Enhancing Fish Passage over Low-head Barrier Dams in the Saginaw River Watershed

December 2005

Prepared for
The Partnership for the Saginaw Bay Watershed
Bay City, Michigan

Prepared by
Public Sector Consultants Inc.
Lansing, Michigan
www.pscinc.com

Contents

EXECUTIVE SUMMARY **1**

OVERVIEW **3**

BACKGROUND **6**

THE SAGINAW BAY WATERSHED 6
MICHIGAN DAM HISTORY 8
EMBRACING DAM REMOVAL AS AN OPTION FOR FISH PASSAGE 10
DECLINE IN ABUNDANCE OF IMPORTANT FISH SPECIES 11
PROJECT RATIONALE 12
Great Lakes Fish Community Objectives *12*
Environmental Objectives for Lake Huron *12*
1999 Fisheries Scoping Study—The Conservation Fund *13*
Measures of Success—Remedial Action Plan *13*
The Lake Huron Initiative *14*
Michigan Department of Natural Resources Saginaw Bay Walleye Recovery Plan *14*

DAM ASSESSMENT **17**

SUB-BASIN 19
COUNTY 21
CURRENT USE 22
YEAR CONSTRUCTED 23
CURRENT OWNERSHIP TYPE 24
HAZARD POTENTIAL 24
FISH PASSAGE OPTIONS 25
Fish Species *28*
Design Alternatives *32*
Sea Lamprey Control *32*
DAM REMOVAL CONSIDERATIONS 34
Issues to Consider Prior to Removal of a Low-head Dam *35*
Technical Aspects *35*
Environmental and Ecological Issues *35*
Economics and Social Dimensions *36*
Legal Perspectives *36*
Design and Construction Approaches *37*
Trade-offs of Dam Removal versus Dam Retention *37*
FRANKENMUTH DAM 39
Conclusions and Recommendations *43*
DOW DAM 45
CHESANING DAM 47

FUNDING FISH PASSAGE AND DAM REMOVAL **55**

CONCLUSION AND RECOMMENDATIONS **60**

REFERENCES **62**

APPENDIX A: ***PROJECT WORK PLAN*** **..... 65**
APPENDIX B: ***CHARACTERISTICS OF CURRENT DAMS, BY SUB-BASIN*** **..... 66**

Executive Summary

In October 2003, The Partnership for the Saginaw Bay Watershed, a local stakeholder group comprising citizens, government representatives, and environmental groups, hired Public Sector Consultants Inc. to conduct an assessment and develop information for communities and resource managers to help identify the most cost-effective options—including dam removal—for enhancing fish passage over barrier dams to achieve the targeted, sustainable fish population goals for Saginaw Bay. This report is intended to help dam owners make informed and collaborative decisions about the future of their dam. It strives to establish social, economic, and ecological contexts for decision making and describes potential costs and benefits of enhancing fish passage in several key tributaries in the Saginaw River watershed.

Until recently, installation of dams was a widely supported method of river management in Michigan and the United States. The current consensus among river ecologists, however, is that dams are the single greatest cause of the decline of river ecosystems (World Commission on Dams 2000). Community and public reaction to dam removal at the local level appears biased toward socioeconomic and value-laden judgments that perpetuate the status quo and undermine opportunities for ecological restoration. Consideration of dam removal often incites significant opposition because a dam often is viewed as a site of historical significance, a civic icon of sorts—revered and cloaked in nostalgia and romantic history of the nineteenth and early twentieth centuries with minimal regard for contemporary environmental objectives. In addition, the water impoundments created by dams may be viewed as an economic stimulus for recreation or downtown development.

In Michigan, almost 2,500 dams obstruct fish passage and reproduction on key rivers and streams, all of which drain to the Great Lakes. Approximately 315 of these dams are located in the Saginaw River watershed, with the largest number, approximately 96, occurring in the Flint River sub-basin.

The primary goals of the project were to:

- Increase awareness and understanding of both dams and natural river systems in the Saginaw River watershed
- Improve the process of decision making at the local level so that alternatives to improve fish passage, including selective dam removal, are considered and accepted or rejected on their own merits
- Identify a suite of financing options for enhancing fish passage, including dam removal, by-pass channels, or other innovative approaches such as rock ramp installation

The City of Frankenmuth participated in the project as a demonstration site to assess opportunities and cost estimates for fish passage at its local dam. Cost estimates were developed for fish passage alternatives at this site. In addition, the Chesaning Dam on the Shiawassee River and the Dow Dam on the Tittabawassee River provide a focus for some of the analysis. According to the Michigan Department of Natural Resources, the ability

to move fish past these three barriers, and others, represents one of the most significant opportunities to help reestablish and sustain desirable fish populations in the Saginaw Bay watershed.

The report concludes that improving fish passage and natural reproduction and considering selective dam removal in tributary streams is limited primarily by:

- Lack of understanding and knowledge on the part of dam owners and local citizens of the value and type of ecological restoration techniques now possible
- Lack of public support for dam removal as a viable tool for river restoration
- Lack of complete and accurate information when decisions on dam removal are made, often in an emotionally charged and divisive atmosphere
- Lack of financial resources to achieve desirable fish passage techniques, including dam removal

The report also concludes that enhancing fish passage in tributary streams is not incompatible with local socioeconomic goals. In fact, interaction among fishery managers and local community officials at the earliest stages to assess opportunities for fish passage and consider dam removal may lead to enhanced recreational opportunities while stimulating local economies.

Removing dams to reestablish free-flowing tributary rivers and providing fish passage over remaining useful structures offers a major opportunity for restoration of certain Great Lakes fish populations that have historically relied upon rivers for spawning and nursery areas. Restoration of the natural flow regime of tributary rivers and their watersheds continues to emerge as a significant component of recovery efforts throughout the Great Lakes region and Michigan in particular.

Overview

This project sought to implement a recommendation of a 1999 *Fisheries Scoping Study* (The Conservation Fund 1999) funded by the Saginaw Bay Watershed Initiative Network (WIN), a consortium of communities, conservationists, foundations, and businesses working together to balance the region's economic, environmental, and social goals, and carried out by The Conservation Fund. The study suggested that the best opportunity to enhance walleye populations may be in projects that allow fish passage around impoundments to access historical spawning grounds. This project also addresses recommendations of the 2000 Saginaw River/Bay *Measures of Success* report (PSC 2000) and the Lake Huron Initiative (MDEQ/OGL 2000) to restore habitat required to enhance and sustain valuable fish populations of Saginaw Bay and Lake Huron. Furthermore, the project was designed to advance fish community objectives for Lake Huron—established for the Great Lakes under the auspices of the Great Lakes Fishery Commission—by developing critical information required to access spawning habitat in tributary rivers and streams now blocked by dams. A project steering committee composed of agency representatives and local stakeholders was formed in November 2003 to help guide the project.

Dams and other man-made barriers constructed in tributaries to the Great Lakes over the last 150 years are a major factor limiting the establishment of sustainable populations of valuable Great Lakes fish species. Rivers are an integral element of the Great Lakes system. The quality of water entering the Great Lakes system through tributaries affects the health of the organisms within the system. Many fish species found in the Great Lakes depend wholly or partially upon tributaries for spawning and nursery areas. Many species, including salmon, steelhead, walleye, and lake sturgeon, spawn in streams and rivers and remain there for the early part of their life stages. Physical and chemical deterioration of river and stream habitats has been a significant factor limiting the natural reproduction of certain Great Lakes fish populations.

The Great Lakes fishery and the ecological system upon which it depends cannot be fully restored to the conditions that existed prior to European settlement of the Great Lakes region. The loss of several fish species, the purposeful and accidental introduction of nonindigenous species, and the irreversible effects of major land use changes and related human activities in the Great Lakes basin will require adaptive management approaches that recognize these limitations. However, opportunities are now available that take advantage of increased public support for protection of the Great Lakes and expanded efforts to restore critical elements of the ecosystem. This support is invaluable to the recovery and stabilization of native and non-native fish populations that offer the potential for long-term, sustainable benefits to residents of the Great Lakes basin.

Restoration of Saginaw Bay and Lake Huron fisheries depends on reestablishing natural reproduction to achieve management objectives. The deforestation and conversion of land to agriculture by early settlers set the stage for silt and sediment erosion to cover a sizeable portion of Saginaw Bay's historically important open-water spawning reefs, significantly impairing natural reproduction. During the same period, many dams were constructed to accommodate sawmills and gristmills and to generate electricity. This

severed significant portions of the tributary rivers from the Great Lakes, blocking spawning runs for such fish species as sturgeon, walleye, whitefish, white bass, and suckers. In order to meet fishery objectives for the watershed, the available habitat for spawning must be expanded into tributary rivers and streams now obstructed by dams.

The Saginaw Bay watershed is the largest watershed in Michigan and is home to a renowned walleye fishery. The majority of natural reproduction for this species occurs in rivers within the watershed. A combination of factors has slowed walleye recovery in Saginaw Bay. These include alewife predation on walleye fry, habitat degradation, and blocked access to critical spawning habitat by dams and spillways.

While the bay's walleye sport fishery has returned, studies suggest that a large proportion of the locally produced walleye are stocked fish. Recent research (Fielder 2002) shows that increased bay sedimentation rates since the early to mid-1900s, specifically sediment transported from rivers, has virtually eliminated the inner-bay rock reefs that once were major spawning sites for bay-area walleye populations. While providing access to fish spawning and nursery areas upstream of dams offers the greatest potential for restoring fish populations in Saginaw Bay to historic levels, there is no framework or strategy to address the complex issues associated with fish passage past existing barriers.

Management agencies such as the Michigan Department of Natural Resources (MDNR) seek to build sustainable fish populations based on natural reproduction to help reduce reliance on fish production and stocking. This will be achieved by implementing several strategies, including reconnecting tributaries to the Great Lakes that have been blocked by dams, many of which have outlived their useful life and negatively affect natural flow regimes, stream hydrology, and aquatic habitats.

While the MDNR has established tentative goals based on historic levels for sustainable fish production from Saginaw Bay, achievement of these goals depends on continued progress in pollution control and increased habitat protection and restoration. In general, the fisheries management goal is to take advantage of available forage species in the bay to enhance the abundance of larger predator species such as walleye, northern pike, muskellunge, and catfish; to accomplish this goal, stocking, harvest regulation, and habitat protection will be employed. Recovery goals have been proposed by the state for a majority of the sport and commercial species taken from the river and bay.

Unfortunately, no statewide or watershed strategy is available to help dam owners and resource managers identify dams for removal or determine other opportunities for enhancing fish migration above these structures. Moreover, there is limited technical information on the relative cost and designs needed to provide passage above current barriers for such species as walleye, sturgeon, and white bass while minimizing sea lamprey access to these same areas.

In October 2003, The Partnership for the Saginaw Bay Watershed, a local stakeholder group comprising citizens, government representatives, and environmental groups, hired Public Sector Consultants Inc. to conduct an assessment and develop a strategy for dam owners and resource managers to help identify the most cost-effective options—including dam removal—for enhancing fish passage past barrier dams to achieve the targeted,

sustainable fish population goals for Saginaw Bay. (The project work plan is provided in Appendix A.)

The primary goals of the project were to:

- Increase awareness and understanding of both dams and natural river systems
- Improve the process of decision making at the local level so that alternatives to improved fish passage, such as selective dam removal, are considered and accepted or rejected on their own merits
- Identify a suite of financing options for dam retirement, removal, and enhancing fish passage

Specific project objectives were to:

- Conduct an assessment of dams in the Saginaw River watershed based on current use, ownership, age, hazard potential, sea lamprey barrier issues, and other factors such as potential for increasing spawning habitat
- Develop technical and economic information to help dam owners, local officials, and resource managers assess and evaluate options for fish passage
- Analyze technical information, including costs and funding options, and select viable alternatives for fish passage at the Frankenmuth Dam
- Identify significant obstacles to restoring natural flows and enhancing fish passage in the Saginaw River watershed

A project advisory committee composed of agency representatives and local stakeholders was formed in November 2003 to help guide the project. Member organizations were:

- City of Frankenmuth
- Dow Chemical Company
- Michigan Department of Environmental Quality—Dam Safety Unit
- Michigan Department of Environmental Quality—Office of the Great Lakes
- Michigan Department of Natural Resources—Fisheries Division
- The Partnership for the Saginaw Bay Watershed
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service

The City of Frankenmuth participated in the project as a demonstration site to assess opportunities for fish passage at its local dam. The Chesaning Dam on the Shiawassee River and the Dow Dam on the Tittabawassee River were focal points for additional analysis. The ability to move fish past these three barriers represents one of the most significant opportunities to help reestablish and sustain desirable fish populations in the Saginaw Bay watershed.

Background

THE SAGINAW BAY WATERSHED

Located in the east central portion of Michigan's lower peninsula, the Saginaw Bay watershed consists of all of the land area and waterways that drain into Saginaw Bay. This watershed, Michigan's largest, includes all or part of 22 counties and America's largest contiguous freshwater coastal wetland system. It extends from Iosco, Ogemaw, and Roscommon Counties in the north to Livingston and Oakland Counties in the south, and includes parts of Huron and Sanilac Counties in the east. The bay has a large surface area of 2,960 square kilometers and its drainage basin covers 22,557 square kilometers. Twenty-eight rivers, creeks, and agricultural drains flow directly into Saginaw Bay (MDNR/SWQD 1988). The Saginaw Bay watershed is home to about 1.4 million people. Land use is diverse, ranging from relatively undisturbed natural areas to intensive agricultural and heavily industrialized urban settings. The majority of industrial activity is in the four urban centers—Bay City, Flint, Midland, and Saginaw. Agriculture comprises approximately 50 percent of the land use. Residents rely on the watershed for irrigation, electrical power generation, industrial processes, and drinking water.

The rich resources of the Saginaw Bay watershed also support tourism, outdoor recreation, and a vast variety of wildlife, including more than 138 endangered or threatened species (MDNR/SWQD 1994). Wetlands along the shores of Saginaw Bay provides vital habitat for millions of migrating waterfowl and songbirds and over 90 fish species. The watershed also features more than 175 inland lakes, about 7,000 miles of rivers and streams, and drains approximately 15 percent of Michigan's total land area. Exhibit 1 highlights the watershed boundaries and major tributaries.

The Saginaw River/Bay fisheries were important to the residents of the region even before European settlement of the area occurred in the mid-1800s. Native Americans relied on the abundant fish populations found in the river and bay as a significant source of food. Commercial fishing activities around Saginaw Bay flourished in the last half of the 1800s, supplying food for a growing population in the area and the Great Lakes region. Commercial fishing became a major industry in many ports along Saginaw Bay, peaking just after the turn of the century, when a record 14.2 million pounds of fish were harvested.

EXHIBIT 1
Saginaw Bay Watershed Boundary and Major Tributaries and Cities

SOURCE: Michigan Department of Environmental Quality, 2000.

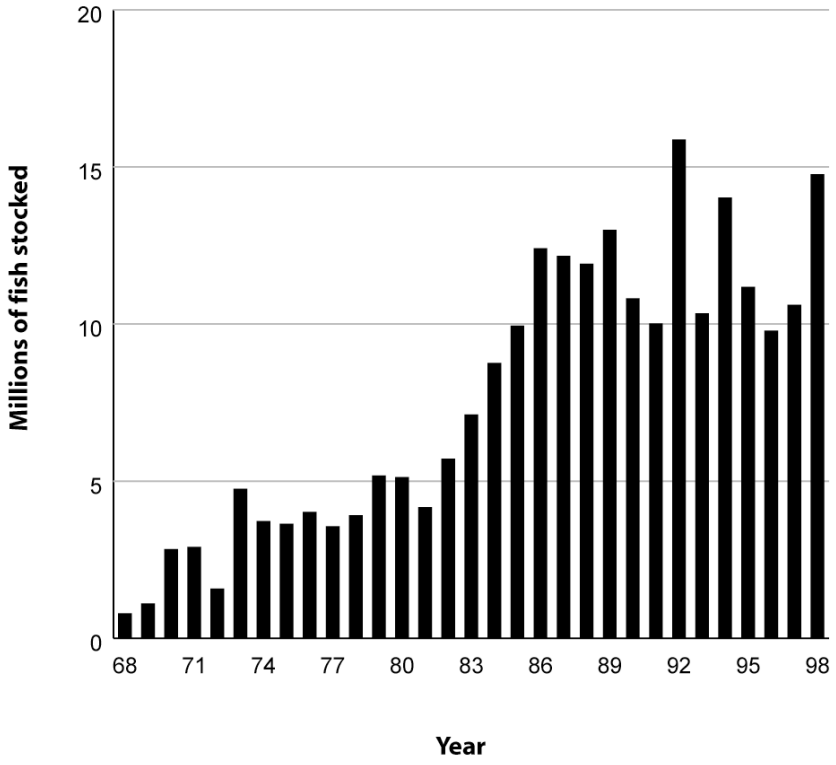
A significant loss of fish habitat in the Lake Huron basin has occurred in Saginaw Bay, where the largest human population in the Lake Huron basin is found. More than 75 percent of the historic lakewide yields of walleye, yellow perch, lake herring, and channel catfish were derived from Saginaw Bay before pollution dramatically reduced productivity of the bay in the mid-1900s. Lake Huron's aquatic community health and biodiversity are relatively good, at least in contemporary terms and in comparison to other Great Lakes. The fish community in Lake Huron is recovering, but remains unstable after decades of overharvesting and being subjected to the effects of nonindigenous species. Modest numbers of stocked lake trout are reproducing in the lake, and populations of whitefish are more abundant than at any other time in this century (MDEQ/OGL 2002).

Major areas of contention and opportunity in Lake Huron are: (1) habitat management, e.g., wetland restoration and reconnection of historical spawning grounds; (2) sea lamprey control; (3) introduced nonindigenous species; (4) public demands; (5) monitoring; and (6) research requirements (MDEQ/OGL 2002).

Most of Lake Huron's main predatory fish and their associated communities and recreational fisheries are still dependant on stocking. Exhibit 2 shows that since 1968, the annual stocking rate for predator fish (salmon, trout, and walleye) has increased from less than one million to over 14 million (Lake Huron Technical Committee, 1999). Walleye are reproducing in some Saginaw Bay tributaries but not sufficiently to replace the need

for stocking. Dams on Lake Huron tributaries block the vast majority of spawning sites for chinook salmon, steelhead trout, walleye, sturgeon, and many other fish.

EXHIBIT 2
Predator Fish Stocked into the Lake Huron Basin



SOURCE: Lake Huron Technical Committee, 1999.

The Great Lakes Fishery Commission Lake Huron Committee has identified fish community objectives for Lake Huron relative to habitat and the environment (Lake Huron Technical Committee 1999). They include:

- Protect and enhance fish habitat and rehabilitate degraded habitats.
- Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities.
- Restore damaged habitats.

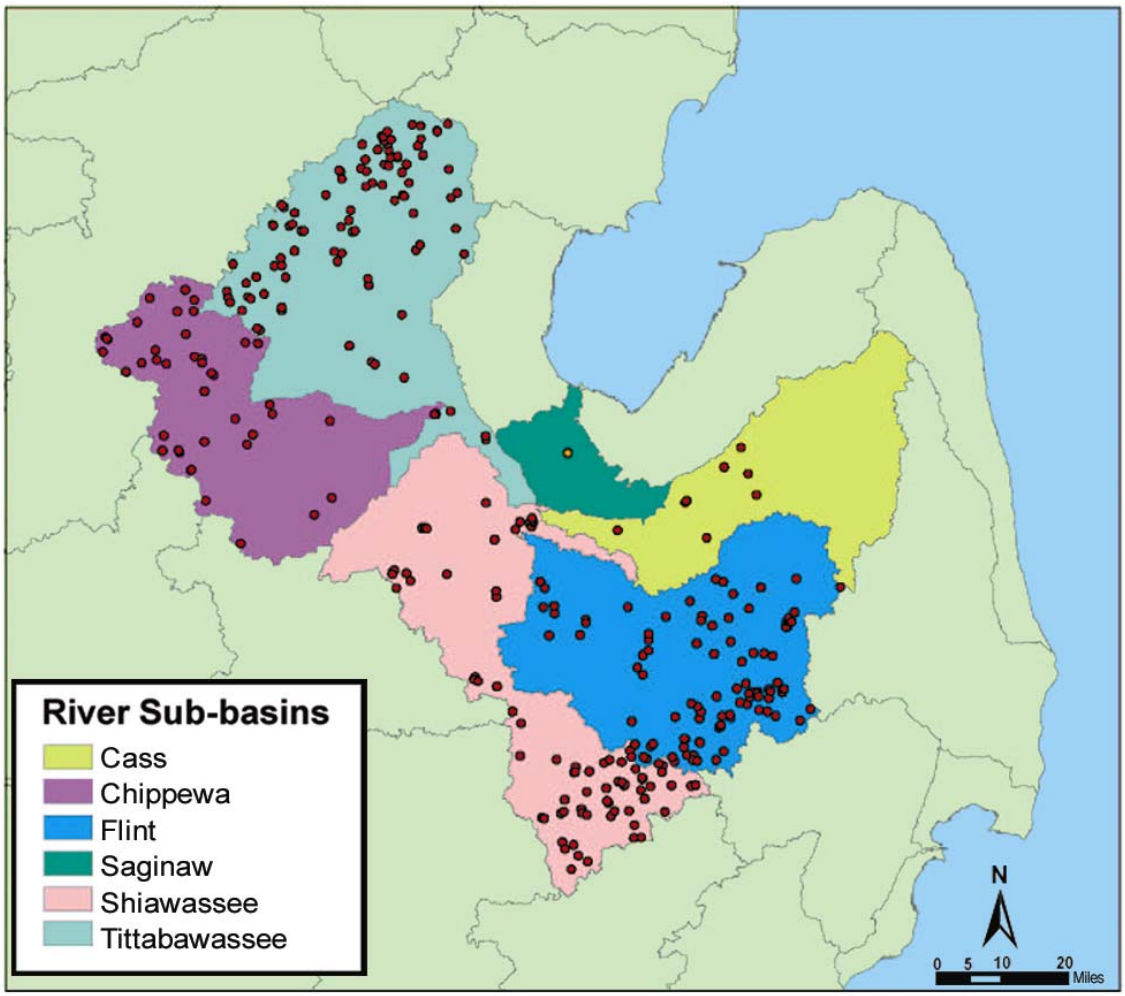
MICHIGAN DAM HISTORY

Beginning in the 1800s the construction of dams on the Great Lakes tributaries—first for the transport of timber, then for waterpower, and later for electric generation and water supply purposes—blocked access to spawning areas and in other ways negatively affected habitat essential to many indigenous fish species. By 1940 dams had been constructed in the lower portion of nearly every major tributary to the Great Lakes; hundreds of dam structures remain in some tributary watersheds. Many dams have outlived their original purposes and are in a state of disrepair; others are nearing the end

of their useful life as hydroelectric generation facilities. While these may be candidates for removal, others continue to provide benefits such as electric power generation, barriers to sea lamprey migration, sediment containment, recreation, flood storage, and water supplies. Existing and ongoing benefits, however, must be factored into the overall decision-making process when considering the current level of these benefits versus the potential for new and enhanced benefits.

It is difficult to say with certainty how many dams are present on Michigan's rivers. A variety of water level–control structures have been built over the last two centuries, ranging from small rock and timber crib structures to large dams of earth and concrete. Formal records do not exist for many of these structures. The most extensive effort to catalog dams in the United States is the National Inventory of Dams (NID), maintained by the U.S. Army Corps of Engineers and the Federal Emergency Management Agency (FEMA). This database includes dams that are considered a high risk to downstream areas; dams that are higher than six feet with more than 50 acre-feet of storage; or dams that are higher than 25 feet with more than 15 acre-feet of storage. The NID identifies 880 dams in Michigan (FEMA 1999). However, a more comprehensive database compiled by the State of Michigan has identified more than 2,500 structures. Informal estimates suggest that there may be upwards of 3,000 dams in the state (Chadwick et al. 2003). Approximately 315 of these dams are located in the Saginaw River watershed, which encompasses approximately three-quarters of the Saginaw Bay watershed. Exhibit 3 shows the location of these dams in each of the six sub-basins.

EXHIBIT 3
Dams in Saginaw River Watershed



SOURCE: MDNR, Fisheries Division, Institute for Fisheries Research, 2004.

EMBRACING DAM REMOVAL AS AN OPTION FOR FISH PASSAGE

Over the past decade, the scientific community has advanced our understanding of rivers and helped us to realize the significant impacts that dams have on river ecosystems. With these impacts better understood, evaluations have shifted from a one-sided look at the flood control, power, navigation, and irrigation benefits of dams to a well-balanced view that includes the substantial ecological and economic costs of dams. These more thorough and balanced evaluations of the costs and benefits of dams will in some cases conclude that the costs of the dam outweigh the benefits—and point toward dam removal as a preferred alternative.

While dams serve a number of human needs, society has developed ways to address many of these needs without dams. For instance, flood control can often be accomplished

more effectively and less expensively by restoring wetlands, maintaining riparian buffers, or helping residents and businesses relocate out of the floodplain. Updating antiquated irrigation systems and replacing inappropriate crops can dramatically reduce the need for dams and reservoirs in arid regions.

Dam removal may become a desired alternative for many deteriorating, unsafe, or abandoned dams. In many cases, dam removal costs less than repairing the dam and is a particularly attractive option when the benefits of the dam are marginal or nonexistent. Even if the costs for removal or repair are comparable, dam removal eliminates the need (and cost) for future repairs.

Over the past several years, dam removal has received significant media attention. The decision to remove the Edwards Dam on the Kennebec River in Maine was covered in almost all major papers, and other removals have been covered at both the national and local levels. This broad media attention has helped to educate the public about the economic and environmental benefits of removing dams that don't make sense. In addition, it has prompted grassroots organizations and local decision makers to examine their hometown dams to determine whether dam removal is an appropriate approach.

Although dam removal has only recently become considered a reasonable river restoration tool, there are already numerous dam removal success stories. At least 465 dams have been removed from United States waterways—and at least 100 more are either slated for removal or under active consideration for removal (American Rivers 1999). By continuing the trend to remove unnecessary dams, restoration of both the economic and ecological benefits associated with free-flowing rivers can begin.

DECLINE IN ABUNDANCE OF IMPORTANT FISH SPECIES

During the period from the early 1900s to the 1940s, Saginaw Bay accounted for over 28 percent of the commercial fishery harvest from Lake Huron (Baldwin and Saafeld 1962). The commercial catch records for this period indicate that the fish community of inner Saginaw Bay was primarily composed of walleye, yellow perch, channel catfish, white sucker, northern pike and several members of the sunfish family. In the outer portions of Saginaw Bay, lake trout, lake herring and lake whitefish were also significant and seasonally provided a fishery in the inner bay areas as well (Keller et al. 1987). The annual harvest of fish from Saginaw Bay peaked in the early part of the twentieth century and declined steadily through the 1970s. A number of factors contributed to the 70-year decline of the Saginaw Bay fishery, including destruction of nearshore spawning and nursery habitat, deterioration of water quality, blocking of spawning migrations in major tributaries, invasion of exotic species, and, particularly beginning in the 1940s, excessive commercial harvest of already stressed populations (Fielder et al. 2000).

Major chemical, industrial, and municipal wastewater discharges into the Saginaw River and upstream tributaries such as the Cass, Flint, and Tittabawassee Rivers have significantly affected fish populations in the Saginaw River and inner bay. By the early 1950s, physical barriers and/or pollution had effectively blocked major migrations of walleye and other species that previously had moved from Saginaw Bay into the Saginaw River watershed to spawn.

PROJECT RATIONALE

The basis for this study is found in several reports and initiatives, outlined below.

Great Lakes Fish Community Objectives

In 1995, both United States and Canadian fisheries managers, through the Great Lakes Fishery Commission (GLFC), developed fish community objectives (FCOs) for protection and restoration of Lake Huron's fish community. Fish community objectives provide an umbrella under which management agencies are expected to develop more specific plans and strategies for Great Lakes fisheries protection and restoration. The objectives reflect the understanding that natural systems are dynamic; thus the objectives provide some latitude in adjusting management approaches to various conditions that might arise. A fish community may be described by its species mix, the qualities that enable it to persist (stability, balance, sustainability, and diversity), and the measures of the fishing opportunities that it offers (yield and recreation hours).

Environmental Objectives for Lake Huron

To further facilitate and support the fish community objectives described above, draft environmental objectives (EOs) describing the biological, chemical, and physical needs of desired fish communities have also been developed under the auspices of the Great Lakes Fishery Commission. The draft EOs for Lake Huron are intended to provide practical and effective suggestions to overcome existing environmental impediments to achieving FCOs. In order for these EOs to be relevant and accessible they should, to the extent possible:

- Address current and emerging ecosystem issues (nutrient inputs, climate change, stocking and prey base dynamics, changes in food web structure, etc.)
- Identify critical habitats and their attributes (wetland size, integrity, diversity)
- Be quantifiable (provide desirable end-points)
- Address habitat impairment issues identified in the FCOs
- Promote and maintain biodiversity (genes, populations, communities, and landscapes)

In many cases desirable endpoints for environmental conditions are not quantified due to a lack of information or incomplete knowledge of environment/fish community relationships. However, the identification of environmental factors affecting fish community structure and function help provide awareness and direction for future inquiries into environmental impacts.

This project supports several fish community and environmental objectives for Lake Huron by developing information that can be used to enhance fish passage past barrier dams and restore habitat for native and naturalized species within the lake's tributaries. Fisheries managers recognize that these tributaries are an integral component of meeting the overall objectives for the lake.

The fisheries management goals for Saginaw Bay are consistent with and contributed to those established for the fish-community objectives in Lake Huron developed under the auspices of the GLFC. Expanding the availability of walleye spawning habitat above downstream barriers on the Tittabawassee River and other Saginaw River tributaries is

critical to successfully increasing the current walleye population through natural reproduction in the bay and tributaries (Fielder and Thomas 1997). Dam removal and/or fish passage is also critical to the successful restoration of lake sturgeon that historically used the upper portions of the Saginaw River watershed as spawning and nursery areas (Hay-Chmielewski and Whelen 1997).

1999 Fisheries Scoping Study—The Conservation Fund

This project sought to implement a recommendation of a 1999 *Fisheries Scoping Study* prepared by The Conservation Fund, a national, nonprofit conservation organization that purchases and protects land—more than 1.6 million acres since 1985. The fund also assists local communities, private individuals and organizations, and government agencies with programs that balance conservation with economic development. The scoping study was funded by the Saginaw Bay Watershed Initiative Network (WIN), a consortium of communities, conservationists, foundations, and businesses working together to balance the region's economic, environmental, and social goals. The study suggested that the best opportunity to enhance walleye populations may be in demonstration projects that restore spawning grounds and allow fish passage around impoundments, with an emphasis on several tributaries including the Tittabawassee, Shiawassee and Cass Rivers (The Conservation Fund 1999).

Measures of Success—Remedial Action Plan

The Partnership for the Saginaw Bay Watershed, a local watershed group comprising citizens, government representatives, and members of the environmental community, received funding in 1999 from WIN and the Bay Area Community Foundation to identify what success for the Saginaw River and Bay looks like through the development of understandable and achievable endpoints. Environmentally sound restoration measures that are sensitive to the regional economy and community concerns were developed. Twelve out of 14 beneficial uses were identified as being impaired. The end products of the project include

- development of clear targets for restoring the beneficial uses of the Saginaw River/Bay that are environmentally sound, understandable to the general public, and acceptable to the community;
- development of a concise summary of past success in the Saginaw River/Bay Area of Concern (AOC) that celebrates accomplishments; and
- development of an action agenda identifying next steps to be taken. This agenda will generate priority projects to restore the Saginaw River/Bay. The process is intended to develop concurrence among diverse interests on what needs to be done to restore the Saginaw River/Bay.

The abundance, diversity, and general health of fish populations in the Saginaw River/Bay area are some of the best measures of the overall status of this complex ecosystem. The four primary factors related to fisheries that led to the designation of the Saginaw River/Bay as a Great Lakes AOC were loss of fisheries habitat, chemical contaminant levels in fish, fish odor and taste issues, and accelerated eutrophication of the bay. Various actions over the past 25 years have improved the status of the fishery in

both the river and the bay. The status of the fishery has been measured annually since at least the early 1980s through creel census, survey netting, and trawling.

A targeted restored condition for the fisheries impairment is increased walleye abundance in the bay, ultimately through natural reproduction, such that growth rates approximate more closely statewide averages for this species and reflect improved use of available forage in the bay. One of the key recommendations to achieve this targeted restored condition is for the Partnership for the Saginaw Bay Watershed to work with individual communities, residents, and businesses within the watershed to identify dams for potential removal or for installation of fish passage devices.

The Lake Huron Initiative

Unlike the other Great Lakes, Lake Huron does not have a lakewide management planning (LaMP) process to drive future efforts. Led by the Michigan Office of the Great Lakes and partially funded by the U.S. Environmental Protection Agency, the Lake Huron Initiative was formed in 1999 and released the original *Lake Huron Initiative Action Plan* in March 2000 (MDEQ/OGL 2000) and an update in 2002 (MDEQ/OGL 2002). The 2002 *Lake Huron Initiative Action Plan* was developed with extensive agency involvement and began discussions of issues of importance to Lake Huron, actions that need to be taken to protect and restore the Lake Huron ecosystem, and development of partnerships to begin undertaking efforts that could not be accomplished by individual agencies alone.

The Lake Huron Initiative developed Priorities for Inventorying, Planning, Restoration/Protection, Monitoring and Education for Lake Huron (MDEQ/OGL 2000). Among the action items recommended is to

> identify dams that are having major ecological impact; pursue long-term remediation efforts; support development of upstream fishways and downstream passage facilities; and develop lakewide or shared policies on dams, dam removals, maintaining run-of-the-river flows, and dam retirement funding approaches.

Michigan Department of Natural Resources Saginaw Bay Walleye Recovery Plan

The Saginaw Bay Walleye Recovery Plan is a science-based blueprint for management actions intended to achieve a self-sustaining walleye population through natural reproduction and restore ecological balance to the fish community. The proposed recovery plan (Fielder and Baker 2004) comprises a suite of strategies to address limiting factors; it defines recovery decision points; includes ongoing research needs; provides for ecosystem recovery; and offers a platform for collaboration and investment. The recovery plan strategy addresses:

- Riparian/land use management
- Stream and bay habitat
- Stocking

Included are strategies that involve fish passage/dam removal, stream habitat improvement via sediment reduction, and possibly some reef renovation. Local suppression of the abundant alewife population within the bay is also sought partly by increasing stocking to the extent possible.

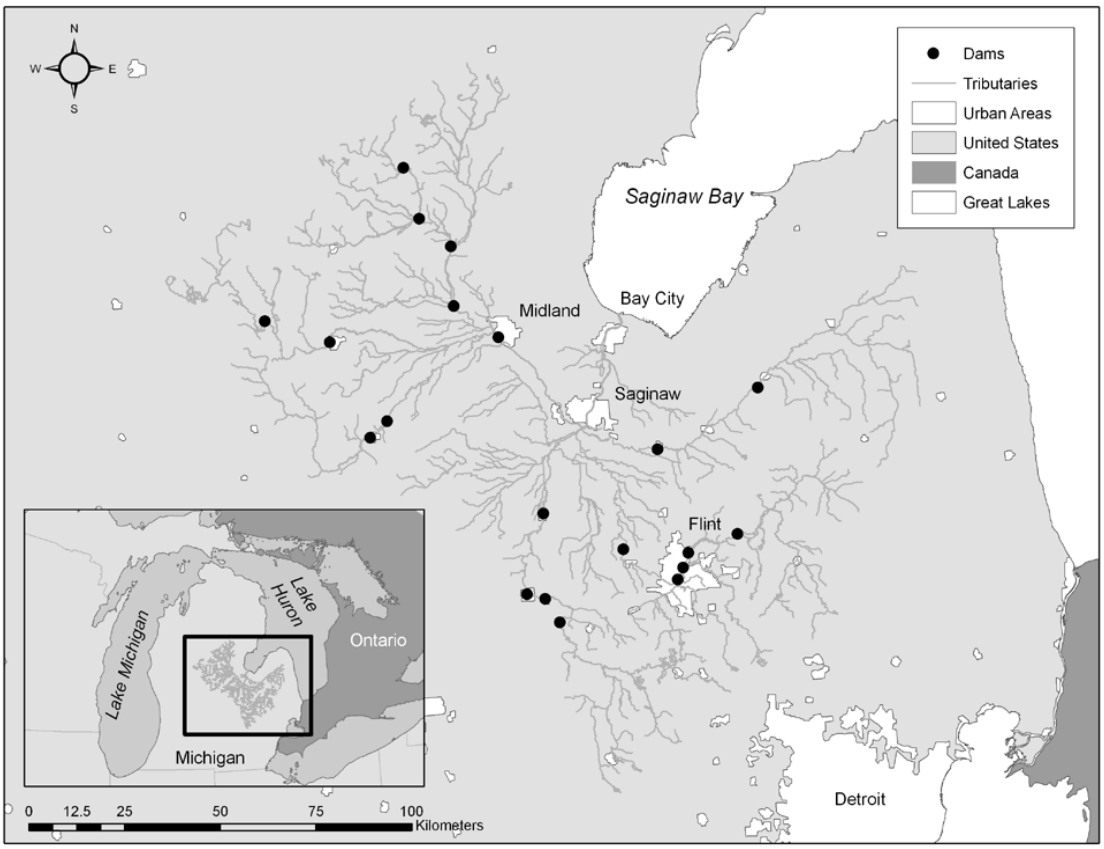
Recovery goals include predator/prey balance in Saginaw Bay; walleye population at carrying capacity; and walleye population sustained by natural reproduction. Expected outcomes include an improved walleye fishery; increased yellow perch growth rate; eventual elimination of dependence on stocking; native species recovery; and restoration of ecosystem integrity/resiliency.

To address recruitment limitation from lack of inland reproduction, 20 dams (out of approximately 315 within the watershed) on six different rivers were identified as candidates for either removal or fish passage (see Exhibit 4). They include:

- Shiawassee River: dams at Chesaning, Owosso, Corunna, and Shiatown.
- Cass River: dams at Frankenmuth and Caro.
- Pine River: dams at St. Louis and Alma.
- Chippewa River: dams at Mount Pleasant and Lake Isabella.
- Tittabawassee River: dams at Dow Chemical Company, Sanford, Edenville, Beaverton, and Chappel Dam (Gladwin County).
- Flint River: Inflatable Fiber Dam, Hamilton Dam, Utah Dam, Mott Dam, and Holloway Dam.

Sites initially identified for passage include the Midland, Chesaning, and Frankenmuth Dams, which provide the focal point for this study. Other dams in the watershed no longer serving a useful purpose continue to be evaluated for potential removal or providing fish passage.

EXHIBIT 4
Dams That Are Candidates for Fish Passage or Removal



SOURCE: MDNR, Institute for Fisheries Research.

Dam Assessment

Dams and other man-made barriers constructed in tributaries to the Great Lakes over the last 150 years are a major factor limiting the establishment of sustainable populations of valuable Great Lakes fish species. Many fish species found in the Great Lakes depend wholly or partially upon tributaries for spawning and nursery areas. Many species, including salmon, steelhead, walleye, and lake sturgeon, spawn in streams and rivers and remain there for the early part of their life stages. Physical and chemical deterioration of river and stream habitats has been a significant factor in limiting the natural reproduction of certain Great Lakes fish populations.

Dams negatively impact fish populations and their habitats by impeding fish migration up rivers and altering downstream habitats physically, biologically, and chemically. Fish and other aquatic organisms are also subjected to increased direct and indirect mortality when they pass downstream through turbines or over hydroelectric dams. Fish adapted to lentic environments (i.e., lake, ponds, or wetlands) are better able to survive in impoundments created by dams, and thus species composition may improve.

Dams impede fish movements to spawning habitats, isolate populations, and inundate high gradient reaches that provide critical spawning habitat for a variety of river-spawning fishes. Dams and impoundments within the Saginaw River watershed currently limit access of many fish populations to historical spawning areas. Successful passage of fish above these barriers may hold the key to achieving self-sustaining populations of predators like walleye needed to restructure the ecological balance in Saginaw Bay. Recent research shows that increased bay sedimentation rates since the early to mid-1900s, specifically sediment transported from rivers, has virtually eliminated the inner-bay rock reefs that once were major spawning sites for bay area walleye populations, considerably reducing natural reproduction. While the bay's walleye sport fishery has returned, a substantial proportion of the locally produced walleye are stocked fish.

Despite their effects on natural river function, dams still provide some human benefit. They provide vital water supply to municipalities and industries. Impoundments created by some dams provide valuable recreational uses where water-based recreational opportunities are otherwise lacking. Impoundments in some areas also provide valuable wildlife habitat and refuge. These benefits must be considered when debating dam removal.

The average life expectancy of a dam is 50 years, and a full one-quarter of all U.S. dams are now more than 50 years old. The American Society of Civil Engineers estimates that by the year 2020 that figure will reach 85 percent. (FEMA 1999) In many cases, dam removal costs less than repairing an unsafe dam, especially where the benefits of the dam are marginal or non-existent. In the Saginaw Bay watershed, a majority of dams (97 percent) were constructed prior to 1981, which suggests that over the next 25 years all will have outlived their normal design life. While age can be an indicator of the need for attention, age in itself does not necessarily result in a hazardous condition. The design life of a dam will vary, but it is not unusual for a dam to function effectively for 100 years or

more if properly maintained (DEQ 2005). In any event, aging dams will require considerable maintenance and significant reinvestment in the coming years.

Historically the Michigan Department of Environmental Quality (MDEQ) administered the state's dam safety program. The purpose of the program was to protect people and property from the damaging consequences of catastrophic dam failures. In the United States between 1960 and 1997, there were at least 23 dam failures that caused one or more fatalities. The worst of these failures, in terms of loss of life, was the 1972 failure of a privately owned dam in Buffalo Creek, West Virginia, which devastated a 16-mile-long valley with 6,000 inhabitants. As a result of that one failure, 125 people were killed and 3,000 were left homeless. In all, the 23 failures between 1960 and 1997 resulted in 318 deaths. The intent of the MDEQ Dam Safety Program was to ensure the operational safety and structural integrity of dams in Michigan to minimize the possibility of a catastrophic failure of a dam that falls under its jurisdiction. The Dam Safety Program regulated the design and construction of dams in the state in order to secure the health and safety of the residents of Michigan. Once dams were completed, the task of MDEQ was one of long-term monitoring to assure that proper maintenance and repairs are performed in a timely manner. However, in March 2005 a Governor's Executive Order (2005-7) eliminated funding of the Dam Safety Program. Many organizations and stakeholders are hopeful that program funding will be restored at a future date.

Many local communities, natural resource agencies, and environmental advocates want to remove selected dams that have outlived their purpose, are unsafe, or have costs that outweigh their benefits. The decision to remove a dam is often driven by safety concerns, but there may be compelling environmental and economic concerns as well. In many cases, dam removal saves significant taxpayer dollars compared to repair or environmental mitigation costs.

Clearly, dam removal is not appropriate for all Michigan's dams. Many dams continue to serve public or private functions such as flood control, irrigation, and hydropower generation. This does not mean, however, that rivers should continue to be heavily affected by these dams. Most dams could be operated in a fashion that reduces their current negative impacts on the river. Some dams, however, cause such significant environmental damage that no amount of work and resources will alleviate the environmental harm. In many instances, dams no longer serve a purpose and may be abandoned. For these dams, where the environmental impacts of the dams outweigh the benefits, dam removal is often a reasonable and viable solution for restoring river functions.

For the purposes of this study, the 315 dams in the Saginaw River watershed were sorted by the attributes discussed below. Ongoing efforts to map dams have revealed notable limitations in available databases. The National Inventory of Dams (NID), while useful, includes only dams above a certain size (height, capacity) and human risk. State databases are typically maintained by dam safety programs and are more comprehensive than the NID. Mapping and expert opinion reveal significant errors in dam location in a small fraction of instances, and minor inaccuracies (100–500m) in most. Data are adequate to provide statistical descriptions and describe geographical patterns, but must be viewed with caution at the level of the individual dam location.

An analysis of current use, year of construction, ownership, and hazard potential of dams within each sub-basin is provided in Appendix B.

The purpose of this study was to develop information focusing on fish passage opportunities, including dam removal as a potential option, and to transfer this knowledge to local governments, watershed organizations, and dam owners to support strategic planning activities. The study was not designed to make specific recommendations for dam removal at any location.

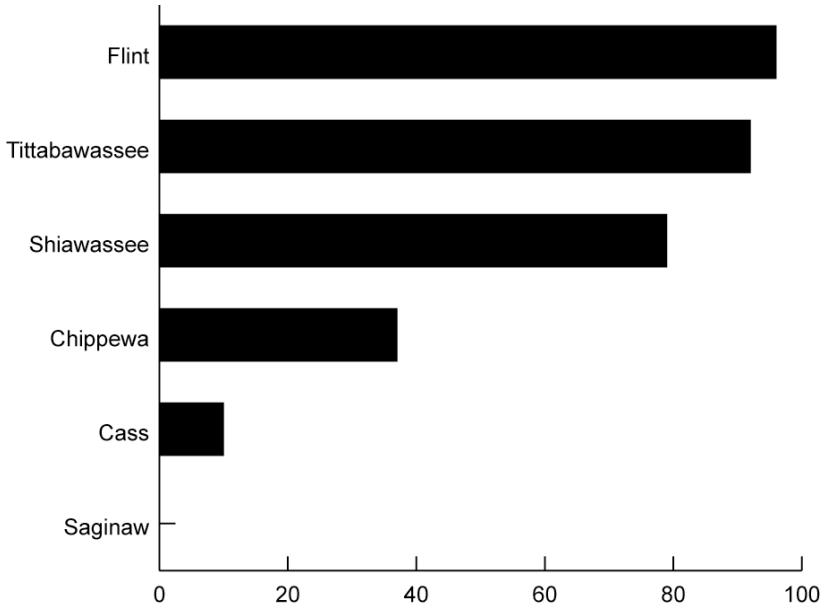
SUB-BASIN

There are six sub-basins in the Saginaw River watershed:

- Cass River
- Chippewa River
- Flint River
- Saginaw River
- Shiawassee River
- Tittabawassee River

The 315 dams were categorized based on their location within these sub-basins (see Exhibit 5). Nearly 85 percent of dams are located in three sub-basins: the Flint, Tittabawassee, and Shiawassee. Approximately 60 percent are located in the Flint and Tittabawassee sub-basins.

EXHIBIT 5
Current Dams, by Sub-basin

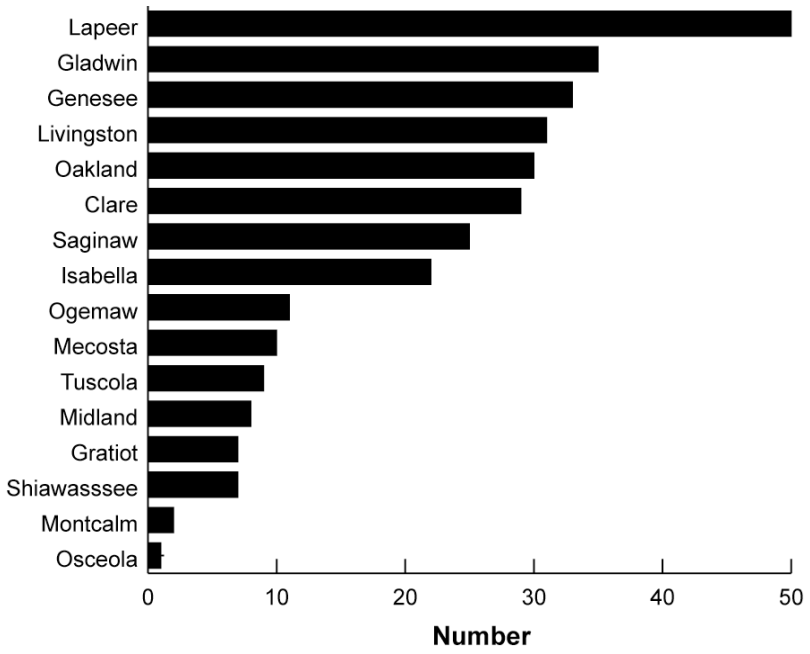


SOURCE: PSC, with data provided by MDNR, Fisheries Division, Institute for Fisheries Research, 2004.

COUNTY

Dams were sorted by the Michigan county in which they are located (see Exhibit 6). Approximately 65 percent of the dams are located in six counties: Lapeer, Gladwin, Genesee, Livingston, Oakland, and Clare. With 50 dams, Lapeer County, located in the Flint River sub-basin, has the most.

EXHIBIT 6
Current Dams, by County

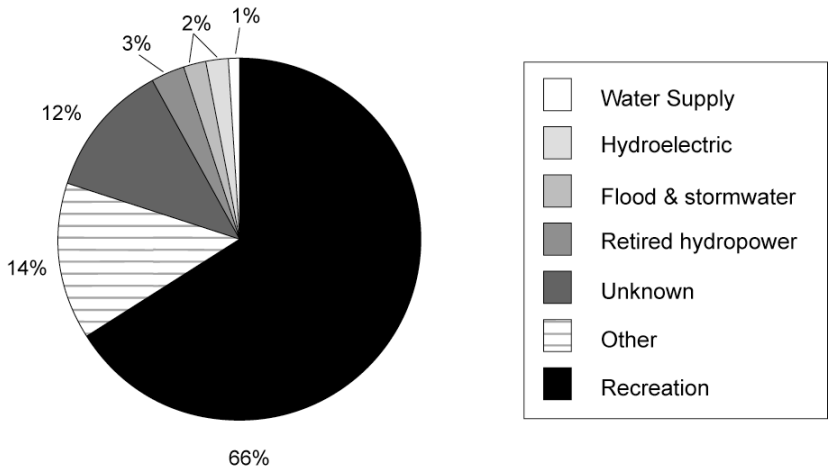


SOURCE: PSC, with data provided by MDNR, Fisheries Division, Institute for Fisheries Research, 2004.

CURRENT USE

Dams were categorized by the primary purpose or use of the reservoir or impoundment. As shown in Exhibit 7, two-thirds of the 315 dams serve recreational purposes.

EXHIBIT 7
Current Dams, by Purpose

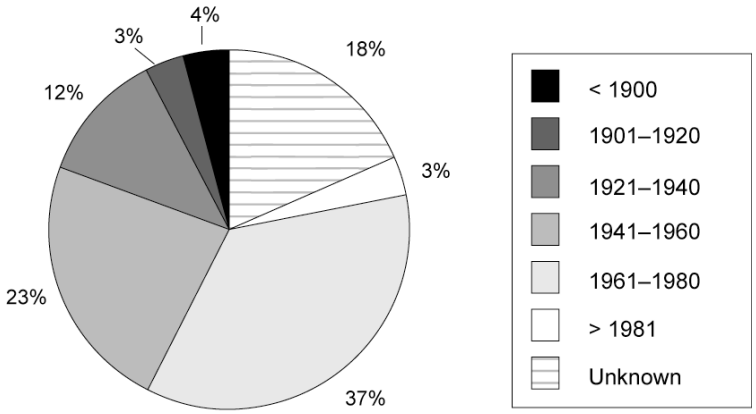


SOURCE: PSC, with data provided by MDNR, Fisheries Division, Institute for Fisheries Research, 2004.

YEAR CONSTRUCTED

Dams were also sorted by the year original construction was completed, if known (see Exhibit 8). Sixty percent of the dams are approximately 25 to 65 years old; 19 percent were built prior to 1921. Considering the 50-year average design live of dams, 97 percent of all dams in the watershed will have surpassed that mark by the year 2030. This is consistent with the situation nationwide: by the year 2020, more than 85 percent of the dams in the United States will be near the end of their operational lives (FEMA 1999).

EXHIBIT 8
Current Dams, by Year of Construction

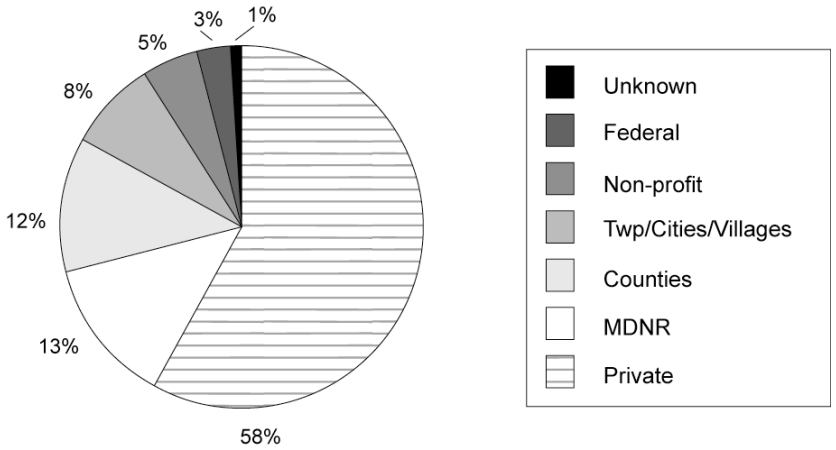


SOURCE: PSC, with data provided by MDNR, Fisheries Division, Institute for Fisheries Research, 2004.

CURRENT OWNERSHIP TYPE

As shown in Exhibit 9, more than half of the dams in the Saginaw Bay watershed are privately owned, with each of the remaining ownership categories at 13 percent or lower. Townships, cities, and villages comprise only 3 percent of known dam owners.

EXHIBIT 9
Current Dams, by Ownership

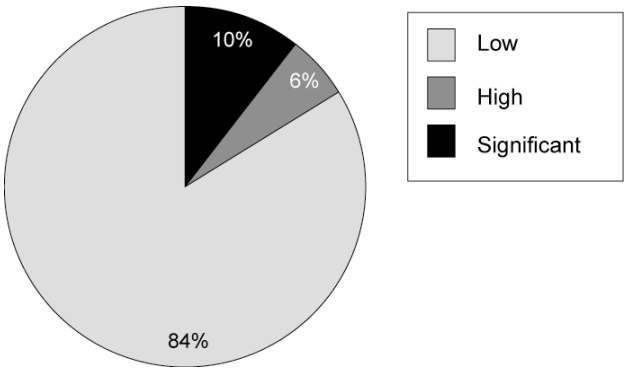


SOURCE: PSC, with data provided by MDNR, Fisheries Division, Institute for Fisheries Research, 2004.

HAZARD POTENTIAL

This attribute is a characterization of the potential for damage if the dam were to fail; it does *not* indicate the current condition of the dam. Hazard potential may be coded as high, significant, or low. Hazard classifications are based on the definitions in Part 315 of the Michigan Natural Resources and. Environmental Protection Act, 1994 PA 451. As shown in Exhibit 10, most of the dams in the Saginaw Bay watershed fall into the "low" hazard potential category.

EXHIBIT 10
Hazard Potential of Dams in Saginaw Bay Watershed



SOURCE: PSC, with data provided by MDNR, Fisheries Division, Institute for Fisheries Research, 2004.

FISH PASSAGE OPTIONS

This project included a demonstration component in the City of Frankenmuth in Saginaw County to assess the feasibility of enhancing fish passage at the city-owned dam on the Cass River in downtown Frankenmuth. In March 2004, Public Sector Consultants Inc. (PSC) contracted with Cochran & Wilken Inc./FishPro (FishPro) to provide conceptual layouts for fish passage options at the Frankenmuth Dam. The following section is adapted from a separate report completed and released in February 2005, *Frankenmuth Dam: Fish Barrier Assessment Project* (FishPro 2005). While the concepts were developed for the Frankenmuth Dam, they may be applied to similar structures throughout the Saginaw Bay watershed and beyond. It should be noted that this is a conceptual report and many assumptions were made regarding feasibility. Under normal design activities, modeling and measurements will verify these assumptions.

In May 2004, an advisory committee comprising representatives from the Partnership for the Saginaw Bay Watershed, City of Frankenmuth, MDNR, MDEQ, and the U.S. Fish and Wildlife Service (USFWS) met to discuss the requirements necessary to achieve fish passage at the Frankenmuth Dam. For many of the technical questions, the advisory committee relied heavily on information provided by members of the Lake Huron Basin Team—a group of MDNR fisheries personnel with management responsibilities in the Lake Huron basin. FishPro also added to the responses. The following questions and answers highlight the discussion that occurred.

1. **What types of fish passage structures can be evaluated for fish passage in the Saginaw Bay watershed?**

For passage, any structure that has been proven to pass non-jumping warmwater fish can be considered. In general, the Lake Huron Basin Team strongly advocates for a modified riffle/constructed rapids structure such as the project on the Chippewa River in Mt. Pleasant. A design such as this would be aesthetically pleasing, could maintain the desired water level for a ponded area, and would allow for optimal reconnection of the currently fragmented habitat. While lamprey passage would be a temporal issue with this design, alternative “portable” lamprey weirs may provide an effective solution.

In addition, it was recommended that a review of a sturgeon spiral passage structure, funded by the Great Lakes Fishery Trust, be evaluated for effectiveness at the Frankenmuth location. The advisory committee determined that the use of other structures such as Denil or vertical slot fish ladders is less desirable and should be pursued as a last alternative. These ladders are less aesthetically appealing than a bypass channel or rock weir and have displayed variable results for efficiency at similar locations in the basin.

2. **What species should be able to pass?**

Primary fish species for passage consideration are walleye and lake sturgeon. The lake sturgeon is a state-listed threatened species while walleye are the focus of a MDNR Fisheries Division recovery plan for Saginaw Bay (Fielder and Baker 2004). Walleye access to spawning habitat in tributaries is critical for their recovery and sustainability in the bay. Other species for consideration include white bass, white sucker, smallmouth

bass, channel catfish, northern pike, largemouth bass, and steelhead. If a constructed rapids (rock ramp) design were selected, the entire fish community would benefit.

3. **What are the target size classes?**

For upstream movement, adult walleye (> 15 inches) and lake sturgeon. For downstream movement, both adults and larval fish must be able to pass downstream successfully (i.e., live and unharmed).

4. **What seasonal period is targeted for fish passage?**

Upstream passage during spawning season; January–May open for upstream and downstream passage.

5. **What are the target velocities?**

For the development of swimming criteria, three levels of ability should be evaluated. These levels include burst, prolonged, and sustained (cruising):

- Burst speeds—Speeds that a fish can reach in a single effort (generally less than 20 seconds)
- Prolonged speeds—Speeds that a fish can maintain for a limited period of time (20 seconds to several minutes)
- Sustained speeds—Speeds that a fish can maintain without fatigue for an extended period of time (hours)

Swimming performance has been defined as the capability to swim at a maximum rate of speed (McPhee and Watts, 1976, in Wilcox et al., 2003). Several factors can influence the swimming ability of fish in the Cass River, including size of fish, water temperature, and other ambient river conditions. For this reason, swimming abilities can vary among species and also within species that are targeted for passage. When selecting target velocities for passage, river stage at time of passage, water temperature, and length of fish passage alternative should be considered to maximize the opportunity for passage at the selected time of year. In order to provide a wide range of opportunities for passage, the swimming ability of the weakest swimmer selected for passage should be considered. For the purposes of discussion, the critical swimming speed ($Ucrit_x$) will be discussed. The critical swimming speed is the maximum speed that can be maintained without exhaustion over a period of time. For example, the 10-minute critical swimming speed ($Ucrit_{10}$) for a fish would be the maximum velocity that a fish could maintain for a 10-minute period.

The fish species discussion provided below outlines passage requirements for the targeted species.

6. **What is the target vertical drop per step of fish passage?**

This parameter needs to consider the limits for the nonjumping species, e.g., sturgeon, walleye, and white sucker. In general, less than a 5 percent slope should be achieved for a fish ladder. It is assumed that a rock ramp or bypass channel would require no jumping.

7. **What criteria are needed to attract fish to the fishway?**

Sufficient attraction flow and appropriate channel depth. The contractor will need to find the best available current scientific information to identify this parameter.

In order to successfully attract fish to the fishway, the entrance should be located as close to the dam as possible. While flow rates in the range of 0.9 meters per second (m/s) to 1.8 m/s, or 3 feet per second (f/s) to 6 f/s, will attract fish to the fishway, locating the entrance too far from the structure will increase the chance of fish moving past the entrance. In addition, it is recommended that approximately 5 percent to 10 percent of the "normal" river flow be diverted through the fishway during target months to ensure that fish attraction continues.

8. **What steps can be taken to ensure a successful exit from the fishway?**

Exiting the fishway is also an important aspect of successful migration through a structure. The exit from the fishway should be oriented such that fish are not introduced back into the main flow of the river and swept back over the dam. Water quality concerns also can deter a successful exit. If conditions are unfavorable, the species may return downstream and not exit the fishway upstream of the entrance. Efforts to maintain water quality in the upstream pool should be encouraged. These include dissolved oxygen management and periodic water quality sampling to detect changes in undesirable constituents. The detection of undesirable conditions has been documented as a fish passage obstacle even when the velocity conditions within the fishway offer good passage options.

9. **How will successful passage be measured?**

A formal study should be designed to evaluate the fish community prior to and after installation of a fish passage device. Methods could include fish tagging above and below the dam and other marking studies.

10. **Other considerations**

Visitor outreach and education were also identified as important requirements for any of the fish passage alternatives. The advisory committee agreed that a fish passage project should include a public education component such as kiosks or literature highlighting fish life stages and the importance of Great Lakes tributaries.

Selection of any fish passage option must consider the age of the existing structure and current need to resolve erosion problems underneath the dam. Moreover, public safety must be a primary concern.

11. **What nuisance species must be deterred?**

Sea lamprey (if possible). The Cass River main stem has never been treated with lampricide. However, Juaniata Creek is a tributary to the Cass and was treated in 1998. Juaniata is above the dam in Frankenmuth and surveys have found lamprey larvae above the dam in most years since 1997. A 1998 lamprey treatment in Juniata Creek cost $51,000.

12. **Engineering questions/comments**

Are there downstream watercraft access issues that would limit fish sampling? What are the flood-flow concerns considering the potential for rapid rise in flows of the river? Concerns about the sustainability of the structure?

Since this barrier assessment did not include a detailed engineering study, it was not possible to analyze all existing and needed information and data. Therefore, the conceptual layouts may need to be significantly revised based on further clarification, including, but not limited to, the following factors:

- City property line/ownership on the north bank
- Depth and foundation detail of the concrete Corps of Engineers flood-control wall
- Layout and/or integration of the proposed park on private property (Concept plan includes overlay of "Master Plan—Zehnder Park" dated June 6, 2002.)
- Current topographic survey upstream and downstream of the dam and along the north shoreline
- River stage versus flow data and historical gage information; monthly analysis of dam head differential during fish passage periods
- Budgetary or permitting limitations

In addition to the questions summarized above, it was also suggested that consideration be given to a "flexible" alternative. The group noted several failed passage structures and encouraged development of a passage structure that can be manipulated or enhanced to increase the efficiency of passage after the construction is complete.

Fish Species

A wide variety of fish species are present in the Cass River. Passage requirements for the fish species were broken into three upstream passage categories: **Priority 1**, high priority for passage; **Priority 2**, medium priority for passage; and **Priority 3**, desirable for fish passage. In all options, attention to downstream passage in addition to upstream passage should be maintained for all size classes and fish species. Exhibit 11 lists the passage species by priority for the Frankenmuth Dam location.

EXHIBIT 11
Prioritized Species to Pass

Priority 1 species	Priority 2 species	Priority 3 species
Lake Sturgeon (adult) Walleye (adult)	Channel Catfish (adult) Largemouth Bass Northern Pike (adult) Smallmouth Bass (adult) Steelhead (adult) White Sucker (adult) White Bass (adult)	All species (excluding sea lamprey) All sizes

SOURCE: FishPro.

Walleye have been selected as a target For Priority 1 species in an effort to reconnect the species with critical spawning habitat above the Frankenmuth Dam location. Lake sturgeon has been placed in this category based on its listing on the state threatened species list (MDEQ/SWQD 1994).

Passage of Priority 2 and Priority 3 species would enhance river connectivity for a large variety of fish species that would directly benefit the overall diversity of Cass River and Saginaw Bay watershed species.

Walleye (Sander vitreus)

Walleye have been successfully passed in a variety of structures, including ladders such as vertical slots and Denils (Katapodis et al. 1991), and also more seemingly natural fishways such as rock ramps and fish bypass channels. In general, walleye swimming speeds have been characterized by tail fork length and can be influenced by temperature. Swimming performance in the literature suggests that walleye can swim at burst speeds between 5.30 (1.60 m/s) and 8.50 f/s (2.60 m/s) when startled (Peake et al. 2000). Prolonged swimming speeds for walleye have been reported at ranges of 1.20 f/s (0.38 m/s) to 2.76 f/s (0.84 m/s) (Jones et al. 1974). Peake et al. (2000) reported that $Ucrit_{10}$ and $Ucrit_{60}$ ranged from 1.40 f/s (0.43 m/s) to 3.74 f/s (1.14 m/s) and from 0.98 f/s (0.30 m/s) to 2.39 f/s (0.73 m/s), respectively. Sustained speeds have been reported to range from 0.02 f/s (0.01 m/s) to 0.16 f/s (0.05 m/s).

The reported swimming speeds of the species correspond with observed performance in fishways. Walleye have readily passed fish ladders with velocities ranging from 2.30 f/s (0.70 m/s) near the bottom of the fishway to velocities greater than 4.90 f/s (1.50 m/s) near the surface. Maintaining velocities within this range should pass walleye at the target size in a variety of passage structures. In addition to providing velocities passable by walleye, consideration should be given to providing resting opportunities when the $Ucrit_x$ has been reached or exceeded. Providing velocity conditions without resting opportunities beyond the designated $Ucrit_x$ for a species would result in fatigue and could result in the fish being swept back down the fishway.

Lake Sturgeon (Acipenser fulvescens)

Lake sturgeon passage criteria differ from many species due to fish swimming ability and size of migrating adults. Due to the asymmetrical nature of the lake sturgeon tails, the burst speeds attained by sturgeon may be slower than for other species at a similar size; however, the sturgeon that will be migrating will be larger adults and may have swimming criteria similar to walleye that are smaller in size (Kynard et al. 2003). Lake sturgeon reach sexual maturity between 39 and 59 inches (100 and 150 cm) and fish in these size ranges can maintain themselves in flow up to 3.20 f/s (0.97 m/s) and can reach speeds close to 5.90 f/s (1.80 m/s) for short periods of time (Peake et al. 1997).

Selected Characteristics

The swimming ability of other species desired for passage will vary by species and size. Exhibit 12 provides a partial listing of characteristics for species selected to pass the structure at Frankenmuth. Where possible, swimming characteristics are noted.

EXHIBIT 12
Selected Characteristics, Priority 1 and 2 Species

Common name	Scientific name	Primary food source	Preferred habitat	Spawning habitat	Adult size range	Swimming mode
Channel Catfish	*Ictalurus punctatus*	Insects, mollusks, crustaceans, fish, and some plant material	Cool, deep, clean water with a sand or gravel bottom	Late spring or early summer when water temperatur es reach 75°F	Up to 48"	Subcarangiform[a]
Lake Sturgeon	*Acipenser fulvescens*	Bottom-dwelling organisms including small clams, snails, crayfish, side-swimmers, aquatic insects, algae, and other plant matter	Deeper part of channels or deep pools	April–June, migrate to areas with gravel bottoms	Up to 98”	Subcarangiform/ Carangiform[b]
Largemouth Bass	*Micropterus salmoides*	Fish and other vertebrates	Shallow vegetated areas; prefers deeper cooler water in summer months	Mid-May–June, prefers shallow marshy areas	12–20"	Subcarangiform
Northern Pike	*Esox lucius*	Fish and other vertebrates	Shallow vegetated areas; prefers deeper cooler water in summer months	March–April, prefers shallow marshy areas	Up to 31"	Subcarangiform/ Labrifrom[c] as predator
Smallmouth Bass	*Micropterus dolomieu*	Fish	Clear, strong-flowing streams and rivers with gravel or boulder shores	Mid-May through end of June in a gravel bed near a log or boulder	12–20"	Subcarangiform
Steelhead	*Oncorhyn-chus mykiss*	Fish, insects, mollusks, crustaceans	Cool, clean water with a sand or gravel bottom, pools and riffles	Gravel riffles in late March to May	Up to 38”	Subcarangiform
Walleye	*Sander vitreus*	Opportunistic feeder; mainly feeds on other fish and large insects	Backwaters, generally in deeper pools with quiet water; prefer slightly turbid conditions	Turbulent rocky areas when in rivers spawning	Up to 30"	Subcarangiform

Common name	Scientific name	Primary food source	Preferred habitat	Spawning habitat	Adult size range	Swimming mode
White Bass	*Morone chrysops*	Water fleas, insect larvae, and fish	Clear water, some current over sandy or rocky bottoms with little to no vegetation	Spring (May) in tributaries with hard bottom of sand, gravel, or rubble	Up to 13"	Subcarangiform
White Sucker	*Catostomus commersoni*	Primarily benthic insects	Sandy or gravelly creeks; wide tolerance to habitats	Gravel riffles in late March to May	15–20"	Subcarangiform

SOURCE: FishPro.
[a] Between 1/2 and 2/3 of body muscle mass is used to generate undulating waves down the body.
[b] Last 1/3 of body muscle mass is used to generate propulsion.
[c] Pectoral fins are used to push water.

Species of Concern

In addition to the species desired to pass the structure at Frankenmuth, there are some undesirable species in the Cass River. In cases where migrations do not already occur, the highest priority of nuisance species that should be restricted from passing is the sea lamprey (*Petromyzon marinus*). Lamprey ascend streams in the spring and early summer to spawn and have been characterized as weaker swimmers compared to native riverine species such as those selected for passage at the Frankenmuth location. Swimming speeds for sea lamprey have been reported at 1.20 f/s (0.36 m/s) and burst speeds of 3.90 f/s (1.20 m/s). These speeds are considerably lower than the speeds obtained by walleye and lake sturgeon; but sea lamprey have the ability to attach themselves to structures for great lengths of time. They can attach to a surface, make a short burst forward, and then reattach themselves to rest. Movement in this manner gives the lamprey a unique ability to ascend passage structures that have higher velocities than the species can maintain.

The detrimental impacts of the lamprey have been well documented and will not be discussed in this report; however, strategies to exclude or manage the species should be a part of every fish passage plan. A variety of measures have been used to slow or stop the movement of lampreys. These include baiting and trapping, weirs (portable and permanent), electrical barriers, barrier dams, velocity barriers, and lampricides. The construction of a fish passage at the Frankenmuth location will increase the likelihood of lamprey movement above the dam. Coordination between MDNR, USFWS, and the City of Frankenmuth will be required to provide management alternatives and strategies for lamprey management, and must be completed during the design of the selected alternative.

Passage Monitoring

It is highly recommended that a method of fish passage measurement be approved by the MDNR so that appropriate steps can be considered during design of a fish passage. Several types of measurement can be used to evaluate the success of the selected fish passage. These measures include, but are not limited to, tagging of fish above and below

the dam, trap netting at the exit of the fishway (where feasible), visual measurement of activity in the fishway, and telemetry studies.

Design Alternatives

An alternative to fishway ladders such as Denils and vertical slots is a more natural fish passage system incorporating native features such as boulders, rocks, and usually including some form of sinuosity. This type of fishway can have a natural stream appearance instead of the more "constructed" look of traditional technical fishways. Several types of seemingly natural fishways are currently gaining in popularity, including rock-ramp fishways, ramp fishways with boulders and pools, boulder block fishways, stream bypass with step pools, and stream bypass channels with natural riffles. Successful fishways of this sort vary in slope and can range from 1:8 (1 vertical to 8 horizontal distance) to 1:1000. More typically, these types of fishways range from 1:10 to 1:30 and are increasingly proving successful over a variety of conditions and flow velocities. These types of fishways can be less costly than ladders depending on the configuration and materials selected, and can also provide more flexibility for anticipated conditions.

In addition to requirements for the upstream passage of species, conditions for downstream movement should also be considered. In recent years, the advancement of fish passage alternatives has focused primarily on upstream movement around structures with little attention toward the downstream movement. Like tolerances for upstream passage, tolerances for species passing downstream will also depend on species and size.

While specific requirements may not exist for all fish species, some general downstream criteria have been developed that focus more on downstream passage in association with turbine and intake structures than on more natural bypass channels or rock ramps. The impacts of upstream passage structures on downstream movement of fish have been documented. These impacts are similar to concerns over entrapment or entanglement of fish for screening or intake facilities. In general, fish passage structures that cause an increase in water velocity near the fish exit (water entrance) of a bypass or fishway should be avoided. These conditions can "sweep" weaker swimming and juvenile fish through the upstream passage structure. Additionally, structures that cause unnecessary turbulence or velocity resulting in stressful conditions, conditions that disorient the fish, or conditions that cause injury (such as descaling or even death), should be evaluated and avoided.

Sea Lamprey Control

Sea lamprey control is a critical fishery management action delivered to support the Fish Community Objectives developed by the lake committees as part of the Strategic Plan for Great Lakes Fishery Management. Objectives for acceptable levels of mortality that allow the establishment and maintenance of self-sustaining stocks of many game fish have been established on all of the lakes. In some cases, the lake committees have established specific targets for sea lamprey populations in the fish community objectives or the lake trout rehabilitation plans. The current control program reflects actions by the USFWS and Department of Fisheries and Oceans Canada as contract agents of the Great Lakes Fishery Commission to meet these targets.

In 1995 the Lake Huron Committee established the following specific targets for sea lamprey populations in its Fish Community Objectives (DesJardine et al. 1995):

- Reduce sea lamprey abundance to allow the achievement of other fish community objectives; obtain a 75 percent reduction in parasitic sea lamprey by the year 2000 and a 90 percent reduction by the year 2010 from present levels.

While lakewide lamprey abundance has been relatively stable throughout the 1990s, at least twice as many lamprey remain in Lake Huron than in any of the other Great Lakes. Estimated abundance of spawning-phase sea lamprey during 2002 was one of the measures used to determine success of applications of Bayluscide 3.2 percent Granular Sea Lamprey Larvicide in the St. Marys River during 1998–1999. This sea lamprey target supports the objectives for the other species groups in the fish community including, for example, the salmonine community objective:

- Establish a diverse salmonine community which can sustain an annual harvest of 5.3 million pounds, with lake trout the dominant species and anadromous species also having a prominent place (DesJardine et al. 1995).

The sea lamprey management program benefits substantially from a number of dams built and operated for other purposes. A geographic information system (GIS) inventory of these “de-facto” barriers has been initiated. This will be a useful tool in identifying dams of value to sea lamprey management. The inventory is complete or nearing completion for Ontario, Michigan, and Wisconsin.

Chemical control of sea lamprey, beginning in 1960 in Lake Huron, also has set the stage for recovery. Large-scale plantings of lake trout, Pacific salmon, rainbow trout, and walleye have reestablished some control by top predators. Lake whitefish have responded to reduced mortality from sea lampreys, fishing, and changing species interactions, thereby resuming their historically prominent position in the cold-water community. Bloaters, likewise, have made a modest recovery, and yellow perch numbers have started to rise once more. However, lake herring and lake sturgeon remain scarce in much of the lake. Walleyes occur as relatively discrete stocks that range from productive in lower Lake Huron to depressed in much of the Canadian Shield area. Despite evidence of a recovering fishery in the Saginaw River and Saginaw Bay, the populations of the most desirable sport and commercial species have not reached historical levels.

Since the late 1970s, efforts have been made to develop an integrated pest management approach with the addition of management tools such as low-head barriers, new styles of electrical weirs, and sterilization of male sea lamprey for release. The Great Lakes Fishery Commission has stated a goal to achieve at least 50 percent of sea lamprey suppression with alternative technologies while reducing the use of TFM, a chemical used to kill juvenile lampreys, by 20 percent through increased use of current methods such as sterile-male-release, trapping, and barrier deployment. Low-head barriers have been constructed on some U.S. and Canadian streams that are difficult to treat. These barriers, combined with traps, block spawning runs of adult sea lamprey while allowing for passage of jumping fish such as rainbow trout. Larger and more efficient trapping facilities are concurrently being developed for use at low-head barriers or existing

hydroelectric dams in order to provide more male sea lamprey for sterilization and the removal of female sea lamprey.

The USFWS Sea Lamprey Barrier program is carried out under the auspices of the Great Lakes Fishery Commission. Barriers are constructed on streams in strategic locations throughout the Great Lakes basin to prevent sea lamprey from spawning, and thus, to effectively reduce the number of streams that produce sea lamprey. The goal is to construct these barriers to prevent sea lamprey passage while still allowing the passage of most other fish species.

It is important to note that there is a difference of opinion between the MDNR Fisheries Division and the USFWS regarding the priority that should be assigned to existing dams that are allegedly barriers to sea lamprey migration. While the USFWS might argue that stopping sea lampreys trumps any environmental damage the dam might do, the MDNR Fisheries Division believes that fish passage is the paramount concern. This is especially true in river systems that the USFWS is already routinely treating with TFM. TFM treatments have been performed in recent years on the Shiawassee and Chippewa rivers and on tributaries of the Cass River above Frankenmuth; thus the dams have not been complete barriers to lamprey passage in their present condition. Consequently, the MDNR Fisheries Division believes that there would be substantially more environmental benefit in allowing fish passage over these dams, or in complete dam removal. Sea lamprey could still be controlled in these rivers with TFM, as has been the case in the past.

DAM REMOVAL CONSIDERATIONS

Dam removal continues to garner attention as a potential river restoration tool. Restoration of flow regimes has resulted in increased biotic diversity through the enhancement of preferred spawning grounds or other habitat. By returning riverine conditions and sediment transport to formerly impounded areas, riffle/pool sequences, gravel, and cobble have reappeared, along with increases in biotic diversity. Fish passage is another benefit of dam removal. However, the disappearance of the reservoir may also affect certain publicly desirable fisheries (Bednarek 2001).

For decades, dam removal was considered a fringe, radical approach to river restoration. The concept of dam removal can elicit strong emotions, leading to divisive and heated debate on all sides of the issues. Although it is important that the concerns behind the emotions be expressed and considered, a decision about whether or not to remove a dam needs to be based on a balanced and rational analysis of the pros and cons of both dam removal and dam retention (Aspen Institute 2002). Regardless of the controversy, dam removal will become an increasingly important issue in many communities.

Today selective dam removal can be an integral component of successful watershed management and generally occurs when a dam no longer serves a useful purpose or is considered a significant safety risk. Removing dams to enhance fish passage and address unsafe and unwanted dams is still a relatively new phenomenon. Dam removals have been documented since the early 1900s—including a large number removed in just the last decade—and many more are undocumented. In part this reflects America's aging dam infrastructure; in part, it reflects significant changes in land uses and the structure of

our economy, which has reduced our need for certain dam functions, as well as a growing concern about river ecology.

Once perceived as almost entirely beneficial, dams are seen more realistically today as having both positive and negative effects (Aspen Institute 2002). And many dams across the country have aged beyond their planned life expectancy, causing safety risks for communities downstream. Dam owners, whether private or government, rarely plan or accept responsibility for the costs of decommissioning. Yet dam removal costs in many cases are significantly less than estimated expenditures for long-term safety and environmental compliance, repair, and maintenance.

Removal costs of 70 small dams in Wisconsin, for example, were found to be an average of two to five times less than estimated repair costs. On the Baraboo River in Wisconsin, the cost of removing the three-meter-high Oak Street Dam was $30,000, compared to dam repair estimates of $300,000. In Maine, removal costs for the eight-meter-high Edwards Dam were roughly one-third the $9 million price tag of upgrading fish ladders to meet mandatory relicensing conditions. On average, removal costs were only 37 percent of the estimated dam repair costs for 10 dams profiled in the report, *Dam Removal Success Stories: Restoring Rivers Through Selective Removal of Dams that Don't Make Sense* (American Rivers 1999).

Issues to Consider Prior to Removal of a Low-head Dam

Dam removal issues can be organized around the following subject areas:

- Technical aspects
- Environmental and ecological impacts
- Economics and social dimensions
- Legal issues
- Design and construction

Technical Aspects

Removing a dam requires a multidisciplinary approach, and there are often unforeseen challenges that must be managed or mitigated (Graber et al. 2001). Most dam removal projects have unique issues, different project goals, and regional differences based on geography and natural processes. Myriad issues apply in varying degrees to particular projects. For example, some dams trap very little sediment, so managing sediment may not be a significant issue. Some run-of-river dams that have small impoundments require very little channel reconstruction or revegetation following dam removal. Thus, there are no universal solutions or methodologies to address many of the technical issues that arise during dam removal projects. It is advisable to enlist the aid of local experts, engineers and biologists, who are familiar with local resources and possess the necessary technical expertise.

Environmental and Ecological Issues

Dams are known to impact river systems by altering several key parameters including: flow regimes and physical habitats, channel shape, sediment transport, water temperature

and chemistry, and populations of algae, benthic macroinvertebrates, riparian vegetation, and resident and migratory fish (Poff and Hart 2002).

Short-term ecological impacts of dam removal include an increased sediment load that may cause suffocation and abrasion to various biota and habitats. However, several recorded dam removals have suggested that the increased sediment load caused by removal should be a short-term effect. Preremoval studies for contaminated sediment may be effective at controlling toxic release problems.

Economics and Social Dimensions

From an economic standpoint, dam removal is not unambiguously good (The H. John Heinz III Center 2002). Economic analysis can be helpful for setting priorities and facilitating communication among stakeholders and agencies. Benefit-cost analysis provides a process for identifying and measuring the outcomes of dam removal, whether they are perceived as positive or negative, and for clarifying tradeoffs.

People feel passionately about rivers, and, sometimes, about dams and their reservoirs as well. Efforts to restore rivers, fisheries, and livelihoods lost to dams can be met with resistance and skepticism, especially if decommissioning advocates neglect to educate important stakeholders, address technical, legal, and economic cost issues, or examine feasible alternatives and possible negative impacts. Moreover, consideration of dam removal often incites significant opposition because a dam often is viewed as a site of historical significance, a civic icon of sorts—revered and cloaked in nostalgia and romantic history of the nineteenth and early twentieth centuries with no regard to contemporary environmental objectives. In addition, the water impoundments created by dams may be viewed as economic stimulus for recreation and downtown development. The perceived ongoing benefits provided by a dam must be objectively evaluated against opportunities for dam removal and/or enhanced fish passage.

Legal Perspectives

For many, the dismantling of a particular dam in Michigan may signify the end of an era. After decades of harnessing the forces of nature for economic progress, many have now turned to assess the ongoing environmental and maintenance costs and assessing dam removal options. Federal and local dam licensing regulations make the current time period one in which dam removal is a realistic option (Doyle et al. 2000).

Depending on the regulatory environment at a particular site, the permitting process can significantly guide project design. Removing a small dam requires federal, state, and local permits. These permits ensure that the project is handled safely and minimize short- and long-term impacts to the river and floodplain. While federal permits are administered by the U.S. Army Corps of Engineers (ACOE) and, if applicable, the Federal Energy Regulatory Commission (FERC), each state and local government has different permitting requirements (Graber et al. 2001).

The MDEQ Dam Safety Program administers the provisions of Part 307 and Part 315 of The Michigan Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. There are over 2,500 dams in the state, with 91 of those regulated by Part 307 (Inland Lake Levels) and 816 regulated by Part 315 (Dam Safety). Part 307 regulates

dams that establish legal lake levels while Part 315 regulates all other dams over six feet in height and with more than five acres impounded during the design flood. An MDEQ permit must be acquired prior to any construction or repair of regulated dams. Additionally, these dams must be inspected every three to five years based on hazard potential rating. Staff at MDEQ are responsible for reviewing all inspection reports, inspecting all MDNR dams, and inspecting municipal dams if requested.

Design and Construction Approaches

While the physical removal of the dam structure itself can be a relatively straightforward process, there are several associated issues to address in order to protect and restore aquatic and riparian habitat and the stream channel. Careful planning can limit the effects of released sediment on aquatic life, prevent extensive erosion in the restored stream channel, and limit the potential intrusion of exotic plant species in the former impoundment (Graber et al. 2001). Each restoration project is unique and in some cases these issues may be minor. In other cases they can be complex and need to be appropriately managed.

While certain techniques may be necessary for a particular project, the greatest expenses incurred by small dam removal projects have included dredging, off-site disposal of materials, developing access to the structure, and water control during construction (Graber et al. 2001). Often the time and labor required to physically remove the dam is the least expensive component of the project.

Because dam removal is relatively new in many areas, the permitting process can be challenging. Many state and federal agencies are not yet practiced at moving restoration projects, such as dam removals, through the permitting process. For the most part, the relevant permitting requirements were designed for projects that are potentially more destructive to navigation or environmental quality, and therefore dam removal does not fit easily into the requirements. The Michigan Departments of Environmental Quality and Natural Resources are currently examining options for streamlining the permitting process for dam removal projects.

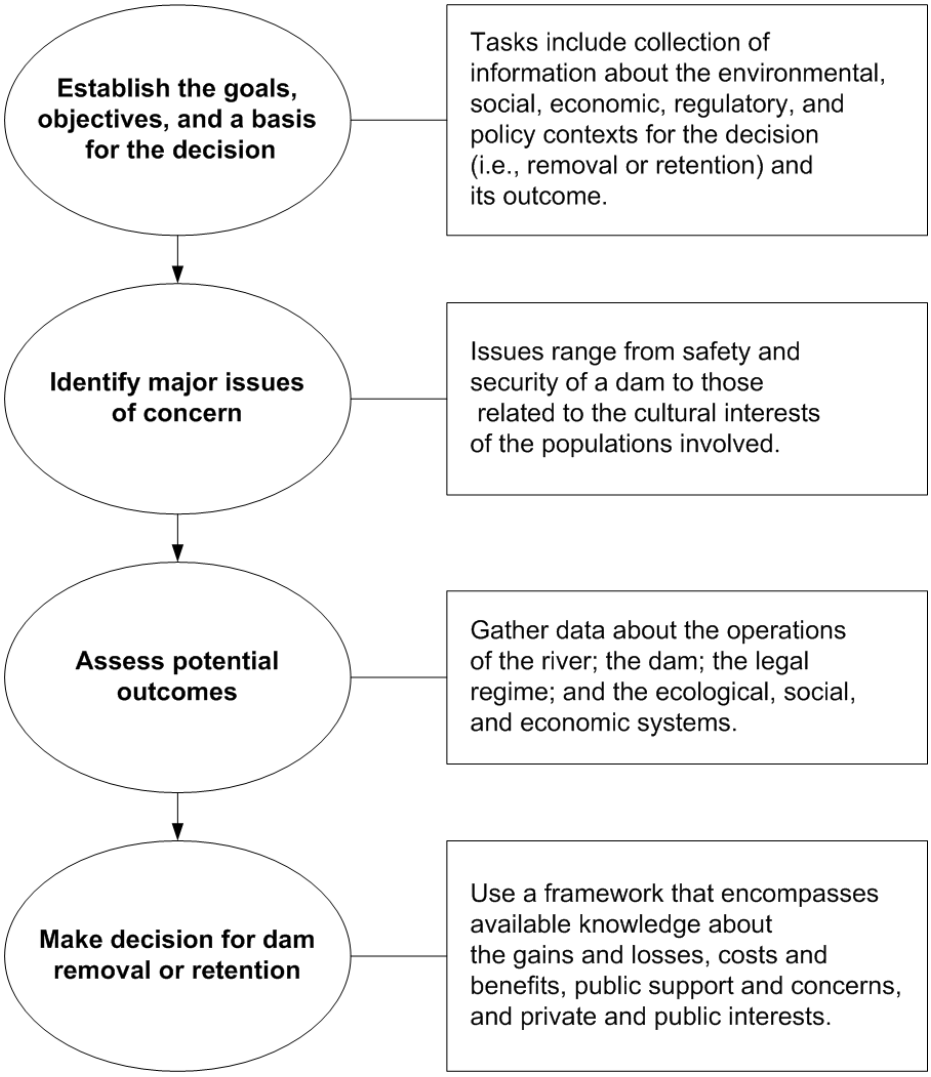
Trade-offs of Dam Removal versus Dam Retention

Dam removal may result in fundamental changes to the local environment. Depending on the size of the dam, the reservoir will be eliminated, and with it the flat-water habitat that had been created. Wetlands surrounding the reservoir will also be drained, although new wetlands are often created both in the newly restored river reach above the former dam site and in the river below. Sediment that collects behind a dam, sometimes over decades, may contain toxics such as PCBs, dioxide, and heavy metals. Resuspension of these toxic-laden sediments in the process of dam removal has the potential to damage downstream water quality and threaten the health of fish and wildlife and water users. Short-term impacts of the dam removal itself can include increased water turbidity and sediment buildup downstream from releasing large amounts of sediment from the reservoir, and water quality impacts from sudden releases of water and changes in temperature. These impacts, however, can be prevented through proper removal techniques.

Dam removal has the added benefit of restoring spawning habitat to flowing reaches; this benefit does not occur in impounded reaches if the structure remains, even if fish passage is accomplished. Although monitoring and dam removal studies are limited, a continued examination of the possible ecological impacts is important for quantifying the resistance and resilience of aquatic ecosystems. Although controversial, dam removal is an important alternative for river restoration. Long-term social, technical, and biological impacts of dam removal should be given paramount consideration over short-term impacts**.** Exhibit 13 highlights the steps necessary when considering dam removal versus retention.

EXHIBIT 13

Decision Matrix for Dam Removal versus Dam Retention



SOURCE: Adapted from *Dam Removal: Science & Decision Making*, Heinz Center, 2002.

FRANKENMUTH DAM

The Frankenmuth Dam was built in the 1850s in order to provide a water supply for a local mill. Originally constructed with earth and stone, the dam was later converted to a wooden structure and ultimately a concrete structure. The dam was deeded to the City of Frankenmuth in the 1950s and has been managed by the city ever since. The spillway crest has a total length of approximately 240 feet and a total structural height of approximately 14 feet. Frankenmuth provides periodic maintenance and patchwork to ensure structure stability. For example, in 1995 approximately $60,000 was spent to make repairs along the north part of the dam; to grout the inside of the dam to address severe leaking; and to make repairs on north shoreline. In 2002 the city received estimates of $200,000 to make repairs on the south side of the dam and spillway area. The ongoing maintenance and costs associated with the dam prompted the city to consider a long-term solution for the site. As a result, city officials were eager to participate in a study that would assist in identifying options for achieving fish passage while considering long-term solutions for the structure itself.

Three alternative designs were evaluated for passage at the Frankenmuth Dam. These alternatives are a fish bypass channel, a spiral fish ladder, and a rock ramp. The criteria outlined in the previous section of this report were applied to the development of the conceptual layouts. Many assumptions were also necessary in order to estimate the river stage at the time of passage, and elevations of entrance and exit conditions. These assumptions must be confirmed during a schematic design phase of the passage alternative.

The location of a fish passage is recommended for the north shore of the Cass River around the north side of the existing abutment of the dam. This location is the least problematic, is potentially accessible for visitors, and is within close proximity to other activities in the area. A south shore location going around the south abutment presents problems due to topography, existing utilities, and distance from potential visitor activities, and is therefore not recommended. The following sections outline placement of a fish bypass channel or a spiral fish ladder along the north shore around the existing abutment and placement of a rock ramp downstream of the existing dam.

Fish Bypass Channel

There are several advantages to utilizing a bypass channel for improved fish passage at the Frankenmuth location:

1. A bypass channel will allow a wide range of fish species to pass. The slope of a bypass channel can be generally low. In the conceptual plan, a 3.2 percent slope is provided in the bypass. The low slope allows for a long, slow rise from the bottom elevation to the top elevation. Along the length of the bypass, strategically placed boulders, rocks, and riffle areas will allow for a variety of velocities and will not select for a single species in the velocity criteria.

2. The use of a seemingly natural bypass channel allows the fish passage to be aesthetically pleasing. The bypass channel and surrounding area can be incorporated into recreational activities.

3. A bypass channel is more flexible than a ladder. The placement of boulders and riffle areas can be adjusted over time to fine-tune the fishway for better passage efficiency.

4. The bypass channel is more conducive to the downstream movement of fish species than traditional fishways. Most fish ladders present flow patterns designed to attract fish for ascending above a structure. While downstream passage is possible in a fish ladder, fish injury often results, especially for juvenile fish.

5. Other species beyond the target fish species have the ability to use a bypass structure. The naturalistic setting of a bypass channel can provide habitat for other organisms important to the river ecosystem.

There are also some disadvantages to the bypass channel option:

1. Maintenance of flow conditions may be required to ensure that the desired amount of water is delivered though the bypass and is not disruptive to normal historical flow patterns over the dam. During lower flow events, the bypass channel may discharge more water than desired, diverting water away from the south side of the dam. This may result in areas that are normally wet during low flows becoming dry for the duration of the low flow.

2. Slope and shore stabilization would be required for the areas between the bypass and the river, and the area between the bypass the existing retaining wall.

Exhibit 14 provides a list of assumptions for the bypass channel.

EXHIBIT 14
Bypass Channel Assumptions

Change in head	8.7 feet/2.7 meters
Bottom width of channel	8.0 feet/2.47 meters
Length of bypass	271.0 feet/2.6 meters/82.6 meters
Slope of channel	3.2%
Number of riffle areas	17
Spacing between riffle areas	16.0 feet/4.9 meters
Elevation change between pools	0.5 feet/0.2 meters

SOURCE: FishPro.
NOTE: Change in head was estimated and would be dependent upon river stages at the time of passage in both the headwater and tailwater.

Costs associated with constructing a bypass channel may include excavation and shaping, slope stabilization, water control structure, and materials and labor, and would range from $500,000 to $700,000.

Spiral Fish Ladder

The second alternative is a spiral side-baffle fish ladder of the type that has been studied at the S. O. Conte Anadromous Fish Research Center (Kynard et al., 2003). The spiral

side-baffle ladder may resemble a vertical slot with baffles spaced at periodic intervals over a defined length of fishway but has several features that differ from a vertical slot. The side baffles are placed in the fishway with alternating patterns from the inside and outside of the fishway wall. The study fishway also provided bottom baffles to provide roughness and allow for bottom fish to hold position. The overall flow patterns in the side-baffle ladder were a continuous dominant flow that alternated from side to side through the baffle slots and an eddy area downstream of each baffle that provided a resting area. The objective of the fish passage device is to maintain a constant slope but maximize linear layout space by extending the fishway vertically. A primary disadvantage of a fish ladder is that walleye, a primary species targeted for passage, are not jumping fish, and have difficulty navigating through a ladder structure.

Exhibit 15 lists assumptions made for the spiral side-baffle ladder.

EXHIBIT 15
Spiral Side-Baffle Ladder Assumptions

Change in head	8.7 feet/2.7 meters
Width of fishway	3.3 feet/1.0 meters
Length of ladder	145.0 feet/44.2 meters
Slope of ladder	6.0%
Number of baffles	TBD
Spacing between baffles	TBD
Estimated elevation change between pools	0.5 feet/0.2 meters

SOURCE: FishPro.
NOTE: Change in head was estimated and would be dependent upon river stages at the time of passage in both the headwater and tailwater.

Costs associated with a spiral fish ladder may include minor excavation and shaping, water control structure, and materials and labor, and would range from $800,000 to $1 million.

Rock Ramp

The third alternative consists of placing rock material downstream of the dam, creating a gradual slope known as a rock ramp. A slight modification of this type of passage to include rock weirs is outlined. This type of structure would not require a separate bypass around the dam and would still incorporate some naturalistic features with the use of rock material. This design also allows nonjumping fish to pass through notches within the weir structures. If the notches are sized correctly, fish can move through the weir structure under low flow conditions. When the river reaches flood stage the additional water flows over the top of the rocks, which create a flow resistance that allows fish to slither through the system. There are several advantages to providing a modified rock ramp with rock weirs at the Frankenmuth location:

1. A major advantage to this alternative is that is can be placed in front of the existing dam, thus providing structural support to the current dam.

2. Variable flow can occur around the rocks and boulders placed in the river. This can be advantageous to varying fish sizes, allowing them to find areas of passable velocity among the various-sized material. This type of structure may allow a wider range of species and sizes to make the transition above the existing dam.

3. A rock ramp is relatively simple to incorporate into the existing area, requiring mainly the placement of material. This type of structure would require some additional features in addition to the rocks and boulders to reduce or eliminate permeability near the dam. Such additional features may be the use of grouted riprap and/or concrete.

4. A rock ramp can also have aesthetic appeal. Rocks of varying sizes can be positioned to provide a natural look.

5. Maintenance may be slightly reduced in a rock ramp scenario since the structure creates more of a natural area within the river itself and is not a maintained channel around the dam.

This option, too, has some disadvantages:

1. As in the case of a bypass channel, by allowing a wide range of species to pass the structure, unwanted species such as the sea lamprey may also pass. However, since a bypass option is a confined channel it can be equipped with traps for lamprey. While lamprey control is technically feasible in a rock ramp, this option should be addressed carefully and coordinated with the USFWS.

2. The construction of a rock ramp will require placement of material in the Cass River and will change the area immediately downstream of the existing dam. However, a rock ramp will still provide habitat for native species such as crustaceans and macroinvertebrates.

Exhibit 16 lists assumptions made for the rock ramp alternative.

EXHIBIT 16
Rock Ramp Assumptions

Change in head	8.7 feet/2.7 meters
Width of ramp	240.0 feet//73.2 meters
Length of ramp	200.0 feet/61.0 meters
Slope of ramp	5.0%
Number of rock weirs	8
Spacing between weirs	20.0 feet/3.1 meters
Elevation change between pools	1.0 feet/0.3 meters

SOURCE: FishPro.
NOTE: Change in head was estimated and would be dependent upon river stages at the time of passage in both the headwater and tailwater.

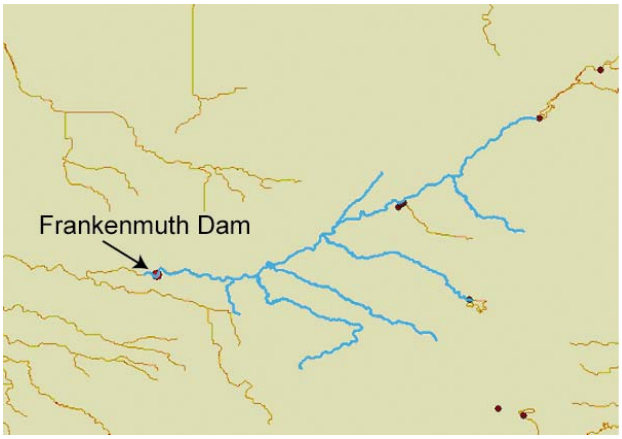
Costs associated with a rock ramp may include excavation and shaping, minor sediment removal, slope stabilization, and materials and labor, and would range from $1.8 million to $2 million. This range includes $200,000 for dam repairs that would need to occur simultaneously if this alternative is pursued. Cost projections for the bypass channel and spiral fish ladder do not include dam repair costs because they could be carried out independent of making needed dam repairs to the existing structure.

Conclusions and Recommendations

While the Frankenmuth Dam no longer serves its original purpose as a source of power for a mill, the current dam creates an impoundment adjacent to the city's downtown district and there is a strong community desire to retain the current structure while supporting successful fish passage to achieve ecological and economic goals.

The species selected for passage in Frankenmuth have been shown either through actual installations or in experimental installations to successfully ascend all three alternatives reviewed. Roughly 73 miles of river and tributary habitat, of varying quality, up to the dam in the City of Caro would be opened up if passage options were provided at Frankenmuth (see Exhibit 17). Approximately 24 miles occurs on the mainstem. Reconnecting spawning fish with this critical habitat makes providing passage opportunities at the Frankenmuth Dam an important step in the MDNR Walleye Recovery Plan. All three alternatives achieve the primary goal of moving fish past the Frankenmuth Dam and opening new river habitat for walleye, sturgeon, and other species in the Cass River basin. Based on the specific conditions identified by the advisory committee and unique characteristics of the Frankenmuth Dam, however, a rock ramp is best suited to meet the conditions necessary to achieve successful fish passage.

EXHIBIT 17
Potential Upstream Habitat, Frankenmuth Dam



SOURCE: MDNR Institute for Fisheries Research.

Either a rock ramp or a bypass channel provide the greatest potential for aesthetic appeal and fish movement at the Frankenmuth location when compared to a fish ladder. The advantages of these alternatives include potentially wider range of velocities for species passage, better downstream passage opportunities, flexibility of design, and the potential for future modification. However, the advantages and disadvantages of these options should be fully recognized before proceeding to preliminary design. For the bypass, the location relative to the surrounding amenities could allow visitors and researchers alike access to the channel for visual inspections and aesthetic enjoyment. A bypass could also be modified to trap sea lamprey and other undesirable species. Disadvantages for this option include the limited area available for placement of the channel and the need to address the condition of the aging dam. In contrast, a rock ramp could provide structural stability to the dam without costly dam replacement while still providing a visually attractive alternative. However, this option potentially provides the most passage opportunities for the undesirable sea lamprey.

Both a bypass and a rock ramp have the ability to pass a larger range of fish than a fish ladder, due to their unstructured design. The placement of irregularly sized boulders and rocks commonly used to shape and construct these types of passages provides a wide range of possible velocities that allow for multiple species and size classes. Finally, both of these options can be flexible. The ability to rearrange the boulders, rocks, and associated riffle areas will allow for changes to the flow, velocities, and general appearance. With these options, a “fine-tuning” is possible.

Most importantly, construction of a rock ramp addresses the city’s concern about the age and condition of the dam while also meeting the goal to enhance fish passage. Thus, although it is the most expensive option, construction of a rock ramp is recommended.

Many assumptions were necessary to complete the conceptual layouts for the Frankenmuth Dam. In order for the project to move beyond the conceptual stage, several

tasks must be accomplished. These tasks may take from two to five years to complete and include the activities outlined in Exhibit 18.

EXHIBIT 18
Necessary Tasks

Task 1	Development of schematic design-level documents and cost estimates for the approved alternative. Included within this task would be an updated topography survey, soil borings, development of a hydrograph, and development of plan sets for review. Analysis and design of any necessary improvements to the existing dam and abutments must be completed. Application must be made for all necessary regulatory and environmental permitting.
Task 2	Secure funding to complete the construction of the designed passage structure. Based upon the schematic-level design, funding should be secured in order to complete final design and begin construction.
Task 3	Complete final design phase and accept bids. After the final design is complete, bidding to select a contractor can begin.
Task 4	Award contract and complete construction.
Task 5	Implement management and monitoring strategies to maintain the passage structure and monitor the successful passage of target species. It should be noted that species monitoring could begin before construction of the structure in order to provide important data for preconstruction conditions.

SOURCE: Fishpro 2005.

DOW DAM

The Dow Dam is situated on the Tittabawassee River in the City of Midland and currently owned by the Dow Chemical Company. The Tittabawassee River has several major tributaries, comprising 128 river-miles subject to fisheries restoration and lamprey infestation. Approximately 12 miles occurs on the mainstem up to the Sanford dam. The Chippewa River flows into the Tittabawassee above the Dow Dam and ranks among the most productive streams in the Great Lakes for sea lamprey. The Great Lakes Fishery Commission currently spends approximately $180,000 on an annualized basis for chemical control of sea lamprey in the Tittabawassee and its tributaries.

Because of the productivity of the Chippewa River, the ability to control sea lamprey is a significant concern of the USFWS when discussing fish passage around the Dow Dam. The barrier is an important location for the USFWS to capture adult lamprey for the sterile male program and assess population density. In addition, it is important to note that the current dam configuration does not stop lamprey from migrating upstream into the Chippewa, which necessitates annual chemical treatments in upstream habitat by the USFWS.

In 1970 the Dow Dam was converted from a hydraulically controlled structure to a concrete, fixed-crest dam. A vertical-slot fishway was installed in 1971 to facilitate expansion of salmon migration as a result of the MDNR's stocking program. However, in 1972 Dow reported that large numbers of sea lamprey were using the fishway while intended desirable fish reportedly did not use the ladder. In response to a request by the

USFWS, the fishway was closed from March 1 to July 15, beginning in 1977, to reduce the number of lamprey passing upstream. Lamprey reproduction above the dam was not eliminated, but was greatly reduced.

In 1982 two drownings occurred in a pool at the foot of the dam. In 1984 large riprap was installed below the dam, reaching nearly to the crest, to eliminate the pool and safety hazard. The placement of the riprap again facilitated the movement of sea lamprey over the barrier and in 1985 spawning lamprey were so abundant that they produced the strongest year-class on record. In subsequent years, sea lamprey management personnel from the USFWS observed greater densities of faster-growing larvae in the Chippewa River than had been seen in any Great Lakes stream. The Chippewa River is a tributary to the Tittabawassee River and located upstream from the Dow Dam.

The riprap below the Dow Dam has since migrated downstream, however, and no longer provides enhanced sea lamprey access. Larval densities currently are lower than they were in the 1980s but growth rates continue to be well above the state average. In 1990 the fishway was closed permanently, but lamprey continue to bypass the dam during high water events, which occur on a seasonal basis.

In 1993 Dow cooperated with the USFWS to install small, portable lamprey traps at the dam as part of an integrated control program to reduce reliance on TFM. These traps have been operated annually since then during April and May and it is not uncommon to catch more than 2,500 lamprey in a season. These lamprey provide an index of lakewide abundance in Lake Huron and are an important component of the sterile male program which releases sterilized male lamprey in the St. Marys River to reduce overall reproductive capacity.

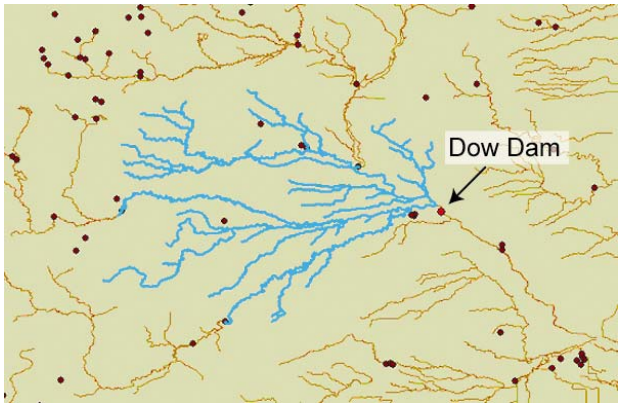
When the downstream water level is below the crest, the Dow Dam now functions as a barrier to all fish except lamprey. Lamprey may bypass the structure using the boat passage area on the east side of the dam. Tagging studies suggest that other nonjumping fish such as walleye, smallmouth bass, white bass, and channel catfish pass upstream only when the dam is inundated, an event that usually occurs each year during the lamprey migration. Lamprey also move upstream under these conditions.

The fishway has been opened for the purpose of conducting several engineering studies at the Dow Dam. Wu and Katapodis (1997) conclude that the current fishway passes lamprey well but presents a problem for other fish due to the fishway floor elevation. The report suggests that fishway replacement may not enhance lamprey passage but will greatly increase the passage of other fish. The report also concludes that possible solutions to the fish passage and lamprey concerns need further investigation before their feasibility is established. Bunt (1999) concludes that a feasible management strategy to pass walleye while minimizing passage of sea lamprey involves “exploitation of the temporal separation between peak migration periods of each of these species.” By operating the fishway prior to April 15, walleye can be expected to have access before peak lamprey migration. Bunt also concludes that “attraction” of walleye to the fishway entrance may be improved by creating a channel to guide them toward the fishway entrance. Bunt (2001) suggests that contrary to earlier reports, underwater videography

taken in April 2001 clearly demonstrates that fish other than sea lamprey are able to use the fishway, although they are primarily white suckers.

It is clear from these studies that the most desirable fish species are currently unable to pass the existing dam. Given the potential of the mainstem river and tributary habitat of 358 miles above this barrier (see Exhibit 19), the ability to pass fish at this location represents one of the largest single opportunities within the watershed; thus it is recommended that more exhaustive engineering feasibility and design studies be conducted. Fish passage at this location is quite possible and should be pursued aggressively by the Partnership with support of the Dow Corporation.

EXHIBIT 19
Potential Upstream Habitat, Dow Dam



SOURCE: MDNR Institute for Fisheries Research.

CHESANING DAM

Located on the Shiawassee River in the Village of Chesaning, the Chesaning Dam was originally constructed in 1863 and consisted of a rock-filled timber crib dam approximately 211 feet wide. The contributing drainage to the Shiawassee River is approximately 605 square miles. The dam has a structural height of 9 feet, a hydraulic head of 14 feet, and creates an impoundment with an estimated surface area of approximately 120 acres. At some time a concrete cap was placed over the timber crib. Pipe inserts in the cap allow the temporary placement of lumber to raise the impoundment during the annual Chesaning Showboat Festival that occurs each July. The upstream side of the dam has trapped sediments, so the depth of the water is approximately 3 to 4 feet deep. The downstream side has a vertical drop of about 10 feet onto a concrete slab, and then transitions further downstream to rocks and boulders, which serve as baffles. In the early spring of 2005, excessive flow and ice damage resulted in a partial collapse at the dam. The village is now reviewing its options to either repair or remove the dam.

The dam has served as a barrier to minimize sea lamprey migration since 1937, when the lamprey was first detected in Lake Huron. Under certain flow conditions lamprey were

able to move over the barrier until 1991, when a concrete wall was poured on the east end of the dam.

Prior to the recent partial collapse, the dam was last inspected on August 7, 2003, and described to be in “fair” condition. At the time of inspection, there were no apparent structural deficiencies that might lead to the immediate failure of the dam. However, flow continues to pass under the dam, and left unabated, could lead to an eventual failure of the spillway.

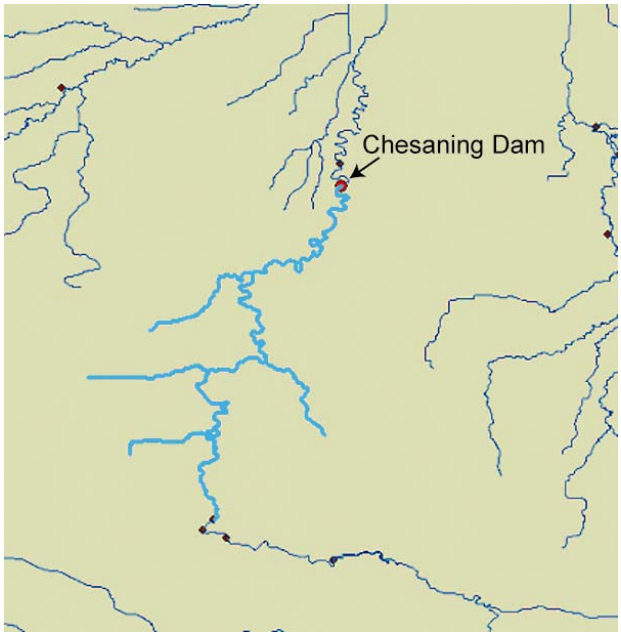
The dam acts as a broad, crested weir and its flow capacity is unlimited, since the depth of flow is a function of flow volume, water elevations, and slope of the riverbed. Significant repairs were made during the summer of 1998 due to the deterioration of the timber cribbing and the concrete/mortar used in the dam. Whirlpools observed in the impoundment during the last inspection, and the flow passing beneath the spillway, are indicators of significant holes in the spillway. As the old timber cribbing in the dam and the mortared spillway face continue to deteriorate, the rate of flow passing through the spillway will continue to increase. As this occurs, the potential for additional erosion will also increase. This could lead eventually to a partial or total failure of the spillway. Due to the age of the dam, these same problems will continue to require maintenance by the Village of Chesaning.

The 100-year flood flow is 8,420 cubic feet per second. The dam can pass a flood of this magnitude with approximately five feet of head on the spillway. Flows of this magnitude will overtop each of the abutment walls and flow along the natural floodplain of the Shiawassee River but not result in a major impact on the downstream area. Even if the dam were removed, this overbank flow would occur.

The Village of Chesaning’s Department of Public Works (DPW) performs all maintenance, including periodic inspections between the state mandated five-year interval. The DPW also places and removes stop logs during drawdowns, and the boards to raise the impoundment during the Showboat Festival. This type of dam requires no operation procedures.

If fish passage could be achieved at Chesaning, approximately 37 miles of mainstem river and tributary habitat would be opened to the next barrier—Hospital Dam located near the City of Owosso (see Exhibit 20). Approximately 23 miles occurs on the mainstem. As a result of the recent partial collapse, the Village of Chesaning has undertaken a comprehensive assessment of needed dam repairs and to identify opportunities for improving fish passage.

EXHIBIT 20
Potential Upstream Habitat, Chesaning Dam



SOURCE: MDNR Institute for Fisheries Research.

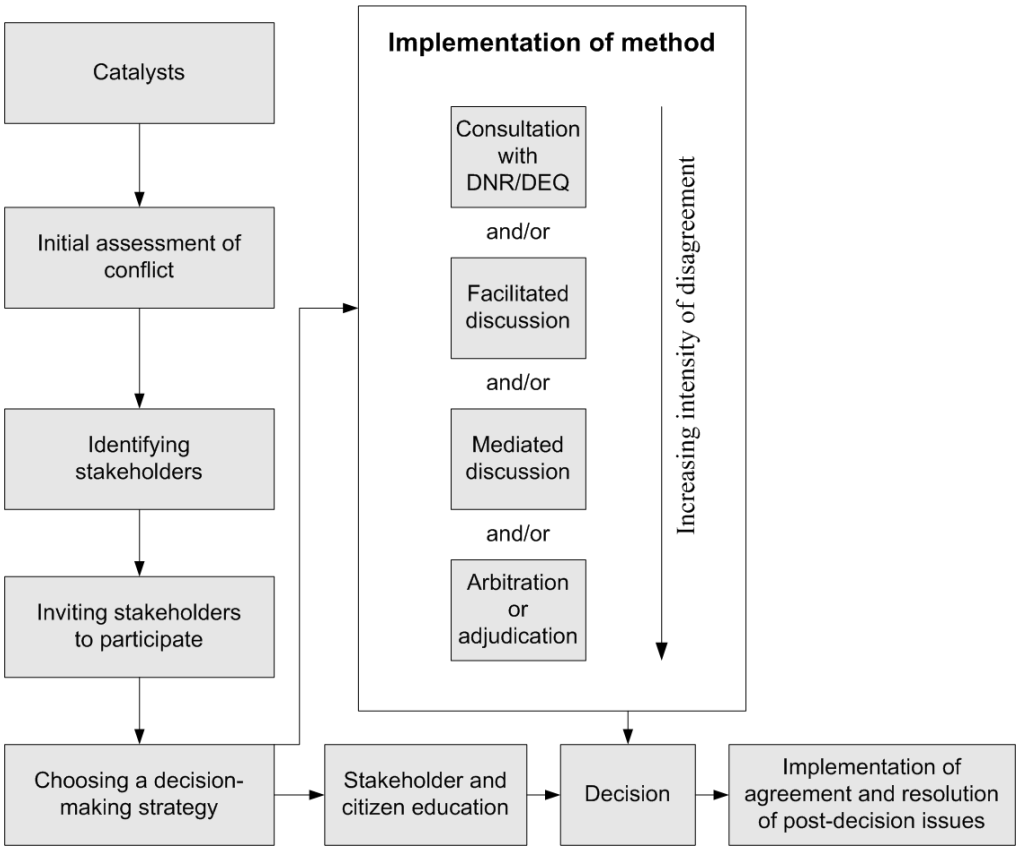
Decision-making Processes

Dam removal decisions require careful planning and review. The process used to arrive at a decision to determine the ultimate fate of the dam is critical to the outcome. The ultimate goal is that these decisions be made with complete information in economic, ecological, cultural and sociologic contexts. The decision to remove a dam by its owner may not be made in the public arena. However, because of state and federal regulations, the decision to remove a dam generally becomes a public process (Heinz Center).

Extensive literature is available to help guide a decision-making process. Exhibit 21 below was developed under the auspices of a 2000 Water Resources Management Practicum, *Dam Repair or Removal: A Decision Making Guide.*

EXHIBIT 21

Principal components involved in designing and implementing an appropriate decision-making process



SOURCE: Wisconsin Department of Natural Resources.

The following questions are example of issues that should be addressed as part of the decision-making process when considering a dam removal[*]:

- What is the basic purpose/reason for considering removal of the dam?
- What group is coordinating the efforts to remove the dam?
- Who are the major stakeholders involved in the discussion?
- What are the past, current and future potential uses of the dam and its pool?
- What are the future potential uses of the stream/river if the dam is removed?

Safety and Security Issues

Identify safety and security issues associated with keeping or removing the existing structure.

- Did the dam fall under the Michigan Dam Safety Program?
  - Does the dam currently meet dam safety standards?
- Is there a significant potential for loss of life, injury, and/or property damage if the dam should fail or be removed?
- Is the dam vulnerable to failure because of either aging or inadequate maintenance?
  - What is its current condition
  - What are the major deficiencies?
- Is the dam vulnerable to acts of terrorism?
- Are people safe around the dam?
  - Boating safety (hydraulics)
  - Playing on dam (broken concrete, slipping off, etc.)
  - Safe portages
  - Injuries or death caused by the presence or condition of the dam
- Would safety be improved if the dam were removed?

Environmental Issues

Identify environmental issues associated with keeping or removing the existing structure.

- Will removal of the structure help to enhance the recovery of threatened or endangered species?
  - What species?
  - How will dam removal enhance the recovery of the species?
- What species might need to be reintroduced to the exposed mudflats/bank areas after dam removal?
  - What costs will be associated with this effort?

[*] The following section is adapted from *Low-head Dam Removal Framework for Decision Making: Issues to Consider Prior to Removing a Low-head Dam*, Ohio Department of Natural Resources, Dam Safety, *http://www.dnr.state.oh.us.water/dsafety/lowhead_dams/framework.htm*.

- Will removal of the structure lead to changes in unwanted invasive species?
  - What invasive species?
  - How will removal of this dam lead to increasing concerns about invasive species?
- Are there likely to be problems associated with contaminated sediments currently contained behind the dam if the dam is removed?
  - What contaminated sediments are of concern?
  - What data has been collected on contaminated sediments? By whom?
  - What analysis has been completed on contaminated sediments?
  - What are the cost estimates associated with removing, sampling, testing, and disposal of the sediments?
- Will removing the dam cause sediment to move downstream to help build beaches?
- Are there other potential beneficial uses for the removed sediments?
- What is the stream's/river's natural ability to carry sediments and how does this relate to the sediments currently deposited behind the dam?
- Will dam removal lead to a net gain or loss in wetland area?
- Have so many other changes occurred in addition to the dam that removal of the dam will not achieve the desired ecosystem restoration goals?
- How will new lands created by the dam removal be used?
- What is the relationship of the dam and its removal to other parts of the watershed?
- How will drinking water supplies be affected?
- How will groundwater tables be affected?
- What time of year would be ideal for the dam removal? Consider safety, weather, environmental issues such as fish spawning, flooding, etc.

Legal and Administrative Issues

Evaluate concerns and needs from a legal and process perspective.

- Are there current existing or potential conflicts with laws and regulations designed to protect natural systems? (e.g., Clean Water Act, Endangered Species Act, National Flood Insurance Program, FERC, Navigation – Section 10 Rivers and Harbors Act, COE 404)
- Are there current existing or potential conflicts with laws and regulations designed to protect social, historical, or cultural values (e.g., National Historic Preservation Act, tribal water rights)?
- Are there existing contracts for water supply and delivery that would be affected by dam removal?
- Are there 6f or 4f conversion issues [pertaining to P.L. 88-578, the Land and Water Conservation Fund Act of 1965] that might be a factor if certain federal dollars were used?

Social Issues

Identify social issues associated with the existing dam as well as those associated with its removal.

- Will there be changes in the types of, and access to, recreational opportunities?
  - How many recreational boaters, anglers, or other recreational users will be impacted?
  - Will the impact be positive or negative?
- Will there be effects on local and regional populations in terms of economics or economic stability (or lack thereof), displacement, water supply, and or loss of access to traditional use areas?
- Will there be direct and indirect effects on the cultural relationships of people to the landscape?
- Will there be direct and indirect impacts related to any necessary service that was provided by the dam, and how this service will be replaced?
- How will dam removal affect aesthetic values in the area for individual property owners or the area in general?
- Does the dam honor someone in particular?
- Are there historical values associated with the dam or the pool it creates?

Economic Issues

Identify economic issues associated with the dam removal project.

- What are the long-term and short-term costs of maintaining the dam versus the cost of removing the dam?
  - Have all costs and benefits been identified?
  - Are there accurate cost and time estimates for the project?
  - Have risks and uncertainties been thoroughly explored and identified?
- Who is financially responsible for the dam and for any damage that might occur if the dam were breached (intentionally breached or breached during a flood event)? What are the potential costs (estimates) of repair and annual maintenance of the existing facility?
- What is the status of the repayment on the debt for the project? Has it met the financial criteria defined in its authorization language if it was a public project?
- Are there financial criteria that must be met or maintained if the project is funded with international or public funds?
- Is the dam providing a service that will need to be replaced by some alternative, and what is its cost?
- What are the costs of alternative measures to mitigate project impacts?
- What are the costs to provide additional security measures if necessary?
- How will property values be affected?
- How do the owners of the dam perceive the alternatives and their potential liability?

- How do the owners of the dam perceive any conflicts over removal?

Management Issues

Identify the management issues associated with the dam and water control.

- How does the existing structure fit into the overall management plan for the river system? Is it a critical element to meeting any legal agreements and providing a service to the local economy such as flood control, water supply, power production, irrigation, fire protection, or recreation?
- Do the operations fit into a broader context of river basin control?
- Will flood control alternatives need to be formulated once the dam is removed?
- Will modification need to be made to structures upstream or downstream of the dam such as bridges, road culverts, or other dams?
- What sources of funding have been identified for removal or restoration efforts?

Public Involvement and Decision Making

Identify the public involvement issues and planning associated with the dam removal project.

- What plans have been made to involve stakeholders in the discussion?
  - Who are the major stakeholders?
  - What are the stakeholders' opinions about dam removal?
- What plans have been made to involve the public?
  - Has the public been notified?
  - What is the general public opinion?
- What political issues have been identified?
- Who are the primary local, regional, state, and federal political stakeholders?
- How would information on the project be communicated to all interested parties?
- How will the final decision be made?
- What are the main factors in the decision-making process?

Next Steps

From this series of questions, a suite of potentially contentious issues can be identified. This will help decision makers and the public assess whether the dam should be considered for removal, what alternatives exist, and whether the process should move to further study.

Funding Fish Passage and Dam Removal

Finding funding for dam removal or enhancing fish passage is a significant impediment to carrying out successful projects. There are almost no funding programs dedicated specifically to this purpose or to the annual maintenance and repair. However, many federal, state and local government programs intended to improve water quality, protect or enhance wildlife habitat, restore natural resources or alleviate dam safety concerns can be used to finance projects. In addition, there are many sources of private funding, such as corporate environmental damage mitigation funds (these funds may be government-administered). For example, dams in Maine, Pennsylvania, Wisconsin, and other states have been successfully removed using creative approaches that combine multiple types of public and private financing (American Rivers 1999).

The information provided in this report is cause for both concern and optimism. The lack of dedicated funds for dam removal portends an increasing problem as dams across Michigan age and the need for investment in repair and removal becomes more critical. It also exposes the potential for a significant lost opportunity. As we better understand the negative impacts that dams have on rivers, fish and wildlife, and water quality, removal of dams that don't make sense can be a simple, cost-effective way to alleviate many of these problems. It would be unfortunate and shortsighted to miss these restoration opportunities simply because of the lack of funds for important projects.

At the same time, until dedicated funds for dam removal can be developed, projects have been, and can be, financed through existing pools of funding by using creative thinking and being willing to combine a variety of funding sources. These existing funding pools will not be able to address all of the current and future needs, but they will help to make improvements to rivers through financing high-priority projects.

Exhibit 22 below provides general information about available funding options for dam removal and/or fish passage research. This information may be useful both in crafting a funding package for an individual project and in identifying potential new sources of funding.

EXHIBIT 22
Funding Sources

Agency/ Organization	Program	Description
American Rivers		American Rivers is a national nonprofit conservation organization dedicated to protecting and restoring healthy natural rivers and the variety of life they sustain for people, fish, and wildlife. The American Rivers organization is a valuable source of information to anyone who is interested in dam removal and river restoration. To learn more about dam removal and potential funding sources visit the American Rivers website,

Agency/ Organization	Program	Description
		http://www.amrivers.org.
Fish America Foundation	Marine and Anadromous Fish Habitat Restoration	Community-based nonprofit organizations, such as local sporting clubs and conservation associations, as well as state and local agencies, are encouraged to submit proposals. Projects must result in on-the-ground habitat restoration, clearly demonstrate significant benefits to marine, estuarine, or anadromous fisheries resources, particularly sport fish, and must involve community participation through an educational or volunteer component tied to the restoration activities. Website: *www.fishamerica.org*
The Great Lakes Commission—under a cooperative agreement with the U.S. EPA-Region V, and the U.S. Department of Agriculture-Natural Resources Conservation Service (NRCS)	Great Lakes Basin Program for Erosion and Sediment Control $750,000 annually	The purpose of this program is to coordinate the efforts of the various levels of government with the specific goal of protecting and improving Great Lakes water quality by controlling soil erosion and sedimentation.
Great Lakes Fishery Trust	1996 court settlement for fish losses at the Ludington Pumped Storage Project hydroelectric facility No match required $3.5 million	The GLFT provides grant funds to nonprofit organizations and government entities for research projects that benefit Great Lakes fishery resources; rehabilitation of lake trout, lake sturgeon and other Great Lakes fish species; protection and enhancement of Great Lakes fisheries habitat; public education about the Great Lakes fishery; property acquisition for the above purposes or to provide access to the Great Lakes.
Great Lakes Protection Fund (GLPF)	GLPF 1989 Articles of Incorporation No match requirement $3.4 million	The Fund seeks projects that lead to tangible improvements in the health of the Great Lakes ecosystem, promote the interdependence of healthy ecological and economic systems, and are innovative, creative, and venturesome. The GLPF is a private, nonprofit corporation formed in 1989 by the governors of the Great Lakes states.
Michigan Department of Natural Resources	Inland Fisheries Grants 50 % match	The program offers grants up to $200,000 for local projects that enhance the state's aquatic resources. The program is intended to foster citizen and community understanding and appreciation of inland fisheries resources and to encourage participation and commitment to the improvement and protection of inland fishing opportunities, habitat and fish communities.

Agency/ Organization	Program	Description
Michigan Department of Natural Resources	Natural Resources Trust Fund 25% match	The Fund provides financial assistance to local governments and the Department of Natural Resources to purchase lands for outdoor recreation and/or the protection of natural resources and open space.
National Fish and Wildlife Foundation (NFWF)	Matching Grant Program	NFWF funds projects to conserve and restore fish, wildlife, and native plants through matching grant programs. The foundation awards matching grants to projects that address priority actions promoting fish and wildlife conservation and the habitats on which they depend; work proactively to involve other conservation and community interests; leverage foundation-provided funding; and evaluate project outcomes. Website:.*http://www.nfwf.org/programs/grant_apply.htm*
National Oceanic and Atmospheric Administration (NOAA)	1. Damage Assessment and Restoration Program (DARP) 2. Community-based Restoration Program (CRP) 3. Restoration Research Program (RRP)	The NOAA Restoration Center plans, implements, and funds coastal restoration projects throughout the United States. Three primary programs allow the Restoration Center to restore fisheries habitat. Key to this commitment is the Restoration Center's mission to expand local habitat restoration techniques into broad-scale, ecosystem restoration approaches in all coastal, estuarine, and anadromous fish habitats within the United States and its territories. Website: *http://www.nmfs.noaa.gov/habitat/restoration*
National Oceanic and Atmospheric Administration/ Great Lakes States except Illinois	Coastal Zone Management Program Coastal Zone Management Act 50 percent match	Federal/ state partnership dedicated to comprehensive management of the nation's coastal resources, ensuring their protection for future generations while balancing competing national economic, cultural, and environmental interests. National program supports states through financial assistance, mediation, technical services and information, and participation in priority state, regional, and local forums.
Private Foundations Andrew W. Mellon Foundation C. S. Mott Foundation Joyce Foundation Doris Duke Foundation Frey Foundation George Gund Foundation Pew Charitable Trusts Rockefeller Family Fund Surdna Foundation Weeden Foundation Wege Foundation	Varies by program	Great Lakes habitat and ecological restoration. Priorities vary by program.

Agency/ Organization	Program	Description
Saginaw Bay Watershed Initiative Network (WIN)	Water Resources—Addresses environmental issues of concern to watershed residents, particularly water quality issues	The Saginaw Bay Watershed Initiative Network (WIN) is a consortium of communities, conservationists, foundations, and businesses working together to balance the region's economic, environmental, and social goals. Website: *http://www.saginawbaywin.org*
U.S. Army Corps of Engineers (USACE)	Aquatic Ecosystem Restoration/Section 206 WRDA 1996 Cost Share 65/35	USACE evaluates and supports projects that benefit the environment through restoring, improving, or protecting aquatic habitat for plants, fish, and wildlife. A project is accepted for construction after a detailed investigation shows it is technically feasible, environmentally acceptable, and provides cost-effective environmental benefits. Each project must be complete within itself, not a part of a larger project.
U.S. Army Corps of Engineers	Great Lakes Fishery and Ecosystem Restoration (GLFER) 506 WRDA 2000 Cost Share 65/35	WRDA 2000 authorized $100 million for the USACE to plan, design, and construct projects to restore the fishery, ecosystem, and beneficial uses of the Great Lakes with 35 percent matching funds from nonfederal project sponsors.
U.S. Army Corps of Engineers	Great Lakes Remedial Action Plans (RAPs)/ Section 401 WRDA 1990 Cost Share 50/50	USACE supports RAP activities, including physical and environmental monitoring; remedial planning and design; construction management; development of geographic information systems (GIS); computer modeling and analysis; cost estimating; real estate and public outreach support.
U.S. Army Corps of Engineers	Habitat Restoration-Project Modifications for Improvement of the Environment/ Section 1135 of WRDA 1986 Cost Share 75/25	USACE is authorized to plan, design, and construct fish and wildlife habitat restoration measures. To be eligible, restoration projects must involve modification of structures or operations of a project constructed by the USACE, or modification of an off-project site when it is found that the USACE project has contributed to degradation.
U.S. Army Corps of Engineers	Sediment Management Program	USACE develops sediment transport models for Great Lakes tributaries. These computer models simulate the erosion, transport, and deposition of sediments within a watershed and can be used to evaluate the effectiveness of soil conservation and other source control measures on the loadings of sediments and sediment contaminants to Great Lakes harbors and navigation channels.

Agency/ Organization	Program	Description
U.S. Fish and Wildlife Service	Fish Passage Program	The goal of this program is to restore native fish and other aquatic species to self-sustaining levels by reconnecting habitats that have been fragmented by artificial barriers, where such reconnection results in a positive ecological effect. Since 1999, the Regional Fish Passage Program and 33 partner organizations have completed 18 projects that have improved fish passage.
U.S. Fish and Wildlife Service/ Great Lakes Fishery Commission (GLFC)	Great Lakes Fish and Wildlife Restoration Act Public Law 105-265, 25% nonfederal match $500,000 annually	Project priorities identified by the GLFC Lake Committees to be consistent with Great Lakes interjurisdictional fisheries and aquatic ecosystem programs. Emphasis placed on cooperative conservation, restoration, and management of the fishery resources of the Great Lakes Basin.
Dam Owners		Current dam owners must consider the contribution of private funding to enhance fish passage or to remove a dam.

Conclusion and Recommendations

To reestablish naturally producing Great Lakes fish populations, management agencies such as the Michigan Department of Natural Resources are seeking to build sustainable fish populations based on natural reproduction, with an emphasis on Great Lakes tributaries. However, a significant number of dams block or impede the spawning runs of Great Lakes fish and restrict their access to prime spawning and nursery areas. Many of these dams have outlived their useful life and negatively affect natural flow regimes, stream hydrology, and aquatic habitats. Many are candidates for removal, but others continue to provide benefits such as electric power generation, barriers to sea lamprey migration, sediment containment, recreation opportunities, flood storage, and water supplies.

More and more, fish and wildlife professionals are developing management programs acceptable to a large and growing array of stakeholders with competing interests to achieve environmental objectives. Two key project goals included increasing awareness and understanding of both dams and natural river systems in the Saginaw Bay watershed and to enhancing the process of decision making at the local level so that alternatives to improve fish passage, including selective dam removal, can be considered and accepted or rejected on their own merits. Thus, stakeholder involvement emerged as a key factor to help facilitate enhanced fish passage opportunities in the Saginaw Bay watershed. Incorporating and consolidating the sometimes conflicting input from citizens, regulatory authorities, and pubic interest groups and developing a solution that addresses the majority of their concerns and inspires sufficient public support is a formidable challenge.

Improving fish passage and natural reproduction and considering selective dam removal in tributary streams is limited primarily by the following factors:

- Lack of understanding and knowledge at the local level of the value and type of ecological restoration techniques now possible
- Lack of public support for dam removal as a viable tool for river restoration
- Lack of complete and accurate information when decisions on dam removal are made, often in an emotionally charged and divisive atmosphere
- Lack of financial resources to achieve desirable fish passage techniques, including dam removal

Enhancing fish passage in tributary streams is not incompatible with local socioeconomic goals. In fact, interaction among fishery managers, local community officials, and members of the public at the earliest stages to assess opportunities for fish passage and consider dam removal may lead to enhanced recreational opportunities while stimulating local economies.

Removing dams to reestablish free-flowing tributary rivers or providing fish passage over remaining useful structures offers a major opportunity for restoration of certain Great Lakes fish populations that have historically relied upon rivers for spawning and nursery areas. Restoration of the natural flow regime of tributary rivers and their watersheds

continues to emerge as a significant component of recovery efforts throughout the Great Lakes region and Michigan in particular.

RECOMMENDATIONS

- The Michigan Legislature should adopt legislation to create a loan/grant fund for the removal of dams and alternative measures to achieve fish passage.
- The Michigan Departments of Natural Resources and Environmental Quality should develop educational materials explaining the benefits of dam removal.
- The Partnership for the Saginaw Bay Watershed should expand efforts to inform elected officials, consultants, conservation and community organizations, dam owners and other stakeholders on the potential benefits and techniques of dam removal in the Saginaw Bay watershed.
- The Partnership and other stakeholders should support comprehensive assessments of potential fish passage options at the Dow and Chesaning Dam sites.
- The Partnership should encourage community involvement in the decision-making, education, and restoration processes and develop and implement effective community outreach initiatives.

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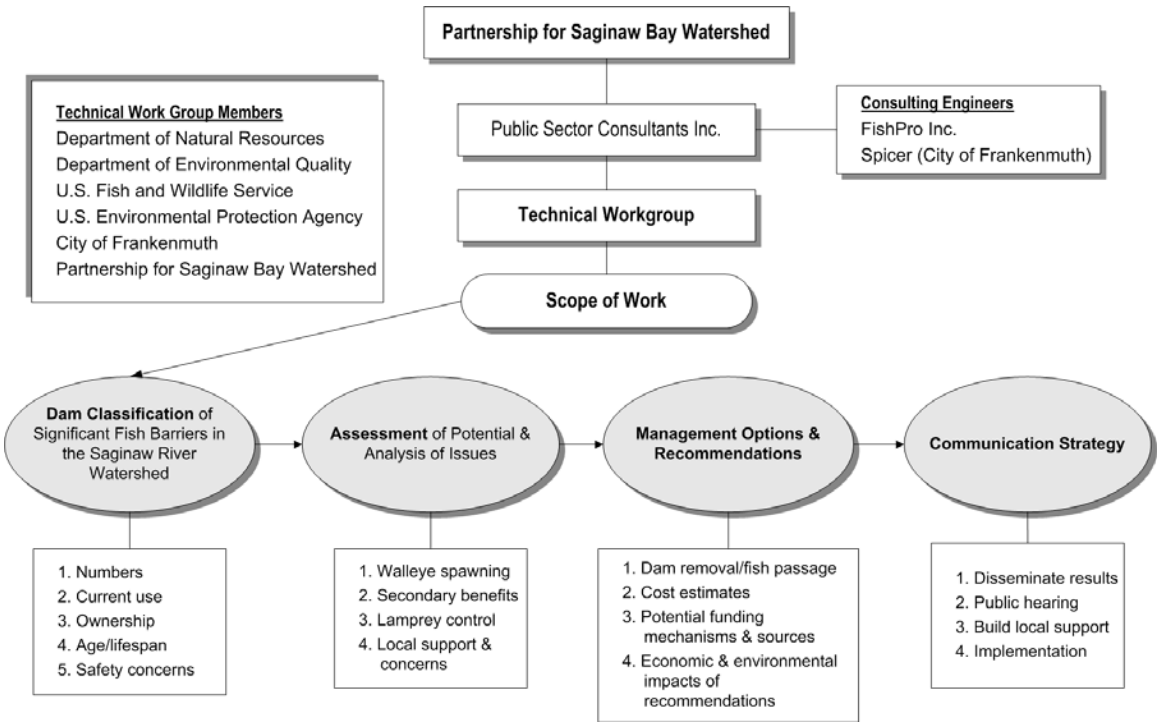
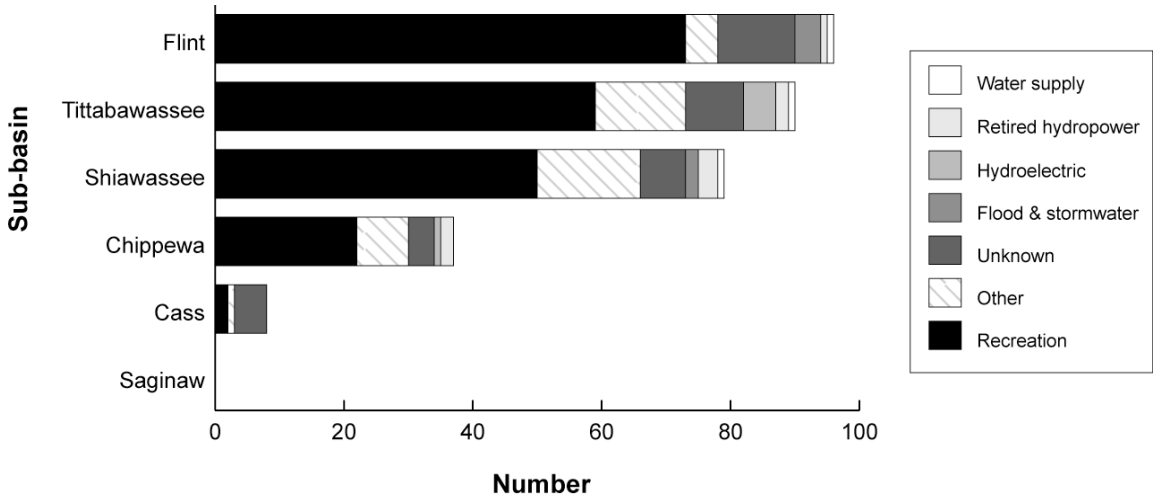
Appendix A:
Project Work Plan

Restoring Natural Flows and Enhancing Fish Passage of Low-head Barrier Dams in the Saginaw River Watershed



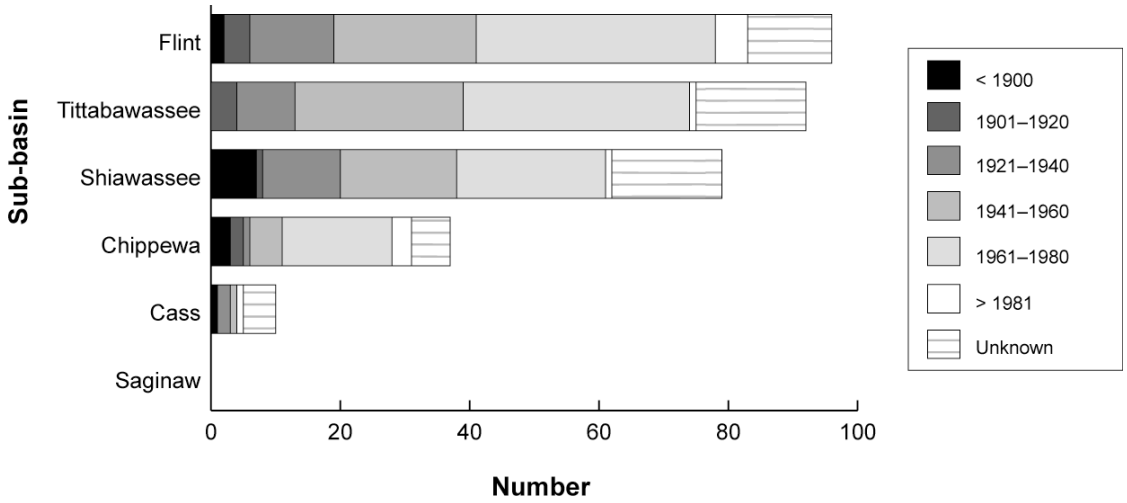
Appendix B:
Characteristics of Current Dams, by Sub-basin

EXHIBIT B-1
Purpose, by Sub-basin



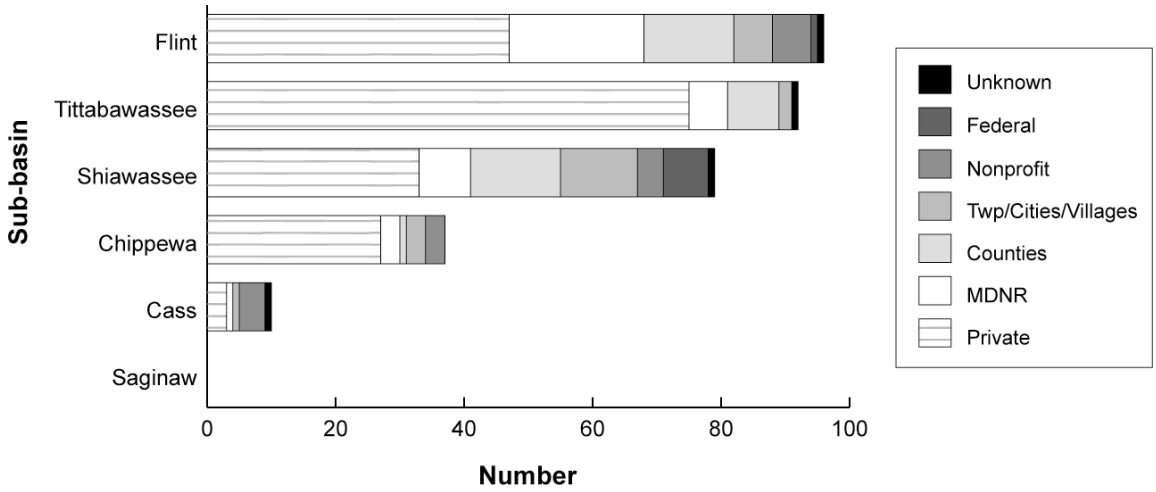
SOURCE: PSC, with data provided by MDNR/Institute for Fisheries Research, 2004.

EXHIBIT B-2
Year Constructed, by Sub-basin



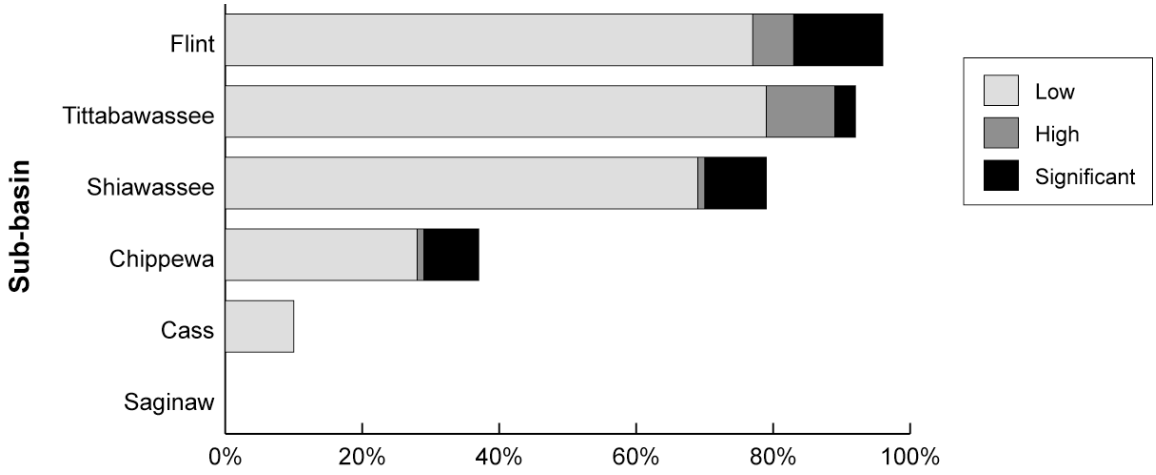
SOURCE: PSC, with data provided by MDNR/Institute for Fisheries Research, 2004.

EXHIBIT B-3
Dam Ownership, by Sub-basin



SOURCE: PSC, with data provided by MDNR/Institute for Fisheries Research, 2004.

EXHIBIT B-4
Hazard Potential, by Sub-basin



SOURCE: PSC, with data provided by MDNR/Institute for Fisheries Research, 2004.