STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

SR37 February 2006

Thunder Bay River Assessment

Tim A. Cwalinski,
Neal A. Godby, Jr.,
and
Andrew J. Nuhfer

www.michigan.gov/dnr/

FISHERIES DIVISION
SPECIAL REPORT 37

Above: Thunder Bay River below Seven Mile Dam, May 2, 1924. Photo courtesy of Brian McNeill, Alpena, Michigan.

Cover photo: Log drive atop the Thunder Bay River; location is between Four Mile and Ninth Street dams, but before these dams existed. Photo courtesy of Brian McNeill, Alpena, Michigan.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Special Report 37
February 2006

Thunder Bay River Assessment

Tim A. Cwalinski,

Neal A. Godby, Jr.,

and

Andrew J. Nuhfer

Printed under authority of Michigan Department of Natural Resources
Total number of copies printed 325 — Total cost $4,985.40 — Cost per copy $15.34

Suggested Citation Format

Cwalinski, T.A., N.A. Godby, Jr., and A.J. Nuhfer. 2006. Thunder Bay River Assessment. Michigan Department of Natural Resources, Fisheries Special Report 37, Ann Arbor.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

(published in a separate volume)

ACKNOWLEDGEMENTS

We thank the many individuals who contributed to this report. We especially appreciate the following individuals for providing their input and data for the different sections of this report: Barbara Mead-Michigan Department of State, Bureau of History; Lisha Ramsdell- Northeastern Michigan Council of Governments; Mark Mackay, Sharon Hanshue, Gary Whelan, Roger Lockwood, Carl Latta (retired)- Michigan Department of Natural Resources-Fisheries Division; Matt Tonello and Dave Arnold-Michigan Department of Information Technology, Spatial Information Resource Center; Bill Taft, Michigan Department of Environmental Quality-Water Division, Surface Water Quality Assessment Section; Russ Minnerick, United States Geological Survey-Water Resources Division; and Challenge Chapter of Trout Unlimited. We are grateful for the assistance from previous river authors (especially Troy Zorn, Steve Sendek, George Madison, and Jay Wesley) whose documents and advice helped serve as guides for this assessment. Thanks to reviewers Liz Hay-Chmielewski, Kurt Newman, Dave Fielder, Rich O' Neal, Kyle Kruger, and Dave Borgeson Jr. for helpful comments and input along the way. Ellen Johnston and Lindsey Dowlyn also deserve praise for their assistance with the compilation and organization of this river assessment. A big thanks to Al Sutton and his trusty computer skills for producing the maps and many figures in this report. Funding for this project was provided by the Michigan Department of Natural Resources through Federal Aid in Sport Fish Restoration, F-82 Study 232210.

EXECUTIVE SUMMARY

This is one in a series of river assessments being prepared by the Michigan Department of Natural Resources Fisheries Division for Michigan rivers. This report describes the physical and biological characteristics of the Thunder Bay River, discusses how human activities have influenced the river, and serves as an information base for future management of the river.

River assessments are intended to provide a comprehensive reference for citizens and agency personnel who need information about a river. By pulling together and synthesizing existing information, river assessments show the intertwined relations between the river, watershed landscapes, biological communities, and humans. These assessments will provide an approach to identifying opportunities and solving problems related to aquatic resources in the Thunder Bay River watershed. We hope it will encourage citizens to become more actively involved in decision-making processes that provide sustainable benefits to the river and its users. Assessments also identify the types of information needed to better understand, manage, and protect the river.

This document consists of four parts: an introduction, a river assessment, management options, and public comments (with our responses). The river assessment is the nucleus of each report. It provides a description of the Thunder Bay River and its watershed in twelve sections: geography, history, geology, hydrology, soils and land use, channel morphology, dams and barriers, water quality, special jurisdictions, biological communities, fishery management, recreational use, and citizen involvement.

The Management Options section of the report identifies a variety of actions that could be taken to protect, restore, rehabilitate, or better understand the Thunder Bay River and its watershed. These management options are categorized and follow the main sections of the river assessment. They are intended to provide a foundation for public discussion, setting priorities, and planning future management activities for the watershed.

The Thunder Bay River drains 1,250 square miles of northeastern Lower Michigan in Lake Huron. Its basin contains portions of five counties: Montmorency, Oscoda, Alcona, Presque Isle, and Alpena. For the purposes of discussion, the mainstem Thunder Bay River is divided into five segments, each reflecting the characteristic of the river as it flows across different landforms, receives tributaries, and passes through impoundments. The major tributaries to the Thunder Bay River are also divided into segments.

Like the rest of northern Michigan, glaciers left behind the intricate Thunder Bay River watershed. Glacial scouring of the land formed many lakes, creeks, tributaries, and mainstem that we know today. Indian tribes occupied the land prior to European settlement, particularly near the river mouth and at Hubbard Lake. Their occupancy in the watershed, however, was typically in low numbers. This was a product of the harsh climate and extensive forest and swamp land within the watershed's interior. The early European settlers harvested the plentiful biological resources of the region to survive. Soon afterwards, the interior virgin forests were stripped with the onset of the logging industry. The great arterial system of the watershed was then suitable for transportation of logs. Dams were built to harness the river's power and to enhance log transport. Logging then gave way to farming, and wetlands were drained to accommodate agricultural practices. Alpena continued to prosper even after the logging industry as a result of limestone excavation. The history and growth of the Thunder Bay River watershed parallels Michigan's growth as a state.

The geology of the Thunder Bay River watershed supports high groundwater inflow in the headwaters, and lower amounts in the downstream reaches. The headwaters typically have stable flows and colder water temperatures. River flows in the downstream reaches are less stable and typically have warmer water temperatures. The differences in geology and hydrology and the operation of some dams results in low flow stability in some parts of the watershed.

The mainstem Thunder Bay River from its headwaters to Hillman Dam receives the highest inflows of groundwater. Some tributaries to this segment are the highest quality trout streams found in the watershed. However, most of the mainstem is classified as a second-quality cold water stream because groundwater inflows are insufficient to offset water warming by natural lakes and human-made impoundments whose outlets flow into the river.

The mainstem from Hillman Dam to the confluence with the Upper South Branch flows through peat and muck soils, receiving little or no inflow of groundwater. However, flow stability remains relatively high in this river reach. The Hillman Dam is operated in run-of-river mode so it rarely affects flow stability, although the impoundment does increase water warming. Groundwater inflow is also relatively low throughout the remainder of the mainstem from the confluence with the Upper South Branch to the river mouth at Alpena. Flow stability decreases steadily through this reach, in part due to the influence of the major tributaries, the Lower South Branch and the North Branch.

Groundwater inflow is generally high in the headwaters of both the Upper and Lower South Branch Thunder Bay River. All top-quality cold water streams are located in this portion of these river segments. Flow stability is very low at the mouths of these rivers after they flow northward through Fletcher Pond (also known as Fletcher Floodwaters) and Hubbard Lake. Operation of the Fletcher Pond and Hubbard Lake dams to raise and lower lake levels by two feet each spring and fall, respectively, contributes to flow instability of these rivers. The entire North Branch Thunder Bay River has low flow stability due to a lack of groundwater inflow. Spring flood flows are relatively high due, in part, to drainage from agricultural lands.

Although a relatively small portion of the watershed is classified as “urban” in land use, development is having an effect on the watershed. A dramatic loss of wetlands has occurred since 1800 as those lands were converted to agriculture and residential development increased. Oil and gas wells are presently found in high density in the watershed in comparison to other regions in Michigan.

Gradient, or drop in elevation over distance, is an important factor in determining habitat characteristics of a river. River gradient can affect important factors such as water velocity, substrate composition, and overall channel form. Gradient in the Thunder Bay River watershed was calculated using a geographic information system, and categorized into recognized classes. Based on this analysis, approximately 38% of the basin is of very high gradient (10-70 ft/mi) with excellent hydraulic diversity. Most high gradient habitat is in the small tributaries or masked by effects of impoundments. The rest of the watershed is of relatively low gradient with poor hydraulic diversity.

Channel cross section and discharge measurements can be used as a measure of habitat diversity in a river system based on expected widths for a given discharge. Deviations from the expected widths can indicate alterations such as impoundments or channelization. Most mainstem measurements were within the expected widths, while less than 40% of the tributary measurements were within the expected range. The majority of the unexpected widths were in flashy tributaries with variable streamflow.

Seventy-three dams are presently in the Thunder Bay River watershed. More than 90% of these structures are on tributaries to the mainstem and most are small in size. Except for four hydropower dams and two storage reservoirs, effects of dams in the watershed have not been quantitatively evaluated. By changing flowing water habitats to impounded reaches, dams may affect rivers by: altering dissolved oxygen and temperature regimes; interrupting flow and sediment/woody structure transport; altering channel morphology and making suitable substrates unavailable; starving catch basins of nutrients; preventing proper fish passage and invertebrate drift; and changing biotic communities permanently. Lake-level control structures are also prominent in the Thunder Bay River watershed. These dams often: disrupt natural variations in lake levels needed to maintain shoreline wetlands; disrupt spawning activities of fishes associated with shoreline wetlands; prevent movement of fishes between lake and river habitats; and if improperly managed, produce detrimental flow conditions downstream.

Four dams in the Thunder Bay River watershed are large hydroelectric facilities and two are storage reservoirs associated with the hydropower projects. Four of these structures impound reaches of the mainstem, while the remaining two structures are on the Upper and Lower South branches. These two latter dams are on Fletcher Pond and Hubbard Lake. These are two very popular water bodies in respect to recreational use. Alteration of temperature and dissolved oxygen regimes of the river are less evident from the mainstem dams, especially the lower hydroelectric facilities such as Seven Mile, Four Mile, and Ninth Street dams. Their detriment to aquatic communities arise more from their fragmentation and isolation of fish communities. These lower dams block spawning migrations of native walleye and lake sturgeon, a state-threatened species. They also prevent development of valuable potamodromous fisheries by inhibiting popular naturalized species such as Chinook salmon and steelhead from reaching upstream spawning grounds. In addition to preventing proper downstream transport of sediments and woody structure, hydroelectric dams entrain and kill all types of fish. Operating licenses issued to Thunder Bay Power Company in 1998 provide mitigation for some of the effects of hydroelectric projects on the Thunder Bay River. Selective dam removal and/or fish passage structures at the lower mainstem dams would help alleviate some negative effects of these projects and ensure a free flowing, healthier lower mainstem Thunder Bay River.

Recent surveys by the Michigan Department of Environmental Quality (MDEQ) indicate that most of the watershed is meeting state water quality standards. The Thunder Bay River watershed has relatively few point source pollutant sources. Few factories and wastewater treatment plants can be found in the watershed, with only six permitted discharges in the basin. Nonpoint source pollution, such as sedimentation, is a threat to the Thunder Bay River watershed. Sedimentation can cover substrate suitable for fish spawning and nursery habitat, and decrease invertebrate diversity and density. Air borne pollutants also are deposited in the watershed, and contribute to fish consumption advisories.

Many governmental units have varying degrees of jurisdiction over the Thunder Bay River watershed. The Federal Energy Regulatory Commission regulates the dams associated with hydroelectric projects on the mainstem and Upper and Lower South branches. Twenty-five percent of the Thunder Bay River watershed is managed as state (24%) and federal forests (1%). Sport fishing regulations, fish consumption advisories, and legal “navigability” of portions of the river are established by various state government agencies. Water quality within the watershed is administered by state government through the Federal Clean Water Act. Local units of government influence the river through special ordinances and restrictions, road commission activities, and maintenance of legal-lake levels (through state law).

Currently, 81 fish species inhabit the Thunder Bay River watershed. Coldwater fish communities, typically with brook/brown trout and mottled/slimy sculpin, are found primarily in the southern portion of the watershed. The remainder of the riverine portion contains a mix of cool- and warmwater species whose distribution is a product of progressively warmer water temperatures downstream. Coolwater species include esocids (e.g., northern pike) and percids (e.g., walleye and yellow perch), while warmwater species include centrarchids (e.g., smallmouth and largemouth bass and bluegill) and many cyprinid species.

The biological communities of the Thunder Bay River watershed are affected by numerous dams. These dams serve as a barrier to migrating fish, and fragment the biotic communities of the inland watershed. If the river system were open to Lake Huron, it would likely support seasonal migrations of many fish species and provide spawning and nursery habitat for some.

Two rare fish species are found in the Thunder Bay River watershed. The lake sturgeon, although rare, may currently be found below Ninth Street Dam. This species is precluded from accessing the rest of the watershed because of this and other dams. The pugnose shiner is also present in the watershed, but its distribution is limited due to specific habitat requirements.

Aquatic invertebrates in the watershed have been sampled by the MDEQ during water quality surveys. These surveys show a diverse and abundant macroinvertebrate community in most locations sampled. A variety of amphibians, reptiles, birds, and mammals inhabit the Thunder Bay River watershed. Habitat loss and specific habitat requirements threaten some of the rare species. Aquatic nuisance species such as purple loosestrife and zebra mussels have also colonized parts of the watershed and compete with native species.

Historical and recent fisheries management in the Thunder Bay River watershed has been shaped by the wide variety of aquatic habitat types present. Early fish management can be traced to the first half of the twentieth-century. Early managers surveyed many water bodies at this time to gain baseline fish community and habitat information. Simultaneously, fish stocking became a widely used and popular management tool. Early stream stocking efforts centered on trout species, with little regard to the thermal nature of these waters. This management practice was slowly abandoned, as managers began to understand the limitations of each individual reach of river or creek. Stocking was then redirected to lakes and impoundments by the middle part of the century. Current fish stocking efforts are a result of the learning associated with the success and failure of this management activity over the twentieth-century. Today, fish managers strive to understand the system and any associated limitations. The few remaining stocking programs are based on the survival of the species and the establishment of a fishery.

Most lakes and streams in the Thunder Bay River watershed today are managed for natural, self-sustaining fisheries. Standard State of Michigan fishing regulations apply at most of these water bodies. Size and harvest limits for warm- and coolwater species have changed over time not only in the watershed, but also throughout the state. Regulations are an important form of fish management established by the Michigan Department of Natural Resources. Fishery regulations have been designed to provide for sustainable fisheries. Special trout regulations apply for some streams and a handful of lakes in the watershed. With the exception of the lower mainstem, the trout streams of the Thunder Bay River watershed are managed with Type 1 stream regulations.

The unique character of the Thunder Bay River watershed is derived from the variety of lake and stream environments within the system. Fish communities typical of high-gradient, cool water, large river habitats have been reduced or eliminated in some areas as a result of impoundments. Fragmentation of the river system has resulted in lost production of fishes and reduced the potential of the river for supporting popular fisheries. Future management activities should attempt to restore connections between isolated reaches and Lake Huron.

Little is known about recreational use in the Thunder Bay River watershed. Angling pressure is highest on the lakes of the watershed, while the upper and lower mainstem segments provide quality seasonal fisheries. Habitat fragmentation by dams limits the fishing potential in the middle reaches of river. The high-gradient reaches of the lower mainstem suggest that in a fully, free-flowing state it would provide considerable recreational angling and canoeing potential. Present recreational use on lower mainstem ponds needs to be better documented to help guide management of the lower watershed reaches.

The management options offer a variety of ways for communities and governments to look at the opportunities and problems that are before them now and that will be in the future. Public involvement is critical for the long-term protection and enhancement of the Thunder Bay River watershed. Many forums exist for which interested people may become actively involved. Groups must work together at identifying important issues in the watershed, and developing a shared vision and a set of common goals for the watersheds future.

This page was intentionally left blank.

Michigan Department of Natural Resources
Fisheries Special Report 37, 2006

Thunder Bay River Assessment

Tim A. Cwalinski

Michigan Department of Natural Resources
Gaylord Operations Service Center
1732 M-32 West
Gaylord, Michigan 49735

Neal A. Godby, Jr.

Michigan Department of Natural Resources
Gaylord Operations Service Center
1732 M-32 West
Gaylord, Michigan 49735

Andrew J. Nuhfer

Michigan Department of Natural Resources
Hunt Creek Fisheries Research Station
1581 Halberg Road
Lewiston, MI 49756

INTRODUCTION

This river assessment is one of a series of documents being prepared by Fisheries Division, Michigan Department of Natural Resources, for rivers in Michigan. We have approached this assessment from an ecosystem perspective, as we believe that fish communities and fisheries must be viewed as parts of a complex aquatic ecosystem. Our approach is consistent with the mission of the Michigan Department of Natural Resources, Fisheries Division, namely to "protect and enhance the public trust in populations and habitat of fishes and other forms of aquatic life, and promote optimum use of these resources for benefit of the people of Michigan".

As stated in the Fisheries Division Strategic Plan, our aim is to develop a better understanding of the structure and functions of various aquatic ecosystems, to appreciate their history, and to understand changes to systems. Using this knowledge, we will identify opportunities that provide and protect sustainable fishery benefits while maintaining, and at times rehabilitating, system structures or processes.

Healthy aquatic ecosystems have communities that are resilient to disturbance, are stable through time, and provide many important environmental functions. As system structures and processes are altered in watersheds, overall complexity decreases. This results in a simplified ecosystem that is unable to adapt to additional change. All of Michigan's rivers have lost some complexity due to human alterations in the channel and on surrounding land; the amount varies. Therefore each assessment focuses on ecosystem maintenance and rehabilitation. Maintenance involves either slowing or preventing losses of ecosystem structures and processes. Rehabilitation is putting back some structures or processes.

River assessments are based on ten guiding principles of Fisheries Division. These are: 1) recognize the limits on productivity in the ecosystem; 2) preserve and rehabilitate fish habitat; 3) preserve native species; 4) recognize naturalized species; 5) enhance natural reproduction of native and desirable naturalized fishes; 6) prevent the unintentional introduction of invasive species; 7) protect and enhance threatened and endangered species; 8) acknowledge the role of stocked fish; 9) adopt the genetic stock concept, that is protecting the genetic variation of fish stocks; and 10) recognize that fisheries are an important cultural heritage.

River assessments provide an organized approach to identifying opportunities and solving problems. They provide a mechanism for public involvement in management decisions, allowing citizens to learn, participate, and help determine decisions. They also provide an organized reference for Fisheries Division personnel, other agencies, and citizens who need information about a particular aspect of the river system.

The nucleus of each assessment is a description of the river and its watershed using a standard list of topics. These include:

Geography - a brief description of the location of the river and its watershed; a general overview of the river from its headwaters to its mouth. This section sets the scene.

History- a description of the river as seen by early settlers and a history of human uses and modifications of the river and watershed.

Geology and Hydrology - patterns of water flow, over and through a landscape. This is the key to the character of a river. River flows reflect watershed conditions and influence temperature regimes, habitat characteristics, and perturbation frequency.

Soils and Land Use Patterns - in combination with climate, soil and land use determine much of the hydrology and thus the channel form of a river. Changes in land use often drive change in river habitats.

Channel Morphology - the shape of a river channel: width, depth, sinuosity. River channels are often thought of as fixed, apart from changes made by people. However, river channels are dynamic, constantly changing as they are worked on by the unending, powerful flow of water. Diversity of channel form affects habitat available to fish and other aquatic life.

Dams and Barriers - affect almost all river ecosystem functions and processes, including flow patterns, water temperature, sediment transport, animal drift and migration, and recreational opportunities.

Water Quality - includes temperature, and dissolved or suspended materials. Temperature and a variety of chemical constituents can affect aquatic life and river uses. Degraded water quality may be reflected in simplified biological communities, restrictions on river use, and reduced fishery productivity. Water quality problems may be due to point source discharges (permitted or illegal) or to nonpoint source runoff.

Special Jurisdictions - stewardship and regulatory responsibilities under which a river is managed.

Biological Communities - species present historically and today, in and near the river; we focus on fishes, however associated mammals and birds, key invertebrate animals, threatened and endangered species, and pest species are described where possible. This topic is the foundation for the rest of this river assessment. Maintenance of biodiversity is an important goal of natural resource management and essential to many fishery management goals. Species occurrence, extirpation, and distribution are also important clues to the character and location of habitat problems.

Fishery Management - goals are to provide diverse and sustainable game fish populations. Methods include management of fish habitat and fish populations.

Recreational Use - types and patterns of use. A healthy river system provides abundant opportunities for diverse recreational activities along its mainstem and tributaries.

Citizen Involvement - an important indication of public views of the river. Issues that citizens are involved in may indicate opportunities and problems that the Fisheries Division or other agencies should address.

Management Options follow and list alternative actions that will protect, rehabilitate, and enhance the integrity of the watershed. These options are intended to provide a foundation for discussion, setting priorities, and planning the future of the river system. Identified options are consistent with the mission statement of Fisheries Division.

Copies of the draft assessment were distributed for public review beginning May 1, 2005. Three public meetings were held July 26, 2005 in Hillman and July 27, 2005 in Alpena. Written comments were received through August 31, 2005. Comments were either incorporated into this assessment or responded to in the **Public Comment and Response** section.

A fisheries management plan will be written after completion of this assessment. This plan will identify options chosen by Fisheries Division, based on our analysis and comments received, that the Division is able to address. In general, a Fisheries Division management plan will focus on a shorter time period, include options within the authority of Fisheries Division, and be adaptive over time.

Individuals who review this assessment and wish to comment should do so in writing to:

Michigan Department of Natural Resources
Fisheries Division
1732 M-32 West
Gaylord, MI 49732

Comments received will be considered in preparing future updates of the Thunder Bay River Assessment.

RIVER ASSESSMENT

Geography

The Thunder Bay River (TBR) drains an area of northeast Lower Michigan encompassing about 1,250 square miles (Figure 1). The watershed drains parts of five counties: Presque Isle, Montmorency Oscoda, Alcona, and Alpena. The basin is approximately 45 miles long and 38 miles wide with more than 70% forested land. The mainstem Thunder Bay River originates at the outlet of McCormick Lake, about seven miles northeast of Lewiston, Montmorency County at an elevation of about 940 feet above sea level. From here, the river flows primarily in a northeasterly direction for about 75 miles to its confluence with Thunder Bay of Lake Huron at an elevation of 577 feet above sea level. Major tributaries to the mainstem Thunder Bay River are the North Branch, which drains the northern portion of the basin, and the Upper and Lower South branches, which drain the south central and southeastern portions of the watershed (Figure 1).

The character of the TBR and its associated biota varies considerably along the course of the mainstem and its major tributaries. We will discuss the Thunder Bay River's mainstem and tributaries (Tables 1 and 2) using a variation of the Valley Segment Ecological Classification System described by Seelbach et al. (1997). They defined 84 valley segments within the Thunder Bay River watershed that were relatively homogeneous in terms of geological setting, hydrology, channel morphology, temperature regime, and other factors. We pooled contiguous valley segments into larger geographic units to provide a more cogent framework for describing the watershed. We used criteria such as confluences with major tributaries, major changes in geology or soil types, and human-made borders such as dams, to set boundaries for our larger units. Consequently, this assessment is organized around fourteen segments (Figure 2). We defined five segments for the mainstem Thunder Bay River, two for the Upper South Branch, three each for the North Branch and Lower South Branch, and one for Wolf Creek. A description of the various geological features through which the river flows can be found further in this report (see **Geology**). We will later discuss historical and current fish management at the many lakes (Table 3) in the watershed.

Mainstem Thunder Bay River - Headwaters to Hillman Dam

The upper headwaters of the TBR, Stanniger and Sheridan creeks arise in southwestern Montmorency County. They flow into McCormick Lake, whose outflow is designated as the upstream boundary of the mainstem TBR. From its origin, the river flows northeast approximately five miles before entering Lake Fifteen, and then to Atlanta where it is impounded by the Atlanta Dam. Thermal suitability for trout in this designated trout stream reach is marginal though due to the warming effect of the lakes and impoundments. Crooked Creek flows into the mainstem several miles downstream of the Atlanta Dam. This creek drains Avery and Crooked lakes. The mainstem flows southeast from the confluence with Crooked Creek for about six miles where it is joined by Hunt Creek from the south. The river then flows northeast toward the town of Hillman in east-central Montmorency County. Gilchrist Creek is the most significant tributary entering the mainstem in this river reach. Seven of the eight tributaries entering the mainstem between Atlanta and Hillman are designated trout streams. Hunt and Gilchrist creeks are recognized as blue ribbon trout streams (see **Special Jurisdictions**). Eighty-five percent of the catchment upstream of Hillman Dam is forested while 9% is agricultural. The towns of Atlanta and Hillman are the only population centers.

Mainstem Thunder Bay River - Hillman Dam to Confluence with the Upper South Branch Thunder Bay River

The upper end of this segment originates at the Hillman Dam outfall and flows east for about one mile. Brush Creek, a cold water tributary, flows into the mainstem from the north just downstream from the dam. The river continues east until the confluence with the Upper South Branch. The mainstem meanders extensively through this low-gradient stream reach. The river corridor is nearly undeveloped and there are no road-stream crossings downstream of County Road 451 in Hillman. The riparian zone is almost entirely forested with deciduous and coniferous tree species. The fish community is dominated numerically by small-bodied fish species.

Upper South Branch Thunder Bay River - Headwaters to Fletcher Pond Dam

The headwaters of the Upper South Branch arise in northeast Oscoda County and flow in a northerly direction to Upper South Dam on Fletcher Pond. The northern half of this segment receives high groundwater inflow. Most of the segment, except for the impounded reach, supports trout populations all year. Above T29N, R4E, S14, Montmorency County, the Upper South Branch and its tributaries are designated trout waters. The Upper South Dam, owned by the Thunder Bay Power Company, is the only major dam in this segment. Its impoundment, Fletcher Pond, is 8,970 acres and is the largest impoundment in the basin (see **Dams and Barriers**). Virtually all the land in this segment is privately owned, but there is little residential development along the stream which flows primarily through large private hunting club lands.

Upper South Branch Thunder Bay River - Fletcher Pond Dam to mainstem Thunder Bay River

This segment begins at Upper South Dam and flows approximately five miles north to its confluence with the mainstem. The river receives moderate inflows of groundwater. However, waters are heated in the impoundment such that the resident fish population downstream is composed of only cool- and warmwater species. There are no tributaries or dams in this segment. Riparian lands are privately owned, but there is little residential development in the riparian corridor. Some row-crop agricultural activities do occur adjacent to the stream, particularly in the reach near the river mouth.

Mainstem Thunder Bay River - Upper South Branch Thunder Bay River confluence to Four Mile Dam

This segment begins at the Upper South Branch confluence, which enters from the south, and extends to the dam on Lake Winyah. River gradient is very low between the confluence of the Upper South Branch and the upstream end of Lake Winyah, whose surface elevation is about 673 feet above sea level. Lake Winyah is a 1,530-acre impoundment formed by Seven Mile Dam which impounds about 4 miles of the mainstem. The North Branch TBR and the Lower South Branch TBR flow into the north and south arms of Lake Winyah, respectively. Much of the land in this downstream portion of the watershed is used for agricultural production, particularly soils draining to the North and Lower South branches of the TBR. However, most of the riparian zone along the mainstem in this segment is relatively undeveloped and deciduous trees predominate. Approximately one mile of this river segment is impounded by Four Mile Dam. The backwaters formed by this dam extend upstream to the outfall from Seven Mile Dam, forming an impoundment of 98 acres.

North Branch Thunder Bay River - Headwaters to Montmorency–Alpena County Line

This segment originates as two unnamed tributaries which flow into Rush Lake in northeastern Montmorency County. The only named tributary in this stretch is Long Lake Creek. This warm water river segment receives relatively low inflows of groundwater due to flat topography. There are no designated trout streams. The western two-thirds of the catchment are almost entirely forested, while row-crop agriculture is the primary land use in the downstream portion of the catchment.

North Branch Thunder Bay River - Montmorency–Alpena County line to Quinn Creek

This segment flows northeast through the northwest corner of Alpena County and into Presque Isle County. Quinn Creek is the major tributary. The uplands are comprised of extensive forested wetlands. There are no dams.

North Branch Thunder Bay River - Quinn Creek to mainstem Thunder Bay River

This river segment flows southeast from the confluence with Quinn Creek to its terminus at Lake Winyah. Erskine Creek is the only significant tributary. The low-gradient, unconfined channel flows through broad valleys and extensive agricultural areas. The North Branch and tributaries to this reach are classified as non-trout water.

Hubbard Lake tributary - headwaters to Hubbard Lake Dam

Headwaters of this segment drain water-permeable soils in north-central Alcona County that flow in a northerly direction to Hubbard Lake. The major tributaries to Hubbard Lake include Sucker Creek and West Branch River. Both these small streams and their tributaries are designated trout streams. The only major dam is Thunder Bay Power Company’s Hubbard Lake Dam. Extensive wetlands adjacent to these streams limit much residential development in the riparian corridor, but some adjacent land is used for agricultural purposes (row-crops and pasture).

Lower South Branch Thunder Bay River - Hubbard Lake Dam to Wolf Creek

This segment flows north from the Hubbard Lake to its confluence with Wolf Creek. The stream channel in this ten-mile long segment is confined by a relatively narrow glacial-fluvial valley. Groundwater inflows are relatively low and the fish community is comprised primarily of small-bodied warmwater fish species. The uplands in this region are intensively farmed, as both row crops and pasture.

Wolf Creek - Headwaters to Lower South Branch Thunder Bay River

Wolf Creek originates from highly water-permeable soils in northwest Alcona County and flows northeasterly to the confluence with the Lower South Branch TBR. High groundwater inflows to the upstream tributaries and a paucity of lakes results in headwater streams that are highly suitable for trout species. Wolf Creek and all its tributaries upstream from T30N, R7E, S32 are designated trout streams. Wolf Creek and its tributaries flow through large, privately owned land parcels, many of which are hunting clubs. There is little residential development along the riparian corridors of the extensive Wolf Creek tributary system (Table 2).

Lower South Branch - Wolf Creek to confluence with mainstem

The majority of this segment flows north and receives limited amounts of groundwater. Wolf creek, the upstream boundary of the segment, is the most significant tributary (Table 2). The riparian corridor is forested and relatively undeveloped, although uplands to the west are extensively farmed.

Mainstem Thunder Bay River - Four Mile Dam to Ninth Street Dam

The segment between Four Mile and Ninth Street Dams is approximately five miles in length. Gradient is moderate in the river reach between Four Mile Dam and the city limits of Alpena. This three-mile reach contains rapids and good quality sequences of riffle and pool habitat. There is substantial coarse substrate, gravel, cobble, and fractured bedrock in the riffles and rapids. The river flows into Lake Besser (392 acres) near the western limits of the city of Alpena. Ninth Street Dam, located about one river mile upstream of Lake Huron, forms the downstream boundary for this segment.

Mainstem Thunder Bay River - Ninth Street Dam to Lake Huron–Thunder Bay

This one-mile long segment begins at the Ninth Street Dam and terminates at the river mouth where it flows into Thunder Bay of Lake Huron. Substrate in the first quarter mile below the dam is dominated by rubble and gravel substrates. This short river segment is the only part of the entire Thunder Bay River that is accessible to potamodromous fish from Lake Huron.

History

The TBR watershed was formed in the Wisconsin period of glaciation approximately 11,000 years ago when the last ice sheets retreated to the Straits of Mackinac (Farrand 1988). A number of diverse glacial advances and retreats occurred within this period, leaving behind a complex landscape. Rock particles of varying sizes, known as till, were the most common material deposited in the Thunder Bay River watershed (Farrand 1988). Smaller materials such as clays and silts were carried away while the heavier particles remained to create more stable, permeable soils. An arterial system of water drains the upland moraines in the headwater reaches and lower flat ground closer to Lake Huron.

Few traces of Paleo-Indian evidence exist in the Thunder Bay River drainage (B. Mead, Michigan Department of State, Archaeological Section, personal communication). People were visiting the area more frequently by 2000 BCE and living a sedentary lifestyle (Archaic period). Innovations were slow to reach the inhabitants of the region compared to the more populated regions in southern Michigan. Populations increased by 1000 CE partly due to bow and arrow use and horticulture (B. Mead, Michigan Department of State, Archaeological Section, personal communication).

The name of Thunder Bay arose from a Native American myth involving romance, jealousy, and murder. A young, jealous Ottawa Indian longed for a relationship with the daughter of a prominent Ottawa chief. However, the daughter gained the friendship and bonding of a young Huron Indian instead. This led to murder of the couple on Thunder Bay. Legend indicates that after this murder, “then followed peal after peal of thunder and flashing lightning and the tribe knew that the Great Spirit was offended, and never more would they trust themselves on the waters of what they then named Thunder Bay” (Trelfa collections).

The Thunder Bay region was occupied by the Ojibwa tribe of Indians as of 1768 (Tanner 1987). A major Ojibwa village was situated near the site of present day Alpena in 1810. Few established tribal villages existed in the Thunder Bay River basin compared to the rest of the Michigan territory. This may have been a result of the harsh climate and land. Most of the watershed was occupied by both Ojibwa and Ottawa Indians by 1830, with four prominent villages along Thunder Bay (Tanner 1987). The Thunder Bay band of Indians was only comprised of about 25 individuals in 1840 (Oliver 1903). Eventually, Europeans began occupying the Thunder Bay shoreline region. Indian land cessions to the United States occurred as early as 1819 in the lower watershed and by 1836 in the upper watershed.

Many remaining Native Americans moved to the Hubbard Lake area in what is now northern Alcona County (Tanner 1987). This area was ceded to the Indians in 1819 in a treaty with the Michigan government and became an important tribal gathering ground for ceremonies and meetings (Prescott 1934; Gauthier 1982). Large numbers of Chippewa (Ojibwa) Indians settled in this area as can be traced by the mounds, artifacts, and burial grounds found along the southern shore of Hubbard Lake.

Early trading posts were established by the French, the American Fur Company, and other independents along the Thunder Bay River. Fish and other supplies were often transported to southern markets via boats, which returned with supplies to the Thunder Bay region (Trelfa collections). The first surveyor found the river in 1822 to be 40 yards wide, with 6 feet of water over the bar at the mouth and 11 feet within the river (Trelfa collections; Haltiner 1986). The area around the river mouth was heavily forested and the shoreline rocky. There are accounts of small, non-permanent residences from 1834-1856 with some of the first European settlers moving near Alpena for the fishery resource. The first permanent European resident to the region was the lighthouse keeper at Thunder Bay Island around 1833 (Trelfa collections).

Alpena County and especially the river mainstem interior was one of the last wildernesses in the Lower Peninsula to be developed. Prescott (1934) describes this wilderness:

> Until shortly before the World War, when the gravel highways from the south penetrated the section, the county was isolated. The D. & M. Railroad followed the Huron shore on the extreme eastern border, with a couple of stub lines (hangovers from the timber days) penetrating a short distance into the interior. Barring a fringe along the eastern side and limited agricultural settlements spotted here and there, the interior was a wilderness. Auto travel from the outside was impossible, no auto roads leading out, and few existing within the county. The fact that this section was the last frontier in the Lower Peninsula to be opened to the tourist, and that large areas are unsuitable for agricultural purposes and are still unsettled, resulted in the retention of many historic landmarks which in other sections have been obliterated by the plow of the settler and the development of the country.

Surveys were conducted around 1840 for parts of Alpena and Alcona counties. Much of the land was, however, considered worthless according to a party surveyor. Despite this, immigrants in search of pine and farm lands were rapidly inhabiting the region with land office sales reaching as high as 30,000 acres per day. During the 1856-1857 winter, large tracts of land were cleared along the Thunder Bay River from the mouth to the Lower South Branch confluence (Trelfa collections). Bridges began to be built across the river with the first one constructed in 1865. Approximately 233 buildings had been erected in the fast growing river town of Alpena by 1871, which now had a human population of more than 2,500. This population would soon boom with the exploitation of the inland forests. Alpena was originally named Fremont and even Thunder Bay at one time, before the early immigrants settled on the name that it is today.

The fishing industry propelled the young Thunder Bay region economy prior to Michigan’s renowned logging era (Law and Law 1975; Haltiner 1986). The river, by 1819, was the northern boundary of land ceded to the United States by Indian tribes as stated in the Treaty of Saginaw (Trelfa collections). This incorporated much of Thunder Bay and was considered some of the highest quality fishing areas in the Great Lakes. According to Trelfa, Thunder Bay Island was a "large fishing station with thirty-one fishing boats and a population of 160" by 1845. The island became the center of the local fishing industry near the river mouth, but the commercial fishers soon moved their operations to the booming town of Alpena (Law and Law 1975). In 1882 alone, nearly two-million pounds of fish were shipped for food consumption to markets further south (Haltiner 1986).

Lake sturgeon were once abundant to the Thunder Bay harbor and near-shore areas of Lake Huron. These fish were often killed for sport, or because their abundance was considered a nuisance to the commercial fisher's netting operations (Prescott 1934). They were often left to rot on beaches, used for fertilizer, or at times would feed the community.

Recognizing the value of the fishing resource, the federal government established a fish hatchery in Alpena in 1882 and began to stock lake trout and lake whitefish in area waters (Haltiner 1986). Early community pioneers also recognized the value of the Hubbard Lake fishery and its possibilities as a resort attraction (Gauthier 1982). Nearly 300,000 young walleyes were stocked within the lake beginning in 1908. An early account from the Alcona County Review in 1895 stated:

> The editor enjoyed his first visit to Hubbard Lake this week. He found a beautiful sheet of water charmingly set in the midst of high hills, which surrounds it on every side. It is a long and monotonous trip out there but the excellent fishing and bathing and quiet enjoyment of nature amply repay one.

Alpena County had one of the largest fishing operations in the Great Lakes by 1930 with 20 fishing tugs in service (Law and Law 1975; Haltiner 1986). Problems did, however, loom for the fishery due to exploitation and mortality from invading sea lamprey. By the 1950s, lake trout and lake whitefish numbers had declined and most commercial catch included chubs, perch, and lake herring. Chinook salmon (1968) and brown trout (1961) were eventually stocked in the river.

The extensive pine forests of the interior Thunder Bay River region would eventually increase human immigration to the city of Alpena and adjacent counties. Some of the first proprietors to the region included George N. Fletcher and James R. Lockwood who had interests in the interior coniferous forests beginning around 1856 (Haltiner 1986). Land was cleared along the river in preparation of timber operations. According to Oliver (1903), regional growth escalated around the onset of the civil war. Timber became a valuable resource for many reasons including recovery of tar and turpentine. Timber removal operations were in full swing through the 1880s and no stretch of the mainstem or its tributaries was left unexploited. Life of a Thunder Bay watershed lumberjack was tough, but rewarding:

> Nelson LeBlanc, of Alpena, was a lumberjack and riverman for more than 20 years, working mainly on Thunder Bay River waters. His wages as a loader were usually $26 per month and board, and as a riverman he was paid $2 a day. He drove logs on Gilchrist, Hunt, Beaver, and McGinn creeks and on the Little Wolf and Big Wolf, all tributaries to Thunder Bay River, and on the main river and its branches, besides working other streams of the region. (Michigan State College 1941)

The Thunder Bay River became a tool to transport logs downstream to Alpena. The Thunder Bay River Boom Company, where the logs were sorted, began business in 1868 and was located on an island in the river at Alpena (Michigan State College 1941). In 1887, the company produced 138,000,000 board feet of timber, which ranked fifth most among fourteen Michigan rivers used for this purpose (Oliver 1903; Meek 1976).

Lumbermen came to the Hubbard Lake area and cut vast amounts of timber in the winter. The wood was stacked on the frozen banks of the lake, moved to the river outlet after winter thaw, and floated along the Lower South Branch and mainstem to the working mills in Alpena (Gauthier 1982). Many winter logging camps still flourished in the swamplands near Hubbard Lake years after the timber decline in other parts of the state and Thunder Bay watershed (Prescott 1934).

Alpena was the lifeblood of the Thunder Bay region as a result of the logging industry's reliance on the river. Lumber production peaked in 1889 and the town population was around 10,000 (Haltiner 1986). Seventeen mills existed in town. The once abundant white pine and white cedar forests of the watershed were exploited. Pulpwood factories were built which enabled further harvest of interior forests comprised of spruce, jack pine, balsam, and hardwoods (Haltiner 1986). This process extended the logging era in the region and further increased utilization of the river. Logging began to decline in the Thunder Bay River watershed by 1926.

The largest and most significant long-term alteration of the river system began with the construction of dams. Early dam building practices date back to the 1830s when a pioneer built a non-permanent dam on the river for a sawmill (Trelfa collections). The first official Thunder Bay River dam was built by businessman George N. Fletcher in 1858 as a product of the lumber boom. Most early Thunder Bay River dams were built and maintained to control the swiftness of the river and for log transport (Michigan State College 1941). The Richardson Dam, or Ninth Street Dam, was built in 1863. It had three sluice ways to move rafts and logs, and large waste-gates and flumes. This dam washed out in 1881, but was quickly rebuilt. Floods continued to present problems along the river corridor. The Seven Mile Dam was built in 1924 for the purpose of alleviating flooding as well as generating electricity (Haltiner 1986). Construction of the Four Mile Dam began in 1898 to provide hydropower for a ground wood pulp mill.

The first hydroelectric dam was constructed on the Lower South Branch Thunder Bay River in 1890 to create power for an increasing local human population. This dam created 8,800-acre Hubbard Lake. Six additional hydroelectric related dams were constructed from 1900-1930. The eight dams built from 1888-1924 impounded nearly 12,000 surface acres. With the exception of Upper South Dam, most dams built from 1930 to the present time impounded much less water than those constructed from 1888-1924. However, they increased fragmentation of the inland stream system and degraded water quality. Roughly 75 miles of TBR mainstem habitat were available to Lake Huron fishes prior to dam construction. With the construction of the Ninth Street Dam, this number would be narrowed down to one mile.

Farming practices became more prominent in the Thunder Bay River watershed after much of the land was deforested (Prescott 1934; Wakefield 1995). The area around the small town of Curran was a good example. Land near Curran was lumbered heavily until about 1920 at which point farming became important to the local settlers (Gauthier 1982).

According to Comer (1996), Alpena County historically contained a greater relative proportion of wetland (53%) than any other Michigan county, totaling nearly 200,000 acres. These wetlands were mainly comprised of tamarack and white cedar coniferous swamps and were most often associated with the Thunder Bay River and its tributaries. Nearly 66% of this historical swamp acreage has been converted to other land types as a result of deforestation and farming (Comer 1996). The same is true for adjacent Montmorency County, but loss of wetlands was estimated at 12%. Most of the Thunder Bay River watershed lies in Alpena and Montmorency counties.

The town of Alpena, and thus the Thunder Bay region, started to decline by the 1890s as the logging boom came to an end. Farming was marginal at the time due to poor soils. During this period, the right ingredients for cement making were found in the area. Business increased again with the formation of the Alpena Portland Cement Company near the mouth of the river in the late 1890s

(Haltiner 1986). Limestone helped fuel the regional economy and even attract other businesses. The region industry did well through the Great Depression of the 1930s.

All these historical developments have left archaeological remnants. The State Archaeological Site maintained by the Michigan Historical Center lists 132 sites within the Thunder Bay River drainage (Table 4; B. Mead, Michigan Department of State, Archaeological Section, personal communication). However, professional archaeologists have inspected less than 0.01% of the total river basin. Local residents have reported some of these sites, but most are discovered by archaeologists. According to Mead (personal communication), there are an estimated 4,000 archaeological sites within the river basin. Prehistoric sites are most common along the lake and river banks, especially the lower reaches of the river and precede the late seventeenth century CE in Michigan (B. Mead, Michigan Department of State, Archaeological Section, personal communication).

To date, none of the archaeological sites in the river basin presently are listed on the National Register of Historic Places (B. Mead, Michigan Department of State, Archaeological Section, personal communication). Many sites are eligible and about 15% meet the appropriate criteria associated with listing. Two landmarks are listed on the National Register; the Alpena County Courthouse, and the Thunder Bay Island Light Station. Locations recognized as State Historical Markers include: St. Bernard’s Catholic Church and Portland Cement in Alpena, Big Rock marker near Atlanta, and the Calvary Church in Hillman.

Geology

The geology of a watershed is a dominant factor in determining the character of a river. Surficial geology influences channel shape, drainage network density, quantity of groundwater inflow, stream temperatures, water chemistry, and the biota found in a stream (Wiley and Seelbach 1997, Bedient and Huber 1992, Wehrly et al. 2003).

Surface Geology

Albert et al. (1986) classified the lower peninsula of Michigan into relatively homogeneous units – districts and subdistricts – using a suite of landscape characteristics, including surficial geology. This classification provides a useful framework for examining general landscape differences within the Thunder Bay River watershed. The TBR basin lies within the Highplains and Presque Isle districts of the Southern Lower Michigan Regional Landscape Ecosystem.

The Highplains district is represented by two subdistricts: Grayling and Vanderbilt (Figure 3). The Grayling subdistrict comprises only a small portion of the watershed, just touching the southwest portion of the basin. This outwash plain is characterized by sand and is well-drained. The Vanderbilt subdistrict is made up of steep end- and ground-moraine ridges composed primarily of sand (Albert et al. 1986). Most of these soils are well-drained and provide high groundwater infiltration, thus supporting most of the cold water streams.

The Presque Isle district is also represented by two subdistricts: Onaway and Cheboygan (Figure 3). The Onaway subdistrict is characterized by drumlin fields on coarse-textured ground moraines. This subdistrict contains a variety of soil types and drainage, from well-drained sand ridges to poorly drained swamps. The Cheboygan subdistrict is a lake plain and is characterized as poorly drained (Albert et al. 1986; Corner et al. 1999). Swamps and bogs are numerous in this subdistrict.

The headwaters of the TBR, Stanniger, and Sheridan creeks arise from high-end moraines of medium-textured till. From its origin, the river flows northeast through glacial outwash sand and gravel and postglacial alluvium before entering Lake Fifteen, and then to Atlanta where it is impounded by the Atlanta Dam. The mainstem flows southeast from the confluence with Crooked Creek through coarse-textured glacial till for about six miles, where it is joined by Hunt Creek from the south. The TBR flows east through end moraines of medium-textured glacial till, then through extensive areas of peat and muck until the confluence with the Upper South Branch TBR. From its confluence with the Upper South Branch TBR, the river flows initially through coarse-textured glacial till and then through lacustrine sand and gravel. The entire Thunder Bay River watershed is comprised primarily of coarse-textured glacial till (50%); glacial outwash sand, gravel, and postglacial alluvium (17%); and ice-contact outwash sand and gravel (10%) (Michigan Geographic Data Library; Figure 4).

The headwaters of the Upper South Branch TBR arise from ice-contact outwash sand and gravel and then flow through coarse-textured glacial till. From Fletcher Pond Dam, the Upper South Branch TBR flows through coarse-textured glacial till to its confluence with the mainstem. The Upper South Branch TBR basin is composed primarily of coarse-textured glacial till (46%), outwash sand and gravel (29%) and ice-contact sand and gravel (22%) (Figures 4 and 5) which forms many cold water streams.

The North Branch TBR flows through coarse-textured glacial till, glacial outwash sand and gravel, and post-glacial alluvium, then through extensive deposits of peat and muck. The underlying peat and muck surficial geology changes to coarse-textured glacial till less than one mile downstream of the Quinn Creek confluence. Below Quinn Creek, the North Branch TBR drains coarse-textured glacial till, then transitions to lacustrine sand and gravel closer to the mainstem. The North Branch TBR basin is composed primarily of course-textured glacial till (63%), peat (16%), and lacustrine clay and sand (10%) (Figures 4 and 5) which forms warm water habitat.

The Lower South Branch TBR flows through coarse-textured glacial till to its confluence with Wolf Creek. Below Wolf Creek, the Lower South Branch flows through lacustrine clay and gravel with very low groundwater inflows. Wolf Creek flows through ice contact outwash sand and gravel. Surficial geology of the Lower South Branch TBR catchment is composed primarily of coarse-textured glacial till (54%), ice-contact sand and gravel (21%), and outwash sand and gravel (13%) (Figures 4 and 5) which forms a mixture of cold and cool water streams.

Bedrock Geology

The bedrock is comprised primarily of Antrim Shale, Cold Water Shale, and Traverse Group Reef formations (Michigan Geographic Data Library; Figure 6). The bedrock of the region is economically important, as these rock types may contain oil and natural gas, as well as dolomite and limestone (Dorr and Eschman 1970). For more information on oil and gas production in watershed, see the **Soils and Land Use** section. Limestone quarries are economically important in the region.

Karst formations are a unique geological feature in the watershed. Sinkholes are formed when the caves in the underlying limestone collapse. Sunken Lake (Presque Isle County) is an example of this karst formation.

Hydrology

Annual Streamflows

Discharge records were collected and reported by the United States Geological survey (USGS) at six locations in the watershed (Table 5). The mainstem TBR near Hillman is the only reach where discharge is unaffected by dams. Mean annual discharge at this site is 215 ft^3/s (cfs or cubic feet per second) which equates to an annual runoff of 0.92 $ft^3/s/mi^2$ (Table 6). Mean annual discharge at the other gauged sites on the mainstem was 463 ft^3/s near Bolton and 913 ft^3/s near Alpena (Table 6). Seasonally, highest discharges occur in April and lowest discharges in August in the mainstem TBR. This discharge pattern is typical for streams located in Michigan's Northern Lower Peninsula. The North Branch TBR, whose flow is relatively unaffected by impoundments, exhibits the same typical seasonal pattern of low and high discharges. By contrast, seasonal flow patterns of the Upper and Lower South Branches TBR are virtually the reverse of normal (Table 5). Seasonal flow patterns in these streams are altered by the lake-level control dams in Fletcher Pond and Hubbard Lake. The present seasonal pattern of discharge in both the Upper and Lower South Branch is slightly different than it was at the time that USGS gauges were operated during 1945-54. Thunder Bay Power Company now lowers the level of Fletcher Pond two feet between 15-October and 15-December and raises it two feet during the month of March (Federal Energy Regulatory Commission 1996). Hubbard Lake is lowered two feet between 1-November and 31-January and raised two feet during the month of April. Thunder Bay Power attempts to maintain a minimum flow of 15 ft^3/s through the Hubbard Lake and Upper South (Fletcher Pond) dams when water elevations are less than 0.12 feet of minimum pool levels. When minimum pool levels are higher than 0.12 feet, minimum flows of 40 ft^3/s are maintained.

Base Flow and Groundwater Inflows

The groundwater inflow into streams within the Thunder Bay River watershed varies considerably between different river segments (Figure 2) due to variation in soil permeability and topographical relief. Streams flowing through coarse-textured glacial deposits with high differences in elevation are characterized by higher groundwater inflows than streams flowing through less permeable deposits where elevation differences are small (Wiley et al. 1997). Streams with high groundwater inflows have higher summer drought flow (base flow) and their summer water temperatures are cooler relative to streams with lower base flow. Low-flow yield to streams can be calculated by dividing 90% exceedence flows by drainage area. Characteristics of biotic communities in rivers are linked to groundwater inflows because of its effects on temperature, flow stability, channel form, and other physical habitat features (Zorn et al. 1997, 2002).

The mainstem TBR segment from the headwaters to Hillman Dam receives the highest groundwater inflows of any valley segments (Tables 1 and 2) due to extensive deposits of glacial outwash sand and postglacial alluvium, and considerable variation in elevation. These conditions are conducive to down-slope transport of groundwater to the river channel. This valley segment has a low-flow yield of 0.65 $ft^3/s/mi^2$, which is high relative to other Michigan catchments of similar size (Figure 7). Low-flow yield for this TBR segment is similar to that of the Au Sable River near Red Oak (0.70 $ft^3/s/mi2$), albeit the catchment of the Au Sable River at Red Oak is larger. Modest groundwater inflow to tributaries can be inferred from cold July water temperatures observed for many creeks (e.g., Stanniger, Sheridan, Hunt, Sage, Nugent, Brush, and Miller) in 2003 in this segment (Table 7).

The mainstem TBR segment between Hillman Dam and the confluence with the Upper South Branch TBR flows through an extensive area of peat and muck and actually appears to lose flow within this segment. Summer discharge loss between Hillman Dam and James Road located about 10 river miles downstream was 28% (MDNR, Fisheries Division, unpublished data). This reduction in discharge was similar to the decline in discharge on the South Branch Au Sable River between the Oxbow Club and the river mouth reported by Coopes et al. (1974). Water loss within this segment could result from a combination of evaporation and infiltration.

Groundwater inflow is low for the mainstem between the Upper South Branch confluence and Four Mile Dam. Although this river segment flows through considerable amounts of coarse-textured glacial till, the flat topography does not provide the hydraulic head needed to drive significant lateral movement of groundwater to the stream channel. Low-flow yield of the mainstem TBR declines from 0.65 $ft^3/s/mi^2$ near Hillman, to 0.55 $ft^3/s/mi^2$ just upstream from the confluence with the North Branch TBR, and to 0.37 $ft^3/s/mi^2$ below Four Mile Dam (Figure 7).

Low-flow yield cannot be quantitatively determined for the Upper South Branch TBR segments because of the lack of appropriate data. Operation of the dam to raise (spring) and lower (fall) the pond level by two-feet, renders the USGS gauge data inappropriate for determining low-flow yield. However, we infer that groundwater inflow is moderate to high in portions of the segment upstream of Fletcher pond, based on the sub-watershed’s geology and land elevation variation. Moreover, mean July water temperature in July 2000 was 63ºF at a site about three miles upstream of Fletcher Pond. Similarly, we infer that groundwater inflow is lower in the Upper South Branch TBR downstream of Fletcher Pond because topography is flatter.

Inflow of groundwater to the North Branch TBR is extremely low in all three river segments (Figure 2). The low-flow yield for the North Branch TBR near the mouth was only 0.1 $ft^3/s/mi^2$ which is even lower than the Rouge River in metropolitan Detroit (Figure 8). North Branch TBR minimum daily flows averaged less than 15 ft^3/s in nine months of the year during the period that a USGS gauge was operated near Bolton (Table 5).

Low-flow yields can not be calculated for Lower South Branch TBR segments due to the USGS gauge location and the two-foot variation in operation between winter and summer levels of Hubbard Lake. Modest groundwater inflow into tributaries to Hubbard Lake and other creeks (e.g., Stevens, Sucker, Fish, Shafer, Holcomb) can be inferred from cold July water temperatures observed in 2003 (Table 7).

Low-flow yields are not available for the Wolf Creek segment (headwaters to Lower South Branch TBR) because there is no flow gauge data. Surficial geology and elevation variation in headwater tributaries suggest that groundwater inflow is very high in the southwestern portion of the watershed. However, as the creek flows into Alpena County, elevation variation is reduced and predicted groundwater inflow is lower. Relatively high mean July water temperature at Wolf Creek road (Table 7) and fish community data collected in this area likewise suggest that groundwater inflow is insufficient to support coldwater fish communities.

Streamflow Variability

The seasonal pattern of flow over a year, or flow regime, strongly influences the abundance and composition of biotic communities in streams (Hynes 1970). Streams with more stable flow regimes–those with more uniform flow throughout the year, typically have more stable channel morphology and more stable fish assemblages (Leopold et al. 1964; Poff and Allan 1995). By contrast, streams with more variable flow regimes–those where high-flow events are more frequent and of greater magnitude, typically have less stable channel morphology because the erosive power of a stream increases in proportion to discharge. In Michigan, streams with less stable flow regimes are typically warmer in summer and intra-annual variability in fish reproductive success is higher.

A particular flow regime can be either harmful or beneficial to stream fishes as discussed by Zorn and Sendek (2001).

> The stability, timing, and volume of streamflows have been shown to influence the reproductive success of warm-, cool-, and cold water fishes (Starrett 1951; Coon 1987; Strange et al. 1992; Bovee et al. 1994; Nuhfer et al. 1994). Increased flow stability has

> been positively related to fish abundance, growth, survival, and reproduction (Coon 1987, Seelbach 1986). Habitat suitability studies have documented the importance of flow stability to many fishes, including pink salmon (Raleigh and Nelson 1985), largemouth bass (Stuber et al. 1982), smallmouth bass (Edwards et al. 1983), walleye (McMahon and Nelson 1984), brook trout (Raleigh 1982), salmon (Raleigh et al. 1986a), and brown trout (Raleigh et al. 1986b).

We used the 10:90% exceedence flow (see **Glossary**) ratio to describe flow stability at gauged sites and as an index to compare these sites to other streams. The 10% exceedence flow is the discharge exceeded at a site 10% of the time. These flows typically occur during March and April in northern Michigan streams. The 90% exceedence flow is the discharge exceeded 90% of the time and represents summer or winter base flow conditions. Higher values for the 10:90% exceedence ratio are an indication of lower flow stability.

The mainstem TBR at Hillman has a very stable flow regime. The 10:90% exceedence ratio for this segment was 2.3, which is lower than the ratio found in many Michigan catchments of similar size (Figure 9) and is lower than the ratio for the South Branch Au Sable River, a renowned trout stream (Zorn and Sendek 2001). The 10:90% exceedence ratio for all gauged sites on the Au Sable River averaged 1.9 (Zorn and Sendek 2001). The stable flow regime in the upper mainstem TBR reflects the high permeability of the coarse-textured glacial deposits that predominate in this portion of the watershed (see **Geology**). Flow regimes are even more stable in top-quality cold water tributaries. The 10:90% exceedence flow for Hunt Creek at a gauge site operated by Michigan Department of Natural Resources, Fisheries Division was 1.3 for 1998-2002 (MDNR, Fisheries Division, file data). Flow stability of the mainstem TBR decreases only slightly as the river flows east toward Lake Winyah. The 10:90% ratio at the mainstem TBR USGS gauge 3.8 miles upstream of the North Branch confluence was 2.7 –similar to the stability of the Pere Marquette River at Scottville (Figure 10). The mainstem TBR at this gauge was considerably more stable than Michigan rivers with similar catchments such as the Flint River near Otisville and the Shiawassee River at Owosso. Flow stability of the mainstem TBR decreases below Four Mile Dam, after receiving flow from the North and Lower South Branch Rivers (Figure 11).

Both the Upper and Lower South Branch TBR have very low flow stabilities, due in large part to operation of the Fletcher Pond and Hubbard Lake dams to raise and lower lake-levels by two feet. The ratio of 10% to 90% exceedence flows is 19 for the Upper South Branch TBR and 25.3 for the Lower South Branch TBR (Figure 12). These unstable flows are not conducive for stable fish communities. The North Branch TBR is also very unstable, and even more so than the River Rouge at Detroit, yet the cause is not dam operation (Figure 13). Extremely low minimum flows in the North Branch, attributable largely to the geology and topography of this valley segment result in minimum flows that approach zero during summer months (Table 5). Low drought flows and unstable flows in the North Branch TBR segments severely limit fisheries management potential.

Climate

The growing season in the TBR watershed of 115-120 days is short compared to other climate districts in the Northern Lower Peninsula (Albert et al. 1986). Shorter growing seasons are associated with less evapotranspiration and thus more rainfall can contribute to streamflow. Mean annual precipitation is about 30.3 inches, but there is considerable local variation in snowfall, precipitation, and temperature. For example, the growing season at Atlanta, Michigan is 108 days compared to approximately 126 days along the shores of the Great Lakes in the Presque Isle district (Albert et al. 1986).

Soils and Land Use Patterns

Soils and Sedimentation

Soils in the Thunder Bay River watershed "range from well-drained sandy soils to loamy and poorly drained soils" (NEMCOG 2002). Fine textured clays, peat, and muck are more prevalent in the lower watershed, while coarse-textured sand and gravel are more common in the upper part of the watershed. Detailed soil information is available for Alpena (Williams 2004) and Montmorency (Purkey 2003) counties from the local county Conservation District.

Zorn and Sendek (2001) discuss some of the effects and causes of sedimentation:

> …Whether in transport or accumulating on the streambed, sediment adversely affects aquatic invertebrates and fishes typical of moderate-gradient, cold water streams (Alexander and Hansen 1983; Alexander and Hansen 1986). Sediment smothers gravel and cobble habitats critical for reproduction and survival of many fish and invertebrate species, and fills in pools that are used by larger fish. This results in habitats that are less diverse and less suitable for many fishes (Alexander et al. 1995)….
>
> Though erosion is a natural process, past and present human activities have dramatically accelerated the rate of erosion of the landscape. Historic logging activities dramatically increased sedimentation rates. Cutting forests, rolling logs into streams, and transporting them downstream to sawmills introduced tremendous amounts of sediment into the system. Even very small streams were dammed for use in logging. Managed flood surges used to push logs downstream further enhanced erosion rates. Sediment introduced by these activities may still be slowly working its way downstream. Raw banks continue to contribute sediment in some areas of the watershed, though actions have been taken to re-stabilize many. Discharge to the river increased in response to reduced evapotranspiration by vegetation remaining on the cutover land. Peaking of hydropower plants dramatically increased the discharge and erosive power of the river... Recent FERC licenses to the projects are helping to reduce some of their effects (see **Special Jurisdictions**) (Zorn and Sendek 2001).

In addition to the natural erosion and sedimentation processes inherent to a sandy watershed, accelerated sedimentation to the Thunder Bay River system occurs primarily at unvegetated stream banks and road-stream crossings. In an effort to quantify some of these sources of sediment, NEMCOG and the Montmorency Conservation District conducted a stream bank erosion inventory for the Thunder Bay River watershed in 2000 and identified 123 stream bank erosion sites. Each site was ranked according to the severity of the erosion. Stream bank erosion was ranked as 'severe' at 14 sites, 'moderate' at 35 sites, and 'minor' at the remaining 74 sites. As of spring 2002, the Thunder Bay River Restoration Committee had repaired the erosion problem at 40 of these sites (NEMCOG 2002).

> Reducing sediment contributions from road-stream crossing involves both education and funding. Incorporation of Best Management Practices (BMPs) for road siting, construction, and maintenance requires training of workers. Topics for discussion should include: ecological and economic effects of sediment on streams; how to properly site road-stream crossings; selection of crossing type and dimensions; recommended grades at crossing and approaches; and ways to minimize sediment delivery from grading and snowplowing. In addition, incorporation of some BMPs, such as those for bridge construction, may protect a stream and save money in the long run, but involve more up-front costs (Zorn and Sendek 2001).

NEMCOG and Huron Pines RC&D inventoried 131 road-stream crossings in the Thunder Bay River watershed in 2000, ranking the severity of the sedimentation problem. Eleven of these crossings ranked ‘severe’, 64 ranked ‘moderate’, and 56 ranked ‘minor’ (NEMCOG 2002). It is estimated that one of the crossings, Eichorn Bridge (Montmorency County; T30N, R3E, S20/21), annually contributes 200 tons of sediment to the river (Lisha Ramsdell, NEMCOG, personal communication).

Past and Present Land Cover

Land cover in the Thunder Bay River watershed has changed substantially over the last 200 years. Historical land cover data from the 1800s show the watershed was comprised almost entirely of forest and wetland (Austin et al. 2000). While forests still predominate (57%) today, much of the wetlands have been drained and converted to agriculture (Figures 15a and 15b). Wetlands comprised 34% of the watershed in 1800, but decreased to 18% by 1983 (Figures 16 and 17) (Austin et al. 2000; USGS National Mapping Program 1994). The loss of 47% of the wetlands in the Thunder Bay River watershed between 1800 and 1983 is substantially more than the 28% loss statewide (Comer 1996). The history of logging and agricultural practices within the watershed is discussed in the **History** section of this assessment. Primary land cover categories in 1983 for the Thunder Bay River watershed were forest and wetland, which comprised 57% and 18% of the watershed, respectively (Figures 15a and 15b).

Current land cover varies in different parts of the Thunder Bay River watershed. Forested wetland and agriculture are prevalent in the North Branch Thunder Bay River watershed, while deciduous and coniferous forests, along with forested wetland, cover much of the Thunder Bay River watershed as a whole (Figure 18).

Land Use

Residential growth and development is increasing rapidly within the Thunder Bay River watershed (Michigan Society of Planning Official 1995). A population increase of more than 56% is projected for Montmorency and Oscoda counties by the year 2020. This population increase may stress aquatic systems since much of the residential housing in the watershed is concentrated along lake and river riparian zones (Albert et al. 1986). Counties within the Thunder Bay River watershed are also popular locations for second homes, including summer residences and cottages. The number of second homes in Oscoda and Alcona counties is expected to increase at least 81% between 1990 and 2020 (Michigan Society of Planning Officials 1995).

Although urban or developed land comprises less than 2% of the watershed, it can affect aquatic environments in a variety of ways as discussed by Hay-Chmielewski et al. (1995):

> Landscape development for urban use also has dramatic effects on the aquatic environment (Leopold 1968; Booth 1991; Toffaleti and Bobrin 1991). Development noticeably increases the percentage of impervious land area, resulting in more water reaching the stream channel more quickly as surface runoff. Urban and higher-density suburban areas typically have 50-100% and 25-45% impervious surface areas, respectively (Toffaleti and Bobrin 1991). Impervious surfaces include pavement (roads and parking lots) and roofs of buildings. These have runoff coefficients 6-14 times greater than for undisturbed land (Toffaleti and Bobrin 1991). Engineered storm water runoff systems also speed surface runoff. Increased runoff causes greater peak flows, harmful to reproduction and survival of many aquatic organisms, more erosion, decreased groundwater recharge and thus base flow, increased summer temperatures, and decreased available habitat (Leopold 1968; Booth 1991). Development that brings the construction

> of wells reduces groundwater table levels and stream summer base flows, with a resulting increase in water temperature and decrease in available stream habitat. Following use, most of this water returns to the system as heated surface water, causing increased and more variable water temperatures.

Oil and Gas Development

There are 2,496 oil and gas wells within the Thunder Bay River watershed (Figure 19) (MDEQ, GSD and MDNR, LMSD 2002). The oil and gas deposits in the Thunder Bay River watershed are near (>90%) full development (T. Black and J. Shoquist, MDEQ-Geological and Land Management Division, personal communication). Further oil and gas well development may pose risks to water resources. As stated by Zorn and Sendek (2001):

> Efforts to minimize the adverse effects of oil and gas development have met with fair success. Improved techniques have been developed for drilling and laying subsurface pipelines. Replanting work areas has reduced sedimentation, but work is needed to ensure that disturbed soils are quickly re-vegetated. Problems with excess noise from facilities have been addressed with varying degrees of success. Density of future wells is limited to one well per 80 acres. Increased spacing of wells and use of angular drilling techniques would reduce the density of well pads and resulting sedimentation. Regulations have been passed that require on-site containment of accidental spills. Most spills from the past (20-40 years ago) have been, or are nearly, cleaned up. However, erosion damage resulting from illegal use of pipeline right-of-ways and access roads by off road vehicles is a concern. Concerns still exist regarding groundwater contamination due to improper containment of drilling fluids, disposal of cuttings from drilling activities, equipment lubricant spills, and leaks from deteriorating flow lines. Potential sedimentation from new roads, well pads, and flow and sales lines is also a cause for concern. Continued vigilance is needed to minimize the effects of oil and gas development on the [Thunder Bay River's] sensitive surface- and groundwater resources. The need to protect groundwater resources from contamination is especially critical when exploiting oil-rich formations, such as the Niagaran (R. Henderson, MDEQ, Geology Division, personal communication).

Channel Morphology

Channel Gradient

River gradient plays an important role in many aspects of a river system. "Stream gradient (drop in elevation with distance, usually in feet per mile) is an important factor determining river channel form and stream bed composition. Gradient is related to streambed particle size, discharge, channel pattern (meandering), and sediment transport (Hynes 1970; Knighton 1984; Wesley and Duffy 1999)."

Zorn and Sendek (2001) summarize the importance of gradient:

> River gradient, together with flow volume, is one of the main controlling influences on the structure of river habitat. Steeper gradients allow faster water flows with accompanying changes in depth, width, channel meandering, and sediment transport (Knighton 1984). In the glaciated Midwest, high stream gradients often occur where streams cut through end moraine deposits. When the deposits are coarse-textured (e.g., sands or gravels) and elevation changes are large, stream channels receive high inflows of groundwater (Wiley and Seelbach 1997). In this way, stream gradient is related to other important variables such as stream temperature, current velocity, bottom substrate, and

> flow stability, and is especially important to cold water fishes (Zorn et al. 1997). Gradient has also been used to describe habitat requirements of cool- and warm water fish species including smallmouth bass (Trautman 1942; Edwards et al. 1983), largemouth bass (Stuber et al. 1982), northern pike (Inskip 1982), white sucker (Twomey et al. 1984), black crappie (Edwards et al. 1982), blacknose dace (Trial et al. 1983), and creek chub (McMahon 1982).
>
> Gradient is measured as elevation change in feet per river mile. As the character of the landscape changes along a river's course, some portions of a river drop more steeply than others. These areas of different gradient create a variety of stream channel habitats for fish and other aquatic life. Typical channel patterns in relation to gradient (G. Whelan, MDNR Fisheries Division, unpublished data) are shown below. In these descriptions, hydraulic diversity refers to the variety of water velocities and depths found in the river. The best river habitat offers a wide array of depths and velocities to support various life functions of different species. Fish and other life are typically most diverse and productive in those parts of a river with gradient between 10 and 69.9 feet per mile (G. Whelan, MDNR Fisheries Division, unpublished data; Trautman 1942). Such gradients are rare in Michigan because of our low relief landscape. High-gradient stream reaches that did occur in the state were [typically] sites for dams.

Gradient in the Thunder Bay River and its tributaries was calculated using a geographic information system and standard methods developed by The Nature Conservancy (The Nature Conservancy, Freshwater Initiative 2000). The spatial data layers used include a digital elevation model (DEM) and the National Hydrography Dataset for streams. The DEM is based on a raster format with a 30-meter grid. Gradients were calculated and classified for various TBR watershed reaches (Table 8).This method produces a conservative estimation of gradient, and was the most efficient technique for calculating gradient across a watershed. The results were intended for broad-scale use and interpretation of gradient, not for use in detecting fine-scale changes. An impoundment, for instance, may cover some higher gradient reaches of river which may not be accurately depicted using this methodology. The results depend on: location of the beginning and ending nodes for each stream of the hydrography layer; and elevation provided by the DEM where each node was located. Again, the gradient numbers provided should be used for large-scale interpretation of gradient data.

Gradient Class	Value (ft/mi)	Channel Characteristics
Low	0-2.9	Mostly run habitat with low hydraulic diversity
Medium	3-4.9	Some riffles with modest hydraulic diversity
High	5-9.9	Riffle-pool sequences with good hydraulic diversity
Very High	10-69.9	Well established regular riffle-pool sequences with excellent hydraulic diversity
	70-149.9	Chute and pool habitats with only fair hydraulic diversity
	>150	Falls and rapids with poor hydraulic diversity

Mainstem Thunder Bay River

The mainstem TBR is 74 miles long, and is predominantly low gradient. The low gradient classification comprises 58% of the mainstem (Table 9, Figure 20). Forty-five percent of the mainstem from the headwaters to Hillman Dam is classified as low gradient, compared to 73% low gradient from Hillman Dam to the confluence with the Upper South Branch TBR (Table 8). Almost 77% of the mainstem from the Upper South Branch confluence to Four Mile Dam is of low gradient as well.

A moderate amount of quality higher gradient reaches does exist along the mainstem, especially above Hillman Dam, in the lower watershed, and under existing impoundments. There is a sharp drop in elevation between Four Mile Dam and Ninth Street Dam, where 72% of the reach is >5.0 ft/mile.

Upper South Branch Thunder Bay River

Of the nearly 29 river miles from the headwaters of the Upper South Branch TBR to Fletcher Pond Dam, 70% are either high or very high gradient. Gradient decreases below Fletcher Pond Dam, where 73% of the river between the dam and the mainstem is low gradient. Much of the river and its tributaries above Fletcher Pond are top- or second-quality cold water streams. It is classified top-quality warm water downstream of Fletcher Pond.

North Branch Thunder Bay River

The North Branch TBR has fairly good gradient, with 57% of the reach from the headwaters to the Montmorency-Alpena County line medium gradient and 28% high gradient. From that point to the mainstem, about 57% of the North Branch is medium gradient. The North Branch TBR and all its tributaries are top-quality warm water streams based on the 1967 classification (Figure 21).

Lower South Branch Thunder Bay River

The Lower South Branch TBR is generally low gradient from its headwaters to Hubbard Lake dam, with 65% of the reach having gradients of 0-2.9 ft/mile. The remaining 35% (4.4 miles), however, is of high (10.0-69.9 ft/mile) gradient. Hubbard Lake is surrounded by hills; streams tributary to Hubbard Lake are of high gradient and most of them are top- or second-quality cold water streams.

Wolf Creek

The Wolf Creek system contains 32.2 river miles from the headwaters of Wolf Creek and Little Wolf Creek to the confluence with the Lower South Branch TBR. A large portion (42%) of this system is low gradient (0-2.9 ft/mile). The Wolf Creek system also has substantial fractions (21% and 24%) of high and very high gradient. Wolf Creek's headwaters arise from the hills region near Curran, Michigan. All of Wolf Creek and its tributaries (above the former impoundment created by Wolf Creek Power Dam at T30N, R7E, sec 32) are cold water (top- and second-quality), except for Beaver Creek, which is a top-quality warm water stream.

Only about 23% of stream miles in the entire Thunder Bay River basin are classified as low gradient when both tributaries and mainstem river segments are considered (Table 10). Surprisingly, 38% of the TBR basin is classified as very high gradient. The high percentage of stream miles in the very high gradient classification can be attributed to the inclusion of small headwater streams in the GIS model. Some of these streams, which are little more than springs, originate in the hills in the upper watershed. As part of the basin, these small tributaries are included, but care should be taken when interpreting the data. The primary branches of the TBR, (e.g., mainstem, Upper and Lower South Branches, and North Branch), are predominantly low-gradient. Higher gradient reaches generally receive higher groundwater inflow, and are more likely to be colder and to support coldwater fish community assemblages.

Channel Cross Sections

Channel cross sections show morphological diversity in a stream channel, and therefore may be used to show the quality of fish habitat in a stream (Schneider 2000). They may also indicate disturbance or change to a river.

> The characterization of habitat by gradient presented above assumes normal channel cross sections for such gradients. However, a variety of factors can cause channel cross sections to deviate from these characterizations. For example, unstable flow acting upon a stream channel whose bed is more resistant to erosion than its banks will often cause the channel to be overly wide and shallow, lacking large woody debris and structure (Heede 1980). Activities, such as log driving can increase bank erosion (see **History**). Overly narrow channels may result from dredging and channelization activities, or simply the existence of stream banks (natural or man-made) that are highly resistant to erosion. Sediment erosion and deposition associated with improper placement of bridges and culverts will also alter channel form. Detailed observations of channel cross-section can be used to identify where significant channel changes may have occurred (Zorn and Sendek 2001).

Channel characteristics were quantitatively evaluated by comparing the average width of rivers to that of similar sized rivers using relationships from Leopold and Maddock (1953) and Leopold and Wolman (1957). Channel widths of the Thunder Bay River were measured by the MDNR and the USGS while measuring stream discharge. Representative cross sections were used when possible. Expected width (ft) was calculated from measured discharge (CFS or ft^3/s) using the following equation given in Zorn and Sendek (2001):

$$\text{Log (Width)} = 0.741436 + 0.498473 * \text{Log (mean daily discharge)}.$$

For sites without long term data, instantaneous discharge was used instead of mean daily discharge.

Rivers that have been dredged or channelized typically are narrower than would be expected based on discharge. Rivers with cross sections that are wider than expected may have substrate that is resistant to erosion, or may be subjected to frequent flood events. Cross sections that are too narrow or too wide may indicate a lack of hydraulic diversity and poor fish habitat.

Channel cross section and discharge measurements were made at 10 locations on the mainstem TBR and at 20 locations on various tributaries to the TBR (Table 11) during low-flow periods in 2000 and 2001. Two measurements were made at an additional location on the mainstem TBR in 2002 by USGS. Channel widths in the mainstem TBR were generally within the expected range of widths, while only about 37% of the tributary widths were within the expected range of values. The widths observed at each of these locations are compared with expected widths below.

Mainstem Thunder Bay River

Ninety percent of channel width measurements in 2000 and 2001 for the mainstem TBR were within the expected range based on discharge values. The mainstem TBR at Ulshafer Road, however, was narrower (43.7 feet) than would be expected based on its discharge (125.1 ft^3/s). Substrate at this location is predominantly sand and silt, allowing the channel to downcut and create large, deep pools and runs. Vegetated clay banks in this area are resistant to lateral erosion. Woody structure is abundant in the upper reaches from Atlanta to M-33 where channel widths are generally less than 40 feet. Gilchrist and Hunt creeks join the mainstem TBR upstream of Hillman. The middle reach of the mainstem below Hillman widens out to about 50-75 feet. In this stretch, woody structure becomes scarce and the substrate transitions to more gravel and cobble.

From the Upper South Branch TBR confluence to Four Mile Dam, the mainstem TBR receives flow from the North Branch TBR, the Lower South Branch TBR, and several smaller tributaries. The river becomes much larger in this reach with a few log jams present. Turbidity increases as the substrate changes from gravel and cobble to clay. Widths are over 100 feet and the river becomes unwadable as it is backed up by impoundments downstream.

A series of 36 discharge measurements made by the USGS on the mainstem TBR near Bolton, between 2002 and 2005, show that channel width was within the expected range based on mean daily flow of 346 cfs, despite drastically variable flows (USGS 2005). Discharge measured in March 2005 was 289 cfs, for instance, compared to a discharge in April 2005 of 1190 cfs. Channel width in both instances was within the expected range.

Upper South Branch Thunder Bay River

At the two sites measured on the Upper South Branch TBR, the upstream site was within the range of expected widths, but the downstream site was wider than expected. The downstream site had a sand and silt substrate with a considerable amount of instream aquatic vegetation. The river ranges from 60 to 100 feet in width, with considerable amounts of woody structure throughout.

North Branch Thunder Bay River

The North Branch TBR channel was significantly wider than expected at the three locations where channel cross section measurements were taken (Table 11). This is probably due to the high spring flows in the North Branch (see **Hydrology).** Substrate at these locations consisted primarily of cobble and gravel, which prevent downcutting of the channel. The low gradient of the river results in slower velocities and pools.

Lower South Branch Thunder Bay River

The Lower South Branch TBR is low gradient. The channel is appropriately sized just below Hubbard Lake, at approximately 53 feet in width. The substrate is predominantly cobble upstream of Scott Road, then changes to silt and sand downstream of the crossing with very little woody structure. At the campground on Indian Reserve Road, however, the river is much wider than expected, and appears to have been straightened in the past.

Wolf Creek

Based on discharge measurements, Wolf Creek was significantly wider than would be expected based on its discharge in June 2001. Parts of this stream have large boulder substrate which prevents downcutting and widens the stream channel.

Other Tributaries

Discharge measurements were made at Hunt and Gilchrist creeks as well. Measurements at County Road 612 for each of these streams indicate that channel widths are significantly different than expected. Care should be taken when interpreting single-point estimates, however. Additional channel width measurements (20) upstream of the road crossing for each of these rivers result in mean widths of 22.4 feet for Hunt Creek, and 26.8 feet for Gilchrist Creeks. The significant differences in width are likely a result of influences from the road crossing, as well as unusual water levels in that particular year.

In general, widths of cold water streams were either narrower or within the expected range. This was because cold water streams in Michigan generally have high flow stability. By contrast, flashy streams are more likely to deviate from expected widths because channel forming flow size is usually different from measured flows. Stream widths measured on Miller, Sucker, and Brush creeks were all within the expected range. All these streams are cold water trout streams. Cold water streams with widths narrower than expected included Hunt, Gilchrist, Beaver, and Greasey creeks. Quinn and Haymeadow creeks all had stream widths wider than expected. The Haymeadow Creek site was downstream of the spillway coming out of Twin Lakes. Flow is very variable at Quinn Creek. High flow variation was deduced from the deeply incised channel and raw eroding banks. In addition, three large culverts were present at the road crossing near the site where discharge was estimated even though flow on that date was only 0.06 ft^3/s.

The mainstem of the TBR generally has channel widths appropriate for its discharge volume. There is a clear dichotomy of character among the numerous tributaries to the TBR, however. Many tributaries are low gradient wetland drainages with soft, silty channel beds, while some drain predominantly forested areas and have hard, cobble-gravel substrate. These differences contribute to unusual channel widths according to processes described above.

We did not estimate hydraulic diversity of stream channels in the TBR watershed because data available for analysis were generally from sites where discharge was estimated. Stream cross sections used to estimate discharge were selected because they had more laminar flow than other cross sections in the same reach. Such cross sections are very likely to have less hydraulic diversity than randomly selected cross sections and hence are not appropriate for calculating hydraulic diversity.

Dams and Barriers

More than 2,500 dams exist on Michigan streams with more than 300 located on mainstem rivers. Dams were built and rebuilt across Michigan to meet a variety of needs reflecting the evolution of the State's economy and society over decades. Dams were built to transport logs (see **History**) and other goods, to generate electricity, and to run milling operations. Dams were built to provide reliable year-round water supplies for irrigation, domestic use, and for navigation and recreational uses. Other dams were built to provide flood control, wood control, and to hold mine tailings. Many state and federally owned dams in Michigan provide water control for waterfowl and fisheries management.

The majority of dams in Michigan were built decades ago and many have deteriorated due to age, erosion, poor maintenance, flood damage, and poor designs (S. Hanshue, MDNR, personal communication). Dams in disrepair that are not removed are at significant risk of failure, particularly during high flow events. Hydropower dams that are no longer economical to operate for power generation are often sold to local government or community organizations interested in protecting the recreational uses or park lands associated with the impoundment. These dams are often taken on without adequate funding budgeted for structure maintenance. Maintenance and licensure can be costly. Many dams are eventually abandoned since local governments and community organizations are not financially prepared for the long-term costs associated with dam ownership.

A variety of structures in addition to hydroelectric facilities can create obstacles to flowing rivers and creeks. These can include the smallest of culverts at a road-crossing or a water-control structure on a lake. Structures that disrupt the natural flow path of water or are obstacles to fish passage pose habitat and biological challenges. Some obstacles, however, are useful in blocking unwanted species such as sea lamprey from entering a river segment.

Seventy-three dams are known to exist in the Thunder Bay River watershed (Table 12), with 6 on the mainstem, 2 on the North Branch, 2 each on the Upper and Lower South Branches, and 61 on various lakes and tributaries (Figure 22). Forty-five dams (62%) have a head of 5 feet or less (total includes small ponds lacking head information); 17 have a head of 6-10 feet; 9 have a head of 11-20 feet; and 2 have a head >20 feet. Water storage capacity for most of these dams is limited. Fifty-two dams store less than 100 acre-feet of water each; 13 dams store 100-999 acre-feet of water each; eight dams store ≥ 1000 acre-feet of water each. There are fewer dams in the Thunder Bay River drainage compared to the Au Sable River drainage to the south (Zorn and Sendek 2001), yet there are more large dams with a greater storage volume in the Thunder Bay River drainage. Five dams are classified as having a high or significant hazard rating. High hazard dam failures could cause loss of life (MDEQ, Land and Water Management Division, unpublished data). All other dams in the watershed are rated as low hazard.

Dam building occurred over a long period in this watershed. The hydropower dams were built between 1890 and 1930, and are now owned by Thunder Bay Power Company. More than half of the dams (with known construction dates) were built between 1900 and 1950. A fair number were built for recreational purposes after 1950. Many of these small dams exist on private club land in the Wolf Creek drainage of northwestern Alcona County.

In the TBR watershed, the State of Michigan regulates 26 dams that impound five or more acres and have a dam height of greater than six feet. Legal lake-levels have been established at ten lakes (see **Special Jurisdictions**). The Federal Energy Regulatory Commission with assistance from the State of Michigan, regulate six dams: Upper South, Hubbard Lake, Hillman, Seven Mile, Four Mile, and Ninth Street. Two hydroelectric dams have been retired, but not removed: Brush Creek and Rhoads.

Effects of Dams on Ecosystems

Dams interrupt and alter most of a river's ecological processes by changing the flow of water, sediment, nutrients, energy, and biota (Ligon et al. 1995; The Heinz Center 2002). Some main ecological issues surrounding dams include temperature change, prevention of fish migration, and altered flow regimes. In many rivers, dams artificially regulate discharge. In particular, hydropower operations that maximize power generation capacity can cause abrupt and severe changes in flow below a dam. Turbine operations also injure, kill, or diminish the viability of fish. Dams transform long river reaches into impoundments and change downstream reaches, resulting in streambed degradation (Sheehan and Rasmussen 1993). River changes induced by dams and other watershed conditions are often reflected in the fish community. Native and desirable stream species are almost always displaced in river segments affected by dams. Dams also limit the normal movement of fish, other aquatic organisms, and organic materials (detritus/woody structure). Specific affects of dams and barriers is further described below.

Temperature/Dissolved Oxygen

Two controversial effects of dams is their influence on water temperatures and dissolved oxygen levels (The Academy of Natural Sciences 2002; Petts 1984; Lessard 2001; Tyler and Rutherford 2002). Lessard (2001) states:

> Dissolved oxygen decreases occur when deep release dams draw water from the anoxic hypolimnion (Ward and Stanford 1987). It has been assumed that dissolved oxygen decreases are not as much of a problem for smaller facilities, like those that are common in Michigan streams. This is primarily due to the fact that the size of impoundment often precludes anoxia, recovery of oxygen levels is fairly rapid downstream, and releases are often from the epilimnion (Brooker 1981; Ward and Stanford 1987).

> The characteristics common to dams that make dissolved oxygen changes unimportant, often cause an increase in downstream temperatures, making temperature the primary habitat concern. Reservoirs act as sinks for heat as well as chemicals and sediment (Brooker 1981; Ward and Stanford 1987). Surface waters spilling downstream from shallow or deep, stratified reservoirs, are often several degrees warmer than upstream reaches (Fraley 1979; Ward and Stanford 1987). Temperature increases downstream of surface release dams are a major habitat concern in Michigan."

The size of a dam may be directly related to the change in temperature regime and dissolved oxygen concentration. Stanley et al. (2002) found that water temperatures were not significantly different in a Wisconsin River before and after removal of a low-head dam. Water temperatures were studied at both upstream and downstream locations at 10 dam sites in Michigan (Lessard 2001). The author found that downstream temperatures averaged 5ºF warmer than temperatures above the dam and stated that dam and impoundment size determined the extent of thermal differences. All dams in the study were surface release structures on cold water streams. Many low-head dams exist in the upper Thunder Bay River drainage and could be affecting stream temperatures.

Thunder Bay River temperature was found to be 7ºF colder upstream of Atlanta Pond on a date in July 1970 when compared to river temperature below the Atlanta Pond Dam. This considerable difference was associated with an 18-foot head dam and 94-acre impoundment size (MDNR, Fisheries Division, unpublished data). In another study (Thunder Bay Power Company, unpublished data), river water temperature and dissolved oxygen were recorded on numerous dates in August 2001 both upstream and downstream of various impounded TBR reaches (Table 13). Impoundment effects on river water temperature were insignificant during this period for the lower mainstem dams (Ninth Street, Four-Mile, and Seven Mile) and Hubbard Lake Dam. This was not the case for the remaining two study sites (Hillman, Upper South). River temperature was nearly 4ºF colder above the Hillman Dam (M-32 bridge) compared to the mean tailrace temperature. The heat accumulation capacity of Fletcher Pond is also evident from Table 13. River temperature above the impoundment (near Turtle Lake) was nearly 10ºF colder than below the dam. Dissolved oxygen concentrations were similar between upstream and downstream impounded reaches and were always at a concentration suitable for fish. These oxygen concentrations met the appropriate water quality standards (see **Water Quality**).

Groundwater inflows can also play an important role in buffering heating caused by impoundments. Various areas of the Thunder Bay River watershed have the potential for high groundwater recharge. Barger Creek, a tributary to the upper Thunder Bay River mainstem, is a good example. The creek flows through an area of high groundwater recharge in eastern Montmorency County. Creek temperature was found to be 13ºF cooler near its confluence with the mainstem TBR compared to about four miles upstream near its source in Lake Inez. This is most likely a result of groundwater recharge (MDNR, Fisheries Division, unpublished data).

Dams built by beaver can adversely affect salmonid populations in Michigan. Beaver populations are believed to be at historically high levels and their activities can devastate trout streams and severely degrade other streams. Beaver dams can cause water warming, increase evapotranspiration, and can even block free movement of resident and potamodromous fish. Beaver activities increase sediment delivery to streams and bury large woody structure and spawning gravel in impounded areas. Warmer habitats created by beaver favor fish species that compete with salmonid species (e.g., creek chub). Loss of canopy trees in riparian corridors due to beaver activity not only increases sunlight exposure, but also causes long-term interruption of supply of woody structure to the system and even long-term manipulation of the riparian corridor.

Beaver dams are relatively rare on the best known trout streams in the TBR watershed such as Hunt and Gilchrist creeks. This is because riparian landowners and local trappers remove excess beaver to reduce property damage. There is little information on beaver dam frequency on other cold water tributaries.

Flow/Substrate

Many biological and morphological functions of a river are linked to the natural flow regime (Petts 1984). Dams may disrupt the natural discharge of a system, alter the flow, and redistribute it (Petts 1984; Tyler and Rutherford 2002). Alteration of streamflow by dams can have a drastic affect on sediment and substrates in various ways.

Lessard (2001) further discusses the affects of dams on sediment flow:

> Dams affect substrate by acting as a “sediment sink”, holding back finer sediments that normally would be transported downstream (Ward and Stanford 1983a; Ward and Stanford 1987; Waters 1995). This is of particular importance for the region of stream adjacent and immediately upstream of the impoundment, often referred to as the “impacted zone” (Klomp 1998; Mistak 2000). In this area, coarse sediments such as cobble can become covered with sand and silt potentially creating conditions unsuitable for the biota normally occurring in those stream sections (Waters 1995). Downstream reaches are often starved of these finer substrates and therefore become dominated by larger, more stable substrates.

Zorn and Sendek (2001) relate the effect of reduction of river velocity on sediment transport:

> Reduction of current velocity in a river by dams disrupts normal processes of sediment transport. Sediment that was being carried downstream by the river is deposited instead at the upstream end of the impoundment. Below the dam, the river is energetically out of equilibrium because it is not doing its normal work of carrying a bedload of sediment. It expends this energy by picking up an unusually large amount of sediment in reaches immediately below the dam and transporting it. This erosion produces channels below dams that are often unusually narrow or wide, depending on whether the banks or bed are more erodible. Dams located near river mouths, such as those in the [Thunder Bay River], prevent the sediment deposition needed to maintain river delta and marsh habitats.

Transport of large woody debris (LWD) is vital to a healthy river environment (Federal Energy Regulatory Commission [FERC] 1996; Zorn and Sendek 2001; Wing and Skaugset 2002). Wing and Skaugset (2002) emphasize this:

> The contributions of LWD include reducing the power of streams (Beschta and Platts 1986), storing sediment in channels (Bilby and Bisson 1998), creating gravel bars (Abbe and Montgomery 1996), contributing organic matter (Bisson et al. 1987), and providing improved winter habitat (Tschaplinski and Hartman 1983).

Dams have largely reduced the transport of large woody debris from the lower TBR to Lake Huron. Large woody debris typically gets waterlogged and sinks in the slack water habitat created by reservoirs. The little that makes it to the dam accumulates on trash racks. Small woody debris is passed downriver by TBR dam operators. For the TBR projects, other debris is typically bound together and placed in the various impoundments to attract fish and provide cover (K. Kruger, MDNR, personal communication).

Morphology

Dams may adversely affect healthy rivers and streams by altering stream and channel morphology. Natural seasonal variation in flows is healthy to river ecosystems (Petts 1984). High flows may be needed to recharge riparian wetlands as well as to invoke a fish spawning migration. Prevention of natural high flows can de-water flood plains which may be critical to some species of fish and wildlife (Petts 1984).

Dams can influence the riffle-run-pool sequence of a river. This important sequence was reestablished after removal of two outdated dams on the Muskegon River in Michigan (USGS 2002). However, temporary erosion problems were created upon removal of these dams. Obvious improvements in habitat quality occurred at upstream reaches of the Muskegon River compared to downstream reaches where quality declined, but was typically still considered good quality. Downstream river parameters typically declined and then recovered once materials were redistributed at downstream locations. This was also found to be true after removal of the Woolen Mills Dam in Wisconsin (Kanehl et al. 1997). Habitat quality was considered good to excellent five years after dam removal.

Dam and impoundment size may ultimately determine stream morphology. Lessard (2001) compared stream morphology (depth and width) upstream and downstream from a number of small dams in Michigan and found that small dams did not significantly alter these parameters between stream locations.

There are various sizes of dams in the watershed (Table 12). Many small dams and control structures exist in the upper watershed and may have little effect on creek and river morphology. The lower watershed is home to many larger dams which impound significant tracts of land. These lower impoundments disturb many miles of previous lotic habitat.

Nutrient Flow

Dams also have an effect on the natural flow of important materials such as phosphorus and nitrogen. Impoundments trap compound particles and act as a “sink” for their storage. This is especially true for phosphorus, which is readily transported downstream by rivers, especially in agricultural lands like the lower TBR watershed. Older impoundments tend to be shallower, broader, and have incoming delta-like fingers (e.g., Lake Winyah). The upper wetland-like portions of impoundments often have reduced water flow which increases phosphorus retention and decreases nutrient availability downstream.

Research on small dams has typically centered around the effects of the structure on migratory taxa and not nutrient dynamics. Lessard (2001) found that phosphorus concentrations were not significantly different at upstream locations compared to downstream locations at ten small dam sites in Michigan. Phosphorus and nitrogen levels vary throughout the TBR watershed, but were typically low and within water quality standards. The Great Lakes, however, derive much productivity from nutrients delivered via rivers over time. Impoundments tend to accumulate many of these nutrients which are destined for the Great Lakes, thus “robbing” the big lakes of their prospective nutrient budgets. This may be especially important for the upper Great Lakes which are considered oligotrophic. Coastal wetlands are directly dependent on natural river mouth sediment as well (Stanley and Doyle 2002). Reduction in nutrients delivered to coastal habitats may cause reductions in fish abundance (D. Fielder, MDNR, personal communication).

Effects of Dams on Biota

Changes in watershed characteristics (flow, temperature, channel morphology) play a major role in determining the composition of a stream biological community. Dams have the most obvious effects on fish and invertebrate populations.

Migration/Movement

The limitation of fish movement due to dams is the largest obvious human induced change to a watershed (Petts 1984; Tyler and Rutherford 2002). According to Petts (1984), fish species may become extirpated or even extinct as a result of evolutionary events, but changes induced by river impoundments have markedly increased extinction rates. Lessard (2001) explains the deleterious affects of dams on aquatic life further:

> While these dams return many benefits to society (e.g., hydroelectric power, flood control, water level regulation), they frequently have negative impacts on populations of aquatic organisms, particularly fish. Reductions in fish populations due to impoundments are well documented, and occur through a variety of mechanisms. The best-known mechanism is the reduction in upstream migration that occurs where dams do not have adequate fish passage facilities (Holden 1979; Vogel et al. 1988). Effects on fish migration are most obvious for anadromous fishes, and can severely reduce or even extirpate local populations (Brooker 1981, Ward and Stanford 1987)…. Creation of a reservoir affects river habitat in many ways, potentially impacting stream-resident fishes as well as migratory species.

Some species of fish such as walleye and brown trout are known to migrate long distances in rivers to spawn or forage (Clapp 1988; Regal 1992; DePhilip 2001). These two species are popular game fish in the TBR watershed. Smaller dams, like those common to the upper TBR watershed, may prevent species such as brook trout from migrating to suitable water temperatures at certain times of the year. Fish access to spawning habitat is blocked by dams, particularly for Great Lakes native species (lake sturgeon, walleye, and lake and brook trout) and naturalized species (steelhead, Chinook, coho, and pink salmon). These species of fish would use the higher gradient reaches of the watershed for spawning if dams were removed or fitted with passage facilities. Dams also affect drift and dispersal of invertebrate nymphs and larvae (Petts 1984; Zorn and Sendek 2001).

Using Rutherford et al. (1997) production rates, we made estimates (Table 14) for potential Chinook salmon production in the Thunder Bay River watershed. Estimates were based on dam removal, habitat availability, and river gradients > 5.0 ft/mi. (Table 8). We believe that the thermal dynamics of the TBR would make it well suited to production of pacific salmon species. These fish would most likely smolt in June and July, thus TBR water temperatures would not be a major limiting factor. This is based on the high-quality spawning substrate and appropriate river gradient available to fish above Ninth Street Dam. We estimate that the removal of Ninth Street Dam and Four Mile Dam would open up enough mainstem water up to Seven Mile Dam as to provide for the production of 300,000 young-of-year (age-0 fish; YOY) annually. The stretch of mainstem between Seven Mile and Hillman dams has lower gradient and would produce fewer Chinook salmon YOY (Table 14). However, the standard method that was used for determining gradient for each river reach (see **Channel Morphology**) (Table 8) may have underestimated gradient for this segment. Higher river gradients can be found above the Hillman Dam, with nearly 17 miles of suitable spawning habitat in relation to gradient (> 5.0 ft/mi). Production of young-of-year salmon would be greatest in the mainstem above Hillman Dam, totaling an impressive approximation of more than 485,000 YOY annually (Table 14).

Salmon production could also be significant in major tributaries to the mainstem TBR following dam removal. Opening up the North Branch TBR to migrating salmon (below Quinn Creek) would open more than 2 miles of river with a gradient > 5.0 ft/mi (Table 8). This could result in the annual production of 62,000 Chinook salmon YOY. The Upper South Branch TBR below Fletcher Pond would offer up more than a mile of suitable gradient and could yield nearly 67,000 YOY at suitable discharge values (Table 5). Nearly 230,000 Chinook YOY could be produced annually in the Lower South Branch TBR below Hubbard Lake, since nearly five river miles of appropriate water would be available following downstream dam removal (Table 14). Estimates were also made for the Wolf Creek watershed based on the assumption of dam removal in the lower mainstem TBR. Approximately 17 miles of Wolf Creek has a gradient > 5 ft/mi. This variable partnered with suitable spawning substrate could produce more than 389,000 YOY Chinook salmon (Table 14).

In total, about 1.5 million Chinook salmon YOY could be naturally produced in this watershed. This is a considerable amount of salmon production when compared to the annual Lake Huron stocking of three million spring smolts annually by MDNR Fisheries Division (D. Fielder, MDNR, personal communication). The TBR salmon estimates do not account for mortality associated with smoltification in the natural river system.

Summer young-of-year steelhead production was also estimated for two reaches of the Thunder Bay River watershed (Table 14). Most reaches are typically classified as first-quality warm water and would not be suitable to pre-smolt steelhead during critical summer months when river temperatures escalate. This would still hold true even if certain dams were removed. Thus, steelhead production was only estimated for the segments of the mainstem above Hillman Dam and in Wolf Creek. About 6,500 fall young-of-year steelhead could be produced in each reach of stream if spawning adults had access to appropriate spawning grounds (Table 14). Estimates were based on summer age-0 steelhead densities found at four lower river sites in four years at Michigan's Betsie River (Newcomb and Coon 1997). The four sites were somewhat similar in temperature, discharge, and width compared to the two Thunder Bay River watershed reaches. However, the TBR estimates do not account for normal mortality likely associated with the smolting process.

Various other small creeks to the TBR mainstem above Hillman along with cold water tributaries to Wolf Creek have great potential for steelhead production, but were not included in the estimates. Based on recent research studies at Hunt Creek, 933 YOY steelhead/acre could be produced in many smaller watershed streams by introducing steelhead to these upper reaches (Nuhfer 2002). This type of steelhead production could be expanded to streams including: Gilchrist, Brush, McGinn, Indian, Widner, Beaver, and Miller creeks.

Hay-Chmielewski and Whelan (1997) classified the Thunder Bay River as highly suitable for lake sturgeon rehabilitation. Lake sturgeon were once abundant in Thunder Bay harbor (see **History**) and probably used the Thunder Bay River for spawning. Lake sturgeon adult run sizes were estimated for the watershed based on the removal of the three lowermost mainstem dams (Seven Mile, Four Mile, Ninth Street) (Table 14). According to K. Smith (MDNR, personal communication), lake sturgeon spawning peaked in the nearby Black River at 243 ft^3/s from 2000-2002. Thus, the lake sturgeon adult run estimates were only made for the TBR reaches where April/May discharge values are typically greater than 200 ft^3/s. The discharge of the TBR can be characterized as medium (low-medium-high). Mean annual discharge of the lower mainstem near Alpena is 913 ft^3/s while mean annual discharge of the river directly above Lake Winyah is 466 ft^3/s. Zorn and Sendek (2001) estimate that 1,900 adult spawning lake sturgeon/mile could be attained in a river reach where mean annual discharge is > 1000 ft^3/s and gradient is > 5 ft/mi. These estimates were based on species and habitat relationships examined in studies by G. Whelan (MDNR, Fisheries Division records) using data from published studies (Carl 1982; Seelbach 1986; Thuemler 1985; Auer 1995; Auer 1996) and unpublished data (R. O'Neal, MDNR, Fisheries Division unpublished data). From this information, we estimated that 500 adult spawning lake sturgeon/mile could be attained in a river reach with mean annual discharge of 500-999 ft^3/s and gradient > 5 ft/mi; and 250 lake sturgeon/mile could be attained when mean annual discharge is 200-500 ft^3/s and gradient is > 5 ft/mi. Based on this and mainstem dam removal, an adult lake sturgeon run size of about 3,000 fish (Table 14) could be achieved based on available gradient and discharge in the TBR system. Spawning lake sturgeon often seek out high gradient areas with suitable substrate in lower river reaches (E. Baker, MDNR, personal communication). Thus, it is hypothesized that the TBR in the vicinity of Seven Mile and Four Mile Impoundments would offer the best lake sturgeon spawning habitat. This estimate would be dependent on re-establishing a viable spawning population in the system, either naturally or by re-stocking. The potential is high for re-establishment of a state-threatened species such as lake sturgeon in the Thunder Bay River and Thunder Bay of Lake Huron.

Thunder Bay historically sustained one of the important walleye stocks in Lake Huron and was believed to be sustained by spawning in the Thunder Bay River (Schneider and Leach 1977). A successful walleye fishery has developed in the lower TBR and Thunder Bay, and is thought to be based both on stocked and wild fish. Some fish which enter the lower river are also thought to migrate from Saginaw Bay. We estimated the potential adult walleye spring spawning run based on dam removal, availability of mainstem and main tributary reaches, appropriate discharge, and suitable substrate (Table 14). Estimates from other large Michigan rivers (Muskegon and Tittabawassee) show that 6,599 adult walleye/mi could be found in river reaches during spawning at gradients > 3 ft/mi (G. Whelan, MDNR, Fisheries Division records). Based on this, adult walleye spawning numbers would be highest in the mainstem between Hillman Dam and Seven Mile Dam followed by the lower North Branch TBR. Other river segments (Upper and Lower South branches) could realize large numbers of spawning adults (Table 14) if appropriate discharge values were attained during the migration run. Walleye estimates for these branches may be high, based on historical water flows, and thus should be interpreted with caution (Table 6). Estimates were not made for Wolf Creek and the mainstem TBR above Hillman Dam, where it is believed that discharge would be a limiting factor for this species. MDNR, Fisheries Division personnel potentially could stock fewer hatchery walleye in this river system if natural production was established at significant levels. In addition, many of the lower TBR (upstream of Lake Winyah) and tributary segments lack significant numbers of predator fish (see **Fishery Management**) and would be appropriate nursery grounds for many fish that could be produced naturally while forage remains abundant. However, the number of river-run walleye would also be dependent upon size and carrying capacity of the source (e.g., Thunder Bay, Lake Huron).

Actual abundance of salmon, trout, lake sturgeon and walleye potentially produced in the Thunder Bay River with dam removal or fish passage would vary depending on broodstock size and stream conditions; particularly flow, temperature, and substrate availability; and the productive capacity of the receiving water (Thunder Bay/Lake Huron). Unfragmented river systems are rare and have great potential for fish production and rehabilitation. This is true for the Thunder Bay River watershed. Removal of lower mainstem dams from Seven Mile Dam downstream could open up a variety of critical spawning grounds and nursery habitat including the lower reaches of the mainstem and lower North Branch TBR. The mainstem upstream of the Seven Mile Dam would give migrating fish access to Speehley Rapids. According to FERC (1996), this reach of river has significant potential spawning habitat. This reach is two miles long and provides about 1,700,000 square feet of high-quality habitat for resident and migrating fishes (FERC 1996). We found gradient to be less suitable for this river reach compared to other segments (see **Channel Morphology**; our technique underestimated high-quality gradient mileage in this reach), but production and run sizes of various species of fish in this and other reaches was still significant based on our calculations. Estimates from Table 14 were for the mainstem and major branches including Wolf Creek when applicable. We did not fully consider potential fish production (salmon and steelhead) in important cool water (e.g., Bean, Beaver, and King creeks), and cold water (e.g., Hunt, Gilchrist, Brush, Widner, and Little Wolf creeks) tributaries.

Dam removal could also enable undesirable species (e.g., sea lamprey, round gobies) to access the upper river. Thus management would be needed to prevent establishment. Steelhead and salmon could also affect naturalized headwater species (see **Biological Communities** and **Fishery Management**) such as brook and brown trout, through competitive interactions (Kruger et al. 1985; Ziegler 1988). Studies indicate that brown trout numbers were suppressed in Hunt Creek as a result of experimentally transplanted steelhead and their offspring (Nuhfer 2002). However, cold water trout streams might remain segregated by selective retention of certain dams to limit lake-run spawning fishes to the mainstem and cool or warm water tributaries.

Human-made and natural barriers significantly reduce sea lamprey spawning potential in Great Lakes tributaries (Lavis et al. 2003). The authors acknowledge that species diversity is typically greater below barriers. Dam removal could enhance species richness upstream, yet simultaneously enable sea lamprey access to more spawning grounds. The U.S. Fish and Wildlife Service (USFWS) oversees sea lamprey control in Michigan by using barriers, lampricides, and stocking sterile males. The agency does not recommend building sea lamprey barriers in the future if: the barrier reduces populations or limits recovery of species classified as endangered or threatened by state or federal agencies; or if the barrier could cause loss of species richness in the watershed. However, where these adverse effects can be avoided, the USFWS is pursuing construction of new sea lamprey barriers in lieu of chemical treatment, including new barrier construction if an old dam serving as a barrier is removed (S. Hanshue, MDNR, personal communication).

Lavis et al. (2003) relate dam removal to sea lamprey invasion:

> The current movement toward dam removal and fishway construction without regard to sea lampreys could result in additional habitat becoming available to sea lampreys. The loss of one or two large dams could easily overshadow the gains made through all the purpose-built sea lamprey barriers to date.

Removal of dams and invasion of sea lamprey into the Thunder Bay River watershed could also have costly consequences.

> We did an estimate in 1989 of what it would cost to treat the Thunder Bay River with all dams removed, based on mean annual flow, water chemistry, and the cost of lampricide and labor. Updated with today’s prices, I estimate conservatively that a treatment would cost about $420,000 and would have to be repeated every four years. (E. Koon, U.S. Fish and Wildlife Service, personal communication)

It is understood that upstream migration of invasive species such as sea lamprey would be a concern following possible TBR dam removal and/or barrier replacement. However, lamprey barrier placement is not a good option when and where it will impede migration of important lake-run spawning fishes, especially if they are a threatened species such as lake sturgeon. The benefits of opening up a large river system such as the TBR to lake-run spawning fish would be highly beneficial both recreationally and economically and would far outweigh the cost of possible lamprey invasion.

Dams can also prevent fish movement downstream. This may hinder a fishes ability to take advantage of seasonally available habitat or food resources. Fragmentation of habitat may also result in remnant populations and lower species diversity. Barriers to fish movement can hinder population mixing between river (Thunder Bay River) and lake (Lake Huron) fish populations.

Four operating hydroelectric dams exist in the TBR watershed and prevent upstream migration of various species of fish. Fish ladders would be an alternative at these power dams, yet most ladders have proven unsuccessful and would need to consider unwanted species. In fact, fish chutes were historically constructed on many large dams in the TBR watershed. These original chutes did not effectively pass fish upstream. Fish ladders are still fairly ineffective today, especially for non-jumping fish such as lake sturgeon and walleye. However, if properly designed, fish ladders can allow fish to move from a riverine environment directly into the impounded upstream reaches. Despite this, high gradient and high-quality river reaches that lie beneath impoundments (Lake Winyah and Four Mile) are not restored if only fish ladder placement is accomplished. In addition, young and adult fish that migrate downstream need to be passed alive through the ladder and dam turbines.

Many studies involving fish mortality at hydroelectric stations have been conducted, often with conflicting results (Gibson and Myers 2002). Acute mortality is often determined, but long-term mortality often goes unassessed. According to Petts (1984), mortality of juvenile fishes through hydroelectric power dams and their associated turbines has been reported at 10-40%. Consequently, fish passage over low-head dams or high-head dams associated with deep plunge pools is often safer (Petts 1984).

Navarro et al. (1996) discuss fish mortality issues associated with hydroelectric and other facilities:

> Mortality from passage through hydroelectric turbines results from various factors, including blade strikes and internal damage from the negative pressure, cavitation, and turbulence produced within turbines (Turbak et al. 1981; Bell and Kynard 1985; Kidder 1985; Taylor and Kynard 1985; Cada 1990); bioenergetic demand and physiological stress from passage (Kao 1985); delayed downstream migration and increased predation of stressed fish by opportunistic feeders in the tailwaters (Mundie 1991; Wood 1993); and gas supersaturation from water spillage aeration (Ebel 1969). Turbine mortality studies, mainly in Wisconsin and Michigan, showed that mortality averaged 6% (EPRI 1992) and depended on the physical characteristics of the facility and fish morphology. In contrast, mortality of fish moving through reservoir spill has been documented at less than 3% (Schoeneman et al. 1961; Bell and Delacy 1972). A study of fish from spill at low-head, non-power-producing facilities in northeast Michigan indicated that there was no mortality (< 24-h) resulting from passage (Navarro and McCauley 1993).

Navarro et al. (1996) conducted a turbine fish passage study at four hydroelectric dams along the Thunder Bay River. Their goal was to determine: fish composition and size structure of fish moving through turbines; time and seasonal movement patterns of fish in relation to turbines; and fish mortality. Study sites during the early 1990s included Hillman Dam (river mile 39), Seven Mile Dam (river mile 6), Four Mile Dam (river mile 5), and Ninth Street Dam (river mile 1). Acute mortality was determined for one representative turbine at each facility. Number and types of fish collected over a one-year period at one turbine for each facility is listed in Table 15. This includes both alive and dead fish.

The authors found that the majority of fish passage through the facilities was at the Ninth Street Dam (62%) (Table 15) and was dominated by young yellow perch and white suckers. Hillman Dam passed (alive and dead) the most fish species (41) followed by Ninth Street Dam (40), Seven Mile Dam (31), and Four Mile Dam (29). Most fish passing through the turbines were minnows, followed by bullheads. Northern pike passed more frequently through the two upper dams, while walleye passed more frequently through the turbines at the lower dams. Relatively large numbers of fish from the sunfish family (smallmouth, largemouth, and rock bass) passed through the turbines (Navarro et el. 1996).

Navarro et al. (1996) further discuss fish composition, size structure, and seasonality in relation to turbine passage on the Thunder Bay River:

> The percent of sport fish (i.e., trout, northern pike, smallmouth bass, largemouth bass, walleye, rock bass, crappies, sunfish, and yellow perch) passing through the turbines

> varied by facility. Four Mile Dam had the highest percent composition of sport fish with 56%, followed by Ninth Street Dam (50%), Hillman Dam (16%), and Norway Point Dam (5%). A smaller percentage of the fish passing through the turbines were creel-sized sport fish. Four Mile Dam, where 15% of the fish passed were creel-sized sport fish, was the only facility with a percent composition of creel-sized sport fish greater than 3%. A majority of the fish passing through the turbines was also small, and these fish were primarily yellow perch, white suckers, minnows, darters, and age-0 bullheads. The passage of smaller sport fish would affect recruitment, and the passage of other small fish would affect the forage base both upstream and downstream of the facility.
>
> Typically, the greatest number of fish passed through the turbines in spring and early summer when water temperatures gradually increased to within the range of several species' spawning temperatures.

The authors discuss fish mortality associated with passage through the TBR hydroelectric facilities:

> A comparison of mortality for the same-sized minnows and bullheads at Norway Point and Four Mile dams indicated that the more delicate species (minnows) had higher mortality. Size was also a factor affecting mortality in our studies; smaller fish suffered the highest mortality…
>
> Mortalities of the primary sport fish at all facilities combined were similar, averaging 19% for bass and 18% for walleyes. Mortality of bass was highest at Ninth Street Dam (33%), followed by Hillman Dam (9%), Norway Point Dam (2%), and Four Mile Dam (0.4%). Mortality of walleyes was also highest at Ninth Street Dam (37%), followed by Hillman Dam (19%), Norway Point Dam (12%), and Four Mile Dam (11%).

Navarro et al. (1996) agree that turbine mortality of certain game fish is an important issue associated with TBR hydroelectric facilities. They also believed that acute mortality associated with the TBR turbines was low. The authors of this assessment believe the cumulative result of acute mortality for each turbine and dam may have a serious effect on TBR and Thunder Bay fish populations. Another affect on fish populations associated with hydroelectric facilities is the possibility of latent fish mortality. This mortality is well masked and could result from delayed mortality associated with turbine passage, or from displacement into sub-optimal habitat (Navarro et al. 1996).

Perched and poorly designed culverts in the TBR watershed are another common hindrance to upstream fish passage. Perched culverts are defined as culverts where the water surface downstream is lower than the base of the culvert. Fish attempting to move upstream through such culverts must jump to gain entrance to the culvert. Hence, young fish and species with poor jumping ability are unable to pass upstream through these structures and may be excluded from habitats needed for spawning, thermal refuge, or other life history requirements. The road-stream crossing inventory made by NEMCOG (2002) identified at least 3 perched culverts in the TBR watershed, and another 18 that were considered a hindrance to fish movement. These culverts should be replaced with properly designed and installed road-stream crossings that do not restrict upstream fish movement.

Aquatic Community

Dams change aquatic communities. This is true for fish as well as algal, macroinvertebrate (The Academy of Natural Sciences 2002) and plant communities. These changes may be for various reasons already mentioned, such as, prevention of natural migrations or ecosystem changes.

Macroinvertebrates are dependent on the natural seasonal variations of discharge (Petts 1984; Poff and Allan 1995). Invertebrate life cycles are related to thermal cues. Warming of water through impoundments can alter these life cycles and lead to community changes. According to Petts (1984), dams that do not operate on a run-of-river mode have both a direct and indirect effect on invertebrates. Fluctuating flows reduce benthos diversity and densities, while low flows associated with water retention can eliminate primary producers which are fed upon by the invertebrate assemblage. Invertebrates must also adapt to excessive and rapid changes in water levels associated with dams. High flows can flush invertebrates from localities. Fluctuating flows may not be a large problem with invertebrate communities in the TBR watershed below the larger hydroelectric dams since they are mandated for run-of-river operation (see **Special Jurisdictions**).

Small dams may have less of an effect on invertebrate populations. Lessard (2001) found that macroinvertebrate diversity was not significantly different at downstream reaches compared to upstream reaches at nine of ten small dams on Michigan streams. Macroinvertebrate taxa did change after removal of a low-head dam on a river in Wisconsin (Stanley et al. 2002). Diversity at upstream (previous reservoir environment) and downstream river sites were similar after dam removal.

Macroinvertebrate communities were assessed at 15 sites in the TBR watershed in 2000 (Taft 2003) (see **Water Quality**). Most of the sites had “acceptable” invertebrate numbers and diversity whereas five of the sites scored “excellent” for invertebrates. One “excellent” site was upstream of Eichorn Bridge on the mainstem a few river miles below the Atlanta Pond Dam. This impoundment significantly warms the mainstem, yet a high-quality (diverse invertebrate populations which are sensitive to environmental perturbations) and quantity of invertebrates were collected at this location.

Dams may lead to a variety of changes to stream fish populations. Lessard (2001) explains how shifts in fish community structure may be associated with shifts in water temperature:

> Increases in stream temperature may shift the temperature out of the range that a given species is genetically adapted to. Cold water stenotherms are genetically adapted to interact, feed grow and survive better in colder temperatures (Carlander 1969; Allan 1995). They have also evolved to exploit the food sources provided by these colder habitats which are typically cold adapted macroinvertebrates and other fish (Allan 1981; Hubert et al. 1993; Rader 1997). Thus, increases in temperature can not only affect their internal physiology but also their food source.

Fish species richness is typically higher below dams (Lessard 2001). Dodd (1999), however, found that this elevated species richness typically declines further downstream from the dam, eventually returning to a level found above the dam. In studying effects of ten small dams in Michigan, Lessard (2001) found that sculpin species, brown trout, and particularly brook trout were often eliminated below dams as a result of increased water temperatures. Thus, dam location was less important than the habitat changes created by dams.

Impounded portions of a watershed often do not reflect typical riverine fish assemblages. This may be true for various impounded reaches in the TBR watershed such as Fletcher Pond. However, an impoundment such as Fletcher Pond provides a popular recreational fishing opportunity. In addition, much of the upper TBR mainstem would still have cool water temperatures (as compared to cold water) regardless of dam removal. For the TBR watershed, dams significantly change fish communities by blocking upstream, and to some extent downstream, fish migration.

Dam Removal

State, local, and private agencies continue to deal with the ongoing burden of dam maintenance and removal as well as their ecological effects. Impounded streams often thwart attempts at biological river restoration efforts (Doyle et al. 2000). Consequently, dam removal is considered the primary tool for restoration of a rivers biological integrity. According to Nelson (WDNR, personal communication), dams are removed in Wisconsin for reasons including: safety issues; question of ownership; and negative environmental effects. It was found that dam removal was much less costly than dam repair. Doyle et al. (2000) also found this to be true. Most Michigan dams are privately owned. State, local, and private groups will need to address the numerous declining dam structures in the Thunder Bay River watershed. The cheapest solution (removal) may be the most enticing while simultaneously restoring free-flowing systems and opening up rivers to fish passage. According to Doyle et al. (2000), most dam removals have occurred on small run-of-river and non-hydroelectric operations. Some small dams have significant historical value to local communities and often provide coveted waterfront properties. This may be true for the Thunder Bay River watershed communities of Atlanta, Hillman, and Alpena. However, some of these “increased values” may only be perceived and complete river restoration can have an even more positive affect on local property values (S. Hanshue, MDNR, personal communication).

There are 73 dams in the Thunder Bay River watershed. These structures come in all shapes and sizes, (Table 12) including lake-level control structures, small dams on upper watershed tributaries, and large hydroelectric facilities in the lower watershed. Specific resource effects of most of these dams have not been evaluated. These dams are barriers to free migration of aquatic organisms and organic matter, as well as human navigation. Along with the biological benefits gained from dam removal, unimpounded rivers offer additional opportunities for recreation including canoeing, kayaking, and drift boating.

Water Quality

General Water Quality, Point and Nonpoint Source Issues

Water quality in the Thunder Bay River is influenced by point- and nonpoint source inflows and atmospheric deposition. Water quality in the basin is generally good, as determined by evaluations summarized below.

Point source pollutants, from sources such as factories and wastewater treatment plants, reach the river from designated outfalls or discharge points. Point source discharges are regulated by National Pollution Discharge Elimination System (NPDES) permits. The Michigan Department of Environmental Quality (MDEQ), Water Division has federally regulated authority to administer the NPDES permit program in Michigan. There are six permitted point source discharges (Table 16). In addition, there are 26 industrial storm water NPDES discharge permits in the Thunder Bay River watershed (Table 17). These storm water permits require the facility to submit a storm water pollution prevention plan and focus more on site management than point source treatment (R. Shoemaker, MDEQ-WD, personal communication).

Nonpoint source pollutants such as nutrients, sediments, and pesticides reach the river and its tributaries through runoff and erosion. Higher concentrations of some of these pollutants may enter the water at poorly designed road-stream crossings or eroding stream banks. Stream bank erosion sites and road-stream crossings were inventoried in 2000 (see **Soils and Land Use**).

Air transport from distant sources also contributes pollutants to the watershed when the contaminants are carried in the atmosphere from areas outside the basin, as well as from local land sources. These pollutants may then be deposited via precipitation and eventually show up in TBR watershed and Lake Huron. Mercury is an example of this type of pollutant.

In a biennial report to the Environmental Protection Agency (EPA), MDEQ reported that 98% of the assessed portion of the Thunder Bay River watershed met Michigan Water Quality Standards (Wolf and Wuycheck 2002). Of the 712 river miles assessed, 15 were cited as needing further site evaluation, while only 1 river mile was classified as not meeting water quality standards. This latter section is the last mile of river (from the mainstem confluence at Thunder Bay upstream to Ninth Street Dam), and fails to meet standards because of the influence of Lake Huron fish that migrate from the lake (J. Wuycheck, MDEQ-WD, personal communication). Fish consumption advisories are one measure of water quality standard attainment. Lake Huron has fish consumption advisories for some species based on PCBs, dioxin, and chlordane. In addition, several lakes in the Thunder Bay River watershed do not meet water quality standards, as discussed below.

Measures of Water Quality

MDEQ Procedure 51 Monitoring

MDEQ-Water Division surveyed the Thunder Bay River watershed most recently in 2000. Water quality surveys were conducted using Qualitative Biological and Habitat Survey Protocols for Wadable Streams and Rivers (Procedure 51, MDEQ-Water Division 1997). Fish and macroinvertebrate communities, instream and streamside habitat, and water quality were evaluated. A total of 22 sites were assessed in the 2000 MDEQ survey, with all meeting Michigan Water Quality Standards (Taft 2003).

Macroinvertebrate community composition was assessed at 15 sites. Ten of these locations had macroinvertebrate communities that were rated acceptable, while five were rated excellent. Macroinvertebrates such as mayflies, stoneflies, and caddisflies are important indicators of water quality because they have a long life history and are intolerant of pollution and low dissolved oxygen. Three orders of insects are often grouped together and termed EPT for their scientific names (mayflies–Ephemeroptera, stoneflies–Plecoptera, caddisflies–Trichoptera). All stations had 23-41 total taxa (Taft 2003) while the EPT taxa were represented at all stations. For those stations that ranked ‘excellent’, 35-54% of the taxa were in the EPT orders. Locations that had excellent macroinvertebrate communities include: Thunder Bay River at Eichorn Bridge (Montmorency County); Sage Creek at County Road 487 (Montmorency County); Thunder Bay River at M-32 (Montmorency County); Upper South Branch TBR at Turtle Lake Hunt Club (Montmorency County); and Wolf Creek at Beaver Lake Road (Alpena County). These latter locations can be found higher in the watershed. For more information on the aquatic macroinvertebrate community of the Thunder Bay River, refer to the **Biological Communities** section.

Water Chemistry

Water chemistry samples were collected at 22 locations (Tables 18a and 18b). Three of the sites (Table 18b) had a more comprehensive water chemistry analysis. Chemistries were evaluated in conjunction with biological and habitat evaluations. Total phosphorus ranged from 0.008 to 0.23 milligrams per liter. As expected, higher (yet acceptable) levels were found in wetland or agricultural drainages (e.g., Smith Creek, Anchor Creek, and North Branch TBR). One of the locations (TBR at Second St.), had much higher phosphorus levels, but this sample site was located downstream of a permitted discharge. No toxic chemicals were found at levels of concern (Taft 2003).

MDEQ, Water Division also administers a water chemistry program for trend monitoring purposes. One trend site is located on the Thunder Bay River mainstem at Bagley Street, in Alpena Township (Table 19). Water chemistry samples are collected at least four times annually. Analytes include nutrients and conventionals; base/neutral organics; methyl tert-butyl ether (MTBE); benzene, toluene, ethylbenzene, and xylene (BTEX); mercury and trace metals; and chlorinated organic bioaccumulative chemicals of concern such as PCBs (Aiello and Smith, 2002). Concentrations of mercury and select indicator trace metals were all within water quality standards in 2000 and 2001

(Table 19) (Aiello 2002 and 2003). Note that the Rule 57 water quality value for trace metals may change from year to year, as this value is a function of water hardness.

Individual mercury concentrations are listed in Table 20. Mercury levels exceeded the water quality value four times (out of 11 samples) in 1998 (Table 20). Despite this, median concentrations of total mercury, total phosphorus, and total suspended solids in the Thunder Bay River were among the lowest of the 18 Great Lakes tributaries sampled that year (Aiello and Smith 2002). Mercury levels were within the water quality standards in 2000 and 2001 (Aiello 2002 and 2003).

The USGS collected water quality samples from the Thunder Bay River immediately downstream from the Four Mile Dam from October 1979 to August 1993. The total number of samples collected was 129, including analysis of nutrients, major inorganics, minor and trace organics, radiochemicals, and sediment. These data are available on the USGS website (USGS 1993).

Temperature and Dissolved Oxygen Issues

Temperature and dissolved oxygen in the Thunder Bay River are influenced by the 73 dams in the system. Dams can increase water temperature and decrease dissolved oxygen concentrations. The federally-licensed Thunder Bay River hydroelectric projects have generally demonstrated compliance with dissolved oxygen and temperature requirements (Kyle Kruger, MDNR, personal communication). Because of the warm water designation for much of the watershed, the dissolved oxygen limit for the projects is five parts per million. There occasionally have been high temperature problems below Upper South Dam (Fletcher Pond), but these are due to the shallow nature of the impoundment, which precludes cold water draw. For more information on dams in the Thunder Bay River watershed, see the **Dams and Barriers** section.

Fish Contaminant Monitoring

The MDEQ also monitors chemical contaminants in fish from waters throughout the State of Michigan. Data from this program are evaluated by MDEQ and the Michigan Department of Community Health (MDCH). Appropriate fish consumption advisories are then issued by MDCH on a species and water body basis.

> Mercury consumption advisories have been issued statewide for piscivorous (fish-eating) fishes common to lakes and reservoirs in the state. Mercury is highly toxic to aquatic organisms and very persistent in the environment. The methyl form of mercury is most common in fish, and bioconcentration factors from water to fish range between 1,800 and 85,000 (O'Neal 1997). Long-term ingestion of mercury-contaminated fish can produce symptoms such as numbness of extremities, tremors, spasms, personality and behavior changes, difficulty in walking, deafness, blindness, and death. Mercury levels in Michigan fish tend to be higher in larger, fattier fishes of inland lakes than fishes in streams" (Michigan Department of Community Health 1998).
>
> Mercury can enter water bodies from point-source discharges, nonpoint source runoff, or atmospheric deposition… Total mercury discharge to Michigan's surface or groundwaters in 1991 was between 200-1800 pounds (Anonymous 1996). Atmospheric emissions of mercury in Michigan range from 8,400 to 10,400 pounds per year (Anonymous 1996). Most emissions are deposited within 622 miles of the source. Electric utility coal combustion (41%), municipal waste incineration (28%), hospital waste incineration (9.4%), and industrial and commercial coal combustion (6.5%) compose the bulk of air emissions of mercury in Michigan. Disposal of mercury in the

> municipal and commercial solid waste stream was estimated at 3,750-3,800 pounds in 1985 (Anonymous 1996). Sources include: lamp manufacturing and breakage; electrical switches; batteries; thermostats; lab use; and dental amalgam preparation (Zorn and Sendek 2001).

A general fish consumption advisory for mercury exists for all Michigan inland lakes. Several lakes in the Thunder Bay River watershed were specifically identified as exceeding standards because specific mercury concentration data are available (R. Day, MDEQ-WD, personal communication). Beaver Lake and Lake Besser (Alpena County), and Hubbard Lake (Alcona County), were reported to the EPA as not meeting water quality standards due to high mercury concentrations found in fish from those lakes (Creel and Wuycheck 2002).

Fish consumption advisories exist for the following Lake Huron fishes: brown, lake, and rainbow trout, burbot, Chinook and coho salmon, and lake whitefish. All these fishes have elevated PCB concentrations. Dioxins are linked to advisories for lake trout, rainbow trout, and lake whitefish. Chlordane was also linked to the lake trout advisory. There are also advisories for walleye (PCBs) and carp (PCBs, dioxin) in Thunder Bay of Lake Huron (Michigan Department of Community Health 2002).

> PCBs are relatively insoluble, persistent, readily bond to organic matter, and have a high bioaccumulation potential (O'Neal 1997). They are commonly detected in the tissue and eggs of fish-eating birds, and have been shown in studies of laboratory animals to suppress the immune system and damage the liver, stomach, kidneys, and thyroid… PCBs were once widely used in various products, including electrical transformers and capacitors, carbonless copy paper, plasticizers in plastic and rubber products, and hydraulic fluids (Science Applications International Corporation 1993). Their high stability contributed to their commercial usefulness and long-term, detrimental environmental and health effects (O'Neal 1997). In 1982, the United States Environmental Protection Agency (EPA) restricted their use to electrical equipment, though use of PCB transformers and large capacitors could continue in limited access areas until they were worn out (Zorn and Sendek 2001).

Stream Classification

In 1967, the MDNR Fisheries Division classified streams throughout the state based on temperature, habitat quality, size, and riparian development. River classification assists with establishing water quality standards for Michigan streams; assessing stream recreation values; designating "wild and scenic" rivers; administering stream frontage improvement and preservation; identifying dam and impoundment problems; administering fishing and boating access; targeting fishing regulations; determining designated trout streams, and guiding riparian land acquisition. Most of the TBR system is classified as top-quality warm water based on this classification scheme (Figure 21). Top-quality warm water contains good populations of warmwater game fish (Anonymous 2000). Many TBR headwater tributaries are top-quality or second-quality cold water streams. Top-quality cold water streams contain good self-sustaining trout or salmon populations, while second-quality cold water streams contain significant trout or salmon populations, but these populations are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution (Anonymous 2000).

Special Jurisdictions

Many federal, state, and local rules are associated with protection of the Thunder Bay River watershed.

Federally Regulated Dams

Six hydroelectric related dams within the Thunder Bay River watershed were relicensed by the Federal Energy Regulatory Commission (FERC) for a 40-year period beginning in 1998. Four of these dams are located along the mainstem, one along the Upper South Branch, and one on the Lower South Branch. The dams are owned by the Thunder Bay Power Company (TBPC) under two separate hydroelectric projects. This includes the Hillman Dam project (Hillman Dam) and the Thunder Bay River project (Ninth Street, Four Mile, Seven Mile, Hubbard Lake, and Upper South Dams). The recent agreement combined all the aforementioned dams under one license (Project 2404) with a proposed total power generating capacity of 8,050 kilowatts (FERC 1996).

The Federal Energy Regulatory Commission provided for review and consideration of any natural resource issues associated with the relicensing process. Various resource agencies and stakeholder groups worked many years studying the effects of these dams on the Thunder Bay River system. Some entities commented during the scoping meetings (Federal Energy Regulatory Commission, 1996). The groups included: Michigan Department of Natural Resources, United States Department of Interior Fish and Wildlife Service, Hubbard Lake Sportsmen and Improvement Association, Seven Mile Impoundment Association, Michigan Hydropower Relicensing, Hubbard Lake Information Center, and Thunder Bay Power Company.

The final agreement, or Settlement Offer, between the aforementioned groups for the two hydroelectric projects is included in Appendix 1. Money was placed in escrow ($1,000,000), as a result of this settlement, to provide for mitigation of resource damages caused by hydroelectric dams. The escrow amount provided the sole source of funds from Thunder Bay Power Company for: 1) upstream fish passage; 2) downstream fish passage and protection; 3) fish entrainment; 4) recreation, except maintenance of recreation sites owned by TBPC; 5) land management; 6) wildlife management; 7) Bald Eagle protection and management; 8) nuisance plant control; 9) aquatic habitat improvement except passing large woody debris and remediation of stream bank erosion; and 10) project retirement. Other activities that could be funded by the TBPC upon fund exhaustion include: 1) compliance monitoring and water quality monitoring; 2) remediation of stream bank erosion; and 3) maintenance of recreation sites owned by TBPC (Appendix 1).

Thunder Bay Power Company is fully responsible for costs related to: 1) operation of each hydroelectric project under run-of-river mode under specified time periods; 2) operation of each hydroelectric project to maintain impoundment water levels established in the settlement; 3) operation of each hydroelectric project to maintain storage reservoir discharge and minimum flow criteria established in this settlement; 4) passing large woody debris collected on log booms and trash racks; 5) remediation of any pollution created by each hydroelectric project; 6) maintenance of specified water quality standards; and 7) any additional FERC license requirements. The escrow amount is independent of the previous Thunder Bay Power Company responsibilities (Appendix 1).

Dredge and Fill Activities

The Thunder Bay River in Alpena County is a Section 10 (Federal Rivers and Harbors Act) river with jurisdictional ending at Ninth Street Dam. Authorization is thus required from the U.S. Army Corps of Engineers for any work or construction waterward of the Ordinary High Water Mark (U.S. Army Corps of Engineers, personal communication)**.**

MDEQ has authority to regulate development activities affecting lakes, streams, or wetlands under the Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, parts 301 and 303. Part 301, Inland Lakes and Streams, gives authority to the state to regulate certain activities including: dredge or fill of bottom lands; construction, enlargement or removal of structures on bottomlands; marina construction and operation; creation, enlargement or diminishing an inland lake or stream; construction or dredging in wetlands within 500 feet of the ordinary water mark of an existing inland lake or stream; and connecting any natural or artificial waterway with an existing body of water. Part 303 provides measures for wetland protection and provides the state with authority for regulating certain activities within wetlands including: placement of fill materials into a wetland; dredging or removal of soils from a wetland; construction within a wetland; or draining surface water from a wetland.

Contaminated Sites

The Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 201, Environmental Response, MDEQ, gives the state the authority to identify sites of environmental contamination; to request liable parties to take response action for site cleanup; and to prioritize contaminated sites for state funded cleanup. As of August 2002, 31 sites have been identified in the Thunder Bay River watershed or inner Thunder Bay harbor (Table 21**)**. Two sites are under closed status meaning there are no further restrictions from MDEQ. No remediation has occurred at 14 sites. The remaining 15 sites are still active, meaning they are under current investigation or in the process of remediation.

Blue Ribbon Trout Stream Classification

The Blue Ribbon Trout Stream Program, administered by the Michigan Department of Natural Resources Fisheries Division, recognizes some of the states' best trout streams. These streams must meet certain standard criteria including: support excellent stocks of wild, resident trout; be large enough to permit fly fishing, but shallow enough to wade; produce diverse insect life and good fly hatches; have earned a reputation for providing a quality trout fishing experience; and have excellent water quality (MDNR, Fisheries Division records). Management of Blue Ribbon Trout Streams is directed toward providing the needs of trout anglers through: protection of wild trout stocks; protection and enhancement of trout habitat; maintenance of the natural stream environment; and providing adequate public access. The Thunder Bay River drainage contains 18 miles Blue Ribbon Trout water, including 10 miles of Hunt Creek and 8 miles of Gilchrist Creek.

Designated Michigan Trout Streams

Many additional streams are classified as Designated Trout Streams, by order of the Director of MDNR (Table 22; Figure 23). These are defined in the Michigan Inland Trout and Salmon Guide as "any stream so designated which contains a significant population of trout or salmon".

Sport Fishing Regulations

The Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 487, Sport Fishing, gives the State of Michigan the authority to regulate the take of fish, mollusks, amphibians, and reptiles. Along with this authority comes the right to establish harvest levels and sizes. MDNR, Fisheries Division is responsible for the designation of trout streams. Trout streams are regulated as cold water or warm water streams under Michigan Surface Water Quality Standards. MDNR, Fisheries Division regulates trout streams and trout lakes under special fishing regulations specified in the Michigan Inland Trout and Salmon Guide. Regulations for other species are specified in the Michigan Fishing Guide.

Inland Lake Levels and Dams Regulated Under State Dam Safety Standards

The Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 307 outlines the process involved in establishing a legal inland lake level. The local circuit court typically establishes a legal lake level with social and economic considerations. Legal lake levels have been established at ten lakes within the watershed: Beaver; Avalon; Avery; Crooked; DeCheau; Grass; Long; Rush; Lake Inez; and Atlanta Dam Pond (J. Pawloski, MDEQ, personal communication).

The Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, gives the State of Michigan MDEQ the authority to regulate: dam construction, removal, and alteration; water quality associated with dams; and dam operation, including those dams regulated under the Federal Powers Act, chapter 41. Federal dam safety regulations supercede state dam safety regulations on FERC licensed dams. Part 315 (Dam Safety) of Public Act 451 specifically regulates dams impounding five or more acres and having a dam height greater than six feet. Twenty-six dams in the Thunder Bay River watershed are regulated under this act.

Navigability

Issues associated with public rights on Michigan waters including navigability are discussed in detail (Anonymous 1997). Water law issues are complex and are established through both legislative and judicial action. The MDNR, Law Enforcement Division generally considers all water bodies as navigable unless otherwise determined by a court. A navigable inland lake is any lake accessible to the public via publicly-owned lands, waters or highways contiguous, or via the bed of a navigable stream, and which is reasonably capable of supporting a beneficial public interest. Yet no public rights exist if the riparian landowners of a “dead end” lake object. A navigable inland stream is defined as 1) any stream declared navigable by the Michigan Supreme Court; 2) any stream included within the navigable waters of the United States by the U.S. Army Corps of Engineers for administration of the laws enacted by congress for the protection and preservation of the navigable waters of the United States; 3) any stream which floated logs during the lumbering days, or a stream of sufficient capacity for the floating of logs in the condition which it generally appears by nature; 4) any stream: having an average flow of approximately 41 ft^3/s; an average width of some 30 feet; an average depth of about one foot; capacity for floating during spring seasonal periods; used for fishing by the public for an extended period of time; and stocked with fish by the state; 5) any stream which has been or is susceptible to navigation by boats for purposes of commerce or travel; 6) all streams meandered by the General Land Office Survey in the mid 1800s.

The right to public use of navigable waters includes the right of trespass upon the submerged soil, but not the adjacent uplands. The public also has the common right of fishing in navigable streams, and is subject to state regulations according to the MDNR, Law Enforcement Division (Anonymous 1997).

The following reaches of the Thunder Bay River watershed have been adjudicated navigable:

1. United States in United States Army Engineering District, Detroit, 1981
   - Thunder Bay River, Dam near upper city limits of Alpena
2. Michigan Supreme Court, navigable by judicial determination, “common right of fishing”
   - Thunder Bay River, Alpena County, downstream from Trowbridge Dam (1875 case)
   - West Branch Creek, Alcona County, 5 miles up from Hubbard Lake (1884 case)
   - Hubbard Lake, Alcona County (1884 case)
3. Michigan supreme court, indicated navigable by judicial determination, (floating log history)
   - Butterfield Creek, Alcona County, seasonally navigable (1884)
   - Brown Creek, Alcona County, seasonally navigable (1884)
   - Comstock Creek, Alcona County, seasonally navigable
   - Main Creek (West Branch), Alpena County, downstream to Butterfield Creek (1886)
   - Thunder Bay River, Alpena County, downstream from section 31 and 32, T32N, R7E (1886)
   - Thunder Bay River, North and South Branch (1886)
   - Thunder Bay River, South Branch (1921)
   - West Branch (Main Creek), Alpena County, downstream from Butterfield Creek (1886)
   - Hubbard Lake, Alcona County, (1921)

Water Quality Regulations

The State of Michigan administers the Federal Water Pollution Control Act (Federal Clean Water Act, Section 404) under the Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 31. Under Part 31, the State has the authority to protect and conserve the TBR water resources and to control pollution of surface or underground waters through the administering authority of the MDEQ.

Local Government

Local units of government have authority to create and implement special ordinances and zoning restrictions that may have an effect on the watershed. County road commissions can influence the amount of sedimentation that infiltrates watershed lakes and streams from roads and road ditches. The county drain commissioner is responsible for maintenance of all legally established county and intercounty drains (Act 40, Public Acts of 1956) which may include an open ditch, swale, stream, underground pipe, or retention pond that transports storm water. Additional duties include managing and financing drain construction projects (Northeastern Michigan Council of Governments, unpublished data). There are two designated drains in the Thunder Bay River drainage area near the town of Alpena. One is the Genshaw Drain which was established in the early 1900s. The other is a small unnamed drain, or drainageway, which is associated with an urban subdivision.

Major Public and Private Landowners

Roughly 25% of the Thunder Bay watershed is managed as state and federal forests. Twenty-two percent of the watershed is in the state of Michigan’s Mackinaw State Forest while 2% is in the Au Sable State Forest. One-percent of the watershed is in the United States Forest Service’s Huron-Manistee National Forest (MDNR, Spatial Information Resource Center, unpublished data). State forest management practices which include land use, timber production, and recreation are planned by the MDNR, Forest Management Division. This planning process allows for comment from various agencies and the public (Zorn and Sendek 2001). The intent of the USFS Huron-Manistee National Forest's Land and Resource Management Plan is to provide direction for multiple use management and the sustained yield of goods and services in an environmentally sound manner (United States Department of Agriculture, Forest Service 1986). For information on this plan, contact the USFS, 1755 S. Mitchell Road, Cadillac, MI 49601.

The Thunder Bay Chapter of the Audubon Society, which manages more than 7,000 acres of land in Montmorency and Alpena Counties: 1) promotes among the people of northeastern Michigan an interest in native birds and wildlife; 2) promotes conservation of wildlife and natural beauty of northeastern Michigan; 3) and cooperates with other organizations to conserve all natural resources. The land encompasses most of Fletcher Pond and its bottomlands.

Biological Communities

Original fish communities

Very little information is available regarding the original fish community of the Thunder Bay River. Madison and Lockwood (2004) provide an overview of the fish colonization of the Great Lakes region:

> The glacial activity that shaped Michigan and the [Thunder Bay River] watershed also played an important role in re-populating the area with numerous fish species. The Great Lakes region has 153 species of native fish. Presence or absence of each species varied throughout glaciation. Connecting glacier-free refugia served as sources for re-population following glacial retreats. Three such areas of particular importance to the Great Lakes region were the Bering, Atlantic, and Mississippi refugia. The Great Lakes region was connected to the Bering drainage (refuge) by lake and river system created along the face of the retreating Laurentide glacier. Current day Great Slave Lake and Great Bear Lake are part of this system. Lake trout, grayling, and northern pike were some of the fish species that used the Bering refugia (Bailey and Smith 1981). The Atlantic refugia extended east from the northern Great Lakes region to the Atlantic Ocean. Fossil remains of walruses discovered near the Straits of Mackinac (Handley 1953) are linked to the North Bay outlet that drained Northern Michigan waters into the Atlantic Ocean. Fourteen species of fish populated the region solely from the Atlantic refugia. However, the primary source for re-population of fish species in the Great Lakes region came from the Mississippi refugia. This refugia alone supplied 122 species of fish to the region (Bailey and Smith 1981).

Archaeological data are available for northern Michigan, giving us a glimpse of the regional fish community composition following the last glaciation. The Juntunen Site, located on Bois Blanc Island, in Mackinac County, is about 70 miles northwest of the city of Alpena. This site was occupied during the Woodland period, from about 800 A.D. to 1300 A.D. (McPherron 1967). Remains of eighteen fish species have been documented at the site, including: lake sturgeon; longnose gar; lake trout; lake whitefish; northern and silver redhorse suckers; white and longnose suckers; brown bullhead; channel catfish; northern pike; yellow perch; walleye; sauger; largemouth, smallmouth, and rock bass; and freshwater drum (Cleland 1966). Although these fish were likely from Lake Huron, they are representative of the fish species present in northern Michigan. Many of these fish species were likely present in the nearby Thunder Bay River watershed as well.

The Thunder Bay River historically had a population of Arctic grayling (Mather 1874, Vincent 1962, Bailey et al. 2003) which was extirpated around 1900. Creaser and Creaser (1935) reported that

Arctic grayling were found in Thunder Bay of Lake Huron. Arctic grayling fry stocked into headwater lakes and the mainstem TBR in Montmorency County during the late 1920s did not survive (Nuhfer 1992). Older Arctic grayling stocked into headwater lakes and creeks during the early 1940s and the late 1980s survived for a short time before disappearing (Nuhfer 1992). Although Vincent (1962) indicates presence of Arctic grayling within the watershed, precise spatial distribution is unknown. Relatively few fishes occupied the same reaches of water with Arctic grayling: suckers, a shiner, pike, and whitefish (Hallock 1873, Mather 1874, and Oatka 1888). The historic abundance of Arctic grayling and its eventual extirpation in the neighboring watershed to the south, the Au Sable River, is well documented.

Modifying Factors

The Thunder Bay River watershed has changed significantly since the arrival of European settlers. These changes had profound effects on the biological communities of the basin. Logging and dam-building in the nineteenth and twentieth centuries had the largest effects on the river system (see **History**). The river and its tributaries were used for transporting timber from the uplands to mills along the river and at the river mouth in Alpena. Loggers removed streamside vegetation and the floating of logs scoured the stream channel.

Species introductions, both intentional and unintentional, have affected the biological communities in numerous ways. Some non-indigenous species, like brown trout and steelhead, have provided valuable recreational fisheries, while other exotic species like zebra mussels, gobies, and ruffe continue to cause problems, as discussed later in this section.

Dams were first constructed in the Thunder Bay River watershed in the late-nineteenth century. The earliest dams were built for saw mills, but later larger hydroelectric dams were built (see **Dams and Barriers**). Dams block upstream migration of potamodromous fishes from Lake Huron, such as sport fish like steelhead and Chinook salmon, and aquatic nuisance species such as sea lamprey. Numerous lake-level control structures have been built in the watershed as well.

Dams not only block migrations of potamodromous fishes, but restrict the movement of resident fish species as well (see **Dams and Barriers**). Zorn and Sendek (2001) summarize the affect of dams on resident fishes:

> Fishes require distinct spawning, growth, and refuge habitats in their life cycle (Schlosser 1991). Equally important, fishes must be able to freely migrate between these habitats [Figure 24]. If any one habitat is lacking or if the ability to migrate from one to another is restricted, the population can become restricted or locally extinct. Migrations allow fish populations to fully use the best available feeding, growth, and refuge habitats within the aquatic system, and thus realize the potential of the river system. Migration corridors also provide a means for populations to recolonize disturbed areas. Dams in the [Thunder Bay River] system prevent the river from realizing its potential to support thriving fish populations.

Urbanization, road construction, and oil and gas development can have negative effects on waters in the basin through both point and nonpoint source pollution (see **Water Quality**). Fetterolf et al. (1965) reported that discharge from the Abitibi and Fletcher Paper companies had degraded the benthic macroinvertebrate community within the Thunder Bay River and Thunder Bay. Current industrial discharges to the river are subject to requirements of National Pollution Discharge Elimination System (NPDES) permits (see **Water Quality**).

Current Fish Communities

Eighty-two fish species are found in the Thunder Bay River watershed (Table 23; Appendix 2). Maps of their known distribution (Appendix 2) within the watershed were prepared using MDNR, Fisheries Division files, University of Michigan's Museum of Natural History records, the Michigan Fish Atlas, and the best professional judgment of the authors. Many stream reaches inhabited by fish may be used only seasonally by some species. These reaches were still included in the distribution map as part of the species range.

Ten species within the watershed were intentionally introduced and five species colonized the river from Lake Huron. The Thunder Bay River also is home to two rare fish species. Historical records indicate the presence of pugnose shiners in the watershed. The pugnose shiner has a special concern status in Michigan. This species requires streams with sand substrate or clear, weedy lakes, and is intolerant of turbidity. The lake sturgeon is a threatened species in Michigan, and has been reported in the Thunder Bay River below Ninth Street Dam, but cannot pass upstream beyond the dam.

Temperature plays such a large role that fish species are often put into categories (or guilds) based on their temperature preference and temperatures at which they spawn. These guilds are comprised of fish species that typically inhabit water bodies of cold, cool, or warm water (Diana 1995). The membership of these guilds is based on a number of factors, including the upper thermal tolerance limits for survival, the thermal preference for fishes in which they achieve optimum growth, and observations of presence-absence under certain conditions (Eaton et al. 1995). Wehrly et al. (2003) studied the effect of mean July temperatures on fish communities and applied it to Michigan rivers. The study found relatively distinct community composition within three thermal categories: cold (<66°F), cool (66°F to <72°F), and warm (≥72°F).

A coldwater fish community is comprised of fishes with a relatively narrow tolerance range of temperatures. In rivers, coldwater fish communities generally have low species richness, and generally include species in the family Salmonidae (e.g., rainbow, brown, and brook trout), as well as Cottidae species (e.g., slimy and mottled sculpin). A coolwater fish community is comprised of fishes with a broader tolerance range of temperatures, and generally has higher species richness than a coldwater community. Coolwater fish species in the TBR watershed include fish in the perch (Percidae) family, such as yellow perch, walleye, and darters; the pike (Esocidae) family, such as northern pike or grass pickerel; suckers; and many Cyprinidae species, particularly blacknose dace, northern redbelly dace, and longnose dace. A warmwater fish community is comprised of fishes with a broad tolerance range of temperatures, and generally has the highest species richness. Certain Cyprinidae species, such as creek chubs and bluntnose minnows, have very wide tolerance ranges, and are nearly ubiquitous in the TBR watershed. Other warmwater fish species include members of the bass and sunfish family (Centrarchidae) and additional Cyprinidae species. Smallmouth and largemouth bass, along with bluegill and pumpkinseed sunfish, are common in the warmer water portions of the TBR. Cyprinidae species found in warmwater fish communities include the golden shiner, rosyface shiner, and common shiner. Members of the catfish family, such as bullheads, are also prevalent in the warmwater communities. Much of the TBR has members of both the warm- and coolwater communities, since the thermal requirements of these communities overlap.

Streams in the TBR watershed with coldwater fish communities are generally confined to the southern portion of the watershed, where the geology and hydrology result in large inflows of groundwater. These streams have stable flows and a cold temperature regime. The rest of the watershed is comprised primarily of cool and warm water streams; of which some cool water habitats provide "marginal" trout water (e.g., mainstem TBR upstream of Hillman Dam). Trout may seasonally occupy these reaches for feeding, spawning, or at times overwintering, but summer temperatures are generally not favorable for coldwater fish species. Some trout may be found in microhabitats, such as springs, within these warmer reaches even in summer. Trout will generally seek these microhabitats, or move into cold water streams, for thermal refuge. The lower portion of the mainstem, below Ninth Street Dam, supports coldwater fish seasonally, as potamodromous fish (e.g., steelhead, Chinook salmon) migrate up the river. This reach normally has a mix of cool- and warmwater fish species.

Larger rivers often provide cold water habitat in headwater areas, cool water in mid-stream segments, and warm water habitats in lower river reaches (Illies 1962). This thermal habitat pattern applies in some ways to the TBR because many of the headwater streams and tributaries are cold, the mid-section is cooler, and a general warming progresses farther downstream. Part of the watershed is difficult to classify into thermal guilds, however, because of the effects of impoundments. Impoundments, for instance, may cause water temperatures to increase, which results in warmer temperatures in downstream river segments. Mixing of thermal guilds in downstream segments of the TBR results from this impoundment warming. Some impoundments (e.g., Fletcher Pond) generally support higher fish diversity and abundance than the free-flowing river would. Perhaps an even greater effect of impoundments in the TBR watershed is that of fragmentation. Much of the TBR watershed would likely be suitable for at least seasonal use (spawning migrations, nursery habitat, etc.) by Lake Huron fish species, if it were accessible.

Aquatic Invertebrates

The MDEQ-Water Division conducted macroinvertebrate community surveys within the Thunder Bay River watershed in 1957, 1965, 1989, 1990, 1995, and 2000. This report will focus primarily on the most recent survey.

A total of 76 aquatic macroinvertebrate families have been identified over 15 sites in the TBR in 2000 (Taft 2003). Richness is defined as the number of families found at a sight. Macroinvertebrates are generally identified only to family so the number of genera and species found in the watershed is much higher than 76. The mean richness throughout the watershed was 29, while individual sampling locations ranged from 23 to 41 taxa (Table 24). In general, taxonomic richness was negatively correlated with water temperature.

Macroinvertebrates are important indicators of water quality and summaries of their diversity in 2000 within the TBR watershed were discussed earlier in this report (see **Water Quality**). A 1990 macroinvertebrate survey of two stations in the Lower South Branch TBR documented 25 taxa. EPT taxa comprised 35-38% of the invertebrate species found during this survey (Wilson 1991). Four invertebrate species in the TBR watershed are listed as being of special concern (Table 25). None is an obligate aquatic species.

Amphibians and Reptiles

Ten species of frogs and toads and seven species of salamanders live within the Thunder Bay River watershed (Harding and Holman 1992). None of these species has a state or federal status of endangered, threatened, or special concern (Table 26).

Eleven species of snakes and one lizard, the five-lined skink, reside within the Thunder Bay River watershed (Holman et al. 1993, Harding and Holman 1990). The eastern massasauga rattlesnake is special concern status in Michigan (Table 26). It is unique since it is the only poisonous snake species in Michigan. Its preferred habitats are marshes and swamps, but may be found in upland meadows and woodlands in summer (Holman et al. 1993).

The Thunder Bay River watershed is home to five species of turtles; two are listed as special concern species (Harding and Holman 1990) (Table 26). The wood turtle is a species of special concern. Populations of wood turtles have been reduced primarily through mortality from crossing roads and collection as pets. Habitat loss and road crossing mortality are the major threats to the Blandings turtle, the other species of special concern (Harding and Holman 1990).

Birds

Doepker et al. (2001) list 121 birds associated with aquatic and wetland habitats in the Thunder Bay River watershed (Table 27). The river, lakes, and wetlands provide valuable habitat for a variety of game and non-game birds (Table 27). Ducks, geese, and mergansers nest and forage along the river, while upland birds forage and travel within its riparian corridor. The state-threatened common loon breeds on the lakes while stream edge habitats are used by several species of shorebirds and wading birds, such as great blue herons. Great Blue Heron rookeries exist within the watershed and are listed on the Michigan Natural Features Inventory (MNFI). These rookeries contain groups of nests and are located in wooded wetlands with large trees. Great blue herons will return to the same rookery on an annual basis (B. Mastenbrook, MDNR, personal communication). The Bald Eagle is a state and federally threatened species while the Osprey and Red-Shouldered Hawk are state-threatened species. These birds of prey co-exist in the TBR watershed.

Mammals

About three-fourths of the Thunder Bay River watershed is forest or wetland (see **Soils and Land Use**). These land features support a variety of mammalian species (Table 28). The river and its riparian corridor provide food, cover, and travel routes for game species including: black bear, bobcat, river otter, muskrat, mink, raccoon, and a variety of non-game species. Consequently, the watershed is a major producer of mammals commonly selected for sport harvest. Large populations of fur-bearing mammals such as coyote, red fox, gray fox, beaver, river otter, raccoon, muskrat, mink, and badger also occur and are an important facet of the trapping industry.

Part of the Thunder Bay River watershed is included in the range of Michigan’s elk herd. Atlanta, in the upper part of the watershed, is known as the “Elk Capital of Michigan”. Elk were reintroduced to Michigan in 1918 with the release of seven animals and has grown to a herd of approximately 1,000 individuals. Rare mammals in the watershed are American marten (threatened) and woodland vole (special concern) (Table 25).

Other Natural Features of Concern

In addition to the eleven vertebrate species discussed above, MNFI lists twelve vascular plants, two plant community types, a bird rookery, and two geological types as being natural features of concern within the watershed (Table 25).

Plant community types listed as natural features are the hardwood-conifer swamp and the southern floodplain forest. The hardwood-conifer swamp is cedar-dominated forest with gently sloping topography and more than four feet of organic matter. Other common species in this community include balsam fir, black ash, and black spruce, with red maple, dwarf blackberry, and speckled alder present as well. The southern floodplain forest has a relatively low diversity of groundcover species.

The Great Blue Heron rookery is also listed as a natural feature by MNFI. These rookeries contain groups of nests and are located in wooded wetlands with large trees. Great Blue Herons will return to the same rookery year after year (B. Mastenbrook, MDNR, personal communication).

Two types of geological formations in this watershed that are listed by MNFI are eskers and karsts. Eskers are glacial material laid down in a tunnel in or under the ice, while karsts are formed when caves in the underlying limestone collapse (Dorr and Eschman 1970). Sunken Lake (Presque Isle County) is an example of a karst formation.

Many natural features listed by MNFI for the TBR are the same as those for the Au Sable River. Zorn and Sendek (2001) summarize potential protective measures for some of these natural features:

> Protection of several key habitats will serve to benefit many of the rare species discussed above. Protection of coniferous forests in headwater wetlands has the potential to benefit rare plant and invertebrate species, in addition to maintaining the quality of downstream cold water stream communities…Protection of forests along riparian corridors can also: help maintain high water quality; provide migration corridors that connect isolated animal populations; and benefit aquatic and riparian organisms by providing a ready source of woody debris to streams. Populations of several rare birds and plants will be bolstered through protection of fire-maintained, open prairie and savannah habitats occurring in coarse-textured, outwash plains… (D. Pearsall, MDNR, personal communication).

Aquatic Nuisance Species

Coscarelli and Bankard (1999) define an aquatic nuisance species as a “waterborne, nonnative organism that threatens the diversity or abundance of native species, the ecological stability of impacted waters, or threatens a commercial, agricultural, aquacultural, or recreational activity”. A MDNR-MDEQ report submitted to the Michigan Legislature indicates that about 160 nonindigenous aquatic species have been introduced into the Great Lakes Basin since the 1800s (Anonymous 2002).

Adult sea lamprey are parasitic and can kill up to 40 pounds of fish per year (Coscarelli and Bankard 1999). Sea lamprey are potamodromous, living most of their lives in the Great Lakes, but returning to tributary streams to reproduce. Sea lamprey are found in the Thunder Bay River below Ninth Street Dam, which blocks further upstream migration. Lampricide is applied to the TBR below Ninth Street about every five years for larval sea lamprey control by the U.S. Fish and Wildlife Service (USFWS). Ruffe and round goby are exotic fish species that can reduce native fish populations through predation on eggs and larvae. These exotics are also common below Ninth Street Dam (A. Bowen, USFWS, personal communication).

Zebra mussels are a small exotic species that attach to hard surfaces underwater and filter microscopic algae from the water. These tiny mussels are prolific; they can form dense colonies of over one million per square meter (Coscarelli and Bankard 1999). Zebra mussels have profound adverse effects upon Michigan’s lakes by killing native clams, and out-competing larval fish and other aquatic organisms for food (Hart et al. 2000). Zebra mussels are present from Norway Pond to the mouth, but appear most abundant in Four Mile Impoundment and Norway Pond (B. MacNeill, Thunder Bay Power Company, personal communication).

Rusty crayfish are an exotic species which reduce native crayfish populations through competition and can dramatically reduce aquatic vegetation. Until recently, survey crews usually did not record the species of crayfish observed during fisheries surveys, so their distribution in the watershed is not well defined. This species, which consumes aquatic plants, is thought to have had a negative impact on vegetation within Hubbard Lake (S. Sendek, MDNR, personal communication). Rusty crayfish were not found at various mainstem and tributary sites upstream of Hillman Dam where survey crews did identify all crayfish caught in 2000. Sites where they were not found during these recent surveys include Hunt, Gilchrist, Greasey, and Brush creeks, mainstem at Lake 15 road, and mainstem at Hossler Road.

Whirling disease is caused by a parasite which infects trout and salmon. The parasite enters the head and spine of young trout, leading to erratic swimming behavior and, potentially, death (Whirling Disease Foundation 2002). Whirling disease spores have been found consistently in Hunt Creek brown trout and rainbow trout sampled in recent years. The spore densities are quite low however, and the species present are not expected to develop clinical signs of the disease (J. Hnath, MDNR (retired), personal communication). Whirling disease has not adversely affected rainbow trout reproduction in this stream, as young-of-the-year (age-0) numbers still average near 1000/acre in August-September estimates. Whirling disease was not detected in Gilchrist Creek and the remainder of the watershed has not been tested.

Thunder Bay Power Company surveyed their impoundments in 2002 to identify sites where vegetation such as Eurasian water milfoil and purple loosestrife may have colonized. Milfoil may form thick mats of vegetation at the waters surface, impeding recreation and altering water conditions (light, water circulation, etc.) below (Hart et al. 2000). Milfoil was documented behind Ninth Street Dam and throughout Fletcher Pond (B. MacNeill, Thunder Bay Power Company, personal communication). Purple loosestrife is a perennial wetland plant that often out-competes native vegetation for sunlight and space (Hart et al. 2000). It is often found in riparian areas in river corridors. This aquatic nuisance plant was found at locations around Fletcher Pond, Lake Besser, Hubbard Lake, Lake Winyah, and below Four Mile Dam (B. MacNeill, Thunder Bay Power Company, personal communication).

Fishery Management

Historical and modern fisheries management in the Thunder Bay River watershed has been shaped by the wide variety of aquatic habitat types in its rivers and lakes. The watershed has a diverse array of warm water and cool water rivers, cold water creeks and a plethora of lake types. The southern half of the drainage has a number of top-quality cold water streams that drain a region of high groundwater loading (see **Hydrology**) and maintain cold summer stream temperatures. Today, these streams are managed primarily by habitat protection measures and angling regulations that promote self-sustaining trout populations. In the past, many streams in the watershed were stocked with trout species, but this management practice was stopped because it was ineffective and costly. The northern portion of the watershed contains many top-quality warm water streams (Figure 21). Habitat protection and angling regulations are also the primary means that warm water streams are managed. Most fisheries management has been directed to lakes in the TBR watershed, where fish stocking, angling regulations, and habitat protection again are the primary forms of management. A primary fisheries management objective for waters is to preserve and restore habitat types, biological communities, and promote self-sustaining fisheries. Healthy fish stocks need food for growth, spawning habitat if sustained naturally, and appropriate shelter for cover (Figure 24).

The Federal Energy Regulatory Commission (FERC) recently relicensed six hydroelectric dams within the Thunder Bay River watershed for a 40-year period beginning in 1998 (Appendix 1) (see **Dams and Barriers**). Thus, the five associated impoundments may exist for this period of time. Fish management of these impoundments should strive to maximize their potential. Management practices must consider their associated high flushing rates and warm water characteristics. High flushing rates often limit plankton production and fish growth rates. Yet the warm water characteristics of many impoundments are suitable for warm- and coolwater species of fish.

The following are optimal summer temperatures (in ºF) for the sport fishes typical of Michigan lakes: walleye 68-75; yellow perch 68-82; northern pike 64-73; rock bass 69-78; smallmouth bass 70-81; largemouth bass 75-86; black crappie 68-82; bluegill 72-86; channel catfish 79-86; bullhead 68-86; white sucker 61-79; and carp 73-86 (Kinney 1999). In comparison, the average August 2001 temperatures (ºF) at the outlets of the six dams were: Hillman -72; Upper South (Fletcher)-76; Hubbard Lake-75; Seven Mile-75; Four-Mile-75; Ninth Street-75 (Table 13). Fishery management should target fish species whose preferred growth temperatures are common to impoundments and lakes. Thus, average summer water temperatures at these impoundments are often conducive for many of the previously mentioned fish species. The ranges associated with these temperatures and high flush rates may be limiting growth factors.

Fish stocking was historically a common fisheries management method. Fish stocking records for the Thunder Bay River watershed are available from 1937 through present (Table 29). Records of fish stocking prior to 1937 are difficult to locate and summarize. Most fish stocking efforts were done by the Michigan Department of Natural Resources (formerly Department of Conservation). Some known private source stocking efforts were also noted (Table 29). Many warmwater and coldwater species of fish were stocked in the watershed prior to the 1950s. Trout stocked during this period were often large enough to be legally harvested and provided short-lived put-and-take fisheries. Warm water temperatures throughout much of the watershed resulted in poor survival and limited natural recruitment. Trout stocked in colder streams also did not survive well because of angler harvest and competition with naturally reproduced trout (Shetter et al. 1964). Virtually all trout stocking efforts into cold water streams were discontinued by 1965 due to competition with naturally reproducing populations. Improvements in rearing techniques for walleye and tiger muskellunge and greater acceptance of these species by anglers led to increased stocking levels by the 1970s and 1980s (Table 29). Trout stocking by this period was reduced to lakes where survival was higher and a fishery was established. Stocking of trout and salmon to create potamodromous fisheries started by the 1960s, but were rarely successful. Today, most lakes and streams in the Thunder Bay River watershed are managed for natural, self-sustaining fisheries. Only nine of the waters listed (Table 29) are presently stocked to improve angling and the primary species stocked is walleye. Current stocking practices are a result of the learning associated with success and failure of fish stocking efforts over the last half-century.

Prior to 2000, inland lake and stream trout populations in nearly the entire Thunder Bay River watershed were managed by uniform regulations, although regulations on creel limits, seasons, and length limits varied substantially in the past (Borgeson 1974). The most recent changes for inland trout regulations were applied in 2000 as a result of a statewide review of regulations. However, the changes for inland lake and stream trout populations in the Thunder Bay River watershed were minor. Today, in inland streams, the minimum size limit for harvest of brook and brown trout is still 8-inches while rainbow trout minimum size is 10-inches (Type 1 stream regulation; see **Glossary**). The daily possession limit was reduced from 10 to 5 fish, of which no more than three can be 15-inches or longer. Minimum length limits for brook and brown trout in the TBR watershed trout streams were not changed. The minimum size for these species remains 8-inches because trout growth rates are generally slow or average compared to other trout streams in Michigan.

Trout populations, both stocked and self-sustaining, have been monitored through research for over half a century in the headwaters of the TBR watershed by the Michigan Department of Natural Resources. These include the waters of Hunt and Gilchrist creeks as well as other creeks and lakes in the Hunt Creek Fisheries Research Area east of Lewiston. Knowledge gathered through research of these trout populations is used to guide statewide trout management.

Creel survey of anglers and their catches is another fisheries division program used to determine the status of fisheries or the effectiveness of other management activities such as regulation changes or habitat work. The oldest survey data for various lakes and streams in the watershed were collected by conservation officers from 1920-65 (Appendix 3). This census was discontinued around 1965, in part, because the methods used did not allow for estimates of total catch, harvest, or angling effort. Survey data useful for evaluating the effectiveness of trout regulations, stocking, habitat work, and other management activities in trout lakes and streams in the watershed are reported in a variety of research studies done by Hunt Creek Research Station personnel (Alexander and Shetter 1961b, McFadden et al. 1967, Shetter 1968, Alexander and Shetter 1969).

The following sections provide a summary of fish management history throughout the TBR watershed. The summaries will follow the river segment approach defined earlier in this report (see **Geography**) (Figure 2).

Mainstem Thunder Bay River - Headwaters to Hillman Dam

Many water and habitat types occur in this reach of the Thunder Bay River watershed (Figure 2, Segment A). Cold water tributary streams (Hunt, Gilchrist, Miller creeks) are located in this segment along with the mainstem above Lake Fifteen. Cool water tributaries designated as trout streams include Haymeadow, Smith, and Crooked creeks and the remaining mainstem. MDNR, Fisheries Division currently manages all streams in this segment as Type 1 trout streams except for a portion of Crooked Creek and the mainstem.

Trout were commonly stocked in this stretch of mainstem, especially from the late 1930s through 1965 (Table 29). Brook trout in particular are self-sustaining in cold water tributaries. Self-reproducing populations of brown trout are also present in many streams even though there are no records of brown trout stocking (back to 1937).

Few fish community surveys have been conducted with the exception of the mainstem below Atlanta, Hunt, and Gilchrist creeks. Surveys of Hunt and Gilchrist creeks were primarily to evaluate regulations, habitat improvement, stocking, or other management actions. Hunt Creek was the site for some of the earliest experiments in the state to evaluate effectiveness of stream improvement structures for improving trout populations and fishing (Hubbs et al. 1932). Structures made of wood included: various types of deflectors, low dams, log covers, log sod covers, stump covers, and various combinations. Many additional stream improvement structures were built during the 1940s and 1950s, particularly immediately after World War II (Reynolds 1974). Contemporary fish management operations for other headwater TBR reaches in this segment of river and its tributaries include periodic fish and habitat assessments, along with stream protection through the environmental permit review process.

During the 1990s, management activities have focused on control of erosion. Much of this work is accomplished through conservation groups that apply for governmental grants and private money sources to fund habitat restoration work. Fifty-six stream bank erosion sites were identified along with a handful of sites on Crooked, Stanniger, Sage, and Gilchrist creeks (USDA 1993). Of those identified, 24 were classified as minor, 25 as moderate, and 7 as severe sources of sedimentation. Since 1996, 34 of these identified sites and an additional 8 sites have been restored by groups led by the Thunder Bay River Restoration Committee, as well as a private group and the local road commission (D. Hardies, Montmorency County Conservation District, personal communication). Remediation techniques included: the use of bio-logs, rock rip-rap, mulch, seeding, tree revetment, culvert extension, and bank sloping. Efforts continue today to monitor the effectiveness of these procedures. One instream erosion site was also restored along Crooked Creek and another was restored through natural processes.

Nine road-stream crossings have been inventoried for sediment contribution, while an additional 48 have been inventoried on the tributaries. Of those identified, 20 were classified as minor, 27 as moderate, and 10 as severe (NEMCOG 2002).

Mainstem Thunder Bay River

The Thunder Bay River mainstem fish assemblages between McCormick Lake and Atlanta Dam Pond were surveyed in 1970 and 2000. Naturally-reproducing brown and brook trout live in the marginally cool waters (Table 7) between McCormick Lake and Lake Fifteen, which is a designated Michigan trout stream reach. Trout use of this reach, however, may be seasonal. Some brown trout may migrate into this reach from nearby lakes that are stocked. The mainstem from the Lake Fifteen outlet to Hillman is not a designated trout stream and has fish assemblages more typical of a warmwater fish community. Some brown trout emigrate into this stream reach from Lake Fifteen, yet it is not managed as a designated trout stream by the MDNR, Fisheries Division.

The mainstem from Atlanta Pond Dam downstream to the impounded waters of Hillman Pond is a designated Michigan trout stream and is managed under Type 1 trout regulations. Despite this designation, it is considered marginal trout water because most of the reach cannot sustain significant trout populations during summer months (Table 7). There are small pockets of cooler water that will sustain trout all year, near areas of high groundwater inflow or below mouths of cold water tributaries, such as Hunt and Gilchrist creeks. This reach of the TBR was stocked periodically with brook, brown, and rainbow trout as early as 1938.

No trout were captured in a 1970 fisheries survey at two locations below the town of Atlanta and above Eichorn Bridge, although many trout were stocked in the previous decade in this TBR reach. A more intensive fisheries survey was conducted by MDNR, Fisheries Division in 1971 at many river locations. Brown trout were most abundant below the Hunt Creek confluence and between M-33 and M-32 highways. Their presence is due to cold water contribution from tributaries in addition to groundwater accrual. Brown trout captured here grew much faster than the state average rate. Brook trout were rare and no rainbow trout were collected. Additional game fish species were captured in low numbers. Growth data was compiled for all trout collected from this reach of mainstem by electrofishing in 1974. Results indicated growth was excellent for all three species of trout.

The most recent fish management survey for this reach of TBR mainstem was conducted by MDNR, Fisheries Division in July 1988. Rotenone was used to sample fish in a 700-foot section of river near M-33 highway. Total standing stock was relatively low, 58 pounds/acre, with game fish species comprising 23% of this biomass. White sucker accounted for about one third of non-game fish biomass at this site. Total numerical abundance was relatively high at about 2,800 fish/acre, but less than 4% of these individuals were game fish. Creek chub and common shiner were the most numerically abundant among the 20 species of fish collected. Game species such as brown trout, rock bass, northern pike, and smallmouth and largemouth bass were collected in low numbers. A similar fish survey with rotenone was conducted during the same year further downstream near the M-32 road-crossing. Game fish made up 27% of the total standing stock of fish at this site at 29 pounds/acre. Only three brown trout were collected. Low catches of trout were attributed to warm summer water temperatures. Other game fish collected, which were all small, included: rock bass, northern pike, smallmouth bass, pumpkinseed, and yellow perch.

Summer water temperature is the primary factor limiting trout availability in the Thunder Bay River mainstem between Atlanta Dam and Hillman Pond. Water temperatures typically increase above the preferred range for trout by mid-June and remain there for extensive periods of time through August. Mean July water temperature in good trout streams in Michigan rarely exceeds 68°F (Wehrly et al. 2003). Maximum daily temperatures during summer may reach 85°F at many sites between Atlanta and Hillman dams (See **Hydrology**). Consequently, brown and brook trout often use this reach of mainstem during cooler months and migrate into cold water tributaries such as Hunt and Gilchrist creeks during summer (K. Ross, MDNR, personal communication). Their presence in the mainstem during cooler periods enhances their growth rates by giving them access to abundant forage fish (see **Biological Communities**). Smallmouth bass and northern pike are present in this reach of mainstem, but in low numbers. Water temperatures appear good for pike growth, but are too cold for optimal growth and abundance of smallmouth bass (Wehrly et al. 2003).

Tributaries

The upper portion of Hunt Creek within the 3000-acre Hunt Creek Fisheries Research Area has been used as a trout research area dating back to even before 1939. Both streams and lakes within the research area have been used for a wide variety of studies of biology and habitat of coldwater species, primarily trout, but also Arctic grayling and sculpin species. A summary of these studies is beyond the scope of this assessment. The primary fish species in lotic waters are brook trout, and mottled and slimy sculpin. Density of brook trout in a high-gradient (45 ft/mi) reach has averaged 2,000/acre during recent years. Densities in a lower-gradient (6 ft/mi) reach average around 1,700/acre (MDNR, Fisheries Division, Hunt Creek Research Station, unpublished data).

Fall brown trout densities in a two-mile reach of Hunt Creek upstream of County Road 612 averaged 670/acre from 1995 to 2002. Brook trout densities in the same reach averaged 40/acre during the same period. Reaches of Hunt Creek downstream of the research area are also currently used to evaluate effects of steelhead competition on resident brook and brown trout populations. Fall density of juvenile steelhead has averaged about 1,000/acre since experimental stocking of adult steelhead commenced in 1998 (Nuhfer 2002).

Brown trout densities in nearby Gilchrist Creek are generally higher than in Hunt Creek, but brook trout densities are lower. Fall density of brown trout in a 1.6-mile reach of Gilchrist Creek upstream of County Road 612 averaged 1,085/acre and density of brook trout was 15/acre during 1995-02 (Nuhfer 2002). Greasey Creek, a small (base flow discharge 2 ft^3/s) high-quality cold water tributary to Gilchrist Creek, has a predominant brook trout game fish community. Brook trout comprised about 25% of the trout assemblage by number captured by electrofishing during a 2001 survey.

Angling pressure on high-quality trout waters such as Hunt Creek can be very high. During 1951-1964, effort expended averaged 708 angler hours per mile (Alexander and Shetter 1957, 1958, 1959, 1960, 1961b, 1962, 1963; Alexander et al. 1964; Williams et al. 1966). Census reports by the same authors found an annual average of 158 angler hours/mile on Fuller Creek—a small Hunt Creek tributary whose discharge varies from 2 ft^3/s at the outlet of Fuller Pond (headwaters) to 8 ft^3/s at its mouth.

Fish populations in Miller Creek, a designated Michigan trout stream, were assessed by the MDNR, Fisheries Division in 1971 and 2000. Brook trout were common in Miller Creek at the one location sampled in 2000, but were more abundant in 1971.

Little fish management has occurred within the smaller headwater streams of the Thunder Bay River. Some streams were stocked at one time or another historically (Table 29). Most recent fish surveys were conducted in the early 1970s at: Barger, Edwards, Haymeadow, Smith, and Sucker creeks. Brook trout were common in the headwaters of Edwards Creek, yet absent from lower reaches. Brook, brown, and rainbow trout were common in lower reaches of Barger Creek. Summer water temperatures were unsuitable for trout in the headwaters of Barger Creek which originates from a lake. Small brook trout were found in the headwaters of Sucker Creek, but were absent in the lower reaches. Summer water temperatures are probably the primary limiting factor for trout in this stream.

No trout were captured in Haymeadow, and Smith creeks, probably due to warmer water temperatures and possibly habitat degradation from agricultural land use. Despite this, these two streams are still managed as Type 1 trout water and are designated Michigan trout streams. No fisheries surveys have taken place on other important tributaries such as Stanniger, Sheridan, and Crooked creeks. Despite this, trout are known to be present in Stanniger and Sheridan creeks which have cold thermal regimes (Table 7). Stanniger Creek, a tributary to McCormick Lake, has a known naturally reproducing brook trout population. Sheridan Creek, a larger tributary to McCormick Lake, has natural brook and rainbow trout populations. The latter species inhabits the lake for part of its life.

Lakes

A variety of lake types are located in the upper mainstem TBR drainage upstream of Hillman Dam. Included among these are two-story fishery lakes that are managed as Type B trout waters. Type B trout lakes are open all year to fishing with all tackle where minimum size limits are: brook trout (10”); brown trout, rainbow trout, and splake (12”). The lakes in this category provide popular summer and winter fishing for trout, since they have sufficient dissolved oxygen and cold water temperatures suitable to trout.

McCormick Lake and Lake Fifteen both have a long history of coldwater fish stocking efforts (Table 29) dating back to 1938. MDNR, Fisheries Division continues to stock brown trout at each lake. Natural reproduction of brown trout is believed to be low whereas rainbow and brook trout reproduction in tributaries add to the lake fishery, particularly at McCormick Lake. Rainbow smelt were illegally introduced to Lake Fifteen prior to 1950. Smelt are now also present in McCormick Lake. This species reproduces naturally in the tributaries and provides a popular fishery in both lakes. Numerous fisheries and limnological surveys have been conducted at both lakes dating as far back as 1925. In addition to trout, both have a warmwater fish community present, while northern pike are considered common in Lake Fifteen. Estimates of boat angler pressure were made for both McCormick Lake (13 hours/acre) and Lake Fifteen (29 hours/acre) in 1982 by MDNR, Fisheries Division (Ryckman and Lockwood 1985). Effort on these water bodies was low compared to other Michigan lakes.

There is a long history of fishery management surveys at both Avery and Crooked Lakes. These lakes are in the Crooked Creek sub-watershed of the upper mainstem. A plethora of early fish stocking efforts (Table 29) at Avery Lake failed based on accounts going back as far as 1944. Fluctuating water levels as a result of control structure management has hindered fish management. Fish surveys were conducted at Avery Lake as early as the 1920s and as late as 1999. Walleye stocking and evaluation intensified by 1982. This program was discontinued by 1998 since survival of walleye was consistently poor. Today, MDNR, Fisheries Division manages for naturally reproducing native fish in Avery Lake.

Walleye management was more successful at neighboring Crooked Lake where alternate year walleye stocking continues today. Five fisheries surveys were made at Crooked Lake between 1925 and 1997. Warm- and coolwater fish species in this lake are naturally sustaining with the exception of walleye. Estimates of boat angler pressure were conducted for both Avery (52 hours/acre) and Crooked (136 hours/acre) lakes in 1982 by MDNR, Fisheries Division (Ryckman and Lockwood 1985). Fishing pressure was probably higher at Crooked Lake due to walleye stocking efforts in this water body.

Two other important lakes in the upper mainstem drainage include Sage and Gaylanta lakes. Sage Lake, a wildlife flooding, has an extensive history of fish management dating back to 1944 when early fish assessments documented the dominant warmwater fish population. The fish population was removed using rotenone in 1963 and restocked with rainbow and brook trout. Since then, fish managers have stocked a variety of species of varying numbers (Table 29). Trout stocking failed at this lake probably as a result of competition and predation from warmwater fish populations that dominate the lake today.

Gaylanta Lake warmwater fish populations are managed by regulations and habitat protection to promote natural reproduction. Fish and habitat surveys date back to 1959 while the most recent fish community assessment was conducted in 2003. Gaylanta Lake continues to support a pike and bass fishery. Estimates of boat angler pressure were conducted for Sage (52 hours/acre) and Gaylanta (58 hours/acre) lakes in 1982 by MDNR, Fisheries Division (Ryckman and Lockwood 1985).

Fuller Pond and East Fish Lake in the Hunt Creek Fisheries Research area have been used as research lakes to study trout biology since about 1939. The findings of many studies are beyond the scope of this assessment. Angler effort that existed on these “trout only” lakes before they were closed to fishing in 1965 illustrates the high value of this type of rare fishery resource. This is a fishery component that may be lacking in the Thunder Bay River watershed today. Annual angling effort on East Fish Lake ranged from 75 to 130 hours/acre during trout seasons in the late 1950s and early 1960s (Alexander and Shetter 1961a, 1969).

The remaining small lakes in this reach of the mainstem are currently managed as warm- and coolwater fisheries under standard State of Michigan fishing regulations. Few surveys were conducted for these waters because they are small and generally inaccessible. Fish in some of these lakes die during winter due to shallow water and low dissolved oxygen levels. MDNR, Fisheries Division used the Voyer Lake Inlet Pond during part of the 1980s to raise fingerling walleye for regional stocking.

Hillman and Atlanta dams form two shallow impoundments in the upper mainstem TBR reaches. Both ponds were stocked (Table 29) in the 1970s with largemouth bass, and walleye were stocked in 1986 (both) and 1993 (Hillman). A fish and habitat survey of Atlanta Pond in 1971 documented limited game fish potential in its shallow waters. A similar survey at Hillman Pond the same year documented good numbers and sizes of important game fish such as yellow perch and northern pike. Bullheads and suckers were common in this impoundment while trout and walleye were rare. A follow-up survey was conducted in 1984 as a result of public perception that angling quality was declining. The survey indicated the fish population was similar to the 1971 survey results. According to FERC (1996), maintenance of the reservoir level in a narrow width would protect shallow near-shore habitat in this impoundment while keeping necessary woody structure submerged. This type of protection would help reproduction of important sport fish such as northern pike. Estimates of boat angler pressure were conducted for Hillman Pond (18 hours/acre) in 1982 by MDNR, Fisheries Division which was considerably lower compared to natural lakes in the same area (Ryckman and Lockwood 1985).

Mainstem Thunder Bay River - Hillman Dam to Confluence with the Upper South Branch Thunder Bay River

This short reach of the Thunder Bay River (Figure 2, Segment B) flows through a lowland swamp east of Hillman and is rather inaccessible (see **Geography**; Figure 2). As a result, very little fish management has taken place in this river segment. Very few tributaries merge with the mainstem, but there is one major Type 1 trout stream and a handful of top-quality warm water streams. Few lakes are located in this watershed reach, but it does include Avalon Lake which is presently managed as a Type B trout regulation lake.

Twenty-two stream bank erosion sites have been identified (USDA 1993). Of those identified, 3 were classified as minor, 16 as moderate, and 3 as severe. Five erosion sites are believed to be healed or are healing, most likely as a result of run-of-river dam operation at Hillman. Road-stream crossings were inventoried for sediment contribution in 2000: 2 were classified as minor and 13 as moderate (NEMCOG 2002) sediment sources.

Mainstem Thunder Bay River

In 1926 early investigators described the mainstem between Hillman and the Upper South Branch confluence as a turbid, rapid-moving warm water river with northern pike and rock bass as the prevalent game fish. A walleye-rearing pond was constructed adjacent to the river by the MDNR, Fisheries Division in 1985. Some walleye fingerlings are drained from this pond into the river annually. Two fish surveys were conducted using rotenone by the MDNR, Fisheries Division in 1988. A 700-foot reach was surveyed both below the bridge in Hillman and upstream of the Upper South Branch confluence. The purpose of the surveys was to evaluate fish community assemblages.

About half of the 59 pounds/acre of fish sampled below Hillman Dam were game fish. Catches included a few large brown trout estimated at 10/acre. These brown trout were probably emigrants from populations upstream of Hillman Dam. Other game fish such as smallmouth and largemouth bass, rock bass, northern pike, walleye, bluegill, and yellow perch were all found in varying numbers below Hillman Dam, yet few legal-size fish were collected. Fourteen species of non-game fish were collected while overall abundance was high at about 2,500/acre. Total density of non-game fish was similar at the site upstream of the confluence with the Upper South Branch, yet game fish comprised less than 2% of the sample by number. Game fish caught were primarily young smallmouth and largemouth bass, rock bass, and bluegill.

Tributaries

Three major tributaries enter the mainstem: Brush, Jewett, and Anchor creeks. Brush and Little Brush creeks are designated Michigan trout streams and managed by Type 1 trout fishing regulations. Little Brush Creek was surveyed in 1971. No trout were collected and very few warmwater fish were found at the sampling site. Brook trout were stocked heavily in Brush Creek from 1938 through 1965 (Table 29). Brook trout were common in 1971 collections at some locations along Brush Creek, while other locations were devoid of trout. Brook trout and coldwater species such as slimy sculpin were common at the only location assessed during a summer 2000 survey. Recent temperature information for this creek (Table 7) verifies its status as a cold water tributary.

Jewett and Anchor creeks are managed as top-quality warm water streams. There are no records of fish stocking in either creek. Jewett Creek supports a warmwater fish community comprised of chubs, minnows, dace, and shiners. This was determined based on a 1982 fish survey. Summer water temperatures appear to verify this warmwater fish assemblage (Table 7). Anchor Creek and its unnamed tributaries have never been surveyed. Eight road-stream crossings over these two creeks and their tributaries contribute moderate amounts of sediment to the creek channels (NEMCOG 2002).

Lakes

The most significant lake is 372-acre Avalon Lake, presently managed with Type B trout regulations. Warm-, cool-, and coldwater species of fish have been stocked in its waters dating as far back as 1937 (Table 29). This is one of the few lakes in the watershed where splake have been stocked and is the only current stocking location for this species. Fish and habitat surveys have been conducted on at least seventeen occasions between 1925 and 1990 at Avalon Lake. Evaluation of splake stocking efforts was the purpose of most assessments. Other species such as smelt, smallmouth bass, and yellow perch are important members of the Avalon Lake fish community along with other warm- and coolwater species. Growth of these species tends to be slow. Estimates of boat angler pressure were conducted at Avalon Lake (5 hours/acre) in 1982 by MDNR, Fisheries Division (Ryckman and Lockwood 1985). Small warm water lakes such as Anchor, Beaver, and Little Brush also exist in this river reach. General statewide angling regulations and habitat protection is used to manage fish populations in these smaller lakes.

Upper South Branch Thunder Bay River - Headwaters to Fletcher Pond Dam

The Upper South Branch Thunder Bay River (Segment C) originates from many small natural lakes and tributaries in northeastern Oscoda and southeastern Montmorency Counties (Figure 2). Very little fish management has occurred because most waters are within large parcels of inaccessible private land. Many lakes, including Fletcher Pond, are managed for warm- and coolwater fish species under standard State of Michigan fishing regulations. The Upper South Branch and tributaries are managed under Type 1 trout stream regulations, with the exception of Weber and Turtle creeks and the mainstem Upper South Branch downstream of T29N, R4E, S14, which are not managed as trout streams.

Fish stocking in streams and lakes is typically limited to Oscoda County (Table 29). State and private stocking efforts of both warm- and coolwater species of fish have occurred at a few lakes in the sub-watershed. The Upper South Branch Thunder Bay River in Montmorency County was stocked with yearling brook trout by a private source in the early 1970s.

Upper South Branch Thunder Bay River

Three fish community surveys have occurred on the Upper South Branch since 1968. Good numbers of small brook trout were found in the colder reaches of the river in Oscoda County during the initial survey. MDNR, Fisheries Division personnel reviewed fish assemblages at a location further downstream and at the county line in 1998. Good numbers of brook and brown trout were captured along with eleven other species. Brook trout were numerically dominant, although no legal-size trout were collected. A more intensive fish survey was made in 2000 even further downstream on the Turtle Lake Club property. This site was close to the downstream boundary of the designated trout waters. Both brook and brown trout were collected in good numbers and sizes. The mean July water temperature at this site was 63ºF in 2000, an excellent temperature for coldwater fish species. Some species collected were more typical of a warmwater fish community and were probably emigrants from nearby lakes. Summer water temperatures for the Upper South Branch should be determined at sites downstream of the confluence of Weber Creek to Fletcher Pond, where it is not a designated trout stream. If temperatures in this reach are also cold enough for trout species, then the downstream boundary of the designated trout stream reach should be extended.

Tributaries

Six major tributaries enter the Upper South Branch above Fletcher Pond including: Marsh, Pike, Bullock, Cole, Weber, and Turtle creeks. The latter two creeks are classified as warm water while the other creeks are managed as Type 1 trout streams that drain many small natural lakes. Recent summer temperatures (Table 7) at Weber Creek verify its status as marginal for trout. Groundwater loading may be significant to some of these remaining creeks to counteract the warm water received from the headwater lakes. Only one known fisheries survey has been conducted at any of these tributaries and took place in 1968 at two sites along Marsh Creek. No trout and only warmwater forage fish were collected at a site in the headwaters of the creek near a marsh. Good physical habitat was observed further downstream where brook trout and forage fish were common.

Lakes

Very few fish community surveys or management practices have been conducted on the lakes upstream of Fletcher Pond in comparison to the number of lakes present. Few fish have been stocked in these waters and most were private stocking efforts. Early aquatic inventories were made at Shamrock, David, Tote Road, and Dollar lakes in the early 1940s by the Michigan Department of Conservation (MDOC). Warm- and coolwater fish populations were present while trout were also stocked in Lake David. Pike Lake No. 4 was chemically reclaimed in 1940 and stocked with rainbow trout in effort to produce a trout fishery. This effort was not successful. No other surveys were made at these lakes until 2002, when Bass Lake was surveyed for the first time. Naturally-reproduced warm- and coolwater fish species comprise the fish community of this lake.

Fletcher Pond is one of the most popular fishing lakes in northern Michigan. This 8,970-acre lake was formed by impounding a stretch of the Upper South Branch Thunder Bay River. Prior to dam construction, MDOC seined a short stretch of the river in what is now the flooded area. Non-game fish were found to be abundant in this reach known as “the deadwater” and water temperature was 71ºF during this July survey. Upper South Dam was constructed in 1930 by the Alpena Power Company to store water. MDNR, Fisheries Division made fish community surveys on Fletcher Pond in 1984, 1992, and 1993. Fish growth and creel estimates were analyzed for this lake back to the 1930s with information gathered by conservation officers (Appendix 3). Angling regulations, angler effort, pike harvest, and pike growth information from 1948 to 1997 is summarized in Table 30. Mail survey estimates of angler effort at Fletcher Pond ranged from 30,200 anglers days in 1970 to 60,210 angler days in 1973. Borgeson (1996) summarizes the management of the lake and its northern pike populations.

> For many years this impoundment provided for excellent northern pike fishing. By 1947, however, anglers were experiencing a decline in the quality of the pike fishery. The average size of pike had decreased. Overfishing and winter spearing were deemed by some anglers to be the cause of the decline. At that time the size limit for pike was 14 inches, and harvest was very high. Growth rate and average size continued to decline for many years with this regulation in place.
>
> Harvest declined after the statewide size limit on northern pike was increased to 20 inches in 1960. After a few years of decreased harvest and an abundance of small pike present, the size limit on pike reverted to 14 inches and the daily creel limit was increased to 10 pike. Spearing was also banned mainly because of the local perception that all the larger pike were taken with a spear. Harvest of pike dramatically increased (Table [30]). The cropping of the pike seemed to have increased the growth rates somewhat of the remaining fish. The size limit and creel limit became consistent with state regulations in 1967 (20 inch limit, 5 fish per day). There was no size limit on pike in Fletchers beginning in 1969 until it again reverted to the statewide 20 inch limit in 1988.
>
> In 1982, precipitated by a drastic drawdown that year, concerns about the fluctuation of the water levels in the impoundment came to the forefront. The drawdown decreased the surface area of the pond significantly and resulted in a very poor year class of pike. The crowding of fish into a much smaller area was suspected to have a substantial effect on the fish community. An agreement was reached between concerned parties, including the Michigan Department of Natural Resources and the Alpena Power Company, assuring adequate water levels for pike spawning.
>
> Prompted by the water level concerns and complaints of poor pike fishing, Fletcher Pond was surveyed in 1984. The survey revealed that the pike population had indeed declined in number. The pike population was no longer a stunted one, but was a fast growing population of pike which was part of a much better balanced fish community.

> Largemouth and smallmouth bass populations were in very good shape in terms of quantity and size of fish. The panfish population, consisting primarily of bluegills, pumpkinseeds, rock bass, crappie and yellow perch, was also in excellent condition.
>
> The Floodwaters was surveyed once more in 1993, again revealing a fish community in excellent condition. The pike population, under the new statewide 24 inch size limit, remained fast growing with a very good size distribution in spite of reported heavy exploitation. The largemouth bass population, now with a 14 inch minimum size limit, was in excellent shape with good numbers of fish and a very good size distribution. Panfish populations were also doing quite well, with bluegills, crappies, rock bass and perch found in adequate abundance and with an acceptable size distribution.
>
> Some anglers and resort owners, however, were still concerned about the northern pike population. For years they had been able to harvest pike with ease. The resort owners have for a long time been an outspoken proponent for their pike fishing customers. Many of those people who kept returning to Fletchers Floodwaters had done so because they had consistently caught pike, although for quite some time they had been of small size. This type of fishery satisfied many anglers who returned year after year. When the number of pike decreased they naturally became concerned, the fishery that they had become accustomed to had changed. They had several of their own theories as to what caused the changes they had seen. The anglers and resort owners thought that the pike were no longer successfully spawning. They also thought that the ice fishermen, particularly the tip-up fishermen, were taking an unacceptable number of pike, either by harvest or by hooking mortality. As a result Fisheries Division was contacted and asked to eliminate tip-up fishing and to approve a northern pike stocking program.
>
> Before approving such measures, Fisheries Division decided to conduct a winter creel census on the Floodwaters. As part of the survey, an estimate of the winter pike harvest, the size of fish harvested, and of overall fishing pressure was needed. Also needed was a survey of anglers as to their impressions of the quality of the pike fishery on Fletchers, and what they would like to see in a pike fishery. Anglers were also asked to estimate probability of survival of released pike.

Borgeson (1996) further describes the fish populations at Fletcher Floodwaters based on results of the 1992 and 1993 fish community assessments and 1995 winter creel survey:

> The species and size composition of the fish community of Fletcher Floodwaters has changed much over the years. Fletcher Floodwaters is currently providing an excellent fishery for a variety of species…
>
> The northern pike population appears to be healthy in number with a very good size distribution, especially considering what the anglers are telling us they want to see in a pike population. The age class structure of the pike reveals a population that is producing a viable year class every year, which suggests that the water level requirements have had the desired effect. Therefore, it does not appear necessary to augment the existing northern pike population with stocking. With the 24 inch size limit the pike population should be able to sustain a substantial fishery while maintaining an acceptable size distribution.
>
> The abundance and size distribution of largemouth and smallmouth bass is exceptional. With the changing of the fish community from the dominance of northern pike to one of more balance, anglers have yet to completely adjust to this relatively new fish community structure. If in the coming years the fish community remains stable, it is expected that more anglers will exploit the bass fishing opportunities that Fletchers provides.

> Panfish anglers have been doing very well on the Floodwaters in recent years. Hopefully, with the diverse and healthy fish community now present, the bluegill, perch and crappie populations will continue to provide ample panfishing opportunities. The increased size limits on predator fish should help in maintaining an acceptable size distribution of panfish in addition to its positive effects on the pike and bass populations.
>
> Fletcher Floodwaters is now at one of its historical highpoints in terms of the variety and quality of the warmwater fishery it provides. No changes in fisheries management, in terms of regulations or stocking, are recommended at this time.

The most recent fish management conducted on Fletcher Floodwaters was an intensive open water creel survey in 1997. Open water harvest of pike was 0.37 fish/acre, which was low compared to most surveyed years from 1948 through 1965 (Table 30) when pike regulations were more liberal. Total fishing pressure was moderate compared to these previous years (which included winter numbers).

Upper South Branch Thunder Bay River - Fletcher Pond Dam to mainstem Thunder Bay River

This five-mile river segment (D) has no significant tributaries and no lakes or impoundments in its sub-drainage. Very little fish management has taken place in this reach of river (Figure 2). The only known direct stocking involved brook trout in the early 1970s by a local private source (Table 29).

Three locations of this river were observed and seined by MDOC personnel in July 1923 prior to construction of the Upper South Dam. Water temperature was warm for this river stretch (77ºF) which averaged 2-4 feet deep. Rock bass were common, as were a variety of forage fish species. A mark and recapture population estimate of game fish was made by MDNR in July 1976. Game fish caught included northern pike, smallmouth and largemouth bass, yellow perch, pumpkinseed, rock bass, and bluegill. Rotenone was used to collect fish in a 700-foot stretch of river below the M-32 bridge in August 1988. Twenty-three species were collected with forage fish dominating by number. Total standing stock of all species was 49 pounds/acre. Game fish such as rock bass, smallmouth and largemouth bass, northern pike, and pumpkinseed comprised 33% of the total standing stock, but most were young and small. Game fish growth rates were average for Michigan.

Adult game fish may have been scarce because of fluctuating water levels, especially prior to 1998. Upper South Dam is now operated at run-of-river mode. The fish assemblages should be resurveyed to evaluate effects of the more stable flow regime. Recent temperature information verifies the cool water status of this river reach (Table 7).

Mainstem Thunder Bay River - Upper South Branch Thunder Bay River confluence to Four Mile Dam

This reach of the mainstem TBR (Segment E) contains a variety of creeks, rivers, and impoundments (Figure 2). No significant natural lakes are found in this reach. River gradient decreases and many major tributaries drain agricultural land or lowland swamps. Major tributaries to the mainstem include both the Lower South Branch and North Branch Thunder Bay River. Important creeks that merge with the mainstem include Truax, Bean, Gaffney, and Fall creeks. These creeks are considered top-quality warm water systems. Also included are impounded stretches of the mainstem such as Lake Winyah (Seven Mile Impoundment) and Four Mile Reservoir. Both reservoirs were stocked with warmwater and coolwater species of fish in the middle of the twentieth century (Table 29) and more recently with walleye. Walleye stocking directly into the impoundments ceased in 2000 for Lake Winyah and in 1996 for Four Mile Reservoir. It is, however, believed that walleye stocked further upstream will provide a walleye fishery in the impoundments downstream (D. Borgeson, MDNR, personal communication).

Forty-six stream bank erosion sites have been inventoried for sediment contribution (USDA 1993). This includes five sites within the impoundments. Of those identified, 12 were classified as minor, 28 as moderate, and 6 as severe sediment sources. Erosion sites were common on the mainstem near the confluence of Bean Creek. Other severe erosion sites have been identified in the Long Rapids reach of the mainstem. Since 1996, four of these were restored by various groups led by the Thunder Bay River Restoration Committee and Thunder Bay Watershed Council (D. Hardies, Montmorency Conservation District, personal communication). Remediation techniques included: rock rip-rap and stairways, bank sloping, vegetation planting, bank seeding, and toe revetment. The effectiveness and longevity of these procedures is being evaluated through monitoring.

Two road-stream crossings have been inventoried for sediment contribution while an additional 49 have been inventoried on tributaries. Of the total inventoried, 26 were classified as minor, 24 as moderate, and 1 as severe (NEMCOG 2002).

Mainstem Thunder Bay River

The mainstem between the Upper South Branch confluence and Four Mile Dam has been indirectly stocked with walleye in most years since 1983 (Table 29). MDNR, Fisheries Division stocks walleye directly above this river segment in hopes of establishing a fishery in the lower impoundments and river itself.

The first recorded agency observations for this reach of river were made in 1925. Bottom substrates were predominantly rock and sand, and the water was described as having a milkish color appearance, most likely from the clay soil types that the river cuts through. Northern pike and rock bass were present along with forage species including darters, shiners, chubs, and dace. The fast flowing waters of the river below Seven Mile Dam were stocked with smallmouth bass fry in the 1920s. The first significant river survey in this reach was conducted by MDOC in a 5½-mile reach of river near Long Rapids. They attempted to make population estimates of a variety of fish species in this reach. Game fish such as northern pike, smallmouth bass, yellow perch, and rock bass were present, but sparse, thus leading to poor population estimates. Smallmouth bass were the primary game fish with few of them large.

The most recent fish assessment was made in August 1988. MDNR, Fisheries Division used the chemical rotenone to evaluate the fish community in a 700-foot reach of river near Long Rapids Road upstream of Lake Winyah. Twenty-one species were collected with forage fish dominating by number. Total standing stock was 48 pounds/acre and nearly half of this biomass was comprised of game fish such as smallmouth bass, walleye, yellow perch, northern pike, and rock bass. The walleye were probably immigrants from upstream stocking efforts. Game fish growth rates were generally average for Michigan.

Management (with fishing regulations) of this reach of the mainstem is tied to its status as a cool water river (Table 7). This segment is marginal to poor for trout, yet appropriate for coolwater species such as northern pike, smallmouth bass, and walleye.

Tributaries

Five major tributaries (excluding the North and Upper South Branches) merge with the mainstem or its impoundments in this drainage segment and include: Truax, Gaffney, Bean, Kingsbury, and Fall creeks. No fish management has occurred on these warm water streams except for a few fish community surveys.

Truax Creek has received the most attention. Initial observations of its waters were conducted in 1925 by MDOC in which it was deemed “unfit for trout”. Trout were occasionally reported, but were probably seasonal migrants from the mainstem TBR. In 1989, a biological site inspection was completed at six sites along the Truax Creek sub-watershed by the MDNR, Surface Water Quality Division (currently MDEQ, Water Division). The purpose was to assess effects of nonpoint source pollutants such as excess nutrients and sedimentation. Four sites were inspected along Truax Creek while two were inspected along Connon Creek, which is a tributary to Truax Creek. Low and intermittent flows were deemed the most limiting fisheries values.

Two sites on Truax creek were surveyed with a direct current stream electrofisher by MDNR, Fisheries Division in 1991. Northern redbelly dace, creek chub, central mudminnow, and brook stickleback were the only species found at an upstream site at Long Rapids road. Their total density averaged nearly 1,300/acre which is quite high. These species are tolerant of low oxygen levels and are commonly found in slow-moving and stagnant streams. Ten fish species were collected at a site near the mouth. Total density of fish was over 5,000/acre. A few young bluegill and black crappie were captured at this site, but over 99% of the 33 pounds/acre of fish at this site were non-game fish species. The warm water designation for Truax Creek is appropriate.

A fish community assessment of Spratt Creek was conducted in 1982. This creek is a small tributary to Bean Creek. The water temperature during the late-August fish assessment was 60ºF indicating a possible cold water regime. The 100-foot stretch of creek surveyed was very near the origination of the stream and may not have provided a clear picture of the fish community. No trout were collected, but species such as chubs, shiners, suckers, central mudminnow, sticklebacks, and dace were prevalent.

No tributaries to this reach are designated trout streams. Available information indicates that management of these streams as small warm water streams is appropriate, despite the fact that Fall Creek had surprisingly cool summer temperatures in 2003 (Table 7). Bean Creek water temperatures were gathered at two locations in 2003 (Table 7). Data suggests that the headwaters of this creek are cold while most of the remaining stream is cool water status. This tributary was stocked with trout in the 1930s and 1940s. Information on temperature regimes, summer flows, and fish assemblages should be collected for tributaries that have never been surveyed.

Lakes

Two reservoirs, Lake Winyah and Four Mile Impoundment, dominate this river segment. Lake Winyah is also known as Seven Mile Impoundment and Norway Point Impoundment. There is an intriguing history of fish management associated with Lake Winyah. The 1,530-acre impoundment was established in 1924 by the creation of a hydroelectric dam (see **Dams and Barriers**). The first aquatic community assessment was conducted in 1950 by MDOC. Both vegetation and fish communities were surveyed. Twenty-one species of plants were identified and fair numbers of game fish were noted. Walleye were not collected during the survey. Suckers, bullheads, and northern pike dominated catches in a June 1976 survey by MDNR, Fisheries Division. In addition, good numbers of other game fish such as smallmouth bass, black crappie, and yellow perch were collected. Growth of most of these species was average for Michigan. MDNR concluded that Lake Winyah had a healthy fish population in 1976. A water temperature and dissolved oxygen profile at the time found conditions highly suitable to the preferred ranges for many fish species.

Fish management at Lake Winyah continued in 1982 when fishing pressure was determined to be 12 boat angler hours/acre (Ryckman and Lockwood 1985) for the open water season. This estimate was low compared to many other natural lakes and impoundments in the area. A fall 1982 netting survey provided very little useful information on fish populations because excessive aquatic vegetation reduced netting efficiency. Michigan Department of Natural Resources began stocking walleye directly into Lake Winyah between 1986 and 1999 (Table 29). In addition, many walleye were stocked into the river upstream of Lake Winyah since 1993. They are believed to emigrate downstream into the impoundment.

Anglers and local interest groups were unhappy by the late 1980s about fluctuating water levels of the impoundment and the excessive levels of submersed aquatic vegetation. A severe lake drawdown to repair Seven Mile Dam in 1989-1990 reduced the acreage of the large impoundment to only 40 acres. Anglers believed that the drawdown limited northern pike reproduction and increased angling mortality because fish were concentrated into less area. Local associations asked for a spearing ban on northern pike to protect larger fish. A spearing ban was not imposed, but northern pike were stocked in 1990 and 1991 to help maintain pike populations. By the mid-1990s, reports of good fishing for pike and even walleye were received. Michigan Department of Natural Resources, Fisheries Division conducted a 10-day netting survey of Lake Winyah in 1998. Over 6,000 fish were captured in 92 net lifts. The lake was judged to have a balanced fish community based on the size and numbers of fish caught. Most species were naturally reproduced fish. Large game fish such as walleye, northern pike, and smallmouth and largemouth bass were abundant and represented by many ages classes and sizes indicating good recruitment and survival. Walleye ranged in age from 2-14. These ages would reflect both previous stocking efforts (Table 29) and some years of possible natural recruitment. All walleye fingerlings stocked upstream of Lake Winyah from 1997-03 were marked with the chemical oxytetracycline. This chemical produces a mark on the fish’s bony structures that allows for differentiation between stocked and naturally reproduced fish. Efforts should be made to determine the proportion of wild to stocked fish in the lower Thunder Bay River and impoundments. Prey species such as bluegill, and especially black crappie were found in good numbers and sizes in the 1998 survey. Growth of most game fish is average for Michigan. Established run-of-river mode should help ensure future water levels suitable for spawning game fish in Lake Winyah.

Four Mile Impoundment is located between Seven Mile and Four Mile dams. It is 98-acres in size. This impoundment was first surveyed in August 1950 when the fish and plant community was inventoried. Twenty-one species of aquatic plants were identified along with 16 species of fish including 6 game fish. Marshes suitable for pike spawning were abundant. A more intensive fish survey in 1977 found that northern pike and white suckers were the primary species. Other predator fish were present, but not common. The impoundment was judged to have a poor quality fishery. Fluctuating water levels caused by operation of the two dams was thought to contribute to the imbalance in the fish community.

MDNR, Fisheries Division personnel used electrofishing gear to survey fish along approximately half the shoreline of Four Mile Impoundment in 1982. Game fish catch was dominated by small smallmouth bass and rock bass. During the same year, angler use was estimated at 40 boat angler hours/acre (Ryckman and Lockwood 1985) for the open water season. This was over three times higher than the estimate for Lake Winyah. Walleye potential was considered to be good and a stocking program began in 1989 and continued intermittently until 1995 (Table 29). MDNR, Fisheries Division conducted a follow-up survey in 1996 to evaluate previous walleye stocking efforts and to assess the remaining fish community. The northern pike and black crappie numbers and size structure were considered excellent and other predators such as smallmouth and largemouth bass were present. Walleye fishing reports, however, were poor and very few were captured during the April 1996 assessment. Thus, walleye stocking in the impoundment was discontinued. MDNR fisheries managers judged that piscivore numbers in the impoundment were adequate.

Walleye stocking in the mainstem further upstream is considered sufficient to produce satisfactory catches by anglers in the impoundment. Four log-brush shelters were placed in the impoundment in the last decade to provide additional fish cover and add woody structure to the system (B. MacNeill, Thunder Bay Power Company, personal communication). Logs for shelters were collected from the trash racks associated with the dam. This management practice was part of the settlement agreement between Thunder Bay Power Company and various watershed interest groups (Appendix 1).

North Branch Thunder Bay River - Headwaters to Montmorency–Alpena County Line

The North Branch Thunder Bay River (Segment F) originates from many small natural lakes and tributaries in northeastern Montmorency County (Figure 2). Fish management in this river reach relies on stocking and fish community surveys of headwater lakes. These water bodies are typically managed for warm- and coolwater fish species with standard State of Michigan fishing regulations applying. The tributaries and North Branch TBR are classified as top-quality warm water streams with limited angling potential.

A variety of fish species ranging from trout to bass were stocked in the three main lakes in this sub-watershed: Rush, Ess, and Long lakes. Fish management at these water bodies reflects knowledge gained from the failure of previous stocking efforts to improve angling. These lakes contain typical warm- and coolwater fish communities. No fish community assessments have been conducted on the North Branch TBR in this river reach or its associated tributaries such as Grass Creek or Long Lake Outlet.

Lakes

About nine lakes drain to the headwaters of the North Branch Thunder Bay River. Standard State of Michigan fishing regulations are applied to the lakes with the exception of Long Lake. The lakes include Bedore, Cranberry, Ess, Gassel, Grass, Long, Lost, Ribble, and Rush.

No record of fish management exists for Bedore, Lost, and Ribble lakes, probably because they are small and inaccessible. A simple fish community survey by MDNR, Fisheries Division on Gassel Lake in 1969 provided information on game fish present such as rock bass, smallmouth bass, northern pike, and yellow perch.

Cranberry Lake is a 26-acre lake flooding with extensive marsh habitat and shallow water depths. A few yellow perch and northern pike were captured in a 1969 gill netting survey. Most fish captured were non-game species. Low dissolved oxygen levels over the winter of 1976 led to an apparent total fish kill at Cranberry Lake. Bluegill, yellow perch, pike, bullheads, and suckers were among the dead fish found along its shores in the spring. Recommendations to restock the lake were made by MDNR, Fisheries Division personnel, yet this did not happen. In 1992, it was reported that the Cranberry Lake dam washed away due to poor construction, thus depositing silt in the North Branch Thunder Bay River directly downstream. It is believed that beaver have replaced this breached dam (J. Pawlowski, Michigan Department of Environmental Quality, personal communication).

The North Branch TBR flows through 384-acre Rush Lake. Fish stocking dates back to the late 1930s at Rush Lake when varying numbers and sizes of bluegill, perch, bass, walleye, and even brook trout were stocked (Table 29). Fish community assessments at this lake date back to 1925 when the first survey indicated the presence of a good pike population. In 1955, an assessment of the lake included fish community structure, vegetation diversity, and water quality. Fourteen species of aquatic vegetation were identified. MDOC surveyed the entire lake shoreline with alternate current electrofishing gear in 1967 capturing eleven species of fish including game fish such as pike, smallmouth and largemouth bass, bluegill, and walleye. Ten species were collected in a 1976 survey and the fish community was judged to be in good condition. Northern pike were abundant and adequate reproductive habitat was observed. Smallmouth and largemouth bass were present and showed good growth while bluegill growth was average with good numbers of large fish present. Boat angler effort was estimated at 59 hours/acre in 1982 which was relatively high compared to many other regional lakes (Ryckman and Lockwood 1985). An intensive fish community assessment was conducted at Rush Lake by MDNR, Fisheries Division in May 2001. Good numbers and sizes of bluegill and largemouth bass were collected along with fair numbers of other game fish. Rush Lake has not been stocked since 1964. The balance between predator and prey fish appears good and natural reproduction is high enough so that stocking is not recommended. Current fishery management focuses on protecting habitat and maintaining a healthy, balanced warmwater fish community.

Grass Lake is a shallow flooding near the headwaters of the North Branch TBR. The Grass Lake dam was originally constructed to facilitate log transport down the North Branch TBR. The structure was rebuilt in 1937, but continued to erode in the following decades with attempts to maintain it taken on by a lake resident. Fishing pressure has fluctuated tremendously at Grass Lake through time as a result of frequent fish winterkills and angler harvest, although fish mortality was usually non-complete and often species specific. A fish community survey following a partial fish winterkill was completed in 1961 by MDOC. Panfish and northern pike were common while largemouth bass and minnow species were practically absent. Fishing pressure was reported as low at Grass Lake in the early 1960s, but increased steadily as a result of rebounding fish populations through the 1960s. Northern pike had been regulated with standard State of Michigan fishing regulations through 1972 (20-inch minimum size). The northern pike size limit was removed in 1973 because the dense population grew slowly. Grass Lake northern pike were regulated with this liberal regulation until 1995 when the statewide minimum size limit was increased to 24 inches. Today, Grass Lake northern pike are regulated with the standard state of Michigan (24”) minimum size limit.

Updated information on the Grass Lake fish community is needed, particularly for northern pike size structure. Recent angler reports have indicated the presence of a large sub-legal northern pike population in Grass Lake. The fish community at this flooding should be reexamined to determine if a 24-inch minimum size limit on pike is effective for this water body, especially in light of frequent winterkills. A liberal size limit on pike at Grass Lake would allow anglers to harvest pike that: may be unable to grow to the 24-inch size limit; or might otherwise die from anoxic conditions during harsh winters.

Ess Lake is a 114-acre natural lake with a long history of fish management. Many historic warm-, cool-, and even coldwater fish species have been stocked in its waters dating back at least as far as 1937 (Table 29). In 1942, early biologists suggested that the fertility of Ess Lake’s sediments promoted “average” plant growth in littoral areas. However, overall lake productivity was considered low as a result of cooler water temperatures and deep water (Allison and Kilpela 1943). Rainbow trout were stocked for many years between 1943 and 1972 because Ess Lake thermally stratified and hypolimnetic waters contained enough oxygen to support trout survival during summer (Table 29). In 1942, thirteen species of aquatic plants were identified and zooplankton abundance was high. Ten species of fish were collected in the 1942 fish community survey including some important game fish. Stocking of various cool- and warmwater fish species was discontinued in Ess Lake by 1942 in lieu of trout management and use of the cold water niche.

In 1961, jack-lights and seines were used to collect fish. Suckers were common and good smallmouth bass production was noted. Suckers and smallmouth bass were also abundant in a more intensive fish survey made by MDOC in 1962. In 1963, MDOC attempted to kill all fish in the lake with rotenone to promote single-species management for trout. The rotenone treatment was only marginally successful since the fish kill was light and consisted primarily of shiners, smallmouth bass, and yellow perch. However, angling pressure at the lake increased after treatment because anglers expected fishing to be better. During the mid-1960s, rainbow trout stocking continued at Ess Lake. Trout growth and survival was considered good based on a gill net survey made in 1966. Yellow perch were abundant in the same survey, but walleye stocked in 1964 had grown slowly. Dissolved oxygen levels in the hypolimnion of Ess Lake were judged suitable for trout survival in 1966. Rainbow trout were considered abundant in 1968 based on electrofishing survey catches while perch, walleye, and suckers were common. Walleye collected during the 1968 survey ranged from 8-12 inches long. These fish may have been offspring of the walleye stocked in 1964 or may have been stocked from an unknown source.

Four fish and angler surveys were conducted at Ess Lake from 1971 through 1982. Good numbers and sizes of yellow perch were caught in a 1971 gill net survey. Walleye were present and some were possibly naturally reproduced. Anglers reported low catches of rainbow trout, although this species had been stocked annually during most years prior to the survey. Northern pike were collected for the first time in a survey in 1971 and were found to be growing well. Poor survival of rainbow trout was attributed to predation by northern pike and stocking was discontinued after 1972. A 1978 fish survey at Ess Lake documented an increase in walleye numbers with growth considered average for this species. Angler reports at this time for walleye were also positive. Thus, by the 1980s, fish management at this water body had changed from a lake managed primarily for trout to an acceptance of the coolwater fish community. Species, such as white sucker and yellow perch, were still considered overabundant at Ess Lake prompting a fish removal by MDNR, Fisheries Division in 1981. The effectiveness of this manual removal as a fish management practice was questioned. A 1982 estimate of boat angler pressure determined it to be 26 hours/acre at Ess Lake which was somewhat below average for many area lakes and impoundments that year (Ryckman and Lockwood 1985).

A general fish survey was again conducted at Ess Lake in 1996 with emphasis on evaluation of walleye stocking efforts in the mid-1980s and 1990s (Table 29). Angler reports of walleye catches were good during the 1990s and the 1996 survey indicated that survival of stocked walleye was acceptable. The majority of walleye were from the 1993 year class. Size structure of walleye, however, suggested significant harvest of legal-size fish. Growth was still somewhat slow compared to the statewide average. MDNR, Fisheries Division continues to stock walleye at Ess Lake today (Table 29). Northern pike populations have increased as well at Ess Lake and are protected by early harvest with a 24-inch minimum size limit. The lake is small and unproductive enough that angler harvest could greatly reduce predator populations. White suckers and bullheads continue to comprise the majority of biomass in Ess Lake. Preliminary results of a 2003 fish survey indicate that walleye numbers and size structure are healthy and that stocking continues to provide a popular fishery. Other game fish such as northern pike, smallmouth bass, largemouth bass, rock bass, and black crappie continue to flourish.

Long Lake is another deep, unproductive 295-acre natural lake in the headwaters of the North Branch Thunder Bay River. It was managed through 2003 as a Type B trout lake where fishing is year-round with a minimum size limit of 12-inches on rainbow trout. Nearly 624,000 fish have been stocked in Long Lake dating back to the late-1930s (Table 29). MDNR, Fisheries Division has experimented with various stocking strains and numbers dating as far back as 1953. Strains of rainbow trout stocked included: Harrietta, Shasta, Arlee, Kamloops, steelhead, and most recently Eagle Lake. Angler reports suggested that trout fishing quality was good at least as recently as 1990, although few trout were caught in a 1990 netting survey. Dissolved oxygen levels suitable for trout in waters as deep as 70 feet were documented during a 1993 limnological survey. However, angler satisfaction with the trout fishery was low by the mid-1990s.

A recent 2001 netting survey to evaluate trout and walleye populations was completed by MDNR, Fisheries Division at Long Lake. Water analysis found suitable oxygen and temperature levels for trout. Few fish were captured in nets while good growing walleye dominated the predator catch. The walleye catch composition consisted of six different year classes indicating natural reproduction since the last walleye stocking (1975). This was also the case for smallmouth bass which were represented by seven year classes. Other cool- and warmwater predators such as northern pike and largemouth bass were found to be common. No trout were collected during the 2001 survey. A fish management plan was prescribed in 2001 to discontinue stocking trout in Long Lake and to manage the lake for the naturally reproducing cool- (walleye and pike) and warmwater (smallmouth bass and largemouth bass) fish species present. Future provisions were made for walleye stocking in case of potential stock exploitation or recruitment-spawning failure. Future fish management direction for Long Lake will focus on warm- and coolwater fish assemblages.

North Branch Thunder Bay River - Montmorency–Alpena County Line to Quinn Creek

This highly inaccessible reach of the North Branch TBR (Segment G) flows through a lowland swamp for about eight miles (Figure 2). No significant tributaries or natural lakes drain directly into this river reach, which is classified as top-quality warm water.

North Branch Thunder Bay River

An initial fish survey on the North Branch TBR was conducted in 1925. Water temperature at the time of the late-August survey was 74ºF. This segment was described as having a sandy bottom with species such as northern pike, rock bass, and largemouth bass. Forage fish included shiners, chubs, darters, and suckers. No trout were found and were not recommended for stocking. This was unusual in a period when trout stocking was a common management practice throughout the State of Michigan. However, early fish managers recognized that the river was too warm to sustain a trout fishery. The next fish assessment was made in 1991 when fish populations were estimated in a 200-foot reach of the river at Truax Road. Numbers of fish (4,379/acre) and standing stocks (114 pounds/acre) were about average for Michigan streams. However, only 2% of the fish were game fish including rock bass and northern pike. About 92% of the standing stock was comprised of non-game fish. White suckers made up about 50% of the fish biomass at this site.

Angler use of this reach is probably negligible because it is inaccessible and desirable game fish populations do not exist here. The warm water designation is appropriate based on recent temperature data (Table 7).

North Branch Thunder Bay River - Quinn Creek to mainstem Thunder Bay River

This segment (H) begins with the confluence of Quinn Creek and ends with its own confluence with the mainstem TBR–Lake Winyah (Figure 2). Very few tributaries other than Quinn and Erskine creeks are found. Only three notable lakes exist and include Sunken and Duck lakes as well as Elowski Pond. The North Branch TBR flows directly through both Sunken Lake and Elowski Pond. The river and lakes are managed for naturally reproducing warm- and coolwater fish species under standard State of Michigan fishing regulations. The tributaries and North Branch are considered top-quality warm water streams.

Relatively few fish management practices have occurred in the entire North Branch TBR watershed, including this reach. Historical fish stocking efforts included trout in the North Branch and Quinn Creek and warmwater species in Sunken Lake (Table 29). Twenty-three stream bank erosion sites have been identified (USDA 1993). Of those identified, 11 were classified as minor, 10 as moderate, and 2 as severe sources of sediments.

North Branch Thunder Bay River

Early habitat and fish observations date back to 1925 when general surveys were conducted at four river locations. Two observations were conducted above Sunken Lake and Elowski Pond. The river was noted as 15-30 foot wide with fluctuating water levels as a result of dam operation on Elowski Pond. Lumber refuse deposits were severe which was a testimony to the importance of the river for log transport. Few game fish were found, yet many forage fish were present. Also in 1925, observations were made at two river locations below both Elowski Pond and Sunken Lake. Pollution from lumber operations was still evident. Deep holes were noted for fish cover, however, and the lower reaches were thought to be important nursery grounds for some game fish. Forage fish such as dace, shiners, and darters were present.

Trout stocking efforts in the river was initiated by 1938 and continued in various years through the mid-1960s (Table 29). Stocked trout provided spring angler fisheries; although it was known that summer water temperatures were lethal for trout. The next fish community assessment was done by MDNR, Fisheries Division in 1991. Fish were collected by electrofishing and population estimates of all fish species were estimated by the Zippin method in two small reaches of the river. One sampling location was above Elowski Pond while the other was downstream of the impoundment in Alpena County. Total standing stock of fish at the upstream site near Thunder Bay Highway was low, 38 pounds/acre, and white suckers comprised 46% of total biomass. Young smallmouth bass were common, 4.4 pounds/acre, along with young rock bass, 2.7 pounds/acre. Nearly 90% of the 2,000 fish/acre were non-game species. Game fish were more common at the downstream sampling location near Cathro Road. They included northern pike, smallmouth and largemouth bass, bluegill, walleye, and rock bass. Total standing stock was also fairly low at this site, 43 pounds/acre, but game fish species made up 57% of this biomass. Black bullhead and blacknose dace were the most common non-game fish, but overall forage fish were much less common here compared to the upstream site. Some predator fish may have been immigrants from the impoundment habitat nearby downstream (Lake Winyah).

Tributaries

Quinn Creek is the only tributary that has been surveyed. Fingerling brook trout were stocked once in 1941 and legal-sized brown trout were stocked in 1950 (Table 29). A 250-foot stretch of the lower creek was surveyed with electrofishing gear in 2000 by MDNR, Fisheries Division to determine fish assemblages and habitat limitations. Game fish were absent with nearly the entire catch comprised of chubs, shiners, darters, suckers, and dace. Tumors were common on half of the chubs collected, although they may have been from parasites. It was determined that channel morphology and flow characteristics in the surveyed reach of Quinn Creek were not adequate to support any significant game fish populations.

Lakes

Elowski Pond is a small impounded stretch of the river that was originally used as a grist mill. The dam was constructed in 1881 and later rebuilt. The pond did support a pike fishery during the 1950s, but questions regarding navigability, recreational use, and fish spearing often arose. Sunken Lake, further downstream, still provides a fishery today. The lake was originally stocked with largemouth bass and bluegill from 1938 through 1945. In 1962, a total of 60 walleye fingerlings were transported to Sunken Lake from nearby Grand Lake by the MDOC. A limnological survey of Sunken Lake was made in August 1978 which found stratified water temperatures and an anoxic zone of water near the bottom.

Hubbard Lake tributary headwaters to Hubbard Lake Dam

Numerous small, cold water streams drain the landscape south of Hubbard Lake and along the east and west shoreline (Segment I, Figure 2). These streams are managed as Type 1 trout streams with the exception of: Holcomb Creek; a creek upstream of Badger Lake; and a handful of small tributaries to Hubbard Lake. About seven small lakes are located in this segment and feed the cold water streams. Hubbard Lake is an 8,850-acre water body which dominates the landscape. Standard State of Michigan fishing regulations apply for Hubbard and the remaining lakes with the exception of Badger Lake where there is no minimum size limit on pike and a bag limit of five fish.

Tributaries

Three major tributaries merge with Hubbard Lake and include: West Branch River, Sucker Creek, and Holcomb Creek. These systems vary in morphology and drainage size.

Various tributaries such as Fish, Pettis, McKay, Dougherty, and Vincent creeks drain a small portion of the watershed southeast of Hubbard Lake. Little management of these Type 1 trout streams has occurred. With the exception of Pettis Creek, these streams were all evaluated by the MDOC in 1925. Observations near the headwaters of Fish Creek noted it as a good brook trout nursery and recent temperature data (Table 7) indicates this still should be true. Pettis Creek, as indicated by recent water temperatures (Table 7) is a warm water stream. Both the East and West Branch of McKay Creek were recorded as having cold thermal regimes with brook trout present, possibly from previous stocking efforts. Dougherty Creek also had trout stocked previously and small brook trout were common during 1925 observations. Further trout stocking was not recommended. Downstream, Sucker Creek receives another tributary, Vincent Creek. This stream also received previous trout stocking efforts. No trout, however, were observed during the 1925 sampling date. This creek was thought to have low or even intermittent flows in many years, which is not conducive to survival of game fish such as trout.

Pettis and Fish creeks merge to form Sucker Creek, which in turn empties into Hubbard Lake. Fish management at Sucker Creek dates back to the 1920s. Brook trout were said to be extremely abundant in Sucker Creek at the confluence of Fish and Pettis creeks. Sucker Creek was stocked with brook trout with recommendations to continue stocking to maintain the population. White suckers commonly migrated into Sucker Creek from Hubbard Lake to spawn. Small forage fish such as sculpin, dace, and chubs were scarce. Both brook and rainbow trout were stocked in this creek from 1938-50.

Most recently, an 800-foot reach of Sucker Creek was surveyed by MDNR, Fisheries Division in 2000 downstream of all its major tributaries. Eleven species of fish were collected including forage such as sculpins, minnows, chubs, dace, and shiners. Brook trout were again collected with 28% of the catch legal-size (≥ 8-inches). This creek along with its tributaries is considered a second-quality cold water stream, despite the cold water present in the Sucker Creek sub-watershed. Sucker Creek is a cold water tributary (Table 7) to Hubbard Lake. It is a designated trout stream managed using Type 1 regulations.

West Branch River enters Hubbard Lake along the southern shore at South Bay. This river and its tributaries drain extensive swamps and forested ridges mostly dominated by private land ownership.

The river is formed from the convergence of Buff, Comstock, and Little North creeks. These three creeks are considered top-quality cold water streams for most of their lengths.

Buff Creek was heavily stocked with rainbow, brook, and brown trout from 1937-1953, with legal-size fish stocked in many years. A fisheries assessment was conducted in 2003 at a 500-foot reach near its headwaters. Creek temperatures were typically cold in 2003 (Table 7), yet flow was minimal and is believed to lead to increased temperatures during summer. Fish collections consisted primarily of chubs and dace, although brook trout were also collected in low numbers.

Brook trout were stocked in Little North Creek from 1944-1946. Observations by MDOC were made at this creek in 1925. Brook trout were common in its waters along with central mudminnow, sculpin, stickleback, and dace. Northern pike migrate into lower Little North Creek from Hubbard Lake and the West Branch River.

Comstock Creek was stocked with rainbow, brook, and brown trout from 1938-1951. Observations in 1925 at a tributary to Comstock Creek, (thought to be Cold Creek) classified it as first class brook trout nursery water. A late July 1978 fish survey conducted by MDNR, Fisheries Division in two reaches of Comstock Creek proved that brook trout were very common in its waters with most of the catch dominated by age-1 fish. Some legal-sized brook trout were present and growth was average compared to the statewide average. Brook trout were found to be present in a 1980 survey by USFS personnel. Type 1 trout classification is suitable for these creeks where trout reproduce naturally today and growth is average.

The West Branch River flows for a short distance through a highly inaccessible lowland swamp on its way to Hubbard Lake. Early professional observations in 1925 noted the presence of fish species most often associated with lake environments. This wide marshy river may be an important nursery and spawning ground for species such as northern pike.

Various small tributaries empty directly into Hubbard Lake. Both the West and East Branch of Holcomb Creek are classified as second-quality warm water streams. In 1925, neither branch was considered suitable for trout, while warmwater fish species were scarce. Recent temperature data at the East Branch Holcomb Creek indicates a borderline cold water regime (Table 7). Shafer Creek, which is managed as a Type 1 trout stream, is a short stream that enters Hubbard Lake along the east shore. Early observations in 1925 of Shafer Creek noted it as nearly dry near the mouth with few dace, stickleback, central mudminnow, and suckers present. Recent temperature data indicates a cold water regime, yet habitat and flow is limited. No fish information exists for Stevens Creek which enters the lake on the west shore. This creek is classified as second-quality warm water, although it has a cold water regimen (Table 7). Madison Creek enters the lake near the outlet and was classified as a very cold stream based on observations in the 1920s. Small brook trout were found in this creek during that year.

Lakes

Sucker Creek and its tributaries drain a handful of small natural lakes including Bear, Lost, Deer, and Badger lakes which have historically been surrounded by the Lost Lake Woods Club and exist on private land. Preliminary lake investigations by MDOC were made in 1936 at all four lakes while follow-up surveys did not occur until the late 1960s at two of the lakes.

Fishing intensity was low at 16-acre Bear Lake in 1936. This shallow water body was highly unsuitable to game fish and home to various minnows, dace, darters, shiners, mudminnows, and sticklebacks (Hazzard et al. 1937). Seven species of submersed and emergent aquatic vegetation were found. Yellow perch and bullheads were present in the 1965 survey while small numbers of bass were found in a 1968 survey. Dissolved oxygen levels were believed unsuitable for many game fish at the time of the last survey.

Fishing pressure was labeled as moderate at nearby Lost Lake in 1936. Species such as bass, walleye, and northern pike were stocked in its waters in 1929. This stocking was credited with creating fishable populations of these species according to the 1936 survey. Seven species of submersed and emergent aquatic vegetation were found in 1936.

Fifty-one acre Deer Lake is an isolated lake on club property with high water quality (Hazzard et al. 1937). Fish were also stocked in this water body in 1929 and yellow perch and walleye were established by 1936. Four species of submersed and emergent aquatic vegetation were found in 1936. Shiners were also stocked in 1935 in order to create a forage base.

Open water fishing pressure was considered high at 83-acre Badger Lake in 1936 (Hazzard et al. 1937). This larger and more popular lake contained dense vegetation and northern pike, smallmouth and largemouth bass, and panfish were present. Eighteen species of submersed and emergent aquatic vegetation were found. Northern pike and walleye were stocked in the late 1920s and early 1930s, and largemouth bass were stocked in 1951. In 1965, MDOC found the lake thermally stratified with anoxic water 18 feet below the surface. Game fish such as yellow perch, pike, bluegill, and largemouth bass were present. Most of these species grew well with the exception of northern pike. Pike, although abundant, grew slowly. Their large numbers were attributed to a spawning marsh connected to the lake. In 1968, the MDOC removed the minimum size limit on pike at the lake while the bag limit was five fish. This regulation still applies today. The intent of this regulation was to reduce pike densities through harvest, thus stimulating better growth of surviving pike. However, less intensive fish surveys made from 1968-1971 found that small pike still dominated the catch. A new fish survey would provide fish managers with information on the effectiveness of this regulation over time.

Very few small lakes exist in the Comstock Creek watershed and include: Lake in the Green, and Bucks Pond. Very little known fish data exists for these lakes because they are inaccessible and surrounded by private land. Bucks Pond was originally managed by the USFS as a designated trout lake.

Cwalinski (2003) summarizes fish management at Hubbard Lake:

> Fishery management practices have been inconsistent through the last century at the popular 8,850 acre Hubbard Lake. This is reflected in the amount and type of fish stockings that have occurred in this time frame. From 1937-1982, a wide array of fish were stocked at various sizes including: 115,444 yellow perch, 3,224,352 walleye fry, 432,900 lake trout, 31,200 shiners, 10,682 brown trout, and 106,000 rainbow trout. Warmwater fish species were the first to be stocked in these early years. An additional 17,181 small fingerling northern pike were stocked in three years including 1983, 1999, and 2001. Tiger muskellunge were planted in Hubbard Lake in 1978, 1980, 1982, and 1985. Approximately 139,420 yellow perch were also stocked from 1987-2001. Good numbers of walleye have been stocked from 1980-1991 (Table [29]).
>
> Fish management practices at Hubbard Lake date back to the first half of the twentieth century when early fish surveys were conducted in the 1920s and 1930s. In 1942, more extensive fish sampling was conducted with seines, and fyke, and gill nets. This effort resulted in 24 species of fish collected in Hubbard Lake. An abundance of bait fish was noted along with good numbers of white suckers, yellow perch, rock bass, and smallmouth bass. Vegetation surveys were completed in August of the same year, which helped identify 24 species of aquatic plants in the lake. Oxygen levels suitable for fish

were found down to approximately 43 feet at the time. The next fish collection was conducted in 1946. Already at that time anglers were referring to 'the good old days' of Hubbard Lake fishing, and believed walleye and bass stocking should commence. In 1947, commercial netting of rough fishes was initiated in effort to reduce numbers. Fish shelters have been installed in the lake in different years as a cooperative effort between local anglers and the state of Michigan.

During the 1960s, pike spawning marshes were constructed to enhance the predator base in the lake. A 1962 fish community survey listed only twelve species of fish. Lake whitefish spearing records also exist for this year. Netting surveys were also conducted in the late 1960s documenting good numbers of northern pike, rock bass, yellow perch, smallmouth bass, bullhead, and white sucker. Also observed were cisco and largemouth bass. Average size yellow perch were noted.

Yearling rainbow trout were stocked at a rate of 7 fish/acre in 1969. A winter gill netting survey the following year produced no trout catches. Trout were not stocked again in Hubbard Lake. Modern walleye stocking began in 1977 by the State of Michigan (Table [29]). In 1979, the first walleye stocking evaluations were conducted to evaluate previously stocked walleye. No walleye were collected with the nighttime electrofishing gear; however, angler catches had been documented.

A general fish survey was completed in mid-May 1986. The purposes of the survey were to determine survival and growth of stocked walleye and tiger muskellunge, and to evaluate the yellow perch population. Effort consisted of 206 total lifts of fyke, trap, and gill nets. Fourteen species of fish were collected. Good numbers of walleye (403) were collected, representing age groups 2-8. Growth of this species was average compared to statewide walleye growth. Only one large tiger muskellunge was collected during the survey. Nearly 700 yellow perch were collected with good numbers of 11-14 inch fish present. Perch growth was superior to the statewide average length-at-age for this species. Also collected in impressive sizes and numbers during the survey were northern pike, smallmouth bass, and rock bass. A fish management prescription was then created for Hubbard Lake which recommended the discontinuation of muskellunge stocking while continuing stocking of walleye every three years.

Evaluations of walleye stocking were made in 1989, 1990, and 1991. Serns indices were used in 1989 to determine walleye year class strength along with experimental gill nets and fyke netting. Using the Serns Index (Serns 1982; Ziegler and Schneider 2000), it was estimated that the 1989 and 1991 stockings performed poorly (1 or less YOY walleye/acre). However, the 1990 collection included 83 YOY, an estimate of four YOY walleye/acre. This was still considered a poor year class of walleye, yet these fish were all from natural reproduction. Older walleyes of several age classes were collected each year (1989-1991). Walleye growth of fish collected in 1989 was average for Michigan. Angler reports in the same year were considered good.

An extensive fish survey of Hubbard Lake was made in mid-May 1996 to examine long term trends in the fish community. The survey was the first in a series of fish collections that will be made at the lake every ten years. Effort consisted of 111 fyke net lifts, 30 trap net lifts and 4 inland gill net lifts. Fyke and trap nets had a variety of mesh sizes and lead lengths. More than 4,000 fish were collected weighing over 7,000 pounds. Good numbers of walleye were collected with the nets. Age-1 and age-4 walleye were collected indicating some level of natural reproduction in 1995 and 1992. Walleye had not been stocked in Hubbard Lake since 1991. Good numbers of age-6 and age-7 fish were represented in the survey catch. These fish averaged 18-19 inches in length. Walleye caught in 1996 were growing slightly slower than average for Michigan waters.

> Very few quality size yellow perch were observed in this survey with only 3% 10-inches and larger. Rock bass were abundant in Hubbard Lake with 80% of the fish captured 8-inches or larger. Good numbers of legal-sized northern pike are available to anglers. These fish grow well in Hubbard Lake. More than 100 smallmouth bass were collected during the survey with 48% 15-inches and larger. Other notable catches included the wide array of bait fish that inhabit the lake including minnows, shiners, and dace. White suckers were the most abundant fish collected during the 1996 survey. Large suckers are common with many fish ranging from 16-22 inches. Small white suckers are a good food source for predators and sucker abundance may help explain good growth of northern pike in Hubbard Lake (Diana 1987).
>
> Another walleye evaluation was conducted in September of the same year (1996) to examine walleye natural reproduction. Sampling effort consisted of two hours of nighttime electrofishing along the south end of the lake. Ninety walleye were collected ranging in length from 3.2-22.9 inches and representing ages zero through four not including the largest fish. Sixty-two YOY were collected at a rate of 32/hour. According to the Serns Index (Serns 1982), there were approximately 7 YOY walleye per surface acre in Hubbard Lake in the fall of 1996. This was considered a poor-average year class, yet all walleye (YOY and adults) collected during the fall survey were again produced naturally which is rare in most Michigan lakes. These fish represent years (1992 through 1996) when walleye were not planted into Hubbard Lake. However, very few fish (1/90) were legal size. Walleye growth has declined and it may take many years for these fish to recruit to legal-size (≥ 15-inches).
>
> The walleye stocking program appears to be a success at Hubbard Lake. This species was planted in the lake during the late 1970s in efforts to provide another sport fishing opportunity for anglers. The spring and fall netting surveys in 1996 documented good numbers and size classes of walleye present. Although early walleye stocking met with limited success, some fish did survive. Walleye from these year classes should carry the fishery for a number of years and bolster young fish numbers through reproduction. Thus, it has been a case in which the MDNR "jump-started" walleye stocks, and now the fish maintain their own numbers with some level of variation in year class strength. Walleye growth, however, remains average to poor at Hubbard Lake.
>
> Angling opportunities for other game fish abound at Hubbard Lake. Good numbers of northern pike, smallmouth bass, and rock bass provide angling. Species such as lake whitefish, brook and rainbow trout add to the fishery via incidental catches. Brook trout are native to some of the Hubbard Lake tributaries while rainbow trout may be offspring from past stockings. An important game fish at Hubbard Lake is the yellow perch. Many factors may lead to the variability of perch numbers over time at this lake including the natural population variation of the species itself, and increased predator levels (walleye, pike, bass). A combination of these possible factors could lead to suppressed perch numbers in various years.

Very little angler catch or effort data have been collected on Hubbard Lake. A special winter creel census was conducted on part of the lake (3,420 acres) in 1935-1936 which documented 894 angler hours and a catch rate of 0.3 fish/hour (Laarman 1976). Eighty-percent of the catch was yellow perch. Laarman (1976) summarizes the extent of the remaining Hubbard Lake angler information:

> A measure of fishing pressure and angler success has been obtained from the general creel census records (1940-64) and from mail surveys in 1970 and 1973. The general creel census was designed only to measure success of those anglers actually interviewed. The mail survey measured total fishing pressure.

From the general creel census, catch rates for Hubbard Lake from 1940-1950 were 0.98 fish/hour and from 1951-1964 were 1.50 fish/hour. More than 90% of the entire species catch in both periods was comprised of yellow perch. Estimated angler effort for Hubbard Lake based on the mail surveys was 28,180 angler days in 1970, and 35,550 angler days in 1973 (Laarman 1976).

Lower South Branch Thunder Bay River - Hubbard Lake Dam to Wolf Creek

The segment of the Lower South Branch TBR from Hubbard Lake Dam to Wolf Creek (Segment J) is relatively shallow with little fish cover (Figure 2). Cobble, boulders, and gravel are the primary bottom type and the primary form of fish cover. Many small intermittent creeks enter the Lower South Branch TBR. All tributaries and this segment of the Lower South Branch are classified as top-quality warm water streams where standard State of Michigan fishing regulations apply.

Lower South Branch Thunder Bay River

Early habitat and fish surveys date back to 1925. Initial observers described a river with a sand, gravel, and boulder bottom type with very little fish cover. This reach was considered unsuitable for both trout and smallmouth bass. Few game fish were found, although chubs, shiners, and darters were present. MDOC began stocking brown and rainbow trout between 1938 and 1957. This was most likely an attempt to create a spring fishery below Hubbard Lake.

The next fish community assessment was conducted at three locations in 1968. The first location was below the Hubbard Lake dam and only three rainbow trout were collected, while many warmwater fish were observed. Rainbow trout had not been stocked (Table 29) in the river since 1957 and may emphasize the importance of nearby cold water tributaries. Two other locations were surveyed a short distance downstream from the dam in 1968. Bottom type consisted of gravel and cobble with very little holding water or cover. No species of trout were collected and the catch, although low, was dominated by warmwater species. Another fish survey was conducted by MDNR, Fisheries Division in 1976 in the same area as the 1968 assessment. Sixteen species of fish were collected, with most fish typical of the Hubbard Lake environment.

Effects of cattle operations on the river were assessed at two locations by MDNR, Surface and Water Quality Division in 1990. Seventeen species of fish were collected and the fish community was classified as slightly impaired. The aquatic macroinvertebrate community and habitat were classified as moderately impaired. Despite this, the cattle operation was deemed not responsible for nutrient input to the system. An 800-foot reach of river two miles below the Hubbard Lake dam was surveyed by electrofishing by MDNR, Fisheries Division in 2000. Fourteen species of fish were collected with fish again typical of the upstream lake environment. Most game fish were scarce with the exception of small yellow perch and rock bass. Mean 2000 July water temperature for this reach of river was 71ºF.

The lack of a sport fishery may be attributable to a variety of factors. Summer temperatures are too warm for trout, although trout may enter the river seasonally from the many small tributaries where temperature data is lacking. Water temperatures in the river are more suitable to cool water species of fish such as northern pike and smallmouth bass, yet legal-sized fish of these species are scarce. This may be attributable to the lack of holding water and cover in the river. The river may be important for the production of forage fish and for retaining young game fish from Hubbard Lake. These species may eventually migrate downstream to Lake Winyah and enhance that fishery.

Tributaries

Many small creeks enter the Lower South Branch TBR in the first four river miles below Hubbard Lake dam. These creeks drain agricultural and forested private lands. These include (in a downstream direction): Pascoba, Scott, Simmons, Bowden, Watson, High Banks, and Big Ravine creeks. Early examinations of the Scott Creek fish community were made in 1925 by MDOC. It was noted as a good trout nursery stream which was previously stocked with trout. Very little information has been collected for these small, yet important, creeks since then. Brief backpack electrofishing fish surveys were made in early-August 1982 at Scott, Simmons, and Watson creeks by MDNR, Fisheries Division. The surveys evaluated the fish community and checked for presence of trout. All three creeks were found to have a cold water regime with instantaneous water temperature readings of 61ºF, 59ºF, and 55ºF, respectively. Brook trout were common in each stream while brown trout were also common in Simmons Creek. Most trout were small with very few legal-size fish captured. Recent water temperature data (Table 7) at Big Ravine, Simmons, and Watson creeks indicate top-quality cold water regimes.

The importance of these small tributary creeks may not be fully understood. Additional water temperature, flow, and fish community data should be collected at the other creeks that have not been surveyed. These small creeks may be significant trout nurseries and because of their small size, may be more vulnerable to poor land management practices. Consideration should be given to their designation as Michigan trout streams and management as State of Michigan Type 1 trout streams.

Wolf Creek – Headwaters to Lower South Branch Thunder Bay River

Wolf Creek (Segment K) is a significant tributary to the Lower South Branch TBR which begins from the formation of many small cold water creeks in northwestern Alcona County (Figure 2). Wolf Creek continues to receive water from many cold water tributaries as it flows in a northeasterly direction to its confluence with the Lower South Branch. Wolf Creek (upstream of T30N, R7E, S32; Alpena County) and all its tributaries are designated Michigan trout streams and managed as Type 1 trout streams. Wolf Creek is unique in that it is designated as top-quality cold water in its upper reaches, second-quality cold water in its middle reaches, and top-quality warm water in it lowermost reaches. It receives a variety of stream types as well. Standard State of Michigan fishing regulations apply in the non-designated trout reach of Wolf Creek. Seventeen small private dams exist on the creeks within this sub-watershed (Table 12). Very few natural lakes exist in its headwater reaches. The more significant lakes include: Beaver, McCollum, and Crooked lakes. Standard State of Michigan fishing regulations apply at these lakes.

Mainstem Wolf Creek

Brown and rainbow trout were stocked in Wolf Creek both above and below what was once known as the Elowski Pond dam (Table 29). This structure was located in Alpena County near the creek junction with the Lower South Branch TBR. Brook trout were stocked in the headwaters of Wolf Creek and its tributaries in Alcona County based on records from the 1920s. At this time, the character of the stream in its middle reaches in Alpena County was first examined (and recorded) through the Land Economic Survey. Stream observations were followed-up by MDOC in 1925 at six locations. The first two locations were near the Alcona–Alpena County line where the stream becomes warmer. This reach was characterized as highly inaccessible and unsuitable for brook trout stocking in a period when trout stocking was a common management tool. The next two surveyed reaches were near and in Elowski Pond further downstream. No game fish stocking was recommended at this location, despite the presence of ample forage. Walleye and trout stocking efforts were believed to have taken place in the pond, but these species were not found in the survey. The final two surveyed reaches were directly below the pond and near the creek's confluence with the

Lower South Branch TBR. The fish chute at the pond was classified as in poor condition in 1925. The fish community in this warm water reach (Table 7) was comprised mostly of forage fish and small rock bass.

In 1960, a fish survey at a stretch in Alpena County near Goodrich Road captured few fish, although small burbot were common. Catches of brook trout by anglers were reported, but none were collected. These fish probably enter Wolf Creek from the tributaries when water temperatures are colder. One hatchery rainbow trout was collected in this reach. It was also around this period that the Elowski Dam was removed. The next survey at Wolf Creek was completed by MDNR, Fisheries Division at two stream reaches in 1982. A 1,620-foot reach of the creek was surveyed in Alpena County near the mouth of Butterfield Creek. Game fish were again scarce in this warm water reach while the fish community was comprised of non-game species. Brook trout were noted as inhabiting this reach in the spring, probably as migrants from upstream reaches or from nearby tributaries. A 2,800-foot reach of Wolf Creek was also assessed in 1982 near the confluence of Schmitt Creek, a cold water tributary near Goodrich Road. This reach of Wolf Creek was also relatively warm. Rock bass were abundant while smallmouth bass were scarce. The one brook trout collected probably emigrated from the cold tributary.

In August 1988, MDNR, Fisheries Division used the chemical rotenone to completely assess the fish community at a 700-foot reach of Wolf Creek downstream of Schmitt Creek in Alpena County. The bottom type was noted as primarily sand and silt. Total standing stock of fish was modest, 92 pounds/acre, and white suckers comprised nearly 60% of this biomass. About 10% of fish were game fish and most of these were small rock bass. The aggregate weight of the 14 smallmouth bass was only 0.7 pounds/acre. Mean July water temperature in 1989 determined from hourly readings was 71ºF.

The habitat and thermal regime of Wolf Creek is a product of the land in which it flows through. The headwaters are highly inaccessible and classified as top-quality cold water. Very little fish data exists for the upper reaches. The downstream fish community in Alpena County consists primarily of non-game fish species and small game fish such as rock bass and smallmouth bass. Reproduction of these species appears adequate in the lower reaches of Wolf Creek. Many young fish may migrate to the Lower South Branch TBR, possibly producing a fishery downstream. Brook trout in the tributaries may use Wolf Creek during colder months. It is not known if a seasonal fishery for trout exists on the lower reaches of Wolf Creek, although occasional catches of trout in the upper reaches are reported. Type 1 trout regulations appear satisfactory for the middle and upper reaches of Wolf Creek.

Tributaries

Numerous tributaries enter Wolf Creek along its course. These include: Little Wolf, Yoder, Bear, Wildcat, Silver, Silver Brook, Robbs, McGinn, Bruster, Indian, Widner, and Davis creeks (designated top-quality cold water); Yoder, Schmitt, Watson, Evans, and Butterfield creeks (designated second-quality cold water); and Pete Ryan, Rayburn, Richmond, and Sucker creeks (designated top-quality warm water). Despite these differences in stream classification, all are managed by the MDNR, Fisheries Division as Type 1 trout streams. Very little fish data exists for these waters. A few streams were stocked with legal-sized trout during the middle of the twentieth-century (Table 29). MDNR, Fisheries Division manages for wild (naturalized) populations of trout in this sub-watershed today. Nearly all Wolf Creek tributaries flow through highly inaccessible private land, so little fish management has been done.

Fish community surveys were made on three of the top-quality cold water streams mentioned above. Davis Creek, which is the headwaters of Widner Creek, was examined in 1925 by MDOC. The current was characterized as swift while water temperature was 55°F on a late-August day. Notes indicate this stream was stocked heavily in 1925. Two significant tributaries to Wolf Creek include McGinn and Indian creeks. Brook trout and slimy sculpin were the primary species captured in these streams during July 2000 electrofishing surveys by MDNR, Fisheries Division. Five percent of the trout catch at McGinn Creek were legal-sized (≥ 8-inches) fish while 3% were legal-size at Indian Creek. The mean July 2000 water temperature, determined from hourly electronic thermometer data, was 53°F at Indian Creek and 58°F at McGinn Creek (Table 7). The small size and cold water temperatures of these top-quality cold water streams limit the growth potential of brook trout. These creeks, thus, are appropriately managed with Type 1 trout regulations. Water temperature in Silver, Little Wolf, McGinn, Indian, and Wildcat creeks were typical of Michigan cold water streams (Table 7).

Only two fish community surveys were conducted for the second-quality cold water tributaries. A survey was conducted in 1982 at two locations along the lower reaches of Schmitt Creek. Stream bottom type was characterized as a mixture of sand, gravel, and silt by MDNR, Fisheries Division. Water temperature at both sites in early-August ranged from 55-58ºF and flow appeared stable. Brook trout were common in both reaches, especially at the upstream sampling location. Twenty-one percent of the trout catch at this latter location were legal-size (≥ 8-inches). Schmitt Creek today continues to have a top-quality cold water regime (Table 7) along with nearby Evans Creek. Classification as a top-quality cold water stream may be more appropriate for Schmitt Creek. Trout in a stream such as this may be more vulnerable to poor land management practices that are often associated with agriculture. In addition, Schmitt Creek may be the source of brook trout that seasonally migrate into Wolf Creek and provide an incidental fishery. Another nearby tributary to Wolf Creek is Butterfield Creek. In August 1982, MDNR, Fisheries Division surveyed a 250-foot reach of Butterfield Creek when water temperatures were 66ºF. Only creek chubs were collected. Recent temperature data at Butterfield Creek indicates a cool water temperature regime which correlates with the fish assemblage (Table 7).

Nearly all top-quality warm water creeks in the Wolf Creek sub-watershed are small tributaries to Beaver Creek which also has a warm water designation. Beaver Creek originates as the outlet of Beaver Lake, yet receives moderate amounts of groundwater prior to reaching Wolf Creek-McGinn Creek. A 550-foot reach of Beaver Creek was surveyed by MDNR, Fisheries Division in late-August 1982. The sampling location was in the lower reaches of the stream and directly below the confluence with Indian Creek (top-quality cold water). Water temperature at the time of the survey was 64ºF. Twelve species of fish were collected. Brook trout were abundant while 55% were legal-sized (≥ 8-inches). A follow-up survey was again conducted by MDNR, Fisheries Division in July 2000 at a 400-foot reach with standard stream electrofishing equipment. The 2000 survey was conducted upstream of the Indian Creek confluence. Beaver Creek is considered marginal above this confluence due to warmer water temperatures. This proved to be true in the 2000 survey. Warmwater species of fish were more abundant and fish diversity was greater with 13 species collected. Only four sub-legal brook trout were collected. Beaver Creek is important to trout seasonally, and below Indian Creek in the summer.

Very little data exists for the small tributaries that feed Beaver Creek or Beaver Lake. Brook trout were stocked in Raymond Creek (West Branch Rayburn Creek) and found to be common in its cold waters (despite warm water designation) as early as 1925. Today, the lower reaches of this stream near its confluence with Beaver Lake are used as a northern pike spawning marsh.

Lakes

At 665-acres, Beaver Lake stands out as the most significant water body in the Wolf Creek sub-watershed. Beaver Lake was first surveyed in 1925 and found to have a typical game and non-game fish community for a northern Michigan lake. An additional fish community and aquatic vegetation survey was made at Beaver Lake in 1950. Sixteen species of aquatic vegetation were identified. Survey effort had intensified by the 1960s, when fish collections occurred in 1962 and 1968. Brush shelters were installed in the lake in 1957 and 1978.

In July 1972, MDNR, Fisheries Division biologists used trap and gill nets to survey the fish community. Smallmouth and largemouth bass, northern pike, yellow perch, bluegill and cisco were among the eleven species caught. Northern pike and smallmouth and largemouth bass growth was fast for Michigan. Cisco were also documented in many older lake surveys. Presence of cisco is an indication that cold well oxygenated waters exist in the hypolimnion of a lake. During the 1972 survey, good levels of dissolved oxygen were present fifty-feet below the surface where water temperature was 43°F.

From 1973-1977, both yearling rainbow trout and steelhead were stocked in Beaver Lake (Table 29). Survival of these stocked trout was determined to be poor during a 1976 gill net survey. In addition, northern pike were abundant in the same survey. Thus, trout stocking was discontinued after 1977. Small yellow perch, bluegill, and cisco were also among the ten species collected during the survey. Angler pressure at Beaver Lake was extremely low, 3 hours/acre from May through September 1977 (Ryckman and Lockwood 1985).

From 1979-2001, 155,700 northern pike fingerlings were stocked in Beaver Lake. Many fish were raised in the pike marsh located on the north shore of the lake. In addition, nearly 13,000 fall fingerling tiger muskellunge were stocked in the lake from 1979-1990. Tiger muskellunge were not stocked after that because fingerlings were unavailable from MDNR, Fisheries Division hatcheries.

Northern pike were collected in a May 1987 netting survey of Beaver Lake, yet no muskellunge were collected. Good numbers and sizes of bluegill, cisco, rock bass, pumpkinseed, largemouth bass, and smallmouth bass were collected as well. Two small yearling walleye were captured from the 1986 stocking effort. Growth for most game fish was average for Michigan, except that pike grew faster than average.

In 1986, MDNR, Fisheries Division began stocking walleye to increase predator numbers in Beaver Lake. Walleye were stocked in 1986, then in alternate years from 1992-2002 (Table 29). In early-fall 1998, an initial walleye recruitment evaluation was conducted. The majority of walleye collected were YOY from the 1998 stocking, indicating fair survival of this year class. The remaining walleye were age-2 fish from the 1996 stocking. No yearling fish were collected indicating little or no natural recruitment. In addition, no larger walleye were collected from the 1988, 1992 and 1994 stocking efforts which may be attributed to sampling bias.

Walleye fingerlings were marked with oxytetracycline in 1998, 2000, and 2002 to differentiate between stocked and naturally reproduced walleye. Due to current insufficient natural reproduction, the walleye spring fingerling stocking program is scheduled to continue at Beaver Lake in alternate years. Walleye survival appears good and anglers are pleased with the fishery.

More than 2,300 fish were collected during the 1999 Beaver Lake fishery survey. Fourteen walleye were collected ranging from 10-25 inches with all, but one fish legal size (≥ 15-inches). Fifty-seven percent of these walleye were larger than 20-inches. Only one walleye from the 1998 year class was collected while no YOY were noted indicating little or no natural reproduction in 1999. These small walleye may, however, not been fully vulnerable to the sampling gear.

Based on netting surveys in 1987 and 1999, the overall fish community at Beaver Lake appears to be in good condition. Game fish diversity is high. In addition to walleye, acceptable numbers of legal size smallmouth bass and northern pike are available to anglers while panfishing opportunities are decent for bluegill, rock bass, and yellow perch. Largemouth bass numbers appeared high in 1987 and lower in 1999. These differences may be a result of the natural variability of fish stocks. Northern pike add diversity to the sport angling component. It was recommended by MDNR, Fisheries Division that the operation of the pike rearing marsh continues at Beaver Lake. The pike fishery is consistent while program cost is low due to cooperation with lake association volunteers. Thus, the program provides for cooperative management and information sharing.

Another important fishing lake in this reach of the watershed is 224-acre McCollum Lake which is the headwaters of McGinn Creek. Good numbers of yellow perch were noted along with lower numbers of predators such as largemouth bass, based on a 1927 survey by MDOC. By the late 1930s and 1940s, a stocking program of warm- and coolwater fish was initiated at McCollum Lake; these stocking efforts ceased by the mid-1940s. From 1961 to 1989, northern pike were the primary species stocked. Presently, no fish are stocked.

An intensive aquatic survey was conducted at McCollum Lake in 1949. At least 16 species of plants were identified at this time. Game fish such as yellow perch, largemouth bass, bluegill, and rock bass were common while predators such as northern pike, smallmouth bass, and walleye were absent from the lake. A less intensive fish seining survey was conducted by MDOC in 1958 which found panfish such as bluegill highly prevalent. Pike, smallmouth bass, and walleye were still absent from the McCollum Lake fish community.

By the 1960s, it was apparent to fisheries managers that another top-line predator could fill a niche in McCollum Lake and add diversity to the fishery. A small, one-acre, impoundment was created adjacent to the lake and would be used for the propagation of northern pike. The first northern pike adults were transported to the marsh from Higgins Lake in 1961. Adults were allowed to reproduce in the marsh while their resulting offspring would be released back into the lake.

In 1970, a fish community survey was again conducted by MDNR, Fisheries Division and found pike to be very abundant in McCollum Lake with good numbers of fish 22-inches and larger. Thus, it appeared that a good pike population had been established. Panfish and largemouth bass numbers and size structure were also considered healthy. By 1983, however, complaints had already arisen from McCollum Lake anglers that the pike population had become stunted. A survey was initiated which confirmed a large population of slow growing pike with very few fish 20-inches or larger or older than age-3.

Operational procedures of the pike marsh had changed by the late 1980s. No longer were adult pike intensively trapped in McCollum Lake and transported to the marsh. This labor and cost intensive practice was replaced by stocking pike fry directly into the marsh by MDNR, Fisheries Division. By 1989, operation of the pike marsh was discontinued due to an abundance of slow growing northern pike already inhabiting the lake and reliance on natural reproduction.

Walleye spring fingerlings were stocked in McCollum Lake in 1988 to create a fishery and possibly self-perpetuating population. A walleye evaluation was conducted in 1990 by MDNR, Fisheries Division to determine survival of the 1988 stocked year class. Only one 2-year old walleye was collected indicating some survival, albeit low. Angler reports at the time however indicated better walleye survival. It was also noted that angler pressure during this period was very high at McCollum Lake, especially for panfish. The yellow perch and largemouth bass populations were still strong.

Today, McCollum Lake has a healthy and balanced fish population based on angler reports. Pike numbers are still high, while some large fish are caught. Young walleye have been caught by anglers as recent as 2002 indicating some amount of natural reproduction. This species has not been stocked since 1988. Growth and abundance information on McCollum Lake panfish is unknown at this time and should be examined.

Fish management at nearby Crooked Lake has closely paralleled that of McCollum Lake. Ninety-acre Crooked Lake has two distinct, yet similar basins and is the headwaters of Silver Creek. Secchi-disk (measure of water clarity) readings through part of the 1980s were gathered by local volunteers at Crooked Lake. Average clarity readings of 13-14 feet indicate this lake is on the oligotrophic-mesotrophic border. In other words, this lake is considered to be somewhat unproductive.

Warm- and coolwater fish stocking was initiated at Crooked Lake from the late-1930s through the mid-1940s (Table 29) at the same time commercial harvest of wigglers was also high. An intensive aquatic community survey was conducted in 1949 by MDOC. Ten species of aquatic plants were identified while a simultaneous survey of bottom invertebrates and water chemistries was conducted. The fish community was surveyed with both gill and seine nets. A typical warm- and coolwater fish community was found which included seven species of game fish.

Another seine survey was conducted at Crooked Lake in 1961 which noted abundant panfish characterized by average growth. Smallmouth bass were also found for the first time. Northern pike were stocked in Crooked Lake in 1962 and 1963 from an adjacent rearing marsh.

In 1981, MDNR, Fisheries Division conducted an extensive survey of the Crooked Lake fish community as a result of local concern over the poor quality of fishing. Slow growing northern pike were now abundant along with average growing bluegill, black crappie, yellow perch, rock bass, bullheads, pumpkinseed, and largemouth bass. An increase in predator numbers was recommended along with manual fish removal efforts of small panfish and bullheads. Labor intensive fish removals were made from 1983 through 1985 at Crooked Lake by MDNR, Fisheries Division personnel and lake volunteers. A total of 1,166 pounds of small fish were removed in hopes of increasing growth rates among remaining sport fish. The majority of biomass removed involved bullheads, yellow perch, and white suckers.

MDNR, Fisheries Division stocked spring fingerling walleye into Crooked Lake at a rate of 69/acre in 1990. Simultaneously, lake residents installed many log crib brush shelters into the lake to attract fish and potentially increase angler catch rates. During fall of the same year, MDNR, Fisheries Division electrofished the entire lake shoreline in order to evaluate survival of spring stocked walleye and to assess the remaining fish community. Sampling conditions were noted as marginal and only one walleye was collected from the 1990 stocking. In addition, an older walleye was collected indicating some low level of natural reproduction of this species in Crooked Lake. Prior to the 1990 stocking effort, walleye had not been stocked in Crooked Lake since 1940. Northern pike and largemouth bass were found to be the primary predators in the lake though growth of pike remained very poor.

New surveys of fish abundance, diversity and growth rates should be made at Crooked Lake. Liberalized minimum size limits of pike may be appropriate if growth remains poor.

Lower South Branch Thunder Bay River - Wolf Creek confluence to Lake Winyah

This river segment (L) flows northerly through a forested corridor with nearby upland agricultural influence (Figure 2). Three significant tributaries merge with the Lower South Branch and include: King, Butterfield, and Robinson creeks. The river and its tributaries are all managed as top-quality warm water streams with standard State of Michigan fishing regulations.

Eight stream bank erosion sites have been inventoried for erosion contribution (USDA 1993). Of those identified, two were minor, five moderate, and one severe sources of sediment.

Lower South Branch Thunder Bay River

Initial observations of this reach of the Lower South Branch TBR were made in 1925 at three river locations. The whole reach was considered too warm for trout. Small forage fish such as shiners, darters, chubs, and suckers comprised the majority of the fish community. An occasional northern pike or smallmouth bass could also be found.

Nearly fifty-years passed until an additional fish community survey was conducted in a 3,200-foot river reach in 1976 by MDNR, Fisheries Division. The survey location was the state forest campground southwest of Alpena. Small game fish such as pike and smallmouth bass were again found to be common along with abundant rock bass. All pike collected were one-year old fish, possibly indicating variable recruitment, poor survival in the system, or migration.

The most recent fish community survey was in 1988 at the same sampling location as in 1976. The piscicide rotenone was used to inventory the entire fish community in a 700-foot reach of the river. No walleye were collected, although they had been stocked near this site and in the mainstem TBR. Standing stocks of fish were modest at 92 pounds/acre. Game fish made up 18% of this biomass, and rock bass and smallmouth bass combined comprised over 90% of game fish biomass. Over half the biomass at the site was white sucker and most of them were large. Total numbers of fish were high, 4,400/acre with over 70% of these fish either bluntnose minnow or common shiner. Although good numbers of rock bass and smallmouth bass were captured, most fish tended to be small.

This reach of river may be vital for its production of both forage and young game fish for Lake Winyah downstream. However, recruitment of game fish to the sport fishing component may be limited as a result of young game fish drifting downstream into a more suitable and productive lake environment.

Tributaries

Very little to no information exists for the three tributaries in this river segment. The smallest of the tributaries, Robinson Creek, was observed by MDOC personnel in 1925. It was designated as a cool water tributary which drained swamp land and had little flow. Trout stocking was not recommended due its small size, but it was regarded as a good nursery stream. Today this stream is managed as a top-quality warm water stream. More updated information on water temperatures, flow stabilities, and fish communities should be acquired at Robinson Creek and at nearby Butterfield Creek where little is known about the habitat and biological community.

King Creek is a more significant tributary with a length of over nine miles. No fish community surveys were conducted prior to 2002 when a 500-foot reach was surveyed by MDNR, Fisheries Division. The survey reach was approximately at the midpoint of the entire creek and thus was a good representative stretch. The general fish community was assessed to gain insight into the abundance and distribution of species in King Creek. Weather conditions were unseasonably warm on the late-July date, yet the creek temperature was a surprisingly cool 62ºF. Despite this cool water, no game fish were collected. The catch was comprised entirely of minnows, suckers, dace, chubs, sticklebacks, darters, and mudminnows. Absence of game fish predators may be partly due to the small size of the creek and lack of deep water. However, forage fish thrive in King Creek which may be a suitable breeding ground for many of these species. It appears that King Creek is managed appropriately as a top-quality warm water stream, although 2003 summer temperatures indicate a periodic cold water regime (Table 7).

Mainstem Thunder Bay River - Four Mile Dam to Ninth Street Dam

This relatively short segment of river (Segment M) is managed as top-quality warm water and includes about three-miles of high gradient river habitat (Figure 2). The remaining stretch is dominated by Lake Besser which is also known as Ninth Street Impoundment. Only one major tributary enters the mainstem in this reach and is an urban stream known as Fletcher Creek. No known fish surveys have been made on this creek. It was the focus of local flooding problems and storm water management recently (NEMCOG 2001).

Seven stream bank erosion sites have been inventoried for sediment contribution. Of those identified, two were classified as minor, and five as moderate sediment contributors (USDA 1993). Two of these identified sites were restored in 1995 by the Thunder Bay Watershed Council (D. Hardies, Montmorency Conservation District, personal communication). Remediation techniques included bank seeding and toe revetment. Efforts continue today to monitor the effectiveness of these procedures. Two road-stream crossings have been inventoried for sediment contribution along the mainstem, while an additional three have been inventoried on Fletcher Creek. Of the total inventoried, three were classified as minor and two as moderate (NEMCOG 2002).

Mainstem Thunder Bay River

Initial observations of the river below Four Mile Dam were recorded in 1925 by MDOC. Bass and pike could be found below the dam along with large numbers of shiners. Further downstream in a rapids stretch, various species of shiners, darters, dace, chubs, and minnows were common along with smallmouth bass, yellow perch, and white suckers. Secondary observations were recorded in 1939 by MDOC (Shetter 1939). Seine hauls in the rapids below Four Mile Dam caught various species of fish including suckers, perch, rock bass, and smallmouth bass. Shetter (1939) discusses early fish management for the river below the dam:

> According to correspondence from Mr. Ben Wright of the Alpena Chamber of Commerce, this section of the Thunder Bay River has, in past years, yielded a few rainbow trout, and it is this section which the Alpena sportsmen wish to stock with lake-run rainbow…
>
> There is considerable doubt as to whether or not any significant run of rainbow trout moves up to the Alpena dam in the Thunder Bay River…
>
> It is suggested that no transference operations be undertaken unless a rainbow run at least as large as was obtained in the Main Au Sable takes place in the Thunder Bay River. An experimental planting of 1,000 tagged adult rainbows might be made late in the fall when the temperature of the river has dropped below 70 to determine the returns from such stocking.

Annual stocking of legal size rainbow trout were made from 1949-1965 (Table 29) to establish a put-and-take trout fishery in the high use area near the town of Alpena. This reach was not stocked after 1965 when a new MDNR, Fisheries Division stocking policy banned stocking of legal-sized trout. Significant trout mortality occurred in 1964 when no water was released for a short period at Four Mile Dam.

Lakes

The only semi-lentic water body in this segment is Lake Besser. Initial aquatic community observations were made at its waters in 1925 by MDOC. Fish typical of a lake environment were found while recommendations to stock walleye, and smallmouth and largemouth bass were made. The impoundment was surveyed by MDOC in 1950 in attempt to gain insight into the plant and fish community. Twenty-three species of vegetation were identified, while gill netting and fish seining produced twenty species of fish including many small game fish. The agency followed up this effort with an electrofishing survey in 1967 which documented a good balance of fish species. Growth of most fish was considered normal except for northern pike which grew well below the statewide average. Growth of game fish in Lake Besser was analyzed again in 1976. Black crappie growth was considered average while pike growth was again extremely slow. Angler fishing pressure was estimated at 14 boat angler hours/acre (Ryckman and Lockwood 1985) at Lake Besser in 1982. This was similar to Lake Winyah upstream, yet much lower than nearby Four Mile Impoundment. The Lake Besser fish population was surveyed again with three types of survey gear from 1982 through 1985. Predator numbers were low, but species diversity was high. Northern pike growth was still considered poor in comparison to the statewide average growth. Only four walleye were captured and were most likely migrants from upstream stocking efforts.

A formal walleye stocking program was initiated in Lake Besser by MDNR, Fisheries Division in 1986 (Table 29). Spring fingerling walleye were stocked on five occasions through 1997. A recent fish community assessment and walleye evaluation was attempted in 1998. Catches indicated a stable fish community capable of supporting a good fishery while forage was abundant enough to sustain predators. Good sizes of largemouth bass, northern pike, and walleye were captured. Walleye stocking was, however, discontinued in the impoundment despite the decent survey catches. Managers felt the migration of young walleye from upstream stocking efforts would sustain the fishery. It was felt among MDNR, Fisheries Division biologists that angler pressure on Lake Besser was too low to warrant direct stocking efforts. Oxytetracycline analysis of the walleye present in this impoundment today would help determine the proportion of fish produced naturally or through the state hatchery system. Walleye that are currently stocked in the river upstream are marked with this chemical, thus allowing for comparative analysis.

Mainstem Thunder Bay River - Ninth Street Dam to Lake Huron–Thunder Bay

No significant tributaries or lakes drain to this short reach of river (Segment N) in the town of Alpena (Figure 2). The Ninth Street Dam impounds the Thunder Bay River about 1.7 miles upstream from Thunder Bay of Lake Huron. A fish ladder to facilitate fish passage was constructed, but did not serve its purpose and did not operate for many years. It eventually was filled and capped. Thus, Ninth Street Dam has served as an impassible obstacle to migrating fish such as sea lamprey, walleye, steelhead, salmon, and lake sturgeon from Lake Huron. The primary direction of fish management is currently focused on potamodromous fish species. MDNR, Fisheries Division has managed it as a Type 3 trout and salmon fishery since 2000. This reach is open year round to fishing with all tackle. Minimum size limits are 15-inches for brook, brown, and rainbow trout, as well as for splake and Atlantic salmon. Minimum size for lake trout is 24-inches and 10-inches for the remaining species of salmon. Warm- and coolwater species of fish are managed with standard State of Michigan fishing regulations.

The river below the dam runs rapidly for a short distance over rubble and gravel substrates. The shoreline is nearly entirely developed and non-natural. Dredging is a significant activity (see **Special Jurisdictions**). One stream bank erosion site was inventoried for sediment contribution (USDA 1993) and was classified as moderate. This site was restored by the Alpena City Council in 1996 with the installation of a formal walk-way. Two road-stream crossings have been inventoried for sediment contribution while an additional two have been inventoried on the municipal intermittent tributaries. Of the total inventoried, three were classified as minor, while one was classified as moderate sources of sedimentation (NEMCOG 2002).

The reach of river directly below the Ninth Street Dam was already considered to be heavily damaged from pollution by 1925 according to MDOC records. A local tannery upstream was considered to be the primary point-source contributor. Despite this, rock bass and smallmouth bass were regarded as fairly common while yellow perch were rare. White suckers, redhorse suckers, walleye, and northern pike were frequent visitors to the lower river during migrations from Lake Huron.

The lower river's potential as a source for migrating trout and salmon began to be realized by the 1960s. Stocking of brown and rainbow trout began by the beginning of the decade. Steelhead, coho, and Chinook salmon stocking was initiated by the late 1960s (Table 29). The purpose of the stocking was essentially two-fold. Migrating fish would provide a seasonal fishery in the river, particularly for shore anglers below Ninth Street Dam. There was also the potential of providing a popular near-shore fishery in Thunder Bay. This was also true for walleye which were stocked in more recent years near the mouth of the river along with ongoing stocking efforts upstream near the town of Hillman.

The near-shore fishery for brown trout in Thunder Bay had become popular by the mid-1970s. Brown trout stocking in the river was eventually discontinued, but the fish were continually stocked directly into the bay. The stocking of Chinook and coho salmon in the river from 1968-1973 was considered a failure by the mid-1970s. The few fish that did return to the river seemed to create a "snagging fishery" while an open water fishery in the bay never materialized. The MDNR, Fisheries Division decided to discontinue salmon stocking and concentrate on the brown trout fishery in Thunder Bay and steelhead stocking in the river. Steelhead runs have created a seasonal fishery below Ninth Street Dam and these stocking efforts continue today (Table 29). The lower river currently receives runs of Chinook salmon from stocking efforts further north in Lake Huron. This produces an additional fall fishery without the expense of stocking directly into the river.

MDNR, Fisheries Division personnel have surveyed parts of the lower river in recent years in attempt to gain insight into nuisance fish species (see **Biological Communities**) and walleye. In 2002, walleye were collected in the lower river and Thunder Bay and analyzed for origin of reproduction. Based on examination of growth structures, it was determined that 55% (32/58) of the walleye were of state-hatchery origin while 45% (26/58) were wild fish (D. Fielder, MDNR, personal communication). Continued examination of wild versus hatchery walleye should continue in the lower Thunder Bay River and Thunder Bay. This would allow fisheries managers to manipulate stocking numbers and sizes.

Recreational Use

The Thunder Bay River watershed offers a variety of recreation opportunities as a result of a vast array of lakes, creeks, and rivers within its boundaries. Considerable amounts of public access can be found in the watershed including state owned canoe and boat ramps as well as many public-owned informal access points (Figure 25). In addition, many water bodies may be accessed through state or federal forest lands (see **Special Jurisdictions**). There is, however, a lack of public access sites or access through forest land in many regions of the watershed. This is especially true for the following locations: Thunder Bay River between Hillman and Long Rapids; the natural lakes of the Upper South Branch Thunder Bay headwaters; the tributaries to Hubbard Lake on the south shore; and the Wolf Creek watershed. Additional access to the lower river and maintenance of sites is being added in compliance with the operating licenses recently issued to hydro-producing projects (Appendix 1). Site maintenance and improvements should be provided at the busier access sites in effort to reduce user conflict and land degradation.

Very little angler pressure and use data exists for the Thunder Bay River watershed. Historical catch rate data was gathered by MDOC conservation officers from the late 1920s through the 1960s (Appendix 3) (see **Fishery Management**). Much of this data was gathered during a period when small inland streams in Michigan were stocked with legal-size trout. Data should, however, be interpreted with caution due to the lack of project design. Fishing pressure data has been gathered during many years at Fletcher Pond (Table 30) and at other various lakes and impoundments (see **Fishery Management**). Angler use, preferences, and demographics are lacking for most parts of the watershed and should be acquired. This may be especially vital for sections of the watershed where fish stocking is an ongoing management tool.

Few lake and wilderness resorts can be found with most located on Fletcher Pond. A significant percentage of the summer tourists who use the floodwater resorts are out-of-state anglers-tourists, with many of the remaining users from the Detroit area. This was the case in 1985 according to a visitors summer market survey (NEMCOG 1985). However, nearly 80% of the winter anglers were local residents in 1995 while only 2% were out-of-state anglers (Lockwood 2000). NEMCOG (1985) summarized Fletcher Pond's importance as a vacation location:

> All the visitors we surveyed came here to fish. But most also came here to relax, enjoy nature, get away, or be with their family. When we conducted our second, more intensive survey, the lake-level was at a low level, making it difficult to launch a boat. This brought many visitors to question returning; this must be addressed to ensure future development around the Floodwaters. Nevertheless, we found that campers are the group most likely to visit even when the lake-level is low. While those renting cabins are most likely to visit when the lake-level is adequate and fishing is good.
>
> In addition to the crucial lake-level/quality of fishing questions visitors felt needed to be addressed. They rated the importance of several accommodations and resources to their returning. They said hot and cold water, showers, clean water, boat rentals, and good roads were very important to their coming back. And, it is important to note, the needs of campers differ from those renting cabins…
>
> This study indicated that Fletcher's Floodwaters attracts visitors from a wide geographic area; their expenditures are important to the local economy. And when combined with expenditures by visitors to similar fishing sites in Northeast Michigan, are now important to the Regional and State economies. To nurture the growth of this market, it is important to know who is coming, why they visit, and what they need to ensure their return.

The Thunder Bay River is used by canoeists and kayakers; however, it is unknown to what extent. Records are not kept by the two liveries that operate in the watershed. Other activities include: trapping, hunting, camping, ORV riding, boating, berry and morel picking, and bird watching. Operation of off-road-vehicles (ORV) is available to the public on two loop systems within state forest land including: the 33 mile Hunt Creek Loop and the 35 mile Brush Creek loop. It is unknown to what extent that operation of ORVs occurs on private land and illegally on public lands. ORVs can lead to stream erosion at crossings. No state parks exist in the watershed, but seven state campground sites can be found with most located on headwater lakes.

Citizen Involvement

Citizen involvement in management of the Thunder Bay River occurs primarily through interaction with government agencies that manage the resource. Government agencies involved are: MDNR; MDEQ; United States Fish and Wildlife Service; United States Forest Service; United States Department of Agriculture – Natural Resource Conservation Service; Huron Pines Resource Conservation and Development Council; various county road commissions; township and county offices; NEMCOG; and the Alcona, Alpena, Montmorency, Oscoda, and Presque Isle Conservation Districts. See **Glossary** for acronym definitions.

Citizens may become involved with non-governmental organizations that also work on various aspects of the TBR watershed. These organizations include: Thunder Bay River Watershed Council; Michigan Council of Trout Unlimited; Thunder Bay Audubon Society; Thunder Bay Chapter of Michigan Steelhead and Salmon Fishermens Association; Friends of Northeast Michigan Ecosystems; Thunder Bay Walleye Club; and the Thunder Bay Trails Association. Lake associations also provide citizens an opportunity to become involved. The Hubbard Lake Sportsmens Association, Thunder Bay River 7-Mile Impoundment Association, Montmorency County Conservation Club, and the Avalon Lake Association are some of the active associations.

The Thunder Bay River Watershed Council provides an excellent avenue for citizen participation. The purpose of the organization is “to protect the water quality and quantity necessary for the fisheries, wildlife, recreational uses, aesthetic enjoyment and general enhancement of the environment” (Thunder Bay River Watershed Council of Northeast Michigan 2003). The Council’s Restoration Committee has coordinated projects such as stream bank stabilization and erosion control.

Public involvement is critical for the long-term protection and enhancement of the Thunder Bay River watershed. Numerous opportunities exist for concerned citizens to become involved in issues affecting the watershed.

MANAGEMENT OPTIONS

The Thunder Bay River is healthy relative to some other rivers in Michigan and characterized between a top-quality cool to warm water system with some portions providing cold water habitat. The thermal regime of the river is directly attributable to the soils and land use types through which the river flows, yet also altered somewhat by dams within the watershed. Physical habitat and biological degradation of the watershed is being addressed in some reaches, but will continually need work. The management options in this assessment are designed to address some of the more important problems that are now understood.

The options follow the recommendations of Dewberry (1992), who outlined measures needed to protect and preserve the health of a river's ecosystem. Stressed are the protection and restoration of headwater streams, riparian corridors, and floodplains. We must view the river system as a whole, for many important elements of fish habitat are driven by whole system processes.

The following options are consistent with the mission statement of the MDNR, Fisheries Division. This mission is to protect and enhance public trust in populations and habitat of fishes and other forms of aquatic life, and promote optimum use of these resources for the benefit of the people of Michigan. In particular, the division seeks to: protect and maintain healthy aquatic environments and fish communities and rehabilitate those degraded; provide diverse angling opportunities and maximize the values of these fisheries; and to foster and contribute to public and scientific understandings of fish, fishing, and fishery management.

We convey option types for correcting problems in the watershed. First, we present options to protect and preserve existing resources, second are options requiring additional surveys, and third are opportunities for rehabilitation of degraded resources. Opportunities to improve an area or its resources, given its present status, are listed last. These options are not intended for MDNR, Fisheries Division action only, but should also be initiated by citizen groups and other agencies.

Hydrology and Geology

The TBR has very stable flows in the segment from the Headwaters to Hillman dam. Flow stability declines further downstream on the mainstem and flow was very unstable in the Upper and Lower South Branches of the TBR when these river segments were last gauged for flow by USGS from 1945-54 (see **Hydrology**). We do not have contemporary discharge information to determine how much this has changed. Spilling and retention of water at the Fletcher and Hubbard Lake dams to achieve different winter and summer lake-levels continues to create unstable flow conditions in these segments. The Thunder Bay River watershed has a diverse and complex surficial geology, ranging from porous glacial deposits to relatively impervious peat. The different geological types result in different water delivery pathways (groundwater or runoff) in the watershed.

Option: Protect natural hydrologic regimes of streams by protecting existing wetlands, flood plains, and upland areas that provide recharge to the water table.

Option: Protect and restore groundwater recharge by requiring that all development-related runoff be captured by infiltration basins.

Option: Protect natural seasonal flow patterns of the river by incorporating best management practices and requiring that no additional runoff enter the river from land development.

Option: Protect existing hydrologic conditions of lakes and remaining natural lake outlets by prohibiting construction of new lake-level control structures. This would ensure natural water level fluctuations needed to maintain wetlands around a lake and at lake outlets as well as reducing drought flow conditions in outlet streams.

Option: Restore natural hydrologic regime of streams by removing dams when possible and requiring existing dams to strictly adhere to run-of-river flow operations.

Option: Restore natural hydrologic regime of lakes and lake outlets by removing lake-level control structures when possible.

Option: Restore headwater, tributary, and mainstem run-of-river flows by operating lake-level control structures as fixed-crest structures with wide spillways rather than by opening and closing gates or adding or removing stop logs.

Option: Explore opportunities to recreate wetland habitats by plugging or otherwise disabling drain tile systems that are no longer needed for their original purpose (such as drainage fields on retired agricultural lands).

Option: Explore the possibilities of reestablishing USGS gauge river monitoring.

Option: Protect all existing stable streams (particularly cold water) from effects of land use changes, channelization, irrigation, and construction of dams and other activities that may disrupt the hydrologic cycle, by working with land managers, planners, and MDEQ permit reviews.

Option: Protect natural movement of water to the river by restricting addition of impervious surfaces in the watershed.

Option: Protect the unique geological features of the watershed, while simultaneously protecting groundwater, by preventing any type of contamination of regional sinkholes.

Soils and Land Use Patterns

While still relatively undeveloped, the Thunder Bay River watershed has a variety of land use issues that can affect the river. Sandy soils are susceptible to erosion, particularly in road construction and maintenance, and riparian development. The loss of wetlands, combined with some agricultural practices, may increase sedimentation.

Option: Protect watershed soils from improper land use by encouraging the participation of the watershed council in land use planning, development, and other river protection issues.

Option: Protect undeveloped private riparian lands by bringing lands under public ownership or through economic incentives such as tax credits, deed restrictions, conservation easements, or other means.

Option: Protect lands through land-use planning and zoning guidelines that emphasize protection of critical areas and discourage alteration of natural drainage patterns. Support development of zoning standards for townships presently not zoned.

Option: Protect the river from excessive sedimentation by encouraging education of workers involved in road siting, construction, and maintenance regarding use of best management practices (BMPs).

Option: Protect the river from excessive sedimentation by reducing densities of oil and gas well pads. This can be accomplished by increasing spacing between oil and gas well pads and supporting increased use of angular drilling techniques.

Option: Protect the river from excessive sedimentation associated with oil and gas development by requiring quicker re-vegetation of soils in affected areas.

Option: Protect channel from excessive sediment delivery by using BMPs at road-stream crossings. Support cooperative funding in situations when local road commission budgets are inadequate for use of BMPs.

Option: Protect and maintain forested buffers along lake shores and river corridors to retain critical habitats and to allow for natural wood deposition.

Option: Encourage completion of soil surveys for the entire basin by the appropriate resource agency.

Option: Rehabilitate or improve instream culverts or road crossings that are under-sized, perched, misaligned, or placed incorrectly.

Option: Encourage the use of bridges to improve road-stream crossings and discourage the use of culverts.

Channel Morphology

While the Thunder Bay River is generally a low-gradient system, there are fair amounts of important higher gradient sections. These higher gradient sections are generally found in cold water reaches of the watershed. Impoundments also mask much of the higher gradient reaches in the system.

Option: Protect diverse stream channel habitats by preventing removal of large woody structure now in the river.

Option: Protect channel morphology by using bridges or properly sized culverts at road-stream crossings.

Option: Protect and restore riparian forests by educating riparian residents on how riparian forests influence water quality, stream temperatures, trophic conditions, channel morphology, bank erosion and stability, and aquatic, terrestrial, and avian communities.

Option: Protect riparian greenbelts through adoption and enforcement of zoning standards.

Option: Prioritize stream sections and erosion locations for communicating biological benefit with restoration groups.

Option: Survey cold water streams to identify where high beaver activity (or beaver dam density) adversely affects riparian habitats and stream channel morphology.

Option: Rehabilitate channel diversity by removing excess streambed sediment load and controlling sediment contributions.

Option: Rehabilitate channel configuration in reaches where dam peaking operations have permanently altered river appearance and function.

Option: Improve channel diversity by adding woody structure or habitat improvement structures in reaches where channel diversity is low, or in reaches where natural contributions of large woody debris have been reduced. Examples are in areas where residential development or past logging practices have eliminated mature forests or instream logjams, and in reaches below dams which block downstream transport of woody structure.

Dams and Barriers

Seventy-three dams remain within the watershed. Some impound considerable high-gradient habitat, block potamodromous migrations of fishes, block migrations and drifting of resident fishes, and may create flow fluctuations in streams. Other dams may elevate stream temperatures, impair water quality, trap sediments and woody structure, and eliminate natural lake-level fluctuations.

Option: Protect fishery resources by screening turbine intakes at operating hydroelectric dams.

Option: Protect the public trust by requiring dam owners to make appropriate financial provisions for future dam removal or perpetual maintenance.

Option: Survey below major dams to determine if run-of-river mode operation has stabilized fish populations. Survey effort should mimic past surveys.

Option: Survey dams throughout the watershed to examine conditions and identify areas where environmental damage and the need for mitigation are greatest.

Option: Survey state-owned dams, especially floodings, and examine ways of creating better impoundment fish habitat.

Option: Survey beaver dams and use throughout cold water tributaries.

Option: Restore free flowing river conditions by removing dams no longer used for their original purpose.

Option: Rehabilitate the former productivity of the Thunder Bay River for Lake Huron fishes by removing dams on the lower mainstem.

Option: Rehabilitate the former partial productivity of the Thunder Bay River for Lake Huron fishes by installing fish passage at Seven Mile, Four Mile, and Ninth Street dams.

Option: Identify and rehabilitate poorly designed road-stream crossings including undersized bridges and culverts, perched culverts, and poor approaches.

Option: Relocate woody structure from trash racks and strategically place them in the river or impoundments.

Water Quality

Water quality is generally good throughout the watershed. Threats to water quality in the basin include nonpoint source pollution such as agricultural runoff and poor road-stream crossings; atmospheric deposition; mercury deposition in inland water bodies and fish, and toxics found in Great Lakes fish migrating into the river.

Option: Promote public stewardship of the watershed and support educational programs teaching best management practices that prevent further degradation of aquatic resources.

Option: Protect water quality downstream of Thunder Bay Power Company dams by continuously monitoring water temperatures and dissolved oxygen levels, and seeking mitigation for violations of water quality standards.

Option: Protect water quality by protecting existing wetlands, rehabilitating former wetlands, and maximizing use of wetlands and floodplains as natural filters.

Option: Protect the river by implementing best management practices for storm water and nonpoint source pollution.

Option: Evaluate water quality characteristics (especially nutrient levels) at sites where historic data exist to better determine the extent of temporal changes in water quality.

Option: Survey effects of nonpoint source pollutants on river water quality characteristics.

Option: Survey temperature elevation effects of dams and develop a list of dams having the greatest thermal effect on downstream reaches.

Option: Survey dissolved oxygen levels below dams to determine where effects are the greatest.

Option: Survey loading of nutrients and sediment to the river and develop strategies to reduce identified problems.

Option: Restore water quality by supporting Act 307 site cleanups.

Special Jurisdictions

The Federal Energy Regulator Commission licenses six active hydropower facilities in the watershed. The State of Michigan owns a fair amount of land in the watershed, including important riparian habitats. Various laws and controls are in place allowing for state regulation of developmental activities. Local units of government and county road commissions are responsible for road-stream crossings and many lake-level control structures which affect sedimentation rates and streamflow conditions in many areas.

Option: Protect and restore the watershed by holding all parties to the terms of the Settlement Agreement reached for the six Thunder Bay Power Company dams.

Option: Protect the quality of wetlands, streams, and lakes through rigorous enforcement of Public Act 451, parts 301 and 303.

Option: Protect riparian habitat by working with agencies to enact best management practices (logging operations, oil and gas development).

Option: Survey contaminated sites to prioritize for state-funded cleanup.

Option: Survey and update fish consumption advisories within the watershed.

Option: Restore biological friendly lake-levels at various lakes.

Biological Communities

Biological communities in the Thunder Bay River watershed have been affected by fragmentation by dams, habitat loss from sedimentation, and exotic species introductions. Impoundments block upstream migration of potamodromous species like lake sturgeon and steelhead; sediment from nonpoint source pollution can cover gravel and other important substrate; and exotic species such as zebra mussels can have large affects on aquatic ecosystems.

Option: Protect gravel habitats from sedimentation due to land development by enforcing local soil and sedimentation codes. Implement nonpoint source best management practices at construction sites.

Option: Protect stream margin habitats, including floodplains and wetlands.

Option: Evaluate fish communities on river segments and lakes without recent survey data. Surveys should encompass the fish community, according to MDNR, Fisheries Division sampling procedures.

Option: Protect resident, naturally-reproducing fish populations by screening all private and public fish stocking efforts to ensure they are free of diseases and undesirable species.

Option: Survey present distribution and status of fishes, aquatic invertebrates, mussels, amphibians, reptiles, aquatic plants, and pest species throughout the river system.

Option: Restore potential for fishes to migrate throughout the river system by removing appropriate dams.

Option: Restore historic runs of potamodromous fishes and the productive capacity of remaining high-gradient, riverine reaches in the lower mainstem by removing barriers or installing fish passage structures to re-connect them to Lake Huron (particularly Seven Mile, Four Mile, and Ninth Street Dams).

Option: Restore lake sturgeon populations in the lower mainstem by stocking.

Fishery Management

Much of the upper mainstem Thunder Bay River and its tributaries provide self-sustaining populations of brook and brown trout. Some of these reaches, particularly the mainstem, are used seasonally by trout due to water temperature limitations. Dams in the lower river prevent migrating salmonid populations and other Great Lakes fishes from accessing habitat upstream. Anglers currently have less than two river miles in which to pursue Great Lakes migrating fish. Downstream reaches of the Thunder Bay River (upstream of Lake Winyah) and its major tributaries lack good numbers of adult game fish possibly as a result of high natural mortalities and drifting. These areas may be suitable for production of Great Lakes salmonids and other important species. Natural lakes may be the key resource in the watershed and typically provide good fishing. High flushing rates in the upper impoundments limit the potential for fish management in some of these water bodies.

Option: Protect self-sustaining trout stocks by discouraging stocking on top of these populations. If fish are stocked, require the stocked fish be certified as disease-free.

Option: Protect habitats for fish by protecting and appropriately managing existing riparian forests (work with loggers, ORV use, agriculture, and oil and gas development).

Option: Protect fish communities by working with private citizens and communities to restrict construction of additional dams.

Option: Continue to survey communities and habitats and improve ability to target fisheries management at the mainstem, tributaries, and lakes.

Option: Survey the percentage of wild versus hatchery-reared walleye through oxytetracycline analysis (especially in the lower impoundments and river) in attempt to gain better insight into stocking effectiveness.

Option: Gather critical fish and temperature data on creeks and change designated Michigan trout stream status where appropriate.

Option: Survey anglers in the watershed, where data is lacking, to gain insight into catches, preferences, and harvest rates.

Option: Survey lakes where walleye and trout stocking efforts continue today.

Option: Identify streams or stream segments, in coordination with the MDNR, Wildlife Division, where more aggressive control of beaver and their dams would restore trout habitat.

Option: Restore fish communities by improving habitat through removing dams and allowing for natural downstream transport of sediment to Lake Huron.

Option: Restore historic runs of potamodromous fishes such as salmonids, walleye, and lake sturgeon and restore the productive capacity of remaining high-gradient, riverine reaches in the lower mainstem and lower tributaries by removing barriers (Seven Mile, Four Mile, and Ninth Street dams) or providing for fish passage.

Option: Restore connections between habitats by removing dams no longer used for their original purpose, dams that are a safety hazard, and dams serving little purpose.

Option: Restore sites of severe in-stream erosion and road-stream crossings by working with interested groups.

Option: Improve survival of fishes migrating downstream by providing fish passage and screening turbine intakes at hydropower facilities.

Option: Establish a quality walk-in fishery or fisheries in the Thunder Bay River watershed, either through an existing water body or through land purchase.

Option: Continue stocking warm- and coolwater fish species in various parts of the watershed in order to maintain diverse fisheries and fish communities.

Option: Explore the option of establishing a muskellunge fishery in the lower river and/or impoundments.

Recreational Use

Little is known about the value of recreational use in the Thunder Bay River watershed. Public access to the river is good in some locations and poor in others. Access to natural lakes and impoundments is greater. Only six public campgrounds exist in the basin while there are no state parks.

Option: Survey the level of recreational use of the lower mainstem, the lower impoundments, Fletcher Pond, and Hubbard Lake. Estimate the economic value of these water bodies and compare with economic estimates made for different Michigan water bodies.

Option: Evaluate options for aquatic vegetation management at Fletcher Pond while maintaining the high-quality fishery already present.

Option: Improve public access opportunity where lacking (especially those already identified) through MDNR, county, township, and other municipal recreation departments.

Option: Improve camping opportunities on the lower impoundments (especially Seven Mile Impoundment) by obtaining land for this purpose.

Option: Improve canoe portages and boat launches at all dams along the mainstem and branches. These sites can be maintained by hydropower facilities under FERC relicensing agreements where applicable.

Option: Improve recreational fishing potential of the lower mainstem and branches by removing dams or providing fish passage when possible and providing upstream passage of Lake Huron fishes into existing riverine reaches.

Citizen Involvement

Citizen involvement is crucial to resource management in the Thunder Bay River watershed. Future management of the watershed should incorporate participation from the public.

Option: Educate citizens and other governmental agencies and resource managers about important management issues by providing information through various media outlets, sports groups, civic leaders, and other management agencies.

Option: Protect the watershed by building public support through a network of citizen involvement groups.

Option: Support and improve communication between interest groups and governmental agencies.

Option: Support citizen group efforts to seek funding for the protection and restoration of the river system.

PUBLIC COMMENT AND RESPONSE

A draft of this river assessment was first distributed for public review in early summer 2005. Statewide MDNR Press Releases were issued in conjunction with the draft. Draft copies were sent to a variety of agencies and individuals. Copies were also sent to libraries in Atlanta, Hillman, and Alpena as well as local townships. A letter explaining the purpose of this river assessment and requesting review comments was enclosed with each copy. All individuals requesting a copy received one. Copies for distribution were available from the Gaylord Fisheries Division office.

Public meetings to receive comments concerning this river assessment draft were held on July 26, 2005 at the community center in Hillman; and at the Days Inn in Alpena on July 27, 2005. Public notices were published before the public meetings in local newspapers. Attendance at these meetings was: Hillman- 13 people and Alpena- 9 people.

The comment period for oral or written comments ended after August 31, 2005. All comments received were considered. Similar comments were combined to avoid unnecessary duplication. Suggested changes were either incorporated into the final document or listed along with the reason why they were not included.

Entire Draft

Comment: Various comments suggested changes in grammatical or spelling structure.

> Response: Thank you. These changes were made.

Comment: Numerous comments were received that the Thunder Bay River Assessment provides an excellent compilation of information describing the Thunder Bay River system, and the authors made great attempts to make it understandable to the layperson. The document should become an excellent resource for future decision making and a reference for watershed issues for years to come.

> Response: Thank you.

Comment: What other additions will be made to the final draft?

> Response: The final publication incorporates all edits along with the **Public Comment and Response** section. A separate management plan is then created addressing management options that Fisheries Division will work on in the next five years.

Hydrology

Comment: We recommend deleting the second part of the first sentence in the Hydrology section. The station was reactivated in July 2002.

> Response: This has been done.

Comment: In the third paragraph of this section, we suggest that low flow yields could not be quantitatively determined for the Upper South Branch TBR due to the lack of appropriate data. We also suggest that the operation of the dam renders the data as "inappropriate" instead of "useless".

Response: Thank you. This has been corrected.

Comment: Several of the "other Michigan streams with similar-sized catchments" from Figures 7-13 are questionable comparison stations, especially when considering low flow. The problem is regulation upstream from some of the stations, and more importantly, the diversion of flow "from" or "to" the stream. A couple of stations are also affected by urbanization. If you want to remove the sites with diversion and re-label the figure caption to indicate some station records are affected by regulation, this might be a way to preserve most of these illustrations.

Response: Thank you for clarifying, we have modified some of the captions to account for diversion and water regulation.

Comment: For Table 5, I retrieved one station from the website and there was at least one disagreement with the means. We will let the authors check the remainder of the other station's data.

Response: We have revisited the numbers in tables 5 and 6 and made any necessary corrections, adding years of data where appropriate.

Soils and Land Use Patterns

Comment: I am concerned over the rate of oil and gas development. Who has jurisdiction over this industry?

Response: The Department of Environmental Quality Office of Geological Survey has jurisdiction over the oil and gas industry. The MDEQ and MDNR work cooperatively to ensure protection of the state's streams, rivers, lakes, and wetlands, through the lease classification review process and permit reviews. Permit and lease requirements for these developments typically include best management practices like buffer zones, which are areas adjacent to waterbodies where activities are limited.

Comment: "Detailed soil information for Montmorency and Alpena counties is available from the local county Conservation District."

Response: Thank you. Citations for these newly published reports have been added to the document.

Comment: The authors pointed out that road-stream crossings are potential sources for environmental problems. Many of these crossings are stereotyped as gravel roads with steel culverts. However, the authors also need to consider the deleterious effects that paved roads can cause when crossing the Thunder Bay River. Runoff from these types of crossings is just as much an issue as runoff from gravel roads. Detention ponds and rain gardens should be used to capture this excessive runoff from paved roads.

Response: The statement regarding the severity of road-stream crossings in the watershed was based on inventories. The authors agree that all road-stream crossings are capable of producing sedimentation or excessive runoff and both are a form of pollution. MDNR Fisheries Division works closely with MDEQ to review all newly constructed bridges and culverts. Private citizens should also work closely with local officials to correct these pollutant sources.

Comment: Boat speed limits should be enforced on the narrow portions of the Thunder Bay River. The wake from power boats erodes the river banks.

Response: Some boating laws are in place that reduce boat speed in narrow or shallow areas of rivers. If these are established, but not followed, then citizens should report the illegal activity to local MDNR Law Enforcement officials. In order to create more stringent boating laws, a citizen(s) should contact the Township Supervisor who begins the process of creating local boating laws through the Township Board. The Township Board would pass a resolution of support and seek out MDNR Law Enforcement for establishing the law.

Channel Cross Sections

Comment: The word "actual discharge" on page 21 is misleading to the reader. To better contrast the single point in time measurement versus the average for the day, I suggest changing the word "actual" to "instantaneous".

Response: This has been done.

Comment: I am puzzled why this paragraph is included. The width information "discrepancy" with the predicted equation is more than likely caused by the bridge cross section where these measurements were made. The discussion ignores the basic assumptions that went into the development of the regression equation on page 21. The USGS does not necessarily measure the discharge at a stream gauging station at the same cross section during each visit. The USGS selects the best cross section to measure the river (each visit) based on the conditions present at that time. If you want to revisit this section, this site now has 36 discharge measurements instead of just two. Pertinent information for all discharge measurements can be obtained from the USGS website.

Response: This paragraph has been modified to account for these comments.

Dams and Barriers

Comment: Fishing has been better in recent years because of improved dam operation.

Response: We are glad to hear this. Run-of-river mode operation definitely helps stabilize flow regimes and aquatic communities.

Comment: How do we stop the continued development of dams in the TBR watershed? What prevents someone from building a dam in order to create more waterfront property?

Response: Development of our aquatic resources is governed by the MDEQ as explained in the **Special Jurisdictions** section. MDEQ seeks assistance from MDNR Fisheries Division (and other agencies) on any potential development along the riparian corridor, including the creation of dams. MDNR Fisheries Division does not support new dam construction.

Comment: Is the Atlanta Pond dam a top- or bottom-draw dam? Would changing the draw of the dam to a bottom draw improve water temperatures below the dam?

Response: Atlanta Pond dam is a top-draw dam. Because of the low head of this dam and the relatively small volume of the impoundment compared to the flow of the Thunder Bay River, practical fisheries benefits that can be attached to the construction of an under-spill at this dam are minimal. Cold water temperatures in the river would be better attained by complete removal of the Atlanta Pond and dam.

Comment: What impact would dam removal have on exotic species?

Response: Un-impounded river sections represent poor habitat for most exotic species (except sea lamprey) that are of growing concern in Lake Huron. With fish passage, these species may become established, but no significant populations would probably develop due to the river's current, cool temperatures, and relatively unproductive waters. Sea lampreys would have to be blocked from river and tributary habitats upstream of the lowermost dam.

Comment: There would be an economic impact if you removed the dams. You could not bring enough economic activity to the area in a restored system compared to what it is now with the impoundments.

Response: The **Dams and Barriers** section of this river assessment describes the effects of dams on the Thunder Bay River watershed. Included in this is a list of a number of possible ways (options) to better manage the river system. In the effort of being inclusive, this included both pros and cons of dam removal. It also included the discussion of fish passage without removing dams. We understand that the system would change if dams were removed or if fish passage was attained (e.g., fish ladders at dams). However, based on our knowledge of fish passage at various other Michigan rivers, we feel that the overall effect would be highly beneficial economically to the Alpena region. Very little information on fishing pressure in the lower TBR impoundments (Besser, Four Mile Pond, Winyah) is available to fish managers, but we feel it is probably low on a per acre basis. Assessing angler pressure is one of the management goals of this river assessment.

Comment: With all the talk of dam removal, what happens to landowners that have lakefront property on impoundments? Waterfront value could be lost with dam removal.

Response: Property owner rights would need to be considered if dams were ever removed along the Thunder Bay River. There could be removal of dams at some locations where riparian rights are not an issue, and fish passage at other dams where riparian rights are an issue. Various studies, from across the country, have documented restored healthy aquatic systems and riparian property values following dam removal. This was discussed in the **Dams and Barriers** section. Some examples in this state are: Stronach Dam—Pine River, Salling Dam—Au Sable River, and Big Rapids Dam—Muskegon River.

Comment: What is the likelihood of fish passage through the Thunder Bay River dams?

> Response: The six main FERC regulated dams, as discussed in this section, on the Thunder Bay River and its tributaries, are currently under a 40-year operation lease (through 2038) and settlement agreement. The goal for the MDNR Fisheries Division is to have complete upstream and downstream fish passage at these dams. This could be from dam removal or fish ladders. We will continue to work with groups and agencies in determining ways to accomplish this option. There currently is a working committee in place leading the way on this subject. It is made up of MDNR, USFWS, and power company personnel.

Comment: The reality is that dam removal/fish passage may not occur in due time. Issues regarding social aspects of dams needs to be considered as well. For example, Thunder Bay Power Company is liquidating their property assets and new riparian owners on TBR impoundments may not favor dam removal.

> Response: We agree with this and understand it is a long process. The purpose of this assessment was to make the readers aware of all biological and social factors that exist in this watershed. The management options are “action items” that may be taken up by not only MDNR, but also other agencies, groups, and individuals. These options can be as simple as purchasing and preserving property along the river corridor, to working with new dam operating agencies which have purchased the rights to the dams. Readers are encouraged to review all management options.

Comment: How is fish passage at dams accomplished when extensions to the power companies are continually filed with the Thunder Bay Working Committee?

> Response: Fish passage will be provided when the members of the Thunder Bay Working Committee (Thunder Bay Power, various resource agencies, and Michigan Hydro Relicensing Coalition [ex-officio member]) deem it prudent and funding is available. Extensions of time have been requested and granted when it was appropriate or necessary to revise plans or documents, gather additional information, or respond to new information. The extensions that have been granted have generally been short term (1-2 months).

Comment: What happens when leases to operate dams expire or are denied? If the lease is denied, do the dams have to be removed?

> Response: When a license is up for renewal, the project is evaluated and a determination made at that time. Very few dams are not relicensed. However, as many dams get older, it may become more of an issue depending on the amount of rehabilitation that the structures will need compared to their ability to generate revenue.

Comment: Removing a dam would be like moving off a lake to a creek.

> Response: MDNR Fisheries Division manages for both healthy lake and stream corridors. There is biological value in both types of water and surrounding ecosystems.

Comment: We should look at alternative methods for passing fish at dams without disengaging people who enjoy the impoundments.

Response: Pros and cons of dam removal or fish passage were discussed in great detail in both the **Fishery Management** and **Dams and Barriers** sections. Understanding and working with social factors would also be a large part of this process. Various means of fish passage accompanied with dam removal could accomplish many goals.

Comment: Hopefully people will keep in mind some of the disastrous floods that Alpena had before the dams were built.

Response: None of the dams on the Thunder Bay River were built for flood control. Of the six dams regulated by FERC, two are for water storage and four are for power operation. Many floods occurred following the logging era when the forests were extensively cleared.

Comment: Fishing for potamodromous salmonids on a river is a specialty sport, while fishing for cool- and warmwater species in the impoundments can be enjoyed by all. This should be taken into consideration if dam removal is a viable management option.

Response: The point is well taken. We feel we made it clear in this river assessment that there are pros and cons to fish passage for a variety of species. The authors would not want to lose viable impoundment fisheries such as Fletcher's Floodwaters or possibly Lake Winyah. However, fish passage (not even considering dam removal) would benefit a diverse array of anglers through walleye, salmon, and steelhead fish migration. Other species such as northern pike, muskellunge, and even whitefish could benefit. Protection of headwaters trout populations and impoundment fisheries would be viable management practices.

Comment: I am concerned that allowing salmon and steelhead to migrate upstream would increase trespassing issues, habitat degradation, and general law enforcement issues due to the increase of anglers pursuing these species.

Response: These are all issues that would have to be investigated if passage of salmonid species was to occur. Purchasing land and providing angler access are management options that could address these issues.

Comment: I am concerned about dams, of all sizes, that still exist because they are "grandfathered in". It seems as though people living downstream of dams have no recourse over dams and their effects upstream.

Response: Private citizens, landowners, and local agencies should work with dam owners to explore ways of removing dams and restoring healthy riverine ecosystems.

Comment: I have property at Hall Road on the Thunder Bay River. What effect would dam removal have on water levels?

Response: The authors believe that dam removal would have no effect on the Thunder Bay River in the Hall Road area.

Comment: Various individuals supported dam removal as viable options to restoring the Thunder Bay River watershed.

Response: Thank you for your comments.

Comment: What better way to produce electricity (dam operation) than through the natural flow of a river, compared to the burning of coal or the fear of nuclear power plants?

Response: Turbine operation does offer a viable means of producing electricity, but it has been at the expense of natural river systems and corridors for far too many decades. Many dams have lost their ability to generate revenues and leave owners with the reality of dilapidated structures and low cost to benefit ratios.

Comment: If the Ninth Street Dam were removed, there is another “dam” that would impede the movement of fish up the river. The “dam” is the old Chisholm Street Bridge. When the latter was replaced in the 1920s, portions of the concrete structure were dropped into the river. During low water periods, this structure is obvious, and could prevent fish passage further upstream. Removal of the Ninth Street Dam would create a waterfall at this location.

Response: Thank you for the information. Based on pictures (old and new), it is the feeling of these authors that this debris would not prevent fish passage upstream, especially in spawning periods. However, if fish passage (dam removal or fish ladders at Ninth Street Dam) ever became a reality, MDNR would need to investigate this possibility and investigate removing the human-created debris.

Comment: Eliminating the Ninth Street Dam would eliminate the unique Alpena Wildlife Sanctuary which is a collection of small islands separated by shallow channels.

Response: This would need to be considered if the option of dam removal at Ninth Street Dam became a reality. Also explored (at great length) in this river assessment was the creation of upstream fish passage (through ladders) at this lowermost dam.

Comment: Eliminating the Ninth Street Dam would make canoeing more difficult. Currently there is a five mile reach of river that is protected from high waves or strong currents.

Response: Removing dams would simply bring the river back to “river status”. We feel that removal of some of the lower dams would provide very popular canoeing and kayaking areas due to the higher gradients in this area. This could become an attractive activity for the Alpena region.

Comment: What would happen to the wildlife on the impoundments if dams were removed?

Response: Wildlife, including eagles, mink, otters, and ducks would still use the watershed, and possibly to a greater extent if dams were removed.

Comment: We feel that the water basin could be improved in other ways (compared to dam removal) such as vegetation control and fish ladders for fish passage.

Response: We agree that fish ladders to create complete fish passage would be highly beneficial to parts of this watershed. We feel we covered this topic in the river assessment in great detail. Dam removal would also be beneficial, since a significant amount of high quality spawning habitat exists under these impoundments. Excessive aquatic vegetation occurs in impoundments as nutrients get stored and invasive species such as Eurasian milfoil spreads. Vegetation makes a system productive since it is the base of the food chain. Aquatic vegetation is part of living on a lake or impoundment, and would be less of a problem if the riverine environment was restored. Some management options call for the control of invasive vegetation types in the upper river and Fletcher's Floodwaters.

Comment: I feel that removing the Ninth Street, Four Mile, and Hillman dams would benefit this river system tremendously. Retention of the Seven Mile Dam would provide a buffer to the upper river and protect the quality Lake Winyah fishery.

Response: Thank you for your comments.

Water Quality

Comment: The USGS collected water quality samples, as part of the Federal NASQAN program between October 1979 and August 1993 at the stream gauging station immediately downstream of Four Mile Dam. This data may be of use to users of this report.

Response: Thank you. We have added a paragraph summarizing the collections and added the website link to the information.

Comment: The USGS does not necessarily "collect" water samples for the MDEQ, more so, it administers the water quality program.

Response: The wording has been changed to reflect this comment.

Special Jurisdictions

Comment: Have analyses regarding the occurrence of petroleum-based contaminants in the Thunder Bay River watershed been conducted?

Response: Petroleum-based contaminated sites (Table 21) in the watershed and inner Thunder Bay Harbor have been identified by the MDEQ, Environmental Response Division.

Comment: Is there any truth to the rumor that portions of the Thunder Bay River will be designated as a natural river?

Response: The State of Michigan, Natural River Program, in its early stages, did list the Thunder Bay River as having potential for designation. However, no studies have occurred to determine the feasibility of designation, and the authors know of no plans to accomplish state designation.

Biological Communities

Comment: Various readers made corrections/suggestions regarding the distribution of fish and birds in the watershed.

> Response: These have been verified and corrected in this river assessment.

Comment: Is there a residual population of Great Lakes muskellunge between the Ninth Street and Four Mile dams, and if so, how would they be served by dam removal?

> Response: Anglers report muskellunge in this lower section of the river, and this is reflected in the appendices. Muskellunge are a native species that survive in low numbers and most likely became extirpated upstream of Four Mile Dam by the dam itself. Dam removal would allow this native species to reclaim habitat that became lost by dam construction. A management option within this assessment calls for a re-introduction of this species above Seven Mile Dam.

Comment: Are there any concerns regarding the impacts of exotic species other than sea lamprey and their potential effects on the aquatic communities of the Thunder Bay River if dams are removed? Could these exotics be controlled?

> Response: We feel that we covered this topic very well in both the **Dams and Barriers** and **Biological Communities** sections. Dam removal would benefit many native species such as walleye and lake sturgeon. Other species could potentially become established in the upper watershed and management would need to be considered for these invasive species.

Comment: What are the effects of cormorants on the entire Thunder Bay River watershed?

> Response: Cormorants are a native species of bird that can pose threats to local fish populations. This species is regulated by the federal government since they are a migratory bird. MDNR Fisheries Division works closely with MDNR Wildlife Division and the federal government to reduce high losses of fish by actively feeding cormorants. This can be done, through permit, by reduction of cormorants or hazing activities.

Comment: Are steelhead native to the Thunder Bay River watershed?

> Response: Steelhead (migratory rainbow trout) are not native to the Thunder Bay River watershed, or even to the State of Michigan. This is a strain of rainbow trout that was stocked statewide in order to create a spring fishery in various rivers.

Comment: Are brook trout native to the Thunder Bay River watershed?

> Response: Brook trout are native to eastern North America, particularly the Appalachian Mountain region and eastern Canadian provinces. Brook trout are native to northern Michigan. There is debate regarding how far their native range reaches down into the Lower Peninsula. It is the belief of the authors that this species is native to the Thunder Bay River watershed.

Comment: How many systems have been damaged by the introduction of species that are desirable to anglers, such as walleye?

> Response: The authors are unaware of occurrences in the Thunder Bay River watershed where the introduction of one fish species has led to the demise of another species. The MDNR Fisheries Division does understand that overstocking of species such as walleye, or making available new river reaches to species such as salmon, may not be desirable to some anglers or to other fish species (e.g., brook trout). One study in Michigan, which coincidentally occurred in Hunt Creek, documents the potential effects of species introduction on other populations (see **Fisheries Management**).

Fishery Management

Comment: Where can I find the latest results of the Hunt Creek steelhead/brook and brown trout competition study? Will the results of the study by published?

> Response: The latest update can be found on the MDNR website, specifically under the Fisheries Division webpage at: http://www.michigan.gov/dnr/0,1607,7-153-10364_10951_11302-96503--,00.html#654. A final report will be posted to the site at the completion of the project.

Comment: Are any stretches of the Thunder Bay River suitable for Arctic grayling? Will there be any attempts to introduce this species to the river?

> Response: Arctic grayling were historically present in the Thunder Bay River system but were extirpated in the late 1800s, presumably due to logging activities and over-harvest. Many attempts were made to restore Arctic grayling in various rivers and streams between 1877 and 1991. Grayling were stocked during thirty of the years within this time period. Waters stocked within the Thunder Bay watershed included McCormick Lake and its headwaters, Bass Lake, Clear Lake, the mainstem Thunder Bay River, Fuller Pond and Fuller Creek, as well as East Fish Lake and its inlet stream. Although some of these stocked fish survived for a number of years in lakes, no natural reproduction of these stocked Arctic grayling has ever been documented in the Thunder Bay River or elsewhere in Michigan. Arctic grayling stocked into small headwater streams quickly migrated downstream and most disappeared within less than one year. Arctic grayling are unlikely to either survive well, or reproduce, in contemporary Michigan rivers. Both lake- and river-strain Arctic grayling appear to make long seasonal migrations. This species needs large, cold, non-fragmented rivers with few competing fish species. Such waters do not exist in the Thunder Bay River watershed.

Comment: The authors should note the presence of rainbow smelt when discussing fish communities in McCormick Lake.

> Response: This has been incorporated into the text.

Comment: What is the balance between politics and biology when making fisheries management decisions? Do more economically significant "sport" species take precedence over less economically significant native species?

Response: Fisheries biologists are charged with the task of preserving fisheries, protecting, and enhancing fish communities and aquatic systems. We are also charged with providing diverse fishing opportunities. There is a fine balance between making management decisions based on biology, while simultaneously considering social ramifications. However, biological reasoning takes precedence in decisions. The Departmental Strategic Plan gives guidance to all employees to consider whole ecosystem management. Thus, biologists typically do not manage for certain species while posing a great risk to others. However, certain species such as salmon, steelhead, and walleye are highly acceptable species statewide, and are often in great demand. The true challenge is providing opportunity for all aquatic user groups while considering the entire concept of ecosystem management.

Comment: How much fishing pressure occurs on the Thunder Bay River impoundments?

Response: Very little information has been gathered on the amount of fishing pressure in Ninth Street, Four Mile, Seven Mile, and Hillman impoundments/ponds. The MDNR Fisheries Division would like to capture this information in future years, particularly at Seven Mile Impoundment. Fishing pressure, on an hour per acre basis, has consistently been very high at Fletcher Pond over the last decade.

Comment: Not everyone wants to fish for salmon or steelhead.

Response: MDNR Fisheries Division manages for a variety of angler types and fishing opportunities. One of the goals of this assessment was to describe the pros and cons of dam removal and fish passage and to estimate fish migration and production if fish passage or dam removal ever occurs. If this ever came to fruition, MDNR would take into account both deleterious and beneficial effects associated with upstream fish passage. For example, some upstream barriers could remain intact so as to prevent mixing of migrating fish (salmon) with upstream native fish (brook trout).

Management Options

Comment: Will management options be prioritized?

Response: Management options are laid out for all agencies to consider. There is no prioritization to management options and appropriate options should be accomplished as time and funding allow.

Literature Cited

Comment: There are several references attributed to “Anonymous”. Why not use the “MDNR” for the reference?

Response: “Anonymous” is the recommended way of citing these four publications.

GLOSSARY

base flow - groundwater discharge to the river

basin - a complete drainage including both land and water from which water flows to a central point

BCE – before the common era

biodiversity - number and type of biological organisms in a system

biological integrity - biotic communities able to withstand and survive natural and human perturbations

biota - animal and plant life

benthic - associated with the bottom of a stream or lake **-** plants and animals living on, or associated with, the bottom of a water body

BMPs - best management practices used to protect water quality, generally from erosion; examples are buffer strips, location and design of roads, proper design of road crossings of streams

boom shocker - an electrofishing boat used to sample fishes in waters that are generally too deep to wade; electrodes mounted on booms extend from the bow of the boat and are used to transfer electricity into the water to temporarily stun fish so they can be captured with dip nets

catchment - the area of the earth's surface that drains to a particular location on a stream

cfs - cubic feet per second; ft^3/s; a unit commonly used to express stream discharge, the amount of water flowing past a point each second; one cubic foot of water equals 7.48 gallons

CE – common era

centrarchidae - sunfishes; species such as bluegill, crappies, and largemouth and smallmouth bass.

channelization - conversion of a stream to a ditch; channelized streams are narrower, deeper, and straighter than natural channels; channelization may be done for navigation, flood control at that site, or to improve drainage for agricultural or other purposes

channel morphology - the structure and form of stream and river channels including width, depth, and bottom type (substrate)

coldwater fish species - term commonly applied to trout species, although non-game species such as slimy and mottled sculpin also need and prefer colder waters

confluence - the joining or convergence of two streams

coniferous - cone-bearing, typically evergreen trees

coolwater fish species - usually used to refer to game fish in the perch or pike families; examples are; walleye, yellow perch, northern pike, and muskellunge; maximum growth potential for walleye and pike occurs when temperatures are in the low 70s

deciduous - vegetation that sheds its foliage annually

discharge - common term used to refer to the volume of water flowing in, or discharged by a stream into another stream or water body; also referred to as streamflow discharge or stream discharge

drought flow - water flow during a prolonged period of dry weather

electrofishing - the process of putting an electric current, either AC or DC, through water for the purpose of stunning and capturing fish

entrain - to pass through the turbines of a hydroelectric dam; varying percentages of fish entrained at hydroelectric dams are killed

EPT – refers to three orders of insects (Ephemeroptera-Mayflies, Plecoptera-Stoneflies, and Trichoptera-Caddisflies). Often used as an indicator of water quality

Esocid - species of fish that are in the Esocidae family, in the TBR this is generally northern pike or muskellunge

exceedence flow - a discharge amount that is exceeded by the stream for a given percentage of time. For example, for 90% of the year the stream's discharge is greater than its 90% exceedence flow value. Consequently, the 90% exceedence flow represents a stream's summer low (drought) flow

exotic species – successfully-reproducing organisms transported by human actions into regions where they did not previously exist

extirpation - to make extinct, eliminate completely

fauna - the animals of a specific region or time

FERC - Federal Energy Regulatory Commission

fixed-crest - a dam that is fixed at an elevation and whose elevation can not be changed

flashy - streams and rivers characterized by rapid and substantial fluctuations in streamflow

flow regime - a term often used to describe the constancy or stability of stream discharge over periods ranging from days to years; discharge of streams with stable flow regimes does not fluctuate quickly or substantially through time whereas streams with unstable flow regimes are referred to as "flashy", see above definition

flushing rate - the amount of time it takes for the total volume of water in an impoundment to be replaced by incoming streamflow; also referred to as retention time

forage fish - term applied to small-bodied fishes that can be eaten by piscivorous fish species such as walleye, pike, or bass

game fish - term applied to fishes that sports fishing anglers are most likely to seek to catch; most of these species are in the trout, sunfish, and perch families

glacial-fluvial valley - a river valley formed by glacial melt waters cutting through deposits left by a glacier

glacial outwash - gravel and sand carried by running water from the melting ice of a glacier and laid down in stratified deposits

GLEAS - Great Lakes and Environmental Assessment Section

gradient - rate of decent of a stream, usually expressed in feet per mile

groundwater - water that is beneath the surface of the ground and is the source of a spring or well water; groundwater may also flow laterally to discharge into streams or lakes at lower elevations

hydraulic diversity - the variability of water depths and velocities in a stream or river channel

hydrology - the study of water

impoundment - water of a river system that has been held up by a dam creating an artificial lake

indigenous - a species that is native to particular area

invertebrates - animals without a backbone

karst - an area of limestone formation, characterized by sinks, caves, ravines, and underground streams

lake plain - land once covered by a lake that is now elevated above the water table

lake-level control structure - a dam placed at the outlet of a lake to control the water-level

large woody structure (debris) - larger trees, logs, and logjams at or beneath the surface of stream or lake waters

lentic - non-flowing water typically associated with lakes; for example lentic fishes typically inhabit non-flowing waters

loam - a soil consisting of an easily crumbled mixture containing from 7 to 27% clay, 28 to 50 % silt, and less than 52% sand

lotic - flowing water; for example lotic habitats are habitats present in flowing waters

low-flow yield - defined in this document as 90% exceedence flow divided by catchment area and expressed as $ft^3/s/mi^2$; streams with high low-flow yields in Michigan generally are colder, have higher drought flows, and are more suitable for habitation by coldwater fish species

LWD - Large woody debris; a term used to refer to larger woody material in a stream or lake that may provide instream fish cover or be colonized by fish-food organisms

macroinvertebrate - animals without a backbone that are visible to the naked eye

mainstem - primary branch of a river or stream

MDEQ - Michigan Department of Environmental Quality

MDNR - Michigan Department of Natural Resources

MDOC - Michigan Department of Conservation; this organization was reorganized and renamed as the Michigan Department of Natural Resources circa 1968

mesotrophic - a term applied to clear water lakes and ponds with beds of submerged aquatic plants and medium levels of nutrients. These lakes are also of intermediate clarity, depth and temperature.

mitigation - action required to be taken to compensate for adverse effects of an activity

MNFI - Michigan Natural Features Inventory

moraine - a mass of rocks, gravel, sand, clay, and other material carried and deposited directly by a glacier

morphology - pertaining to form or structure of a river or organism

naturalized - animals or plants previously introduced into a region that have become permanently established, as if native

NEMCOG - Northeast Michigan Council of Governments

non-game fish - term applied to fishes that sports fishing anglers generally do not attempt to catch; this term is also applied to certain species sought by a minority of anglers, for example, carp, suckers, and bullhead catfishes

NPDES - National Pollution Discharge Elimination System

oligotrophic lakes - lakes where nutrient levels and biological productivity are low; these lakes typically contain high levels of dissolved oxygen in their waters at all depths

oxytetracycline - (OTC), an antibiotic which produces a mark on a fish once it is submersed in the chemical; thus allowing for differentiation between stocked and wild fish

peaking - operational mode for a hydroelectric project that maximizes economic return by operating at maximum possible capacity during peak demand periods (generally 8 a.m. to 8 p.m.) and reducing or ceasing operations and discharge during non-peak periods; in other words, streamflows may alternate between flood and drought on a daily basis

permeability - the ability of a substance to allow passage of fluids; sands and gravels have high permeability for water because it readily moves through them

perched culvert - a culvert that blocks upstream movement of aquatic organisms by creating a significant drop between the culvert outlet and the downstream stream surface

permeable - soils with coarse particles that allow passage of water

piscicide – a chemical applied to water which selectively kills fish

potamodromous - fish that migrate from fresh water lakes up fresh water streams to spawn; in the context of this report, it refers to fish that could migrate into the Thunder Bay River from Lake Huron

private stocking - fish stocking by private individuals; a permit from the Michigan Department of Natural Resources, Fisheries Division is required to legally stock fish in public waters of the state

recruitment - refers to natural reproduction of fishes in the context of this report

riparian - adjacent to or living on the bank of a river or other body of water; also refers to the owner of stream or lakefront property

riverine - a reach or portion of a river that is free-flowing and not impounded by dams

rotenone - a white, crystalline poisonous compound obtained from derris root; fisheries managers use it as a toxicant to kill undesired fish species; it is not toxic to other non-gill breathing aquatic organisms

rotenone survey - method sometimes used to sample fish in a water body; in the context of the TBR, fishes in some stream sections were killed with rotenone and collected with dip nets or when they drifted downstream to blocking nets; the rotenone compound was detoxified at the downstream end of the sampled section with potassium permanganate

run habitat - fast non-turbulent water

run-of-river - instantaneous inflow of water approximately equals instantaneous outflow of water; on impounded systems, this flow regime mimics the natural flow regime of a river

salmonid - fishes in the family Salmonidae; trouts, salmon, whitefish, and herring species are in this family

savanna - a treeless plain or grassland with scattered trees

sedimentation - the deposition or accumulation of sediment

self-sustaining population - a fish population that remains at an acceptable level of abundance by naturally reproducing young

Serns index - a method for determining levels of walleye natural reproduction, or the survival of stocked walleye from boom shocker CPUEs

smolt – physiological change in a young salmon or steelhead that usually corresponds with a migration from a river setting to a lake (Thunder Bay River to Lake Huron)

species richness - the number of different species collected at a site

sport fish - fish sought by anglers for sport and food

substrate - term used to refer to materials lying beneath the waters of a lake or stream; examples are clay, silt, sand, gravel, cobble, and so on

surficial - referring to something on or at the surface

TBR - acronym for Thunder Bay River

temperature regime - phrase commonly used by fisheries biologists to describe the seasonal or daily pattern of temperature fluctuations (maximums, minimums, and averages); for example, streams with cold temperature regimes are those where summer daily mean water temperatures generally are colder than 68 ^{0}F and maximum daily temperatures do not reach levels lethal or unduly stressful to coldwater fish species

till - unstratified, unsorted glacial deposits of clay, sand, boulders, and gravel

turbidity - suspended particles in water that cause it to be less transparent

two-story lake - lakes that thermally stratify during warm weather periods and that contain sufficient dissolved oxygen in the deep and colder strata such that warmwater fishes generally inhabit the upper strata while coldwater fishes such as trout can inhabit the bottom strata

topography - the configuration of the earth's surface including its relief and the position of its natural features

Type 1-7 trout stream regulation - trout streams in the State of Michigan are typically managed with one of 7 regulation types, ranging from more liberal to more conservative; see the Michigan Inland Trout and Salmon Guide

USDA - Unites States Department of Agriculture

USFS - United States Forest Service

USFWS - United States Fish and Wildlife Service

USGS - United States Geological Survey

wadable - a stream that is shallow enough to be traversed by someone wearing chest waders

warmwater fish species - species that grow and thrive best in waters that are warmer, at least seasonally; most game fish species in this classification are members of the sunfish family and maximum growth potential for these species generally occurs at temperatures higher than 78ºF

watershed - an area of the earth's surface that drains toward a receiving body of water (such as a stream or lake) at a lower elevation

wetland - those areas inundated or saturated by surface or groundwater at a frequency and duration sufficient to support types of vegetation typically adapted to life in saturated soil; includes swamps, marshes, fens, and bogs

wigglers – mayfly larva

winterkill - to die from exposure to winter cold; in the context of this text, heavy snow and oxygen depletion in the water may kill fish living in shallow lakes

young-of-year (YOY) - the offspring of fish that hatched this calendar year