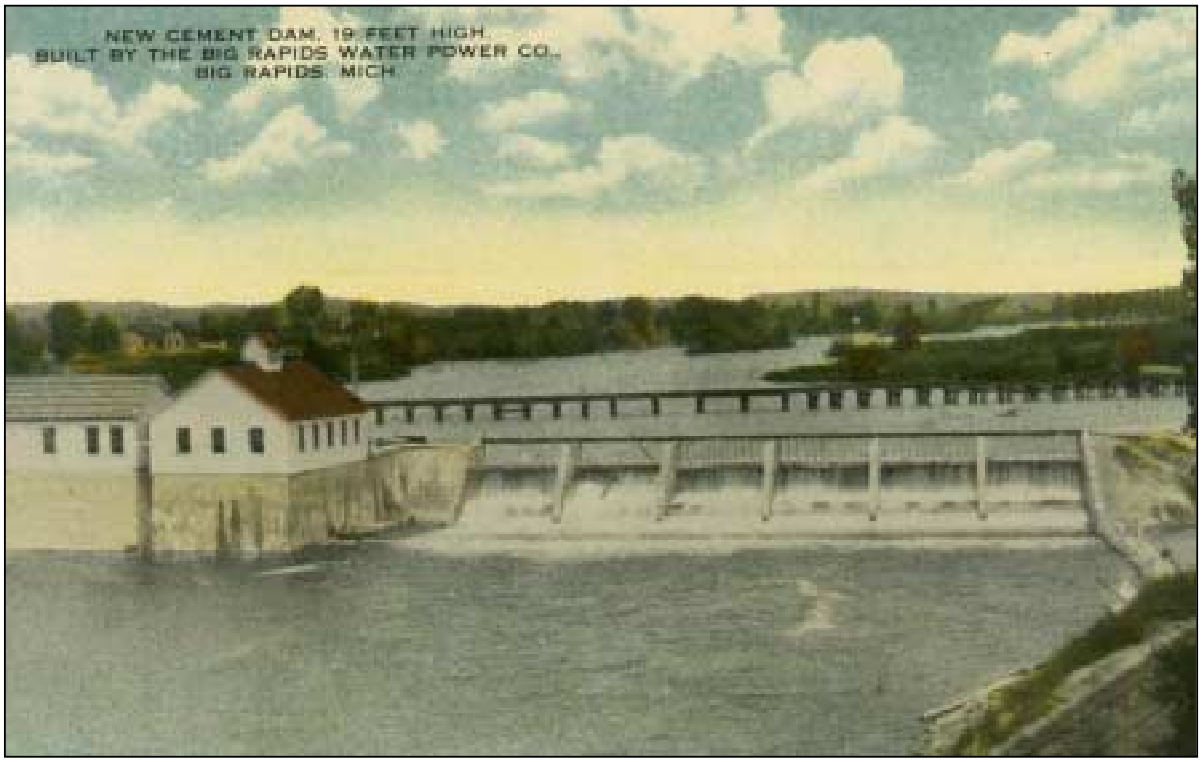
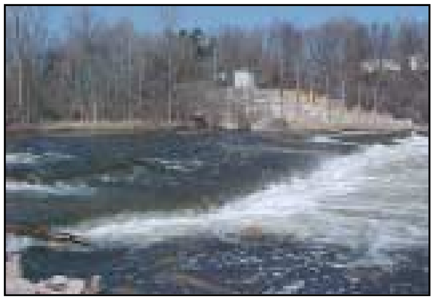
Removal of the Big Rapids Dam Remnant: An Environmental Assessment

Summer 2000





Environmental Management Studies Center

Ferris State University
Big Rapids, Michigan

Center Provides for Excellence in Environmental Studies

The Ferris State University Environment Management Studies Center (FSUEMSC) has been in existence since 1972. The Center provides baccalaureate degree, Environmental Health and Safety Management (EHSM) students with a unique opportunity to conduct "real life" field studies and assist area communities and government agencies.

The Center is unique in the United States in its interdisciplinary approach to teaching environmental planning and management. Since 1972, the Center has completed 31 major community and environmental assessment reports, along with 491 background reports.

Some particularly successful projects over the years include:

- A 1979 study of Chippewa Lake that helped justify a lake sewer project.
- A 1992 study which helped Morley Village obtain funds to refurbish a dam and
- Several Muskegon River reports that have been used by the City of Big Rapids in planning for removal of the Big Rapids dam remnant.

In 1972, a three year, $31,000 grant was obtained to develop the center. Faculty teaching courses in Environmental Conservation (Biology Department), Environmental Engineering, Surveying Engineering (College of Technology), Environmental Management (EHSM Program) and Cultural Geography (Social Sciences Department), were brought together as a team and the FSU campus served as a laboratory and provided real life projects. The course content has changed with the removal of the Cultural Geography course and the modification of the biology course to Environmental Biology. Two new course additions are Environmental Systems Management, and Environmental Assessment and Impact Analysis. Study areas have broadened to include area lakes and hazardous waste sites. Faculty serve as policy makers and professional consultants and students are organized as staff. Students carry out field research, conduct surveys they have developed, and study mapping, photography, surveying, and report writing in addition to classroom studies.

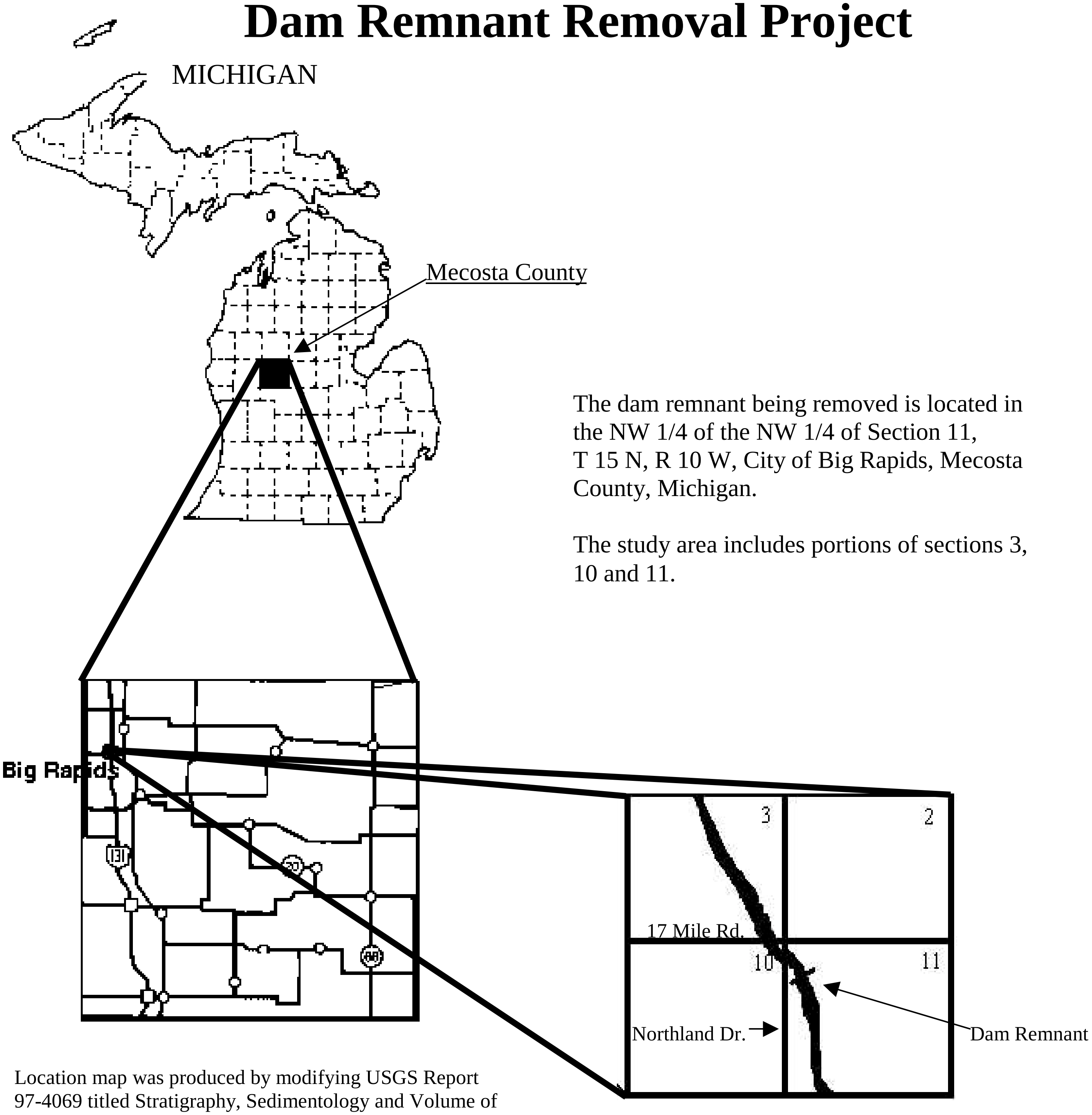
This has proven to be a highly successful educational process, which greatly improves job readiness and develops competencies otherwise, not possible in a traditional academic role. Students improve oral and written presentation skills along with learning teamwork. The process is known as "summer block" and is the environmental health and hazardous materials option student's capstone experience before graduation. Community members interested in receiving a copy of the center's reports may contact the EHSM Department Head in the College of Allied Health Sciences.

Title Page Credits:

Top Center: Post Card Illustration of original dam structure. Undated.
Photo Credits:
Bottom Left: Remaining 4 ft. of dam remnant, March 20, 2000, facing northeast.
Bottom Center: Demolition of dam remnant, June 23, 2000, facing northeast.
Bottom Right: Dam remnant partially removed with diversion structure, July 11, 2000, facing northeast.

* All title page images gathered from the City of Big Rapids web site, dam remnant removal section.

Location of the City of Big Rapids Dam Remnant Removal Project



The dam remnant being removed is located in the NW 1/4 of the NW 1/4 of Section 11, T 15 N, R 10 W, City of Big Rapids, Mecosta County, Michigan.

The study area includes portions of sections 3, 10 and 11.

Location map was produced by modifying USGS Report 97-4069 titled Stratigraphy, Sedimentology and Volume of Sediments Behind Dam Relic on the Muskegon River, Big Rapids, Michigan.

Participants

Abdulaziz Al-Khubaizi
Elisa DuBreuil
Justin Gerding
Loretta J. Manley
Ryan Packer
Craig Preston
Ron Vaughn
Jessica Wolfgang

Mark Casper
Zak Fahrni
Jackie M. Gort
Brian Murphy
Jason Petrone
Harlan Vanterpool
Victoria Weitzel

Faculty

Michael D. Ells, Professor of EHSM
Bruce L. Beetley, Professor of Biology
Kevin D. Besey, Assistant Professor of EHSM
Sayed R. Hashimi, Professor of Surveying Engineering

This Report was prepared in partial fulfillment of the requirements for the 2000 EHSM Environmental Management Studies Block

Acknowledgements

The members of the Ferris State University Environmental Management Studies Center would like to acknowledge the following individuals and organizations for the information and assistance that made this project possible.

- Allied Health Computer Lab Personnel, Ferris State University.
- Bruce Menery, Hydrologist, Michigan Department of Natural Resources, Hydrology Division.
- Craig Colley, Land Information Manager for the City of Big Rapids, Big Rapids, Michigan.
- Heating, Ventilation, and Air Conditioning Engineering Computer Lab and Staff, Ferris State University.
- Roger Schneidt, Operational Supervisory Technician for the City of Big Rapids Engineering Department, Big Rapids, Michigan.
- Steven Stilwell, City Manager for the City of Big Rapids, Big Rapids, Michigan.

Table of Contents

List of Figures

Executive Summary

During Summer 2000, Ferris State University Environmental Management Studies Center (FSUEMSC) students performed an environmental assessment of the Big Rapids Dam remnant area to identify what effects the dam remnant removal will have on the Muskegon River.

An attempt to remove the Big Rapids Hydroelectric Dam in 1966 left a four-foot high remnant in the Muskegon River. Due to unsafe river conditions and the disruption of natural habitat, the city of Big Rapids decided to remove the dam remnant. The dam remnant is located in the NW ¼ of Section 11, T 15 N, R 10 W, City of Big Rapids, Mecosta County, Michigan.

The study area included the reach of the river from White's Bridge, 1.75 miles above the dam remnant to St. Paul's Campus Parish, 2.25 miles below the dam remnant. Research groups included physiography, water quality, and natural history. Each group collected data through field observations, library research, personal interviews, photography, field sampling, and laboratory analysis.

There are six predominant soil types found in the dam remnant study area. The average annual temperature and precipitation of the area is 45.2°F (7.3°C) and 32.32 inches, respectively. The Muskegon River area watershed incorporates over 2,350 square miles of land, is 212 miles long, and has a drop in elevation of 575 feet from its source to the mouth of the river. The physiography of the area is expected to change with the increase of the river flow velocity, aesthetics, and the change in the elevation of the water level.

The overall water quality of this reach of the river meets the Michigan Department of Natural Resources (MDNR) surface water quality standards. The condition of the river has improved since 1991 and there had been no apparent changes in the water quality due to the dam remnant removal during the study period.

The river ecology, past and present river conditions, and species of flora and fauna that can be found within the study area were documented. An aquatic insect survey was conducted to determine counts and species of insects found near the dam remnant site, but because of small sample size the data was inconclusive.

The removal of the dam remnant will have many effects on the river. These effects include:

- Increase in stream gradient to a slope of over 10 ft/mile
- Release of water impounded behind the dam
- Widening of the river banks, exposing additional land to terrestrial plant growth
- Colder water temperatures and higher dissolved oxygen levels
- Removal of the physical barrier to the migration of fish and invertebrates upstream and downstream
- Increase in species diversity and fish and invertebrate biomass due to habitat improvement
- Return of the reach of the river between Reedsburg Dam and Rogers Dam to a cold water ecosystem

1.0 Introduction

Rivers follow natural pathways with water conditions and flow rates that are indicative of the terrain through which the rivers flow. Rivers provide an environment for a variety of organisms. Human actions, including damming and diverting of river waters, can cause substantial environmental changes in a river. Once a river system is dammed the biological, physical, and chemical characteristics of the river are altered. Dams impound waterways, causing the formation of ponds, raising water levels, disrupting the migration of fish and invertebrates, and increasing water temperature due to the slower velocity.

During Summer 2000, the FSUEMSC conducted an environmental assessment of the Big Rapids Dam remnant removal area. The Big Rapids Dam remnant is located in Mecosta County, City of Big Rapids, T 15 N, R 10 W, Sec. 11, approximately 400 feet north of the Baldwin Street Bridge. Studying the dam remnant area provided students with field experience and also supplied the City of Big Rapids with a record of the dam's history, as well as current conditions of the dam remnant area's ecosystem. Data were collected for this study through library research, personal interviews, field observations, photography, field sampling, and laboratory analysis. These studies will be beneficial to the City of Big Rapids and other agencies who may want to investigate the environmental impacts of dam remnant removals, including the Michigan Department of Natural Resources (MDNR) and the United States Geological Survey (USGS).

The FSUEMSC students were divided into individual groups: natural history, physiography, and water quality. The groups developed reports, which were then condensed and edited to create this document. This final document provides information on the following subjects: dam history, procedures for dam removal, physiography, water quality, and natural history.

Figure 1:

Original hydroelectric dam structure. Photo taken facing west (46).

2.0 History

2.1 Glacial History

During the Pleistocene Era 12,000 to 10,000 years before present, the Wisconsin glacier covered Mecosta County. This glacier left deposits of soil material consisting of shale and limestone, 450 to 825 ft. thick. The present topography exists due to glacial deposits left by the melting of the Wisconsin Glacier (1).

The Wisconsin Glacier had two lobes, the Saginaw Lobe and the Lake Michigan Lobe, located in the east and west of Mecosta County, respectively. As these two lobes melted, they left mounds, ridges, moraines, and other distinct accumulations of non-stratified glacial drift.

The water flowing from those lobes formed an outwash plain about two or three miles wide. The Muskegon River is in this outwash plain and the soils on either side of the river are distinctively different for this reason (1).

2.2 Native American History

Archeological evidence suggests that Mecosta County may have been inhabited as early as 11,000 B.C. by Indian tribes. Recorded history however, indicates that the first known inhabitants were three nomadic Native American tribes, the Chippewa, Potawatomi and Ottawa (Odawa). These tribes were food gatherers and never permanently settled in the area. Cut, slash, and burn agriculture produced food crops, including maze. When soil fertility was exhausted, the tribes moved to another location. The tribes camped for periods of time near streams, rivers, and lakes, utilizing the available resources. These resources included white-tail deer, woodland caribou, fish, and sap from maple trees which they used to make sugar and syrup. (39, 41)

2.3 General History of the Study Site

Native Americans were the only people inhabiting the Big Rapids area until the mid-1800’s (35). In 1851, the first European settlers migrated to the Big Rapids Area (48). With the arrival of more people, the need for timber as building material became apparent. By 1855, the first logging operations had been established along the Muskegon River (48). A permanent settlement known as the Village of Leonard was present, until 1859 when the Village of Leonard changed its name to the Village of Big Rapids (48). This name change occurred as a result of the large rapids in the Muskegon River in this area.

As more and more people settled in the area, it became apparent that a permanent means to cross the Muskegon River was necessary. The first bridge to be built in Big Rapids was constructed in 1859. This bridge was located ½ mile south of the current Maple Street Bridge (48).

In 1866, the first dam, known as the Tioga Co. Dam, or Upper Dam, was constructed by F.H. Todd & Co. This dam was owned by J. Milnes (35). The Tioga Co. Dam was a simple structure made of logs and rocks. This dam was initially used to raise the river's water level to impound water behind the dam, and sort logs for various logging operations lining the riverbanks. The Tioga Co. Dam was used for logging purposes until 1907 when the last log drive went through Big Rapids (48).

In 1869, the Village of Big Rapids was incorporated as a city. Subsequently, township officials temporarily handled all government affairs within the city (50).

In 1889, the Tioga Co. Dam was first used to generate electricity. Water was diverted from the impoundment behind the dam through a water wheel, which operated a turbine, generating electricity. The Tioga Co. Dam was used for this purpose until 1912, when the dam was washed out (35).

For the next two years, there was no dam in the reach of the Muskegon River flowing through the Big Rapids area. In 1914, Consumers Power Co., the City of Big Rapids, Tioga Manufacturing, Hanchett Manufacturing, and the Hood & Wright Corporation formed the Big Rapids Water Power and Development Company (35). Which began construction of a new replacement hydroelectric dam. The new Upper Dam was made of reinforced concrete and filled with soil, and had a 17.7-foot head (35). This provided an energy base for the manufacturing companies present in the area. By 1915, there were two power plants supplying power to the Big Rapids area. These plants were the Joseph Bennett Electric Company, located on the west bank near the dam, and the City Power Company, located on the river bank southwest of the dam (35).

In time, the dam began to experience structural problems; in 1934 holes in the pilings of the dam began to be seen (33). Despite repair attempts, those holes kept expanding.

Downstream from the dam, the Big Rapids Water Treatment Plant was constructed in 1936 (48). This location led to problems later on.

By 1965, the Upper Dam was in such a state of disrepair that insurance companies would no longer insure the dam (33). The Big Rapids Water Power and Development Co. was forced to shut down the hydroelectric generation. In 1966, the company publicly announced plans to demolish the dam (33). Keith's Heavy Movers was contracted to do the job for $ 20,000 (35). The dam structure proved to be more intact and stronger than was originally thought. Keith's Heavy Movers eventually went bankrupt trying to remove the dam. As a result, the dam was only partially removed (35).

The attempted dam removal led to several major problems within the Big Rapids area. During the fifty-two years that the dam was present, large amounts of sediments had built up behind the dam. This sediment was thought to be the result of gravel washing operations taking place further upstream by several gravel companies. Once the dam was partially demolished, thousands of yards of these deposits were washed downstream as the water level behind the dam was lowered. This caused new land areas above the dam to become exposed along the riverbanks. Sediment that had been carried downstream can still be found as far down as the upper end of Roger's Dam reservoir (40).

In addition to this, the Big Muskegon Subdivision, consisting of 15 to 16 homes, was flooded causing homeowners to abandon their homes and possessions (33). The homeowners subsequently filed a lawsuit against the Big Rapids Water Power and Development Co., which dissolved shortly thereafter. This lawsuit was settled in 1970 for $ 120,000. Each original shareholder of the Big Rapids Water Power and Development Co. was ordered to pay a percentage of the sum (33).

In 1967, the Big Rapids Water Treatment Plant placed a water main in the riverbed of the Muskegon River to connect the east part of Big Rapids to the city water supply (48). The placement of this water main and continued alterations of the Muskegon River's natural state led to additional problems for the city.

In 1976, the City of Big Rapids purchased the dam remnant and six adjacent parcels of land for $ 6,000 (28). The only explanation for the city purchase was the desirability of the parcels of land along the riverbank.

Between 1985 and 1986, an oxbow began to form in the Muskegon River 200 yards downstream from the Big Rapids Water Treatment Plant (40). This oxbow caused increased erosion of the west riverbanks near the then Big Rapids High School (now the Middle School) and nearby houses. The City Council determined there was a need for some action to prevent further erosion of the west riverbanks. City Council had two options: to hire an engineering firm to solve the problem for $ 70,000 or to hire a contractor to solve the problem for only $ 3,000 (42). The city chose the second option for financial reasons. The proposed plan to stop erosion on the west bank of the Muskegon River near the Big Rapids High School and nearby houses was to change the channel of the river by digging a new course through the midstream islands, which had initially caused the formation of the oxbow (40). This plan seemed to be successful, as the oxbow was eliminated, and the properties along the west riverbanks were safe from erosion (40).

In Winter 1987, operators of the Water Treatment Plant noticed that the previously buried water main, serving the east part of Big Rapids, was exposed and oscillating in the river current (42). This was a result of the effort to stop erosion on the west riverbanks the previous year. In his efforts to excavate the center section of the river's island, Fenstermacher, the contractor originally hired to correct the erosion problem, had removed the hardpan from the bottom of the river creating a head cut, or a process in which the original river bottom is disturbed causing a build-up of water flowing in a backwards motion, slowly eroding the river bottom (38). This head cut slowly eroded the riverbed and progressed upstream overtime. This resulted in the erosive excavation of the water main connection to the east side of the city, and the lowering of the river water level by approximately 3 feet (40). Officials were worried that the water main would be damaged or severed, and that the Big Rapids Water Treatment Plant intake, which pumped water out of the Muskegon River to provide the city water supply, would become exposed (40).

The City of Big Rapids took action and developed a plan to temporarily solve the problem. The plan called for a sediment trap directly downstream from the water main to collect sediment and partially stabilize it; and the use of large rocks and boulders to create a 125 ft. rock berm (cofferdam) across the river, tapered on both ends, 45 feet wide, and 3 to 4 feet high (40). This rock berm was to be completely submerged in the river, and to be gently sloped on the downstream side so that it would not be a hazard for recreationalists.

Unfortunately, the plan was not followed completely, and the rock berm (cofferdam) was not submerged, or sloped on the downstream side as the plan dictated (40). This rock berm is currently known as the cofferdam, and it can be seen protruding from the river to this day. While the rock berm, or cofferdam, solved the problem concerning the water main, there were still problems with the Water Treatment Plant intake. Water levels continued to drop as the rocks from the cofferdam eroded. In order to keep the river water levels high enough to cover the intake, additional rocks were added to the cofferdam each year (42).

In 1987 the City of Big Rapids drilled test wells to determine a possible ground water source to supply the city with water. The city had an ongoing process to analyze groundwater in the area approximately every fifteen years (42). This new water source determination for the city water supply was temporarily abandoned until 1996 when the city discussed moving the Water Treatment Plant intake upstream, above the dam remnant (42). MDNR stated that while this was a good idea, the city should find a new option because the dams currently in place were going to have to be removed in the near future. This factor, along with the liability present with the dam remnant and cofferdam, forced the city to consider removal of the dam remnant, removal of the cofferdam, and a new water source for the city water supply.

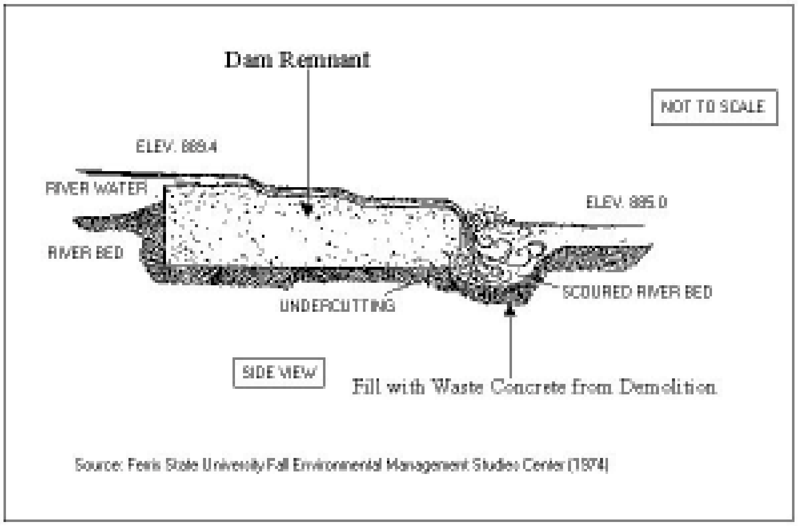
The dam remnant and cofferdam are a liability for the city. The dam remnant has sharp, jagged edges of reinforced steel and concrete and the flow of water over this structure creates a dangerous undertow. The cofferdam has large dangerous boulders protruding from the river's surface. In 1994, a young boy drowned when his innertube got caught on debris above the cofferdam. In 1995, a young couple almost drowned while going over the dam remnant in innertubes, and in 1996 a young man drowned while trying to canoe over the dam remnant (42). Liability is one of the major factors that led to the current removal project.

In 1997, the USGS conducted tests on the sediment located behind the dam remnant in anticipation of the project (25). The plan for removal includes using the cofferdam as a sediment trap; therefore it is not scheduled for removal until the Summer 2001. Before the cofferdam can be removed a ground water source must be developed. This project is currently underway.

3.0 Proposed Procedures for the Dam Remnant Removal

The existing 4-ft. high dam remnant is to be removed, bringing the river bottom back to a more natural state (42). To prevent the migration of sediment and debris downstream during the removal process, mitigation procedures have been developed by Prien & Newhof consultants and the City of Big Rapids. The procedures are based on the Muskegon River sediment study conducted by the United States Geological Survey (USGS) in 1997 (23).

Figure 2: Sketch of Structure After Unsuccessful Removal of Original Dam (35).



Source: Ferris State University Fall Environmental Management Studies Center (1974)

3.1 Dredging

The mitigation calls for the removal of sediments upstream of the dam remnant to prevent the migration of these sediments downstream. It is predicted that the river velocity above the current remnant will increase due to the absence of the 4 ft. high dam foundation. Sediment accumulations are presently from the foundation of the dam to a distance of approximately 3,500 ft. upstream. An estimated 17,000 cubic yards of sediment will need to be removed from the riverbed north of the dam to minimize the volume of sediment that could migrate downstream as a result of increased flow rates (25). Prein & Newhof designed a dredging process to remove this sediment.

The resulting excavation will create a depression on the river bottom that will serve as a sediment trap, collecting re-entrained sediment before it can travel downstream (25). This dredging technique is performed by a specifically designed barge, called a "MudCat™", mounted with an auger-type vacuum that rotates, drawing in water and sediment (Figure 3).

Figure 3:

Ellicott Intl. MudCat™ Dredge, Photo taken facing east, June 28,2000 (46).

The sediment is then pumped through a 12-inch diameter pipe approximately 1,200 ft. downstream to the collection site. From this point, the dredged material is discharged to a collection basin where sediment is allowed to settle and water is drained back into the river. Bails of straw have been placed on the bank of the river to filter the water runoff prior to its return. The collected sediment will then be removed at the completion of the construction phase. If possible, the City would like to treat the sediment as a resource and sell it for road fill, etc. (Figure 4).

Figure 4:

Sediment collection basin. Photo taken facing northeast, July 6, 2000 (46).

3.2 Remnant Removal

While proceeding with sediment removal, the first step in the dam remnant removal project has begun. This step is to construct a water diverting structure that will allow the demolition process to be completed. The water diversion and subsequent demolition will be completed on one section of the dam at a time (Figure 5). Water will be diverted from the west side of the dam first, allowing for its demolition. The barrier will then be removed and placed on the east side of the remnant to complete the demolition. The proposed course of action is to use large industrial pulverizing machines, similar to a "jack hammer", to break the concrete from the dam into boulder like pieces 10" to 16" in diameter. Waste concrete will have the metal reinforcing rods removed, and will be used as retaining material for the riverbanks and fill for the scoured river bottom in front of the dam remnant to prevent erosion (25).

Figure 5:

Aerial photo of remnant removal area with diverting structure and MudCat™ in place, June 29, 2000 (46).

3.3 Cofferdam Removal

A cofferdam is located 1,100 ft. downstream from the dam remnant. The original purpose of this dam was to cover the water line serving the eastside of the city. This dam was intended to be temporary, but has remained in the river since 1988 (37). In 1999 the dam was rebuilt so it could be used as a sediment trap during dredging operations for the hydroelectric dam removal project. The cofferdam is scheduled to be removed Summer 2001. Procedures for the cofferdam removal have not yet been prepared (43).

4.0 Physiography

4.1 Scope/Purpose

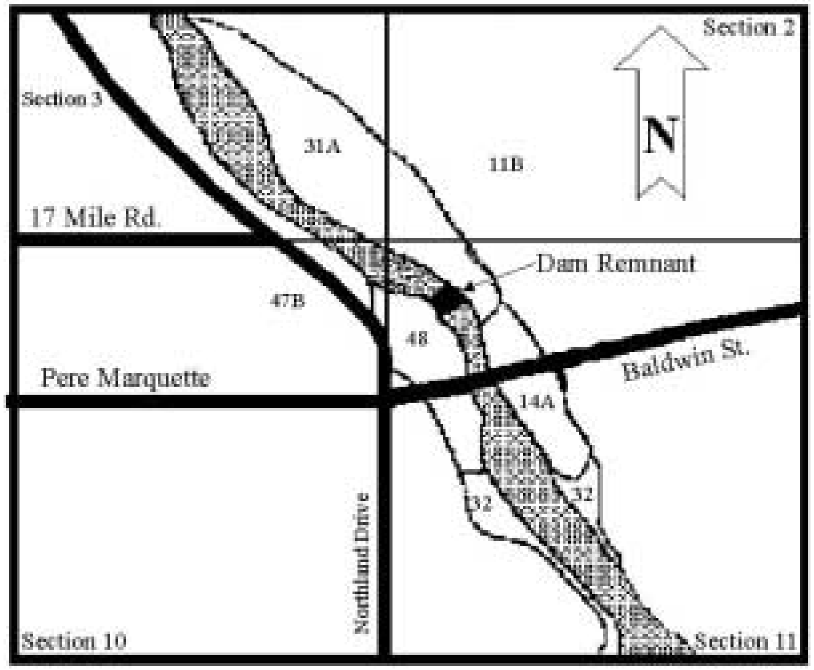
The physiographic assessment included the following areas; glacial history, soils and climate information, possible erosion sites of the riverbed and banks, and migration of sediment downstream. The purpose of this study was to research and document the current characteristics of the physical environment from approximately 850 feet north to 625 feet south of the dam remnant. This documentation may be used in future physiography studies to evaluate and quantify any changes to the environment within the dam remnant removal area due to erosion and dredging.

4.2 Soils

There are six soil types in the study area. The main soil association for is the Mecosta association. Glacial tills form this association, which consists of nearly level to gently rolling terrain that is excessively drained due to sandy soils. The major soil type found on the west bank of the river is Mecosta Sand. Psammaquents and Glendora Loamy Sand are also found in smaller areas on the west side of the river. Coloma Sand is the major soil type found on the east side, while Alganese Loamy Sand, Covert Sand, and Glendora Loamy Sand are also in the same area (Figure 6).

A descriptive summary of the six major soils types found in the dam remnant removal study area are as follows (Map symbols consists of a number or number-letters. The initial number represents the type of soil. The capital letter following the number indicates the class of slope. The letter A represents a slope of 0-3 %, letter B represents a slope of 0-6%, and numbers without a letter indicate nearly level soils or miscellaneous areas) (21):

Figure 6: Major Soil Types Bordering Dam Remnant Removal Area (21).



East Bank:

- <u>Coloma Sand, 11B</u>- This type of soil has 0-6 % slope and is found on flat or slightly convex plains. It has rapid permeability, slow runoff, and is poorly suited for recreational development due to its sandy surface layer.
- <u>Covert Sand, 14A</u>- This soil type has a 0-3 % slope rapid permeability, slow surface runoff, and is poorly suited to recreational development due to the sandy surface and high water table.
- <u>Alganese Loamy Sand, 31A</u>- This soil type has a 0-3% slope, is poorly drained and subject to flooding. It also has rapid permeability, slow runoff, and is poorly suited for camps and playgrounds since it may flood, but is fairly suited for picnic areas, paths, and trails.
- <u>Glendora Loamy Sand, 32</u>- This soil is nearly level and is found on flood plains. Although having a rapid permeability it is located in low-lying areas, therefore being poorly drained. This leaves it frequently flooded and poorly suited for recreational development.

West Bank:

- <u>Glendora Loamy Sand, 32</u>- This soil is nearly level and is found on flood plains. Although having a rapid permeability, it is located in low-lying areas, therefore being poorly drained. This leaves it frequently flooded and is poorly suited for recreational development.
- <u>Mecosta Sand, 47B</u>- This soil type has 0-3 % slope and is found on flat or

somewhat convex plains. It is somewhat excessively drained, has rapid permeability in its upper portion, and is poorly suited to recreational development due to its sandy surface layer.

- Psammaquents, 48- This soil type is nearly level and is made of a sandy fill two to five feet thick which covers poorly drained mineral soils. It has rapid permeability, slow runoff, and is poorly suited for camps and playgrounds since it may flood, but is fairly well suited for picnic areas, paths, and trails.

4.3 Climate and Precipitation

The average temperature and precipitation for Big Rapids, Michigan can be found in Figure 7. Rainfall for this area in the spring ranges from 2.18 to 3.12 inches and in the fall ranges from 2.67 to 3.31 inches. The average annual temperature is 45.2° F (21).

Figure 7: Average Monthly Temperature and Precipitation (21).

		Temperature		Precipitation	
Month	Ave. Daily Max	Ave. Daily Min	Average	Average	Ave. Snowfall
	F	F	F	Inches	Inches
January	28.6	11.8	20.2	2.05	19.9
February	31.4	12	21.7	1.64	14
March	40.2	20.7	30.4	2.18	11.3
April	55.6	32.4	44	3.12	1.9
May	68.5	42.6	55.6	2.92	0
June	77.9	52.2	65.1	3.3	0
July	81.8	56.1	68.9	2.76	0
August	79.6	54.3	67	3.26	0
September	70.7	46.8	58.7	3.31	0
October	60.2	37.7	48.9	2.74	0.5
November	44.5	28.3	36.4	2.67	6.5
December	32.5	17.7	25.1	2.28	16.3
Year	55.9	34.4	45.2	32.23	70.4

4.4 Topography

4.4.1 Elevation

To document current bank elevations and sediment levels on the river bottom a Computer Aided Drafting (CAD) program was utilized to develop several topographic maps of the dam remnant area. Spatial information involving elevations and distance used in developing these drawings was obtained from the City of Big Rapids Engineering Department and Prein & Newhof consulting. In order to fit this information into standard report format, 8 ½” by 11” sheets, the topographic maps were brought to a scale of 1”= 50’ and distributed throughout four sheets. To aid in the interpretation of this broken map image match lines were added to the drawing. Match lines are labeled A through C and act as location indicators from one drawing to the next. For instance, match line A can be found on the first two drawings representing the exact same location on both drawings (Figures 8, 9, 10, 11).

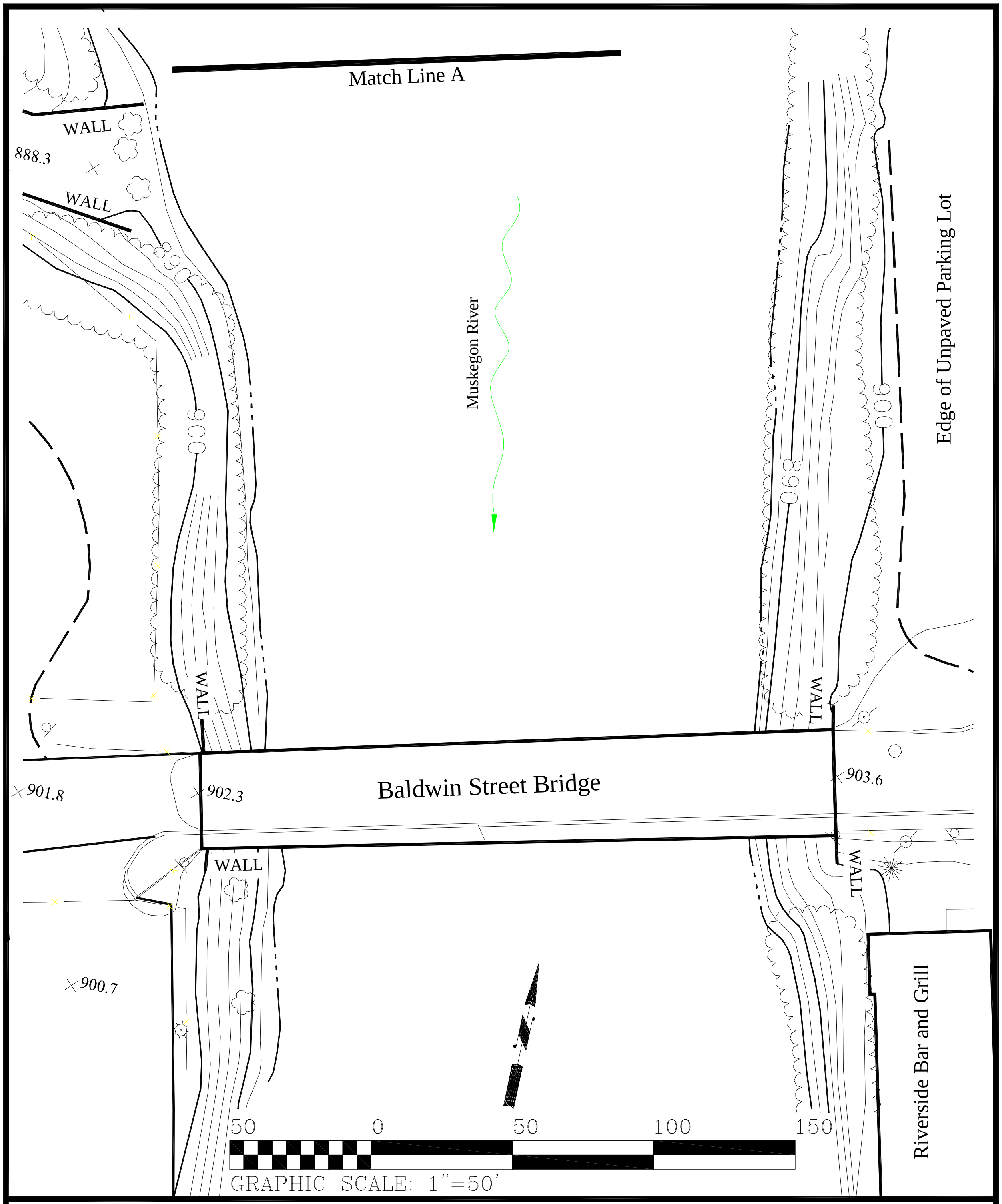
4.4.2 Cross sections & Erosion

The following maps show the location of four cross sections of the existing river bottom at distances of 152 feet, 355 feet, 594 feet, and 846 feet from the north edge of the dam remnant. The maps illustrate widths and topography of the river bottom at the cross section areas. It should be noted that the vertical elevation scale shown on the four cross sections is exaggerated 10 times to emphasize a contrast in depth (Figures 12, 13).

4.5 Unit Summary

The Muskegon River watershed incorporates over 2,350 square miles of land, is 212 miles long, and has a drop in elevation of 575 feet from its source to the mouth of the river. The watershed is contained within eight counties: Roscommon, Missaukee, Clare, Osceola, Mecosta, Montcalm, Newaygo, and, Muskegon. The present physical aspects of the Muskegon River study area are a result of glacial outwash and man-made features (24). The six predominant soil types in the study area are the result of glacial drift.
It is anticipated that the removal of the dam remnant will directly affect the physical characteristics of the river in the study area. Data collected and recorded in this project can be referenced by future studies to assess and evaluate changes that may occur in the study area.

Figure 8:



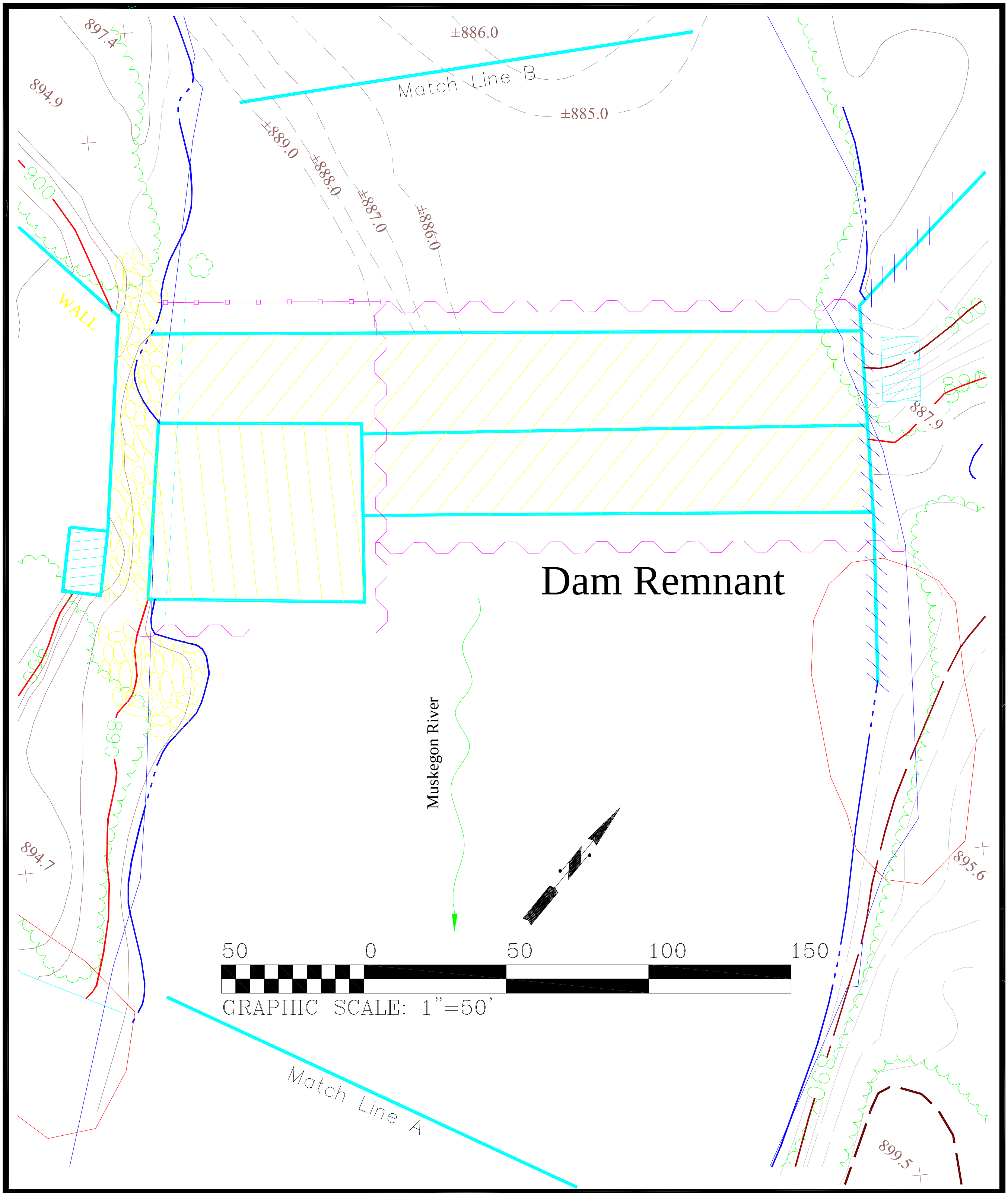
Contour Map of Muskegon River Near Baldwin Street Bridge

Date: June, 2000

Contour Interval: 2 Feet, Unless Noted Otherwise

Source: City of Big Rapids, Engineering Dept.

Figure 9:



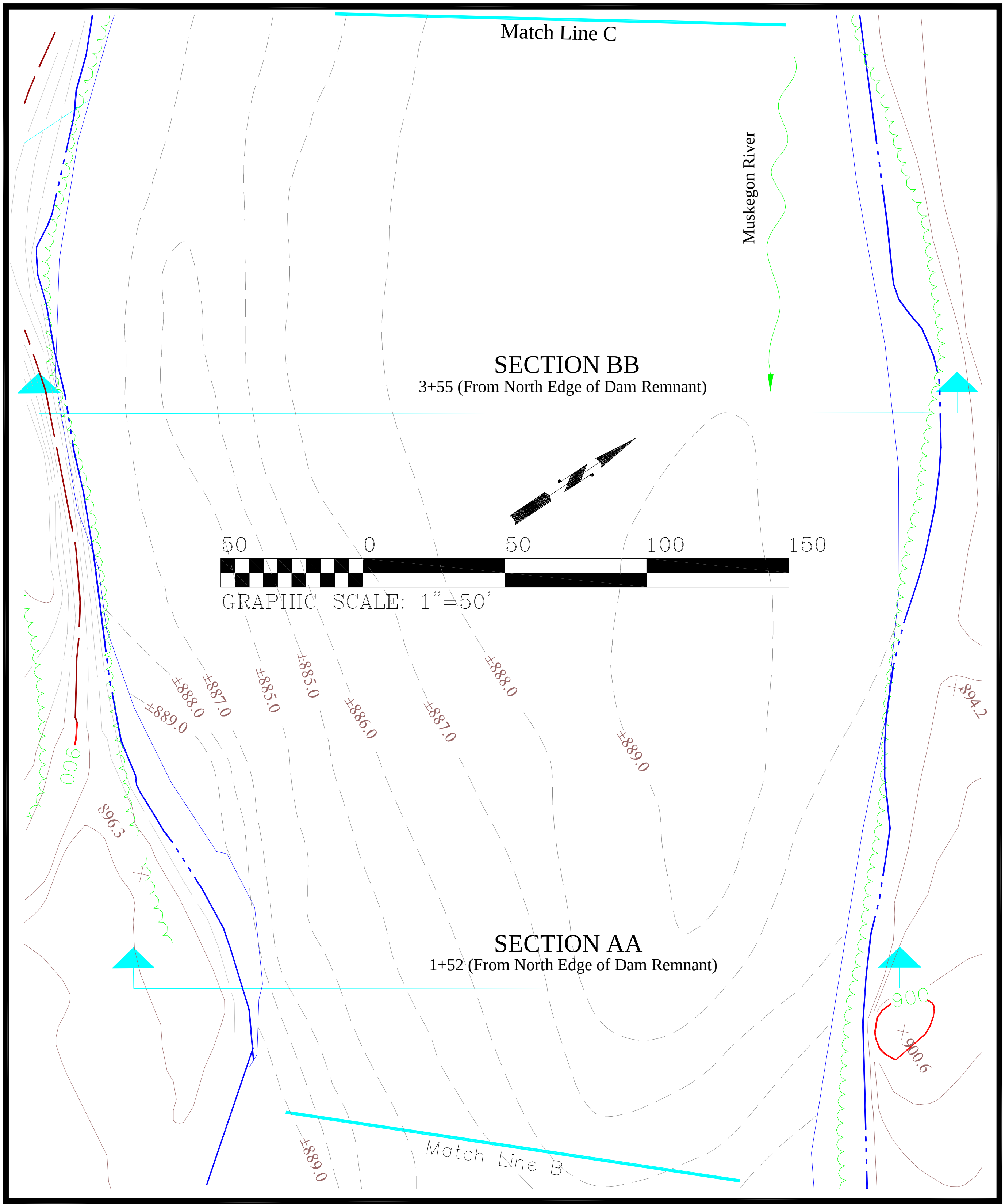
Contour Map of Muskegon River Near Baldwin Street Bridge

Date: June, 2000

Contour Interval: 2 Feet, Unless Noted Otherwise

Source: City of Big Rapids, Engineering Dept.

Figure 10:



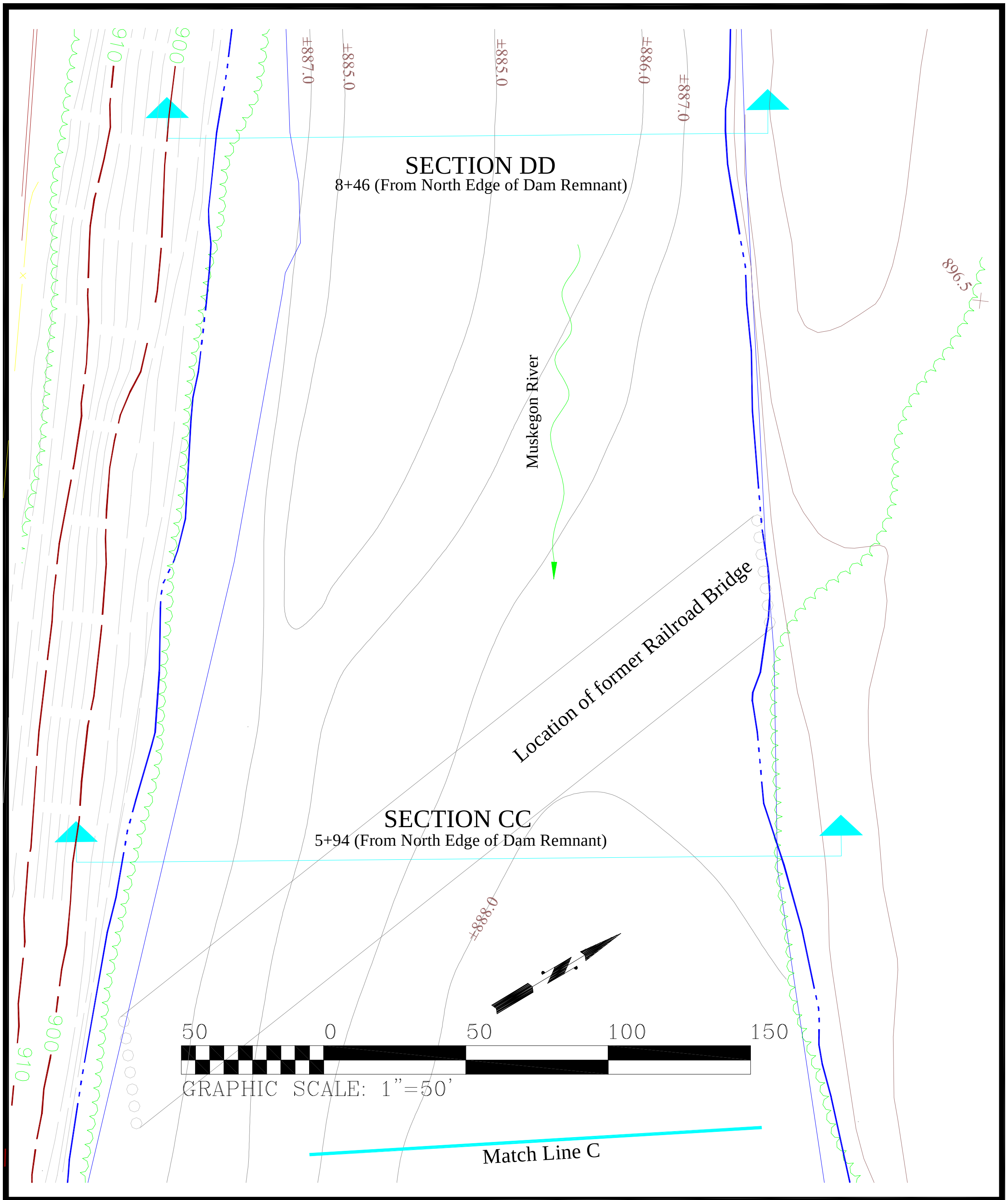
Contour Map of Muskegon River Near Baldwin Street Bridge

Date: June, 2000

Contour Interval: 2 Feet, Unless Noted Otherwise

Source: City of Big Rapids, Engineering Dept.

Figure 11:



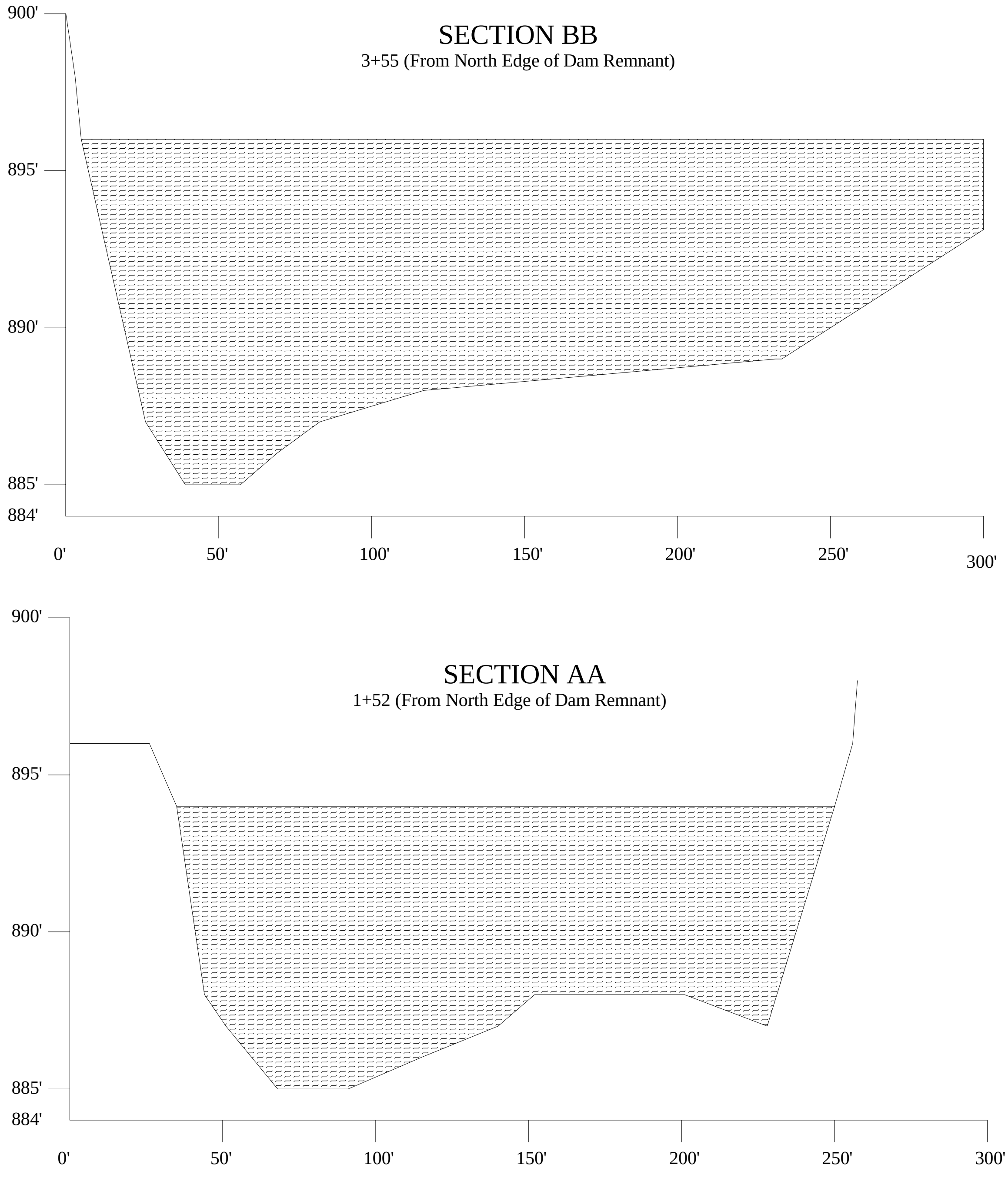
Contour Map of Muskegon River Near Baldwin Street Bridge

Date: June, 2000

Contour Interval: 2 Feet, Unless Noted Otherwise

Source: City of Big Rapids, Engineering Dept.

Figure 12:



SECTION BB
3+55 (From North Edge of Dam Remnant)

SECTION AA
1+52 (From North Edge of Dam Remnant)

Vertical Scale Exaggerated (10x)

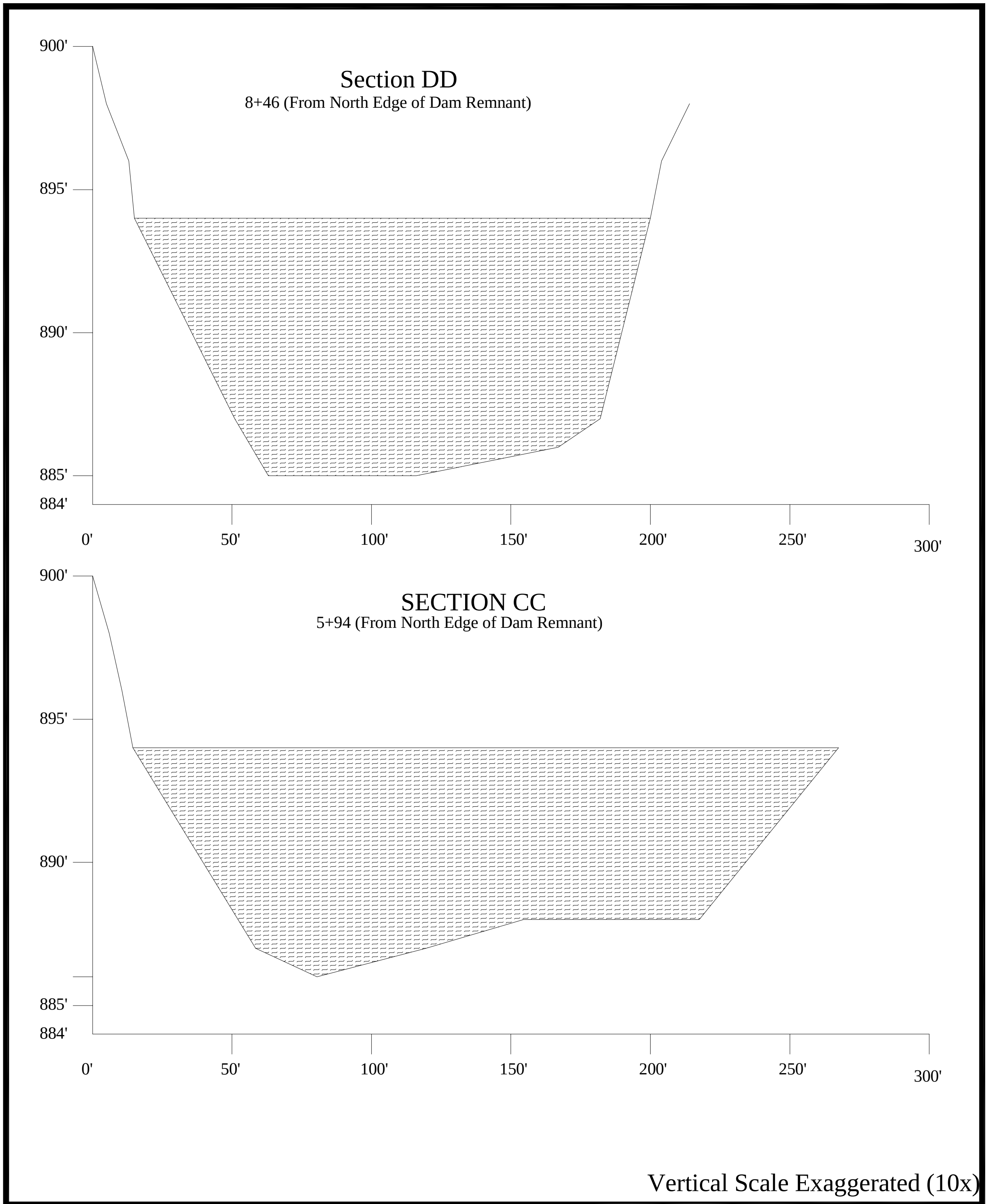
Existing Cross Sections of Muskegon River Bottom

Date: June, 2000

Cross Sections Scaled From 1 Foot Contours

Source: City of Big Rapids, Engineering Dept.

Figure 13:



Existing Cross Sections of Muskegon River Bottom

Date: June, 2000

Cross Sections Scaled From 1 Foot Contours

Source: City of Big Rapids, Engineering Dept.

5.0 Water Quality

5.1 Purpose and Scope

The purpose of this study was to determine the water quality of the Muskegon River upstream and downstream of the Big Rapids Dam remnant, to determine the effects of the dam remnant removal on water quality, and to compare the current water quality with past water quality studies. The study area encompasses a four-mile reach of the river between White's Bridge North of the city and St. Paul's Campus Parish at the end of Damascus Street in Big Rapids. Water samples were obtained at specific points within the study area and were analyzed for various specific indicators of water quality.

5.2 Sampling Locations

Six different sample locations were chosen for the water quality study. These sites represent areas on the Muskegon River in Big Rapids that are above and below the dam remnant. The location of each site was determined using a 1991 model Garmin 50 Global Positioning System (GPS) receiver, which has an accuracy within ± 10 to 15 meters of the "true" position. A GPS receiver is a satellite based positioning system that determines the latitude and longitude of a point in degrees, minutes, and hundredths of a minute.

Figure 14: List of samples and their description

Sample Site	Description
1	Six feet from bank into the river below northwest corner of White's Bridge
2	Thirty feet southeast along the bank of the southern base of White's Bridge and six feet into the river from the bank
3	Fifteen feet north of fishing ramp at Northend Park and six feet into the river from the bank
4	Twenty feet south of the southwest corner of Riverside Bar and Grill and sixteen feet west, six feet into the river from the bank
5	Seventy-five feet south of the east support beams of Maple Street Bridge and six feet west of the bank into the river
6	Eighty feet southwest of the foot of the stairs located due east of the parking lot at St. Paul's Campus Parish, Damascus Road and six feet from the bank into the river

Figure 15: Sample Point Map

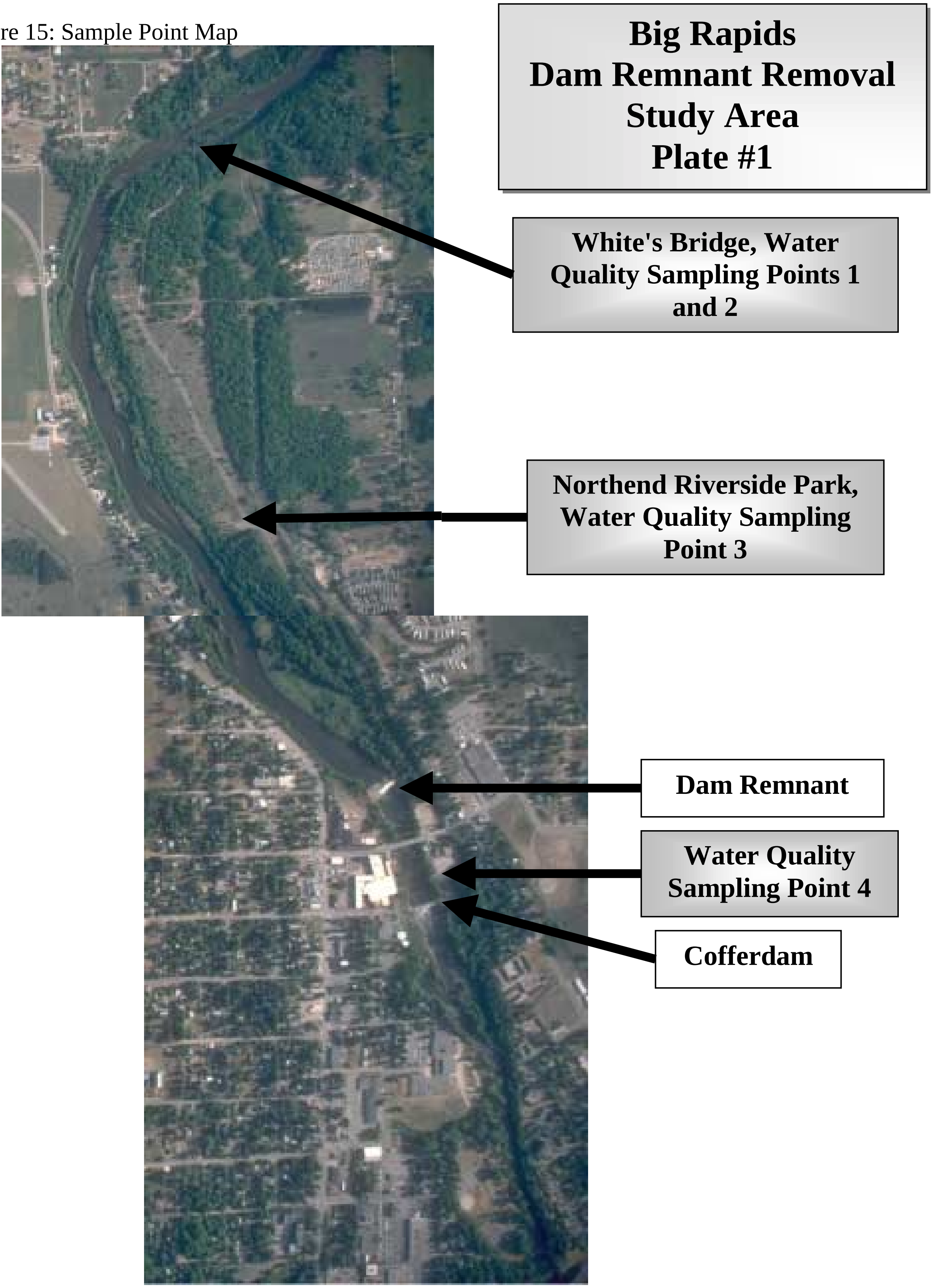
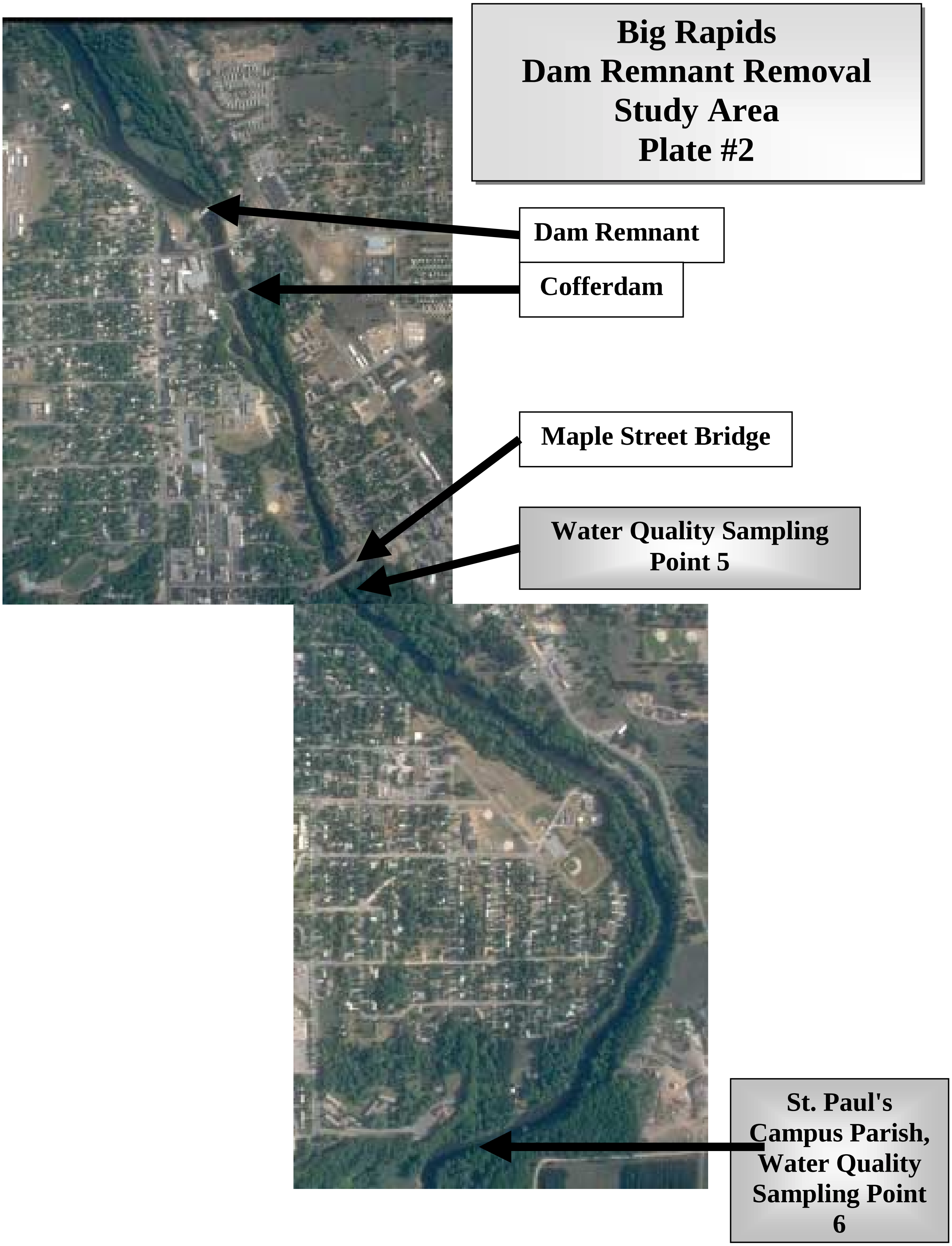


Figure 15: Sample Point Map, Continued



Sample Site 1: This site was chosen to obtain data for that part of the river flowing north of an island at White's Bridge that divides the Muskegon River. The water quality of the river may vary on either side of the island, therefore, a sample site was chosen on each side.

Sample Site 2: This site was chosen because it is directly across the river from sample site 1, thus enabling data collection for the portion of the river that runs south of the island. In addition, a drainage ditch, which may contain runoff from farmland, empties into the river above this site.

Sample Site 3: This site was chosen because any major changes due to sediment loss or erosion caused by the dam remnant removal would be seen at this site. The site is approximately 3500 feet upstream of the dam remnant, and is the area where most ecological and water quality changes are anticipated following the remnant removal. This is also an area of high traffic (canoe removal and fishing) and heavy human activity may negatively impact the river at this point.

Sample Site 4: This is the first site that would show any effects of the dam remnant removal. This site is located just below the dam remnant and above the cofferdam.

Sample Site 5: This site was located at Maple Street Bridge and was selected to detect changes that may be caused by the dam remnant removal or general use of the river, such as tubing or swimming.

Sample Site 6: This site was chosen because it is located downstream of the wastewater treatment plant. Discharge from this plant may affect water quality at any time. This point is also the southernmost extent of the boundary of the City of Big Rapids.

In the 1991 study of the Muskegon River by the FSUEMSC, eleven sites were sampled. In the 2000 study, 6 sites were sampled. Only two sample sites were located in the same place both years. Identical were site 3, at Northend Riverside Park, and site 6, at St. Paul's Campus Parish. When comparing 1991 and 2000 data, only results from these two sample points were used.

5.3 Sampling Procedures

Samples were taken on six different days: May 25 and 31, June 6, 19, and 26, and July 5, 2000. Figure 16 shows the weather condition on each sample date.

Figure 16: Weather Chart

Date	Time	Weather Conditions
5/25/00	2:00-6:00 PM	Rainy, Overcast, 65°F/18.3°C
5/31/00	5:00-6:30PM	Sunny, clear skies, 70°F/21.1°C
6/6/00	5:00-6:30 PM	Sunny ,clear skies, light southeasterly wind, 75°F/23.9°C
6/19/00	8:00-9:30AM	Sunny, clear skies, 78°F/25.5°C
6/26/00	8:00-9:30AM	Slightly overcast, humid, 78°F/25.5°C
7/5/00	8:00-930AM	Sunny, clear skies, 79°F/26.1°C

Samples were taken six feet from the riverbank at each location using a swing sampler and a long handled dipper sampler (Figure 17). The HACH 4600-00 Conductivity and TDS Meter was taken into the field on sampling dates to measure temperature, conductivity, and total dissolved solids (TDS) at each sample site. Three types of sample bottles were used to collect the samples. All bottles used for microbiological sampling were 500-ml sterilized plastic bottles. Bottles used for chemical testing were chemically cleaned 1-liter plastic bottles. Bottles used for collection of Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) samples were 330-ml chemically cleaned glass bottles. All sample bottles used can be seen in Figure 18. DO samples were immediately treated with manganous sulfate and alkali-iodide-azide reagents to encapsulate oxygen molecules. All sampling was completed within ninety minutes, and samples were taken to the laboratory at the Victor F. Spathelf Center for Allied Health, on the FSU campus, for the purpose of immediate analysis. Parameters tested for included: temperature, conductivity, turbidity, total dissolved solids, suspended solids, total hardness, alkalinity, pH, total iron, copper, chromium, tannins and lignin's, dissolved oxygen, biochemical oxygen demand, fecal coliform, fecal streptococcus, E. coli, and Pseudomonas aeruginosa. Data for all tests performed can be seen in Figures 28, 29, and 30.

Figure 17: Water Sample Devices

Top: Swing Sampler
Bottom: Dipping Sampler

Figure 18: Sample Bottles

DO/BOD Biological All Others

5.4 Physical Analysis

5.4.1 Temperature

Each species has an optimal temperature at which it thrives. Water temperature limits the diversity of organisms that will live in a specific water environment. Temperature effects oxygen solubility levels and alkalinity. At lower temperatures larger amounts of oxygen can be dissolved in the water and visa versa. (20)

Throughout the study, water temperatures increased due to seasonal warming of the river. Data collected during this study indicate that demolition of the dam remnant has not reduced the pond volume to a point where it would reduce solar heat gain that would lead to a decrease in river temperature. During a 1991 study conducted in mid-July by FSUEMSC of the Muskegon River, the average river temperature was found to be 67.1°F (19.5°C). This was only slightly higher than the average of 66.6°F (19.2°C) found in May and June during the 2000 study.

5.4.2 Conductivity

Conductivity is a measure of water’s capacity to conduct electric currents. Conductivity depends on the presence of ions, their total concentration, mobility and valence, and the temperature of the water at the time the measurement is taken. The higher the conductivity of a water sample, the greater the total amount of solids dissolved in the water. Solutions of inorganic compounds are good conductor’s (20).

Since it is the ions of dissolved solids that conduct electrical current, it is therefore relevant to compare conductivity results with TDS (18). The results were as expected, when TDS increased, conductivity also increased. No comparison can be made to the 1991 study, as conductivity was not determined.

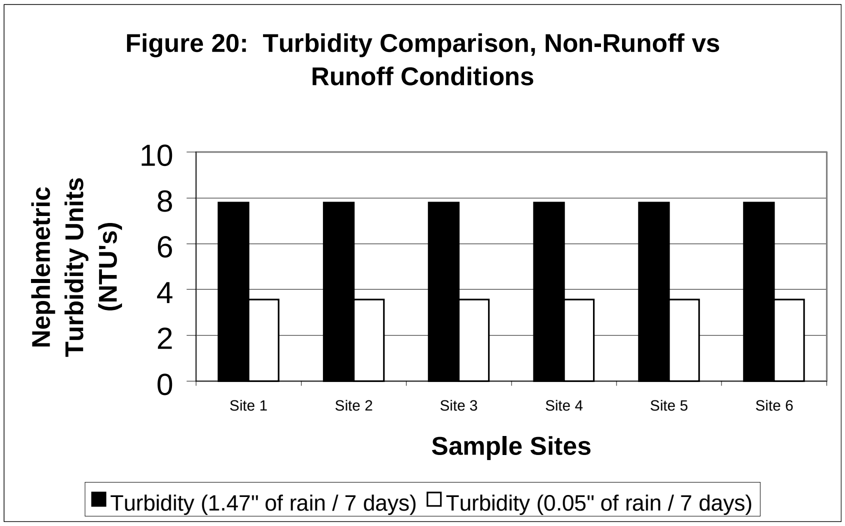
5.4.3 Turbidity

Suspended and colloidal matter such as clay, silt, organic, and inorganic matter cause turbidity. The clarity of a natural body of water is an important factor in the determination of its quality (20).

All turbidity data was obtained from the operators of the City of Big Rapids Water Treatment Plant (WTP), who record this information daily. Turbidity data is expressed in Nephelometric Turbidity Units (NTU) and is located in Figure 19. During the study turbidity values progressively decreased, as did the amount of precipitation the area received. Figure 20 is a graph representing non-runoff vs. runoff conditions for turbidity values. Lower precipitation causes suspended solids in rivers to decrease, which, in turn causes the turbidity to decline.

Figure 19: Turbidity values

Sample Date	Turbidity NTU
5/25/00	7.8
5/31/00	7.93
6/6/00	8.41
6/19/00	6.68
6/26/00	4.6
7/5/00	3.56



5.4.4 Solids

“Solids” are matter suspended or dissolved in water or wastewater. This study included both suspended solids and total dissolved solids (TDS). An increase in solids may create an aesthetically unsatisfactory body of water (20). It is important for the reader to know that precipitation is very low in dissolved solids content, while the Muskegon River, a groundwater discharge river, is high in dissolved solids content. These solids are dissolved from the soils and rocks through which the water flows. Runoff from precipitation picks up suspended solids, which are added to the river. The result is an increase in suspended solids, and a decrease in dissolved solids due to dilution during runoff flow. When runoff is not present in rivers, the suspended solids settle out, while dissolved solids content rises due to a lack of soft dilution water.

5.4.4.1 Total Dissolved Solids (TDS)

TDS is the portion of a sample that passes through a filter and is a measure of the total amount of solids dissolved in water. These solids consist of carbonates, bicarbonates, chlorides, sulfates, phosphorous, nitrogen compounds, and trace amounts of other substances.

TDS values increased throughout the study, as the amount of precipitation received by the study area decreased. The increase in TDS values may be due to the fact that there was less precipitation to cause dilution of solids present. All TDS results were below MDEQ surface water quality standards.

5.4.4.2 Suspended Solids

A suspended solid is that portion of a sample that is retained by a filter. Suspended solids were determined using United States Environmental Protection Agency Method 2540D.

Suspended solids decreased throughout the period of the study. Weather conditions were generally drier during the later portion of the study, decreasing runoff into the river. This decrease in runoff may explain the drop in suspended solids. Non-runoff vs. runoff conditions for suspended solids can be seen in Figure 21. When reviewing the average suspended solids values, site 6 stands out. The value of 33.3 mg/L obtained June 19 could be due to a sampling or analytical error. If this value were excluded, the average would be 10.7 mg/L.

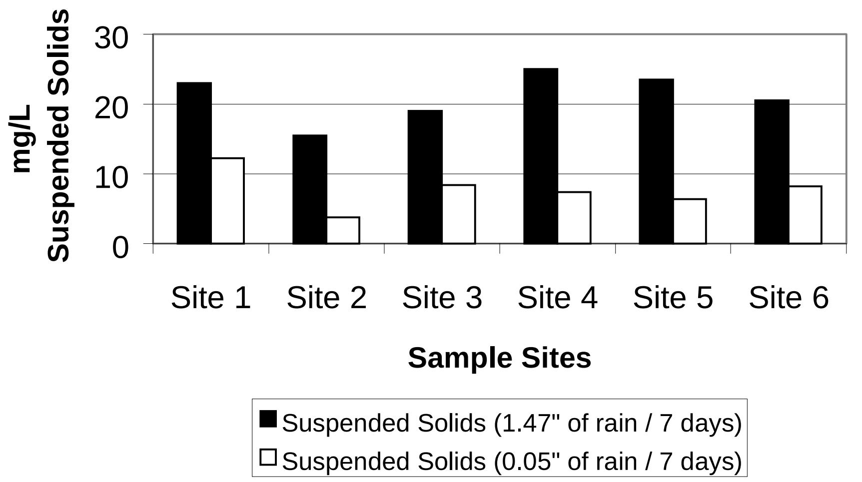
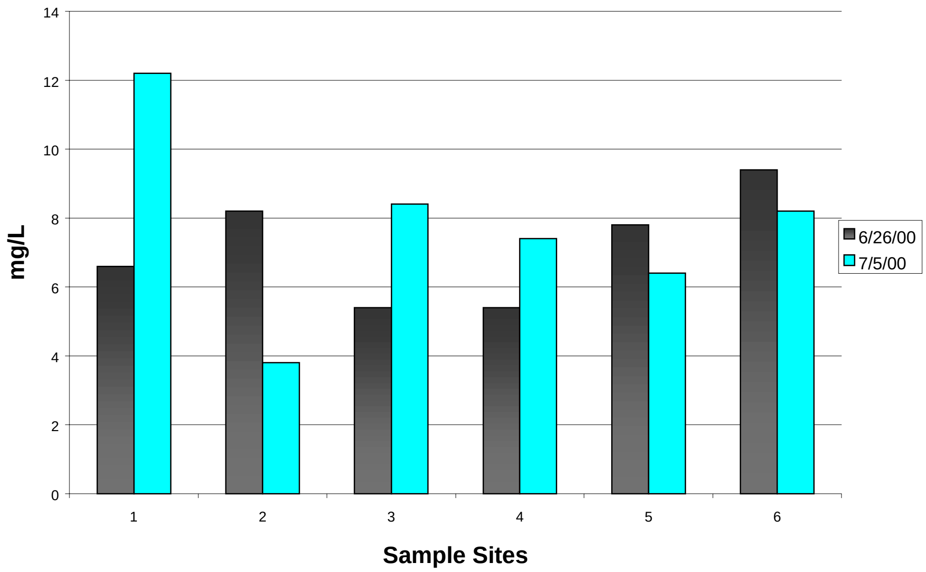


Figure 21: Suspended Solids Comparison, Non-Runoff vs Runoff Conditions

Looking at suspended solids values before and after dredging began on June 30, an increase can be seen at site 4. This site is located between the dam remnant and the cofferdam, and had suspended solids values that increased during the last sample date. Average suspended solids data for the last three sampling dates can be seen in Figure 22. This indicates that the dredging process has had an effect on suspended solids. In samples taken after dredging began, site 5, located below the cofferdam at the Maple Street Bridge, had a lower suspended solids value than site 4, located above the cofferdam. On July 5, the site 4 suspended solids were measured at 7.4 mg/L, while site 5 measured 6.4 mg/L. These values suggest that the solids are settling out at the cofferdam, showing effective removal of the sediment. Sediment from the removal of the west side of the remnant has tended to follow the west bank of the river. Sample sites 4 and 5 are located on the east bank so the true suspended solids content of the river may have gone undetected as the sites are not within the mixing zone. While the suspended solids may not have been completely mixed across the river at site 5, they should have been mixed by site 6. This is suggested by the fact that solids measurements did increase between sites 5 and 6 once dredging began. Site 5 suspended solids measured 6.4 mg/L on July 5, while site 6 measured 8.2 mg/L.

When comparing the suspended solids data from the 2000 study with the 1991 data, a ten-fold decrease has been seen over the nine-year period, from 105.6 mg/L to 10.7 mg/L, respectively. This may be due to a difference in rainfall; however, it definitely suggests an improvement in water quality with respect to suspended solids.

Figure 22: Suspended Solids Before and After Dredging



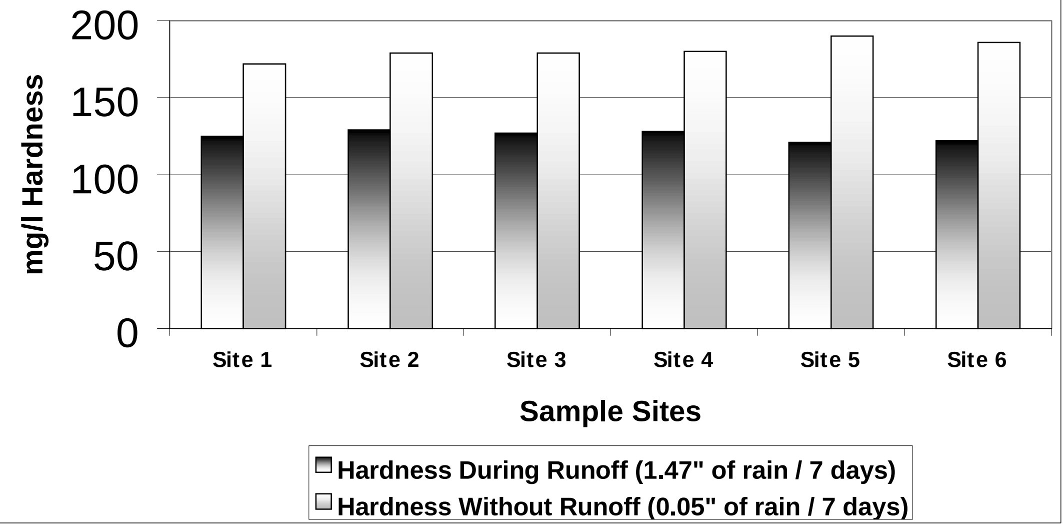
5.5 Chemical Analysis

5.5.1 Total Hardness

Hardness is the concentration of calcium carbonate, magnesium carbonate, and bicarbonate ions dissolved in water. They are both expressed as mg/L for calcium carbonate (20). Water usually acquires its hardness properties by dissolving magnesium, calcium, carbonates and bicarbonates from rocks and soils. Hardness in water serves as a buffer (pH neutralizer). The hardness analysis was performed using HACH method 2340 (20).

Mean hardness values for this project varied from a low of 142.5 mg/L, at sample site 5 to a high of 163.7 mg/L, at sample site 2. These results are fairly consistent and show no large disparities suggesting that outside influences from runoff are not altering the hardness of the water. Since the Muskegon River is a groundwater discharge river it is naturally high in hardness. Rainfall is soft water and higher runoff tends to dilute the hardness of the river water. During the early stage of the study period, precipitation was higher than in the later stages, leading to a consistent increase in hardness throughout the study. Figure 23 shows hardness values as they differ for non-runoff and runoff conditions.

Figure 23 : Hardness during Runoff and Non-Runoff Conditions



5.5.2 Alkalinity

The acid-neutralizing capacity of water is a function of its alkalinity. Alkalinity is primarily due to carbonate, bicarbonate, and hydroxide content and is expressed in amounts of calcium carbonate in the water. Alkalinity serves as a buffer to acid, preventing sudden pH changes and preserving aquatic life that would be affected by acidification (20).

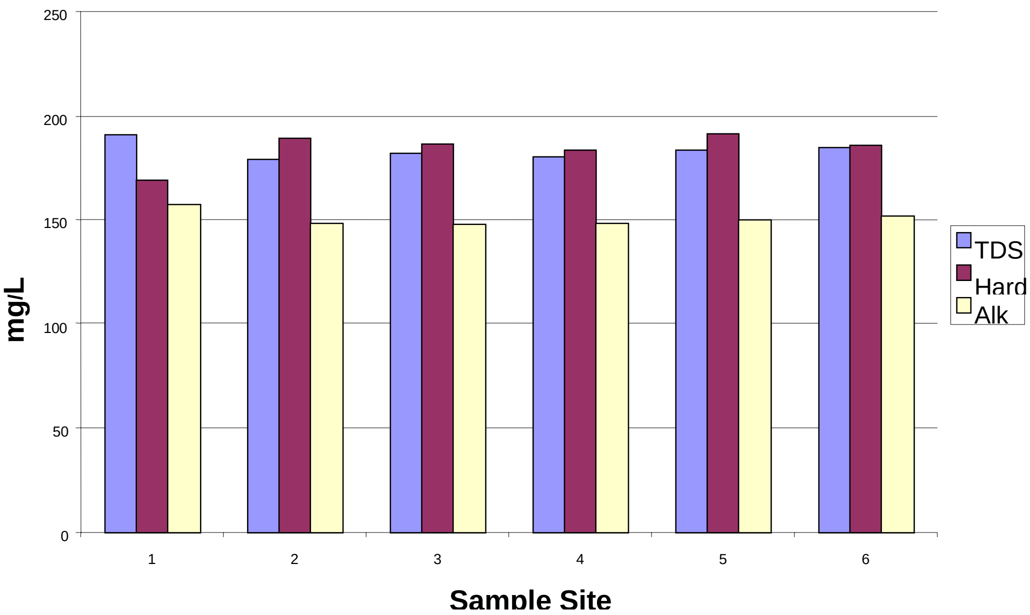
HACH method 8203, Phenolphthalein and Total Method were used to determine alkalinity values. The results were expressed in mg/L calcium carbonate. Mean alkalinity values ranged from 137.3 mg/L at sample site 1, to 130.4 mg/L at sample site 3. Alkalinity values increased throughout the study. The overall increase in alkalinity may be attributed to the decrease in the volume of water in the river, due to less runoff and dilution. Since alkalinity acts as a buffer for pH by balancing the negative hydroxide ions with the positive hydrogen ions, any decrease in pH will likely cause a decrease in alkalinity. With the lower volume of water in the river pH will increase and thereby causing alkalinity to increase.

5.5.3 Alkalinity, Hardness, and TDS Comparison

The ions that make up alkalinity are similar to those that make up hardness. It is for this reason that the values for these two test parameters should be approximately the same. If the balance between these parameters were found to be substantially lower than TDS values, it may indicate the presence of manmade pollutants (20).

When comparing TDS, alkalinity, and hardness results for this study no significant imbalances were found. This suggests that this reach of the Muskegon River is relatively free of manmade pollutants. Figure 24 compares the alkalinity, TDS and hardness data. From the graph, it appears that nearly all of the TDS is in the form of hardness, which is then supplying the ions for alkalinity.

Figure 24: Alkalinity, Hardness, and TDS Comparison



5.5.4 pH

One of the most important and frequently used water quality parameters is pH. pH is a measurement of hydrogen ion concentration in water. This could also be considered an "intensity" factor of acidity. Excessive hydrogen ions may adversely affect the quality of water and are a possible indicator of pollutants (20).

The instrument used for pH measurements was the HACH EC10 portable pH meter. MDNR standards for pH in all waters in the State of Michigan range from 6.5 to 9.0. The average pH for this study was 7.8, well within the recommended range. Average pH values increased overall during the time of study, but have decreased since the 1991 study when the average was 8.3.

5.5.5 Total Iron, Copper, and Chromium

In a 1993 Prein & Newhof study trace amounts of iron, copper, and chromium were found in the sediment behind the dam remnant. Since the dam remnant removal will include removal of the sediment behind the dam, analysis of these three parameters may help in determining whether or not any iron, copper, or chromium was released into the river during dredging. The methods used for determining these parameters were HACH 8112 for total iron, HACH 8506 for copper, and HACH 8023 for chromium.

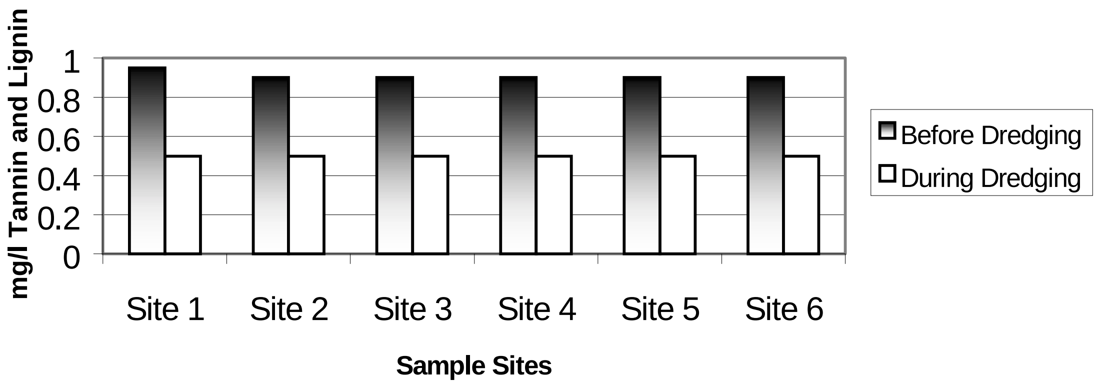
Trace amounts of copper and iron were detected in the water samples analyzed however no chromium was found. The amounts of copper and iron decreased throughout the testing period, suggesting that dredging has not mobilized these ions into the water.

5.5.6 Tannins & Lignins

Both tannins and lignins are plant constituents and are naturally found in water through the process of vegetable matter degradation (20). There are large amounts of organic matter, mostly in the form of wood chips, built up behind the dam remnant structure. Appropriate dredging measures have been planned in order to minimize sediment mobilization downstream. When this material is dredged it is possible that the tannin and lignin concentration in the river will rise. In this way, tannins and lignins may potentially be used as an indication of the commencement, conduction or cessation of dredging.

In determining amounts of tannins and lignins present in river water samples HACH 8193 Tyrosine Method was used. On testing date June 19, tannin and lignins levels were 1.1mg/L, on June 26, levels were 0.7mg/L, and on July 5, levels were 0.5mg/L. Tannins and lignins levels were higher in early summer due to precipitation and runoff, which flushed swamps introducing higher amounts of naturally, produced tannins and lignins into the water. During dry flow conditions concentrations of tannins and lignins decreased. Values at sites 4, 5, and 6 decreased following the commencement of dredging, indicating that dredging has not released tannins and lignins into the water. Figure 25 shows tannins and lignins levels before and during dredging

Figure 25: Tannin and Lignin Comparison, Before and During Dredging



5.5.7 Dissolved Oxygen

Oxygen is a clear, colorless, tasteless gas that most living things need for life. Dissolved Oxygen (DO) is the amount of oxygen dissolved per liter of water. It is essential in rivers such as the Muskegon to support the aquatic flora and fauna found there. Water should generally contain at least 5 mg/L of oxygen; this concentration supports fairly diverse communities of organisms (1). Dissolved oxygen is depleted from water by thermal (heat) pollution, respiration of the organisms found in the water, and from rapid increases in populations of microorganisms that utilize oxygen brought about because of nutrients added by man. When this occurs, oxygen is often quickly depleted. Conversely, oxygen is added to water as it splashes over rocks and picks up oxygen from the air, when plants and algae photosynthesize and by diffusion of oxygen into the water (1). Temperature, pollution, photosynthesis, and turbulence of the water can all influence the amount of dissolved oxygen in a river. High levels of DO in water, indicates that the water is of excellent quality, while low DO levels indicate water is of poorer quality. The method used to determine the dissolved oxygen content of the samples was USEPA Method 8215 (modified Winkler Azide).

The MDNR standard for dissolved oxygen of all Great Lakes and connecting waterways is 7 mg/L. The average dissolved oxygen for the study area was 7.7 mg/L, which is above the standard of 7.0 mg/L. The highest overall DO level of 9.4 mg/L was recorded at sample site 1 and the lowest overall DO level of 6.8 mg/L was recorded at sample site 3. The results were relatively consistent for each sample site, but decreased from sample date to sample date. A possible explanation for the lower DO at sample site 3 is that at this point the river moves slowly, therefore reaeration is not as prevalent, lowering DO levels. Warm water holds less oxygen than cold water. A marked change in the temperature of the water between each sample date was detected. This may explain the decrease in dissolved oxygen levels throughout the study period. In 2000 the average DO was 8.1 mg/L, showing a slight and probably insignificant decrease from the 1991 average of 8.2 mg/L.

5.5.8 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand is a measure of the amount of oxygen used by microorganisms while metabolizing organic matter (9). Low BOD levels of between 0-4 mg/L usually indicate that water is in a stable condition. An elevated BOD level indicates that there is a high demand for oxygen in the water suggesting possible organic pollution of the water. The BOD analysis was performed using USEPA Method 8215.

The average BOD for this study was 0.8 mg/ L. Individual BOD values ranged from a low of 0.2 mg/L at sample sites 1, 2, & 3 to a high of 1.2 mg/L at sample site 5. The higher value at site 5, below the dam remnant, could indicate that some BOD is being entrained into the river by dredging. However, levels at site 6 are consistent with sites 1-4. This data shows that the river is self-remediating. All values were within the 0 – 4mg/L range which is what would be expected in a natural, uncontaminated river. These results suggest that there is no significant continuing manmade source of BOD entering this reach of the river. Comparison of the BOD levels showed a fifty- percent drop in BOD between the 1991 and 2000 reports. This is an indication that the river is more biologically stable now than it was in 1991. This may be due to increased awareness about the environment and better management of the land surrounding this natural resource, or it may be due to different environmental conditions during the two studies.

5.6 Microbiological Analysis

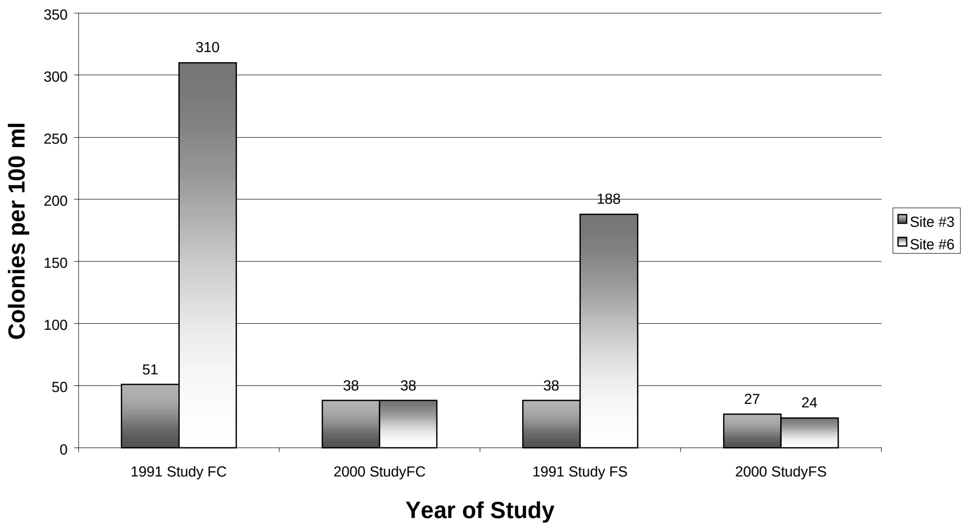
5.6.1 Fecal Coliform (FC)

Fecal Coliform are found in the intestinal tract and feces of humans and animals. When Fecal Coliform are detected it may be an indicator that other harmful pathogens may also be present in the water (20). Standard Method 9222D was used for the analysis of FC.

FC results ranged from 38 colonies at site 6 to 64 colonies at site 1 per 100 ml. There was no large fluctuation in the FC results. From the data it appears as though this reach of the river is self-remediating the water as it flows downstream, and no Fecal Coliforms have been released during the dredging process.

The FC results were compared for identical sites in both studies sites 3 and 6 and can be seen in Figure 26. FC results from the 1991 study are higher for both sample sites, showing there is either less FC contamination entering the river and/or the river is better at remediating itself.

Figure 26: 1991/200 Fecal Coliforms & Fecal Streptococcus Comparisons



5.6.2 Fecal Streptococcus (FS)

Fecal Streptococcus is found in sewage and warm-blooded animals' fecal waste. Although there has been no standard set for FS due to the debate over its significance, a recommendation has been made by the USEPA pertaining to the enterococci group. It is recommended that for freshwater there should be no more than 33 enterococci per 100 ml of water (27). Standard Method 9230C was used in this analysis. FS laboratory results ranged from 24 to 49 colonies per 100 ml. Sites 2, 3, 4, 5, and 6 are below the USEPA suggested total enterococci level of 33 colonies per 100 ml.

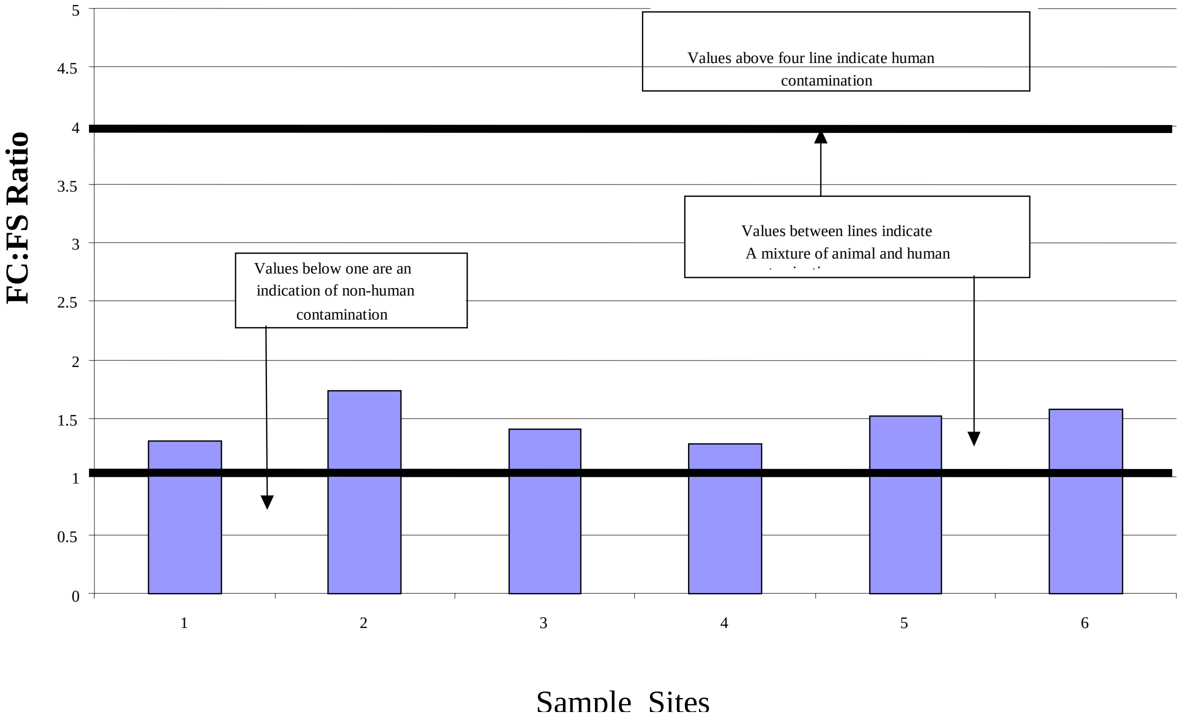
The FS counts at site 1 were 49 per 100ml, well above the USEPA recommendation. The cause for the large counts is unknown. The results were highest at sample site 1, declining rather consistently to sample site 6 (with the exception of site 4). There is a fifty- percent decrease in the number of colonies per 100 ml from site 1 to site 6. The FS results confirm that the reach of the river is self-remediating the bacteria. This data also shows that so far no FS has been released into the river during the dredging process. FS results from sites 3 and 6 were also compared with the 1991 FSUEMSC study. Again, the FS counts were noticeably higher in the 1991 study and are seen in Figure 26.

5.6.3 Fecal Coliform: Fecal Streptococcus Ratio

FC and FS results may be compared to approximate the source of fecal contamination. This is usually done with a FC:FS ratio. The geometric mean of the FS is set as the one value when calculating the FC:FS ratio. Normally if the calculated number is less than 1:1 (FC:FS), the origin of fecal contamination is considered to be non-human (animal). If the number falls between one and four the fecal contamination is most likely a mixture of animal and human wastes. A number above 4:1 generally indicates human fecal contamination (20).

Laboratory results show a FC:FS ratio between one and four. All results can be seen in Figure 26. Although the ratios are slightly greater than 1:1, this does confirm that there is a small element of human contamination in the reach of the river that was studied. Although it would be hard to define exactly where the contamination is coming from, this area of the river is used for recreation, and areas above this reach are lined with private residences. One other possible source of contamination is the treated wastewater that both the towns of Evart and Reed City discharge into the Muskegon River.

Figure 27: Fecal Coliform:Fecal Streptococcus Ratio



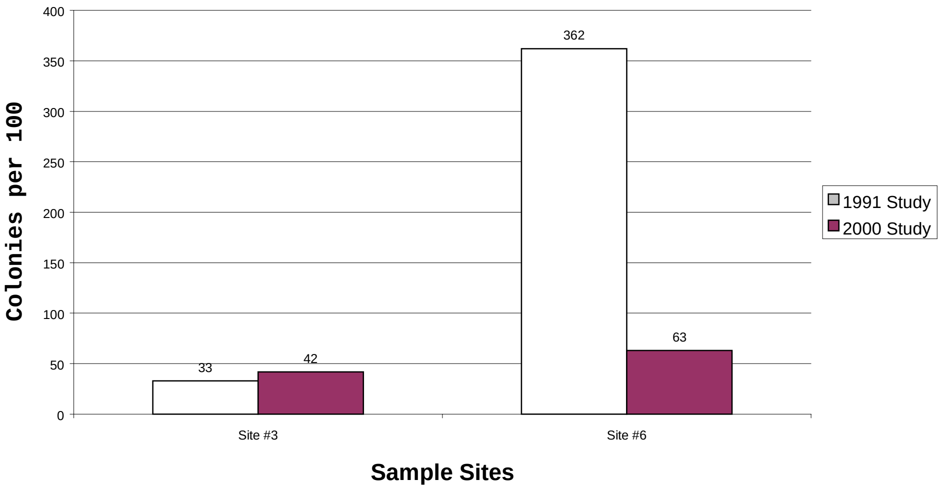
5.6.4 Escherichia coli (E-coli)

E. coli is an indicator organism that can be used to detect fecal contamination from human and animal waste (27). The Michigan Department of Environmental Quality standard is no more than 130 E. coli per 100 milliliters (ml) and at no time should the E. coli exceed 300 per 100 ml of water. Both of these standards are for waters considered to be full body contact recreational area (22). Standard Method 9213D was used to test for E. coli analysis.

The geometric mean for E. coli ranged from 38 to 63 colonies per 100 ml. Sites number 2, by White's Bridge, and 6, by St. Paul's Campus Parish, had higher numbers of E. coli colonies. It is possible that the higher number of E. coli at sample site 6 is due to several creeks that run into the Muskegon River shortly before this site. Large amounts of agricultural runoff may be entering the river immediately above site 2, contributing to the higher levels of E. coli. Although there were varying geometric means, it may be seen from individual site data that E. coli counts did not increase after the dredging process commenced. Laboratory results confirm that all six sample sites are well below the MDEQ full body contact standard of 130 colonies per 100 ml.

E. coli results were also compared for sites 3 and 6 to the 1991 FSUEMSC report on the Muskegon River water quality. Figure 28 is a graph showing the comparison of results for the two studies. Again, like FC and FS, the E. coli results were far below the 1991 results. Levels of all three of these bacteria decreased, indicating an improvement in water quality.

Figure 28: E.coli 1991/2000 Comparison



5.6.5 Pseudomonas aeruginosa (PA)

PA is an opportunistic organism that may cause infection in a compromised host. PA occurs in the feces of humans and domestic animals that are contaminated by humans. This organism is usually found in untreated waters and in the presence of coliform (27). Standard Method 9213E was used for the PA analysis.

There were no PA colonies detected in the analyzed samples. This supports the FC:FS ratio showing that the water is contaminated primarily with animal, not human feces.

5.7 Unit Summary

The physical, chemical and microbiological water quality parameters in the study area of the Muskegon River meet all surface water quality standards established by the MDNR. The condition of the river has improved since 1991, and the overall water quality of this region of the Muskegon River is good. Current dam remnant removal has only shown a possible effect on the amount of suspended solids within the river. Effective removal of sediment, with the cofferdam acting as a sediment trap, appears to be working as planned.

Figure 29: Physical Data

Sample Site	Sample Date	Temp.	Conductivity	Suspended Solids
		°C	mS/cm	mg/L
#1	5/25/00	18.9	0.27	23
	5/31/00	17.3	0.32	10.5
	6/6/00	17.2	0.33	10
	6/19/00	19.5	0.36	2.3
	6/26/00	21.4	0.36	6.6
	7/5/00	20.9	0.40	12.2
Average		19.2	0.34	10.8
#2	5/25/00	17.3	0.28	15.5
	5/31/00	17.3	0.3	13.5
	6/6/00	17.7	0.32	8.5
	6/19/00	18.8	0.34	1.7
	6/26/00	21.6	0.36	8.2
	7/5/00	20.6	0.38	3.8
Average		18.9	0.33	8.5
#3	5/25/00	17.4	0.26	19
	5/31/00	17.4	0.31	13.5
	6/6/00	18.2	0.32	6.5
	6/19/00	19.4	0.34	4
	6/26/00	21.2	0.36	5.4
	7/5/00	19.9	0.38	8.4
Average		18.9	0.33	9.5
#4	5/25/00	18.1	0.27	25
	5/31/00	17.7	0.31	11.5
	6/6/00	19	0.32	5
	6/19/00	19.4	0.34	4.7
	6/26/00	21.5	0.36	5.4
	7/5/00	20.7	0.38	7.4
Average		19.4	0.33	9.8
#5	5/25/00	18.6	0.26	23.5
	5/31/00	18.3	0.31	20.5
	6/6/00	18.6	0.31	9
	6/19/00	19.3	0.35	2
	6/26/00	21.4	0.35	7.8
	7/5/00	20.8	0.39	6.4
Average		19.5	0.33	11.5

Figure 29: Physical Data Cont.

Sample Site	Sample Date	Temp.	Conductivity	Suspended Solids
		°C	mS/cm	mg/L
#6	5/25/00	17.6	0.27	20.5
	5/31/00	18	0.31	9.5
	6/6/00	17.9	0.32	8
	6/19/00	19.7	0.36	33.3
	6/26/00	21.6	0.38	9.4
	7/5/00	21.2	0.39	8.2
Average		19.3	0.34	14.8

Figure 30: Chemical Data

Sample Site	Sample Date	DO	BOD	Hardness	Alkalinity	pH
		mg/L	mg/L	mg/L	mg/L	
#1	5/25/00	7.8	0.8	125	111	7.26
	5/31/00	8.1	0.7	124	115	7.58
	6/6/00	9.3	NA	146	125	7.78
	6/19/00	9.4	1	161	153	7.63
	6/26/00	7.6	0.8	174	149	7.47
	7/5/00	7	0.4	172	171	7.69
Average		7	0.7	150	137	7.57
#2	5/25/00	7.4	0.6	129	104	7.32
	5/31/00	8.2	0.9	144	117	7.7
	6/6/00	9.2	NA	141	126	7.92
	6/19/00	8.2	0.2	171	139	7.97
	6/26/00	7.2	0.8	218	146	8.08
	7/5/00	7.4	0.8	179	160	8.08
Average		7.9	0.67	164	115	7.85
#3	5/25/00	8	1	127	99	6.88
	5/31/00	8.2	0.8	137	112	7.75
	6/6/00	8.8	NA	142	129	7.95
	6/19/00	8.4	0.2	169	146	7.61
	6/26/00	7	0.4	212	146	8.10
	7/5/00	6.8	1	179	151	8.11
Average		7.9	0.7	161	131	7.73
#4	5/25/00	8	1	128	112	7.37
	5/31/00	8.3	0.9	141	116	7.82
	6/6/00	8.1	NA	140	124	8.02
	6/19/00	8.4	0.2	153	145	7.98
	6/26/00	7.2	0.6	217	148	7.82
	7/5/00	7.2	1	180	153	8.16
Average		7.9	0.7	160	133	7.86
#5	5/25/00	8.2	0.8	121	117	7.48
	5/31/00	8.2	0.6	141	120	7.86
	6/6/00	9.8	NA	143	120	8.09
	6/19/00	8.8	1.2	167	147	7.71
	6/26/00	7.8	1.2	217	148	8.11
	7/5/00	7.2	1	190	155	8.14
Average		8.3	1	163	135	7.9

Figure 30: Chemical Data Cont.

Sample Site	Sample Date	DO	BOD	Hardness	Alkalinity	pH
		mg/L	mg/L	mg/L	mg/L	
#6	5/25/00	8.3	1.1	122	101	7.56
	5/31/00	8.8	0.6	131	121	7.91
	6/6/00	9.2	NA	140	121	8.1
	6/19/00	9.2	0.8	156	149	8.06
	6/26/00	7.4	0.7	216	149	8.20
	7/5/00	7.2	0.6	186	157	8.22
Average		8.4	0.8	159	133	8

∗ NA-Not Applicable

Figure 30: Chemical Data Cont.

Sample Site	Sample Date	Copper	Iron	Chromium	Tannins & Lignins
		mg/L	mg/L	mg/L	mg/L
#1	6/19/00	0.01	0.54	0	1.2
	6/26/00	0.03	0.35	NA	0.7
	7/5/00	ND	0.18	NA	0.5
Average		0.02	0.35	0	0.8
#2	6/19/00	0.03	0.3	0	1.1
	6/26/00	0.02	0.12	NA	0.7
	7/5/00	ND	0.22	NA	0.5
Average		0.03	0.21	0	0.8
#3	6/19/00	0.15	0.43	0	1.1
	6/26/00	0.02	0.6	NA	0.7
	7/5/00	ND	0.22	NA	0.5
Average		0.09	0.38	0	0.8
#4	6/19/00	0.02	0.48	0	1.1
	6/26/00	0.02	0.3	NA	0.7
	7/5/00	0.03	0.23	NA	0.5
Average		0.02	0.33	0	0.8
#5	6/19/00	0.01	0.62	0	1.1
	6/26/00	0.06	0.25	NA	0.7
	7/5/00	0	0.11	NA	0.5
Average		0.02	0.32	0	0.8
#6	6/19/00	0.01	0.63	0	1.1
	6/26/00	0.01	0.12	NA	0.7
	7/5/00	ND	0.21	NA	0.5
Average		0.01	0.32	0	0.8

∗ NA-Not Applicable

Figure 31: Microbiological Data

Sample Site #	Date	FC (per 100ml)	E-Coli (per 100ml)	FS (per 100ml)	PA (per 100ml)
#1	5/25/00	62	ND	28	ND
	5/31/00	52	ND	48	ND
	6/6/00	120	ND	ND	ND
	6/19/00	50	12	30	ND
	6/26/00	102	140	72	ND
	7/5/00	34	32	100	ND
Average		62	61	61	ND
#2	5/25/00	58	ND	26	ND
	5/31/00	50	ND	32	ND
	6/6/00	72	ND	ND	ND
	6/19/00	35	136	21	ND
	6/26/00	58	54	40	ND
	7/5/00	48	38	36	ND
Average		47	76	32	ND
#3	5/25/00	36	36	28	ND
	5/31/00	28	ND	48	ND
	6/6/00	50	ND	ND	ND
	6/19/00	41	28	10	ND
	6/26/00	45	82	27	ND
	7/5/00	34	36	42	ND
Average		40	49	26	ND
#4	5/25/00	38	ND	28	ND
	5/31/00	38	ND	48	ND
	6/6/00	42	ND	ND	ND
	6/19/00	42	40	20	ND
	6/26/00	55	64	37	ND
	7/5/00	34	52	32	ND
Average		44	52	30	ND
#5	5/25/00	38	32	22	ND
	5/31/00	24	48	32	ND
	6/6/00	52	ND	ND	ND
	6/19/00	47	40	23	ND
	6/26/00	128	228	44	ND
	7/5/00	26	36	28	ND
Average		67	101	32	ND

Figure 31: Microbiological Data Cont.

Sample Site #	Date	FC (per 100ml)	E-Coli (per 100ml)	FS (per 100ml)	PA (per 100ml)
#6	5/25/00	38	ND	20	ND
	5/31/00	30	ND	15	ND
	6/6/00	36	ND	ND	ND
	6/19/00	50	66	22	ND
	6/26/00	48	86	42	ND
	7/5/00	30	44	28	ND
Average		43	65	31	ND

∗ ND- None Detected

6.0 Natural History

6.1 Scope/Purpose

The purpose of this study was to determine the flora and fauna present in the study area and to discuss the past and present environmental quality of the reach of the Muskegon River that flows through the vicinity of Big Rapids. Furthermore, the study will create a reference baseline for future studies attempting to determine the biological effects of the dam remnant removal. The study included a 100-yard wide area on the riverbank in three places on the east and west shoreline, the dam remnant area, the south bank of the river east of Whites Bridge, and a location on the west riverbank south of Saint Paul's Parish. The study also included an aquatic insect survey to determine current insect populations within the river in the area likely to be the site of the most significant changes due to the removal of the dam remnant.

6.2 Procedures

The procedures used in the natural history study included the following:

- In-depth research into the history of the Big Rapids dam and surrounding area
- Examination of the past and present conditions of the river
- Determination of the species of flora and fauna inhabiting the designated study area
- Research using newspapers, tax records, guidebooks, field manuals, and texts on river ecology

6.3 River Ecology

6.3.1 Past Ecology

The Muskegon River was in a natural state for approximately 11,000 years prior to settlement along its banks in the 1850's by European immigrants. Prior to that, Native American people inhabited the area. The river was characterized by cold water temperature, large amounts of dissolved oxygen, and a boulder or cobbled river bottom and aquatic life typically found within this type of habitat. Typical insect species found within this type of ecosystem are the stonefly (*Pteronarcys spp*.), mayfly (*Rithrogena spp*.), and caddisfly nymphs (*Phryganea spp*.). Fish species included the arctic grayling (*Thymallus arcticus*) and brook trout (*Salvelinus fontinalis*) (34). The Muskegon River in the Big Rapids area was also known for its exceptional rapids, 1.9 miles in length with a gradient of 12.63 feet/mile, a rare habitat for large Michigan rivers (48). These rapids were, in fact, the reason that the settlement of Leonard changed its name to Big Rapids.

6.3.2 Logging and Dam Construction

Logging had a tremendous impact on the ecology of the river. Removal of trees around the river caused erosion problems, increasing the silt and sediment load in the river (34). Increased amounts of silt and sediment change the river bottom, and make it difficult for aquatic fauna with gills to breathe since the sediment covers their gills. Silt also covers spawning beds and reduces the amount of habitat for most aquatic insects (34). The river was also used to transport logs downstream. This practice destroyed fish habitat and spawning beds by scouring the natural river bottom (34).

Another logging practice that disrupted the river's ecosystem was the construction of dams along the river to help sort logs. These dams impounded water and slowed the river. Dams were also constructed later in the Muskegon River to produce hydroelectric power. The Muskegon River initially had fast cold waters, but logging and dam construction slowed the water velocity, and warmed water temperature. This had a negative impact decreasing the dissolved oxygen levels. Rivers with warm water ecosystems are unable to support brook trout and grayling populations and other cold water fish species (34).

Dams break river ecosystems into smaller segments, and block the movement of fish and aquatic insects upstream and downstream (34). Where there was once a single cold water ecosystem 212 miles long, there are now several shorter ecosystems that are much more vulnerable to environmental change (34).

6.3.3 Current Ecology

The river upstream of the dam remnant has a sand and gravel bottom over a gravel substrate (48). Sand and silt ecosystems are characterized by an aquatic community with low species diversity due to the type of habitat present (24). In August 1989, MDNR personnel sampled 1000 feet of similar habitat, near Paris Park, upriver from the dam remnant. One hundred nine fish of fourteen species were caught. Total fish biomass captured during this study was 20 Kg. Only nine fish were considered to be gamefish. MDNR biologists considered the catch to be low, even assuming only fifty percent of the fish were caught in the single effort. Since the stream gradient is similar just above the dam remnant, speciation and abundance are likely to be similar (48).

6.4 Aquatic Flora

6.4.1 Oxbow Flora

Plant zones usually found in ponded water were found in an oxbow 3,600 feet upstream of the dam remnant on the east side of the river. The three zones are an emergent zone which includes cattail (*Typha latifolia*) and bullrush (*Scirpus sp.*); a floating-leaved zone consisting of plants which float on the waters surface such as duckweed (*Lemna sp.*); and a submergent zone in which the plants are completely underwater (4). Shoreline vegetation included reed canary grass (*Phalaris arundinacea*), willow (*Salix babylonia*), and tag alder (*Alnus rugosa*) Figure 33 lists some of the plants found in oxbows and along the banks of the river.


Figure 32:

The oxbow, with willow and tag alder. Photo taken along the nature trail at Northend Riverside Park July 20, 2000.

6.4.2 Muskegon River Flora

The Muskegon River has a detritus food chain where there are few phytoplankton as primary producers, and the primary consumers depend on the detritus (debris) that falls into the river from the river banks (34). Some species of blue-green algae are present in fast-flowing rivers, and one known to be present in the Muskegon River around the Big Rapids dam remnant study area is Rivularia (34). Some of the plants found in and around the Muskegon River study area near the Big Rapids dam remnant are listed below. An asterisk denotes actual observation during fieldwork.

Figure 33: Aquatic Flora (Sources: 4,5,19)

Common and Scientific Name	Habitat
Blue Iris* (*Iris versicola)*	aquatic
Broad-leaved cattail* (*Typha latifolia)*	aquatic
*Rivularia** (Rivularia sp.)	aquatic
Soft-stemmed bullrush* (*Scirpus validus)*	aquatic

6.5 Aquatic Fauna

The removal of the Big Rapids dam remnant will restore a rare habitat type on the Muskegon River (48). No other free-flowing reaches of the river presently have gradients in excess of 10 feet/mile. Gradients this high typically have riffle and pool complexes that increase species diversity. A reach of the river below Croton Dam with a gradient of 7.22 feet/mile contained 26 fish species with a biomass of 213.3 Kg/acre. Thirteen percent of this biomass were game fish (48).

The pool and riffle complexes found in high-gradient stream flows increase habitat diversity for aquatic invertebrates as well (48). Mussel populations are expected to increase since mussels are filter feeders that need high amounts of dissolved oxygen, the type of habitat typically found in pool and riffle complexes. Mussels also rely on fish to distribute their larvae, and removing the barrier to fish migration should increase the spread of mussels (48).

Some aquatic species presently inhabiting the Muskegon River are listed in Figures 34-37. An asterisk by the species name indicates that the species was observed by the natural history group.

Figure 34: Insects & Other Invertebrates. (Sources: 1,4,8,14)

Common and Scientific Name	**Habitat**
Cabbage butterfly (*Pieris rapae*)*	Where flowers are present
Caddis Fly (*Phryganea cincerea*)*	Foliage and tree bark close to ponds and streams
Crayfish* (*Malacostraca astacidae*)	Small quiet streams under stones
Damseflies (*Hetarina americana*)	In mucky-bottomed ponds half filled with vegetation
Deerflies (*Cephenomyia stimulator*)	Stagnant, scummy water near shores
Dragonflies (*Gomphus vulgatissimus*)*	Most of life as nymphs in water, & as dominant insect carnivore
Fingernail clams (*Eupera singlexi*)*	1-6 feet under water
Mayfly (*Rithrogena spp.*)*	Swift streams or rivers with rocky bottom
Monarch butterfly (*Danaus plexippus*)*	Where flowers are present
Riffle beetle (*Psehunus herricki*)*	Swift streams or rivers with rocky bottom
Stonefly (*Pteronarcys perlidae*)*	Streams or lakes
Swallowtail butterfly (*Pepilio glaucus*)*	Mixed in deciduous areas
Water boatmen (*Corixa spp.*)*	Lakes, streams, or ponds
Water scorpion (*Ranata fusca*)*	Bottoms and shallow fresh waters
Water strider (*Gerris remigis*)*	On surface of quiet, gentle flowing water

Figure 35: Amphibians (Sources: 4,36)

Common and Scientific Name	**Habitat**
Green frog (*Rana clamitans*)*	Swamps, ponds, & small streams

Figure 36: Reptiles (Source: 3,5)

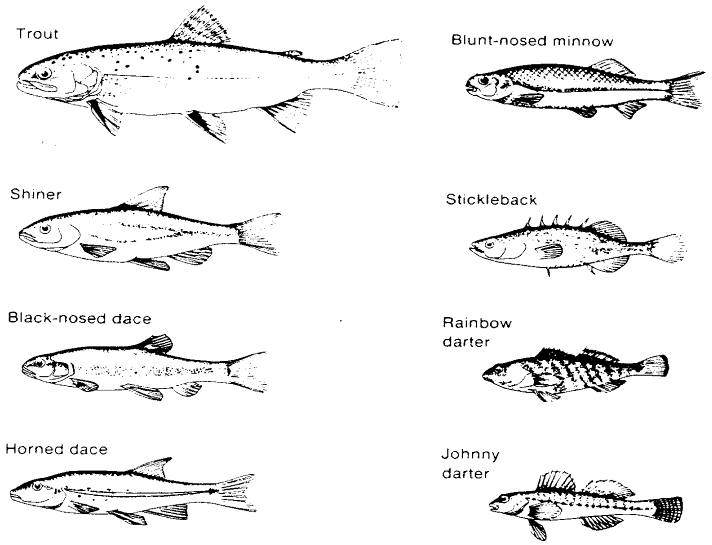
Common and Scientific Name	**Habitat**
Wood turtle (*Clemmys insculpta*)	Open woodland & hibernate in muddy stream bottoms
Painted turtle (*Chrysemys picta*)	Partly overgrown ponds
Northern water snake (*Nerodia sipedon*)	Lying on banks, across stream bed, & borders of larger streams & ponds

Figure 37: Fish (Sources: 4,6,24, 36)

Common and Scientific Name	**Habitat**
Black crappie (*Pomoxis nigromaculatus*)	Warm water & impoundment species
Black redhorse (*Moxostoma duquesnei)*	Cool water
Black-side darter (*Hadropterus maculatus*)	In swift streams lying on the bottom of stones
Bluegill (*Lepomis macrochirus*)	Nests on the pond bottom
Bluntnose minnow (*Pimephales notatus*)	Cool water
Brook stickleback (*Culaea inconstans*)	Slow streams
Brook trout (*Salvelinus fontinalis*)	Native to cold water
Brown trout (*Salmo trutta*)	Europe native released in rivers
Burbot (*Lota lota*)	Cold regions of lowland rivers
Carp (*Cyprinus carpio*)*	Asia native released in river. Tolerate warm water.
Central mudminnow (*Umbra limi*)*	Sluggish or slow moving streams
Channel catfish (*Ictalurus punctatus*)	Ponds and sluggish streams under the stones
Chesnut lamprey (*Ichthyomyzon castaneus*)	Parasite in streams or lakes
Common shiners (*Notropis cornutus*)	Warm or cold brooks & creeks
Creek chub (*Semotilus atromaculatus*)	North America fresh water streams
Fathead minnows (P*imephales promelas*)	Fresh water streams
Golden redhorse (*Moxostoma erythrurum*)	Cool water
Golden shiner (*Notemigonus crysoleucas*)	Freshwater streams
Green sunfish (*Lepomis cyanellus*)	Shallow water
Hogsucker (*Hypentelium nigricans*)	Stream fish in temperate region
Hornyhead chub (*Nocomis biguttatus*)	Cool water
Johnny darter (*Etheostoma nigrum*)	In sluggish & swift streams & ponds
Largemouth bass (*Micropterus salmoides*)	Warm water & impoundment species
Log perch (*Perca fluviatilis*)	Freshwater lakes and streams
Longnose dace (*Rhinichthys cataractae*)	Cold water
Mottled sculpin (*Cottus bairdi*)	Cold water
Northern pike (*Esox lucius*)	Cool water
Pumpkinseed (*Lepomis gibbosus*)	Warm water & impoundment species
Rainbow darter (*Etheostoma macrolepidatum*)	Cool water streams

Common and Scientific Name	Habitat
Redhorse sucker (*Moxostoma macrolepidatum*)	Stream, temperate water
River chub (*Nocomis micropogon*)	Cool water
Rock bass (*Ambloplites rupestris*)	Shallow waters
Rosyface shiner (*Notropis rubellus*)	Cool water
Sand shiner (*Notropis stramineus*)	Sand tolerant forage species
Shorthead redhorse (*Moxostoma macrolepidotum*)	Cool water
Silver redhorse (*Moxostoma anisurum*)	Cool water
Smallmouth bass (*Micropterus dolomieu*)	Cool streams with rocky bottoms
Spotfin shiner (*Cyprinella spiloptera*)	Cool water
Stone cat (*Noturus flavus*)	Cool water
Walleye (*Stizostedion vitreum*)	North America's fresh water
Warmouth (*Lepomis gulosus*)	Warm water & impoundment species
White sucker (*Catastomus commersonnii*)	Shallow ponds upstream
Yellow perch (*Perca flavescens*)	Clear rapid streams & ponds 10 feet or deeper.

Figure 38: Fish typically found in Muskegon River (Source: 1)



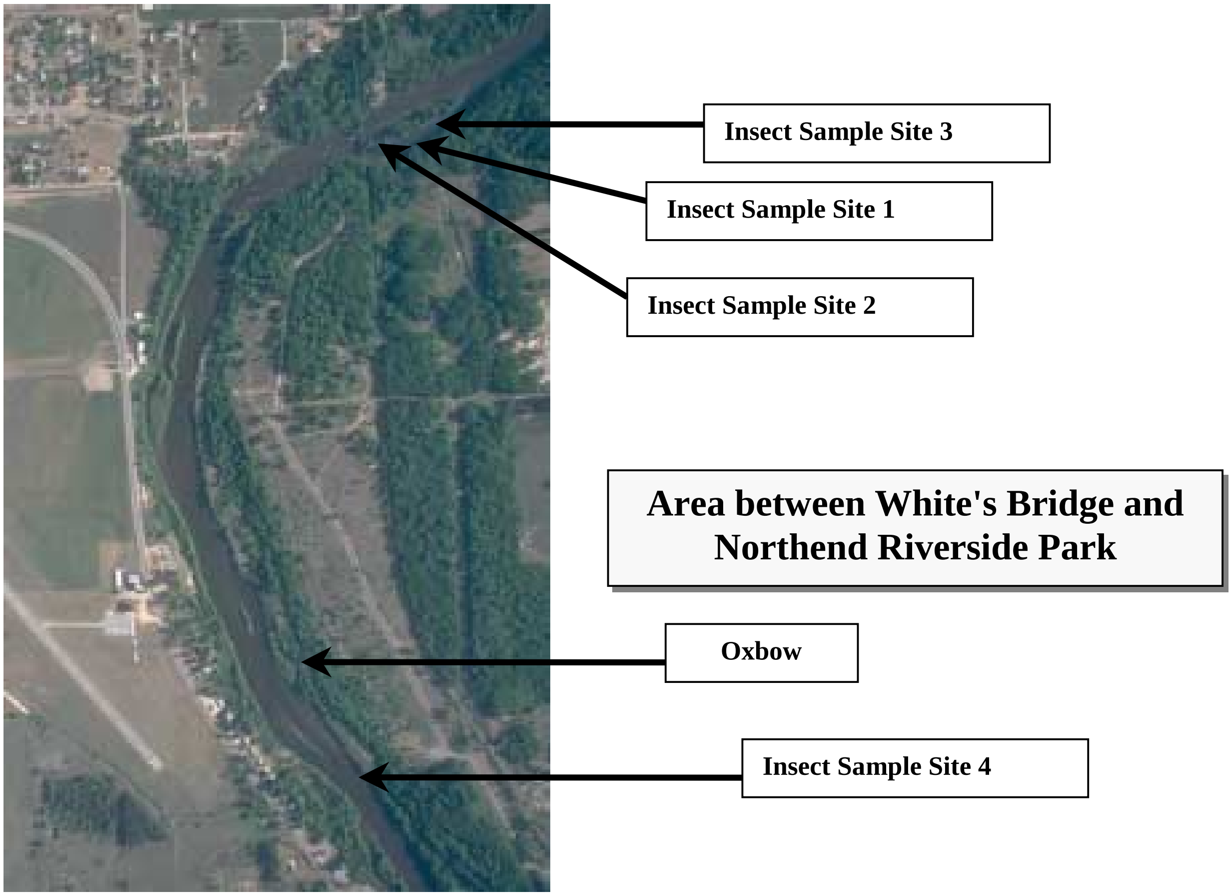
6.5.1 Aquatic Insect Survey

Figure 39:

Professor Beetley and students conducting insect survey above White's Bridge on June 27, 2000.

In order to determine the species and abundance of aquatic insects present in the study area, an aquatic insect survey was completed in four different locations on the Muskegon River by randomly lifting up ten 5-6 inch diameter rocks in each location and counting the number of aquatic insects present. Site 1 was a rocky river bottom with calm water located above White's Bridge. Site 2 was a riffled cobble river bottom with faster water located directly beneath Whites Bridge. Site 3 was a sandy bottom with sparse rocks upstream of White's Bridge on the east bank. Site 4 was an area of sparse rocks and mucky bottom at Northend Riverside Park. Sites 3 and 4 are silty, which may block the respiratory membranes of aquatic insects. Figure 40 displays the sample sites chosen for the aquatic insect survey.

Figure 40: Natural History Field Study Areas


Area between White's Bridge and Northend Riverside Park

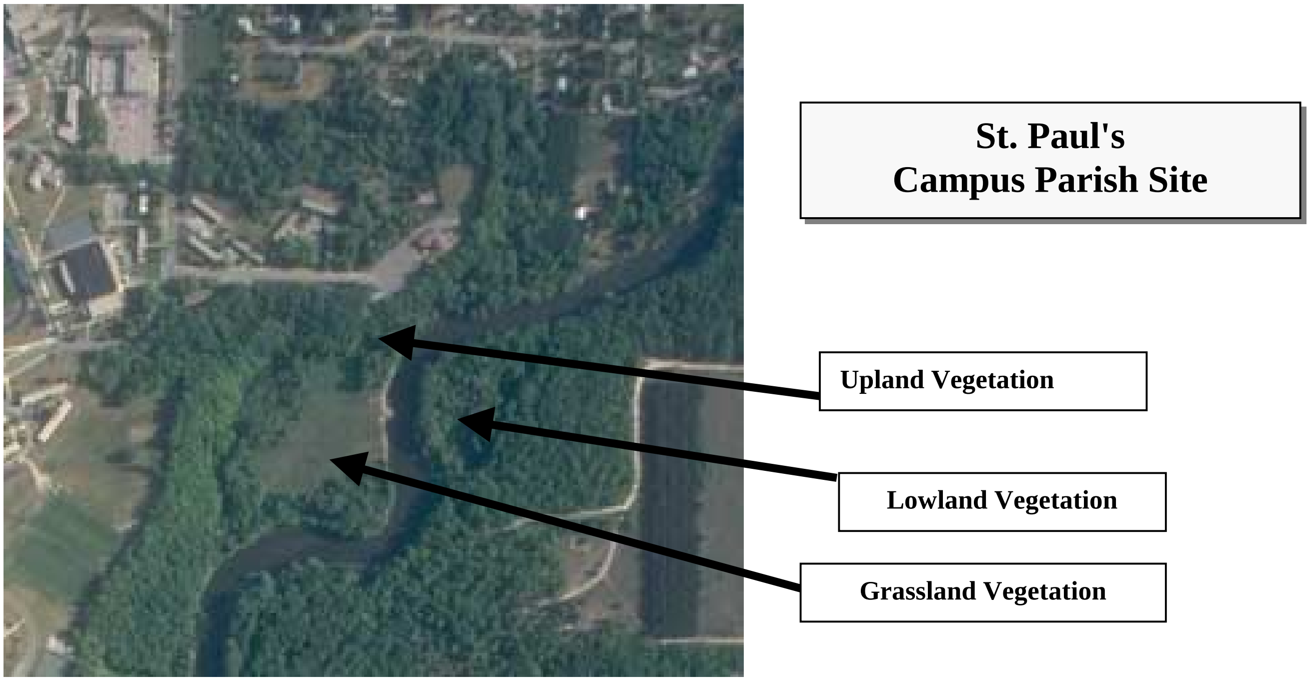

St. Paul's
Campus Parish Site

Figure 41 depicts the number of insects found at each sample site.

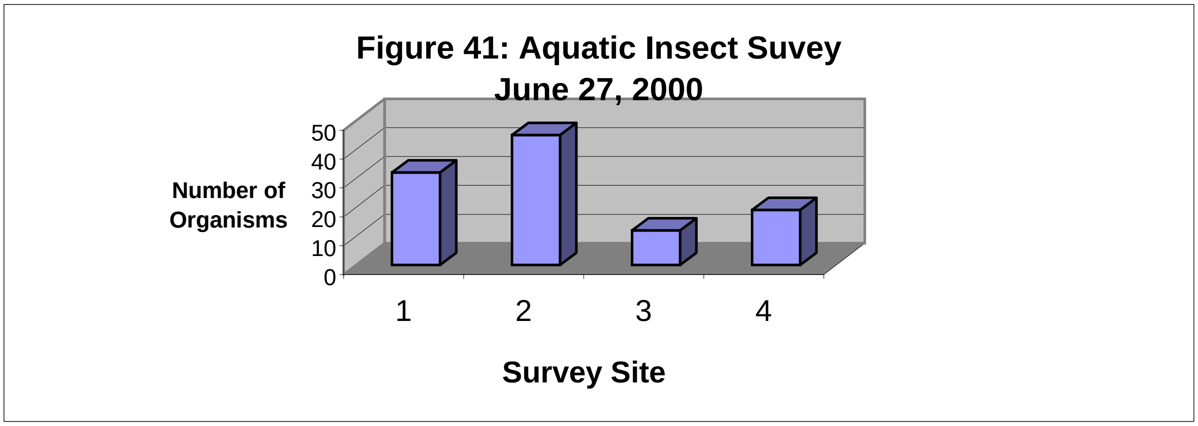


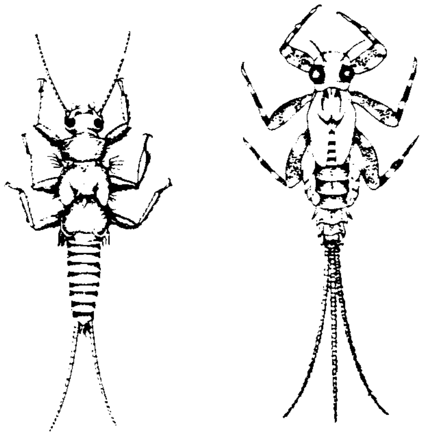
Figure 41: Aquatic Insect Suvey
June 27, 2000

- Sampling in Site 1 revealed 32 aquatic insects.
- Sampling in Site 2 revealed 45 aquatic insects.
- Sampling in Site 3 revealed 12 aquatic insects.
- Sampling in Site 4 revealed 19 aquatic insects.

Due to the low sample size, no conclusions can be drawn from this study. However, it is likely with the increase in habitat due to the river returning to its original gradient that insect populations will increase.

During the aquatic insect survey several types of insects were identified including: caddisfly larva, mayfly larva, stonefly larva, and riffle beetle larva. The survey also found crayfish, minnows, and a water scorpion. Figure 42 illustrates some of the aquatic insects that were observed during the survey.

Figure 42: Aquatic Insects found in Insect Survey (Source: 1)



Stonefly nymph

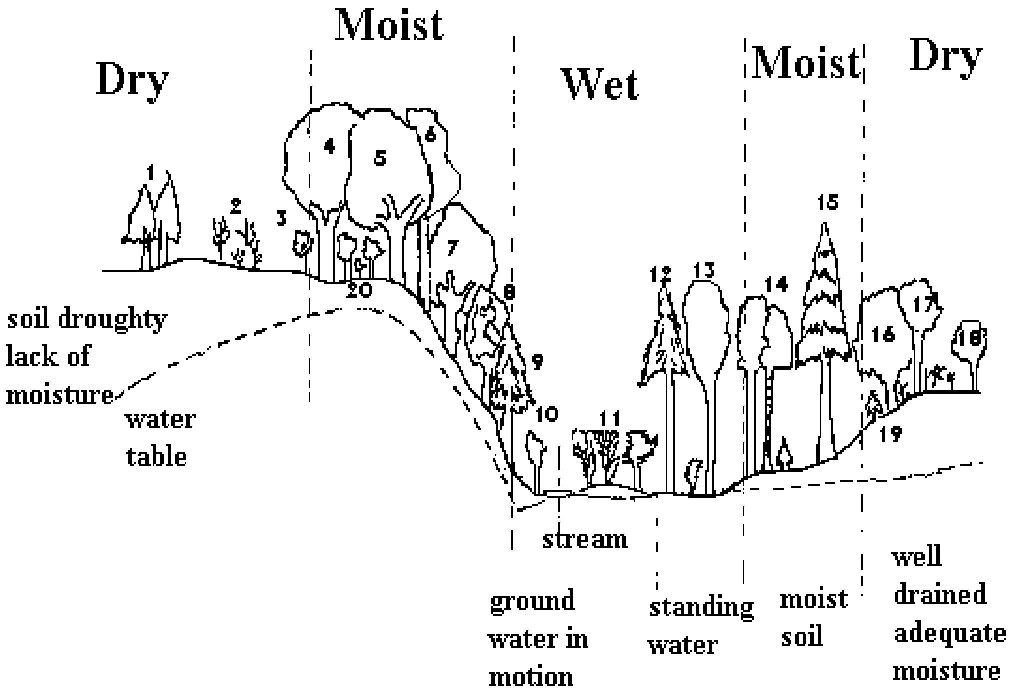
Mayfly nymph

6.6 Terrestrial Flora

Logging removed much of the virgin pine timber in Lower Michigan by the late 1800’s and early 1900’s (36). In the study area climax speciation has changed from white pine (*Pinus strobus*) and red pine (*Pinus resinosa*) to hardwoods such as beech (*Fagus grandifolia*) and maple (*Acer sp.)* Today, Muskegon River Basin forests are composed of 88% hardwood, 11% conifers, and 1% mixed grasses and bushes (36).

Vegetation in the Muskegon River area is classified into three different types, grassland, upland, and lowland (36). Figure 43, on the following page, illustrates grassland, upland, and lowland areas.

Figure 43: Vegetation Types of Lowland, Upland, and Grassland (36)



Legend:

1. Pine
2. Sumac
3. Sweet Fern
4. Beech
5. Sugar Maple
6. Black Cherry
7. Beech
8. Red Maple
9. Hemlock
10. Iron Wood
11. Alder, Willow, and Thornapple
12. Tamarack
13. Elm, Ash
14. Birch, Aspen
15. Red or White Pine
16. Oaks
17. Aspen
18. Pin Cherry
19. White Pine Seedlings
20. Maple and Beech Seedlings

6.6.1 Grassland

Dry soil, grasses and flowering plants characterize grassland areas. Grassland plants include staghorn sumac (*Rhus typhina*), sweet fern (*Myrica peregrina*), white pine, ox-eye daisy (*Chrysanthemum leucanthemum*) and other flowering plants and grasses (36).

6.6.2 Upland

Moist well-drained soils characterize upland areas. Trees and shrubs included in upland areas are black cherry (*Prunus serotina*), sugar maple (*Acer saccharum*), American beech, hemlock (*Carpinus carolinia*), American white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), and white pine (36).

6.6.3 Lowland

The lowland areas have wet soil and plants that tolerate water. Plants in the lowland area include American elm (*Ulmus americana*), white ash (*Fraxinus americana*), tamarack (*Larix laricina*), dogwood (*Cornus florida*), ironwood (*Carpinus carolina*), black willow (*Salix nigra*), and thornapple (*Crataegus sp.*) (36). Species known to exist within the study area are included below in figures 44,45,46,48 and 50. An asterisk denotes actual observation during fieldwork.

Figure 44: Grasses and Sedges (Sources: 4,19,36)

Common and Scientific Name	Habitat
Reed canary grass* (*Phalaris arundinacea*)	Lowland
Sedge* (*Carex sp.*)	Lowland, upland
Timothy* (*Phleum pratense)*	Grassland

Figure 45: Ferns (Sources: 4,19,36)

Common and Scientific Name	Habitat
Bracken Fern* (*Pteridium aquilinum*)	Upland
Cinnamon Fern* (*Osmunda cinnamomea*)	Upland, lowland
Sensitive Fern (*Onoclea sensibilis)*	Lowland
Sweet Fern* (*Myrica peregrina)*	Grassland

Figure 46: Weeds (Sources: 4,11,14,19,36)

Common and Scientific Name	Habitat
*Black-eyed susan** (Rudbeckia hirta)	Grassland
Blue vervain* (*Verbana hastata)*	Grassland
Bramble* (*Rubus fruticosus)*	Grassland
Brier Rose* (*Rosa canina)*	Upland, grassland
Bull Thistle (*Cirsium vulgare)*	Grassland
Canada anemone* (*Anemone canadensis)*	Lowland
Canada goldenrod* (*Salidago canadensis)*	Upland, grassland
Cardinal flower (*Lobelia cardinalis)*	Lowland

Common and Scientific Name	Habitat
*Devil's paint brush** (Hieracium acirantiacum)	Uplands, lowland
Forget-me-not* (*Myosotis scorpioides)*	Lowland
Goat's Beard* (*Tragopogon pratensis)*	Grassland
Hairy vetch* (*Vicia villosa)*	Grassland
*Horsemint** (Monarda punctata)	Grassland
Indian Strawberry* (*Duchesnea indica)*	Grassland
Joe-pye (*Eupatorium maculatum)*	Lowland
Leafy Spurge* (*Euphorbia esula)*	Grassland
Milkweed* (*Ascelepias quadrafolia)*	Grassland
Ox-eye daisy* (*Chrysanthemum leucanthemum)*	Grassland
Poison Ivy* (*Rhus radicans)*	Lowland, upland
Purple loosestrife (*Lythrum salicaria)*	Lowland
Queen Anne's lace* (*Daucus carota)*	Grassland
Red baneberry (*Actea rubra)*	Upland
Roundleaf ragwort* (*Senecio obovatus)*	Upland
Scouring Rush* (*Equisetum fluviatile)*	Lowland, grassland
*Tall coneflower** (Rudbeckia laciniata)	Lowland

Figure 47:

Coneflowers along the Muskegon River in the grassland area below St. Paul's Campus Parish, July 20, 2000.

Figure 48: Shrubs (Sources: 2,9,16,40)

Common and Scientific Name	Habitat
*Autumn-olive** (Elaeagnus umbellata)	Upland
Dogwood (*Cornus florida)*	Lowland
English hawthorn* (*Crataegus sp.)*	Lowland
Honey-suckle* (*Lonicera americana)*	Upland
Spreading juniper* (*Juniperus sp.)*	Upland, grassland
Staghorn sumac* (*Rhus typhina)*	Grassland
Wild grape vine* (*Vitis sp.)*	Upland

Figure 49:

Staghorn sumac along the Nature Trail at Northend Riverside Park. Photo taken July 20, 2000.

Figure 50: Trees (Sources: 2,9,16,40)

Common and Scientific Name	Habitat
*American Beech** (Fagus grandifolia)	Upland
American crabapple (*Malus coronaria)*	Upland
American elm* (*Ulmus americana)*	Lowland
American mountain ash* (*Pyrus americana)*	Lowland
American sycamore* (*Platanus occidentalis*)	Lowland
American white birch* (*Betula papyrifera)*	Upland
American yew* (*Taxus canadensis)*	Upland
Austrian pine* (*Pinus nigra)*	Upland, grassland
Basswood* (*Tilia americana)*	Upland
Bigtooth aspen* (*Populus grandidentata)*	Upland
Black ash (*Fraxinus nigra)*	Lowland
Black cherry* (*Prunus serotina)*	Upland
Black willow* (*Salix nigra)*	Lowland
Choke cherry* (*Prunus virginiana)*	Upland
Colorado blue spruce* (*Picea pungens)*	Upland, grassland
*Cottonwood** (Populus deltoides)	Upland
Hemlock* (*Tsuga canadensis)*	Upland
Ironwood* (*Carpinus caroliniana)*	Lowland
Jack pine* (*Pinus banksiana)*	Upland, grassland
Mountain ash* (*Sorbus americana)*	Lowland
Northern pin oak* (*Quercus palustris)*	Grassland

Common and Scientific Name	**Habitat**
Northern white cedar* (*Thuja occidentalis)*	Lowland
Norway maple* (*Acer platanoides)*	Upland
Norway spruce* (*Picea abies)*	Upland, grassland
Red cedar* (*Juniperus communis)*	Lowland
Red maple* (*Acer rubrum)*	Upland
Red oak* (*Quercus rubra)*	Grassland
Red pine* (*Pinus resinosa)*	Upland, grassland
Scotch pine* (*Pinus sylvestris*)	Upland, grassland
Silver maple* (*Acer saccharinum)*	Upland
Sugar maple* (*Acer saccharum)*	Upland
Swamp white oak (*Quercus bicolor)*	Lowland
Tag alder* (*Alnus rugosa*)	Lowland
Trembling aspen* (*Populus tremuloides)*	Upland, grassland
Willow* (*Salix babylonia*)	Lowland
*Witch Hazel** (Hamamelis virginiana)	Grassland
White ash* (*Fraxinus americana)*	Lowland
White oak* (*Quercus alba)*	Grassland
White pine* (*Pinus strobus)*	Upland, grassland
White spruce (*Picea glauca)*	Upland, grassland
Yellow birch* (*Betula lutea)*	Upland

Figure 51:

White Birch along the nature trail at Northend Riverside Park, July 20, 2000.

6.7 Terrestrial Fauna

Figures 52, 54 and 56 list amphibians, birds, and mammals known to exist within the study area. An asterisk indicates species observed by the natural history group.

Figure 52: Amphibians (Sources: 3,5)

Common and Scientific Name	Habitat
Green frog (*Rana clamitans*)*	Swamps, ponds, & small streams
Red-backed salamander (*Plethedon cinerius*)*	Under flat stones & rapids, & small streams

Figure 53:

Red-backed salamander. Photo taken at Beech-Maple climax forest below St. Paul's Campus Parish July 20, 2000.

Figure 54: Birds (Sources: 5,10,12,16,40)

Common and Scientific Name	Habitat
American Goldfinch (*Spinus tristis*)	Fields, forest edges, grasslands, and shrubs
Bald Eagle (*Haliaetus leucocoephalus*)	In tall trees near water
Barn Swallow (*Hirundo rustica*)*	Farms, suburbs
Belted Kingfisher (*Megaceryle alcyon*)	By rivers, lakes, and coasts
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	Upland shrubs and woodlands
Black-capped Chickadee (*Parus atricapillus*)	Forest, residential areas
Blue Jay (*Cyanocitta cristata*)*	Woods, suburbs, city parks
Broad-winged Hawk (*Buteo platypterus*)	Mixed hardwood forests, aspen trees
Cardinal (*Richmondena cardinalis*)*	Woods, parks, gardens
Canada Goose (*Branta canadensis*)*	Marshes, lakes, ponds, fields, lawns
Cedar Waxwings (*Bombycilla cedrorum*)	Forest, shrubs

Common and Scientific Name	**Habitat**
Common Crow (*Corvus brachyrhynchos*)*	Forest, rocky coasts
Common Merganser (*Mergus merganser*)	Inland lakes and rivers
Eastern Kingbird (*Tyrannus tyrannus*)	Forest edges, roadsides, farms
Gray Catbird (*Dumetella carolinensis*)	Shrubs, parks
Great Blue Heron (*Ardea herodias*)*	Marshes, swamps, rivers, lakes
Great-crested flycatcher (*Myiarchus crinitus*)	Open woods, parks, shrubs
Green Heron (*Butorides virescens*)	Marshes, swamps, streams
House Wren (*Troglodytes aedon*)	Forest edges, shrubs, farms, fields
Indigo Bunting (*Passerina cyanea*)	Forest edges, roadside
Mallard Duck (*Anas platyrhynchos*)*	Rivers, lakes, marshes
Mourning Dove (*Zenaida macroura*)*	Fields, gardens, parks
Osprey (*Pandion haliatus*)	Wetlands and sea coasts
Ring-billed Gulls (*Larus delawarensis*)	Lakes, rivers, bays
Robin (*Turdus migratorius*)*	Woods, farms, parks, gardens
Ruby-throated Hummingbird (*Archilochus colubris*)	Woods, fields, gardens
Ruffed Grouse (*Bonasa umbellus*)*	Broadleaf and mixed forests
Song Sparrow (*Spizella pusilla*)	Forests, thickets, marshes, yards
Spotted Sandpiper (*Actitis macularia*)	Coastal and inland waters
Turkey Vulture (*Cathartes aura*)	Open country and forest
White-rumped Sandpiper (*Erolia fusciollis*)	Sewage ponds, margins, rock dikes
Yellow-shafted Flicker (*Colaptes auratus*)	Forests, open woodland

Figure 55:

Great Blue Heron on west bank of Muskegon River across from the disabled fishing access site at Northend Riverside Park, July 20, 2000. Photo looking west.

Figure 56: Mammals (Sources: 3,5,13,33,36)

Common and Scientific Name	Habitat
Beaver (*Castor canadensis*)*	Burrow in tanks & lodge in ponds
Eastern Chipmunk (*Tamias striatus*)*	Deciduous forests & brushy areas
Eastern Cottontail Rabbit (*Sylvilagus floridanus*)*	Woodlands
Eastern Fox Squirrel (*Sciurus niger*)	Hard wood & pine trees
Eastern Gray Squirrel (*Sciurus carolinesis*)	On grounds or in trees
Mink (*Mustela vison*)	Forest cover & water
Muskrat (*Ondatra zibethicus*)	Marsh, ponds, lakes, & streams
Opossum (*Didelphis marsupialis*)	On grounds in woods
Porcupine (*Erethizon dorsatum*)	Forests
Raccoon (*Procyon lotor*)	Along streams & lake boarders near wooded areas
Red Squirrel (*Tamiasciurus hudsonius*)*	Forests
River Otter (*Lutra canadensis*)	Burrows made in banks in rivers
Striped Skunk (*Mephitis mephitis*)	Semi-open country side
White-tail Deer (*Odocoileus virginanus*)*	Forests & bush-lands

6.8 Unit Summary

Removal of the dam remnant will have many effects on the Muskegon River area upstream of the dam. The water that is currently ponded behind the dam will be gradually released, and decrease the level of water behind the dam. This will cause the banks to widen, exposing former areas of silt/sand river bottom. With lower water levels above the dam, terrestrial plants will begin to grow on the newly exposed areas of land. In the river itself, the dam will no longer be present to slow the water, and capture the sand and silt that settle out. The river will return to having a stream gradient over 10 feet/mile, one of the highest gradients on any Michigan river. The reach of the river from Reedsburg Dam to Rogers Dam will be one of the longest continuous stretches of any river in Michigan, eliminating much of the ecological problems associated with the river fragmentation. The removal of the dam will also increase the movement of nutrients upstream, by allowing migration of fish and insects upstream and downstream. The sediment and silt already present will be carried downstream by the faster flow of water. This will allow the area to return to its fast-flowing, cobble-bottom natural state, complete with colder water temperatures and higher dissolved oxygen. An increase in riffle habitat will increase the amount of invertebrate life, including mussels, which depend on fish for the transportation and distribution of early larval stages. Increases in the amount of riffles and pools present in the river will increase the species diversity, population numbers, biomass, and the desirability of fish species as well. It is likely that this reach of the river will once again support a cold water fish community.

7.0 Summary

The reach of the Muskegon River that flows through the City of Big Rapids has been used for log transportation, hydroelectric power, recreation, and as a municipal water source. These activities, with the exception of recreation, have changed the natural characteristics of the river. The Big Rapids Dam, once used for hydroelectric power, is currently being removed from the Muskegon River as part of an attempt to return the river to a more natural state.

The Muskegon River originates in Houghton Lake in Roscommon County in the north, flows southwesterly through eight counties, and proceeds through Muskegon Lake before discharging into Lake Michigan. The watershed encompasses approximately 2,350 square miles.

River elevations and possible erosion points have been identified and documented to provide future studies with detailed information for comparison of changes that may occur in the river due to the removal of the dam remnant. This information was documented using CAD to create several cross-section drawings of the river upstream of the dam remnant.

The Muskegon River in the study area meets all surface water quality standards established by the MDNR. The only aspect of water quality affected by the remnant removal may be suspended solids. During the study period, laboratory results indicated that the cofferdam has successfully trapped sediments released during dredging.

Some species of aquatic and terrestrial flora and fauna were identified through field observations. An aquatic insect survey was conducted by counting the number of insects present in a specific reach of the river. While the sample size of the study was small, the results of the survey could be compared with future studies to determine any effects that the removal of the dam remnant may have had on the aquatic insect population.

Overall, the removal of the dam remnant is not adversely affecting surface water quality. As previously submerged riverbanks are exposed, new land will appear, beginning a process of biological succession, which will be an outstanding laboratory for field study by middle school, high school, and FSU biology students.

8.0 Conclusions

- Some erosion and the migration of sediments downstream from the sediment removal process and the dam remnant removal process is expected.

- The sediment removal process will reduce the total amount of transportable sediments flowing downstream.

- Dredging activities have increased suspended solids at water quality sample site four, located directly downstream of the dam remnant, but data for site five shows that the cofferdam is acting as a sediment trap.

- The Muskegon Rivers’ water elevation will recede, exposing additional lands.

- The Muskegon Rivers’ velocity should increase due to a narrowing of the river channel.

- The removal of the dam remnant will potentially restore the historic rapids in this area of the Muskegon River, and will partially convert this reach of the river back to its natural state.

- **Currently, dam remnant removal has not lowered river temperatures.**

- Iron, copper, chromium, and tannins and lignins levels at this time have not been affected by the dredging of sediment.

- The Muskegon River is relatively free of manmade pollutants in the study area as indicated by the total hardness, alkalinity and TDS.

- The laboratory results for pH and alkalinity show that this reach of the river has a good buffering capacity.

- **E. coli results were well below the MDEQ standard.**

- The FC:FS ratio was slightly above 1:1 showing small amounts of human and animal contamination.

- No colonies of PA were detected. This supports the FC:FS ratio showing that there is not a large source of human contamination.

- It appears that no FC, FS or E. coli have been released into the river due to the dredging process.

- **The water quality of the river has improved since 1991.**

- Removal of the dam remnant will encourage greater species diversity in the study area.

9.0 Recommendations

- Observe any shoreline erosion and take corrective action if a situation warranted.
-
- Follow conceptual sediment control plans as closely as possible or improve upon it in order to prevent the migration of excess volumes of sediment downstream.

- Several studies should be conducted on the river, two years, six years, and ten years after the removal of the dam remnant to determine what changes have occurred. The study should focus on the following areas:

  - Changes in the physical characteristics of the river.
  - Changes in the quality of the water.
  - Impacts on the fish population.
  - Impacts on the aquatic invertebrate population.
  - Ecological changes in the newly exposed land areas.

List of Sources

Books

1. Andrews, William A.. **Investigating Aquatic Ecosystems.** Scarborough, Ontario: Prentice-Hall. 1987.

2. **Audubon Society Field Guide to North American Trees: The Eastern Region.** New York: Alfred P. Knopf. 1980.

3. Burt,William H. and Richard D. Grossenheider. **A Field Guide to the Mammals: North America north of Mexico.** 3rd ed. Boston: Houghton Mifflin. 1980.

4. Caduto, Michael J. **Pond and Brook: A Guide to Nature Study in Freshwater Environments.** Englewood Cliffs, New Jersey: Prentice-Hall, Inc. 1984.

5. Chinery, Michael, editor. **The Kingfisher Illustrated Encylclopedia of Animals.** New York: Kingfisher Books. 1992.

6. Cooper, Alan. **Fishes of the World.** New York: Grosset and Dunlap, Inc. 1971.

7. Hauer, F. Richard and Gary A. Lambert. **Methods in Stream Ecology.** New York: Academic Press. 1996.

8. Imes, Rick. **The Practical Entomologist.** Toronto: Simon and Schuster, Inc. 1992.

9. Kiely, Gerand. **Environmental Engineering.** 4th ed. Berkshier, England. 1997.

10. Moore, David M. **Marshall Cavendish Illustrated Encyclopedia of Plants and Earth Sciences.** Vol.10. New York: Marshall Cavendish. 1988.

11. McPeek, Gail A. editor. **The Birds of Michigan.** Bloomington, Indiana: Indiana University Press. 1994.

12. Morgan, Ann Haven. **Field Book of Ponds and Streams.** New York: G.P. Putnam's Sons. 1930.

13. Murie, Olaus J. **Animal Tracks.** 2nd ed. Norwalk, Conneticut: The Easton Press. 1974.

14. **National Audubon Society Field Guide to North American Insects and Spiders.** New York: Alfred P. Knopf. 1997.

15. Peterson, Roger Tory and Margaret McKenny. **A Field Guide to Wildflowers.** Boston: Houghton Mifflin Company. 1968.

16. Petriedes, George A. **A Field Guide to Trees and Shrubs.** 2nd ed. Boston: Houghton Mifflin Company. 1958.

17. Robbins, Chandler S. **Birds of North America.** New York: Golden Press. 1966.

18. Salvato, Joseph. **Environmental Engineering.** 4th ed. Albany, New York. 1992.

19. Smith, Helen. **Michigan Wildflowers.** Bloomfield Hills, Michigan: Cranbrook Institute of Science. 1979.

20. **Standard Methods for the Examination of Water and Wastewater.** 19th ed. American Public Health Association. American Water Works Association. Water Pollution Control Federation. 1995.

21. **Soil Survey of Mecosta County, Michigan.** U.S Department of Agriculture. Resources Conservation Service. Big Rapids. 1993.

Government Documents

22. Michigan Department of Natural Resources, Surface Water Quality Division, Water Resources Commission. **General Rules.** October 1986.

23. Westjohn, David. **Stratigraphy, Sedimentology, and Volume of Sediments Behind a Dam Relic on the Muskegon River, Big Rapids, Michigan.** U.S. Geological Survey. Water-Resources Investigations Report 97-4069.

Public Documents

24. O’Neal, Richard P. **Muskegon River Watershed Assessment.** State of Michigan Department of Natural Resources. Fisheries Division Special Report. July, 1997.

25. Prein & Newhof. **Draft Feasibility Study Removal of Dam Remnant, For City of Big Rapids, Michigan.** 1995.

26. SEG/SA-Hydro. **Feasibility Study of Rehabilitating the Big Rapids Dam on the Muskegon River.** March 22, 1981.

27. Sloat, Sharon and Carol Ziel. **The Uses of Indicator Organisms to Access Public Water Safety.** Technical Information Series-Booklet No. 13. HACH Company, 1991.

28. State of Michigan, County of Mecosta, Register of Deeds. **Quitclaim Deed**. Liber 364, Page 1013. Parcel #3. Big Rapids, Michigan: City Hall. March 17, 1976.

Newspaper Articles

29. Alexander, Jeff. "The Muskegon River: Unnatural Wonder-Shadow of its Former Self." **The Muskegon Chronicle.** Pp.7A-9A, 14A, 1B. September 12, 1999.

30. Alexander, Jeff. "The Muskegon River: Unnatural Wonder-Dams: Disasters Waiting to Happen." **The Muskegon Chronicle**. Pp. 1A, 6A- 8A, 12A. September 13, 1999.

31. Alexander, Jeff. "The Muskegon River: Unnatural Wonder-For River… Boom Could be a Bust." **The Muskegon Chronicle.** Pp. 1A, 6A-8A. September 14, 1999.

32. Alexander, Jeff. "The Muskegon River: Unnatural Wonder-Shared Sacrifices." **The Muskegon Chronicle.** Pp. 1A, 6A-7A. September 15, 1999.

33. Clay, Nancy. "Whose Fault? History Reveals few clues about old city Dam." **The Pioneer.** Pp. 1, 6. July 22,1974.

Unpublished Material

34. Beetley, Bruce. In Class Lecture. " **The Biology of the Flowing Water**. **System**." June 5, 2000

35. Ferris State College. Environmental Management Studies Center. "**Environmental Audit and Development Alternatives: Old Dam Site**". Big Rapids: 1974.

36. Ferris State College. Environmental Management Studies Center. "**Natural History of the Muskegon River Area, Big Rapids, Michigan**". Big Rapids: 1982.

37. Ferris State University. Environmental Management Studies Center. “**An In Depth Study to Create a Safe Bypass for Recreationalists over the City Water Main Adjacent to the Big Rapids Water Treatment Plant.** ” Initial Small Group Reports. 1999.

38. Ferris State University. Environmental Management Mini-Block. “**Erosion and Sedimentation Study of the Muskegon River**”. Big Rapids: June 6-24, 1998.

39. Ferris State University. Environmental Management Studies Center. “**Environmental and Community Assessment of Round Lake**”. Big Rapids: 1983.

40. Ferris State University. Environmental Management Studies center. “**A Natural History of the Muskegon River Basin**”. Big Rapids: 1991.

41. Wood, James Carl. “**Mecosta County Chronology**”. Remus, Michigan. 1998.

Interviews

42. Stilwell, Steven. City Manager. City of Big Rapids. Personal Interview. May 31, 2000.

43. Schneidt, Roger. Operations Technician. Department of Engineering. City of Big Rapids. June 13, 2000.

Maps

44. <u>Topograhic.</u> Big Rapids City Map, The City of Big Rapids, Mi.

45. <u>Topograhic.</u> Big Rapids City Map, Prein & Newhof consultants.

Internet

46. City of Big Rapids. "City of Big Rapids Dam Removal Project: Facts about the Project: Photos". June 22, 2000/July 18,2000. Accessed: July 18, 2000. <www.ci.big- rapids.mi.us/damremoval/outline.htm>

47. City of Big Rapids. "Big Rapids Historical Timeline". Revised: April 7, 1999. Accessed: July 20, 2000. <http://www.ci.big-rapids.mi.us/AboutBR/Historical%20Timeline.htm>.

48. Michigan Department of Natural Resources Fisheries Division. "Aquatic Habitat and Fisheries Implications of the Removal of Big Rapids Dam". May 14,1997/May 10, 2000. Accessed: June 15, 2000. <www.ci.bigrapids.mi.us/damremoval/aqhabitat.pdf>

49. Santer, Richard. "Historic Overview of the City of Big Rapids". Revised: September 22, 1999. Accessed: July 20, 2000. <http://www.ci.big-rapids.mi.us/AboutBR/Overview.htm>.