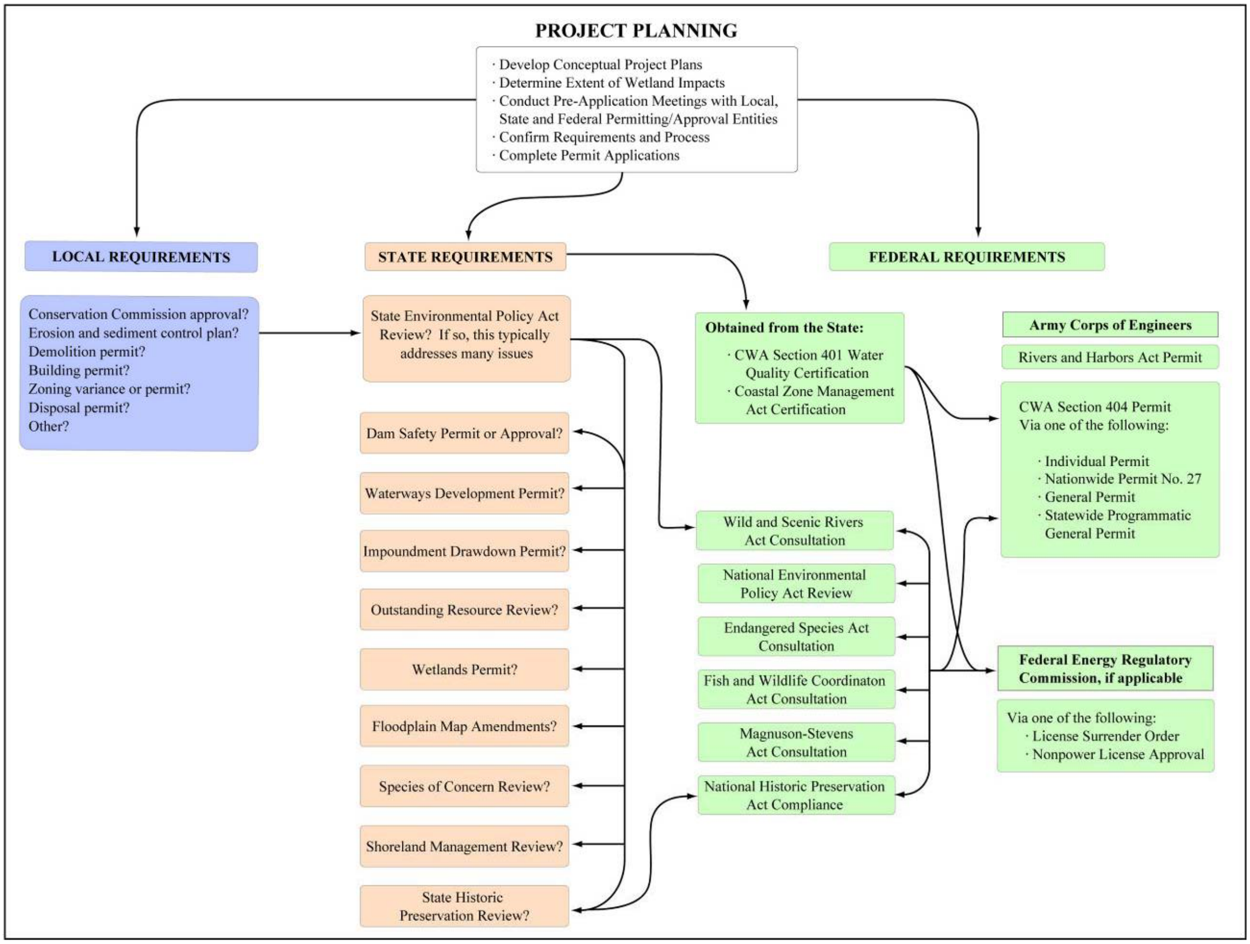
5.1.3 County or Municipal Requirements

Additional permits, approvals, and notifications may be required by county or municipal governments. Examples of requirements include approval from a Conservation Commission approval, erosion and sediment control plans, a demolition permit, a building permit, a zoning variance or permit, and a disposal permit.

5.2 PERMITTING PROCESS

The following pages illustrate a generalized version of the permitting process for dam removal projects. The specific permitting process will vary depending upon project specifics, location and jurisdiction.

Conceptual Permitting Flow Chart



5.3 CWA 404 PERMIT AND 401 CERTIFICATION FOR DAM REMOVAL

5.3.1 How is Section 404 considered for dam removal?

A CWA Section 404 permit has been required for the great majority of dam removal projects conducted in the United States. There are four methods of meeting the CWA Section 404 permit requirement. The USACE District determines which type of permit is applicable for the project.

> **Individual Permits:** Individual Permits are typically required where the level of activities associated with the dam removal project exceeds work thresholds authorized by General Permits or Nationwide Permits. Individual Permits require the applicant to submit a permit application to the USACE directly. The USACE will post public notice for both agency and public review of the project activities (USACE, 2003b).
>
> **Nationwide Permits:** Nationwide Permits (NWPs) are issued by the Chief of Engineers at USACE Headquarters through publication in the Federal Register (33 C.F.R. 330). NWPs are a type of general permit designed to authorize certain activities that have minimal impact on the aquatic environment. Activities that result in more than minimal adverse effects on the aquatic environmental both individually and cumulatively cannot be authorized by NWPs. Individual review of each project authorized by an NWP will not normally occur. Potential adverse impacts and compliance with applicable laws are controlled by the terms and conditions of each NWP which may require notification, coordination and authorization of other federal, state and local government entities.
>
> NWP No. 27 "Stream and Wetland Restoration Activities" has been applied to dam removal projects. This NWP addresses activities in waters of the United States associated with the restoration and enhancement of degraded tidal and non-tidal wetlands and riparian areas, the creation of tidal and non-tidal wetlands and riparian areas, and the restoration and enhancement of non-tidal streams and non-tidal open water areas.
>
> Compensatory mitigation is not required for activities authorized by NWP 27, provided the authorized work results in a net increase in aquatic resource functions and values in the project area. NWP 27 can be used to authorize compensatory mitigation projects, including mitigation banks, provided the applicant notifies the USACE District Engineer accordingly, and the project includes compensatory mitigation for impacts to waters of the U.S. that are caused by the authorized work.
>
> **Regional General Permits:** Regional General Permits (GPs) are developed and issued by the applicable USACE District or Division on a regional basis. Regional GPs typically authorize commonly occurring activities that are specific to the District/Region and that are not addressed by existing NWPs. Certain Regional GPs require notification prior to starting work. As with NWPs, Regional GP activities typically cause minimal impact on the aquatic environment. Where authorized work exceeds the minimal impact

threshold, mitigation may be necessary to lessen effects on aquatic resources (USACE, 2003b).

Statewide Programmatic General Permits: USACE District or Division offices have also issued Statewide Programmatic General Permits (SPGPs) in states with comprehensive wetland protection programs. These SPGPs allow applicants to conduct work that meets the requirements for issuance of a relevant state permit or permits. This programmatic approach reduces delays and paperwork for applicants and allows the USACE to devote its resources to the most significant cases while maintaining the environmental safeguards of the CWA. States that have utilized SPGPs for dam removal activities include MA, NH, PA, and WI.

Through a Memorandum of Agreement (MOA), the USEPA and the Department of the Army (1990) have articulated policy and procedure to be used in determining the type and level of mitigation necessary to comply with the CWA Section 404(b)(1) Guidelines ("Guidelines") which states that "… no discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken which will minimize potential adverse impacts of the discharge on the aquatic ecosystem."

In the MOA, and pursuant to their responsibility under Section 404, the USACE has adopted the goal of "no overall net loss to wetlands." The MOA states that special recognition of wetlands resources does not diminish the value of other waters of the U.S. and that all waters, such as streams, rivers, lakes, etc. will be accorded the full measure of protection under the Guidelines, including requirements for appropriate and practicable mitigation. The Guidelines identify a number of "special aquatic sites," including riffle pool complexes, which require a higher level of regulatory review and protection.

In accordance with the Guidelines and the policy of no net loss to wetlands, the USACE reviews a proposed dam removal project in the following sequence. First, the USACE will make a determination of whether potential impacts have been avoided to the maximum extent practicable. Second, the remaining unavoidable impacts will be minimized to the extent appropriate and practicable. Third, compensatory mitigation will be required for unavoidable adverse impacts to aquatic resource values. The MOA states that it may be appropriate to deviate from the sequence if the USEPA or the USACE agree that the proposed discharge can reasonably be expected to result in environmental gain or insignificant losses.

In some cases, dam removal will result in a net loss of wetlands. To obtain a permit, the USACE will have to find that the benefits of dam removal outweigh the loss of wetlands, or that the loss of wetlands is mitigated by the restoration of wetlands as a result of the dam removal. Otherwise, the applicant is likely to be required to mitigate for the loss of wetlands through the restoration, creation or enhancement of wetlands elsewhere.

5.3.2 How is Section 401 considered for dam removal?

When the USACE District determines that a CWA Section 404 permit is required to remove a dam, a 401Water Quality Certification is also required from the respective State. All methods of meeting CWA Section 404 requirements also require a 401 Water Quality Certification from the respective state.

Likewise, when FERC determines that a License Surrender Order or Non-power License Approval is required to remove a dam, a 401 Water Quality Certification is also required from the respective state. This state certification states that the removal of the dam will not result in the violation of state water quality standards. As part of this certification, the state may issue conditions related to how the dam is removed.

If an Individual 404 Permit is required, an Individual 401 Water Quality Certification is necessary. For Nationwide, Regional, or Statewide Programmatic GPs, the state has three options in issuing 401 Water Quality Certification, and they must do one of the following in order for the Section 404 permit to be utilized: (1) issue a matching General 401 Certification if one exists, (2) issue an Individual 401 Certification, or (3) waive the Individual 401 Certification.

5.4 OTHER LEGAL ISSUES

Dam removal may present additional legal issues that need to be addressed on a site- and state-specific basis. Clarifying ownership of lands that would be exposed as a result of dam removal requires deed research. This research may uncover additional rights and responsibilities associated with the dam and impoundment.

For instance, some riparian landowners may have an established right to guaranteed water surface elevations to ensure direct withdrawals or that water tables are appropriate for wells in the location of the impoundment. Landowners that do not have an established right to guaranteed water surface elevations may find that shallow wells are affected by the removal of a dam. The legal redress for such a situation varies by state.

Similarly, waterfront businesses that depend on predictable water surface elevations in the impoundment may be strongly impacted by a dam's removal. Certain types of water-dependent businesses, such as marinas, may no longer be capable of operating. Other waterfront businesses, such as restaurants with a docking facility, may experience a measurable decline in business.

As discussed by the Aspen Institute (2002), many dams have direct and/or indirect or incidental beneficiaries who would be, or perceive they would be, adversely affected by dam removal. Regulatory authorities need to heed legal contracts and follow fair guidelines in deciding whether and how to beneficiaries should be made whole. However, provided that legal obligations are met, it is unfair to force a dam owner to maintain a dam in perpetuity when the beneficiaries of the dam are not willing to assume the legal and financial responsibilities associated with dam ownership.

The Aspen Institute (2002) recommends that the rights of dam owners, legal beneficiaries, and incidental beneficiaries are clarified at the beginning of the dam removal decision-making process. In appropriate cases, alternatives to services or compensatory for lost services that a dam owner is legally required to provide (e.g., power or water supply) should be considered. Examples of services that a dam owner is typically not legally required to provide include contributing to a local tax base and maintaining property values around an impoundment.

5.5 MITIGATION CREDITS

Historically, impacts to stream systems such as filling, impoundment, and channelization have been compensated with wetland mitigation. To date, limited guidance has been provided to agency field staff in the appropriate considerations for mitigating impacts to streams (USEPA, 2002). It is increasingly recognized that wetland mitigation does not provide appropriate replacement of aquatic functions lost due to impacts to fluvial systems (USACE, 2003b). As a result, it is inappropriate to apply the same mitigation credit structures to stream mitigation as has been developed for wetland mitigation.

The development and approval of compensatory stream mitigation credits via dam removal should concentrate on identifying and replacing the functions proposed to be impacted and applying the same methodology (i.e., functional assessment) to site of the potential dam removal. A mitigation credit structure that adequately addresses short-term and long-term functional gains is of particular importance when dam removal is used to achieve mitigation.

In 2001, the National Academy of Sciences' National Research Council (NRC) published the report "Compensating for Wetlands Loss Under the Clean Water Act." While the report focuses on wetland mitigation rather than stream mitigation, it provides many observations that can be directly applied to stream mitigation via dam removal. For instance, the NRC writes that

> "Linking designs to ecological performance can be extremely difficult, because [river restoration] science and restoration … efforts are still developing and must be tailored to individual sites. Therefore, while site designs should reflect current mitigation science and emerging scientific understanding, the initial designs may not always result in the exact [fluvial] properties that were the original intent of the design. However, much can be accomplished within the limits of the current science. … In short, we can design sites with a high probability of becoming functional [river systems], but whether particular sites will always result in particular functional outcomes is less certain…. Permit conditions for legal compliance with the mitigation obligation should recognize this reality." (NRC, 2001)

It can be argued the state of science on river restoration via dam removal is even less developed than that for wetland restoration. Therefore, it is strongly recommended that applicants coordinate with relevant regulatory entities as early as possible in the dam removal planning and design process. This early coordination should not be limited to the agency requiring the mitigation to occur. The NRC (2001) recommends that a first obligation of the applicant should be to initiate the required compensatory mitigation project concurrent with the permitted activity with the goal of minimizing temporal loss of function. To achieve this goal, the applicant and regulators must work together to design the project appropriately and according to specified criteria included in the permit. The applicant would then construct by that design and coordinate any changes identified in the field as necessary to meet the performance criteria with the regulator (NRC, 2001).

The mitigation plan should concentrate on the project design factors that will ensure the restoration or implementation of ecological and hydrological processes appropriate to the project. The dam removal and subsequent river restoration activities should be designed in recognition of these factors. Consideration of societal values should emphasize functional benefits that dam removal can provide for issues such as water quality improvement, reduction of flooding, stream bank stabilization and reduced risk to the riparian environment (NRC, 2001).

5.5.1 Primary Criteria to Consider When Determining Mitigation Credit.

The guidance document "Determining Appropriate Compensatory Mitigation Credit for Dam Removal Projects" (USACE, 2004) provides an excellent foundation for the development of these criteria. Primary criteria are generally those directly accomplished or established during project construction (USACE, 2003b).

Water Quality. Dam removal may alleviate documented water quality impairments within the impoundment and downstream of the dam. Attainment of some water quality parameters (e.g., temperature) could be sufficiently demonstrated through short-term monitoring (i.e., immediate to three years after removal). However, long-term monitoring (i.e., 5 years or more) will be necessary to document attainment of other parameters (e.g., benthic deposits, hydrologic modification). Impairments associated with and/or exacerbated by the presence of dams include, but are not limited to:

- hydrologic modification impacting biological and aquatic community integrity;
- low dissolved oxygen;
- elevated temperatures;
- elevated turbidity;
- benthic deposits causing a detrimental impact to the benthic community;
- elevated nutrients (phosphorus and nitrogen);
- concentrations of toxic substances that are injurious to the environment; and/or persistent in harmful concentrations.

Additional water quality-related factors that could be taken into consideration include:

- listing of the water body on the state 303(d) list of impaired waters;
- known, repeated violations of water quality standards;
- special aquatic resource classification in segments upstream or downstream of the dam, including Outstanding National Resource Water, Outstanding Resource Water, Exceptional Resource Water, Essential Fish Habitat, or blue ribbon trout stream designation; and
- water supply protection.

Species and Habitats of Concern. Dam removal can benefit federally or state-listed rare, threatened or endangered aquatic and semi-aquatic species, and rare or exemplary habitats.

Benefits can be demonstrated through colonization of the restored river reach, including stream banks, the riparian zone, and restored floodplains. Credit could also be applied to demonstrably increased numbers or documented expansion of the range of distribution extending either upstream or downstream of the former dam site. It must be emphasized that the credit should not be solely limited to the longitudinal and lateral extent of the former impoundment. Riverine species move in both upstream and downstream directions. Focusing entirely on the former impounded reach removes the restoration activity from the larger riverine context. Similarly, credit should not be solely limited to benefits to the aquatic community. Semi-aquatic species (e.g., reptiles, amphibians, birds) may also benefit from dam removal.

Establishment of an appropriate aquatic and semi-aquatic community. Dam removal may provide restoration of a site-appropriate aquatic and semi-aquatic community. This criterion may be evaluated based upon demonstrated improvements during the monitoring period utilizing metrics such as the Index of Biotic Integrity and the Rapid Bioassessment Protocols (Barbour et al., 1999). Demonstrated restoration of appropriate stream community fish species, such as darters, may also receive mitigation credit.

Passage of Target Fish Species. Dam removal typically results in improved conditions for fish passage, both upstream and downstream. Mitigation credit structures should identify target fish species for restoration of movement. The definition of a fish species of interest should be both state- and site-specific and should not be limited to anadromous fish species. Documented benefits to other migratory and resident fish species of interest should also be considered eligible for mitigation credit, including recreational sport fish and host species for freshwater mussels, such as darters. Federal and state natural resource agencies should be consulted for development of state- and site-appropriate mitigation credit for restoration for fish passage and provide feedback on appropriate monitoring and success criteria.

Water Quantity. Low-head dams typically function as run-of-river facilities and therefore will have minimal effects on increasing the quantity of water available for downstream discharge absent specific operating rules. In the case where the operation of a run-of-river facility requires drawing down of the impoundment to augment downstream flows during periods of low water, diminished instream flows could result from dam removal. A potential mitigating factor is increased groundwater recharge to a channel reach following dam removal. This would result from the increased hydraulic gradient between groundwater to the lower channel water surface elevation following dam removal.

Floodplain Functions and Riparian Wetlands. While dam removal may result in increased flood attenuation functions through restoration of riparian wetlands and natural floodplain hydrology, the removal of a low head dam will typically result in no benefits to floodplain wetlands. Potential changes to floodplain functions are highly site-specific, and dependent on factors including channel and floodplain geometries, dam spillway capacity, and the condition of the adjacent floodplain (e.g., developed, undeveloped). Potential benefits to riparian wetlands are similarly site-specific and dependent on floodplain and channel geometries. Where a low head dam has inundated floodplain wetlands bounded by steep upland slopes affording limited areas for the formation of bounding riparian wetland, removal of a low head dam would result in the restoration of riparian wetlands.

Risk to the Environment. Dam removal may eliminate the risk posed to the environment by dam failure. Environmental risk associated with dam failure is increasingly considered by agencies that determine dam safety requirements at the state and federal levels. If the failure or inappropriate operation of a particular dam poses a significant risk to natural resources, the removal of that dam would result in a reduced anthropogenic risk to the environment. Environmental risk of dam failure may include the effects of a sudden, uncontrollable release of impounded water and other materials, such as sediment, that exceeds the downstream channel carrying capacities. This can result in long and short-term damage to channel stability, riparian habitat, spawning substrate, mussel beds, and other components of the river environment.

Long-term Protection and Responsibility of Restoration Site. Adequate protections must be obtained at the former dam site to insure that construction of a new dam will not occur. The extent of protections required for the restored riparian corridor may be limited to the former impoundment site, or an expanded area as necessary to protect the documented benefits that are provided mitigation credit. Long-term protections may be through conservation easements, deed restrictions or public ownership.

In addition to the requirement of long-term protection of the mitigation site, long-term responsibility for the site should be considered eligible for mitigation credit. An adaptive management approach is recommended for wetland mitigation projects (NRC, 2001). The inherent dynamic nature of rivers, in combination with the fundamental change in a river's ability to function naturally that is provided by dam removal, emphasizes the need for a long-term, adaptive approach to management. To this end, the NRC (2001) recommends that applicants transfer the long-term site management and maintenance responsibility, along with a cash endowment for these purposes, to a prescribed management authority (the characteristics for such an authority are discussed in their report).

5.5.2 Secondary Criteria to Consider When Determining Mitigation Credit

Riparian Buffers. Dam removal may provide the opportunity to reestablish riparian buffers through the drawdown of the impoundment and subsequent revegetation of the exposed lands. These buffers can provide important riparian habitat and enable water quality improvements through increases in wooded canopy and filtration of overland runoff. Favorable mitigation credit should be provided in cases where a pre-determined buffer width on one or both sides of the stream is to be revegetated either naturally or with plantings.

Social Value. Dam removal may provide benefits to human uses of stream environments. Consideration of these benefits should not be limited to water-based activities. In some places, the dewatering of an impoundment and exposure of "new land" presents the opportunity to create new community parks and other public spaces that provide public access to the river and riparian corridor. Social benefits of stream restoration via dam removal can include fishing, boating, trails, interpretive signage and other environmental education opportunities, and scientific research beyond that required by the mitigation project. Another social benefit dam removal can provide is the restoration of aesthetically valued natural features, such as riffles, rapids, and waterfalls. The USACE Wilmington District guidelines (2004) note that this criterion is intended to encourage dam removal applicants to incorporate the provision of these benefits in dam removal planning. These activities may help offset negative public perceptions associated with a specific dam's removal, if any.

Public Safety. Dam removal eliminates the public safety hazard(s) posed by the existence of the dam. This includes eliminating the potential of dam failure that, depending upon the dam, could result in loss of human life, damage to property and infrastructure such as roads, bridges, water and sewer lines, etc. The public safety benefit of dam removal may also include elimination of a hazard to recreational users, such as boaters, swimmers and anglers. Lastly, dam removal may eliminate an "attractive nuisance" that is of particular concern for children and others who fail to recognize the type of injury that could be sustained on the property.

Local Economic Benefit. Dam removal may provide benefits to communities through the elimination of their financial responsibility for maintaining and operating aging infrastructure that may no longer generates economic benefit but that 1) represents a legal liability, 2) represents a public safety hazard, and 3) contributes to water quality impairments that necessitate upgrades to other infrastructure, such as water treatment plants and wastewater treatment facilities. Mitigation credit may be appropriate for addressing these local economic issues through the removal of a dam, whether it is publicly or privately owned.

Sediment Regime. Dam removal may provide benefits through the properly designed and managed restoration of the river's sediment regime. These benefits may include beach replenishment, substrate to address downstream channel degradation, transport of woody debris for various riparian habitats and functions, and distribution of nutrients.

5.5.3 Agencies that have Received Mitigation Credits

The concept of obtaining credit for stream mitigation through the use of dam removal is a very new approach in compensatory mitigation. The only completed project that was identified through the survey conducted for this report is the removal of the St. John's Dam in Ohio.

5.6 MITIGATION CASE STUDY – ST. JOHN'S DAM, SANDUSKY RIVER, OHIO

St. John's Dam was located on the Sandusky River upstream of the City of Tiffin in Seneca County, OH, near the intersection of County Rd. 6 and Township Rd. 131. It was a 7.2-foot high and 150-foot long concrete dam, constructed during early 1900s for water supply. The estimated impoundment volume is 455 acre-feet.

The ODNR, Division of Water inspected the dam in 1999, and ordered the owner, Ohio American Water Co. (OAWC), to repair or destroy the dam because of safety issues. The OAWC had the dam evaluated and determined that it would cost $300,000 to make necessary repairs. In 2003, ODNR Division of Natural Areas and Preserves (DNAP), Scenic Rivers Section, approached OAWC and offered to pay for the removal of the structure through the Scenic Rivers License Plate Fund, conditional upon ODNR receiving ownership of the structure and adjacent land. OAWC agreed to turn St. John's Dam over to the ODNR DNAP so that the dam could be removed. ODNR then entered into an agreement with the OH DOT to have the dam removed. The OH DOT agreed to remove the dam and pay all removal costs as part of mitigating a highway project that was recently completed nearby. This dam removal project is now referred to as the St. John's Dam Pooled Stream Mitigation Area.

The St. John's Dam was partially breached in March, 2003 (see Figure 5.1). The deconstruction schedule originally stipulated the complete removal of the dam 1-2 weeks subsequent to the breach, but was postponed as a result of unusually high water levels in April 2003. Deconstruction was further postponed during the fish spawning season in late spring. In early summer of 2003, the elimination of the Civilian Conservation Corp due to state budget cuts put the project in jeopardy since this group was operating the heavy machinery for the removal. Substitution of a private contractor was too expensive, since the state had reduced the operating budget for the Scenic Rivers Program. In mid-summer, the state DOT offered financial assistance for fully removing the dam in exchange for mitigation credit for restoring the riparian zone. The dam was completely removed in November 2003 (see Figure 5.2). The total removal cost (including engineering, permitting, deconstruction, etc.) was $200,000, of which $79,000 was for dam deconstruction. The state funded the entire project.

Before the dam removal, a local landowner whose property is on the Sandusky State and Scenic River expressed concern with the breaching of St. John's Dam. He also objected to the use of public funds to cover the cost of removal. ODNR responded to his objections and proceeded with the project.

After the dam was removed, problems were encountered with sloughing of the banks near some homes. This problem was partially attributed to the fact that the dam was removed in a couple of hours, thereby creating high water levels downstream over the next couple of days. As a result, the banks became saturated with water and sloughing problems occurred. It is conceivable that had the dam been lowered and eventually removed over a couple of days, it might have lessened this problem. The OH DOT sent a Geotechnical Engineer to evaluate the sloughing problem that occurred at Locust Grove. After careful review, it was determined that the worst of the problems were over. The situation was compounded by the fact that the Locust Grove development was built primarily on fill material.

(a)

(b)

Figure 5.1 The St. John's Dam (a) before the breach in March 2003; and (b) after the breach in April 2003.

(a)

(b)

Figure 5.2 (a) The St. John's Dam during removal at 8:30am on November 17, 2003; and (b) The same site two hours after removal.

A CWA 404 permit was not required because the Buffalo District of the USACE determined the work did not involve a discharge of dredged or fill material into the river. The concrete debris was removed from the river to an upland location the same day it was demolished.

The successful removal of the dam eliminated a public safety hazards and provided different benefits including aesthetic enhancement, fish and wildlife habitat improvement, community revitalization, recreational improvement, and water quality improvement.

On June 29, 2004, staff from ODNR and the OH DOT canoed the eight-mile stretch of the former dam pool to evaluate stream morphology and the effects of the dam removal. Staff encountered five new riffle run complexes that had formed naturally under the new flow regime. These initial results are encouraging (ODNR, 2005).

A more comprehensive analysis of the effects of the dam removal project is being conducted over a five-year monitoring period by a research team including ODNR Divisions of Geological Survey, Natural Areas and Preserves, Water and Wildlife; Ohio State University; and Heidelberg College Water Quality Lab. As part of the mitigation agreement, a number of parameters will be monitored over the course of five years. ODNR will conduct Index Biotic Integrity, Invertebrate Community Index, and Qualitative Habitat Evaluation Index (QHEIs) at five existing OH (EPA) habitat and biological monitoring sites above the dam and below the dam. The frequency of monitoring will be twice a year over the next five years.

- OH DOT will perform QHEIs every two miles on the main stem of the Sandusky River starting at the first riffle downstream of the dam to the riffle located at the end of the dam impoundment. The frequency will be once a year on the first, third, and fifth monitoring years following the removal of the dam.

- ODNR Division of Geological Survey will survey substrate composition and conduct channel morphology analyses for five years after removal of the dam.

- The Ohio State University will conduct unionid mollusk (i.e., freshwater mussel) inventories at the riffle below the dam and at one of the OH EPA habitat and biological monitoring sites above the dam once every year for five years after the removal of the St. Johns Dam (ODNR, web).

6 PARTIAL DAM REMOVAL AND/OR DIVERSION/BYPASS STRUCTURES FOR STREAM RESTORATION

Partial dam removal and/or diversion/bypass structures have also been used for stream restoration, recognizing that that complete removal of dams may not always be the best option for a river system. For example, remnant dam structures may serve to stabilize impoundment sediment, or provide a limited buffer against flooding. Also, partial alteration helps to avoid the expense of complete removal or to retain some structure for historic interpretation. Partial dam removal and/or diversion/bypass structures can provide all these benefits while still achieving the ecological objective of improved fish passage and greater instream flows.

Partial dam removal can be a breach which is defined as an opening in a dam that prevents the dam from impounding a significant amount of water or a reduction of the height of a dam to reduce the dam's storage volume.

There is no generic approach to partial dam removal just as there is no generic approach to river restoration. A formal partial dam removal process usually includes initial consultation with stakeholders, designing and planning the best alternative for the partial removal, evaluating assessments and approvals, implementation, monitoring, as well as the related enhancement and/or rehabilitation works that are required after a dam structure is partially removed.

OH DNR Dam Breach Requirements

The following items must be prepared by a registered professional engineer and submitted to the Division of Water for review and approval: a plan for lowering the lake level, construction plans and specifications for constructing the breach, plans and specifications for controlling sediment in the impoundment, calculations or justification for sizing the breach, a description of erosion protection in the breach area, and a schedule for construction. Other items may be required in certain circumstances. It is the responsibility of the owner to hire a qualified registered professional engineer.

http://www.dnr.state.oh.us/water/pubs/fs_div/fctsht63.htm

The Jackson Street Dam, built in 1960 on Bear Creek in Medford, Oregon, resulted in a barrier to migration of Pacific salmon and steelhead, loss of stream habitat, eutrophication, and an algae-choked impoundment in downtown Medford. The 120-foot long and 11-foot high dam was breached in 1998. Because the Jackson Street Dam provided the Rogue River Valley Irrigation District with a cost-effective and mechanically functional irrigation diversion system, a new diversion device (about 3 feet), located 1,200 feet upstream of the old dam site, was constructed to provide the irrigation district with an equally beneficial method of water diversion. The total cost was $1.2 million. The breaching of Jackson Street Dam restored the 1/4 mile of streambed formerly inundated by the reservoir and improved both upstream and downstream fish passage for migratory fish. Coho salmon and other species have already been found upstream of the former dam site. 'In addition to fish passage and habitat restoration, the City of Medford now enjoys a revitalized stretch of river devoid of the sediment, trash, and stench associated with the Jackson Street reservoir.' (American Rivers, et al, 1999)

The concrete wall on the left bank is what remains of the original diversion dam.

Figure 6.1 The Jackson Street Dam after breaching (from *Restoration – A Newsletter about Salmon, Coastal watersheds, and People,* Oregon Sea Grant, Winter 2000)

Dam modifications provide a range of options that have little or no impact on dam function or operations, allowing existing dams to continue providing societal benefits such as electrical power, drinking water, flood protection, etc. Examples of modifications include fish ladders or diversion channels that can improve fish access to spawning or rearing habitat above and below the dam structure without altering the function of the dam itself.

In 1999, a vertical slot fishway was constructed at Bosher's Dam, providing fish with access to 137 miles of the James River and 168 miles of its tributaries for the first time in nearly 200 years (see Figure 6.2). Fish counts taken by VDGIF show that by opening some 137 miles of historic spawning habitat on the James, American shad passings increased steadily from 185 in 1999 to 1066 in 2002.

Figure 6.2 Bosher's Dam and fishway, James River, Richmond, VA (after http://www.dgif.state.va.us/fishing/embrey_dam.html)

It should be noted that partial dam removal may also cause negative effects on the stream. For example, 'following partial removal of the Fort Edwards Dam in 1973, large quantities of oils and sediments rich in polychlorinated biphenyls were released into the river, requiring a costly cleanup effort (Shuman, 1995). The sediment moved into the river where it restricted flow and blocked the navigation channel and access to adjacent riverside businesses. The altered flow created an additional health hazard when sewage, discharged into the river by the town of Fort Edwards, could not be conveyed downstream (Heinz Center, 2002).' (Stanley and Doyle, 2002). Therefore, it is important to evaluate the environmental effects before partially removing a dam.

7 MONITORING TECHNIQUES TO MEASURE PERFORMANCE OF DAM REMOVAL PROJECTS

7.1 IMPORTANCE OF MONITORING PERFORMANCE

Monitoring is necessary to determine the degree to which a mitigation project has successfully met the objectives stated in the project's mitigation plan. Site-specific objectives must be incorporated in the design and implementation of the project. These objectives must be appropriately evaluated. Monitoring should be directed at evaluating primary objectives to be accomplished by the mitigation project. Monitoring of secondary benefits may also be appropriate, depending upon the components of the mitigation plan.

When mitigation projects have higher levels of scientific uncertainty, such as stream mitigation through dam removal, the project should include long-term monitoring, reporting and potential remedial actions (USEPA and Department of Army, 1990). The period for monitoring mitigation projects is typically 5 years; however, it may be necessary to extend this period for projects requiring more time to reach a stable condition (e.g., such as a formerly impounded stream segment) (USACE et al., 1995). The justification for a flexible and adaptive approach to monitoring requirements is that the time it takes to attain different criteria will vary for different parameters and for different projects. For instance, water quality criteria may be achieved rapidly for some dam removal projects, while they may take years for other projects. Similarly, migratory fish criteria may be met within a year in a watershed with few dams, whereas a watershed with many additional dams may preclude attaining increased distribution of migratory fishes. There are many site-specific factors that need to be considered when developing criteria to evaluate the ecological results of dam removal over time.

7.1.1 Relevance to Mitigation

Collection of pre-removal data is critical to monitor the success and failure of dam removal in general, as well as dam removal as a stream mitigation tool. Data should be collected from several locations that may be affected by the proposed project, including both upstream and downstream locations. Both short- and long-term monitoring should be conducted, as the project's impacts on various parameters may change over time.

7.1.2 Cost–Benefit Ratios

The regulatory entity may account for functional changes by recording them as site-specific debits and credits. Guidance developed by the USACE (2002) defines credits and debits as follows:

> Credit: A unit of measure of functional capacity representing the gain of aquatic function at a compensatory mitigation site.

> Debit: A unit of measure of functional capacity representing the loss of aquatic function at a project site requiring compensatory mitigation.

Stream mitigation projects should replace lost stream functions. When sufficient functional assessment is not feasible, mitigation projects for streams should generally replace linear feet of stream on a one-to-one- basis. The measure of function is typically indexed to the number of acres of resource restored, established, enhanced, or protected as compensatory mitigation. Such surrogate mitigation proposals must be carefully evaluated because experience has shown that stream compensation measures are not always practicable, constructible, or ecologically desirable (USACE, 2002).

Mitigation guidance (USACE, 2002) indicates that USACE Districts may require on-site mitigation, off-site mitigation, or a combination of on- and off-site mitigation to maintain stream functional levels within watersheds. Mitigation of wetland impacts is typically required on-site, when practicable, such as in areas adjacent or contiguous to the site where the loss of aquatic function will occur. However, mitigation of stream impacts through dam removal is more likely to be conducted off-site, particularly when off-site mitigation would provide more benefits to the watershed in which the stream impacts will occur.

Dam removal may present opportunities for in-kind mitigation, out-of-kind mitigation, and combinations of in-kind and out-of-kind migration to achieve functional replacement within a watershed. In-kind compensation for a loss of stream function can be provided through a dam removal project that involves replacement of that function by restoring, enhancing, or protecting and maintaining a stream segment of the same physical and functional type. Out-of-kind compensation for a stream function loss involves replacement of that function by restoring, enhancing, or protecting and maintaining an aquatic resource of different physical and functional type. Out-of-kind mitigation may be appropriate when it is practicable and provides more environmental or watershed benefit than in-kind compensation (e.g., of greater ecological importance to the region of impact) (USACE, 2002).

Existing guidance on compensatory stream mitigation through dam removal (USACE, 2004) indicates that the maximum potential credit in linear feet that may be generated by a single dam removal project is the length of stream restored to free-flowing condition as measured from the dam to the upstream edge of the normal pool as indicated by the elevation of the crest of the dam for run-of-river dams or the outfall, which is lower in elevation. This would be measured from the dam to the upstream extent of the former impoundment, and may extend into tributaries as well.

The USACE Guidance (2004) states that, when appropriate, a functional habitat-based calculation may also be used on a case-by-case basis and that additional credit may also be attained for demonstrated downstream functional benefits. However, dam removal may provide demonstrable functional benefits both downstream and upstream of the project site. A range of physical, chemical and biological functions may be attained on a project-by-project basis. It is recommended that credit structures consider the watershed-wide functional benefits that may be possible via dam removal.

7.2 WHAT TO MONITOR

At least one year of pre-removal monitoring must be conducted as part of the mitigation plan. A thorough monitoring plan before, during, and after dam removal is not only necessary to determine attainment of mitigated stream function, but is also necessary as part of an adaptive management program that provides early indication of potential problems and direction for correction actions (USACE, 2002). Monitoring and control of nonindigenous and exotic species should be a part of any effective adaptive management program. Entities conducting monitoring must have an understanding of the processes that drive the structure and characteristics of the river as it responds to the dam removal action. Simply documenting the structure (e.g., hydrology, sediment, fauna, flora, water quality) will not provide the knowledge and guidance required to take adaptive corrections if adverse conditions and need for remedial actions are discovered. Although restoration of stream functions may take years to decades, process-based monitoring will help provide more sensitive early indicators of whether a mitigation site is proceeding along an appropriate trajectory (USACE, 2002).

Previous dam removal projects, not necessarily conducted for mitigation purposes, have incorporated monitoring into project implementation. Published studies exist on the impact of dam removal to fish (Kanehl et al., 1997), macroinvertebrates (Stanley et al., 2002), vegetation (Lenhart, 2000) and geomorphology (Williams, 1997; Wohl and Cenderelli, 2000) (Doyle et al, 2003). Perhaps the most extensive study yet undertaken on the effects of dam removal was conducted by the Patrick Center for Environmental Research of the Academy of Natural Sciences in Philadelphia. This multi-year interdisciplinary study focused on the effects of removing a small lowhead dam on Manatawny Creek in PA (Bushaw-Newton et al., 2002).

The specific parameters that need to be monitored are likely to be tailored to the project site and mitigation plan. The location of the monitoring will also vary (e.g., points within the impoundment, riparian zone, former dam site, points downstream, points upstream). Bushaw-Newton et al. (2002) list several potential ecological responses to dam removal. The Heinz Center (2002) also lists a number of potential outcomes of dam removal. The following potential outcomes may be appropriate parameters to monitor for a stream mitigation project.

<u>Physical</u>

- Change to downstream hydrology
- Sediment degradation within the impounded area and upstream
- Sediment aggradation downstream of the former dam site
- Grain size analysis
- Bedload analysis
- Channel morphology (cross sectional and longitudinal)
- Floodplain morphology (e.g., connection to channel, frequency of inundation)
- Groundwater recharge
- Watershed fragmentation

<u>Chemical</u>

- Water quality parameters
    - Dissolved oxygen
    - Temperature
    - Specific conductance
    - pH
    - Turbidity
    - Suspended particulate material and nutrients (C, N, P)
- Redistributions of organic contaminants
- Redistribution of particulate organic matter
- Change in seasonal nutrients (e.g., due to fish migration)

<u>Biological</u>

- Change in algal biomass and species composition
- Change in benthic macroinvertebrate taxa
- Change to freshwater mussel beds
- Return of host fishes for freshwater mussels
- Change in fish community assemblage (natives, exotics, cold-, cool- and warm water, etc.)
- Restored fish passage and distribution
- Decrease in fish parasites
- Change in populations and distributions of nonindigenous and exotic species
- Change in riffle habitat
- Change in deep pool habitat
- Change in wetland type
- Change in wetland acreage
- Change in connection of floodplain with stream
- Change in riparian vegetation
- Change in waterfowl populations

<u>Economic</u>

- Cost-benefit of dam operations and maintenance versus removal
- Value of services lost and services gained
- Change in property values
- Change in cost of infrastructure maintenance and operation (e.g., bridges, pipelines, water/wastewater treatment)
- Change in local business revenue

<u>Social</u>

- Change in public attitudes to project over time
- Change in recreational patterns
- Change in property ownership near project
- Change in seasonal homeowners
- Change in perceptions of public safety
- Change in zoning or long-term municipal planning

7.3 WHO MONITORS THE PERFORMANCE OF DAM REMOVAL PROJECTS

A number of entities have noted that too little scientific research has been conducted on the benefits and impacts of dam removal (Aspen Institute, 2002; Heinz Center, 2002). There is a clear need for an increased effort to monitor the effects of dam removal, regardless of whether or not the project is taking place as a stream mitigation project. Information gleaned from monitoring the effects of dam removal will further the development of appropriate programmatic approaches to dam removal at the local, state and federal level. Programmatic approaches include decision-making frameworks, laws, and policies regulating dam removal activities, technical guidance documents, and funding arrangements.

Monitoring of dam removal projects have been conducted by a range of entities and has taken a diversity of forms, from funded, multi-year, interdisciplinary studies conducted by academic institutions to volunteer-based monitoring of water quality parameters. In many cases, before and after data at dam removal sites are not reported in refereed scientific literature. Some state and federal agencies now require pre- and post-removal monitoring as a permit condition, or as part of financial assistance to remove the dam.

Several important disconnects exist between research and monitoring conducted by the academic community and the research and monitoring that is needed by decision makers (Heinz Center, 2002; Doyle et al., 2003). Dam removal as a tool for stream mitigation may help address some of this disconnect between science and policy.

The base of scientific knowledge to support regulatory decision-making, permit conditions, and mitigation requirements for dam removal is progressing, but much of the research conducted to date has focused on single dam removal projects. As a result, conclusions drawn tend to be somewhat site-specific. Few studies have attempted to collate information from several sites and develop policy recommendations regarding dam removal on a watershed or statewide basis.

There is an increase of high quality research being conducted and published but many research and monitoring projects are moving forward in isolation of similar work elsewhere (Heinz Center, 2002). The questions and approaches that are most important to a fluvial geomorphologist are likely to be different than questions and approaches that are important to an ecologist. But, if both sets of questions were evaluated on a single project, an integrated analysis of the effects of dam removal would be possible. Also, properly understanding the issues faced by planners, legal experts, property owners, and dam owners require still more integration (Heinz Center, 2002).

This need for an integration of monitoring efforts following dam removals requires a multi-disciplinary dialogue. To establish reasonable policies and permit conditions, decision-makers need to know about the integrative effects of dam removal, not only specific effects such as those to a particular fish species or changes in morphological conditions.

Doyle et al. (2003) recommend that monitoring should be conducted or administered by the agency responsible for a dam’s removal, leaving the responsibility of proving the efficacy of dam removal on the agency permitting the removal. In reality, the budgetary and regulatory constraints under which most agencies operate make this unlikely.

7.4 MONITORING TECHNIQUES

Applicable monitoring methods for low head dam removal projects implemented for mitigation should be determined based upon specific monitoring goals and requirements as defined in project permits. Specific monitoring requirements may include evaluation of primary and secondary indicators of project success.

Primary indicators are directly associated with mitigation requirements, such as the reestablishment of riparian wetlands in previously inundated areas or the restoration of fish passage for migratory fish. Secondary indicators could include water quality suitable for sustaining target fish species and seasonal flooding of adjacent wetlands. Note that the determination of primary and secondary criteria is project specific, and will likely vary depending on mitigation needs and associated requirements.

Guidelines for monitoring techniques should be determined based on monitoring requirements. The following documents are suggested as general references for applicable ecological and biological monitoring protocols. The referenced documents are commonly used by the regulatory community and therefore applicable to the determination of mitigation benefits associated with dam removal. Specific regional guidelines should also be referenced, as required.

- Wetlands – USACE Wetlands Delineation Manual (Technical Report Y-87-1) (Environmental Laboratory, 1987)
- Riverine Fauna – Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (Barbour, 1999)
- River Morphology – Applied River Morphology (Rosgen, 1996)

In addition to the aforementioned references, regional, state, and local guidelines should also be assessed to establish practical and meaningful monitoring strategies.

Monitoring techniques should also consider the timing of specific mitigation components. For instance, monitoring of vegetation and associated control of invasive plant species would typically commence immediately following a dam removal. Monitoring of projects where mitigation objectives include native fish populations may warrant a delay prior to monitoring to allow for a population to adjust to restored conditions, particularly where the restored reach of river is intended to support life-stage specific use (e.g., spawning, rearing).

8 TECHNICAL GUIDANCE AND SITE-APPROPRIATE PRACTICE FOR IMPLEMENTING DAM REMOVAL PROJECTS

Deciding whether to remove a dam can be contentious. Designing and adhering to a well-considered collaborative decision-making process can significantly reduce the conflicts. A well-designed decision-making process can address safety, economic, and environmental concerns and also satisfy the desire of community members and other stakeholders to participate actively in shaping the future of the dam and related natural resources in their community.

In this chapter, we will first briefly review and evaluate the existing guidance documents on decision-making related to dam removal. Based on the review and evaluation, we will propose a simple method for ranking and identifying the candidates of dams that can be removed so that stream remediation credits can be obtained for transportation projects.

8.1 EXISTING TECHNICAL GUIDANCE

8.1.1 List of Existing Guidance Documents

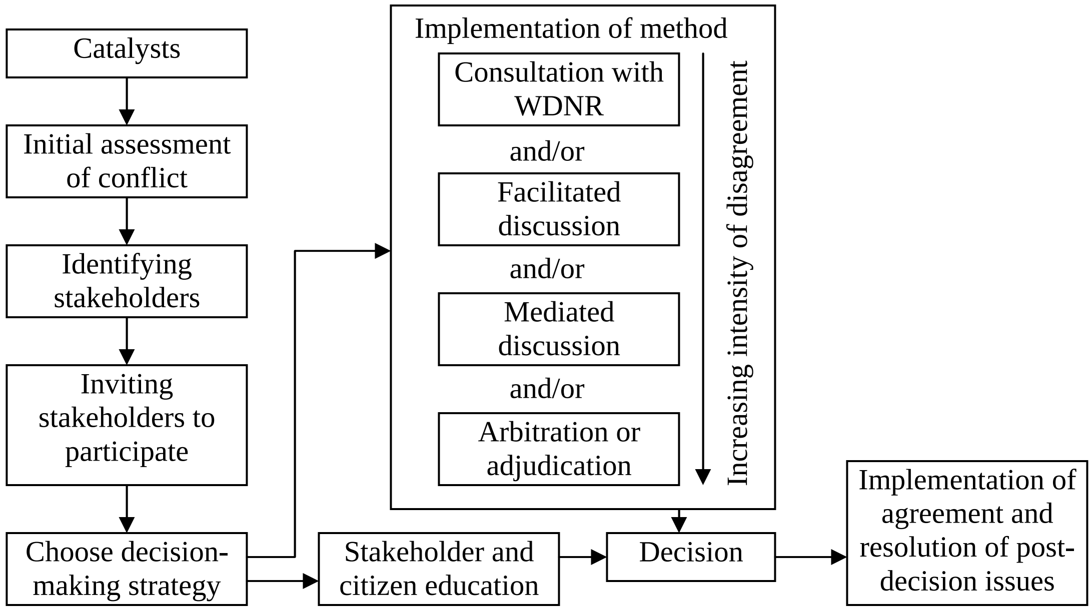
There exist different documents containing guidance information on decision-making related to dam removals. Several of these guidance documents are listed and briefly described below.

Heinz Center (2002). Dam Removal – Science and Decision Making – This document presents a general method for reaching decisions about dam removal involving four basic four steps:

Step 1: Define the goals and objectives
Step 2: Identify major issues of concern
Step 3: Data collection and assessment
Step 4: Decision making
If a decision is reached to remove the dam, two more steps are added:
Step 5: Dam removal
Step 6: Data collection, assessment, and monitoring

For each step, the document provides detailed discussion and related information.

WRM (2000). Dam Repair or Removal – A Decision-Making Guide, Water Resources Management Practicum 2000 – This document gives a brief background and an overview of the pertinent issues associated with dam repair/removal decision-making in WI. The principal components involved in designing and implementing an appropriate decision-making process is presented in the following flow chart.



American Rivers, Inc. and Trout Unlimited (2002). Exploring Dam Removal – A Decision-Making Guide – This guidance document considers four categories of issues for decision-making related to dam removal:

- Ecological
- Economic
- Societal
- Technical/engineering

For each category of issues, the document presents different questions that will help sort out the many issues surrounding dam removal and increase the likelihood that an informed decision can be made.

New Hampshire Department of Environmental Services [NHDES] (2003). Guidelines to the Regulatory Requirements for Dam Removal Projects in New Hampshire – This comprehensive guidance document provides dam owners, communities, regulatory agencies and other interested parties with information about the regulatory process associated with removing a dam in NH.

NHDES has developed a permit application process specifically for dam removal projects. This process addresses the needs of both the NHDES Wetlands and Dam bureaus, with the intent of streamlining the process for project applicants, and achieving a coordinated review with other applicable agencies, such as the NH Division of Historical Resources.

This web-based document has numerous links to other relevant sources of information, such as the Registry of Deeds, lists of consultants, and other government agency programs.

The following is an outline of the document:

Overview: State Laws and Regulations Pertaining to Dam Removal
Step One: Obtaining Necessary Information
- Who to Contact for Information
- Necessary Permits and Permit Applications

Step Two: Researching, Planning and Designing the Project
- Key Technical Issues to Address Early
  - Sediment Management Concerns
  - Potential Effects to Historical Resources
  - Potential Effects to Infrastructure
- Additional Issues to Consider

Step Three: Preparing the Permit Application Package
- Detailed Instructions on Completing and Submitting the Application Package

Step Four: Permit Review and Issuance Process
- Agency Decision-making Timelines
- Public Information Meeting or Hearing Requirements
- General Permit Conditions

NHDES and New Hampshire Office of Emergency Management (2003). Procedure to Assist in the Prioritization of Dam Removal Projects. New Hampshire Department of Environmental Services – This document was developed in response to numerous requests for agency technical and financial assistance in planning and conducting dam removal projects. This procedure is completely distinct from the regulatory permit review process. The document provides a method for agencies to determine which proposed dam removal projects represent the most effective use of limited agency resources, and agency missions and authorities. For example, the New Hampshire Office of Emergency Management (NHOEM) is beginning to receive grant applications from municipalities that are seeking to remove dams in their communities in order to eliminate the hazards that are caused or exacerbated by that presence of a dam. NHOEM is primarily interested in how a dam scores in the category of Hazard Mitigation and Public Safety. However, NHOEM is also interested in other relevant issues, such as whether a project will provide additional benefits, whether it has local support, whether it is technically feasible, etc.

This document provides a prioritization process consisting of six categories of criteria. For each criterion, the document provides guidance for determining the appropriate score.

- Dam Owner Willingness
- Hazard Mitigation and Public Safety Criteria
  - Dam safety enforcement
  - Dam hazard classification
  - Riverine ice regime issues
- Ecological Value Criteria
  - Fishery resource value
  - Existing fish passage
  - Natural resource value
  - Species of concern issues
  - Federal river designation

- Cultural Value Criteria
  - Economic value
  - Historic value
  - Abutter issues
  - Community resource value
  - Community support
  - State designated river
  - Consistency with existing plans
- Recreational Value Criteria
  - Boating resource value
  - Multiple recreational value
  - Regionally unique recreational value
- Project Feasibility Criteria
  - Access to dam
  - Infrastructure issues
  - Sediment issues
  - Land access issues
  - Project funding

MDNR and MDEQ (2004). Dam Removal Guidelines for Owners. Michigan Department of Natural Resources and Michigan Department of Environmental Quality – The purpose of this guidance document is to suggest issues that may need to be considered when deciding the future of a dam and to assist in implementing a dam removal project in MI. The guidance consists of the following seven steps:

Step 1: Consider What Purposes the Dam Serves
- A. Consider whether the dam itself provides any benefits
- B. Consider whether the impoundment created by the dam may serve any services

Step 2: Consider Problems with the Dam Structure
- A. Safety and Security of the Dam
- B. What are the Costs and Liabilities of Keeping the Dam
- C. What Environmental Impacts Should Be Considered?

Step 3: Considerations for Dam Removal
- A. Would Removal Eliminate or Reduce Safety and Security Problems?
- B. Would Removal Improve Recreational Use of the Site?
- C. Cost Estimates
- D. Potential Funding Sources

Step 4: Working with DEQ Dam Safety Program and/or DNR Fisheries Division
- A. Contact the DEQ dam safety program for information about the condition of the dam, and for permit application requirements and procedures.
- B. Contact the DNR, Fisheries Division for Information about the fisheries and wildlife values with and without the dam.
- C. General guidance on the removal of a dam (if a viable option).
- D. Information about potential funding sources for dam removal (if a viable option).
- E. Other requirements for planning, design and modification of the dam.

Step 5: Explore Resident and Community Concerns Including Local Watershed Council, Conservation Clubs, Economic Development Groups, others

A. Historic and aesthetic values of the dam and or impoundment
B. Property Owners Interests
C. Other Social Issues

Step 6: Collect and Assess Information (Professional Engineering and/or Legal Services Necessary)

A. Legal Issues
B. Engineering Issues
C. Economic Issues

Step 7: Taking Action

A. Secure Local, State and Federal Permits.
B. Complete Site Land Survey, Final Design Engineering Plans.
C. Secure Funding (construction, site restoration and monitoring).
D. Determine Sediment Management Plan (may include dredge and disposal or in place stabilization as recommended by DEQ and DNR).
E. Secure Authorization for Site Access.

8.1.2 Evaluation of Existing Guidance Documents

The existing guidance documents are produced by different agencies and are presented in different formats. Some of the guidance documents are detailed covering the information before, during, and after the dam removal while the others only cover the information for making the decision whether a dam should be removed. It is noted that all of the guidance documents cover the issues of safety, costs, ecology, technology, etc.

None of the existing guidance documents describes the issues related to mitigation credits for transportation projects.

8.2 GUIDANCE FOR TRANSPORTATION PROJECTS – DECISION TREE OUTLINE

In this section, we will present a simple method for ranking and identifying the candidates of dams that can be removed so that stream remediation credits can be obtained for transportation projects. The method is illustrated in the flow chart in Figure 8.1. It need be noted that the proposed approach is to find the potential candidate dams for removal so that mitigation credit can be obtained. A potential candidate dam need be studied in detail before it is removed. The proposed approach is not intended to cover the detailed study.

8.2.1 Preliminary Evaluation

The primary driving forces for consideration of dam removal are

1. The cost of maintenance and repair when the benefits of maintaining a dam are diminished;
2. Public safety and liability concerns; and

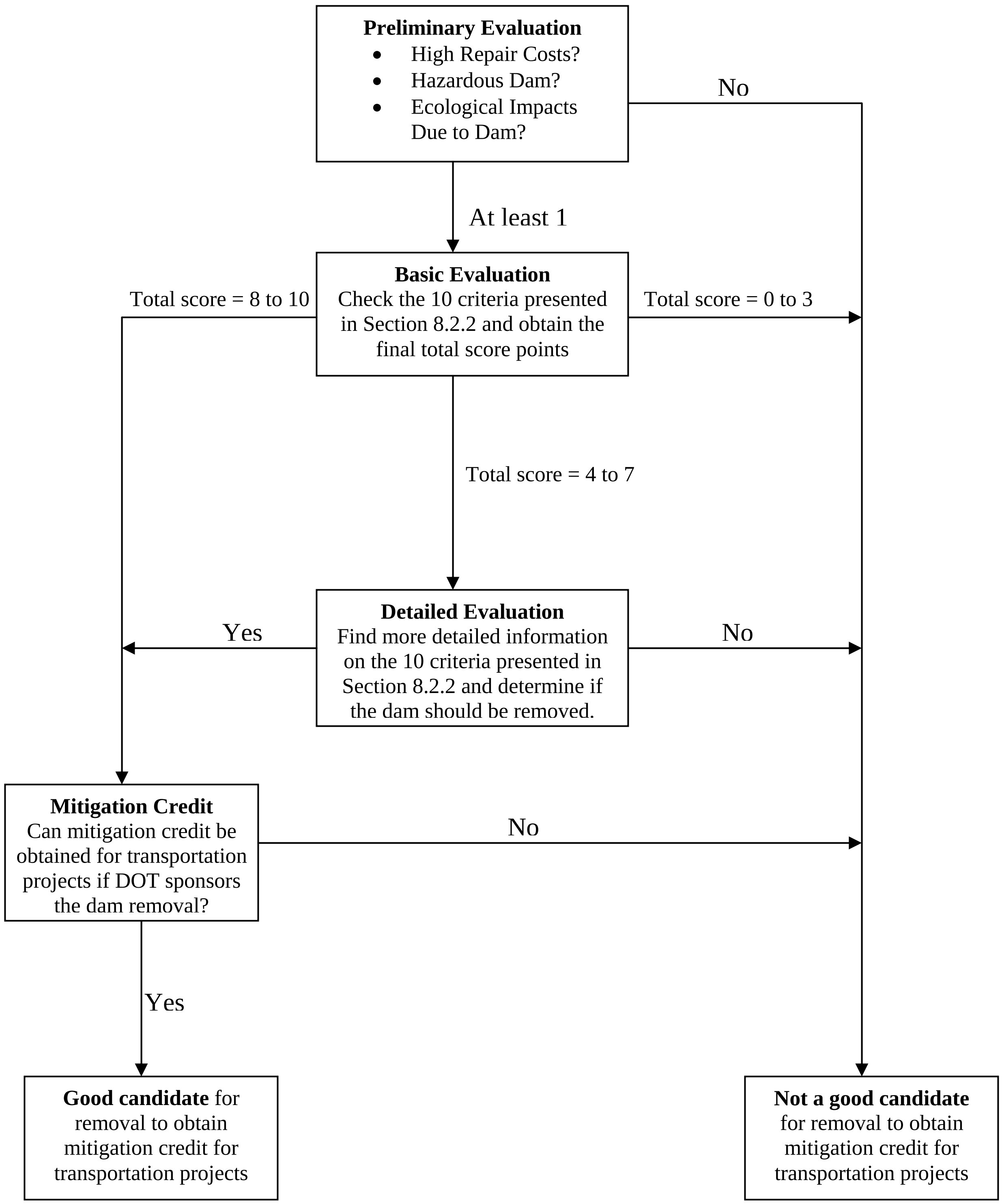


Figure 8.1. Flow chart for determining a dam candidate for removal to obtain mitigation credit for transportation projects.

3. Potential fisheries, water quality and recreational use improvements that can be realized with dam removal.

If a dam satisfies one or more of the above factors, then it can be selected for the potential candidate list. Dams from the potential candidate list are then evaluated based on the individual criteria described hereafter and prioritized according to their final score.

8.2.2 Basic Evaluation

Dams with increased potential for removal are those that provide little or no benefit, are a potential liability, are too costly to maintain or upgrade, and would provide an opportunity for economic, social, or environmental improvements to a river system if they are removed. The potential candidate dams can then be evaluated based on 10-weighted criteria. Each criterion is assigned a weighting of one point. If a dam meets a criterion condition, it receives a score of one point. The maximum score for a dam is 10. The 10 criteria are listed in Table 8.1:

8.2.3 Detailed Evaluation

For a dam with a score of 4 to 7, more detailed information needs to be collected and further evaluation needs to be conducted to determine if it should be removed for the purpose of obtaining mitigation credit.

8.2.4 Mitigation Credit for Transportation Projects

If evaluation determines that an unused dam is a good candidate for removal, one then needs to know if mitigation credit can be obtained for transportation projects (e.g., if state DOTs sponsor the removal). The following questions need be studied related to mitigation credit for transportation projects:

- Will the dam removal be related to any transportation projects?
- Can mitigation credit be obtained if state DOTs sponsor the removal?
- If yes, how much credit can be obtained if state DOTs sponsor the removal?

The process presented in Section 5.5 can be followed to determine the mitigation credits that can be obtained from a low-head dam removal project.

Table 8.1 Basic Dam Removal Evaluation Criteria for Candidate Facilities

(Yes = 1, No = 0, maximum total score = 10)

1 Dam owner is in favor of dam removal or dam is considered to be ownerless or abandoned after a due diligence attempt to identify an owner.

Score:__________

2 Dam presents a potential safety liability or fails to meet current safety standards and is not likely be repaired or upgraded in the near future.

Score:__________

3 Dam does not fulfill its original function or provides little or no economic, social, or environmental benefit to the owner.

Score:__________

4 Dam is not cost effective to operate and maintain. The short term costs of dam removal are justified to eliminate long term operation, upgrade and maintenance costs.

Score:__________

5 Original dam construction resulted in loss or significant deterioration of important fisheries, wildlife, habitats, unique landscapes, or sites of cultural significance.

Score:__________

6 Removal would provide greater economic, social, or environmental benefits to the overall river system than repairing the dam.

Score:__________

7 The community is generally supportive of the dam’s removal, or is indifferent to the dam’s removal.

Score:__________

8 Removal will have no or minimal conflict with laws and regulations (e.g., CWA, Endangered Species Act, National Historic Preservation Act) designed to protect natural systems and social, historical or cultural values.

Score:__________

9 Dam removal will lead to stream restoration and net environmental benefits.

Score:__________

10 There is financial support or technical assistance available for the removal of the dam, and associated river restoration activities, for the stated purpose of obtaining stream mitigation credit.

Score:__________

Total Score:__________

Based on the total score, a dam can be classified into one of the following three categories:

Total Score = 8 to 10:	Good candidate for removal
Total Score = 4 to 7:	Potential candidate for removal – need detailed evaluation for final decision
Total Score = 0 to 3:	Poor candidate for removal

9 TOPICS IN NEED OF ADDITIONAL RESEARCH AND STUDY

The scientific research on the effects of dam removal is still in its initial stages, and elaborate theories on the subject are not yet developed. Although more than 600 dams have been removed in the United States in the past decades, very few published investigations accompanied each removal. While conducting other tasks of this project, we have identified the topics (environmental, economical, social, etc.) associated with low-head dam removals that are in need of additional research and study.

1. Dam removal database – Although more than 600 dams are collected and listed in Table B.2, most of them lack one or more types of information. It is necessary to have one organization or agency such as the National Dam Inventory to take formal responsibility for collecting and compiling these data at the national level.

2. Detailed study of dam removal projects – Very few of the dam removal projects are studied in detail. It is necessary to select several dams and conduct detailed pre- and post-removal study. For example, the OH Scenic Rivers Program is conducting a 5-year pre- and post-removal study of St. John's Dam removal. The study will examine how a formerly impounded river naturally recovers over time. The study includes fish electro-shocking, macroinvertebrate trapping, mussel surveys, water chemistry, sediment transport, Global Positioning System (GPS) mapping of cross sections of the river channel, GPS mapping of the river substrate and morphology (riffles, runs and pools), and monitoring of static water levels in 14 area wells. The researchers come from a variety of agencies including ODNR, Ohio State University, and Heidelberg College's Water Quality Lab. The research is partially funded by monies raised through Scenic Rivers license plate sales (Vargo, 2004).

3. Economic analysis tool - Formal economic analysis can be very helpful in supporting the decision-making process for dam removal, in setting priorities, and in considering the interests of stakeholders and agencies. However, significant challenges remain for the formal economic analysis because dam removal has a number of beneficial and adverse outcomes, some of which can be easily valued monetarily while others are highly uncertain and difficult or impossible to value. It is necessary to develop economic analysis tool specifically for supporting the decision-making process of dam removal.

4. There is little research on social science aspects related to dam removal (Heinz Center, 2002). This is a serious shortcoming because the social context of dam removal decisions is often as important as the environmental and economic contexts, and decisions regarding removal are made by people who are affected as much as the environment. This significant gap could be filled in many ways. For instance, research in sociology, geography, history, and planning could investigate the connections among communities, rivers, and dams. There is also more to learn more about the cultural significance of dams. Some dams or structures directly associated with them may have

substantial historical significance, so there may be reasons to remove only part of a dam or to preserve or restore the associated mill works or power house. A particularly important line of investigation that could be undertaken by nongovernmental organizations with the cooperation of state agencies would be to investigate the social and economics outcomes after dam removal. These after project studies are at least as important as environmental and social impact studies undertaken before the dam removal.

5. Very limited information exists regarding the potential impact that a dam removal may have on property values. This is an issue often of great concern to landowners; therefore, this complex question is in need of additional research. Existing studies of the effect of water quality on lakefront property values are sometimes referenced in relation to dam removal. These studies have found that improvements to water quality often result in increased property values. However, these studies are lacking in the context of dam removal because they have not integrated the change in recreational use, aesthetics, and quality of life issues resulting from a change from a lake or pond environment to a riverine environment. For instance, a study conducted by the Minnesota Headwaters Board and Bemidji State University (2003) applied a hedonic analysis to model the incremental amounts that people are willing to pay for lake and river water quality. Researchers discovered that the model used for lakeshore analysis would apply very differently to river property. The variability of purchase price was far less predictable among riparian property sales than lakefront property sales. The researchers choose not to apply the river data to the hedonic model. This study demonstrates the uniqueness of studying riverfront property values. Research in relation to dam removal is likely to be complex in nature.

6. There is a need to clarify the feasibility and method of conducting a project that would clearly result in credits in excess of those required for mitigation, but where the entity requiring credits does not wish to establish a mitigation bank. Certain projects with the potential for significant restoration benefits may only be possible through a combination of funding from entities requiring mitigation credit and funding from other entities that have an interest in dam removal and river restoration. There is considerable public and private funding available for dam removal projects but, for a variety of reasons, many fund providers do not consider mitigation projects to be eligible for funding. Would such a project be considered eligible for mitigation? How would the credit structure be established, monitored and assigned? How could entities requiring mitigation credit adequately evaluate these projects for their mitigation potential?

10 CONCLUSIONS

This research project has led to the following conclusions:

1. The existing dam removal databases do not include all the dams removed in the United States and, for the dams that are included in the existing databases, only limited information is included for each dam removal project. To bridge the data gaps, a survey was conducted for this study. The survey results and the final list of the collected dam removal projects are presented in Appendix B. Analyses of the survey results and the final dam removal project database lead to the following conclusions:

    a. Dam removal appears to have been relatively uncommon before the 1980s but has escalated significantly in the 21st century. The recent acceleration of dam removals reflects problems associated with aging structures, growing interest in restoring rivers and fish passage, new funding opportunities to support dam removal, and national policies aimed at improving the safety of aging structures and mitigating the environmental impacts of these structures.
    b. The three most common reasons for dam removals are, in order, ecology, economics, and safety.
    c. Most of the dams removed have a structural height smaller than 20 feet. This is in agreement with Heinz Center's (2002) conclusion that "almost all of the dams removed thus far have been small ones."
    d. Most of the dams (79%) were totally removed, and only 21% were breached or partially removed.
    e. The deconstruction cost is about half (52%) the total removal cost.

2. Removal of low-head dams has different impacts, both beneficial and adverse, including physical and chemical impacts, ecological impacts, social impacts and economical impacts.

3. Removing dams can have distinct economic benefits, such as cost savings over repairing and maintaining the dam, potential for community riverfront revitalization, increased income to local fishing and boating industries, and decreased costs related to water quality improvements and fisheries management. However, these dam removal benefits may come at a price, due to the loss of economic benefits from the dam. To determine the economic benefits of a dam removal, one has to consider different costs and benefits including the costs and benefits to the dam owner, the societal costs and benefits, the recreational costs and benefits, and the environmental costs and benefits.

4. There are different legal and regulatory requirements for dam removal projects. It is important to follow a permitting process for dam removal projects so that the relevant legal and regulatory requirements are met.

5. Partial dam removal and/or diversion/bypass structures have also been used for stream restoration, recognizing that that complete removal of dams may not always be the best option for a river system. The impacts of partial dam removal, both beneficial and adverse, also need to be evaluated appropriately.

6. It's been several decades since low-head dam removals were first used for stream restoration; but only several years since transportation agencies started to use low-head dam removal projects as a method of stream restoration to receive stream mitigation credit. The primary and secondary criteria need to be considered for determining the mitigation credit for dam removal.

7. Monitoring is necessary to measure the performance of dam removal projects. For a specific dam removal project, it is important to decide who should do the monitoring, what to monitor, and what applicable monitoring techniques to use.

8. Various guidance documents—produced by different agencies and presented in different formats—exist on decision-making related to dam removal. Some documents cover information related to each stage of dam removal (before, during, and after) while others cover only the information for deciding whether a dam should be removed. All guidance documents cover the issues of safety, costs, ecology, technology, etc. However, none describes the issues related to mitigation credits for transportation projects. Our review and evaluation of the information available led to a simple method for ranking and identifying dams that can be removed so that stream remediation credits can be obtained for transportation projects. This method consists of four progressive evaluation steps: preliminary, basic, detailed, and mitigation-credit evaluation.

9. Scientific research on the effects of dam removal is still in its initial stages, and elaborate theories on the subject are not yet developed. Although more than 600 dams have been removed in the United States in the past decades, very few were accompanied by published investigations. The following topics associated with low-head dam removal need additional research and study:

    a. Dam removal database – one organization or agency, such as the National Inventory of Dams, should take formal responsibility for collecting and compiling these data at the national level. The database should include the important information for each dam removal project such as the parameters listed in Table.2.1.
    b. Detailed case studies of dam removal projects – select several dams and conduct detailed pre- and post-removal studies.
    c. Economic analysis tool – develop an economic analysis tool specifically for supporting the decision-making process in dam removal.
    d. Sociological study method – develop a methodology to analyze the social impacts of dam removal capable of supporting decision-making.
    e. Impact of dam removal on property values – The information about the impact of dam removal on property values is very limited. This issue is often of great concern to landowners and needs additional research.
    f. Mitigation credit for transportation projects – The concept of receiving stream mitigation credits for transportation projects by removing low-head dams is relatively

new. Studying how to determine mitigation credits and developing corresponding guidelines are necessary.

11 REFERENCES

American Rivers (2002). The Ecology of Dam Removal: A Summary of Benefits and Impacts. American Rivers, Washington, D.C. 15 pp.

American Rivers, Friends of the Earth, and Trout Unlimited (1999). Dam Removal Success Stories – Restoring Rivers through Selective Removal of Dams that Don't Make Sense.

Aspen Institute (2002). Dam Removal: A New Option for a New Century. Washington, D.C.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling (1999). Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Bednarek, A. T. (2001). Undamming rivers: A review of the ecological impacts of dam removal. *Environmental Management*, 27, 803-814.

Bowman, M. (2002). Legal Perspectives on Dam Removal. *Bioscience*, 52(8), 739-747.

Bushaw-Newton, K. L., D. D. Hart, J. E. Pizzuto, J. R. Thomson, J. Egan, J. T. Ashley, T. E. Johnson, R. J. Horwitz, M. Keeley, J. Lawrence, D. Charles, C. Gatenby, D.A. Kreeger, T. Nightengale, R.L. Thomas, and D.J. Velinsky (2002). An Integrative Approach Towards Understanding Ecological Responses to Dam Removal: The Manatawny Creek Study. *Journal of the American Water Resources Association* 38:1581-1599.

Chang, H. H. (1998). Fluvial Processes in River Engineering. Krieger Publishing Company. Malabar, FL. 432pp.

City of Kent, Ohio (2004). Cuyahoga River Restoration Project: October 2004 Progress Report. http://www.kentohio.org/reports/dam.asp.

Doyle, M.W., J. M. Harbor and E. H. Stanley (2003). Toward Policies and Decision-Making for Dam Removal. *Environmental Management* 31(4): 453-465.

Environmental Laboratory (1987). Corps of Engineers Wetlands Delineation Manual, Technical Report Y-87-1, US Army Corps of Engineers Waterways Experiment Station, Vicksburg, Miss.

Federal Highway Administration (2001). River Engineering for Highway Encroachments: Highways in the River Environment. Hydraulic Design Series No. 6. U.S. Department of Transportation Publication No. FHWA NHI 01-004.

[FEMA] Federal Emergency Management Agency (1999). National Dam Safety Program, http://www.fema.gov/mit/ndspweb.htm.

French, R.H. (1985). Open-Channel Hydraulics. McGraw-Hill, USA, 739 pages

Hannon, H. H. (1979). Chemical Modifications in Reservoir-Regulated Streams. *In:* The Ecology of Regulated Streams, J. V. Ward and J. A. Stanford (Editors). Plenum Press, New York, New York, 75-94.

Hart, D. D., T. E. Johnson, K. L. Bushaw-Newton, R. J. Horowitz, A. T. Bednarek, D. F. Charles, D. A. Kreeger and D. J. Velinsky (2002). Dam Removal: Challenges and Opportunities for Ecological Research and River Restoration. *Bioscience* 52: 669-681.

Heinz Center (2002). Dam Removal: Science and Decision Making. Washington, D. C.

Hitzhusen, F. (2003). Economic analysis of selected river corridor impacts and improvements: a Northeast U.S. case. Selected paper presented at the International Association of Agricultural Economists Meeting in Durbin, South Africa.

Kanehl, P. D., J. Lyons and J. E. Nelson (1997). Changes in the Habitat and Fish Community of the Milwaukee River, Wisconsin, following the removal of the Woolen Mills Dam. North American Journal of Fisheries Management 11: 387-400.

Kaufman, J. H. (1992). Effects on Wildlife of Restoration the Riverine Forest in the Rodman Pool Area. *In:* The Case for Restoring the Free-flowing Ocklawaha River. Florida Defenders of the Environment. 38-41.

Kruse, S. A. (2005). Creating an interdisciplinary framework for economic valuation: a CVM application to dam removal. PhD Thesis, Ohio State University, Ohio.

Lenhart, C. F. (2000). The vegetation and hydrology of impoundments after dam removal in southern Wisconsin. M.S. thesis. University of Wisconsin, Madison, Wisconsin.

Martin, L. A., P. J. Mullholland, J. R. Webster, and H. M. Valett (2001). Denitrification Potential in Sediments of Headwater Streams in the Southern Appalachian Mountains, USA. Journal of the North American Benthological Society 20(4):505-519.

Minnesota Headwaters Board and Bemidji State University (2003). Lakeshore Property Values and Water Quality: Evidence from Property Sales in the Mississippi Headwaters Area. Mississippi Headwaters Board.

Morris, G.L. and J. Fan. (1998). *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs, and Watersheds for Sustainable Use.* The McGraw-Hill Companies, Inc. New York, NY

Mulholland, P. J. (1996). Role of Nutrients Cycling in Streams. In: Algal Ecology: Freshwater Benthic Ecosystems, R. J. Stevenson, M. L. Bothwell, and R. L. Lowe (Editors). Academic Press, New York, New York, 609-633.

Naiman, R. J. and J. M. Melillo (1984). Nitrogen Budget of a Sub-arctic Stream Altered by Beaver (*Castor canadensis*). *Oecologica* 62:150-155.

Naiman, R. J., C. A. Johnston, and J. C. Kelley (1988). Alteration of North American Streams by Beaver. *Bioscience* 38:753-762.

Newbold, J. D. (1987). Phosphorus Sprialing in Rivers and River-Reservoir Systems: Implications of a Model. *In:* Regulated Rivers, J. F. Craig and J. B. Kemper (Editors). Plenum Publishing, New York, New York. 303-327.

[NHDES] New Hampshire Department of Environmental Services (2005). Dam Removal and River Restoration Program web site: http://www.des.state.nh.us/dam/damremoval/faqs.asp.

NHDES (2003) Guidelines to the Regulatory Requirements for Dam Removal Projects in New Hampshire. New Hampshire Department of Environmental Services, Concord, NH. DES-WD-03-35. http://www.des.state.nh.us/dam/damRemoval/Guidelines.pdf

NHDES and New Hampshire Office Emergency Management (2003). Procedure to Assist in the Prioritization of Dam Removal Projects. New Hampshire Department of Environmental Services, Concord, NH.

NRC (2001). National Research Council, Compensating for Wetland Losses under the Clean Water Act. Washington, D.C., National Academy Press.

Oakland, M. W. and I. M. Bolender (2003). Retirement isn't the end of a historic dam's career. *In:* Proceedings of the 2003 Annual Conference of the Association of State Dam Safety Officials, Minneapolis, Minnesota.

[ODNR] Ohio Department of Natural Resources. (undated) Web site http://www.dnr.state.oh.us/water/dsafety/lowhead_dams/case_study_stjohn.htm.

ODNR (2005). Ohio Non-point Source Pollution Management 2005-2010. http://www.epa.state.oh.us/dsw/nps/NPSMP/docs/stjohncasestudy.html.

Pansic, N., Austin, R. J. and Finis, M. (1998). Sediment Management for Dam Decommissioning. 15th Annual USCOLD Lecture Series, USCOLD, Denver.

Poff, N. L. and D. D. Hart (2002). How Dams Vary and Why It Matters for the Emerging Science of Dam Removal. *Bioscience* 52:659-668.

Rosgen, D. (1996). Applied River Morphology. Wildland Hydrology. Pagosa Springs, CO.

Scruton, D. A. , Anderson, T. C. and King, L. W. (1998). Pamehac Brook: A case study of the restoration of a Newfoundland, Canada, river impacted by flow diversion for pulpwood transportation. *Aquatic Conserv.*, 8, 145-157.

Shafroth, P. B., J. M. Friedman, G. T. Auble, M. L. Scott, and J. H. Braatne (2002). Potential Responses of Riparian Vegetations to Dam Removal. *BioScience* 52:703-712.

Shuman, J. R. (1995). Environmental considerations for assessing dam removal alternatives for river restoration. *Regul River*, 11, 249–61.

Stanley, E. H. and M. W. Doyle (2001). Phosphorus Transport Before and After Dam Removal From a Nutrient-Rich Creek in Southern Wisconsin. *Bulletin from the North American Benthological Society* 18:172.

Stanley, E. H. and M. W. Doyle (2002). A Geomorphic Perspective on Nutrient Retention Following Dam Removal. *BioScience* 52:693-701.

Stanley, E. H., M.A. Luebke, M.W. Doyle, and D.W. Marshall (2002). Short-term changes in channel form and macroinvertebrate communities following low-head dam removal. *Journal of the North American Benthological Society* 21: 172-187.

St. Louis, V. I., C. A. Kelly, E. Duchemin, J. W. M. Rudd, and D. M. Rosenberg (2000). Reservoir Surfaces as Source of Greenhouse Gases to the Atmosphere: A Global Estimate. *Bioscience* 50:766-775.

[USACE] U.S. Army Corps of Engineers (2002). Guidance on Compensatory Mitigation Projects for Aquatic Resource Impacts Under the Corps Regulatory Program Pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. Regulatory Guidance Letter 01-2. December 2002.

USACE (2003b). Stream Mitigation Guidelines. Wilmington District, Regulatory Division. April 2003.

USACE (2004). Determining Appropriate Compensatory Mitigation Credit for Dam Removal Projects. Wilmington District, Regulatory Division. March 22, 2004.

USACE, Environmental Protection Agency, National Resources Conservation Service, US Fish and Wildlife Service, and National Marine Fisheries Service (1995). Federal Guidance for the Establishment, Use and Operation of Mitigation Banks. Federal Register 60: 58,605-58,614.

[USEPA] United States Environmental Protection, U.S. Army Corps of Engineers, Department of Agriculture, Department of Commerce, Department of Interior and Department of Transportation (2002). National Wetlands Mitigation Action Plan. Dec. 24, 2002.

USEPA and Department of the Army (1990). Memorandum of Agreement between the EPA and the Department of the Army Concerning the Determination of Mitigation Under the Clean Water Act Section 404(b)(1) Guidelines. February 6, 1990.

Vargo, B (2004). Dam removal benefits stream ecology. *Natural Ohio*, Ohio Department of Natural Resources, 27(1), 6.

Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems (Third Edition). Academic Press, New York, New York.

Williams, D. T. (1977). Effects of dam removal: an approach to sedimentation. Hydrologic Engineering Center Technical Paper No. 50. US Army Corps of Engineers, Davis, California.

Wohl, E. E. and D. A. Cenderelli (2000). Sediment Deposition and Transport Patterns Following a Reservoir Sediment Release. Water Resources Research 36: 319-333.

Yang, C. T. (1996). Sediment Transport Theory and Practice. The McGraw-Hill Companies, Inc. 396pp.

Appendix A

Survey Cover Letter and Contact List

Cover Letter

Dear Colleagues,

ICF Consulting is preparing a report entitled A Summary of Existing Research on Low-Head Dam Removal Projects for the Transportation Research Board's National Cooperative Highway Research Program (NCHRP). As part of our research, we have prepared a survey to fill data gaps related to dam removal in general and its application to environmental mitigation in particular. You have been identified as a professional who could potentially increase the body of knowledge related to dam removal.

Do you regulate or deal with low-head dams in any way? If so, we thank you in advance for taking time from your schedule to complete the survey in the Microsoft Excel file attached. If not, can you direct us to an authority that can better assist with this survey? Please feel free to forward them this message with the survey attached.

The survey has three parts:

Tab #1: Respondent Information – Seven entries for your contact information
Tab #2: Survey questions – Eight questions to fill specific knowledge gaps. For the first two questions, please enter your input under Tab #3. For the remaining six questions, please enter your response directly in the right-hand column of Tab #2.
Tab #3: Case Study Database – A case study database on dam removal projects for you to fill in gaps or add new case studies. Please keep the "track changes" feature on to facilitate the handling of the new information.

Please send the completed survey to the following address: fsilva@icfconsulting.com

Thank you again for your help in this important undertaking.

Additional information: For the subject study, we are inclined to adopt the definitions shown below. However, do not fail to include a project because of conflicts with the definitions adopted for the study. We prefer to make our survey more inclusive rather than exclusive.

> **Low-head dam**: A constructed barrier in a river with a hydraulic height (head water to tail water) not exceeding 25 feet. For the subject study, this definition encompasses run-of-river dams as well as other small dams but omits dams not built to create an impoundment in a river.

Run-of-river dam: A constructed barrier in a river where the river inflow normally overflows from behind the dam from one side of the waterway to the other. A run-of-river dam has limited short-term storage capacity.

Small dam: A constructed barrier in a river with a structural height not exceeding 50 feet. For the subject study, this definition omits dams not built to create an impoundment in a river.

We apologize for any duplicate e-mails.

Francisco Silva, Sc.D., P.E.
Senior Vice President
ICF Consulting
33 Hayden Avenue
Office 326
Lexington, Massachusetts
U.S.A. 02421-7918

+1-781-676-4087 Tel
+1-781-676-4066 Fax

fsilva@icfconsulting.com
www.icfconsulting.com

List of Contact Email Address

nsouthall@interfluve.com
richard.j.baugh@mvr02.usace.army.mil
Cynthia.J.Lester@usace.army.mil
bryan.r.cisar@usace.army.mil
Chief.Public-Affairs@usace.army.mil
mark.carnes@usace.army.mil
daniel.malanchuk@usace.army.mil
houston.l.hannafious@usace.army.mil
james.e.mace@usace.army.mil
william.r.jeffries@usace.army.mil
Kevin.D.Ewbank@usace.army.mil
Kathy.L.Higdon@usace.army.mil
larry.b.rosenberg@usace.army.mil
lrcregweb@usace.army.mil
michael.f.keegan@usace.army.mil
Mary.H.Glenn@usace.army.mil
sawweb-ralreg@usace.army.mil
sawweb-reg@usace.army.mil
sawweb-washreg@usace.army.mil
sawweb-wilmreg@usace.army.mil
Tracy.Hurst@usace.army.mil
carbina.resendez@seattle.gov
Michael.DiBara@state.ma.us
ramendra.dutta@ky.gov
MarilynC.Thomas@ky.gov
pao@spk.usace.army.mil
SiteManager@spk.usace.army.mil
Art.Coleman@epa.state.oh.us
Bsimmons@heinzctr.org
sdavid@heinzctr.org
Sweeney.Paul@epamail.epa.gov
ebyrd@kda.state.ks.us
H2omail@adem.state.al.us
brian.terhune@anr.state.vt.us
steve.bushman@anr.state.vt.us
Robert.H.Fulton@sad01.usace.army.mil
Sallie.McGuire@spl01.usace.army.mil
James.A.DeLapp@spl01.usace.army.mil
Kim.M.Gavigan@spl01.usace.army.mil
John.Keever@spl01.usace.army.mil
jibeck@state.mt.us
kkerbel@state.mt.us
flemik@dnr.state.wi.us
dam@dcr.virginia.gov
David.A.Pezza@hq02.usace.army.mil
Beverley.B.Getzen@ hq02.usace.army.mil
Mark.F.Sudol@ hq02.usace.army.mil
Charles.M.Pearre@HQ02.usace.army.mil
david.b.olson@hq02.usace.army.mil
dickerv@wes.army.mil
lazorb@wes.army.mil
Cheryl.L.Fromme@nao02.usace.army.mil
Mark.Pawlowski@ferc.gov
rmlent@usgs.gov
tvainfo@tva.com
dcum461@ecy.wa.gov
Dennis.E.Hughes@lrh01.usace.army.mil
Michael.Keathley@lrh01.usace.army.mil
Public.Affairs@lrh01.usace.army.mil
Mike.K.Black@swl02.usace.army.mil
wpsc401cert@dnr.mo.gov
Water.supply@state.tn.us
Dan.eagar@state.tn.us
robert.j.whiting@mvp02.usace.army.mil
john.j.bailen@mvp02.usace.army.mil
nanette.m.bischoff@mvp02.usace.army.mil
Joseph.H.Mose@mvp02.usace.army.mil
lvida@library.berkeley.edu
Andrew.Commer@swt03.usace.army.mil
regpagemaster@poa02.usace.army.mil
clevine@mt.gov
Dana.gauthier@dnr.state.mn.us
dclark@dem.state.in.us
pfreeman@tnc.org
robert.j.desista@nae02.usace.army.mil
dowinfo@gw.dec.state.ny.us
jeanne.christie@aswm.org
joseph.davia@nab02.usace.army.mil
water_inquiry@dnr.IN.gov
Charles_Karpowicz@nps.gov
iru@idahorivers.org
Rwtompkins1@tva.gov
macones@tva.gov
wlpoppe@tva.gov
Dann.White@state.mn.us
Dave.Allen@dnr.state.ia.us
deq-ead-env-assist@michigan.gov

suppnicj@michigan.gov
CDL-CEDSPMT@dms.usace.army.mil
Brenda_Duty@dec.state.ak.us
SSattert@kdhe.state.ks.us
seoleg@state.wy.us
Fischenich@erdc.usace.army.mil
william.m.myers@erdc.usace.army.mil
David.L.Derrick@erdc.usace.army.mil
Brian.J.Mulvenna@nap02.usace.army.mil
David.S.Biedenharn@erdc.usace.army.mil
Donald.C.Wilson@erdc.usace.army.mil
john.e.hite@erdc.usace.army.mil
Kathleen.D.White@erdc.usace.army.mil
Andrew.J.Bruzewicz@erdc.usace.army.mil
Robert.C.Gunkel@erdc.usace.army.mil
Robert.W.Lichvar@erdc.usace.army.mil
liscek.bonnie@epa.gov
mulder.kathy@epa.gov
wetlands.helpline@epa.gov
pbw@pwa-ltd.com
Beverley.H.Stout@sam.usace.army.mil
CESAM-PA@sam.usace.army.mil
CESAM-DE@sam.usace.army.mil
bruce.yurdin@epa.state.il.us
epa1132@epa.state.il.us
rscarney@state.pa.us
dkristine@state.pa.us
jim.alexander@dnr.mo.gov;
crbearden@owrb.state.ok.us;
dbenne@state.wy.us;
Lyle.Bentley@state.tn.us;
stephen.partney@dep.state.fl.us;
dedickey@state.pa.us;
john.a.falk@wrd.state.or.us;
ed_fiegle@mail.dnr.state.ga.us;
bob.finucane@state.vt.us;
dana.gauthier@dnr.state.mn.us;
wcjenkins@adwr.state.az.us;
djsd461@ecy.wa.gov;
meg.galloway@dnr.state.wi.us;
blong@wvdep.org;
pmauer@dnrmail.state.il.us;
Mike_Meadows@deq.state.ms.us;
Mike.Misslin@state.ma.us;
John.Moyle@dep.state.nj.us;
Dewey.Lima@dep.state.nj.us
mark.ogden@dnr.state.oh.us;
Keith.Banachowski@dnr.state.oh.us
paul.guglielmino@dem.ri.gov;
tim.schaal@state.sd.us;
alvin.simmons@mail.state.ar.us;
lsiroky@state.mt.us;
mrstanki@gw.dec.state.ny.us;
hvanaller@mde.state.md.us;
sverigin@water.ca.gov;
kesmith@dnr.state.in.us;
wes.marsh@po.state.ct.us;
epacheco@ose.state.nm.us;
robertm@water.nv.gov;
jack.byers@state.co.us;
wsamuels@tceq.state.tx.us;
jgallagher@des.state.nh.us;
hamiltod@michigan.gov;
max.fowler@ncmail.net;
charlesc@dnr.state.ak.us;
Tony.Fletcher@state.me.us;
edwin.y.matsuda@hawaii.gov;
bradlesm@dhec.sc.gov;
jfile@kda.state.ks.us;
dianna.sheesley@dcr.virginia.gov;
jboyle@state.nd.us;
kgoff@state.nd.us
M-Perez-DSAD@prepa.com;
BoBolourchi@dotd.state.la.us;
guy.paul@idwr.idaho.gov;
pdiederich@dnr.state.ne.us;
frank.piorko@state.de.us;
leslied@adeca.state.al.us
Brent.Trauger@saj02.usace.army.mil
Tatsuji.Hirata@usace.army.mil
donald.rostofer@dot.state.oh.us
Robert.E.Taylor@lrdor.usace.army.mil

Notes:
** = Responded with new information; and ** = Responded without new information.

Appendix B

Answers to Survey Questions and

Final List of Dam Removal Projects

Table B.1 Answers to survey questions.

#	Survey Questions	AL-USACE	AZ-Dept. of Water Resources	IL-Dep of Natural Resources	IN-Department of Natural Resources	KY-Division of Water	NC-Dept of Environment and Natural Resources
1	The worksheet "*Database for Your Input*" lists all the dam removal projects we have collected. However, we were unable to find much information. If you have information to bridge these knowledge gaps, please fill in as many blank or partially completed cells as possible, particularly for those projects with your name in column "AC." For ease of navigation, the projects have been sorted by state.	New data is included in Table B.2					
2	If you can, please **add any other dam removal projects** not listed on the sheet. Even partial information that could help us track down the information will help.						
3	What federal, state and local **permits/approvals** are required to conduct the dam removals which you have participated in? Please provide citations for applicable laws, statutes, regulations and/or codes, where possible.	Nationwide permits in lieu of water quality certification		Have never participated. State permit required Part 3702 IL Adm Code	We have not participated in dam removals in rivers. Permits/approvals are required for dam removals if the drainage area is greater than 1 square mile (Construction in a Floodway, Indiana Code 14-27-7).	NONE REQUIRED	If a dam is more than 15 feet in structural height and impounds more than ten acre-feet, OR is classified by the Department of Environment and Natural Resources as high hazard potential, a dam safety permit is required to breach it. The applicable statutes is NCGS 143-215 and NCAC 15A-2K.
4	Have you used or do you know any **regulatory guidelines specifically applicable to dam removal projects**? If so, please cite.	None specifically applicable.			No	NO	NCGS 143-215 and NCAC 15A-2K.
5	How do you or your organization define **low-head** dams?	Your organization's definition: Your own personal definition: A structure across a flowing waterbody that does not prevent the passage of water.	Your organization's definition: N/A Your own personal definition: N/A	Your organization's definition: None Your own personal definition:	Your organization's definition: Not defined by Rules. Dams with a structural height of less than 10 feet in rivers are generally considered low-head dams by our staff. Your own personal definition:	WE DON'T DISTINGUISH BETWEEN LOW DAMS AND OTHER DAMS.	Your organization's definition: The NC Dam Safety Program does not have a specific classification for low head dams. Your own personal definition:
6	Do you know of any dam removal projects that have qualified for **stream mitigation credits** to transportation agencies? If so, please provide project name and contact information. (Note: **Stream Mitigation Credit** refers to credits assigned to project owners to compensate for adverse impacts to the stream due to new construction.)	No	N/A	No	No	NO	No
7	Does your organization have **technical guidance documents** regarding which dams are good candidates for removal? If so, please provide reference(s).	No	N/A	No	No	NO	No
8	How does your organization handle the issue of land ownership for previously inundated lands that become accessible after the removal of the reservoir? Please provide references to any guidance documents.	Not applicable	N/A	Removal cannot change ownership in IL.	That would generally be considered by the owner.	WE DON'T	No

Table B.1 *Continued*.

#	Survey Questions	ND-State Water Commission	NH-Department of Environmental Services	NJ DEP, Dam Safety Section
1	The worksheet "*Database for Your Input*" lists all the dam removal projects we have collected. However, we were unable to find much information. If you have information to bridge these knowledge gaps, please fill in as many blank or partially completed cells as possible, particularly for those projects with your name in column "AC." For ease of navigation, the projects have been sorted by state.	New data is included in Table B.2		
2	If you can, please **add any other dam removal projects** not listed on the sheet. Even partial information that could help us track down the information will help.			
3	What federal, state and local **permits/approvals** are required to conduct the dam removals which you have participated in? Please provide citations for applicable laws, statutes, regulations and/or codes, where possible.	No permits are needed for dam removal. Approval is typically necessary from the dam owner(s) and any parties that hold water rights for the impounded water. However, section 61-03-21.2 of the North Dakota Century Code gives the State Engineer the authority to order the removal of any unsafe or unauthorized structure, in which case the approval of other parties is not required. Dam owners are advised to remove dams in a safe manner because they would potentially be liable for any damage downstream.	NHDES Wetlands permit with dam removal attachment, ACOE 404 permit, Section 106 Historical review,	State permit from NJ Dam Safety (part of NJDEP). New Jersey Dam Safety Standards, N.J.A.C. 7:20
4	Have you used or do you know any **regulatory guidelines specifically applicable to dam removal projects**? If so, please cite.	none	New Hampshire has completed a document titled, "Guidelines to Regulatory Requirements for Dam Removal Projects in New Hampshire" available on the NHDES website.	New Jersey Dam Safety Standards, N.J.A.C. 7:20 contains guidelines in connection with removal of dams
5	How do you or your organization define **low-head** dams?	Your organization's definition: run-of-river dams that span the entire stream or river and that raise the water level less than 10 to 15 feet (unofficial definition) Your own personal definition:	Your organization's definition: NHDES doesn't have a definition for low-head dams, however those that are less than 6 feet high and store less than 50 acre-feet of water can be considered non-menace dams depending on downstream hazards. Your own personal definition: Less than 6 feet high	Your organization's definition: Your own personal definition:
6	Do you know of any dam removal projects that have qualified for **stream mitigation credits** to transportation agencies? If so, please provide project name and contact information. (Note: **Stream Mitigation Credit** refers to credits assigned to project owners to compensate for adverse impacts to the stream due to new construction.)	none	The Homestead Woolen Mill Dam removal feasibility study used some of these funds. The funds were available for the West Henniker Dam removal but were not needed. An upcoming project will use these funds for removal of an earthen dam in exchange for filling wetlands for an airport.	No
7	Does your organization have **technical guidance documents** regarding which dams are good candidates for removal? If so, please provide reference(s).	none	A document was completed titled "Guidelines for Prioritizing Dam Removal Projects in New Hampshire" This document is not available on the NHDES website.	No
8	How does your organization handle the issue of land ownership for previously inundated lands that become accessible after the removal of the reservoir? Please provide references to any guidance documents.	Whoever owns the inundated land would retain ownership of the land after removal of the reservoir. In some cases, easements were granted to the state for the construction, operation, and maintenance of dams. Section 61-02-14.1 of the ND Century Code allows the state to release such easements if the dam is determined to no longer be useful.	Abutters of impoundments, created by the run of the river dams, that become drained gain land to the thread of the stream. Flowage rights can complicate the issue. Head of the tide dams have to be treated on a case by case basis. If the high tide mark extends into the former impoundment following a dam removal, the State will own to the high tide mark. Contact DES land agent for more specifics at 603-271-3406.	No specific guidelines

Table B.1 *Continued*.

#	Survey Questions	NY-USACE	OH-EPA	OH-ODOT	OK-USACE
1	The worksheet "*Database for Your Input*" lists all the dam removal projects we have collected. However, we were unable to find much information. If you have information to bridge these knowledge gaps, please fill in as many blank or partially completed cells as possible, particularly for those projects with your name in column "AC." For ease of navigation, the projects have been sorted by state.	New data is included in Table B.2			
2	If you can, please **add any other dam removal projects** not listed on the sheet. Even partial information that could help us track down the information will help.				
3	What federal, state and local **permits/approvals** are required to conduct the dam removals which you have participated in? Please provide citations for applicable laws, statutes, regulations and/or codes, where possible.	NYSDEC SEQR, Dam Safety and Stream Encroachment permits	No 401 certification unless discharge or fill involved.	404; 401; ODNR, Scenic Rivers Approval; ODNR,Division of Wildlife; ODNR, Division of Water (Dam Safety); FEMA; and USFWS	Section 404 Clean Water Act Permits 33 USC 1344, USACE
4	Have you used or do you know any **regulatory guidelines specifically applicable to dam removal projects**? If so, please cite.	None	See above.	OEPA's Draft "Compensatory Mitigation for Stream Impacts"	No.
5	How do you or your organization define **low-head** dams?	Your organization's definition: Height of dam above d/s water surface "It would be height of dam (and maximum impounded water surface elevation) above water surface elevation immediately downstream of the dam – in this case – 10' maximum. I believe the Corps uses 10' up to 40' for the low head definition, above 40' being high head. " Your own personal definition: same	Ohio EPA. We do not have a formal definition. Check with ODNR for there definition.	Your organization's definition: ODOT shares the same definition as ODNR, Division of Water. Your own personal definition: I think the above definition is reasonable.	Your organization's definition: Your own personal definition: Low height dam for which impoundment effects are limited to the river channel - does not impound water into the flood plain
6	Do you know of any dam removal projects that have qualified for **stream mitigation credits** to transportation agencies? If so, please provide project name and contact information. (Note: **Stream Mitigation Credit** refers to credits assigned to project owners to compensate for adverse impacts to the stream due to new construction.)	Not aware of any	The St. John's Dam (Sandusky River) was used by ODOT for stream mitigation. For details, check with Don Rostofer, ODOT, (614) 387-3057. ODOT also is pursuing other low-head dam removal projects for mitigation (e.g. Lover's Dam on Mahoning River).	Yes, ODOT has negotiated with the OEPA and USACE for the use of dam removals for stream mitigation credit. They are the St. John's Dam, Lover's Lane Dam and North River Road Dam.(see Database page for details)	No.
7	Does your organization have **technical guidance documents** regarding which dams are good candidates for removal? If so, please provide reference(s).	Not aware of any	No.	Yes, We work closely with the ODNR to establish those dams that should be removed.	Not to my knowledge.
8	How does your organization handle the issue of land ownership for previously inundated lands that become accessible after the removal of the reservoir? Please provide references to any guidance documents.	Have not had a dam removal where that has been an issue. Ownership remains same whether flowed or not.	We have not discussed this issue.	ODOT has to produce NEPA documents for all dam removals because we use federal funds. During the NEPA process ODOT must include public involvement. This is achieved by working with sponsors to get input from the local communities and adjacent property owners.	Not applicable.

Table B.1 *Continued*.

#	Survey Questions	PA-Fish and Boat Commission	RI-Department of Environmental Management	TN-Department of Environment and Conservaion	TX-TX Commission of Env Quality	WA-State Dam safety
1	The worksheet "*Database for Your Input*" lists all the dam removal projects we have collected. However, we were unable to find much information. If you have information to bridge these knowledge gaps, please fill in as many blank or partially completed cells as possible, particularly for those projects with your name in column "AC." For ease of navigation, the projects have been sorted by state.	New data is included in Table B.2				
2	If you can, please **add any other dam removal projects** not listed on the sheet. Even partial information that could help us track down the information will help.					
3	What federal, state and local **permits/approvals** are required to conduct the dam removals which you have participated in? Please provide citations for applicable laws, statutes, regulations and/or codes, where possible.	federal-Section 404 of Clean Water Act as amended, Section 10 of River and Harbor Act, PA State Programmatic General Permit. State: waiver provision of Title 25, Section 105.12(a)(1) of the Pennsylvania Code (DEP), Drawdown Permit (PFBC), Erosion and Sediment Control Plan (County).		Removal would require a state Aquatic Resource Alteration Permit under the Tennessee Water Quality Control ACT and The Rules of the Water Quality Control Board Chapter 1200-4-7	State approval is required to remove a dam. See 30 Texas Administrative Code Chapter 299, §299.51.	Federal - USACE 404 and/or 404 permits, State - Dam Construction Permit/approval (RCW90.03.350 and WAC 173-175) for other permits, visit our web page at http://www.ecy.wa.gov/pubs/9255b.pdf (pages 5 through 8)
4	Have you used or do you know any **regulatory guidelines specifically applicable to dam removal projects**? If so, please cite.	covered under above	No.	Dam removal activities cannot result in violation of state water quality criteria (not specific to dam removal, but applicable to all activities requiring a permit).	We have no regulatory guidelines for dam removal other than the rule given above.	No
5	How do you or your organization define **low-head** dams?	Your organization's definition: Your own personal definition:	None.	Your organization's definition: Your own personal definition:	We have no definition for low-head dam in the rules.	Your organization's definition: we don't have a "low-head" definition. We do define a "small Dam" as being < 15 feet high Your own personal definition: same as a "small dam"
6	Do you know of any dam removal projects that have qualified for **stream mitigation credits** to transportation agencies? If so, please provide project name and contact information. (Note: **Stream Mitigation Credit** refers to credits assigned to project owners to compensate for adverse impacts to the stream due to new construction.)		No.	No, but construction of new impoundments is an activity that, if permitted, requires compensatory mitigation. Dam removal would be one of a variety of mitigation measures to offset a permitted loss of water resource value.	I do not know of any removal projects that qualified for a stream mitigation credit.	NO
7	Does your organization have **technical guidance documents** regarding which dams are good candidates for removal? If so, please provide reference(s).	Project Selection Protocol and Guidelines for Pennsylvania Fish And Boat Commission Consultation and Grant Program for Fish Passage and Habitat Restoration	No.	No.	We have no guidance documents regarding dams that may be a candidate for removal.	NO
8	How does your organization handle the issue of land ownership for previously inundated lands that become accessible after the removal of the reservoir? Please provide references to any guidance documents.		Has not come up, to my knowledge.	N/A	We have not addressed ownership of the reservoir area.	NO

This page is intentionally left blank.

Table B.2 Final list of dam removal projects.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**		**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
AK	Unnamed Dam	Allison Creek	2004					6		30			1970	Gravel				Stream Gauging	
AK	Davidson Ditch Diversion Dam	Chatanika River	2002										1920s	Concrete butress					
AK	Switzer One Dam	Switzer Creek (trib.)	1988					15											
AK	Switzer Two Dam	Switzer Creek (trib.)	1988					15											
AL	Marvel Slab	Cahaba River	2004	216,000	105,000	Federal, Other	Removed	7	5	210		State government	1965	Concrete		Non-regulated	Yes	Other	Other
AR	Lake St. Francis Dam	Crow Creek	1989					45											
AR	Mansfield Dam	Coop Creek						19											
AR	Winton Spring Dam	Unknown						4											
AR	Hot Springs Park Ricks Lower #1 Dam	Unknown	1986					11											
AZ	Golder Dam	Canada del Oro	1980																
AZ	Concrete Dam	Walsh Canyon	1982					39											
AZ	Perrin Dam	Walsh Canyon	1980			Owner	Breached	32				Local government		Earth fill	High	State	Yes	Water Supply	
CA	York Creek Diversion Structure	York Creek	2004											Concrete masonry				Diversion	
CA	A-Frame Dam	Brandy Creek	2003					30		100			1950s	Earth				Recreation	
CA	Haypress Pond Dam	Haypress Pond	2003					20						Earth				Watering stock	
CA	Cascade Diversion Dam	Merced River	2003					18		184			1916	Timber crib				Supply power	
CA	Unnamed Dam	Murphy Creek	2003	700,000				12						Earth				Watering hole	
CA	Mumford Dam	Russian River	2003							60									
CA	East Panther Creek Dam	East Panther Creek	2003									Pacific Gas & Electric							

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
		E$		Restore creek's ecological integrity by restoring free movement of fish and other aquatic organisms				Meagan Boltwood, Anchorage Waterways Council, (907) 743-1052, Meagan@awcgroup.org.	
		F		Open upstream habitat to fisheries; Increase recreational opportunities				Mike Roy, U.S. Fish and Wildlife Service, (907) 786-3825, Michael_Roy@fws.gov	
Good	Unregulated	E	Aesthetics	Expands the potential range of fish; Increases habitat;	None	No	Yes		The Nature Conservancy partnered the project. TNC proposes future monitoring.
									Verified by Pohl and not included in database.
									DATA LACKING. Need measurements and removal verification.
									Verified by Pohl and not included in database.
		S							
		S							
Poor	No	S						Bill Jenkins, AZ Dept of Water Resources, (602) 417-2445, WCJenkins@azwater.gov	
				Open 2.5 miles of high-quality shaded habitat for steelhead and native rainbow trout; Increase delivery of spawning-sized gravel to lower York Creek and the Napa River				Steve Rothert, American Rivers, (530) 478-5672, srothert@americanrivers.org	
		E$S						Jerry Wheeler, National Park Service, (530) 242-3430, jerry_wheeler@nps.gov	
		E						Darren Fong, Golden Gate National Recreation Area, (415) 331-8716, Darren_Fong@nps.gov	
		$		Restore the river				Steve Evans, Friends of the Rivers, (916) 442-3155, sevans@friendsoftheriver.org	
		E						John Brody, Natural Resources Conservation Service, (209) 327-2823	
				Restore approximately 720 feet of stream channel below Dam; Provide fish passage				Ron Benkert, Sonoma County Water Agency, (707) 547-1905, rcb@scwa.ca.gov	Partial removal
				Restore natural flow patterns				Pete Bell, Foothills Conservancy, 209-296-5734	Partial removal and removal of the remaining structure scheduled for 2008

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
CA	West Panther Creek Dam	West Panther Creek	2003					16				Pacific Gas & Electric	1930s					Hydropower	
CA	Crocker Creek Dam	Crocker Creek	2002	460,000				30		80			1904	Concrete				Recreation	
CA	Unnamed Arizona Crossing	Solstice Creek	2002																
CA	Unnamed Dam	Ferrari Creek	2002					5						Earth					
CA	North Debris Dam	Unnamed Tributary to the LA River	2002					20						Earth				Catch debris	
CA	Trancas Debris Dam	Unnamed Tributary to Trancas Canyon	2002					15						Steel & timber				Debris control	
CA	Two Swim Dams	Alameda Creek	2001																
CA	McCormick-Saeltzer Dam	Clear Creek	2000					18		60									
CA	D.B. Fields/Johnson Dam	Indian Creek	1946															Mining	
CA	Henry Danninbrink	Canyon Creek	1927															Mining	
CA	Moser Dam	Swillup Creek	1949															Mining	
CA	Three C. Picket Dam	Beaver Creek	1949																
CA	Trout Haven Dam	Monkey Creek																	
CA	unnamed dam (1)	Guadalupe River	1998	317,140		Federal, State, Other													
CA	unnamed dam (2)	Guadalupe River	1998	317,140		Federal, State, Other													
CA	Red Hill Mining Co. Dam	Canyon Creek	1951					30										Mining	

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
				Restore natural flow patterns; Open additional habitat for trout ; Allow sediment to more naturally disperse throughout the system				Pete Bell, Foothills Conservancy, 209-296-5735	
		$		Opened 2 miles of habitat for chinook and steelhead				Ron Benkert, Sonoma County Water Agency, (707) 547-1905, rcb@scwa.ca.gov	
		E						Charles Karpowicz, National Park Service, (202) 513-7022, charles_karpowicz@nps.gov	
				Fish have returned; Vegetation has reestablished itself				Katherine Elliot, Trust for Public Land, (415) 495-5660	
		$						Charles Karpowicz, National Park Service, (202) 513-7022, charles_karpowicz@nps.gov	
								Charles Karpowicz, National Park Service, (202) 513-7022, charles_karpowicz@nps.gov	
								Pete Alexander, East Bay Regional Park District, (510) 635-0135 ext. 2342	
				Opened 12 miles of spawning habitat to threatened salmon and steelhead, providing enough habitat to produce an additional 2,000 fish of each species per year				Steve Evans, Friends of the River, (916) 442- 3155, sevans@friendsoftheriver.org. http://www.friendsoftheriver.org/riversreborn/clear.html	
									DATA LACKING. Dam removed (CA Dept Water Resources). Need measurements.
									DATA LACKING. Dam removed (CA Dept Water Resources). Need measurements.
									DATA LACKING. Dam removed (CA Dept Water Resources). Need measurements.
									DATA LACKING. Dam removed (CA Dept Water Resources). Need measurements.
									DATA LACKING. Need measurements and removal verification. Article from the San Jose Mercury News (9/28/98) Authorities Will Dismantle Fish Barriers on San Jose, Calif., River By Frank Sweeney
									DATA LACKING. Need measurements and removal verification. Article from the San Jose Mercury News (9/28/98) in files Authorities Will Dismantle Fish Barriers on San Jose, Calif., River By Frank Sweeney

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
CA	Lone Jack Dam	Trinity River (East Fork of North Fork)						24										Mining	
CA	Anderline Dam	Rush Creek	1936					20										Mining	
CA	Clarissa V. Mining Dam	Redding Creek	1950					20										Mining	
CA	Minnie Reeves Dam	Indian Creek						20										Mining	
CA	North Fork Placers Dam	Trinity River (North Fork)	1950					15										Mining	
CA	McCormick-Saeltzer Dam	Clear Creek	2000					15		150			1902-1912					Irrigation	
CA	Big Creek Mfg. Dam	Big Creek						14											
CA	Quinn Dam	Trinity River (East Fork of North Fork)	1951					14										Mining	
CA	Todd Dam	Trinity River (East Fork of North Fork)	1949					14										Mining	
CA	Altoona Dam	Kidder Creek	1947					12		60								Mining	
CA	Barton Dam	Scott River (South Fork)	1950					12		25									
CA	Big Nugget Mine Dam	Horse Creek	1949					12		40								Mining	
CA	McPherrin Dam	Butte Creek	1998	9,500,000				12				McPherrin family						Irrigation	
CA	Bonally Mining Co. Dam	Salmon River (North Fork)	1946					11		177								Mining	
CA	Russel/Hinkley Dam	Hayfork Creek	1922					11											
CA	Bennett-Smith Dam	Salmon River (South Fork)	1950					10											
CA	Hessellwood Dam	Hayfork Creek	1925					10											
CA	Salt Creek Dam	Salt Creek						10											
CA	Trinity Cty. Water & Power Co. Dam	Trinity River (East Fork)	1946					10										Water Supply	
CA	Western Canal East Dam	Butte Creek	1998					10										Irrigation	
CA	Smith Dam	White's Gulch	1949					8		25								Mining	
CA	Upper Dam	Lost Man Creek	1989	29,000				7		57			1936					Water Storage	
CA	D.B. Fields Dam	Indian Creek	1947					6										Mining	
CA	McGowan Dam	Butte Creek	1998					6										Irrigation	
CA	Point Four Dam	Butte Creek	1993					6										Irrigation	
CA	Unnamed Dam #1	Wildcat Creek	1992					6											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
								sevans@friendsoftheriver.org	Verified by Ashley and included in database.
		E							
		E							
		E							
		E							
									Verified by Pohl and not included in database.
		E							
		E							

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
CA	Unnamed Dam #2	Wildcat Creek	1992					6											
CA	Rock Creek Dam	Rock Creek	1985					12		63		Pacific Gas & Electric Co.	1925	Concrete Gravity				Diversion	
CA	John Muir #1 Dam	Unknown																	
CA	Rogers Dam	Unknown	1983					40											
CA	Hagmmaier North Dam	Unknown						30											
CA	Upper Murphy Dam	Unknown						25											
CA	Bear Valley Dam	Unknown	1982					15											
CA	Arco Pond Dam	Unknown						10											
CA	Happy Isles Dam	Unknown	1987					8											
CA	Lower Murphy Dam	Unknown						6											
CA	Lake Christopher Dam	Cold Creek	1994	80,000				10		400		City of South Lake Tahoe	1950s	Earth				Irrigation	
CO	Two Unnamed Dams	Unnamed Tributary to the Platt River	2002																
CO	Unnamed Dam #21	Unknown	1990																
CO	Pear Lake Dam	Cony Creek	1988					28											
CO	Sand Beach Dam	Sand Beach Creek	1988					25											
CO	Unnamed Dam #15	Unknown						15											
CO	Unnamed Dam #17	Unknown						15											
CO	Unnamed Dam #22	Unknown						15											
CO	Unnamed Dam #8	Unknown	1990					12											
CO	Glacier #1Dam	Unknown	1985					11											
CT	Chase Brass Dam	Naugatuck River	2004					4		100			~1900 ?	Timber crib				Water supply	
CT	Baltic Mills Dam	Shetucket River	1938					26											
CT	John Dee's Dam	Mad River						17		45		Homart, Inc.	~1900						
CT	Woodings Pond Dam	Qunnipiac River (trib.)	1971					15											
CT	Indian Lake Dam	Indian River	1994					12											
CT	Lower Pond Dam	Cedar Swamp Brook	1991					12											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
		E							
								sevans@friendsoftheriver.org	
									DATA LACKING. Dam removed (CA Dept Water Resources). Need measurements.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
		E						Charles Karpowicz, National Park Service, (202) 513-7022, charles_karpowicz@nps.gov	
									DATA LACKING. Need measurements and removal verification.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
		S		Provide access to historic spawning habitat for several migratory fish species; Improve water quality				Ray Spry, Waterbury's Water Pollution Control Facility, 203-753-0217	
		F							
								rick.jacobson@po.state.ct.us	
		$							
		$							

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
CT	Turner & Seymour Dam	Gulf Stream	2000					12											
CT	Anaconda Dam	Naugatuck River	1999					11		330		Waterbury House Wrecking	~1800						
CT	Unnamed Dam	Bradley Brook	1993					11											
CT	Little Pond Dam	Bigelow Creek (trib.)	1994					10											
CT	Platts Mills Dam	Naugatuck River	1999					10		231		Platts Brothers and Co.	~1800						
CT	Sprucedale Water Dam	Mill Brook	1980					10											
CT	Muddy Pond Dam	Muddy Brook	1992					8											
CT	Simpson's Pond Dam	Wharton Brook	1995					8											
CT	Frost Road Pond Dam	Mad River (trib.)	1983					7											
CT	Paradise Lake Dam	Blackwell Brook (trib.)	1991					6											
CT	Freight Street Dam	Naugatuck River	1999					2		158		City of Waterbury	~1930						
CT	Union City Dam	Naugatuck River	1999					16		200	120	NID - unknown; Borough of Naugatuck	1860	Concrete Gravity				Recreation	
DC	Unnamed Ford	Rock Creek	2004					3				Smithsonian National Zoological Park							
DC	Unnamed Ford	Rock Creek	2003					3.5				Smithsonian National Zoological Park							
DC	Ford Dam #3	Rock Creek	1991																
DC	Millrace Dam	Rock Creek						18											
FL	Dam and Lock	Kissimmee River	2000																
FL	Wysong Dam	Withlacoochee River	1988					3					1963						
FL	Dead Lakes Dam	Chipola River	1987	32,000				22		820	34800	Dead Lakes Water Management	1962	Other Gravity				Recreation	Fire Protection /Farm Pond
FL	Pace's Dike Dam	Unknown	1991					6											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
									DATA LACKING. Need measurements and removal verification.
		E						rick.jacobson@po.state.ct.us	An ice dam caused a breach in the dam which in turn caused the City of Waterbury to remove the rest of the dam. The dam was one of 5 dams scheduled to be removed on the Naugatuck. Information obtained from Rivers Alliance Newsletter (2/17/99)
		S							
		U							
		E						rick.jacobson@po.state.ct.us	
		S							
		$							
		S							
		$							
		E						rick.jacobson@po.state.ct.us	
		E						rick.jacobson@po.state.ct.us	
		E		Open additional habitat for alewife, blueback herring, and American eel				Serena McClain, American Rivers, (202) 347-7550, smcclain@americanrivers.org	
		E		Open additional habitat for alewife, blueback herring, and American eel				Serena McClain, American Rivers, (202) 347-7550, smcclain@americanrivers.org	
				Reconnected and restored 14 miles of natural meandering river channel; Allowed water to overflow on the floodplain, amplifying wetlands				Lou Toth, South Florida Water Management District, (561) 682-6615. http://www.sfwmd.gov/org/erd/krr/index.html	
		$							Dam rebuilt in 2002.
		E							1990-93 Apalachicola River Watershed Investigation
									Verified by Pohl and not included in database.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
GA	Hamilton Mill Lake Dam	Wahoo Creek																	
ID	Buster Lake Dam	Garden Creek																	
ID	Colburn Mill Pond Dam	Colburn Creek	1999	30,000				12		35									
ID	Dip Creek Dam	Dip Creek																	
ID	Kashmitter Dam	John Day Creek-TR	1988																
ID	Kunkel Dam	Soldier Creek	1994																
ID	Lane Dam	Elkhorn Gulch																	
ID	Malony Lake Dam	Lake Fork Creek	1986																
ID	Packsaddle Dam	Packsaddle Creek																	
ID	Skein Lake Dam	Skein Lake	1980																
ID	Sunbeam Dam	Salmon River	1931										1910						
ID	Timber Creek Dam	Little Timber Creek	1970																
ID	Lewiston Dam	Clearwater River	1973	633,428				45		1060		Washington Water Power	1927					Hydropower	
IL	Hofmann Dam	Des Plaines River	2004					8		250				Concrete	Medium	State	Yes	Recreation	
IL	Fairbanks Road Dam	Des Plaines River	2004					2		158				Concrete			Yes		
IL	Armitage Avenue Dam	Des Plaines River	2004					5		115				Concrete			Yes		
IL	South Batavia Dam	Fox River	2004					7		700		Kane County Forest Preserve District	1917	Timber crib	Low	State	Yes	Electrical Power Generation	

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
									DATA LACKING. Need removal verification and measurements.
		E							
		U							DATA LACKING. Need removal verification and measurements.
									Verified by Pohl and not included in database.
		E							
									DATA LACKING. Dam removed by US F&W. Need measurements. Sent e-mail to bbowler@idahorivers.org. Located north of Stanley about 20 miles, the Sunbeam Dam was built in 1910 across the Salmon River.
									DATA LACKING. Need removal verification and measurements.
		E							
	Yes	E		Improve water quality; Open habitat for northern pike, smallmouth bass, and walleye; Eliminate safety hazards and obstructions to recreational boating				Jenni Reichard, U.S. Army Corps of Engineers, Chicago District, (312) 846-5562	
		E		Improve water quality; Open habitat for northern pike, smallmouth bass, and walleye; Eliminate safety hazards and obstructions to recreational boating				Jenni Reichard, U.S. Army Corps of Engineers, Chicago District, (312) 846-5563	
		E		Improve water quality; Open habitat for northern pike, smallmouth bass, and walleye; Eliminate safety hazards and obstructions to recreational boating				Jenni Reichard, U.S. Army Corps of Engineers, Chicago District, (312) 846-5564	
	No	EF		Eliminate safety hazards; Provide fish passage				Drew Ullberg, Kane County Forest Preserve, (630) 232-5980	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
IL	YWCA Dam	Brewster Creek (Tributary to Fox River)	2004									YWCA Camp Tu-Endie-Wei		Concrete	Low	State	No	Recreation	
IL	Garden Forest Pond Dam	Wolf Branch-TR												Earth fill		State	No		
IL	Lake Marion Dam	Delta Creek	1982											Earth fill	High	State	No		
IL	Turkey Bluff Dam	Mississippi River (trib.)						43						Earth fill	Medium	State	No		
IL	Peabody #5 Dam	Cypress Ditch (trib.)						42						Earth fill	Low	State	No	Mining	
IL	Faries Park Dredge Disposal Dam	Sangamon River (trib.)						29						Earth fill	High	State	No	Derdge Disp.	
IL	Old Ben Dam	Ewing Creek (trib.)						29						Earth fill	Low	State	No	Mining	
IL	Springfield Dam	Sugar Creek (trib.)	1989					25						Earth fill	High	State	No	Mining	
IL	Peabody #1A Dam	Cypress Ditch (trib.)						24						Earth fill	Low	State	No	Derdge Disp.	
IL	Paradise Lake Dam	Wood River (trib.)						20						Earth fill	High	State	No		
IL	Consol/Burning Star 5/20 Dam	Little Muddy River (trib.)						18						Earth fill	Medium	State	No	Mining	
IL	Olsens Lake Dam	Sevenmile Branch						17						Earth fill	Medium	State	No	Sediment	
IL	Lake Adelpha Dam	Negro Creek (trib.)	1990					15						Earth fill	Medium	State	No	Mining	
IL	Woodhaven North Impoundment Dam	Unknown	1992					12						Earth fill	High	State	No	Derdge Disp.	
IL	Amax Delta Basin 31 Dam	Brush Creek (trib.)						11						Earth fill	Medium	State	No	Mining	
IL	Woodhaven South Impoundment Dam	Unknown	1992					11						Earth fill	High	State	No	Derdge Disp.	
IL	Stone Gate Dam	Waubonsie Creek	1999		130,000	Federal, State		4		100				Concrete		State	No		
IN	Pinhook Dam	Unknown						15											
IN	Flat Rock River Dam #2	Flatrock	1997				Removed	8		140		Local government		Concrete	Low	State	Yes	Old Mill Dam	
IN	Weekly Camp Dam	Flatrock	1997				Breached	2		60		Local government		Boulder/Rock	Low	State	Yes	Old Mill Dam	
KS	Kansas Gas & Electric Dam																		
KS	Robert Yonally Dam																		

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
	No	$S						Karen Kosky, Kane County Department of Environmental Management, (630) 208-8665 or Steve Pescitelli, Illinois Department of Natural Resources, (630) 553-0164, spescitelli@dnrmail.state.il.us	
	No	S							DATA LACKING. Need removal verification and measurements.
	No	S							DATA LACKING. Need removal verification and measurements.
		S							
	Yes	$							
	Yes	$							Rebuilt in 2004
	Yes	$							
	Yes	$							
	Yes	$							
	No	S							
	Yes	$							
	No	O							
	No	$							
	Yes	$							
	Yes	$							
	Yes	$							
		EFS							
									No Records available
Good		E		to reduce the flood damage on the adjacent farm lands	CWA404 & 401			Wilbur Hoeing, Project Steering Committee, 3787 West 415 South, Rushville, IN 46173	Robert Downy, 609 North Hickory, Kokomo, IN 4690, Data needs to be verified!
Failed		E		to reduce the flood damage on the adjacent farm lands	CWA404 & 401			Wilbur Hoeing, Project Steering Committee, 3787 West 415 South, Rushville, IN 46173	Data provided needs to be verified!
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
KS	Chapman Lake Dam	Unknown						38											
KS	City of Wellington Dam	Unknown						36											
KS	Edwin K. Simpson Dam	Unknown						25											
KS	Moline Middle City Lake Dam	Unknown						21											
KS	Mott Dam	Unknown						21											
KS	Soldier Lake Dam	Unknown						14											
KY	Ebenezer Lake Dam	Pond Creek (trib.)						15		515		Industrial/Utility				surface mining	No	Other	
KY	Unnamed #1 Dam	Great Onyx Pond	1982					5								Non-regulated			
KY	Unnamed #2 Dam	Great Onyx Pond	1982					5								Non-regulated			
KY	Sharpsburgh Reservoir Dam	Little Flat Creek	1985					35											
KY	West Fork Pond River #2 Dam	Pond River						16											
LA	Kisathie Lake Dam	Dry Pong Creek						25											
LA	Bayou Dupont #13 Dam	Bayou Dupont (trib.)						23											
LA	Castor Lake Dam	Pond Branch						10											
LA	Shirley Willis Pond Dam	Bayou Dorcheat						10											
MA	Silk Mill Dam	Yokum Brook	2003					15						Concrete				Power	
MA	Billington Street Dam	Town Brook	2002											Earth					
MA	Old Berkshire Dam	Housatonic River (East Branch)	2000			Owner		15		120	10	Crane & Company	1915	Gravity				Water Supply (inactive)	
MD	Octoraro Rubble Dam	Octoraro Creek	2004																
MD	Bishopville Pond Dam	St. Martin River	2004					4				Maryland Department of Transportatio		Steel pile					
MD	Polly Pond Dam	Big Run	2002					25					Earth					Part of a canal waste weir	
MD	Bacon Ridge Branch Weir	Bacon Ridge Branch	1991																

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
								Thomas, Marilyn (EPPC DEP DOW) [MarilynC.Thomas@ky.gov]	
								Thomas, Marilyn (EPPC DEP DOW) [MarilynC.Thomas@ky.gov]	DATA LACKING. Need removal verification and measurements.
								Thomas, Marilyn (EPPC DEP DOW) [MarilynC.Thomas@ky.gov]	DATA LACKING. Need removal verification and measurements.
		E		Benefit resident and migratory fish populations (Atlantic salmon)				Karen Pelto, Massachusetts Riverways Program, (617) 626-1542, karen.pelto@state.ma.us	
		E		Restored migration of fisheries				Karen Pelto, Massachusetts Riverways Program, (617) 626-1542, karen.pelto@state.ma.us. http://www.state.ma.us/dfwele/River/riv_toc.htm	
								Karen Pelto, Massachusetts Riverways Program, (617) 626-1542, karen.pelto@state.ma.us. http://www.state.ma.us/dfwele/River/pdf/rivWinsert.pdf	
		E		Provide fish passage				Sara Nicholas, American Rivers, (717) 232-8355, snicholas@amrivers.org	
		E		Restore the original stream channel				Kevin Smith, Maryland Department of Natural Resources, (410) 260-8797, kmsmith@dnr.state.md.us	
		$						Charles Karpowicz, National Park Service, (202) 513-7022, charles_karpowicz@nps.gov	
									DATA LACKING. Need removal verification and measurements.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
MD	Boy Scout Dam	Octoraro Creek	1998																
MD	Deep Run Dam	Deep Run	1989																
MD	Horsepen Branch Dam	Horsepen Branch	1995																
MD	Route 214 Dam	Western Branch	1998																
MD	Stony Run Dam	Stony Run	1990																
MD	Railroad Trestle dam	Dorsey Run	1994																
MD	Railroad Bridge at Elkton Dam	Little Elk Creek	1992																
ME	Gardiner Paper Mill Dam	Tributary to Kennebec River	2004	110,000				10		200								Hydropower & Water supply	
ME	Saco Falls Dam	Pleasant River	2004										1926					Hydropower	
ME	Main Street Dam	Sebasticook River	2002																
ME	Sennebec Dam	St. George River	2002					15		240								Hydropower	
ME	Smelt Hill	Presumpscot River	2002	1,017,000	311,000	Federal, State	removed	15		151		Industrial/Utility	1732; reconstructed in 1898	Timber crib & concrete	Low	Federal	Yes	Mechanical Power Generation	Electrical Power Generation
ME	East Machias Dam	East Machias River	2000					16		50			1926						
ME	Bangor Dam	Penobscot River	1995								7000	City of Bangor	1875	Concrete Timber Crib Gravity				Water Storage	Fire Protection/Farm Pond
ME	Canaan Lake Outlet Dam	Machias River	1999																
ME	Columbia Falls Dam	Pleasant River	1998	30,000				9		350									
ME	East Machias Dam	East Machias River	2000																
ME	Souadabscook Falls Dam	Souadabscook Stream	1998	56,000				14		150									

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
									Verified by Pohl and not included in database.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
		E$S		Reduce liability; Improve safety; Restore impounded habitat; Restore fish passage				Doug Watts, Friends of the Kennebec Salmon, 207-626-8178, fks@gwi.net	
		E		Enhance fish passage; Restore impounded habitat				Jed Wright, USFWS Gulf of Maine Program, (207) 781-8364	
				Fish passage and riverine habitat were restored for alewife on the Sebasticook River				Jeff Reardon, Trout Unlimited, (207) 623-1470, jreardon@tu.org or Tom Squiers, Maine Department of Marine Resources, (207) 624-6348, tom.squires@maine.gov	
		E$		Restore fish passage Maintain lake levels				David Glasser, Sennebec Pond Association, at (207) 236-8330, agavedave@msn.com; Jeff Reardon, Trout Unlimited, (207) 373-0700, jreardon@tu.org ; or Laura Wildman, American Rivers, (860) 652-9911, lwildman@americanrivers.org	
Good		E	Aesthetics	Restore the lower portion of the Presumpscot, creating habitat for river herring, striped bass, smelt, and American eel and opening passage for other migratory fish	CWA404 & 401	No	No	Dusti Faucher, Friends of the Presumpscot, (207) 892-8281, coveredbridge45@mindspring.com; Larry Oliver, U.S. Army Corps of Engineers; 978-318-8347; lawrence.r.oliver@usace.army.mil	
		ERS						Dwayne Shaw, Downeast Salmon Foundation, (207) 483-4336. http://www.mainesalmonrivers.org/east_machias/home.html	
									DATA LACKING. Dam was removed (http://www.nefsc.noaa.gov/USASAC/2002%20USASAC%20Report/atsasscom.pdf). Need measurements.
									DATA LACKING. Need removal verification and measurements.
		$							

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
ME	Archer's Mill Dam	Stetson Stream	1999	13,000				12		50									
ME	Brownville Dam	Pleasant River	1999	78,000				12		300									
ME	Hampden Recreation Area Dam	Souadabscook Stream	1999					2										Recreation	
ME	Edwards Dam	Kennebec River	1999	2,100,000				24		917	16985	Edwards Manufacturing Co.	1837	Timber Crib Rockfill Gravity				Hydropower	
ME	Grist Mill Dam	Souadabscook Stream	1998	56,000				14		75	58	Maine Energy Partners	1920	Earth Concrete Stone				Hydropower	
MI	Charlotte City Dam	Battle Creek River	2005	180,100				8					1903	Earth				Recreation	
MI	Elm Street Dam	Battle Creek River	2004					13.5		100			1920s	Sheet Pile				Maintain water level for cooling	
MI	Marquette City Dam #1	Dead River	2004	200,000				10		200		Marquette Board of Light and						Hydropower	
MI	Dimondale Dam	Grand River	2004	442,400				5		300		Lansing Board of Power and Light	1880	Earth				Recreational & mill use	
MI	Rice Creek Dam	Rice Creek	2004	203,000				10		500		The city of Marshall	1835					Mill pond	
MI	Kimberly-Clark Dam	North Branch Spars Creek	2004					2		200		Michigan DNR	1965	Earth				Recreation	
MI	Tannery Creek Dam	Tannery Creek	2004																
MI	Copemish Dam	First Creek (tributary to Bear Creek)	2003	50,000				8				Village of Copemish	1950	Earth				Recreation	
MI	Sturgeon River Dam	Sturgeon River	2003					45				We Energies						Hydropower	
MI	Mill Pond Dam	Chippewa River	2002					15		100				Concrete					

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
									DATA LACKING. Need measurements. Dam was breached, not fully removed. Breaching occurred June 1999.
								mbowman@amrivers.org	NID has year built as 1870, height of 42, length 1044
		E							
				Improve water quality; Reduce erosion; Provide habitat for fisheries				Chris Freiburger, MDNR, 517-373-6644, freiburg@michigan.gov	
		$		Restore fish passage; Improve water quality; Improve stream habitat				Chris Freiburger, MDNR, 517-373-6644, freiburg@michigan.gov	
		E$		Restore fish passage; Improve fisheries habitat				Jessica Mistak, MDNR, 906-249-1611, mistakjl@michigan.gov	
		EF		Restore fish passage; Improved use of park and river				Chris Freiburger, MDNR, 517-373-6644, freiburg@michigan,gov	partially removed and replaced with a "W" weir
				Improve stream habitat; Aesthetics; Safer recreational use of adjacent park				Chris Freiburger, MDNR, 517-373-6644, freiburg@michigan,gov	
								Sharon Hanshue, Michigan DNR, (517) 335-4058, hanshus1@michigan.gov	
		E		Restore three miles of fragmented brook trout habitat				Susan Wells, U.S. Fish & Wildlife Service, (989) 356-5102	
		E						Sharon Hanshue, Michigan Department of Natural Resources, (517) 335-4058, hanshus1@michigan.gov.	
				Open spawning habitat for lake sturgeon				Sharon Hanshue, Michigan Department of Natural Resources, (517) 335-4058, hanshus1@michigan.gov.	Removing the dam in stages to allow for the reservoir and sediment transport to stabilize and reduce fish and wildlife impacts
		ES		Opened 71 miles of habitat for steelhead, bluegills, and other resident fish				Greg Baderschneider, Director of Parks, City of Mount Pleasant, (989) 779-5331	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
MI	Stronach Dam	Pine River	2002					18		350			1918	Concrete				Hydropower	
MI	Big Rapids Dam	Muskegon River	2000																
MI	Air Force Dam	Silver Lead Creek	1998																
MI	Marquette Dam	Dead River	1912																
MI	Newaygo Dam	Muskegon River	1969	1,300,000				18											
MI	Three River City Dam	Unknown	1992					13											
MI	Wager Dam	Grand River	1985					10											
MI	Wacousta Dam	Looking Glass River	1966					4											
MI	Foster Trout Pond Dam	Unknown	1983					17											
MI	Salling Dam	AuSable River	1991					17		250	370	Estate of Augsta Katona	1914	Earth Gravity				Recreation; Hydropower	
MN	Appleton Mill Pond Dam	Pomme de Terre River	1999																
MN	Berning Mill Dam	Crow River	1986					10											
MN	Flandrau Dam	Cottonwood River	1995	200,000				12					1938						
MN	Hanover Dam	Crow River	1984					12											
MN	Pomme de Terre River Dam	Pomme de Terre River				State													
MN	Stockton Dam	Garvin Brook	1994					30											
MN	Frazee Dam	Otter Tail River	1999					21		60								Hydropower	
MN	Lake Florence Dam	Root River						12											
MN	Old Mill State Park	Middle Two Rivers	1997					11		92									
MN	Kettle River Dam	Kettle River	1995					25		321	200	State of Minnesota	1908	Gravity				Recreation	

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
		$		Increase trout populations; Increase recreational opportunities				Sharon Hanshue, Michigan Department of Natural Resources, (517) 335-4058, hanshus1@michigan.gov	
		S		Safer for canoeing and swimming; More aesthetically pleasing; Habitat quality has dramatically improved				Steven Stilwell, City of Big Rapids, (231) 592-4021. http://www.ci.big-rapids.mi.us/damremoval/outline.htm	
									DATA LACKING. Need removal verification and measurements.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
		ER							Dam was removed according to US F&W and several other sources.
		F							Removed in late 1980s? (confirm) Hanover Dam and Berning Mills Dam were both removed with public $ after the dams partially failed. Caoneists had drowned at the sites.
		E							
		F							Removed in late 1980s? (confirm) Hanover Dam and Berning Mills Dam were both removed with public $ after the dams partially failed. Caoneists had drowned at the sites.
		F							DATA LACKING. Dam was removed according to MN DNR Dam Removal report. Need measurements.
									in Stewartville, MN
									Dam removed: MN DNR
								ian.chisholm@dnr.state.mn.us	Information from River Network, River Voices, Winter 1995, Vol. 5, No. 4.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
MN	Welch Dam	Cannon River	1994	46,000				9		120	10	Welch Villiage Ski Area	1900	Gravity				Hydropower	Recreation
MN	Sandstone Dam	Kettle River	1995	208,000				20		150									
MO	Alkire Lake Dam	Unknown	1990					30											
MT	small dam	Rock Creek																	
MT	Peet Creek Dam	Peet Creek	1994					43											
MT	Vaux #1 Dam	Lone Tree Creek	1995					34											
MT	Three Bears Lake-West Dam	Bear Creek						20											
MT	Three Bears Lake-East Dam	Bear Creek						10											
MT	Wallace Creek Dam	Wallace Creek	1997			Owner		29		720	100	Roy P. Handley	1922	Earth Gravity				Irrigation	
NC	Freedom Park Dam	Little Sugar Creek	2002					10		60			Early 1970s	Hollow-concrete				Regulate water levels Recreation	
NC	Unnamed Dam	Unnamed Tributary of Marks Creek	2002					25		400				Earth fill					
NC	Rains Mill Dam	Little River	1999																
NC	Ash Bear Pen Dam	Unknown	1990					10											
NC	Forny Ridge Dam		1988					4											
NC	Cherry Hospital Dam	Little River	1998	69,000		Federal, State		7		135		State of North Carolina	1940's					Water Storage	
NC	Quaker Neck Dam	Neuse River	1998	205,500		Federal, State		7		260	360	Carolina Power & Light Co.	1952	Earth Gravity				Other	
ND	Epping Dam	Stony Creek	1979					47											
ND	Kunick Dam	tributary of Elk Creek						24											
ND	Antelope Creek Dam	Knife River	1979					22											

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
		ES							Information from River Network, River Voices, Winter 1995, Vol. 5, No. 4. Canoeing hazard and fish barrier.
		ER							
									tributary to Ninemile
		S							
		S							
									Verified by Pohl and not included in database.
									Wallace Creek Dam is located on Wallace Creek, a tributary to the Clark Fork River, in Missoula County.
		E		Improve water quality (temperature and oxygen levels); Uncover prime fish habitat				Andrew Burg, Mecklenburg County Storm Water Services, (704) 336-4328,burgaa@co.mecklenburg.nc.us	
		E						Brad Fairley, Stantec Consulting, (919) 851-6866, bfairley@stantec.com	
								mike_wicker@mail.fws.gov	
		$							
									DATA LACKING. Need removal verification and measurements.
		E							
		E							Removed in December, 1997..removal opens up 75 miles of the Neuse and 925 miles of tributaries NID has year built 1955, height 12, length 170
								Karen Goff, ND State Water Commission, (701) 328-4953, kgoff@state.nd.us	Verified by Pohl and not included in database. This was not a dam removal. The reservoir was temporarily lowered in 1979 after the spillway was damaged during spring runoff. The dam was rebuilt in 1980.
		U						Karen Goff, ND State Water Commission, (701) 328-4953, kgoff@state.nd.us	This dam was lowered but was not removed.
		S							

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
ND	Iverson Dam (Main)	Little Coulee	1997				Breached	18		385	123	Local government	1937	Earth fill		State	No	Recreation	Recreation
ND	Grand Forks Riverside Park Dam (old)	Red River	1989				Removed	19		185	2106	Local government	1925	Timber crib & rock	Medium	State	Yes	Water Supply	Water Supply
ND	Logan Center Dam	tributary of Goose River	1958				Breached				990	Local government	1936	Earth fill	Low	State	No	Recreation	Recreation
ND	Lester Schatz Dam	Big Muddy Creek	1989				Breached	15			242	Private	1959	Earth fill	Medium	State	No	Irrigation	Irrigation
ND	Mantador Dam	Wild Rice River	1957				Breached					Local government	1936		Low	State		Recreation	Recreation
NE	Helen Fehrs Trust Dam	Timber Creek (trib.)	1995					35											
NE	Diehl Dam	Camp Creek	1981					34											
NE	Golf Course Dam	Unknown						25											
NE	Lake Crawford Dam	Bozle Creek	1987					25											
NE	Bennet Dam	Lodgepole Creek	1982					21											
NE	Fullerton Power Plant Dam	Cedar River						15											
NH	Bellamy River Dam V	Bellamy River	2004	13,000		Federal, State	Removed	4	4	90		Private	1928	Timber crib	Low	State	Yes	Mechanical Power Generation	Unknown
NH	West Henniker Dam	Contoocook River	2004	116,000		Federal, State	Removed	18	10	137	31	Local government	1936	Concrete	Low	State	Yes	Mechanical Power Generation	Recreation
NH	Badger Pond Dam	Tioga River	2004	30,000		Private	Breached	18	12	800	99	Private	1934	Concrete Masonry	High	State	No	Water Supply	Recreation
NH	Bearcamp River Dam	Bearcamp River	2003	73,000		Federal, State	Removed	20	20	231	4	Private	1929	Timber crib & concrete	Low	State	Yes	Mechanical Power Generation	Unknown
NH	Winchester Dam	Ashuelot River	2002	31,400		Federal, State	Removed	5	3	105	40	Local government	1910	Timber crib	Low	State	Yes	Mechanical Power Generation	Unknown

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
Failed		$				No	No	Karen Goff, ND State Water Commission, (701) 328-4953, kgoff@state.nd.us	
Poor		$				No	No	Karen Goff, ND State Water Commission, (701) 328-4953, kgoff@state.nd.us	
Failed		$	Not needed			No	No	Karen Goff, ND State Water Commission, (701) 328-4953, kgoff@state.nd.us	
		$				No	No	Karen Goff, ND State Water Commission, (701) 328-4953, kgoff@state.nd.us	
Poor		$	Poor condition			No	No	Karen Goff, ND State Water Commission, (701) 328-4953, kgoff@state.nd.us	
		U							Verified by Pohl and not included in database.
		$							Verified by Pohl and not included in database.
		S							Verified by Pohl and not included in database.
		$							
		F							Verified by Pohl and not included in database.
Failed	No	E	Poor condition	Provide additional habitat for smelt and river herring	None	No	Yes	Cheri Patterson, New Hampshire Fish and Game Department, (603) 868-1095, cpatterson@nhfgd.org	
Good	No	RS	Environmental benefit (fisheries, water quality, river restoration)	Restore river to free-flowing condition; Benefit juvenile Atlantic salmon, American eel, and trout	None	No	No	Grace Levergood, New Hampshire Department of Environmental Services, www.des.nh.gov/dam/damremoval, (603) 271-1971, glevergood@des.state.nh.us	
Poor	No	S	Liability	Reconnect 12 miles of the Tioga River and tributaries; Benefit trout, darters and additional resident fish species	None	No	No	Grace Levergood, New Hampshire Department of Environmental Services, www.des.nh.gov/dam/damremoval, (603) 271-1971, glevergood@des.state.nh.us	
Failed	No	E	Recreational safety	Increase spawning habitat for brook trout and landlocked Atlantic salmon	None	No	No	Grace Levergood, New Hampshire Department of Environmental Services, www.des.nh.gov/dam/damremoval, (603) 271-1971, glevergood@des.state.nh.us	
Failed	No	E	Recreational safety	Opened additional spawning habitat for American shad, river herring, American eel, and Atlantic salmon; Expected to benefit the dwarf wedge mussel, a federal endangered species indigenous to the Ashuelot River	None	No	No	Grace Levergood, New Hampshire Department of Environmental Services, www.des.nh.gov/dam/damremoval, (603) 271-1971, glevergood@des.state.nh.us	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
NH	McGoldrick Dam	Ashuelot River	2001	54,000		Federal, State	Removed	6	6		5	Private			Low	State	Yes	Mechanical Power Generation	Unknown
NJ	Harry Pursel Dam	Lopatcong Creek	2004					15				Henry Pursel	1925					Water supply	
NJ	Pottersville Dam	Cold Brook	1985					20		180									
NJ	Upper Blue Mountain Lake Dam	Van Campens Brook	1995			Federal, Owner	Breached	26		210	187	Federal government		Earth fill	Low	State	No		
NJ	Lake Success Dam	Delaware River (trib.)	1995			Federal, Owner	Breached	20		300	320	Federal government		Earth fill	Low	State	No		
NJ	Patex Pond Dam	Crooked Brook	1990				Breached	20		340	22	Private		Earth fill	Low	State	No		
NJ	Knox Hill Dam	Whippany River (trib.)	1996					18		150						State			
NJ	Glenside Dam	S. B. Timber Creek	1997				Breached	12		130	13	Private		Earth fill	Low	State	No		
NJ	Fieldsville Dam	Raritan River	1990					10		400									
NJ	Pool Colony Dam	Van Campens Brook (trib.)	1999					8											
NV	Katherine Borrow Pit Embankment	Unknown	1992					15											
NY	Cuddebackville Dam	Neversink River	2004	2,200,000	1,400,000	Federal	Breached	10	6	107	run of river	Orange County	1907	Stop Log Pier and concrete overflow weir	Low	NYSDEC Dam Safety	yes	Originally water supply feeder for canal, then hydropower	Aestetics (water for canal remnant in County park)
NY	Gray Reservoir Dam	Black Creek	2002	300,000				34		385		Upper Mohawk Valley Regional	1905-1906	Buttress				Water storage	
NY	Fort Edward Dam	Hudson River	1973					31		586		Niagara Mohawk Power Corp.	1898	Timbercrib				Hydropower	
NY	Luxton Lake Dam	Unknown						15											
NY	Curry Pond Dam							3											
OH	Kent Dam	Cuyahoga River	2004																
OH	St. John’s Dam	Sandusky River	2003	200,000	79,000	State	Removed	8.5		150		Ohio-American Water Company	Early 1900s	Concrete Arch	High	Federal	Yes	Water Supply	Water Supply

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
Poor	No	E	Recreational safety	Restore river to free-flowing condition; Benefit juvenile Atlantic salmon, American eel, and trout	None	No	No	Grace Levergood, New Hampshire Department of Environmental Services, www.des.nh.gov/dam/damremoval, (603) 271-1971, glevergood@des.state.nh.us	
		S		Eliminate safety hazards; Restore fish passage; Improve fish habitat				Sara Nicholas, American Rivers, (717) 232-8355, snicholas@americanrivers.org	
		S							
Poor	No	S						JMOYLE@dep.state.nj.us	Removed for dam safety reasons
	No	S						JMOYLE@dep.state.nj.us	Removed for dam safety reasons.
Poor	No	S						JMOYLE@dep.state.nj.us	Removed for dam safety reasons
		S						JMOYLE@dep.state.nj.us	Removed for dam safety reasons.
		S						JMOYLE@dep.state.nj.us	Removed for dam safety reasons.
		E						JMOYLE@dep.state.nj.us	Removed for fish migration
poor	yes	E	Debris collector, maintenance problem, attractive nuisance liability	4 miles of river opened, removed debris trap	CWA404 & 401	No	Yes	Colin Apse, The Nature Conservancy, (845) 255-9051, capse@tnc.org	Plans for restoration include regrading the streambed, planting, and long-term monitoring.
		$		More natural stream channel; Restored brook trout fishery; Increased public access to the river				Dick Goodney, Upper Mohawk Valley Regional Water Board, (315) 792-0336	
		S							
									DATA LACKING. Need removal verification and measurements.
		E		Improve water quality				Bob Brown, City of Kent, (330) 676-7241, bbrown@kent-ohio.org	Because of the importance of the dam to the city's history, they voted to leave most of the dam in place while routing the river through an old lock at the dam. In order to maintain the appearance of the dam, water will be continually cycled over the dam,
Poor	No	S	Environmental benefit (fisheries, water quality, river restoration)	Improve water quality; Improve fish habitat, reestablis free flowing conditions of river, establish in-stream habitat, mitigation credits	CWA404 & 401	Yes, for transportation project	No	Don Rostofer, Ohio Department of Transportation, (614) 387-3057, donald.rostofer@dot.state.oh.us	Baseline date was collect prior to removal. ODOT is required by USACE and OEPA to monitor the river system for five years. The protocol for monitoring is found in the 401 conditions of varoius transportation projects within the Sandusky River 8 Digit HU

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
OH	Unnamed Dam	Ottawa River	2003					5		50									
OH	Dennison Dam	Olentangy River	2002	17,000		State		2		225		Private	Early 1900s	Concrete Arch				Electrical Power Generation	
OH	Milan Wildlife Area Dam	Huron River	2002					5		100			1969	Concrete				Hold coho salmon	
OH	Chapel Church Lake Dam	Silver Creek-TR	1989																
OH	Foster Dam	Little Miami River	1984																
OH	Howard's Lake Dam	Jackson Run (trib.)																	
OH	Silver Creek Dam	Silver Creek																	
OH	Poston Fresh Water Pond Dam	Hamley Run (trib.)	1988					42											
OH	Williams Dam	Brush Creek (trib.)						40											
OH	Altier Pond Dam	Black Ford (trib.)	1989					33											
OH	Derby Petroleum lake Dam	Timber Run (trib.)	1984					30											
OH	Fair Haven lake Dam	Ice Creek (trib.)	1980					30											
OH	Lake Hill #1 Dam	Robinson Run (trib.)						30											
OH	Lake Hill #2 Dam	Robinson Run (trib.)						30											
OH	Yankee Lake Dam	Yankee Run	1980					26											
OH	Ashworth Lake Dam	Seven Mile Creek (trib.)						25											
OH	State Route 800 Dam	Spencer Creek (trib.)	1989					25											
OH	Strip Mine Pond Dam	McLuney Creek (trib.)						25											
OH	Modoc Reservoir Dam	Modoc Run	1981					24											
OH	Old Jenkins Lake Dam	Little Yellow Creek (trib.)						22											

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
								Larry Goedde, Ohio Department of Natural Resources, (419) 429 8370, larry.goedde@dnr.state.oh.us	
		E		Improve water quality; Improve fish and aquatic habitat; Already uncovered a natural waterfall	CWA401			Tim Peterkoski, Ohio Department of Natural Resources. PHONE NUMBER, EMAIL?	
		$		Opened 25 miles of spawning habitat for steelhead and coho salmon				Larry Goedde, Ohio Department of Natural Resources, (419) 429 8370, larry.goedde@dnr.state.oh.us	
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need measurements. Removed approximately 1984. Had a breach in it at the time so there was no significant sediment build-up to speak of.
									Verified by Pohl and not included in database.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
OH	Jones Lake Dam	Ogg Creek						20											
OH	Burt Lake Dam	Little Auglaize River (trib.)	1992					18											
OH	Cottingham Lake Dam	Hocking River (trib.)	1991					17											
OH	Ohio Power Company Pond Dam	Brannon Fork	1987					17											
OH	Brashear Lake Dam	Sugartree Creek (trib.)	1991					16											
OH	Marshfield Lake Dam	Porter Creek	1973					15											
OH	Mastrine Pond Dam	Little Pine Creek (trib.)	1978					15											
OH	Toronto Band Father's lake Dam	Town Fork	1991					15											
OH	Wonder Lake Dam	East Reservoir (trib.)	1986					15											
OH	Dutiel Pond Dam	Licking River (trib.)	1986					14											
OH	Georgetown Freshwater Dam	South Fork (trib.)	1988					13											
OH	Ohio Power Company Pond Dam	Collins Fork						13											
OH	Consol Pond Dam	Stillwater Creek						12											
OH	Okie Rice Dam	Little Darby Creek	1990					12											
OH	Carr Lake Dam	Johnny Woods River (trib.)	1985					10											
OH	Glen Hellen Dam	Little Miami River	1997	10,000				8		100									
OH	Killiany Lake Dam	Wills Creek (trib.)						8											
OH	Village at Rocky Fork Lake Dam	Rocky Fork (trib.)						7											
OH	Little Darby Dam	Little Darby Creek	1989					20				Columbia/Franklin County Metropolitan							
OH	Foxtail Dam	Unknown						30											
OH	Armington Dam #2	Unknown	1991					15											
OH	Slippery Run (Stahl) Dam	Unknown	1990					14											
OH	Jacoby Road Dam	Little Miami	1997	10,000		State	Removed	8		100		Private	1910	Concrete				Electrical	Recreation
OH	Middletown Hydraulic Dam	Great Miami River	1993	231,975		State	Removed	10				Local government	1840	Timber crib				Other	

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
		S							
									Used to divert water through a mill race to power a mill that no longer operates.
		O							
									Removed approximately 1989. Little Darby Creek is a tributary of Big Darby Creek, which between the two contain some of the most diverse aquatic life in the state.
	No	E						Ohio Department of Natural Resources	
	No	S						Ohio Department of Natural Resources	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
OH	Coho Dam	Huron River	2003	20,000		State	Removed	5		114		State	1960s	Concrete					
OH	Lover's Lane Dam	Mahoning	2005	30,000	20,000	State	Removed	3		125		Private	1950s	Rock & concrete	Low	Federal	Yes	Cooling Water	Unknown
OH	North River Road Dam	Mahoning	2006	40,000	30,000	State	Removed	4		150		Private	1950s	Rock & concrete	Low	Federal	Yes	Cooling Water	Unknown
OH	Panhandle Road Dam	Olentangy River	2005	50,000	35,000	State	Removed	7		150		Private/ ODOT	1950s	Concrete Arch	Low	Federal	Yes	Fisheries Management	
OH	Grinnelle Road Dam	Little Miami River	2007	100,000	80,000	State	Removed	14		160		Private	1900s	Timber crib & concrete	Medium	Federal	Yes	Diversion-Grain Mill Race	
OK	Sand Springs ReRegulation Dam	Arkansas	1985				removed	19	13	1651	5,600	Federal government	1968	Concrete		Federal	No	Other	Other
OR	Buck & Jones Diversion Dam	Little Applegate River	2003					5		100				Concrete				Diversion	
OR	Dinner Creek Dam	Dinner Creek	2003					10		35			1925	Concrete				Water supply	
OR	Unnamed Dam	Wagner Creek	2003					4						Concrete				Diversion	
OR	Byrne Diversion Dam	Beaver Creek	2002					3						Concrete				Irrigation diversion	
OR	Irrigation Push-Up Dam	Applegate River	2002					4						Gravel pushup				Irrigation	
OR	Rock Creek Dam	Tributary to the Powder River	2002									Oregon Trail Electric Cooperative						Hydropower	
OR	Maple Gulch Diversion Dam	Evans Creek	2002					13					Early 1900s	Concrete				Supply water	
OR	Three Unnamed Dams	Ashland Creek	2000																

Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
	No	S						Ohio Department of Natural Resources	
Poor	No	E	Environmental mitigation credit	Improve water quality, re-establish free flowing conditions of river, USACE-Mahoning River Dredging Project in the State of Ohio	CWA404 & 401	Yes, for transportation project	No	Don Rostofer, Ohio Department of Transportation, (614) 387-3057, donald.rostofer@dot.state.oh.us	Mitigation was established impactes associated with a single transportation project in Mahoning County.
Poor	No	E	Environmental mitigation credit	Improve water quality, re-establish free flowing conditions of river, USACE-Mahoning River Dredging Project in the State of Ohio	CWA404 & 401	Yes, for transportation project	No	Don Rostofer, Ohio Department of Transportation, (614) 387-3057, donald.rostofer@dot.state.oh.us	Mitigation was established impactes associated with a single transportation project in Mahoning County.
Good	Yes	E	Environmental mitigation credit	Improve water quality, re-establish free flowing	CWA404 & 401	Yes, for transportation	No	Don Rostofer, Ohio Department of Transportation, (614) 387-3057, donald.rostofer@dot.state.oh.us	ODOT is establishing a Pooled Stream Mitigation Area for future stream mitigation needs regional area.
Poor	No	E	Environmental mitigation credit	Improve water quality, re-establish free flowing conditions of river, USACE-Mahoning River Dredging Project in the State of Ohio	CWA404 & 401	Yes, for transportation project	No	Don Rostofer, Ohio Department of Transportation, (614) 387-3057, donald.rostofer@dot.state.oh.us	ODOT is establishing a Pooled Stream Mitigation Area for future stream mitigation needs regional area.
Excelent	Yes	$	Recreational safety		CWA404 & 401	No	No	Andrew Commer, USACE Tulsa, OK 918-669-7616, Andrew.Commer@usace.army.mil	Original purpose of the dam was to re-regulate hydropower releases from an upstream dam to provide water quality baseflow, during periods of non-generation
				Improve fish passage				Daniel Newberry, Applegate River Watershed Council, (541) 899-9982	
		E						Laura Bernstein, Umpqua National Forest, (541) 767-5041	
				Open additional habitat for coho salmon, steelhead, and cutthroat trout				Lester Naught, City of Talent, (541) 535-3828, pubworksles@cityoftalent.org	
		U		Increased access to spawning habitat for steelhead and coho salmon				Jerry Vogt, Oregon Department of Fish and Wildlife, (541) 826-8774, jerry.f.vogt@state.or.us	
								Daniel Newberry, Applegate River Watershed Council, (541) 899-9982	
								Stephanie Burchfield, Oregon Department of Fish and Wildlife, 503-872-5255, ext 5580, stephanie.burchfield@state.or.us	
		$		Restore natural sediment flow and fish passage			Monitoring sediment transport	Jane Lafore, Medford District Bureau of Reclamation, (541) 618-2364	
		$S		Opened additional habitat to steelhead and resident species				Jerry Vogt, Oregon Department of Fish and Wildlife, (541) 826-8774	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
OR	Unnamed Dam	Poorman Creek	1999																
OR	Lafayette Locks Dam	Yamhill Basin	1963																
OR	Jackson Street Dam	Bear Creek	1998	1,200,000				11		120		Rogue River Valley Irrigation District	1960s					Irrigation	
OR	Marie Dorian Dam	Walla Walla River	1997	300,000		State		8		100		Milton-Freewater Water Control District	1880s	Concrete				Irrigation	Hydropower (inactive)
OR	Alphonso Dam	Evans Creek	1999	55,000				10		56			1890s					Irrigation	
OR	Catching Dam	Willamette River (North Fork of Middle Fork)	1994	64,708		State		28		225	190	private individual	1924	Timbercrib; Concrete; Wood; Steel; Gravity				Water Diversion	Log Storage
PA	Bear Rock 1 and 2 Dams	Bear Rock Run	2005				Removed	26		560	24	Local government	1903 1904	Earth fill	High	State		Water supply	
PA	Benscreek Intake	Ben's Creek	2005				Removed	6		60			1900 - 1905			State		Water supply	
PA	Detter's Mill Dam	Conewago Creek	2004	35,000	25,000	Federal, State	Removed	7		250	20	State government		Rock & concrete	Low	State	Yes	Mill Dam	Recreation
PA	Sharrer's Mill Dam	Conewago Creek	2005				Removed	8		220	10	Private		Concrete	Low	State	Yes	Mill Dam	Recreation
PA	Siloam Dam	Conococheague Creek	2005				Removed	10				City of Chambersburg		Concrete	Low	State	Yes		
PA	Durham Dam	Cooks Creek	2004	50,000	35,000	Private	Removed	10			3	Private		Concrete		State	Yes		

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
									Verified by Pohl and not included in database.
									DATA LACKING. Need measurements. In 1963, a dam was removed at Lafayette locks in order to restore fish runs to the Yamhill Basin. According to OR Fish Commission, coho and steelhead runs now exist above the site of the old dam.
		E							
		E							Removed in April 1997.
		E							taken from: http://www.spokane.net/news-story-body.asp?Date=080399&ID=s616522&cat= Irrigation dam torn down in Oregon Action expected to improve fish habitat in Rogue River area August 3, 1999
								Jeffrey.S.Ziller@state.or.us	
		$S			CWA404 & 401			Ed Englehart, Highland Water and Sewer Authority, eenglehart@highlandwater.net	
		$S		Reduce liability concerns; Eliminate financial burden of maintenance; Restore habitat	CWA404 & 401			Ed Englehart, Highland Water and Sewer Authority, eenglehart@highlandwater.net	
Poor	No	$		Eliminated safety concerns; Opened seven miles of spawning habitat for American shad, blueback herring, and American eel	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
	No	E$S			CWA404 & 401			Sara Nicholas, American Rivers, (717) 232-8355; snicholas@amrivers.org	Partial Removal
		E$S			CWA404 & 401			Bruce Mcnew, City of Chambersburg, (717) 261-3288, bmcnew@chbgboro.com	actively monitoring this site and the downstream dam at Wilson College slated for removal in 2005 to record pre- and post-removal changes in water quality and benthic life
		E$S			CWA404 & 401			Vince Humenay, Pennsylvania Department of Environmental Protection, (717) 783-7482, vhumenay@state.pa.us	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	Dam	River	Removal Date	Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)	Removal Cost in US$ (deconstruction cost only)	How was removal funded?	Indicate whether dam was removed (total removal) or breached (partial removal)	Dam Maximum Structural Height (ft)	Dam Hydraulic Height (ft)	Dam Length (ft)	Reservoir Volume (acre-ft)	Owner	Date Built	Type of Dam	State Hazard Classification	Who regulates dam	Run–of–river dam? (Yes or No)	Original purpose of dam	Most recent use of dam and reservoir
PA	Cussewago Creek Dam	Cussewago Creek	2005				Removed	6		70		Private		Concrete	Low	State	Yes		
PA	Girl Scout Dam	Laurel Run	2005				Removed	9		50		Private		Stone masonry	Low	State	No		Recreation
PA	Lower Lloydell Dam	South Fork of the Little Conemaugh	2004	31,000	23,000	State	Removed	9		70		Lloydell Water Co.	1900 - 1910	Stone masonry	Low	State	No	Water reservoir	
PA	Cleversburg Water Supply Dam	Milesburn Run	2004				Removed	4		90	3	Local government	1902	Concrete		State		Water supply	
PA	Frankford Dam	Pennypack Creek	2005				Removed	12.5		150		City of Philadelphia				State			
PA	Binky Lee Preserve	Tributary to Pickering Creek	2004					8				Natural Lands Trust		Stone masonry		State			
PA	Two Unnamed Dams	Poplar Run	2004				Removed	11						Stone masonry		State		Water supply	
PA	Irving Mill Dam	Ridley Creek	2004	95,000	60,000	Federal, State, Private	Removed	12		100		Private	1919	Stone masonry		State	Yes		
PA	Twining Valley Golf Course Dam	Tributary to Sandy Run	2004					15		200	2	Private				State		Irrigation to a golf course; Aesthetics enhancement	
PA	Reedsville Milling Company Dam	Tea Creek	2004	70,000	45,000		Removed	14		130		Private	1970s	Timber crib, rock and concrete		State			
PA	Charming Forge Dam	Tulpehocken Creek	2004	55,000	35,000	Federal, State	Removed	10		204	71	State government	1919	Concrete Gravity		State	Yes	Power	Recreation
PA	Upper Grove City Dam	Wolf Creek	2004	15,000	10,000	State	Removed	10		100		Local government	1885	Concrete		State	Yes	Power	
PA	Mohnton Dam	Wyomissing Creek	2005	70,000	50,000		Removed	6				Local government	mid 1800s Early 1900s	Concrete Gravity	Low	State	No	First power then water supply	
PA	Reading Museum Dam1	Wyomissing Creek	2004	45,000	30,000	Federal, State	Removed	3		45		Private	~1900			State			
PA	Reading Museum Dam2	Wyomissing Creek	2004	45,000	30,000	Federal, State	Removed	8		60		Private	Early 1900s	Rock		State			
PA	Hoffman Dam	Yellow Breaches Creek	2005				Removed	12		130		Private	~1900	Concrete	Low	State	Yes	Power	Other

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
					CWA404 & 401			Ginny Crowe, Conneaut Lake / French Creek Valley Conservancy, (814) 337-4321, conserve@mdvl.net	
Poor	No	E$S		Expand available habitat for fish species	CWA404 & 401			Scott Carney, Pennsylvania Boat and Fish Commission, (814) 353-2225, rscarney@state.pa.us	
		$S		Restore habitat	CWA404 & 401			Ed Englehart, Highland Water and Sewer Authority, eenglehart@highlandwater.net	
		E$		Stream restoration	CWA404 & 401			Vince Humenay, Pennsylvania Department of Environmental Protection, (717) 783-7482, vhumenay@state.pa.us	
		E		Provide fish passage; Restore ecological health	CWA404 & 401			Jason Cruz, Philadelphia Water Department, (215) 685-4946, Jason.e.cruz@phila.gov	Partial Removal
		E$		Restore creek to free-flowing state	CWA404 & 401			Vince Humenay, Pennsylvania Department of Environmental Protection, (717) 783-7482, vhumenay@state.pa.us	
		$			CWA404 & 401			Vince Humenay, Pennsylvania Department of Environmental Protection, (717) 783-7482, vhumenay@state.pa.us	
Poor		E$		Open two miles of spawning habitat for blueback herring, alewife, and possibly American and hickory shad	CWA404 & 401			Sara Nicholas, American Rivers, (717) 232-8355, snicholas@americanrivers.org	
		E$S			CWA404 & 401			Vince Humenay, Pennsylvania Department of Environmental Protection, (717) 783-7482, vhumenay@state.pa.us	
		E			CWA404 & 401			Scott Carney, PA Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		E			CWA404 & 401			Sara Nicholas, American Rivers, (717) 232-8355, snicholas@americanrivers.org	
		E			CWA404 & 401			Bob Beran, project manager, (724) 735-2766, Berans@pathway.net	
		E$		Restore creek; Provide fish passage	CWA404 & 401			Dennis Rearden, Berks County Conservancy, (610) 372-4992	
		$			CWA404 & 401			Pete Ponchieri, Reading Museum, (610) 371-5850, ex 225, pete356@aol.com	
		$			CWA404 & 401			Pete Ponchieri, Reading Museum, (610) 371-5850, ex 225, pete356@aol.com	
Poor	No	$S			CWA404 & 401			Scott Carney, PA Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
PA	Black Dam	Conodoguinet Creek	2003	65,000	40,000	Federal, State	Removed	10		400	31	Private	1919	Concrete		State	Yes	Water supply	
PA	Collegeville Mill Dam	Perkiomen Creek	2003	45,000	30,000	State	Removed	5		200		Local government	1708	Stone masonry		State	Yes		
PA	Daniel Esh Dam	Mill Creek	2003		1,500	State	Removed	2								State		Impound water for skating and	
PA	Young's Dam	Lititz Run	2002	10,000	20,000	Federal, State	Removed	3								State			
PA	Four Amish Dams	Muddy Run	2001		25,000	Federal, State	Removed									State		Water supply	
PA	Good Hope Dam	Conodoguinet Creek	2001	45,000	30,000	Federal, State	Removed	6		300		State government	1821	Concrete		State	Yes		Recreation
PA	Meisers Mill Dam	Manantango Creek	2001	22,000	15,000	Federal, State	Removed	5		75						State			
PA	Intake Dam	Rife Run	2001	25,000	15,000	Federal, State	Removed	4		47	1	Local government	1962	Concrete		State	Yes	Water Supply	
PA	Hammer Creek Dam	Hammer Creek	2001				Removed	4		60		State government		Concrete		State	Yes	Recreation	
PA	Two Unnamed Dams	Huston Run	2001		10,000	Federal, State	Removed									State		Generate power	
PA	Barnitz Mill Dam	Yellow Breeches Creek	2000	30,000	20,000	Federal, State	Removed	5				Dickenson Township		Concrete		State	Yes		
PA	Franklin Mill Dam	Middle Creek	2000	24,000	14,000	Federal, State	Removed	4			2.5	Private		Concrete		State	Yes		
PA	Hinkletown Mill Dam	Conestoga River	2000				Removed									State			

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
		$		Open 22 miles of habitat for American shad, blueback herring, alewife, and potentially American eel	CWA404 & 401			Scott Carney, PA Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
Poor		$S			CWA404 & 401			Scott Carney, PA Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
					CWA404 & 401			Sara Nicholas, American Rivers, (717) 232-8355, snicholas@americanrivers.org	
					CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		$			CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
				Opened 22.2 miles of spawning habitat for migratory fish; Removed a significant safety hazard	CWA404 & 401		multi-year study of physical, chemical, and biological parameters	Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		E$			CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		$S		Restored free-flowing character of the stream; Opened additional habitat for aquatic organisms	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		S			CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	Unfortunately the sediment dispersal was not managed correctly during the removal process, and as a result negative impacts have occurred to downstream habitat.
				Restoration of the native coldwater fishery; Improvements in water quality and habitat	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		$S		Improve stream habitat and ecosystem health; Enhance public recreation; Provide a public park at the site	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		$		Opened approximately 40 miles of habitat for migratory fish; Removed a public safety hazard; Improved stream habitat	CWA404 & 401		Penn State is monitoring fish and aquatic macroinvertebrate populations	Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		O		Stream habitat and ecosystem restoration; Enhanced public safety	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
PA	Martins Dam	Cocalico Creek	2000	30,000	20,000	Federal, State	Removed	4		60	4	Private		Stone masonry		State	No		Recreation
PA	Muren's (Seitzville Mill) Dam	South Branch of Codorus Creek	2000	40,000	35,000	Federal, State	Removed	7		225	7.5	Private		Stone masonry		State	Yes		Recreation
PA	Wild Lands Conservancy Dam	Little Leheigh Creek	2000	5,000			Removed	5		75						State			
PA	Unnamed Dam	Manatawny Creek	2000				Removed					State government	~1850	Concrete Masonry		State	Yes		
PA	Cabin Hill Dam	Spring Creek	1998	100,000	90,000	State, Private	Removed	15		284	5	State government	1915	Concrete Gravity		State	No		Recreation
PA	Dauphin County Park & Recreation Dam	Spring Creek	1999	22,000	15,000	Federal, State	Removed									State			
PA	Greenville Dam #3	Little Shenango River	1999													State			
PA	Hellberg's Dam	Conestoga River	1999	45,000	35,000	Federal, State	Removed									State			
PA	unnamed dam	Lititz Run	2000	15,000	10,000	Federal, State	Removed									State			
PA	unnamed dam	Noels Creek	1999													State			
PA	Yorkane Dam	Codorus River-TR	1997			Private	Removed									State			
PA	Coal Creek Dam #3	Coal Creek	1995					24						Stone Masonry		State		Water Storage	
PA	Pomeroy Memorial Dam	Sugar Creek (West Branch)	1996					24		442	54	Local government	1923	Earth fill		State	No	Water Storage	
PA	Coal Creek Dam #2	Coal Creek	1995					23		116	6		1876	Stone Masonry		State	No	Water Storage	
PA	Maple Hollow Reservoir Dam	Gillians Run	1995					22		192			1902	Earthfill w/concrete spillway		State		Water Storage	
PA	Niederriter Farm Pond Dam	Mill Creek	1995					21		350			1960s	Earthfill		State		Recreation	
PA	Clear Shade Creek Reservoir Dam	Clear Shade Creek	1998					14		190	18	Local government	1800s	Concrete		State	Yes	Hydropower	

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
		S		Stream habitat and ecosystem restoration; Enhanced public safety; Reduced owner liability	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		E$		Improved stream habitat and passage for trout and resident fish; Improved water quality	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
		E		Restored fish passage; Improved substrate conditions; Increased habitat for the macroinvertebrate community; Improved quality of the natural fishery; Fewer obstructions for summer floaters face as they move downstream	CWA404 & 401			Scott Carney, Pennsylvania Fish and Boat Commission, (814) 353-2225, rscarney@state.pa.us	
					CWA404 & 401			Elizabeth Lynch, Academy of Natural Science, (570) 893-1137. http://www.acnatsci.org/research/pcer/manatawny/	Academy of Natural Sciences is conducting in-depth research on the effects of the removal in order to help develop a balanced, scientifically based policy regarding dam removal in Pennsylvania
					CWA404 & 401			scarney@lazerlink.com	DATA LACKING. Dam removed. Need measurements. Project completed in August 1998. Information obtained from the PA Fish & Boat Commission.
					CWA404 & 401				
					CWA404 & 401				Verified by Pohl and not included in database.
					CWA404 & 401			scarney@lazerlink.com	Verified by Pohl and not included in database.
					CWA404 & 401				DATA LACKING. Need removal verification and measurements
					CWA404 & 401				Verified by Pohl and not included in database.
					CWA404 & 401			scarney@lazerlink.com	DATA LACKING. Need removal verification and measurements Information obtained from the PA Fish & Boat Commission.
					CWA404 & 401				Info from PA DEP. Info indicates that the nearest downstream dam is .38 miles and there are not any upstream dams
					CWA404 & 401				According to the DEP there are no other dams upstream or downstream of this location. It's not clear how many stream miles were opened up.
					CWA404 & 401				Info from PA DEP. Info indicates that the closest downstream dam is .19 miles and there are no dams upstream
					CWA404 & 401				Information from PA DEP indicates that there are not any dams upstream or downstream from this location
					CWA404 & 401				Info from PA DEP -- info indicates that there are no dams above or below this site.
					CWA404 & 401				Info from PA DEP

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
PA	Coal Creek Dam #4	Coal Creek	1995					14		356	18	Private		Stone masonry		State		Water Storage	
PA	Rock Hill Dam	Conestoga River	1997	120,000	110,000	Federal, State	Removed	13		300		State government	<1918	Rock fill		State	Yes	Hydropower	Recreation
PA	Rose Hill Intake Dam	Kettle Creek	1998	15,000	10,000	Federal, Private	Removed	12		150		Private		Stone Masonry		State		Water Storage	
PA	Mill Port Conservancy Dam	Lititz Run	1998	15,000	10,000	Federal, State	Removed	10		10			1600s			State			
PA	unnamed dam	Kishacoquillas Creek	1998	30,000	25,000	State	Removed	9		175						State			
PA	Diverting Dam	Coal Creek						8		55				Concrete and Stone Masonry		State		Water Storage	
PA	Red Run Dam	Red Run	1996					7		40				Masonry		State		Water Storage	
PA	Maple Grove Dam	Little Conestoga River	1997	17,000	10,000	Federal, State, Private	Removed	6		60				Concrete		State		Hydropower	
PA	unnamed dam	Tinicum Creek Tributary	1998					6		40			1965	Concrete and Stone Masonry		State		Recreation	
PA	Castle Fin Dam	Muddy Creek	1997	200,000	180,000	Federal, State, Private	Removed	5		383			1917	Concrete		State		Hydropower	
PA	unnamed dam	Laural Run	1998			Private	Removed	5		50			1923	Concrete		State		Recreation	
PA	Yorktowne Paper Dam	Mill Creek	1997			Private	Removed	5		60				Stone Masonry		State		Water Storage	
PA	American Paper Products Dam	Conestoga River	1998	60,000	25,000	Federal, State, Private	Removed	4		130			1800s	Stone Masonry		State		Hydropower	
PA	East Petersburg Authority Dam	Little Conestoga River	1998	5,000	5,000	Federal, State, Private	Removed	4		20						State			
PA	unnamed dam (1)	Lititz Run	1998	10,000	10,000	Federal, State, Private	Removed	4		10						State			
PA	Amish Dam	Muddy Creek		1,500		Federal, State		3		40						State			
PA	Snavely's Mill Dam	Fishing Creek	1997	10,000		Federal, State	Removed	3		106		Private	1800s	Concrete		State	Yes	Hydropower	

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
					CWA404 & 401				Info from PA DEP. This info indicates that the nearest downstream dam is 1 mile and there are none above this location.
		E			CWA404 & 401			scarney@lazerlink.com	Project completed in January 1997. Information obtained from the PA Fish & Boat Commission. PA DEP info indicates that the nearest upstream dam is 19.2 miles and there are no downstream dams.
					CWA404 & 401			scarney@lazerlink.com	Project completed in Summer 1998. Information obtained from the PA Fish & Boat Commission. Info from PA DEP indicates that removal was done in 1/99
		E			CWA404 & 401			scarney@lazerlink.com	Project completed in December 1998. Information obtained from the PA Fish & Boat Commission.
					CWA404 & 401			scarney@lazerlink.com	Project completed in November 1998. Information obtained from the PA Fish & Boat Commission.
					CWA404 & 401				Verified by Pohl and not included in database. Info from PA DEP
					CWA404 & 401				Info from PA DEP. Unclear how many miles were opened up -- the info indicates that there are no dams above or below this site.
		E			CWA404 & 401			scarney@lazerlink.com	Project completed in August 1997. Information obtained from the PA Fish & Boat Commission. Info from PA DEP indicates that the dam was breached in 1995 -- was this a two year removal or are these dates inconsistent?
					CWA404 & 401				Info from PA DEP. Their info indicates that there are not any dams upstream or downstream of this one.
					CWA404 & 401			scarney@lazerlink.com	Project completed in August 1997. Information obtained from the PA Fish & Boat Commission. Additional info from PA DEP -- this info indicates that three is a dam 3 miles upstream but none downstream
					CWA404 & 401			scarney@lazerlink.com	Project completed in Summer 1996. Information obtained from the PA Fish & Boat Commission.
					CWA404 & 401			scarney@lazerlink.com	Information obtained from the PA Fish & Boat Commission.
		E			CWA404 & 401			scarney@lazerlink.com	Project completed in September 1998. Information obtained from the PA Fish & Boat Commission.
		E			CWA404 & 401			scarney@lazerlink.com	Project completed in December 1998. Information obtained from the PA Fish & Boat Commission.
		E			CWA404 & 401			scarney@lazerlink.com	Project completed in December 1998. Information obtained from the PA Fish & Boat Commission.
		E			CWA404 & 401				Verified by Pohl and not included in database.
					CWA404 & 401			scarney@lazerlink.com	Project completed in August 1997. Information obtained from the PA Fish & Boat Commission.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
PA	Mussers Dam	Middle Creek	1992			State	Removed	31		384		American Hydro Power Company	1906	Timber Earth		State		Hydropower	Water Storage; Recreation
PA	Lower Friendship Dam	Unknown	1982					30								State			
PA	Carpenters Pond Dam	Delaware River (trib.)						17								State			
PA	Fire Pond Dam at Incline #10	Unknown						16								State			
PA	Lemon House Pond Dam	Unknown	1984					15								State			
PA	Butterfield Pond Dam	Unknown	1992					13								State			
PA	Upper Friendship Dam	Unknown	1982					12								State			
PA	Van Horn #5 Dam	Unknown	1991					12								State			
PA	Van Horn #2 Dam	Unknown						10								State			
PA	Va Horn #1 Dam	Unknown	1991					8								State			
PA	Lake Lettini Dam	Delaware River (trib.)						7								State			
PA	Unnamed Dam, Peace Light Inn	Unknown	1991					7								State			
PA	Williamsburg Station Dam	Juniata River (Frankstown Branch)	1996	150,000	125,000	Private	Removed	13		260	199	Pennsylvania Electric Co.	1922	Earth Concrete Gravity		State		Water Storage	
RI	Jackson Pond Dam	Pawtuxet River	1979					20											
SC	Gallagher Pond Dam	Burgess Creek	1989					42											
SC	Miller Trust Pond Dam	Tools Fork (trib.)	1993					38											
SC	Pole Branch Dam	Pole Branch River	1990					26											
SC	Old City Reservoir Dam	Turkey Quarter Creek	1988					25											
SC	Unnamed Dam, State Road 11-58	Cowpens National Battlefield	1979					7											
SD	Arikara Dam	Unknown	1978					39											
SD	Menno Lake Dam	Unkown	1984					38											
SD	Lake Farley Dam	Unknown	1980					25											
SD	Mission Dam	Unknown	1987					25											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
					CWA404 & 401				
					CWA404 & 401				
					CWA404 & 401				Verified by Pohl and not included in database.
					CWA404 & 401				
					CWA404 & 401				
					CWA404 & 401				
					CWA404 & 401				
					CWA404 & 401				
					CWA404 & 401				
					CWA404 & 401				
					CWA404 & 401				Verified by Pohl and not included in database.
					CWA404 & 401				
		E			CWA404 & 401			scarney@lazerlink.com	Project completed in August 1996. Information obtained from the PA Fish & Boat Commission. According to the PA DEP, the neares downstream dam is 61.5 miles and there are no dams upstream.
		$							
		S							
		S							
		F							
		S							
									Verified by Pohl and not included in database.
		O							

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
SD	Farmingdale Dam	Unknown	1986					24											
SD	Norbeck Dam & SD Highway 87	Unknown						40											
SD	P6L-Lower Bigger Dam	Unknown						10											
SD	Unnamed Dam #26	Unknown	1987					10											
SD	Unnamed Dam #30	Unknown	1987					10											
SD	Unnamed Dam #32	Unknown						10											
SD	Unnamed Dam #35	Unknown	1987					10											
TN	Spence Farm Pond Dam #5	Snake Creek (trib.)	1983			Owner	breached	35	25	300	70	Private	1987	Earth fill	Low	State	No	Irrigation	Irrigation
TN	Monsanto Dam #9	Helms Branch	1990			Owner	breached	33	23	1413	1700	Industrial/Utility	1963	Earth fill	Low	State	No	Aesthetics	Other
TN	Rhone Poulenc Dam #20	Quality Creek	1995			Owner	breached	33	18	3854	1230	Industrial/Utility	1978	Earth fill	High	State	No	Aesthetics	Other
TN	Walkers Dam	Walker Stream	1992			Owner	breached	32	16	291	26	Private	unknown	Earth fill	Low	State	No	Irrigation	Irrigation
TN	Ballard Mill Mine Dam	Fork Creek (trib.)	1992			Owner	breached	30	25	691	403	Private	1956	Earth fill	Low	State	No	Detention	Other
TN	Cities Service Company Dam	Burra-Burra Creek	1995					30											Unknown
TN	L. Thompson Dam #1	Unknown	1990					10											Unknown
TN	L.C. Hancock #1	Unknown	1990					8											Unknown
TN	L.C. Hancock #3	Unknown						8											Unknown
TX	Alamo Arroyo Dam	Alamo Arroyo	1979				Removed	48		1,940	1234	Local government	1960	Earth fill	High	State	No	Flood control	
TX	H & H Feedlot Dam	Cottonwood Creek	1980				Breached	35		225	128	Private	1960	Earth fill	Low	State	No	Feedlot lake	
TX	Barefoot Lake Dam	Mill Creek	1994				Breached	27		1,610	819	Ray Reily	1964	Earth fill	High	State	No	Recreation	
TX	Lake Downs Dam	Big Sandy Creek (trib.)						26		470	54	Private	1963	Earth fill	High	State	No	Recreation	
TX	Millsap Reservoir Dam	Daves White Branch	1988				Breached	25		1,062	162	Missouri Pacific RR	1928	Earth fill	High	State	No	Water Supply	Recreation

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
Good	Unregulated	$S							
Good	Yes	$							
Good	Yes	$							
Good	Unregulated	$							
Poor	No	$							
		$							
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5195	
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5196	
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5197	
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5198	
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5199	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
TX	Nix Lake Dam	Wasson Branch						23		525	609	Nix Club lake	1940	Earth fill	Low	State	No	Recreation	
TX	Bland Lake Dam	Mustang Creek (trib.)	1989					21		1,410	54	Union Pacific RR	1969	Earth fill	Low	State	No	Other	
TX	Hilsboro Lake Park Dam	Pecan River (trib.)					Removed	15		1,200	65	Union Pacific RR		Earth fill	High	State	No	Other	
TX	Harris Back Lake Dam	Tributary of Parker Creek	1989				Breached	15		810	77	Private	1900	Earth fill	High	State	No	Recreation	
TX	Railroad Reservoir Dam	Willis Creek (trib.)	1992				Removed	10		840	26	Union Pacific RR	1904	Earth fill	High	State	No	Other	
TX	Boot Spring Dam	Unknown						15						Earth fill		State	No		
TX	Duke Dam	Unknown						8						Earth fill		State	No		
UT	Box Elder Creek Dam	Box Elder Creek	1995					50											
UT	Brush Dam	Muddy Creek	1983					49											
UT	Bell Canyon Dam		1979					30											
VA	Embrey Dam	Rappahannock River	2005																
VA	McGaheysville Dam	South Branch of the Shenandoah River	2004										1920s					Power source	
VA	Chancellorsville Brygadier A & B Dam	Tributary of Hunting Run	2000	15,000															
VA	Fredricksburgh & Spotsylvania Dam #1		2000																
VA	Fredricksburgh & Spotsylvania Dam #2		2000																
VA	Fredricksburgh & Spotsylvania Dam #3		2000																
VA	Fredricksburgh & Spotsylvania Dam #4		2000																
VA	Sykes Dam		1992					22											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5200	
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5201	
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5202	
								Warren D. Samuelson, P. E, Dam Safety Program Coordinator, MC-174, Texas Commission on Environmental Quality, P. O. Box 13087, Austin, Texas 78711, wsamuels@tceq.state.tx.us, 512/239-5203	
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
		S							
		$							
		$							
				More than 170 miles of habitat open to several species of migratory fish				John Tippett, Friends of the Rappahannock, (540) 373-3448, john_tippet@riverfriends.org	
		E$S						Sara Nicholas, American Rivers, (717) 232-8355, snicholas@americanrivers.org	
		$						Gregg Knapp, National Park Service, (540) 785-7448	
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
VA	Berryville Reservoir							15											
VA	Adney Gap Pond Dam		1984					12											
VA	Fredricksburgh & Spotsylvania Dam #2							5											
VA	Fredricksburgh & Spotsylvania Dam #3							5											
VA	Osborne Dam							12											
VA	Fredricksburgh & Spotsylvania Dam #5							5											
VA	Picnic Area Dam	Manassas NP Battlefield	1984					5											
VA	Fredricksburgh & Spotsylvania Dam #6							4											
VT	Cold River Dam	Cold River	2003					7		90			1970s	Boulder					
VT	Hillside Farm Dam	Tributary to the Ompompanoosuc River	2003					18						Earth					
VT	Johnson State College Dam	Tributary to the LaMoille River	2003					30						Earth				Aesthetic purposes	
VT	Lyndon State College Lower Dam	Passumpsic River-TR																	
VT	Red Mill Dam	Battenkill River																	
VT	Youngs Brook Dam	Youngs Brook	1995					46											
VT	Lower Eddy Pond Dam	Mussey Brook	1981					20											
VT	Norwich Reservoir Dam	Charles Brown Brook						20											
VT	Winooski Water Supply Upper Dam	Winooski River (trib.)	1983					19											
VT	Newport 11 Dam	Clyde River	1996	550,000				19		90	20	Citizens Utility Co.	1956	Concrete Buttress Gravity				Hydropower	
VT	Groton Dam	Wells River	1998					5				Town of Groton	1803	Timber Crib					

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
		E					Monitoring after removal	Jim MacCartney, Trout Unlimited and National Park Service, (603) 226-3436, jmaccartney@tu.org	
		F						Brian Fitzgerald, Vermont Agency of Natural Resources, (802) 241-3468, brian.fitzgerald@anr.state.vt.us	
		$F						Brian Fitzgerald, Vermont Agency of Natural Resources, (802) 241-3468, brian.fitzgerald@anr.state.vt.us	
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
		S							Verified by Pohl and not included in database.
		S							
		S							Verified by Pohl and not included in database.
		S							Verified by Pohl and not included in database.
		E							
									DATA LACKING. The dam was washed out in January of 1998. A permit to rebuild it was denied by the VT Water Resources Board in March of 1998. Detailed account of decision in files.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
WA	Three Unnamed Barriers	Icicle Creek						9										Hold adult salmon and steelhead	
WA	Goldsborough Creek Dam	Goldsborough Creek	2001	4,800,000		Federal, State	Removed	14		100	1	Simpson Timber Company	1921	Timber crib & concrete	Low	State	Yes	Electrical Power Generation	Diversion
WA	Unnamed Dam	Headquarters Creek at Willapa National Wildlife Refuge	2000					5					Early 1940s					Source of water	
WA	Maiden Dam	Touchet River	1998																
WA	Pomeroy Gulch Dam	off-channel dam					Removed	38											
WA	North End Reservoir	Unknown OFFSTREAM					Removed	28											
WA	Wind River Dam	Wind River						20											
WA	Darrington Water Works Dam	Sauk River (trib.)	1985	20,000		State	Breached	19	19	200	100	Local government	1966	Earth fill	Medium	State	No	Water Supply	
WA	Sultan Mill Pond Dam	Wagleys Creek						15											
WA	Black Mud Waste Pond Dam A	off-channel dam					Removed	15											
WA	Black Mud Waste Pond Dam B	off-channel dam					Removed	15											
WA	Black Mud Waste Pond Dam C	off-channel dam					Removed	15											
WA	City Lakes Dam	off-channel dam						15											
WA	Mill Creek Settling Basin Dam	Mill Creek						15											
WA	PEO Dam #32A	Hanford Creek (trib.)						14											
WA	Coffee Creek Dam	Coffee Creek						10											
WA	Bow Lake Reservoir							7											
WA	Stromer Lake Dam	Columbia River-TR						5											
WA	PEO Dam #48	Hanford Creek (trib.)						3											
WA	White River Mill Pond Dam	Boise Creek						3											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
		E		Open an additional two to three miles of habitat for salmon; Return flow to the original channel of Icicle Creek				Buford Howell, Icicle Creek Watershed Council, (509) 548-6017	
Poor	No	$	Environmental benefit (fisheries, water quality, river restoration)	Amount of wildlife seen in the area has increased	CWA404 & 401	No	Yes	Patti Case, Simpson Timber Company, (360) 427-4733	See info on Friends of the Earth website: http://www.foe.org/camps/reg/nw/river/golds.html
		E		Return of cutthroat trout; Increase in salmon runs; Restore some of the rich amphibian diversity				Charlie Stenvall, U.S. Fish and Wildlife Service, (360) 484-3482, Charlie_stenvall@r1.fws.gov	Pratial Removal
									DATA LACKING. Dam removed. Need measurements.
									Offstream Storage Reservoir - removed and replaced by a tank.
									Dam was an in-city reservoir and was drrained, the site was regarded, and an above ground tank was put in place of the open reservoir
Poor	No	S		Removed Safety Hazard	None	No	No	Doug Johnson, Washington State Dam Safety djsd461@ecy.wa.gov	
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									Dam was not on a stream
									Verified by Pohl and not included in database.
									DATA LACKING. Need removal verification and measurements.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
WA	Rat Lake Dam	Whitestone Creek	1989	52,000	52,000			32		240									
WI	Country Dam	Apple River	2004																
WI	Ball Park Dam	Maunesha River	2004	125,000				11											
WI	McCaslin Brook Dam	McCaslin Brook	2004					8		108				Large boulders, wood crib structures					
WI	Knowles Dam	Oconto River	2004					7.5											
WI	Hemlock Dam	Oconto River	2004					7.5											
WI	Kenosha Country Club Dam	Pike River	2004					4						Concrete					
WI	Athens Dam	Totato Creek	2004					9						Rock & concrete					
WI	Planning Mill Dam	Waupaca River	2004																
WI	Two Boulder Creek Dams	Boulder Creek	2003											Timber crib & cement					
WI	Clark's Mill Dam	Magdantz Creek	2003					7		166				Earth					
WI	Unnamed Dam	Branch River	2003					5		40									
WI	Waubeka Dam	Milwaukee River	2003					10		222				Rock					
WI	White River Dam	Fox River	2003					12		250				Rock & timber crib					
WI	Afton Dam	Bass Creek	2002																
WI	Grand River Dam	Grand River	2002					11						Concrete					

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
		S							
								Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424 ext. 112, hsarakinos@wisconsinrivers.org	
		$		Improve fish movement, species and habitat diversity navigation and water quality				Laura Stremick-Thompson, WI Department of Natural Resources, (920) 387-7876, Laura.Stremick-Thompson@dnr.state.wi.us	
		E$		Improve water quality; Increase population of native brook trout				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424 ext. 112, hsarakinos@wisconsinrivers.org	
				Restore a cold-water fishery; Benefit native brook trout populations				Tom Moris, Wildlife Biologist, Chequamegon-Nicolet National Forest, (715) 674-4481	
				Restore a cold-water fishery; Benefit native brook trout populations				Tom Moris, Wildlife Biologist, Chequamegon-Nicolet National Forest, (715) 674-4482	
		E		Increased habitat for Lake Michigan migratory species				Art Kitchen, U.S. Fish & Wildlife Service, (608) 221-1206, art_kitchen@fws.gov	
		$						Keith Patrick, WI Department of Natural Resources, (715) 241-7502, Keith.Patrick@dnr.state.wi.us	
								Dean Stitgen, WI Department of Natural Resources, (608) 266-1925 dean.stitgen@dnr.state.wi.us	
		ES		Restore fish habitat; Improve water quality				Helen Sarakinos, River Alliance of Wisconsin, (608) 275-2424 ext. 112, hsarakinos@wisconsinrivers.org	
		$		Restore fish habitat; Return creek to free-flowing status				Linda Hyatt, Wisconsin Department of Natural Resources, (920) 787-4686, linda.hyatt@dnr.state.wi.us	
		E						Helen Sarakinos, River Alliance of Wisconsin, (608) 275-2424 ext. 112, hsarakinos@wisconsinrivers.org	
		$S		Improve water quality; Expose riffle habitat for smallmouth bass				Helen Sarakinos, River Alliance of Wisconsin, (608) 275-2424 ext. 112, hsarakinos@wisconsinrivers.org	
		$S		Remove safety liability; Open up the Fox River to fish migration for species such as lake sturgeon, flathead catfish, and walleye				Linda Hyatt, Wisconsin Department of Natural Resources, (920) 787-4686, linda.hyatt@dnr.state.wi.us	
		S		Improve habitat for fish; May upstream wetland restoration				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org or Sue Josheff, Wisconsin Department of Natural Resources, (608) 275-3305. http://www.wisconsinrivers.org/SmallDams/20by2000-detailed-list.html#Afton%20Dam	
								Linda Hyatt, Wisconsin Department of Natural Resources Dam Safety Engineer, 920-787-4686, linda.hyatt@dnr.state.wi.us	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
WI	Schweitzer Dam	Cedar Creek	2002					8		30				Timber crib					
WI	Woods Creek Dam	Woods Creek	2002					16		200								Hydropower	
WI	Silver Springs multi-dam complex (13 dams)	tributary of Onion River	2002					6						Wood and Concrete					
WI	Deerskin Dam	Deerskin River	2001	15,000															
WI	Franklin Dam	Sheboygan River	2001					13		280	94	Franklin Volunteer Fire Department	1850	Gravity Earth Rockfill				Recreation	
WI	Kamrath Dam	Tributary of Onion River	2001					5											
WI	LaValle Dam	Baraboo River	2001																
WI	Linen Mill Dam	Baraboo River	2001	58,000															
WI	New Fane Dam	East Branch of the Milwaukee River	2001	50,000															
WI	Orienta Dam	Iron River	2001	500,000				44					1930s					Hydropower	
WI	Waubeka Dam	Milwaukee River	2001															Power	

Removal Details								Supplementary Information	
Condition of dam prior to removal	Did dam meet applicable safety requirements	Primary Removal Reason	Other (secondary) Removal Reasons	Benefits	CWA 404 Permit or 401 Certification	Stream Mitigation Credit assigned? (Yes or No)	Study after Removal? (Yes or No). Please provide reference in comments column.	Contact Information (please include e-mail address)	Additional information or comments
		E		Restored the entire creek from a shallow and algae-filled impoundment to a free-flowing stream and natural floodplain open to public use				Will Wawrzyn, Wisconsin Department of Natural Resources, (414) 263-8699	
		O		Return stream to free-flowing state; Allow brook trout access to overwintering habitat				Bob Martini, Wisconsin Department of Natural Resources, (715) 365-8969	
		E		Restore trout habitat; Restore stream channels				Laura Hewitt, Trout Unlimited, (608) 250-2757, lhewitt@tu.org	
		$S		Improve water quality; Restore fish habitat				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org. http://www.wisconsinrivers.org/SmallDams/deerskin_dam.html	
		$		Restored 10 miles of free flowing river; Improved water quality; Benefited smallmouth bass and northern pike; Populations of mayfly and kadisfly increased above the former dam site				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org. http://www.wisconsinrivers.org/SmallDams/deerskin_dam.html	
		E		Stream returned to its historic, meandering path; Benefited the health of the entire Great Lakes Basin				Laura Hewitt, Trout Unlimited, (608) 250-2757, lhewitt@tu.org. http://www.wisconsinrivers.org/SmallDams/20by2000-detailed-list.html#Onion%20River%20Project	
								John Laub, Sand County Foundation, (608) 244-3512	
		$		Restored river to free-flowing state; Habitat improvements for fish				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424. http://www.wisconsinrivers.org/SmallDams/baraboo_casestudy.html	
		$		Restored 6 miles of free flowing river; Benefited many species				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org	
		$		Improved at least 1.5 miles of spawning habitat for salmon and trout migrating from Lake Superior				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org. http://www.wisconsinrivers.org/SmallDams/20by2000-detailed-list.html#Orienta%20Dam	
		$		Restored oxygen and temperature levels; Return of sediment and nutrients to sediment-starved downstream reaches; Decreased flood risk; Additional habitat for smallmouth bass and other warmwater sportfish; Additional public land to create public parks				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org	

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
WI	Chair Factory Dam	Milwaukee River	2001	175,000															
WI	Oak Street Dam	Baraboo River	2000	30,000				12		208									
WI	Rockdale Dam	Koshkonong Creek	2000																
WI	Shopiere Dam	Turtle Creek	2000	100,000				9		250	35	abandoned by private owner	1939	Gravity Earth				Recreation	
WI	Beardsley Dam	Madden Branch Tributary	1990	12,000				12											
WI	Bowen Mill Dam	Pine River	1996					12											
WI	Carpenter Creek Dam	Carpenter Creek	1995	8,500				4											
WI	Cartwright Dam	Shell Creek	1995					7			10								
WI	Colfax Light Power Dam	Red Cedar River	1969	120,000				21			52								
WI	Crivitz Dam	Peshtigo River	1993	35,000															
WI	Dunlop Creek Dam	Dunlop Creek	1955																
WI	Ettrick Dam	Beaver Creek (North Fork)	1976																
WI	Fulton Dam	Yahara River	1993	375,784		State, Other		16			350	Rock County	1800s (mid)					Hydropower	
WI	Funks Dam	Oconomowoc River	1993	40,000				5			80								
WI	Greenwood Dam	Black River	1994	80,000				16				unknown	1905					Hydropower	
WI	Huigen Dam	Handsaw Creek	1970					6											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
		$		Exposed riffle habitat important to smallmouth bass and other sportfish; Improved water quality				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org. http://www.wisconsinrivers.org/SmallDams/20by2000-detailed-list.html#Chair%20Factory%20Dam	
		$		Opened up spawning grounds important to sturgeon, endangered paddlefish, and small mouth bass; Grown canoeing activity, increasing revenue in the town of Baraboo; The town plans to develop the waterfront as recreation and a community-gathering place				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org. http://www.wisconsinrivers.org/SmallDams/oakstreet_pics.html	
		$						Sue Josheff, Wisconsin Department of Natural Resources, (608) 275-3305	
		$		Restored 30 miles of free-flowing river; Improved habitat for fish populations; Improved water quality				Helen Sarakinos, River Alliance of Wisconsin, (608) 257-2424, wisrivers@wisconsinrivers.org. http://www.wisconsinrivers.org/SmallDams/shopiere_dam.html	
									Dam removal improved water quality on this stretch of the river.
									DATA LACKING. Dam removed. Need measurements. This dam was built without legal consent. It was removed because it was a boating hazard.
									The WI DNR states that this is an excellent small mouth bass site -- it is unclear how much the dam removal contributed to this.
									A boating hazard was removed with the dam was taken out.
									DATA LACKING. Need removal verification and measurements.
		E							One of the dams studied in the Wisconsin small dam removal report. The removal of the dam decreased the rough fish population and established a warm water fishery.
									Dam removed. Need measurements. Removal of the dam increased water fowl habitat and increased the spawning runs of walleye and small mouth bass.
									One of the dams studied in the Wisconsin small dam removal report. abandoned dam (under WI criteria) A boating hazard was removed with the dam was taken out.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
WI	Huntington Dam	Apple River	1968	35,000							60	Northern States Power Co.	1910					Hydropower	
WI	Island Woolen Co. Dam	Baraboo River	1972																
WI	Lowe Creek 1 Dam	Lowe Creek									35								
WI	Lowe Creek 2 Dam	Lowe Creek									12								
WI	Marengo Dam	Marengo River	1993	120,000				17			80								
WI	McClure Dam	Apple River	1968	50,000							22	Northern States Power Co.	1910					Hydropower	
WI	Mellen Dam	Bad River	1967	150,000							150								
WI	Mellen Waterworks Dam	City Creek	1995					12			5								
WI	Northland Dam	Flume River	1992					10			30								
WI	Oslo Dam	Manitowoc River	1991	19,000				8											
WI	Port Arthur Dam	Flambeau River	1968	600,000							250								
WI	Pulcifer Dam	Oconto River	1994	40,000		State		5					1869					Hydropower	
WI	Readstown Dam	Kickapoo River	1985								30								
WI	Schiek Dam	Handsaw Creek	1970	15,000				6											
WI	Upper Tigerton Dam	Embarrass River	1997					4			200								
WI	Whitehall Dam	Trempealeau River	1988								30								
WI	Wonewoc Dam	Baraboo River	1996					28											
WI	Young America Dam	Milwaukee River	1994	75,000				11			130								
WI	Klondike Dam	Otter Creek	1978					30											
WI	Token Creek Dam	Token Creek	1999					13											
WI	Centerville Dam	Centerville Creek	1996					12											
WI	Cross Plains Dam	Black Earth Creek	1955					11											
WI	Mount Vernon Dam	Sugar River	1950					11											
WI	Black Earth Dam	Black Earth Creek	1957					9											
WI	Reedsburg Dam	Baraboo River	1973					9											
WI	Hamilton Mill Dam	Cedar Creek	1996					8		100									

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
									One of the dams studied in the Wisconsin small dam removal report. The WI DNR states that this is an excellent small mouth bass site -- it is unclear how much the dam removal contributed to this.
		E							Removal of the dam restored trout habitat to this stretch of the river.
		E							One of the dams studied in the Wisconsin small dam removal report. The dam removal helped restore a small mouth bass habitat.
		E							Dam was removed to aid trout stream restoration. The old dam site is now a state park with a 50 ft natural falls.
		E							Removal of the dam opened four additional miles of steelhead fishing.
		E							The removal of the dam developed 5 miles of cold water fishery.
									DATA LACKING. Dam removed. Need measurements. One of the dams studied in the Wisconsin small dam removal report. A boating hazard was removed with the dam was taken out.
									Dam removal restored trout fishing to this stretch of the river.
									DATA LACKING. Dam removed. Need measurements.
									DATA LACKING. Dam removed. Need measurements.
									Removal of the dam improved the small mouth bass fishing and water fowl habitat. It also provided better access to the river.

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
WI	Spring Valley Dam	Eau Galle River	1997					3			3								
WI	Ward Paper Mill Dam	Prairie River	1999					18		640	709	Ward Paper Co.	1905	Gravity Earth				Hydropower	Water Storage
WI	Oak Street Dam	Baraboo River	2000			State		14		270	60	Robert McArthur	1929	Gravity				Hydropower	Recreation
WI	Rassussen #1 Dam	Unknown																	
WI	Unnamed Dam #1 Larrabee Tract	Unknown	1990																
WI	McNally Trout Pond Dam	Unknown	1983					5											
WI	Rassussen #2 Dam	Unknown	1982					3											
WI	Rassussen #3 Dam	Unknown	1982					3											
WI	Poppe Dam	Unknown	1982					2											
WI	Schaaf #1 Dam	Unknown	1982					2											
WI	Schaaf #2 Dam	Unknown	1982					2											
WI	Weingarten Dam	Unknown	1982					2											
WI	Evans Pond Dam	Rathbone Creek	1998	5,000				10											
WI	Lemonweir Dam	Lemonweir River	1992	190,000		State, Other		14			80		1914					Hydropower (inactive)	Recreation
WI	Nelsonville Dam	Tomorrow/Waupaca River	1988	62,000		Other					180	private owner	1860s					Hydropower	
WI	Ontario Dam	Kickapoo River	1992	47,000							121	unknown	1865					Hydropower (inactive)	Other
WI	Somerset Dam	Apple River	1965	75,000							83	Village of Somerset	1856					Hydropower	
WI	Woolen Mills Dam	Milwaukee River	1988	202,000				18			70	City of West Bend	1870					Hydropower	Recreation; Other
WI	Colfax Dam	Eighteen Mile Creek	1998	241,000				20		350	42	Village of Colfax	1938	Rockfill Earth Gravity				Recreation	
WI	North Avenue Dam	Milwaukee River	1997	345,000				19		432	200	City of Milwaukee	1920	Gravity Other				Recreation	

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
									Verified by Pohl and not included in database.
								lindloff@wisconsinrivers.org	Taken from River Alliance's 20 by 2000
								lindloff@wisconsinrivers.org	
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.
									Verified by Pohl and not included in database.
									Verified by Pohl and not included in database.
									DATA LACKING. Need removal verification and measurements.
									WI DNR owned the dam. The dam was located on a trout stream. The dam was removed because it was in poor shape -- and because its costs outwieghed its benefits in the b-c analysis.
									One of the dams studied in the Wisconsin small dam removal report. The removal of the dam allowed walleyes to return upstream of the dam site.
									One of the dams studied in the Wisconsin small dam removal report. Not sure of exact date that the dam was removed -- either late 1980s or early 1990s. Dam was sold to WDNR for removal.
									One of the dams studied in the Wisconsin small dam removal report. Removal of the dam improved both recreational canoeing and trout fishing at this stretch of the river.
									One of the dams studied in the Wisconsin small dam removal report. The area is now a recreation area for tubing with 100,000 people per year that participate.
		$							N.A. Journal of Fisheries Management One of the dams studied in the Wisconsin small dam removal report. Removal of the dam restored a sport fishery on this stretch of the river.
									Taken from River Alliance's 20 by 2000

Table B.2 *Continued*.

Dam ID			Removal Information					Dam Characteristics											
State	**Dam**	**River**	**Removal Date**	**Total Removal Cost in US$ (Engineering, Permitting, Deconstruction, etc.)**	**Removal Cost in US$ (deconstruction cost only)**	**How was removal funded?**	**Indicate whether dam was removed (total removal) or breached (partial removal)**	**Dam Maximum Structural Height (ft)**	**Dam Hydraulic Height (ft)**	**Dam Length (ft)**	**Reservoir Volume (acre-ft)**	**Owner**	**Date Built**	**Type of Dam**	**State Hazard Classification**	**Who regulates dam**	**Run–of–river dam? (Yes or No)**	**Original purpose of dam**	**Most recent use of dam and reservoir**
WI	Parfrey Glen Dam	Pine River	1996	154,000				19		450	90	City of Richland Center	1934	Earth Other Gravity				Recreation	
WI	Hayman Falls Dam	Embarrass River	1995	146,000				17		200	415	Shawano County	1918	Gravity Earth				Recreation	
WI	Hebron Dam	Bark River	1996					17		170	100	Hebron Rod & Gun Club	1933	Gravity Earth				Recreation	
WI	Upper Waterloo Dam	Maunesha River	1995					17		115	320	Waterloo Malting Co.	1915	Gravity Earth				Recreation	
WI	Manitowoc Rapids Dam	Manitowoc River	1984	45,000		State, Private		16		400	45	Ray Bertler	1854	Gravity Earth Rockfill				Recreation	
WI	Waterworks Dam	Baraboo River	1998	213,770		State, Other		14		220	190	City of Baraboo	1913	Gravity				Recreation	Water Storage
WI	Slabtown Dam	Bark River	1992	30,000				10		60	70	unknown	1948	Gravity Earth				Recreation	
WI	Wilmot Dam	Fox River	1992					3		200	177	Kenosha County	1941	Gravity Earth				Recreation	
WV	Ladoucer Pond Dam	Unknown	1993																
WY	Sheridan Heights Reservoir	City of Sheridan (trib.)																	
WY	Unnamed Dam	Laramie River	1997																
WY	White Grass Dude Ranch Dam	Unknown	1988																
WY	North Dam	Unknown						15											
WY	East Dam	Unknown						7											
WY	South Dam	Unknown						7											
WY	Unnamed Dam #1	Unknown						7											
WY	West Dam	Unknown						7											

Removal Details								Supplementary Information	
Condition of dam prior to removal	**Did dam meet applicable safety requirements**	**Primary Removal Reason**	**Other (secondary) Removal Reasons**	**Benefits**	**CWA 404 Permit or 401 Certification**	**Stream Mitigation Credit assigned? (Yes or No)**	**Study after Removal? (Yes or No). Please provide reference in comments column.**	**Contact Information (please include e-mail address)**	**Additional information or comments**
									One of the dams studied in the Wisconsin small dam removal report.
		E							One of the dams studied in the Wisconsin small dam removal report. The dam removal created 40 miles of steelhead fishing.
								lindloff@wisconsinrivers.org	Taken from River Alliance's 20 by 2000
									The removal of the dam increased the available water fowl habitat.
									Verified by Ashley and included in database.
									DATA LACKING. Need removal verification and measurements.
		$							
									DATA LACKING. Need removal verification and measurements.
									DATA LACKING. Need removal verification and measurements.