LOWER MUSKEGON RIVER

PRELIMINARY HABITAT ASSESSMENT

MR-2000-01

Prepared for:

The Community Foundation *for* Muskegon County

Prepared by:

Dr. Richard Rediske, Senior Program Manager
Michael VanOoteghem, Student Research Assistant
Annis Water Resources Institute
One Campus Drive
Allendale MI 49401

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Executive Summary

The Muskegon River is a divergent system of scenic and biologically productive areas that are subject to the adverse impacts of excessive sedimentation and unstable hydrology. While the Muskegon State Game Area acts as a buffer zone around the river and protects it from urban development and local runoff, the export of sediment from upstream locations has resulted in an extensive change in landcover. As part of this project, a study of landcover changes in the lower Muskegon River watershed was performed using aerial imagery from 1978 and 1997. The most significant changes that occurred during this period are summarized below:

- 240 acres of wetland shrubs were lost in the area of the Muskegon River between US-31 and the Causeway from 1978 to 1997. The wetland shrubs were replaced by emergents and aquatic beds more tolerant of elevated water levels.
- 1723 acres of wooded wetland forest were lost in area of the Muskegon River between Mill Iron Road and US-31 from 1978 to 1997. The wooded wetland vegetation was replaced by wetland shrubs, emergents, and aquatic beds. This vegetation is more tolerant of elevated water levels.

The lower Muskegon River watershed contains an extensive marsh/wetland environment that provides critical transitional habitats for fisheries and wildlife. Sedimentation during the last 25 years has filled in the river channels and caused the water to spread laterally across the wetland. Highways and railroad bridges at the western edge of the watershed have created artificial restrictions in the watercourse, resulting in the pooling of flood waters and the subsequent deposition of additional sediment. As a consequence, extensive sand deposition is evident in the eastern end of Muskegon Lake and in the wetlands near the river channels during field surveys performed in 1999. While the wetlands and tributaries of the lower Muskegon River watershed are recognized as natural features significant to the region and to the Great Lakes, very little is known about their ecology and overall function in the system. It is therefore imperative that a detailed assessment of the area fisheries, wetlands, and terrestrial communities be performed. This assessment should document current environmental conditions, define community structure, identify areas of significant change, and determine stress factors. Similarly, the hydrologic variables that have accelerated the export and deposition of sediment in the river from 1978 to 1997 also need to be evaluated in order to develop management plans to mitigate this problem. The lower Muskegon River watershed is a complex system and will require an in depth analysis to obtain the information necessary to develop effective management and restoration plans.

The sedimentation problems of the lower Muskegon River that have developed since 1978 highlight three important paradigms of watershed management:

- knowledge is required to make informed decisions,
- effective resource management must consider the broad range of habitats present, and
- a regional approach is the key to success.

From the above discussion, it is clear that we need more information about the watershed to develop management plans. Without this information, it is impossible to prioritize issues, formulate mitigation strategies, and initiate changes that are beneficial to the system. We must also communicate this information through a public educational process that fosters resource preservation and stewardship. Education will help foster lasting change.

The data from this project also illustrate the importance of a holistic approach to watershed management. The establishment of the Muskegon State Game Area by the Michigan Department of Natural Resources saved a large part of the lower Muskegon River watershed from development. This action however amounts to a large-scale local effort that must be coordinated with other preservation and enhancement activities upstream. Similarly, the current waterfowl management program has been effective in preserving the wetlands for this purpose; however, sedimentation has changed plant communities, altered the hydrology, and impacted fisheries and wildlife. The management of one designated use does not result in the protection of the entire resource. It is important therefore to act on a watershed basis and implement plans to preserve the entire resource.

While the Muskegon River has a large section of protected land that acts as a buffer zone, a majority of the Cedar Creek watershed is privately owned and subject to future development. This stream supports a healthy coldwater fishery that is an important local resource. Cedar Creek is a successful fishery because of its dense riparian vegetation, abundance of woody debris, and ongoing programs to mitigate stream bank erosion and improve benthic habitats. The poor soils and steep slopes characteristic of the upper section of the watershed are very susceptible to erosion by development in riparian areas and the creation of unstable stream hydrology from the introduction of stormwater. These factors underscore a high level of vulnerability in the watershed that will require stewardship and protection of the resources. It is important that stream bank and habitat restoration activities continue to improve vegetative cover and mitigate the sources of siltation. As with the Muskegon River, the future of this important tributary depends on a detailed assessment of the resource, the development of a holistic preservation plan, and a strong public education component.

1.0 Introduction

The Muskegon River is an important part of the Great Lakes ecosystem. Through its riparian forests, wetlands, and flowing waters, the 2,634 square mile Muskegon River watershed provides the necessary habitat diversity to support fisheries and wildlife resources of regional and national significance. The Muskegon River is the second largest river in Michigan with headwaters located near Houghton Lake and Higgins Lake in Roscommon County. The river flows for 220 miles before discharging to Lake Michigan. The history of the Muskegon River was described by Alexander (2000). Approximately 11,000 years ago, the glacial activity that formed the Great Lakes also created the Muskegon River. During the 1700s, Native American tribes depended on the river's natural resources for food and transportation. They named the river the "Maskigon", which means river with marshes. In its natural state, the Muskegon River was a continuous system of dense riparian forests, sprawling wetlands and marshes, inland lakes, and extensive riffle areas. The system was drastically changed in the 1800s when lumber barons harvested the region's timber resources and left behind a legacy of barren riparian zones and severe erosion. This was followed in the 1900s by electric utilities that utilized the steep river valleys and swift currents to generate hydroelectric power through the construction of dams. After two centuries of perturbation, the Muskegon River stands at an ecological crossroads with respect to its recovery. State and local resource management efforts have resulted in considerable reforestation and the establishment of wildlife reserves and buffer zones that protect the river. Today, the Muskegon River is a divergent system of scenic and biologically productive areas subject to the adverse impacts of excessive sedimentation and urban development in addition to the effects of a discontinuous hydrology from multiple dams. The continued uncontrolled input of sediment and development of the riparian zone will ultimately result in significant degradation of this valuable resource.

The lower Muskegon River watershed is located in Muskegon County and contains an extensive marsh/wetland environment that provides critical transitional habitats for fisheries and wildlife. The river gradient flattens in this area and forms a large freshwater estuary consisting of wooded wetlands, emergent beds, and open water marshes. Much of this area is part of the 10,000 acre Muskegon State Game Area (MSGA) and is managed for the protection and enhancement of fisheries and wildlife habitat. The MSGA acts as a buffer zone around the river and protects it from urban development and local runoff. Two smaller tributaries of the Muskegon River are also located in the area of the MSGA. Cedar Creek and Mosquito Creek are important waterways that support coldwater fisheries and provide a transitional environment from the larger river to first and second order streams. While the wetlands and tributaries of the lower Muskegon River watershed are recognized as natural features significant to the region and to the Great Lakes,

very little is known about their ecology and overall function in the system. It is therefore important to conduct an initial survey of the lower Muskegon River watershed that documents current environmental conditions and identifies any areas of significant change. These data will serve as the basis for future assessments of problem areas and the development of management and restoration plans.

1.1 PROJECT OBJECTIVES AND TASK ELEMENTS

The objectives of this project were to conduct a preliminary assessment of the aquatic and terrestrial habitats present in the lower Muskegon River watershed and to identify areas of significant change. In addition, a series of benthic macroinvertebrate and water chemistry samples were collected to further assess the nature of the aquatic habitat and water quality. Because of the size of the project area, the aerial data and interpretations from the Michigan Resource Information System (MIRIS) was used (MDNR 1978 and 1997). For the purposes of this habitat assessment, the lower Muskegon River watershed is defined as the watershed area in Muskegon County ending at Maple Island Road. Specific objectives and task elements are summarized below:

- review existing soils, hydrology, and ecology data and identify significant data gaps;
- inventory current environmental conditions and develop an assessment of current conditions;
  - analyze and summarize MIRIS data for 1997
  - conduct a preliminary field survey on major tributaries
  - collect benthic macroinvertebrate and water quality samples at 17 representative locations
- review 1978 MIRIS data and determine areas that have undergone significant landcover changes from 1978 – 1997; and
- identify significant areas of concern for the lower Muskegon River watershed.

This project developed a set of baseline data that is important in the identification of areas of concern in the watershed and to the development of environmental management plans. It contains information useful to scientists who are involved in conducting detailed assessments of fisheries and wildlife habitats. In addition, the project serves as an important tool for public education about the ecological importance of the lower Muskegon River watershed and the significance of problem areas.

1.2 SOILS

The soil types found in the project area can be classified as a mixture of poorly drained low land soils and well drained up land soils. The distribution of soil associations is shown in Figure 1.2.1. The lower Muskegon River watershed is composed of the following major types:

- Kerston soil association
- Sloan soil association
- Saranac soil association
- Grayling soil association
- Rubicon soil association

The characteristics of these associations are presented in Table 1.2.1. (USDA 1972).

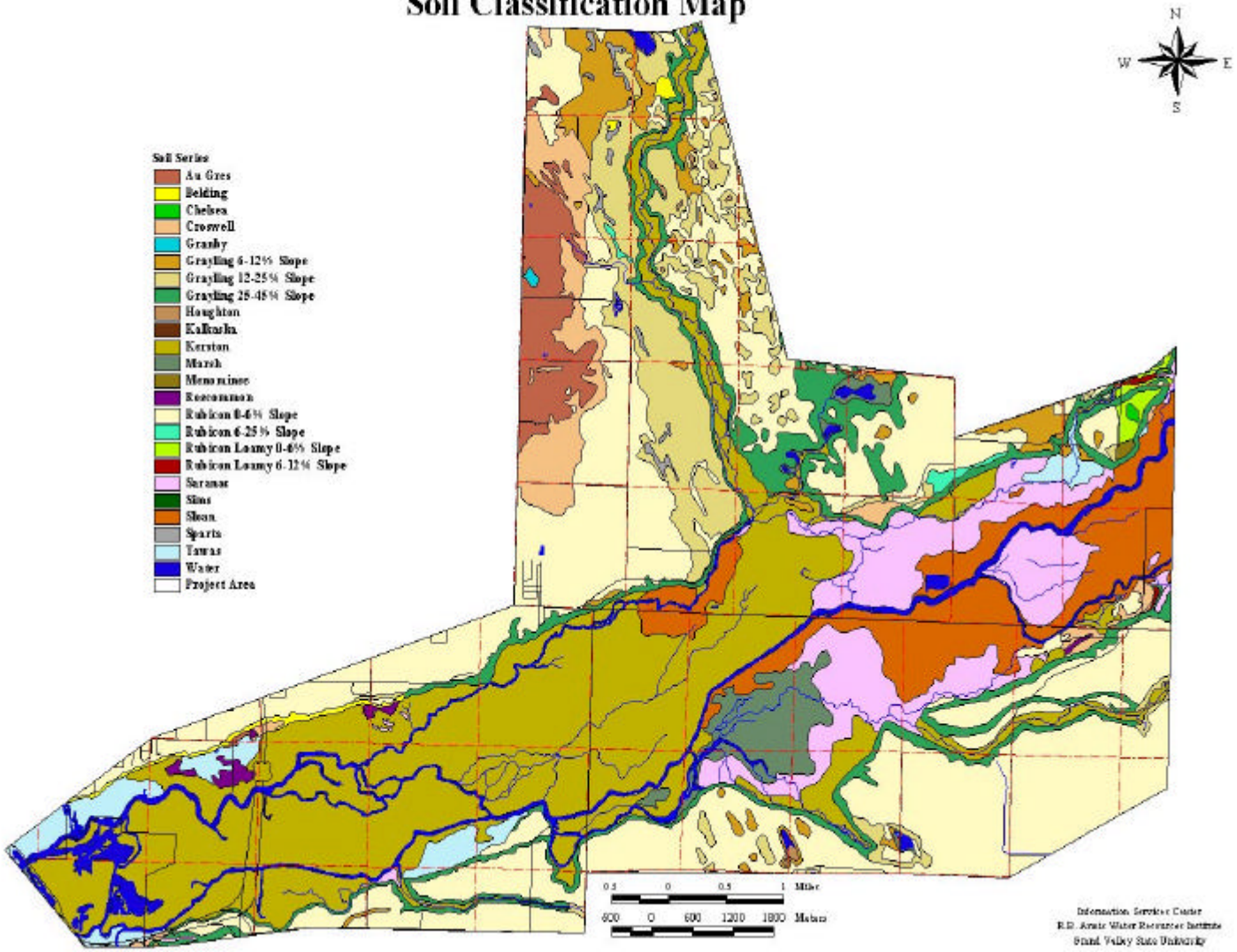
Table 1.2.1. Lower Muskegon River Watershed Soil Characteristics Of The Five Major Soil Classifications In The Project Area

Soil Association	Permeability	Fertility	Water Holding Capacity	Soil Texture	Drainage Class
Kerston	Low	Low	High	Muck	Poor
Sloan	Moderate	High	Moderate	Loam	Poor
Saranac	Low	High	High	Loam	Poor
Grayling	High	Low	Low	Sand	Well

The majority of the assessment area is composed of the Kerston soils. These soils are characterized by poorly drained organic and mineral layers that alternate due to the deposition of material during high flood events. The surface layer is approximately 10 inches of muck soil, with the lower layers alternating between mineral and organic soils. Because of the texture and the alternating layers, these soils have a high water holding capacity. The water table remains approximately one foot from the top of the soil, which is characteristic of hydric soil formations. The Sloan soil association is characterized by poorly drained soils of sloping terrain near or along waterways. The water holding capacity of this association is relatively high due to the elevated water table and the silt loam texture of the soil. Sloan soils are found 2.49 linear kilometers northeast of the Mill Iron Road public access, paralleling the river until reaching Maple Island Road to the east. The Saranac soil association is found in lower lying depressions and bayou areas of the lower Muskegon River watershed. This soil has a low infiltration rate and a high water holding capacity. The soil alternates in texture because of the depositional periods by which the soil formed. Saranac soils are found mainly in the eastern portions of the project area starting at the headwaters of Spring Creek and running in a northeasterly direction. They parallel the Sloan association on both the north and south sides of the Muskegon River. The Grayling and Rubicon soil associations parallel the Muskegon River and

Cedar Creek at higher topographic elevations. These associations contain well-drained, sandy textured soils which are located on sloping hills and terraces (Grayling series) and on upland plains (Rubicon series). The soils have a very thin organic layer (approximately 1-2 inches) followed by a coarse, sandy textured soil. The coarse texture results in a soil that has very organic content provides high permeability and very low water holding capacity. In addition, the low a poor medium for plant growth and soil is easily eroded by wind and water action. In most areas, the well drained, sandy soils are found in the higher elevations of the watershed and along the slopes. The poorly drained soils are typically found in the flood plains and pocket depressions. While the lower Muskegon River watershed contains a high percentage of hydric soils, the close proximity of sandy associations with poor organic horizons results in a high potential for erosional impacts.

Figure 1.2.1 Lower Muskegon River Watershed Project Area
Soil Classification Map



1.3 TOPOGRAPHY

There are several distinct changes in topography throughout the project area. The flood plain surrounding the Muskegon River is relatively flat alluvial lowland. Glacial moraines and outwash plains characterize the upland areas. The elevation at Muskegon Lake is 177 meters above sea level and the elevation at Maple Island Road, at the eastern border of the project area, is 182.5 meters. The overall gradient for the Muskegon River, based on the South Branch, is 0.82 m/km. The uplands on both sides of the Muskegon River range from 200 meters to 210 meters and have a relatively flat terrain. Most of the valleys along the north and south border of the Muskegon River have 10% slopes consisting of mixed hardwood forests. No severe areas of erosion were observed, and there is an adequate floodplain separation between the river and the slope. In contrast, there are many areas within the northern Cedar Creek watershed that have very steep slopes (25%-45%) adjacent to the stream. Erosion sites are common along Cedar Creek, and local efforts to stabilize the stream bank have been completed at 12 locations. The contour map of the project area is presented in Appendix A (Figure A-1).

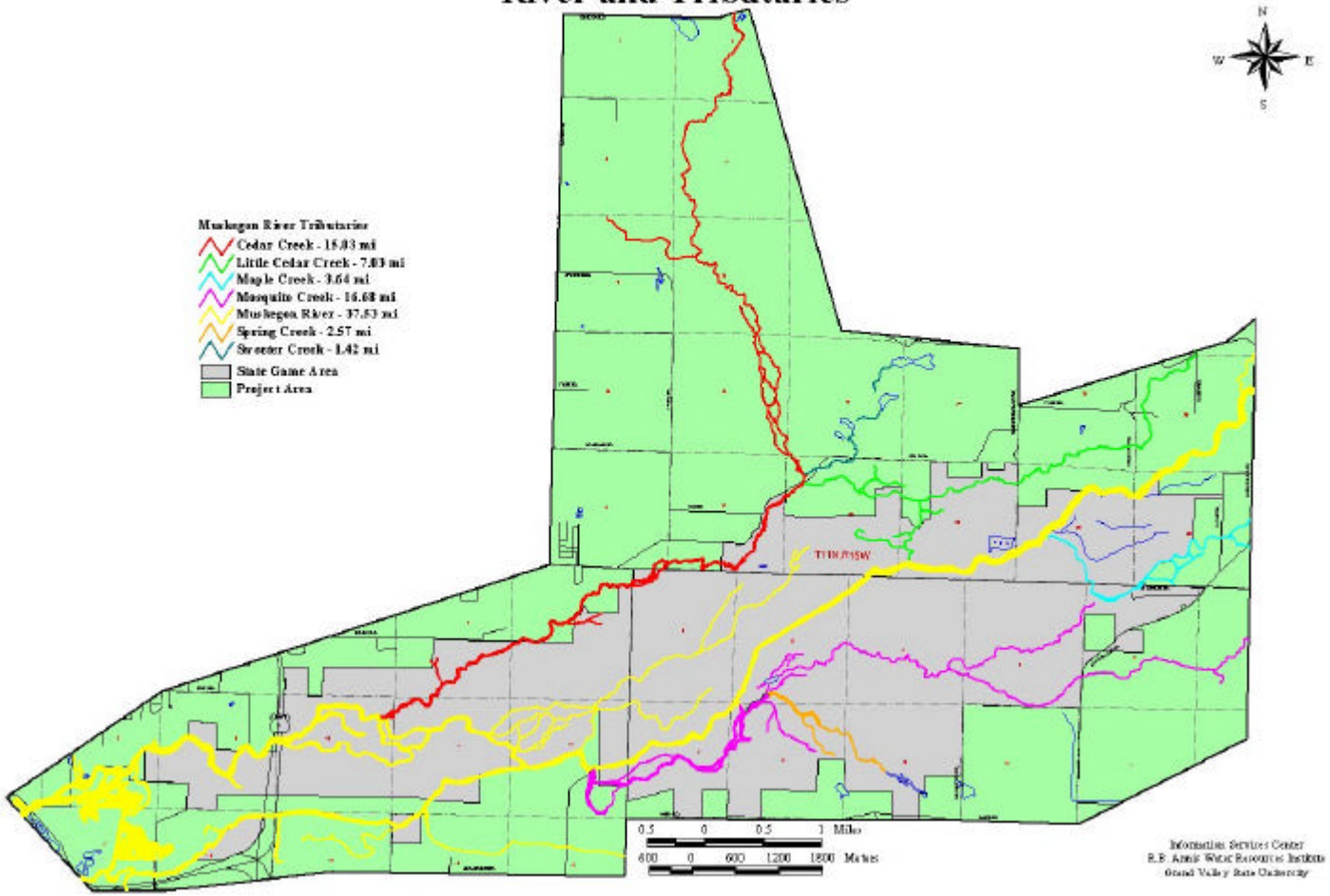
1.4 HYDROLOGY

The lower Muskegon River watershed is shown in Fig 1.4.1. This section covers 9,892.6 acres and includes the sub-watersheds of Cedar Creek and Mosquito Creek. Approximately 127.3 river kilometers are present in the study area. The Muskegon River splits into the North Branch and the South Branch approximately 1.21 river kilometers downstream of Mill Iron Road. The Middle Branch splits off the South Branch between the Causeway and US – 31. The three branches discharge along a 40.0 square kilometers area at the western end of Muskegon Lake. Total river miles for each branch are:

North Branch – 9.16 kilometers
Middle Branch – 0.97 kilometers
South Branch – 11.08 kilometers
Main Channel – 12.72 kilometers

Stream gradients are relatively flat with a total drop in elevation from Maple Island Road to Muskegon Lake of 5.5 meters. Gradients for the North Branch and the South Branch are 0.21 m/km and 0.22 m/km respectively. The U.S. EPA (1975) estimated the discharge of the North and South Branches to be 32.4 m^3/sec and 26.5 m^3/sec respectively at their confluence with Muskegon Lake. Discharge data for the Middle Branch was not available. It should be noted that very little flow was observed in the Middle Branch during the field survey. A large flood event in 1986 caused a massive movement of sediment from the old Newaygo Dam, and the Middle Branch was closed off by depositional action. While flow did return to the Middle Branch at a later date, the low water levels recorded during 1999 were insufficient to keep water flowing in the channel. The North Branch currently appears to represent the largest discharge volume of water to Muskegon Lake.

Figure 1.4.1 Lower Muskegon River Watershed Project Area
River and Tributaries



The lower Muskegon River watershed contains two important tributaries. The largest tributary is Cedar Creek, which originates in the vicinity of Brunswick in Muskegon County. The stream flows approximately 24.19 kilometers before joining the North Branch of the Muskegon River. The stream gradient is 0.91 m/km. Cedar Creek is also joined by Little Cedar Creek and Sweeter Creek near River Road, which have shallow gradients. Mosquito Creek flows about 19.31 kilometers before entering the South Branch of the Muskegon River near Mill Iron Road. The stream gradient for this tributary is 0.61 m/km. Mosquito Creek is joined by a smaller stream, Spring Creek, near Hilton Park Road. An old meander section of the South Branch also joins Mosquito Creek near Mill Iron Road. This section appears to have a flat gradient and consists mostly of wetland environments. The Cedar Creek and Mosquito Creek systems have stable base flows and are managed for coldwater fisheries.

Very limited information is available on the hydrology of the lower Muskegon River and its tributaries. Robertson (1997) conducted a hydrological analysis of the Muskegon River watershed in order to estimate sediment and total phosphorus loadings to Lake Michigan. His estimates did not include the effects of Muskegon Lake and the wetland to the east and west of US-31 on sediment deposition. The estimates reported for suspended sediment and total phosphorus therefore overstate actual loadings to Lake Michigan. They do, however, reflect potential loadings to the study area. A summary of his analyses is presented below:

Watershed area	6890 km^2
Long-term daily average flow	58 m^3/sec
10-year, 1-day flow	292 m^3/sec
Flashiness	5
Stream gradient	0.40 m/km
Land Use	45% Ag, 53% Forest, and 1% Urban
Surficial deposits	6% Clay, 94% Sand, and Gravel

The Muskegon River has a shallow gradient, almost equal percentages of forested and agricultural land, and a predominance of sandy soils in its watershed. A flashiness value of 5 indicates that during the 10-year, 1-day maximum flow event, the discharge of the Muskegon River is equivalent to 5 days of normal flow. The combination of a low stream gradient and an elevated degree of flashiness indicate that the hydrology of the system is highly influenced by surface runoff.

Water quality and discharge results for samples collected at the Newaygo USGS Gauging Station from 1975-1993 were used to estimate loadings and watershed yields. Robertson's data (1997) is summarized below:

Average Yields	92 kg/ha/yr Suspended Sediment 0.12 kg/ha/yr Total Phosphorus
10-year, 1-day Yield	5.5 kg/ha/d Suspended Sediment 2.8 g/ha/d Total Phosphorus
Average Loadings	173,000 kg/d Suspended Sediment 226 kg/d Total Phosphorus
10-year, 1-day Loading	3,762,000 kg/d Suspended Sediment 3,175 kg/d Total Phosphorus
Suspended Sediment Flashiness	22
Total Phosphorus Flashiness	14

These values reflect the strong influence of surface runoff in the Muskegon River watershed. The effects of stream bank erosion and channel scouring is also reflected in the high loadings of sediment. Based on flashiness values, the suspended sediment loading during the 10-year, 1-day flood event is equivalent to 22 days of normal flow. Suspended sediment yields for the Manistee River, which is similar in watershed area and total discharge to the Muskegon River, are only 41 kg/ha/yr on an average basis and 0.7 kg/ha/yr during the 10-year, 1-day flood event. This river has a more stable hydrology even though its gradient is twice as steep (0.73 m/km).

The suspended sediment carried by the Muskegon River is deposited in the wetlands of the Muskegon State Game Area and in Muskegon Lake. The change in stream gradient, the attenuation effects of the wetlands, and the buffering properties of Lake Michigan and Muskegon Lake all act to cause the deposition of sediment in the region. Data from the Lake Michigan Mass Balance Study (Blumer et.al. 1996) illustrate these phenomena. Using a temporary gauging station established in the Muskegon Lake Channel to Lake Michigan, the following discharge and loading information was obtained:

Average Flow	83 m^3/sec
Maximum Flow	182 m^3/sec
Minimum Flow	13.5 m^3/sec
Average Loading of Suspended Solids	21,500 kg/d
Maximum Loading of Suspended Solids	62,900 kg/d

Based on the average loading of suspended solids from the Lake Michigan Mass Balance Study and Robertson (1997), the data can be extrapolated to predict that 151,500 kg/d of sediment are deposited in the lower Muskegon

River watershed and Muskegon Lake. This estimate is significant since large amounts of sediment are destructive to the riverine, wetland, and lake habitats present in the area.

The hydrology of the lower Muskegon River is complex due to the topography, meander patterns, and the strong influences of the wetlands and Muskegon Lake. The minimum flow of 13.5 m^3/sec measured above also indicates that the currents of Lake Michigan influence the system. Given the high discharge of the river, the system has the energy capacity to continuously move coarse sand along the bottom. In addition to the suspension of smaller particles in the water column, the movement of bedload sand along the bottom is a significant sediment transport mechanism. Simple hydrologic models and estimates are not capable of evaluating the significance of the above factors. Consequently, a detailed investigation of the hydrology of the lower Muskegon River is necessary to understand the dynamics of sediment deposition and the factors that can control and ultimately reduce loadings.

1.5 TERRESTRIAL HABITAT

A diverse assemblage of flora and fauna are found in the lower Muskegon River watershed. A complete inventory of species has not been performed and consequently, the information included in this report is based on field observations and reviews of species inventories conducted in other areas of western Michigan. The fauna species range from migratory and transient species to native animals (MDNR 1977) and are summarized in Appendix B (Tables B-1 through B-5). Species common to upland forests and wetland environments are present.

Figures 1.5.1 and 1.5.2 show typical habitat and species found in the area. MIRIS data is available for the lower Muskegon river watershed that describes landcover and habitat. These classification schemes are defined in Table 1.5.1. The MIRIS classifications will be used for the habitat inventories and analyses conducted in this project. A map of current land cover classifications is presented in Figure 1.5.3.

Wetland environments are the predominant natural features of the area from M-120 to Mill Iron Road. Four types of wetlands are present (Satterlund et.al. 1992):

- Aquatic Beds - rooted aquatic plants and water lilies. 6" - 36" water depth
- Emergent Bed - cattails, sedge grass, pickeral weed, and reeds. 0" - 6" water depth
- Wetland shrub – willow, alder, dogwood, and elderberry. 0" - 12" water depth
- Lowland hardwood - ash, elm, sycamore, cottonwood, oak, and maple. Area prone to seasonal flooding.

Aquatic beds serve as environments that support regional and Great Lakes fisheries (Jude and Pappas 1992). Emergent beds, wetland shrubs, and lowland hardwoods provide valuable habitats for wildlife and are an important source of organic materials for the aquatic food web. US - 31 crosses the wetlands near the center of this area and is built on an elevated levee. Bridges provide passage for the water of the three branches of the Muskegon River. In addition, a second elevated levee runs due west, above the South Branch of the river. This levee was built to access the power lines that run through the wetlands. While neither levee affects normal river flow, they do function as unnatural barriers during flood events and act to spread peak water to the north and south of the channels.

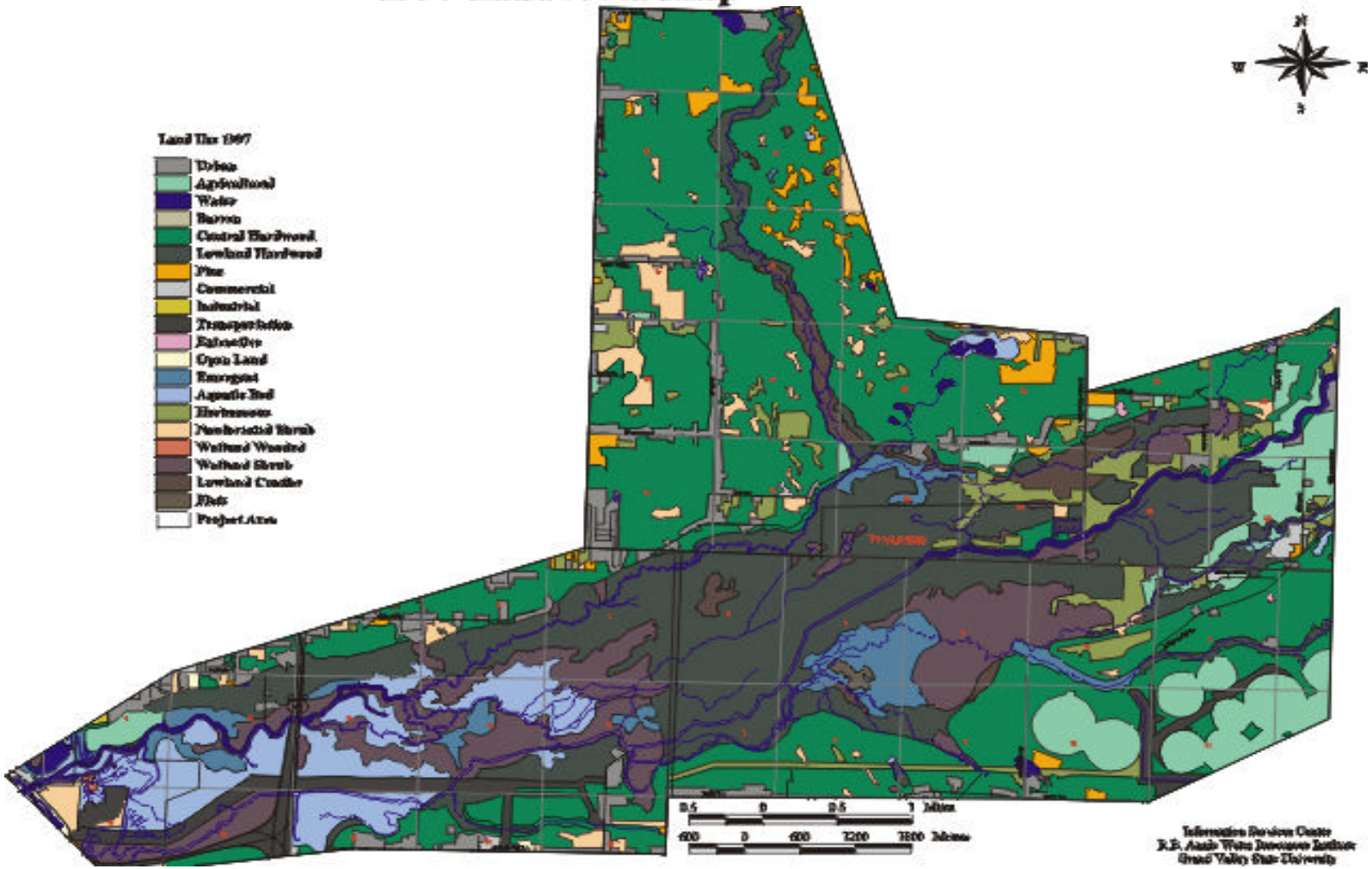
Figure 1.5.1. Riparian Habit Along The Muskegon River, Upstream Of Mill Iron Road.

Figure 1.5.2. Mallard Duck Nest Found In The Cedar Creek Watershed Near Sweeter Road.

Table 1.5.1. MIRIS Classification Definitions For Landcover Maps

Land Use Descriptions	
MIRIS Classification	Description
Urban	Characterized by intense use and land that is covered by structures. Includes townships, villages, strip development, and metropolitan areas.
Agricultural	Land used primarily for production of farm commodities.
Water	Areas of land that are persistently water covered including lakes, rivers, stream, and creeks.
Wetland Shrub	Wetlands dominated by shrubs where the soil surface is seasonally or permanently flooded with up to 1 foot of water. Meadow or marsh emergents occupy open areas.
Barren	Land that has a limited ability to support life and little or on vegetation.
Central Hardwoods	Areas dominated by white, black, and red oak, hickories, and black locust.
Lowland Hardwoods	Areas dominated by ash, elm, sycamore, and maple species
Pine	Areas that are dominated by pine plantations.
Commercial	Areas that are primarily used for the sale of products and services.
Transportation	Areas that are dominated by transportation routes, which include airports utilities, sea ports, and railways.
Extractive	Areas of land that is dominated by both surface and subsurface mining operations.
Aquatic Bed	Includes wetlands dominated by plant that grow principally on or below the surface of the water for most of the growing season, during most years.
Herbaceous	Areas supporting native grasses and forbs. These areas are often subjected to continuos disturbance.
Non-forested Shrub	Areas that are dominated by herbaceous wetland vegetation.
Lowland Conifer	Areas dominated by cedar, spruce, and fir species.
Open Land	Land used for recreational purposes that does not contain heavy structures or native vegetation, including zoo's, cemeteries, ski areas, and botanical gardens.
Wooded Wetland	Wetlands dominated by trees. The soil surface is seasonally flooded with up to 1 foot of water. Several levels of vegetation are usually present, including trees, shrubs, and herbaceous plants.
Emergent	Wetlands dominated by robust or marsh emergents, with an average water depth less than 6 inches during the growing season. Surface water may be present throughout the year or absent during the late summer and abnormally dry periods. Floating leafed plants and submergent plants are usually present in open areas.
Flats	Areas of land that support little or no vegetation and are exposed during periods of low water.
Industrial	Areas that contain manufacturing facilities that include light and heavy industries, which produce various commercial goods.

Figure 1.5.3 Lower Muskegon River Watershed Project Area
1997 Landcover Map



The land west of Mill Iron Road and south of River Road consists of a wooded wetland system with some areas of shrubs, emergents, and aquatic beds. Upland plains to the north of River Road and along the southern edge of the study area are characterized by central hardwood forests, meadows, and agricultural fields. A more detailed description of the habitats in the project is presented in Section 3.

A major feature in the lower Muskegon River watershed is the Muskegon State Game Reserve (MSGR). A map of the reserve is provided in Figure 1.5.4. In 1931, the State of Michigan purchased the parcel of land shown in Figure 1.5.5 and formed the MSGR. Additional purchases of land occurred up until 1968. Currently the reserve covers over 10,000 acres and runs from US 31 to Maple Island Road. The Muskegon River, Mosquito Creek, Spring Creek, and part of Cedar Creek lie within the game reserve boundaries. Since the floodplain and much of the adjacent upland area are part of the MSGR, there is a large buffer zone around these waterways. The buffer zone will minimize the effects of urbanization and runoff while providing a stable and diverse natural habitat. The Muskegon State Game Reserve is currently managed for waterfowl habitat (MDNR 1977).

The Cedar Creek watershed north of River Road is not part of the Muskegon State Game Area. While a wide riparian zone is present in most areas, a majority of the land is privately owned. The scenic nature of this land and its proximity to the metro Muskegon area suggests there will be more pressure to develop residential and commercial uses that may impact Cedar Creek. The steep valleys and sandy soils make this part of the Cedar Creek watershed especially sensitive to runoff and changes to environmental quality.

1.6 FISHERIES

The lower Muskegon River watershed has a diverse aquatic habitat that supports a variety of cold water and warm water fish species. This area provides multiple environments for these fish, including spawning grounds, migratory corridors, nursery habitats, and feeding areas. Historical records describe 97 species of fish that originally inhabited this area (O'Neal 1997). Currently, 77 fish species are found in the river, with 7 introduced to the region. A list of fish species found in the lower Muskegon River watershed is presented in Appendix B Table B-4 (O'Neal 1997).

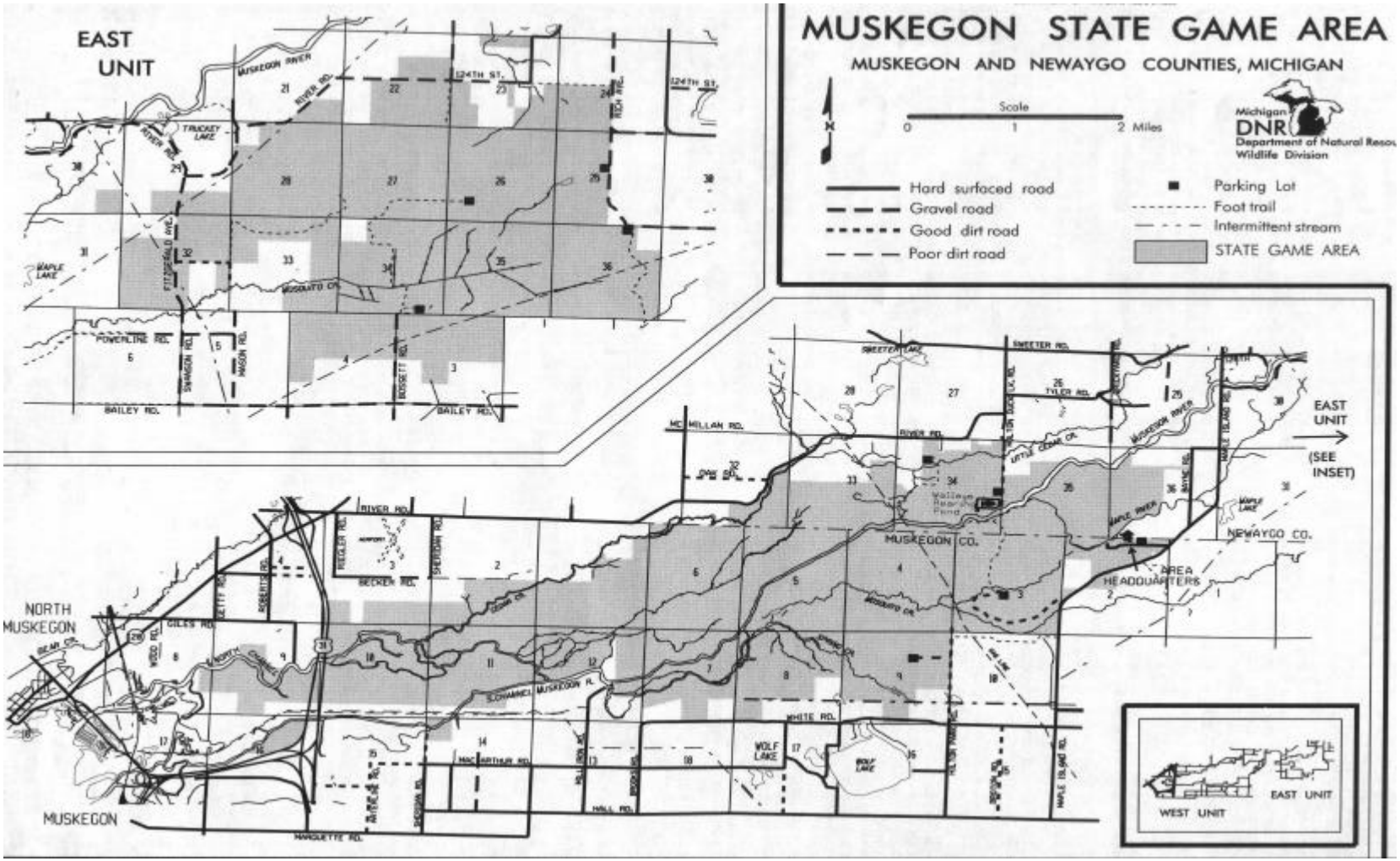


Figure 1.5.4. Muskegon State Game Area: Current Boundaries

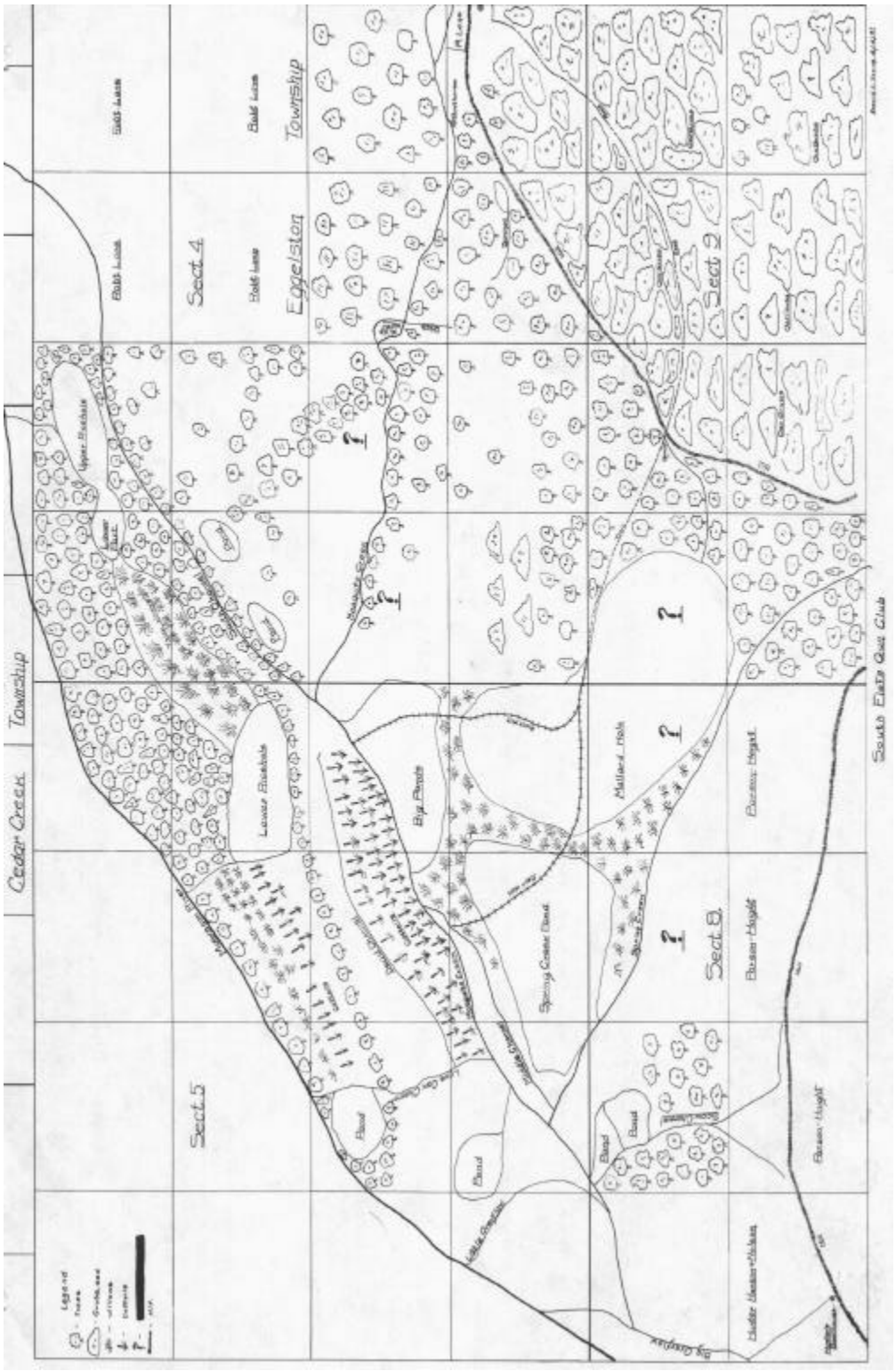


Figure 1.5.5. 1931 Sketch Of Land Prior To The Muskegon State Game Area

The Muskegon River fisheries have been slowly dwindling throughout the last century because of a variety of environmental problems. Riparian habitat destruction, sedimentation, and the construction of hydroelectric dams on the river have all impacted the productivity and sustainability of fisheries in the Muskegon River. Logging scoured the River's banks and increased erosion. During this period, critical spawning grounds for certain migratory species were covered with sediment. The use of hydroelectric dams on the River cut off migratory routes for certain fish species, which utilized the coldwater streams in the headwaters of the Muskegon River for spawning grounds. Because of these actions, the fisheries within the Muskegon River have diminished to a point at which certain species are absent in portions of the river where they once thrived. The lake sturgeon and arctic grayling are examples of fish species currently not present in the Muskegon River.

O'Neal (1997) listed four critical areas related to the improvement of fisheries in the Muskegon River:

- Recruitment
- Temperature
- Fish passage
- Sedimentation

Healthy fisheries are characterized by large numbers of young fish. Rainbow trout, brown trout, smallmouth bass, and northern pike have low numbers of young fish in their distribution, which indicates a problem with recruitment. Walleye recruitment is also below historical levels. Low recruitment can be caused by a variety of factors including unstable temperature and flow regimes, siltation, poor habitat, and blockage of spawning areas (Jude and Pappas 1992). While the Muskegon River supports both cold and warm water fish species, the presence of numerous impoundments and the destruction of riparian vegetation contribute to an elevation of water temperature in localized areas and influence the overall thermal budget of the river. The combination of higher water temperatures and sedimentation favor the proliferation of less desirable fish species such as carp and catfish. In addition to problems associated with recruitment and spawning, the restriction of fish passage by dams in the river destroys ecological continuity and results in a series of dysfunctional environments. Generalized management options to improve fisheries in the Muskegon River include providing fish passage at the hydroelectric dams, limiting runoff, and enhancing riparian zones. O'Neal (1997), however, states that critical information is lacking with respect to habitat structure, food resources, recruitment numbers, and the structure and distribution of the fish populations in watershed. This information is required to develop more specific recommendations for the watershed.

Cedar Creek and Mosquito Creek contain important coldwater fisheries that support natural reproduction. Siltation and loss of riparian vegetation are problems for both streams that adversely impact fish populations. Most of

Mosquito Creek is in the Muskegon State Game Area and will remain in its current condition as long as MDNR management programs are in effect. A large part of the Cedar Creek watershed is privately owned and subject to future development. It is important to limit siltation, continue the remediation of erosional areas, and maintain the existing riparian zone if the stream is to support a strong coldwater fishery.

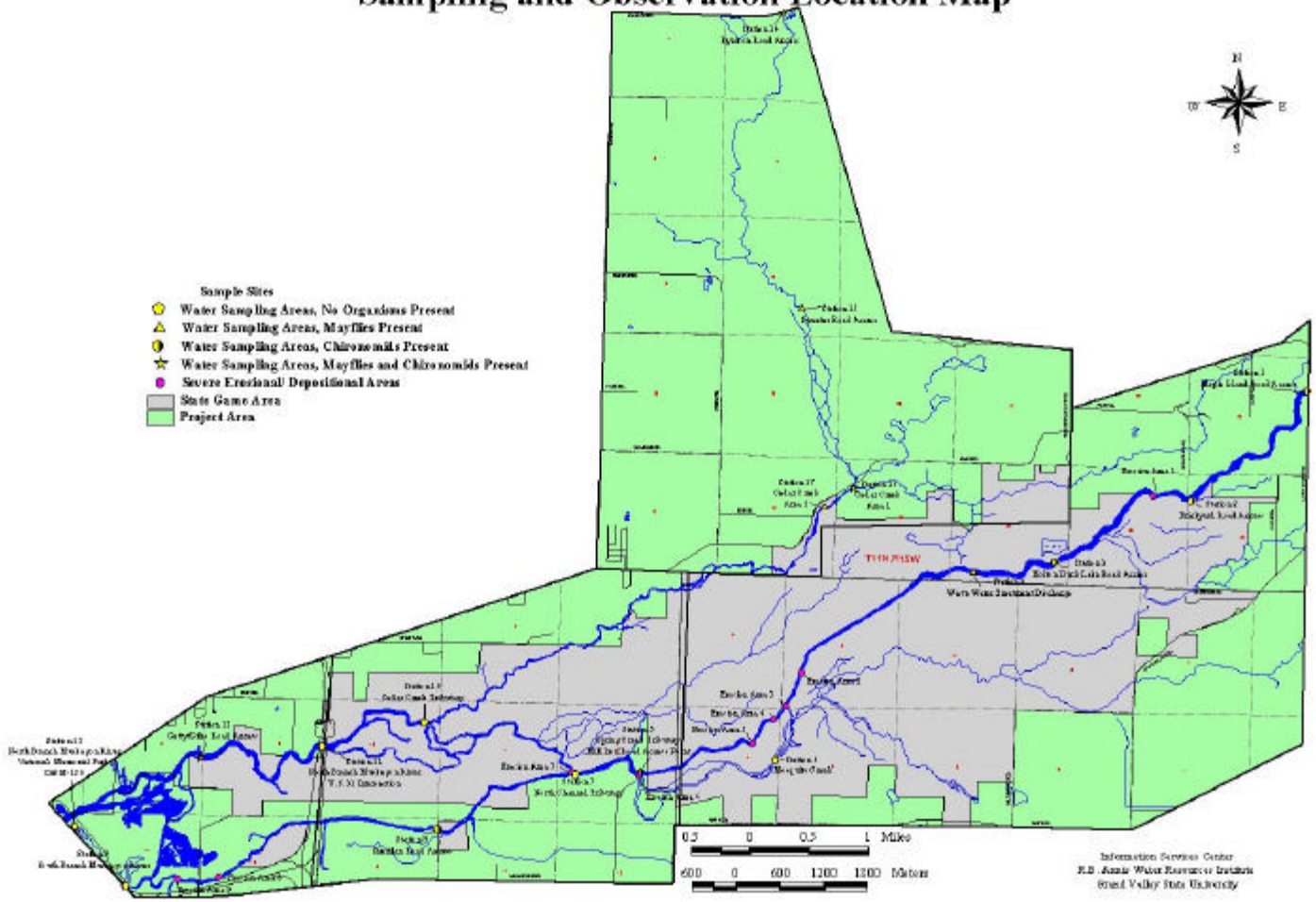
1.7 EXPERIMENTAL DESIGN

For the purposes of this assessment, the project area was divided into four zones using the natural and man-made boundaries found in the region. Seventeen sampling and observation locations were established in the study area. A map of the four zones and the sampling locations is presented in Figure 1.7.1. Zone 1 covers the land area from Muskegon Lake to the US-31 overpass. There were four sampling and observation station located within this zone. Most of Zone 1 is classified as wetlands. Zone 2 covers the land area east of the US-31 overpass to approximately Mill Iron Road. The area is also primarily comprised of wetland environments. There were four sampling and observation stations located within this zone. Zone 3 is located north of River Road and south of Ryerson Road. Zone 3 includes most of the upper Cedar Creek watershed. There were four sampling and observation stations located within this zone. Zone 4 covers the remaining land area east of Mill Iron Road and west of Maple Island Road, and it includes the Muskegon State Game Area and outlying areas. The watersheds of Mosquito Creek and the lower section of Cedar Creek are located in Zone 4. Descriptions of the sampling locations are found in Table 1.7.1.

Table 1.7.1. Lower Muskegon River Watershed Project Area Sampling And Observation Locations

Sampling Station	Zone	Latitude Longitude	Description
Station 1	4	1,546,061.95 667,180.92	Maple Road Public Access
Station 2	4	1,540,876.77 662,290.28	Brickyard Road Public Access
Station 3	4	1,534,753.19 659,557.27	Holton Duck Lake Road Public Access
Station 4	4	1,531,109.18 659,112.04	Waste Water Treatment Discharge
Station 5	2	1,516,192.99 650,748.62	Mosquito Creek Tributary Mill Iron Road Public Access
Station 6	4	1,522,232.04 650,748.62	Mosquito Creek
Station 7	2	1,513,308.66 650,100.35	North Channel Tributary Of The Muskegon River
Station 8	2	1,507,121.72 647,590.94	Sheridan Road Public Access
Station 9	1	1,493,148.44 645,090.81	South Branch Muskegon River Near M-120
Station 10	2	1,506,512.10 652,392.54	Cedar Creek Tributary
Station 11	1	1,501,963.93 651,351.39	North Branch Muskegon River Us - 31 Intersection
Station 12	1	1,496,552.71 650,878.76	Getty/Giles Road Public Access
Station 13	1	1,490,881.21 647,769.03	North Branch Muskegon River Veterans Memorial Park Off M-120
Station 14	3	1,522,588.22 684,181.74	Ryerson Road Public Access
Station 15	3	1,523,417.02 670,941.38	Sweeter Road Access Off Two-Track
Station 16	3	1,525,759.60 662,934.14	River Road Road/Stream Crossing Of The Cedar Creek
Station 17	3	1,524,444.47 662,023.14	River Road Public Access

Figure 1.7.1 Lower Muskegon River Watershed Project Area Sampling and Observation Location Map



When significant signs of erosion were observed, the GPS coordinates were recorded along with a visual description of the area. A list of the erosional sites is included in Table 1.7.2.

Table 1.7.2. Lower Muskegon River Watershed Project Area Erosional And Depositional Areas

Erosion Area	Latitude Longitude	Description
Area 1	1,539,137.92 662,508.96	Severe bank failure
Area 2	1,523,384.35 654,595.18	Severe bank failure
Area 3	1,522,695.20 653,107.55	Severe bank failure and undercutting near the meanders
Area 4	1,522,141.23 652,488.13	Undercutting on the meanders
Area 5	1,521,191.49 651,438.65	Undercutting on the meanders
Area 6	1,516,108.35 650,049.30	Areas of deposition and undercutting around the meanders
Area 7	1,513,101.86 650,159.63	Undercutting near tributary banks
Area 8	1,497,333.16 645,472.71	Areas of deposition including sand bars and covered organic materials
Area 9	1,495,472.98 645,395.06	Areas of deposition including sand bars and covered organic materials

2.0 Methods

2.1 SAMPLING METHODS

All samples for nutrients and water chemistry were collected in pre-cleaned, plastic 1-liter bottles. Water samples were collected 12 cm below the surface and maintained at 4^0C until delivery to the laboratory. Benthic macroinvertebrates were collected using a modified Surber Sampler. The samples were sieved on site with a 250 um screen and preserved in 90% ethanol solution.

2.2 ANALYTICAL METHODS

Laboratory methods are summarized below:

PARAMETER	METHOD
NITRATE	4110*
AMMONIA	4500N-F*
TOTAL SUSPENDED SOLIDS	2540C*
ORTHO PHOSPHATE	365.3**
TOTAL PHOSPHATE	365.3**

* AWWA 1989.
**USEPA 1983.

3.0 Lower Muskegon River Watershed Project Results

The results of the GIS landcover analyses and field surveys are presented in sections 3.1-3.4 for Zones 1-4 respectively. Summaries of the chemical and biological data are included along with the landcover changes from 1978 to 1997.

3.1 ZONE 1

Zone 1 covers 2022.3 acres and includes the section of the Muskegon State Game Area located west of US-31. The GIS landcover data for this zone is summarized in Table 3.1.1. Zone 1 consists primarily of aquatic bed (25%), wetland shrub (13%), emergent (7%), transportation (17%), hardwood forest (central 5% and lowland 9%), and urban (7%). A total of 1220.2 acres are classified as wetlands (60%). The stream gradient is relatively flat with only a 0.9 m drop in elevation occurring over 4.76 river kilometers on the North Branch of the river. The South Branch has a drop in elevation of 1 meter over 3.14 river kilometers. Landcover change statistics for the period of 1978-1997 are presented in Figure 3.1.1 and summarized in Table 3.1.2. A total of 35.18 acres changed during this period. Dramatic increases in aquatic beds (93.1 acres) and emergents (146.1 acres) were noted. In contrast, wetland shrubs decreased by 239.8 acres. These changes occurred in the same general area and were the result of increasing water levels. While wetland shrubs are tolerant of seasonal high water, they cannot survive in the hydrologic conditions that support emergent and aquatic bed vegetation. The only major land cover change was the loss of 89.1 acres designated as transportation and the addition of 66.3 acres of non-forested shrub. This change was the result of the establishment of a vegetative cover on the fly ash disposal area operated by Consumer's Energy.

Figure 3.1.1 Lower Muskegon River Watershed Project Area Landcover Changes for Zone 1, 1978-1997

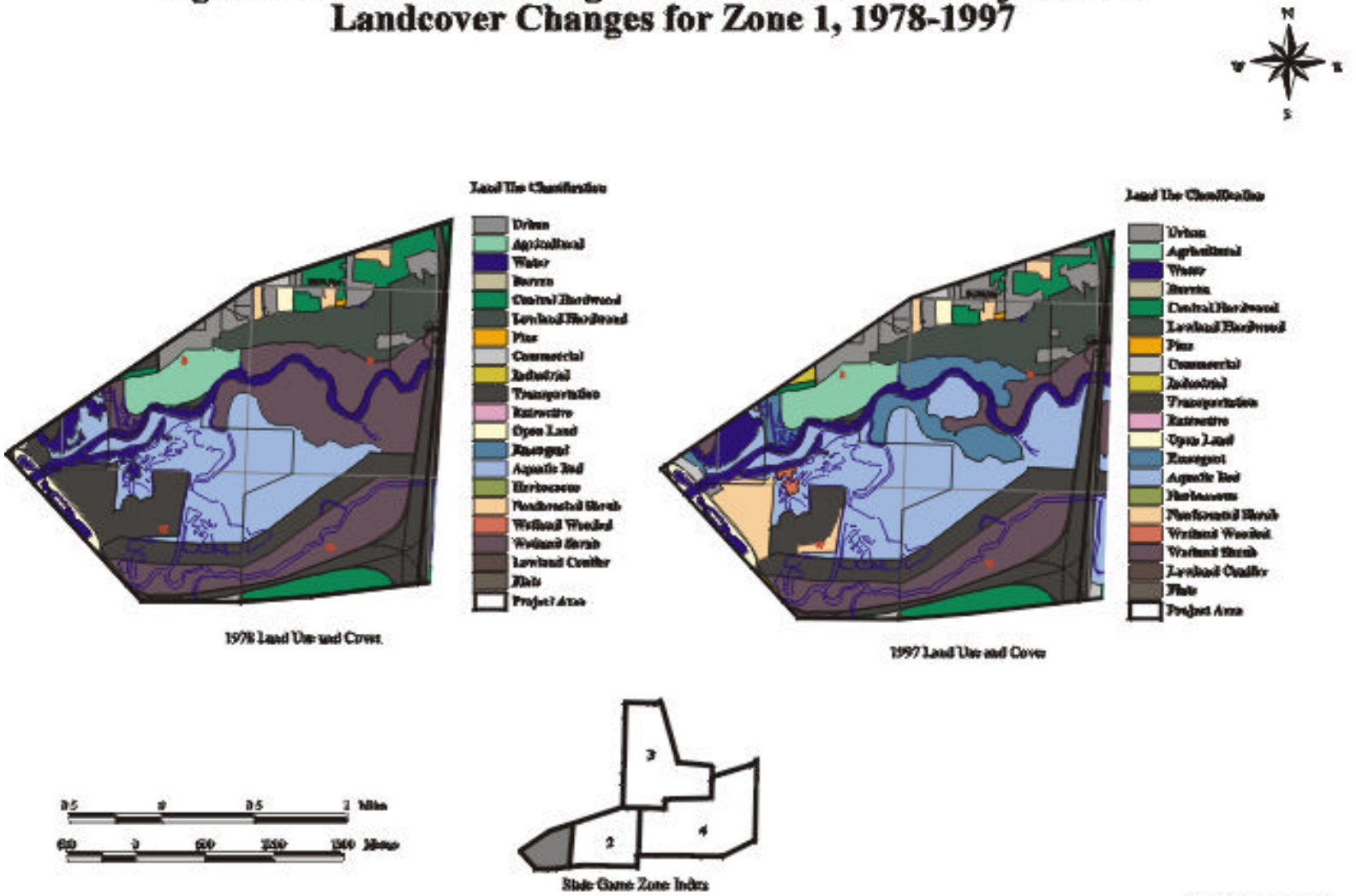


Table 3.1.1. Lower Muskegon River Watershed Project Area 1997 Landcover Data For Zone 1

Classification	Acreage	Percent of Total
Agricultural	82.6	4
Aquatic Bed	502.8	25
Central Hardwood	104.4	5
Commercial	13.4	1
Emergent	146.4	7
Industrial	8.1	0.4
Lowland Hardwood	175.3	9
Non-forested Shrub	87.8	4
Open Land	30.8	2
Pine	1.0	0.05
Transportation	338.6	17
Urban	135.3	7
Water	128.4	6
Wetland Shrub	261.9	13
Wetland Wooded	5.5	0.3
Total Acres	2022.3	100
Total Wetlands	1220.2	60

Table 3.1.2. Lower Muskegon River Watershed Project Area Landcover Changes From 1978 To 1997 In Zone 1

Classification	Acreage 1978	Acreage 1997	Change in Acres	Percent Change
Agricultural	82.6	82.6	0.0	0.00
Aquatic Bed	**409.7**	**502.8**	**93.1**	**4.60**
Central Hardwood	130.1	104.4	-25.7	-1.27
Commercial	8.4	13.4	5.0	0.25
Emergent	**0.2**	**146.4**	**146.1**	**7.23**
Industrial	2.8	8.1	5.3	0.26
Lowland Hardwood	176.5	175.3	-1.2	-0.06
Non-forested Shrub	**21.5**	**87.8**	**66.3**	**3.28**
Open Land	30.8	30.8	0.0	0.00
Pine	1.0	1.0	0.0	0.00
Transportation	**427.7**	**338.6**	**-89.1**	**-4.40**
Urban	104.4	135.3	30.9	1.53
Water	124.9	128.4	3.6	0.18
Wetland Shrub	**501.7**	**261.9**	**-239.8**	**-11.86**
Wetland Wooded	0.0	5.5	5.4	0.27
Total Water and Wetland Areas	1213.0	1220.2	7.2	0.84

(Significant landcover changes in bold print)

A field survey of Zone 1 was conducted along the North and South Branch of the Muskegon River. The Middle Branch was too shallow to float a canoe. The major plant and animal species observed in the area are summarized in Table 3.1.3 along with habitat characteristics. Forest species include elm, willow, maple, and ash. Emergent and aquatic vegetation includes cattails (*Typha* sp.), reeds (*Sparganuim sp.*), rushes (*Scirpus* sp.), sedge grasses (*Carex* sp.), and vascular hydrophytes such as water lilies (*Nuphar sp.* and *Nymphea* sp.), submerged coontail (*Certophyllum* sp.) and pondweed (*Potamogeton* sp.). Figure 3.1.2 shows a typical wetland environment found in Zone 1. Plant species and distributions were consistent with the 1997 GIS data. Depositional levies are found along some banks. These levies are usually covered with sedge grasses and wetland shrubs. Dead woody vegetation (trees and shrubs) is also common.

Areas of sand deposition are also found in Zone 1 as shown in Figure 3.1.3. A large sand bar has formed under the highway bridge over the Middle Branch near Johnson Park. This sand bar acts as a restriction in the channel. Evidence of streambank erosion and/or sediment deposition is present at all sampling locations. The most predominant form of erosion is sand bar deposition in the channel. Sand deposition was also noted on top of the organic sediments in the wetlands. Minor areas of bank scouring near or around the meanders are also present. The absence of major erosional sources along the banks suggests that the sediment was exported to the area by upstream sources. A summary of erosional impacts is presented in Table 3.1.4.

Table 3.1.3. Lower Muskegon River Watershed Project Area Major Plant And Animal Species Within Zone 1

Sampling Location	Primary Vegetation and Habitat Type	MIRIS Classification	Wildlife Sightings or Signs
Station 11 North Branch Muskegon River US-31 Intersection	Sedge grass species, aquatic vascular plants, and cattails (60%)elm, oak, maple, and willow species (40%)	Wetland Shrub and Aquatic Bed	Barn swallow, robin, red-winged black bird, geese, ducks, turtles, bullfrogs, northern water snake, and muskrat
Station 12 Getty/Giles Road Public Access	Aquatic vegetation, cattails, and sedge grass (70%) oak, elm, willow, and maple species (30%)	Emergent	Barn swallow, robin, red-winged black bird, ducks, turtles, bullfrogs, garter snake, and muskrat
Station 13 North Branch Muskegon River Veterans Memorial Park	Open water (90%) willow, sedge grass species and cattails (10%)	Urban	Swan, robin, barn swallow, and sparrow
Station 9 South Branch Muskegon River near M-120	Cattails and reeds (85%) willow, elm, and maple species (10%) aquatic vascular plants (5%)	Wetland Shrub	Geese, ducks, swans, robin, sparrow, barn swallow, garter snake, and muskrat

Figure 3.1.2 Wetland Environment West Of US – 31. A Large Number Of Trees Have Died Due To Prolonged Flooding.

Figure 3.1.3. Large Area Of Sand Deposition Near The Bridge At Johnson Park In The City Of Muskegon.

Table 3.1.4. Lower Muskegon River Watershed Project Area Erosion Observations Within Zone 1

Observation Area	Description
Erosion Area 8 0.34 river km downstream of the Middle Branch	Areas of deposition upstream, including sand bars and covered organic materials
Erosion Area 9 0.17 river km downstream of the Middle Branch	Areas of deposition upstream, including sand bars and covered organic materials
Station 9 South Branch Muskegon River near the Causeway	Areas of deposition upstream, including sand bars and covered organic materials
Station 11 North Branch Muskegon River at the US-31 Intersection	Bank scouring and undercutting on the meanders
Station 12 Getty/Giles Road Public Access	Bank scouring, undercutting on the meanders, and areas of deposition upstream
Station 13 North Branch Muskegon River at Veterans Memorial Park	Bank scouring on the meanders and areas of rip-wrap are visible on the River edge

Water chemistry and benthic macroinvertebrate data are presented in Tables 3.1.5 and 3.1.6, respectively. Total Phosphorus and suspended solids concentrations were lower at the discharge points of the North and South Branches into Muskegon Lake than the sampling locations near US-31. Reductions in stream velocity and the effects of the heavy wetland vegetation result in the settling of particulates and the loss of phosphorus. The stream depth ranged from approximately 1 m to 4 m and the bottom material consisted of coarse sand at all locations except for Station 11. The area near this location contained large amounts of organic detritus and woody debris. The presence of mayflies (*Hexagenia* sp.) indicates this location is a stable deposition area of organic matter. The absence of organic matter at the other locations indicates an unstable substrate that is subject to movement as part of the bedload and to export from periodic scouring. Benthic macroinvertebrates were absent from these unstable and sandy areas.

Table 3.1.5 Lower Muskegon River Watershed Project Area Water Chemistry Results For Zone 1

Date	Station	Total Phosphorus ($T\text{-}PO_4$)	Nitrate ($NO_3\text{-}N$)	Ammonia ($NH_3\text{-}N$)	Suspended Solids
		(mg/L)	(mg/L)	(mg/L)	(mg/l)
8/4/99	Station 12	0.05	0.34	<0.1	7
8/4/99	Station 11	0.03	0.20	<0.1	5
8/4/99	Station 13	0.03	0.28	<0.1	5
8/16/99	Station 9	0.04	0.49	<0.1	8

Table 3.1.6. Lower Muskegon River Watershed Project Area Macroinvertebrate Results For Zone 1

Station	Chironomids	*Hexagenia*	Plecoptera	Odonata	Hemiptera	Coleoptera
	# / m^3	# / m^3	# / m^3	# / m^3	# / m^3	# / m^3
11	60	182	0	30	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
9	0	0	0	0	0	0

3.2 ZONE 2

Zone 2 covers 4604.3 acres and includes the section of the Muskegon State Game Area located between US-31 and Mill Iron Road. The GIS landcover data for this zone is summarized in Table 3.2.1. Zone 2 consists primarily of lowland hardwood (24%), central hardwood (19%), and aquatic bed (18%). A total of 3072.4 acres are classified as wetlands (67%). Central hardwoods, urban, and transportation classifications dominate the upland regions. Wetland environments (open water, aquatic beds, emergents, wetland shrubs, and lowland hardwoods) cover the land in the lower elevations. The stream gradient for the South Branch of the River had an elevation drop of 1.5 meters over 5.56 river kilometers. The North Branch has a drop in elevation of 1 meter over 4.73 kilometers. Landcover change statistics for the period of 1978-1997 are presented in Figure 3.2.1 and summarized in Table 3.2.2. Dramatic increases in aquatic bed (729.4 acres), wetland shrub (884.6 acres),

urban (108.7 acres), and emergent areas (109.2 acres) were noted. In contrast, pine forested areas decreased by 156.7 acres, lowland hardwoods by 730.5 acres, and lowland conifers by 992.8 acres. A total of 47% of the wooded wetland environment was lost in this region from 1978 to 1997 and replaced by aquatic beds and wetland shrubs. The remnants of the former forest cover are visible as stands of dead timber and fallen trees. These changes occurred as a result of increasing water levels throughout the zone. While lowland conifers and hardwoods are tolerant of seasonal high water, they cannot survive in the hydrologic conditions that support emergent and aquatic bed vegetation. Standing water was present in much of the wetland areas during the summer of 1999. The only other major land cover change was the addition of 108.7 acres of urban areas. This change was the result of residential and commercial development along the borders of the Muskegon State Game Reserve.

Table 3.2.1. Lower Muskegon River Watershed Project Area 1997 Landcover Data For Zone 2

Classification	Acreage	Percent of Total
Agricultural	0.0	0
Aquatic Bed	831.3	18
Central Hardwood	857.2	19
Commercial	14.9	0.3
Emergent	109.2	2
Herbaceous	21.5	0.5
Lowland Hardwood	1096.9	24
Non-forested Shrub	78.7	2
Open Land	7.0	0.2
Pine	16.0	0.3
Transportation	260.5	6
Urban	306.0	7
Water	29.5	1
Wetland Shrub	976.1	21
Total Acreage	4604.6	100
Total Wetlands	3042.9	6

Figure 3.2.1 Lower Muskegon River Watershed Project Area Landcover Changes for Zone 2, 1978-1997

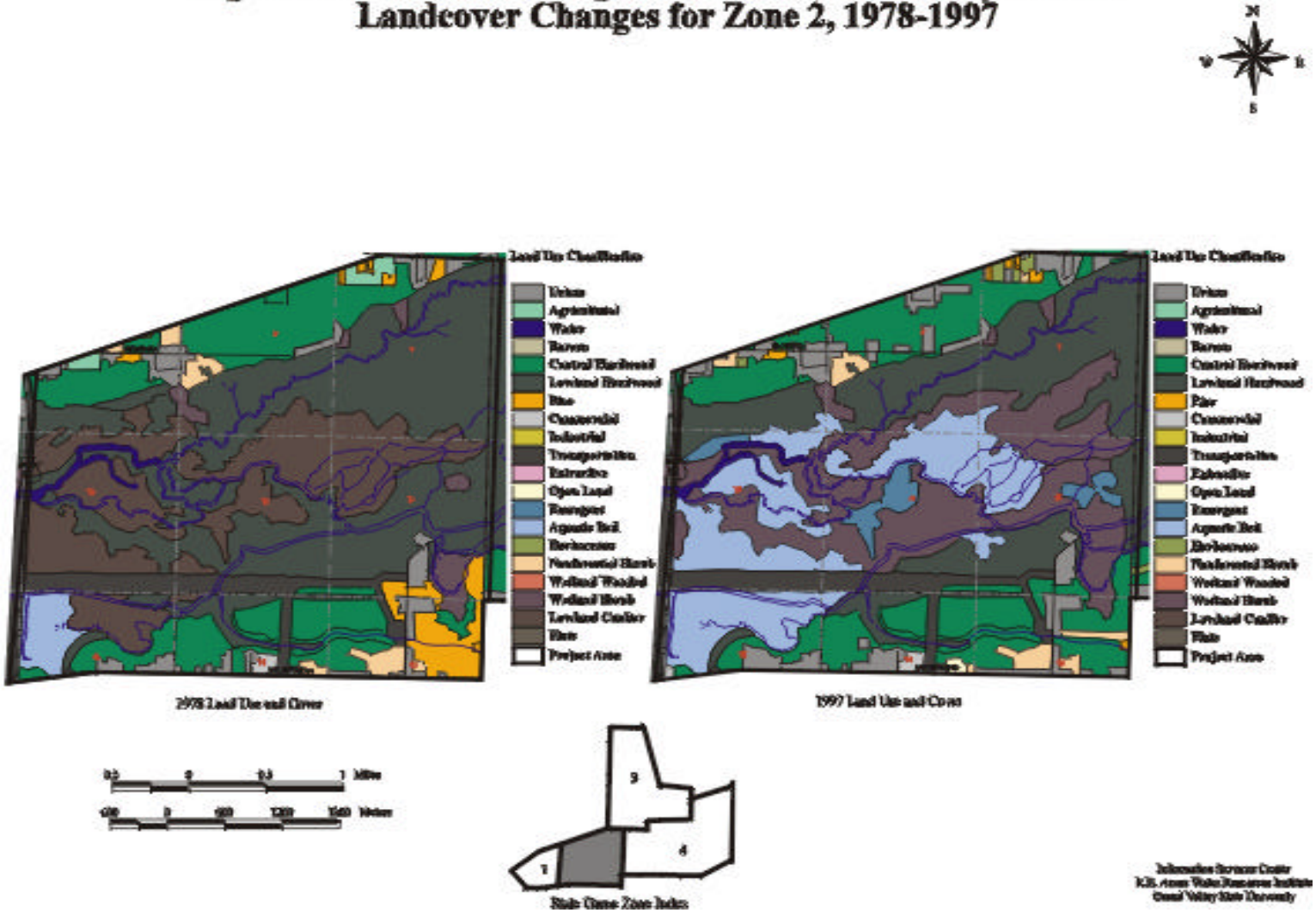


Table 3.2.2. Lower Muskegon River Watershed Project Area Landcover Changes From 1978 To 1997 In Zone 2

Classification	Acreage 1978	Acreage 1997	Change in Acres	Percent Change
Agricultural	40.0	0.0	-40.0	-0.87
Aquatic Bed	**101.9**	**831.3**	**729.4**	**15.84**
Central Hardwood	799.8	857.2	57.4	1.25
Commercial	11.5	14.9	3.4	0.07
Emergent	**0.0**	**109.2**	**109.2**	**2.37**
Herbaceous	0.7	21.5	20.7	0.45
Lowland Conifer	**992.8**	**0.0**	**-992.8**	**-21.56**
Lowland Hardwood	**1827.3**	**1096.9**	**-730.5**	**-15.86**
Non-forested Shrub	77.1	78.7	1.6	0.03
Open Land	0.0	7.0	7.0	0.15
Pine	**172.7**	**16.0**	**-156.7**	**-3.40**
Transportation	262.5	260.5	-2.1	-0.04
Urban	**197.3**	**306.0**	**108.7**	**2.36**
Water	29.5	29.5	0.0	0.00
Wetland Shrub	**91.5**	**976.1**	**884.6**	**19.21**
Total Water and Wetland Areas	3042.9	3042.9	0.0	0.00

(Significant landcover changes in bold print)

Field surveys were conducted throughout this zone along the North Branch and South Branch of the Muskegon River. The North Branch was widest at the mouth (approximately 400 feet) then narrowed to approximately 10 feet, finally expanding to approximately 120 feet at the tributary of the South Branch of the Muskegon River. Major plant and animal species observed in the area are summarized in Table 3.2.3 along with the habitat characteristics. Forest species include willow, elm, ash, oak and maple. The trees were concentrated on the higher elevation portions of the streambank and along depositional levies. Areas beyond the depositional levies contained dead trees and emergent/aquatic bed vegetation. Emergent and aquatic vegetation included sedge grasses, cattails, and hydrophytic vegetation described in Zone 1. Figure 3.2.2 depicts the typical wetland environment found within Zone 2. Transitional environments are common with open waters moving to aquatic beds and then to emergents. Wetland shrubs and trees are found along the banks and shore. No evidence of lowland conifer trees was noted in the area of Zone 2 that was shown in the 1978 MIRIS data. The standing dead trees all appeared to be deciduous. Based on these observations, the 1978 MIRIS data may be in error and should be reclassified as wooded wetland.

Table 3.2.3. Lower Muskegon River Watershed Project Area Major Plant And Animal Species Within Zone 2

Sampling Location	Primary Vegetation And Habitat Type	MIRIS Classification	Wildlife Sightings Or Signs
Station 5 Mosquito Creek Tributary at Mill Iron Road Public Access	Willow, elm, and maple (33%) reeds and cattails (33%) aquatic vascular plant (33%)	Wetland Shrub and Lowland Hardwood	Red-winged blackbird, turkey vultures, sparrows, canaries, bullfrogs, and garter snake
Station 7 North Channel Tributary	Elm, maple, ash, willow, and oak species (50%) sedge grass species (50%)	Wetland Shrub, Lowland Hardwood, and Aquatic Bed	Barn swallow, sparrows, red-winged black bird, and robin
Station 8 Sheridan Road Public Access	Elm, ash, maple, and willow species (50%) sedge grass and reed species (25%) dead snags (15%) aquatic vascular plants (10%)	Aquatic Bed and Lowland Hardwood	Red-winged blackbird, sparrows, barn swallow, woodpecker, and robin
Station 10 Cedar Creek Tributary	Sedge grasses and cattails (70%) dead snags (10%) elm, maple, and willow (20%)	Aquatic Bed and Wetland Shrub	Red -winged black bird, barn swallow, turtles, garter snake, and muskrat

A typical depositional area is shown in Figure 3.2.3. These sand bar formations occur along the banks near meanders and are covered with shrub and grass type vegetation. Sandy sediments are found in the transition zone to the open water and in the channel. A summary of the erosion impacts observed in Zone 2 is presented in Table 3.2.4. Bank scouring is the most predominant type of erosion, occurring in all locations except Station 10. Extensive undercutting in the meander areas was observed at this location. These conditions are all impacts related to unstable hydrology and sediment deposition. While streambank scouring will contribute sediments to the system, the flat topography and the presence of a heavy vegetative cover suggests the deposited sediments do not originate in this reach of the river and are exported from upstream sources.

Figure 3.2.2. Typical Marsh Environment Located Within Zone 2 At The Confluence Of Mosquito Creek Near Mill Iron Road.

Figure 3.2.3. Sediment Deposition Area Located Within The Muskegon River In Zone 2 That Is Colonized by Emergent Vegetation.

Table 3.2.4. Lower Muskegon River Watershed Project Area Erosion Observations Within Zone 2

Observation Area	Description
Station 5 Mosquito Creek Tributary Mill Iron Road Public Access	Bank scouring of the meanders and areas of deposition
Erosion Area 6 Mill Iron Road Public Access Muskegon River	Areas of deposition and undercutting around the meanders
Erosion Area 7 Upstream of North Branch Tributary	Undercutting near stream banks at meanders and areas of deposition on opposing banks
Station 7 North Channel Tributary	Bank scouring
Station 8 Sheridan Road Public Access	Bank scouring and undercutting
Station 10 Cedar Creek Tributary	Undercutting on the meanders

Water chemistry and benthic macroinvertebrate data are presented in Tables 3.2.5 and 3.2.6 respectively. Total Phosphorus and suspended solids concentrations were lower in the smaller creeks (Mosquito and Cedar) than the branches of the Muskegon River. Mosquito Creek and Cedar Creek have a more stable hydrology and do not have sufficient energy during normal flow to transport high amounts of solids. The stream depth ranged from approximately 1 meter to 4 meters in depth along the South Channel. The North Channel ranged from 1 meter to 3 meters in depth. With the exception of Station 5 on Mosquito Creek and Station 10 on Cedar Creek, the predominant benthic habitat consisted of coarse sand that appeared to be in constant motion. The substrate at Station 5 was more stable and contained detritus and fine clays. Emergent macrophytes were also present and provided a suitable environment to support a large population of aquatic beetles. A pocket of detritus was also present at Station 10 that supported a small population of chironomids.

Table 3.2.5 Lower Muskegon River Watershed Project Area Water Chemistry Results For Zone 2

Date	Sample Area	Total Phosphorus ($T\text{-}PO_4$)	Nitrate ($NO_3\text{-}N$)	Ammonia ($NH_3\text{-}N$)	Suspended Solids
		(mg/L)	(mg/L)	(mg/L)	(mg/L)
8/16/99	Station 8	0.03	0.50	<0.1	6
8/4/99	Station 5	0.02	0.38	0.1	3
8/4/99	Station 10	0.02	0.34	<0.1	3
8/4/99	Station 7	0.03	0.36	0.1	6

Table 3.2.6. Lower Muskegon River Watershed Project Area Macroinvertebrate Results For Zone 2

Station	Chironomids	*Hexagenia*	Plecoptera	Odonata	Hemiptera	Coleoptera
	# / m^2	# / m^2	# / m^2	# / m^2	# / m^2	# / m^2
5	30	30	0	0	0	152
7	0	0	0	0	0	0
8	0	0	0	0	0	0
10	30	0	0	0	0	0

3.3 ZONE 3

Zone 3 covers 8070.6 acres, which includes most of the Cedar Creek Watershed. A majority of the middle and northern portions of Zone 3 are characterized by upland forests and shrubs growing in areas of well-drained soils. The southern quarter of Zone 3 contains wetland vegetation and poorly drained soils. The GIS landcover data for this zone is summarized in Table 3.3.1. The landcover consists of hardwood forest (central 19% and lowland 24%), aquatic beds (18%), and wetland shrubs (21%). There is a total of 3378.4 acres of water and wetland areas located within this Zone. The stream gradient on Cedar Creek has a drop of 10.5 meters over 11.02 river kilometers (0.95 m/km) to where it empties into the Muskegon River. The streambed is found at the bottom of a long moraine system. The banks of the Cedar Creek range from 25% to 45% slope and are heavily vegetated in most areas. Areas

without adequate vegetative cover are subject to the extreme erosional influences of the sandy soil and steep slopes. The erosional influence on this stream is depicted by sand traps located upstream of the project area. These traps collect approximately 2644 yd^3 per year. This volume of sand comes from the flowing sediment within the water of the Cedar Creek. The landcover change statistics between 1978 and 1997 are presented in Figure 3.3.1 and summarized in Table 3.3.2. The largest increase of land cover classification occurred in lowland hardwood (152.3 acres), herbaceous (292.2 acres), and urban areas (194.8 acres). In contrast, there was a decrease in lowland conifers (154.7 acres), non-forested shrubs (216.4 acres), and agricultural (209.4 acres). These areas of change occurred throughout the middle and northern sections of Zone 3. The loss of agricultural landcover corresponds to an increase in herbaceous plants. This pattern indicates the farmland was taken out of active production. Although there was a loss in the lowland conifers, according to MIRIS data, field observations revealed dense growths of lowland conifers (hemlock) bordering the northern portions of the Creek system. Many of the hemlocks are shaded by the larger hardwoods in the riparian canopy. Because of the sloping banks and shading, the lowland conifer trees may not be visible in the aerial imagery and incorrectly represented in the landcover analysis. The other area of significant change was the increase in urban development and the corresponding loss of non-forested shrubs. Most of the residential development appears to be occurring in open areas.

Table 3.3.1. Lower Muskegon River Watershed Project Area 1997 Landcover Data For Zone 3

Classification	Acreage	Percent of Total
Agriculture	86.5	1
Aquatic Bed	54.9	1
Barren	0.1	0
Central Hardwood	5212.4	65
Commercial	11.2	0
Emergent	105.9	1
Herbaceous	378.9	5
Lowland Conifer	283.0	4
Lowland Hardwood	608.0	8
Nonforested Shrub	423.8	5
Pine	318.1	4
Urban	522.9	6
Water	51.9	1
Wetland Shrub	13.6	0
Total Acreage	8071.2	100
Total Wetlands	1128.5	14

Table 3.3.2. Lower Muskegon River Watershed Project Area Landcover Changes From 1978 To 1997 In Zone 3

Classification	Acreage 1978	Acreage 1979	Change In Acres	Percent Change
Agriculture	**295.9**	**86.5**	**-209.4**	**-2.59**
Aquatic Bed	54.8	54.9	0.1	0.00
Barren	4.1	0.1	-4.0	-0.05
Central Hardwood	5284.5	5212.4	-72.1	-0.89
Commercial	16.2	11.2	-5.0	-0.06
Emergent	105.9	105.9	0.0	0.00
Herbaceous	**86.7**	**378.9**	**292.2**	**3.62**
Lowland Conifer	**437.7**	**283.0**	**-154.7**	**-1.92**
Lowland Hardwood	**455.8**	**608.0**	**152.3**	**1.89**
Non-forested Shrub	**640.2**	**423.8**	**-216.4**	**-2.68**
Pine	295.7	318.1	22.4	0.28
Urban	**328.2**	**522.9**	**194.8**	**2.41**
Water	51.3	51.9	0.6	0.01
Wetland Shrub	13.6	13.6	0.0	0.00
Total Water and Wetland Areas	1013.2	1011.4	-1.8	-0.02

(Significant landcover changes in bold print)

Field surveys of Zone 3 were conducted along Cedar Creek and the southern portion of the Muskegon River. Cedar Creek was easily wadded and contained dense areas of woody debris. The major plant animal species observed in the area are summarized in Table 3.3.3 along with the habitat characteristics. Forest species include willow, elm, maple, hemlock, and pine. The riparian areas of Cedar Creek provide a large amount of shading where forested areas are present. Figure 3.3.2 shows a typical riparian zone found within the upper Cedar Creek watershed. The stream is heavily shaded and both small and large pieces of woody debris are abundant.

Evidence of erosion was observed at all Stations in Zone 3. The type of erosion observed is presented in Table 3.3.4 and shown in Figure 3.3.3. The undercutting of the banks is the most predominant type of erosional activity observed. A large area of erosion was recently corrected near Station 15 by installing a rock rip-rap along the foot of the bank. Throughout Zone 3 there have been five stabilization projects performed to restore the riparian area to a more natural state. A combination of local areas and export from upstream sources contribute to the influx of sediment to Cedar Creek.

Water chemistry and benthic macroinvertebrate data are presented in Table 3.3.5 and 3.3.6 respectively. Nutrient and suspended solids concentrations were similar at all locations except for Station 15 off Sweeter Road.

Figure 3.3.1 Lower Muskegon River Watershed Project Area Landcover Changes for Zone 3, 1978-1997

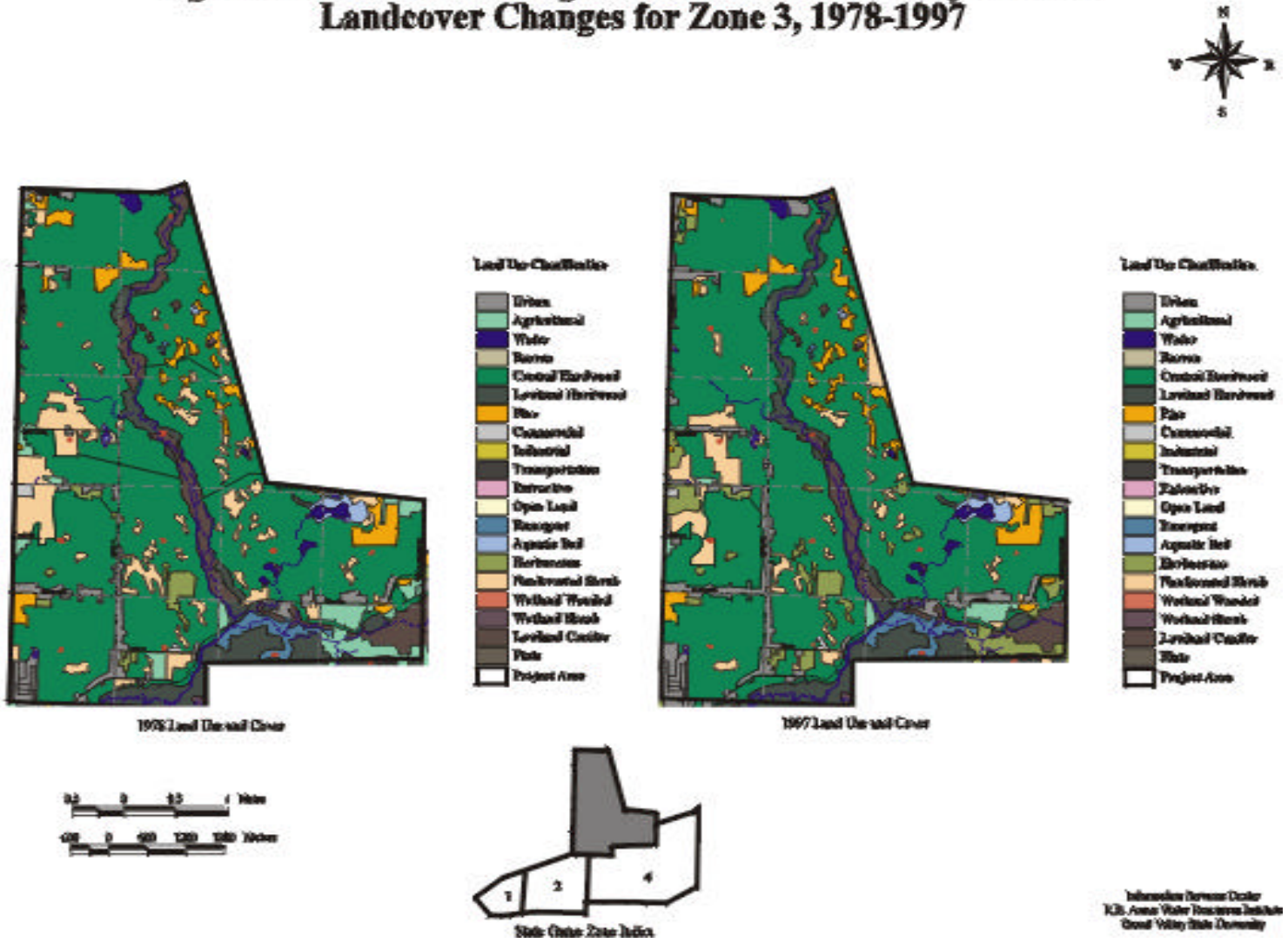


Table 3.3.3. Lower Muskegon River Watershed Project Area Major Plant And Animal Species Within Zone 3

Sampling Location	Primary Vegetation And Habitat Type	MIRIS Classification	Wildlife Sightings Or Signs
Station 14 Ryerson Road Access	Elm, maple, and ash species (80%) sedge grass species (20%)	Lowland Hardwood	Barn swallow, sparrow, robin, raccoon, and white-tailed deer
Station 15 Sweeter Road Access	Elm, ash, maple, hemlock, and willow species (95%) sedge grass species (5%)	Lowland Conifer and Central Hardwood	Ducks, robins, sparrow, white-tailed deer, raccoon, muskrat, and garter snake
Station 16 Area 1 River Road Road/Stream Crossing	Sedge grass species (50%) willow and maple species (50%)	Emergent and Lowland Hardwood	Barn swallow, robin, sparrow, and ducks
Station 17 River Road Public Access	Elm, ash, maple, and willow species (95%) sedge grass species (5%)	Lowland Hardwood and Central Hardwood	Sparrow and robin

Table 3.3.4. Lower Muskegon River Watershed Project Area Erosion Observations Within Zone 3

Observation Area	Description
Station 14 Ryerson Road Access	Bank undercutting
Station 15 Sweeter Road Access	Bank undercutting
Station 16 River Road Road/Stream Crossing	Bank undercutting and areas of deposition
Station 17 River Road Public Access	Bank undercutting and areas of deposition

Table 3.3.5. Lower Muskegon River Watershed Project Area Water Chemistry Results For Zone 3

Date	Sample Area	Total Phosphorus ($T\text{-}PO_4$)	Nitrate ($NO_3\text{-}N$)	Ammonia ($NH_3\text{-}N$)	Suspended Solids
		(mg/L)	(mg/L)	(mg/L)	(mg/L)
8/16/99	Station 15	0.05	0.60	<0.1	5
8/3/99	Station 14	0.03	0.16	0.2	2
8/5/99	Station 16	0.03	0.24	<0.1	2
8/5/99	Station 17	0.02	0.18	<0.1	3

Table 3.3.6. Lower Muskegon River Watershed Project Area Macroinvertebrate Results For Zone 3.

Station	Chironomids	*Hexagenia*	Plecoptera	Odonata	Hemiptera	Coleoptera
	# / m^2	# / m^2	# / m^2	# / m^2	# / m^2	# / m^2
14	91	152	0	0	30	0
15	182	300	0	0	0	0
16	30	95	0	30	0	0
17	30	61	30	0	0	0

The elevated levels of total phosphate, nitrate, and suspended solids suggest a source of nonpoint source pollution is present upstream. The Creek's depth ranged from approximately 6 inches to over 6 feet in the meander pools. The stream bottom consisted mainly of sand with small pockets of silt near the hydrophytic vegetation and coarse woody debris. There were areas of sediment deposition on the opposing banks near the River Road access point. These areas were colonized by aquatic and emergent vegetation such as sedge grasses and cattails. Large populations of *Hexagenia sp*. were found near the Sweeter Road access point and in several other areas along the waterway. The benthic organisms were predominately found in the organic detritus and muck sediments near the stream edge and in association with aquatic and emergent plants.

Figure 3.3.2. Riparian Zone Of Cedar Creek Near Sweeter Road.

Figure 3.3.3. Area Of Significant Stream Bank Erosion Along Cedar Creek Near Sweeter Road.

3.4 ZONE 4

Zone 4 consists of 9662.7 acres and includes the area between Mill Iron Road and Maple Island Road. The GIS landcover data for this zone is summarized in Table 3.4.1. Zone 4 consists primarily of central hardwood (26%) and lowland hardwood (33%). There are a total of 4727.3 acres of water and wetland area located within Zone 4 (49%). The stream gradient in the Muskegon River is moderately flat with a drop of 3 meters over 11.05 river kilometers. The landcover change statistics from 1978 to 1997 are presented in Figure 3.4.1 and summarized in Table 3.4.2. In this Zone, the largest change in landcover decrease in agricultural land (489.7 acres) and the corresponding increase in herbaceous species (545.2 acres). The landcover in this area changed primarily due to a decrease in farming activity in the State Game Area. The only other area of significant change was related to the replacement of 71 acres of lowland conifers with emergent vegetation along Mosquito Creek below the former discharge of the Muskegon County Wastewater Management System. The water added to the stream from the wastewater discharge may have caused localized flooding which resulted in the loss of the conifer trees. The fact that the conifers were replaced by emergent beds indicates a persistent elevation in water table.

Table 3.4.1. Lower Muskegon River Watershed Project Area 1997 Landcover Data For Zone 4

Classification	Acreage	Percent of Total
Agriculture	1296.4	13
Aquatic Bed	12.1	0
Central Hardwood	2545.2	26
Commercial	40.9	0
Emergent	407.0	4
Extractive	6.8	0
Flats	0.0	0
Herbaceous	575.9	6
Lowland Conifer	126.7	1
Lowland Hardwood	3186.6	33
Non-forested Shrub	64.3	1
Open land	28.2	0
Pine	49.6	1
Transportation	177.0	2
Urban	179.2	2
Water	133.7	1
Wetland Shrub	833.1	9
Acreage Sum	9662.7	100
Total Wetlands	4727.3	49

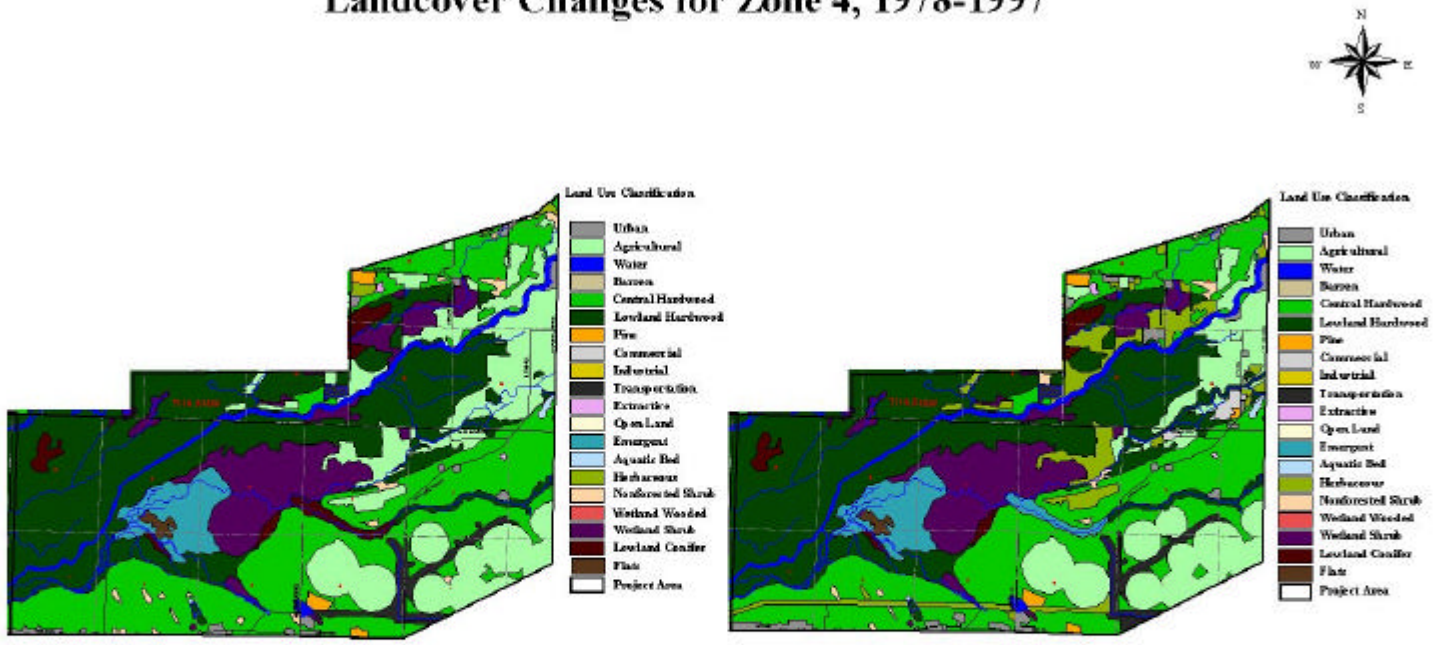
Table 3.4.2. Lower Muskegon River Watershed Project Area Landcover Changes For Zone 4 From 1978 To 1997

Classification	Acreage 1978	Acreage 1997	Change in Acres	Percent Change
Agriculture	**1786.1**	**1296.4**	**-489.7**	**-5.07**
Aquatic Bed	12.1	12.1	0.0	0.00
Central Hardwood	**2679.6**	**2545.2**	**-134.4**	**-1.39**
Commercial	0.0	40.9	40.9	0.42
Emergent	336.0	407.0	71.0	0.73
Extractive	5.8	6.8	1.1	0.01
Flats	28.2	0.0	-28.2	-0.29
Herbaceous	**30.7**	**575.9**	**545.2**	**5.64**
Lowland Conifer	197.7	126.7	-71.0	-0.73
Lowland Hardwood	3133.5	3186.6	53.0	0.55
Non-forested Shrub	75.1	64.3	-10.7	-0.11
Open land	0.0	28.2	28.2	0.29
Pine	44.9	49.6	4.7	0.05
Transportation	202.7	177.0	-25.8	-0.27
Urban	100.2	179.2	79.1	0.82
Water	133.7	133.7	0.0	0.00
Wetland Shrub	896.6	833.1	-63.5	-0.66
Total Water and Wetland Areas	4709.5	4699.1	-10.4	-0.11

(Significant landcover changes in bold print)

Field surveys of Zone 4 were conducted along the Muskegon River and Mosquito Creek. The Muskegon River, during the field study, was relatively deep and navigable. The Muskegon River contained large amounts of dead snags and coarse woody debris. Areas of deposition were found throughout the system. At these locations, aquatic and emergent vegetation were found. The major plant and animals species observed in the area is summarized in Table 3.4.3. Forest species include the willow, maple, ash, oak, and hemlock. The distribution and species type are consistent with 1997 MIRIS data used in the GIS system. The riparian areas of the Muskegon River provide partial shading due to the width of the river and the quality of the tree cover. Periodic flooding along the banks apparently limits the growth of larger trees. Mosquito Creek is partially shaded by larger overhanging trees above the creek. Figure 3.4.2 shows a typical riparian area found within the zone. This area is located downstream from the wastewater discharge site. It is important to note the number of trees that are in various stages of falling into the channel. The Muskegon River's depth ranges from approximately 2 meters to 3.5 meters. The stream bottom consists of coarse sand, with small areas of organic sediments. Within these organic deposits are large amounts of coarse woody debris and hydrophytic vegetation.

Figure 3.4.1 Lower Muskegon River Watershed Project Area
Landcover Changes for Zone 4, 1978-1997



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R.R. Annis Water Resources Institute
Grand Valley State University

Table 3.4.3. Lower Muskegon River Watershed Project Area Major Plant And Animal Species Within Zone 4

Sampling Location	Primary Vegetation And Habitat Type	MIRIS Classification	Wildlife Sightings Or Signs
Station 1 Maple Road Public Access	Open water (80%), Elm and maple species (15%), and sedge grass species (5%)	Urban	Ducks, barn swallow, and sparrow
Station 2 Brickyard Road Public Access	Sedge grass species (60%) elm, maple, ash, willow, and oak (40%)	Lowland Hardwood and Herbaceous	Ducks, geese, sparrows, hawks, robin, garter snake, white-tailed deer and muskrat
Station 3 Holton Duck Lake Road Public Access	Sedge grass species (40%) elm, maple, ash, willow, and oak (60%)	Herbaceous and Wetland Shrub	Sparrow, ducks, geese, muskrat, white-tailed deer
Station 4 Waste Water Treatment Discharge	Willow and ash species (30%) sedge grasses (70%)	Herbaceous and Lowland Hardwood	Garter snake, ducks, geese, swan, white-tailed deer, and muskrat
Station 6 Mosquito Creek	Hemlock (80%) sedge grass species (20%)	Lowland Hardwood	Sparrow, red-winged black bird

Figure 3.4.2. Typical Riparian Areas And Vegetation Within Zone 4.

Figure 3.4.3. Typical Areas Of Erosion Within Zone 4.

A typical area of erosion in Zone 4 is shown in Figure 3.4.3. While this figure shows mass wasting of the stream bank due to periodic flood events, the sandy consistency of the material suggests the structure is a depositional levy. These formations cause the pooling of water on the opposite side and restrict normal drainage patterns. A summary of other erosional features is provided in Table 3.4.4. All of these impacts are caused by water with a high erosional velocity. There is no evidence that local runoff is the source of the erosional affects observed in Zone 4.

Table 3.4.4. Lower Muskegon River Watershed Project Area Erosion Observations Within Zone 4

Observation Area	Description
Station 1 Maple Road Public Access	Undercutting on the meanders
Erosion Area 1 0.15 river km downstream of Brickyard Road Public Access	Severe bank failure
Station 2 Brickyard Road Public Access	Undercutting on the meanders
Erosion Area 2 0.90 river km upstream of Mill Iron Road Public Access	Severe bank failure
Station 3 Holton Duck Lake Road Public Access	Undercutting on the meanders and areas of deposition
Erosion Area 3 0.73 river km upstream of Mill Iron Road Public Access	Severe bank failure and undercutting near the meanders
Station 4 Waste Water Treatment Discharge	Bank undercutting
Erosion Area 4 0.67 river km upstream of Mill Iron Road Public Access	Undercutting on the meanders
Erosion Area 5 0.52 river km upstream of Mill Iron Road Public Access	Undercutting on the meanders
Station 6 Mosquito Creek	Undercutting on the meanders

Water chemistry and macroinvertebrate data collected within Zone 4 are shown in Table 3.4.5 and Table 3.4.6 respectively. Suspended solids and total phosphate were similar at all Muskegon River stations. Nitrate at Station 4 was higher due to its proximity to the wastewater discharge site. In contrast, water chemistry results from Mosquito Creek (Station 6) were considerably lower for suspended solids and total phosphate. The substrate at this location was primarily composed of coarse sand, which accounted for the lack of benthic organisms found. The other locations contained organic detritus and woody debris that provided a more stable habitat. Mayflies were abundant in the area below the wastewater treatment discharge.

Table 3.4.5. Lower Muskegon River Watershed Project Area Water Chemistry Results For Zone 4

Date	Sample Area	Total Phosphorus ($T\text{-}PO_4$)	Nitrate ($NO_3\text{-}N$)	Ammonia ($NH_3\text{-}N$)	Suspended Solids
		(mg/L)	(mg/L)	(mg/L)	(mg/L)
8/16/99	Station 1	0.03	0.49	<0.1	18
8/16/99	Station 2	0.02	0.48	<0.1	17
8/16/99	Station 3	0.03	0.48	<0.1	16
8/16/99	Station 4	0.03	4.9	0.1	15
8/4/99	Station 6	0.01	0.38	0.1	3

Figure 3.4.6. Lower Muskegon River Watershed Project Area Macroinvertebrate Results For Zone 4.

Station	Chironomids	*Hexagenia*	Plecoptera	Odonata	Hemiptera	Coleoptera
	# / m^2	# / m^2	# / m^2	# / m^2	# / m^2	# / m^2
1	90	0	0	0	0	0
2	60	0	0	0	0	0
3	124	0	0	0	0	0
4	60	240	0	30	0	0
6	0	0	0	0	0	0

4.0 Discussion

4.1 LANDCOVER CHANGES

A summary of landcover changes in the lower Muskegon River watershed is shown in Figure 4.1.1. The most significant changes are summarized below:

- 240 acres of wetland shrubs lost in Zone 1 and replaced by emergents and aquatic beds;
- 1723 acres of wooded wetland areas lost in Zone 2 and replaced by wetland shrubs, emergents, and aquatic beds;
- 195 acres of new urban development in Zone 3; and
- 490 acres of agricultural land taken out of production in Zone 4.

Zones 1 and 2 have clearly been impacted by rising water levels and siltation. While the MIRIS data does not have sufficient resolution to show changes in channel morphology, the NOAA navigation charts for Muskegon Lake show that a dramatic change in the channels of the three branches occurred from 1979 to 1997. The 1979 navigation chart (Figure 4.1.2) shows the clear channels for the North, Middle, and South Branches of the Muskegon River. In contrast, the 1997 navigation chart (Figure 4.1.3) shows the Middle Branch almost closed with a small meander lake located north of the channel. This body of open water was once a channel that connected the north and the Middle Branches of the Muskegon River. The Middle Branch has several large sediment deposits in the channel. The small island shown downstream of the bridge is the same feature shown in Figure 3.4.3. The green area in the channel indicates shallow water and submerged vegetation. The 1979 channel was deeper and clear. In contrast, the South Branch remains open although pockets of submerged vegetation are prevalent indicating shallower water depths. Similarly, the North Branch has also changed with respect to morphology and depth. Islands of sediment deposits are visible and submerged vegetation is common. The upper branch of the river had a depth of 5 ft to the west of the CSX railroad in 1979. This area is depicted as a shallow aquatic bed on the 1997 map. In addition, a large, new area of submerged vegetation is visible between M-120 and the CSX bridge. The current shallow morphology of the channel is not a function of lake levels, since the water level of Muskegon Lake actually increased from 576.6 ft to 577.5 ft. during this timeframe. The MIRIS data and the NOAA charts support the hypothesis of a shallower and wider Muskegon River that has been severely impacted by siltation.

In its natural state, the North and South Branches of the Muskegon River would flood during rain events and discharge over a wide area into the lake. The elevated roads and bridges that make up the M-120 and Business US31 highway systems have created artificial restrictions in the river valley that act to pool water behind the structures during flooding. In addition, the

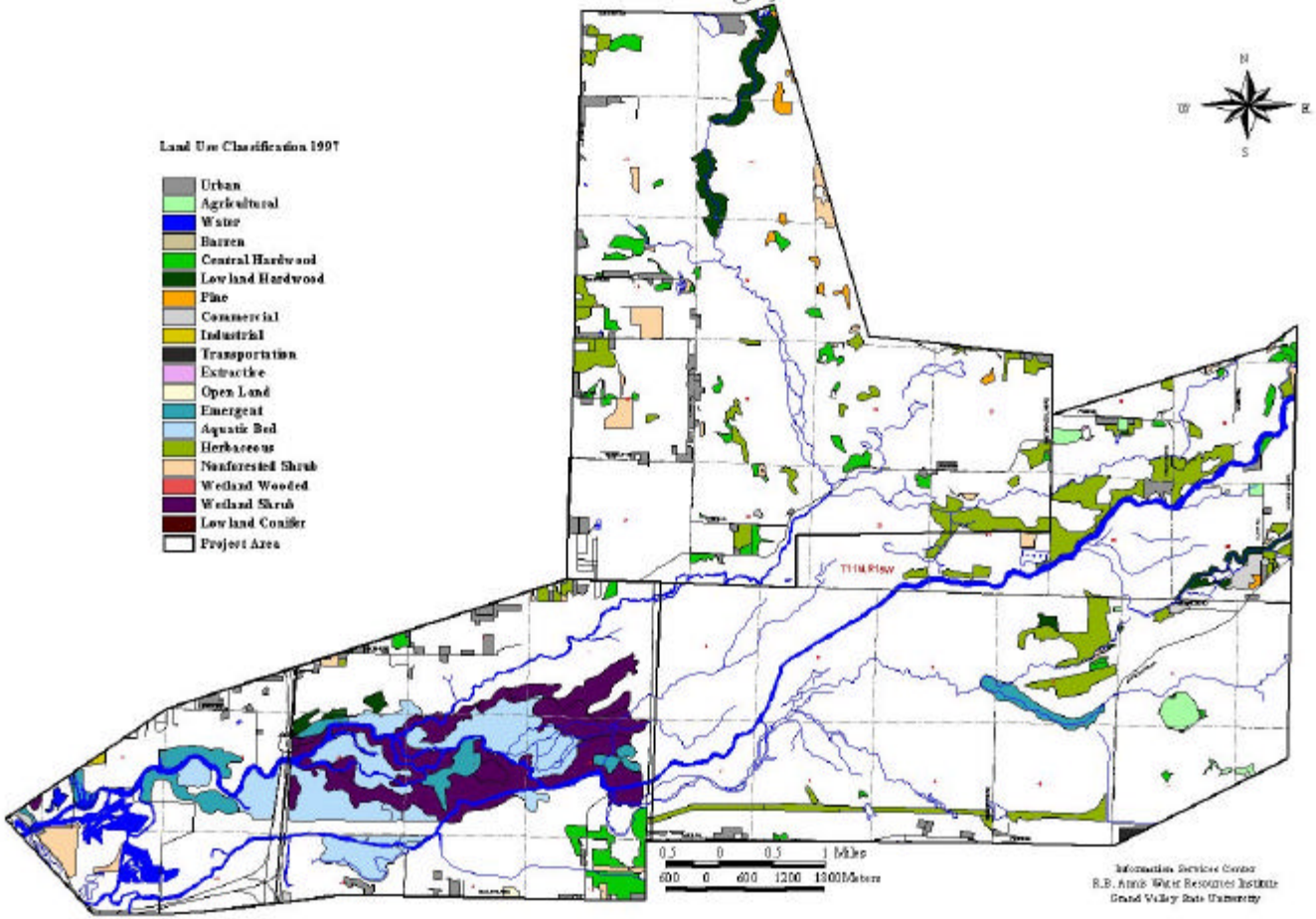
Consumers Energy fly ash disposal area would also act as a barrier and pool water in the direction of the South and Middle Branches. As the flood water is pooled, it loses energy, and suspended sediments are deposited in channels and wetland areas. As the river becomes shallower, floods are more frequent and the deposition cycle continues, forcing wider areas of water behind the bridge and road restrictions.

Depositional levies also form along the stream banks that act to inhibit drainage and elevate water levels. The loss of 240 acres of wetland shrubs and their replacement by emergents and aquatic beds is a direct result of the broadening of the watercourse behind the road and bridge system.

The same flooding phenomenon is evident in Zone 2. The results, however, are more dramatic, as 1723 acres of wooded wetland areas was lost in Zone 2 and replaced by wetland shrubs, emergents, and aquatic beds. Based on a review of aerial images from 1938, wooded wetland vegetation was well established and stable in Zone 2 for at least 40 years prior to the 1978 MIRIS map. The causative factors that resulted in the extended flooding of Zone 2 are again related to sedimentation and the restrictions in the watercourse. The US-31 highway and bridge system creates an artificial restriction to the flow of flood water. Energy loss occurs as the water is pooled and the suspended sediment is then deposited. The results are a shallower and wider river in this section of the watershed. A rise in elevation occurs to the east of Mill Iron Road and is evident in the stream gradient and the topography. This increase in elevation will act to confine the flooding to the area of Zone 2. It is interesting to note the hydrologic changes in Zone 2 were sufficiently robust to maintain high water conditions during the record low lake levels recorded during the fall of 1999. This observation suggests a relatively permanent change in river hydrology has occurred and fluctuations in lake levels do not drive the system.

In contrast to Zones 1 and 2, the Muskegon River maintained its riparian character in Zone 4 as landcover changes from persistent flooding were not evident in the MIRIS data. However, erosional impacts were visible during the field survey with respect to streambank erosion and sediment deposition in the riparian zone. While Figure 3.4.2 shows a dense riparian zone, many of the trees are in various stages of falling into the water from erosional uprooting. Historically, the stream banks were stable enough for the large trees to become established and mature. The recent hydrology has become more unstable and is now uprooting the riparian vegetation closest to the banks. The most significant observation from this zone was the presence of moving bedload sand. The river bottom is composed of coarse sand greater than one foot in depth. Sufficient energy is available to continuously move bedload sand downstream during normal flow regimes. When the coarse grained material settles out after a flood event, it is still mobile as bedload sand along the bottom. This sand is then moved to the wetlands and Muskegon Lake for final deposition. The absence of significant internal

Figure 4.1.1 Lower Muskegon River Watershed Project Area Landcover Change, 1978-1997



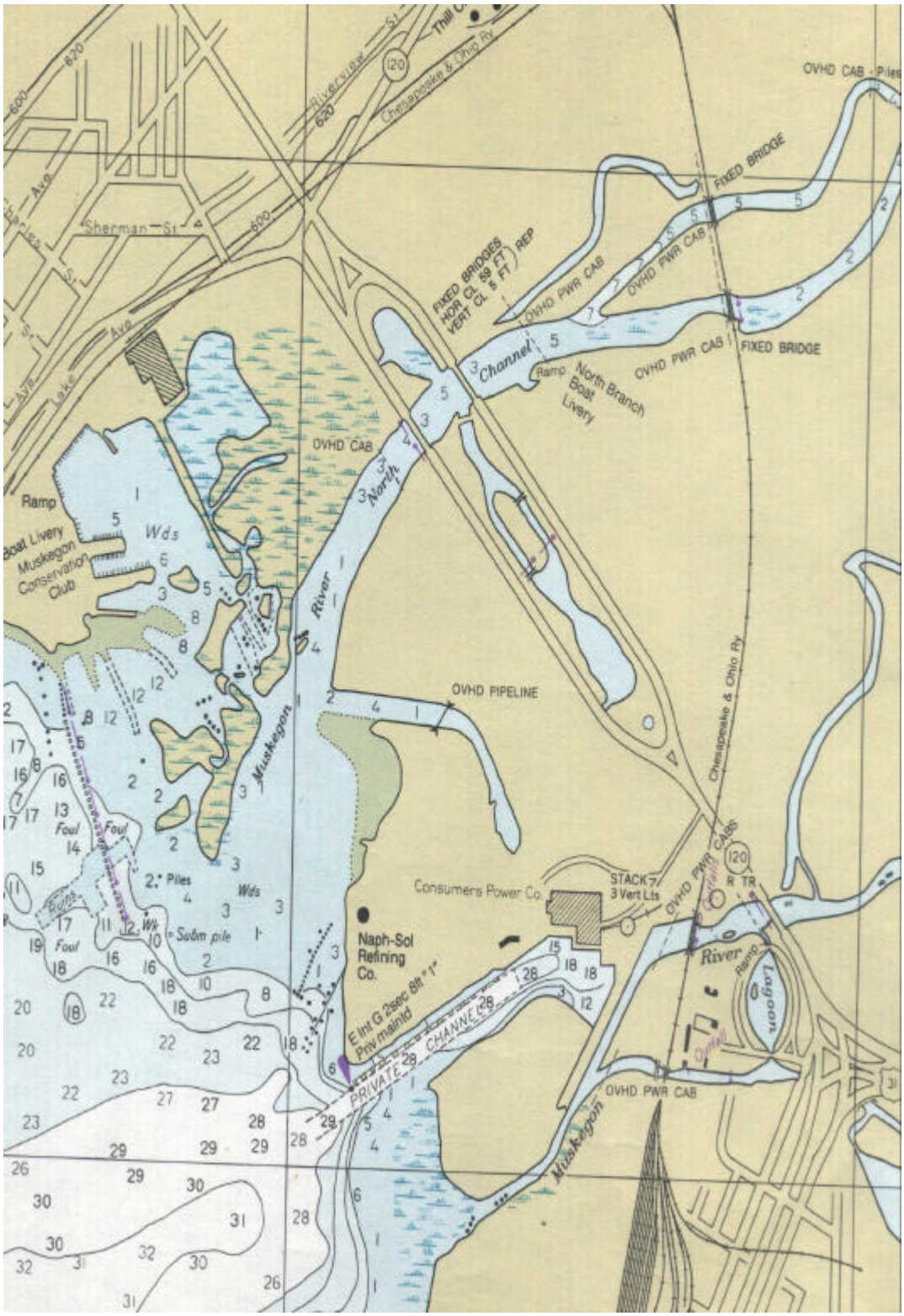


Figure 4.1.2. 1979 NOAA Navigation Chart For Muskegon Lake.

Figure 4.1.3 1997 NOAA Navigation Chart For Muskegon Lake.

sources of sediment indicates that massive erosion from the upstream river segment between Maple Island Road and Croton Dam in Newaygo is the source of the problem.

The only significant landcover change to occur in Zone 4 was the removal of 490 acres of agricultural land from active production. A majority of this land was located in the Muskegon State Game Reserve and leased for crop production. While there are advantages to allowing the natural vegetation to reestablish in the area, a food source for wildlife is lost when agricultural production is eliminated. It may be beneficial to evaluate specialized plantings in some of these areas to provide a food source for enhancement of wildlife populations.

Very little landcover change was noted in the riparian corridor of Cedar Creek. The most significant trend outside the riparian zone was the addition of 194 acres of urban development and conversion of 209 acres of agricultural land to herbaceous plants. Given the proximity to the metro Muskegon area and the aesthetic value of the land, this area will undoubtedly be subject to more development pressure. While the Muskegon State Game Reserve protects the riparian corridor of the Muskegon River, much of the land on Cedar Creek is privately held. Zoning ordinances have not been implemented that regulate development in the areas adjacent to Cedar Creek. Given the sandy soil conditions and the steep slopes adjacent to the stream bank, uncontrolled development in the Cedar Creek watershed could pose a serious threat to this fragile system. Breaks in the riparian zone can promote erosion, reduce the influx of woody debris, and increase the temperature of the steam. These conditions would be deleterious to the thriving coldwater fishery found in the stream.

4.2 TERRESTRIAL HABITAT

Two of the key natural features of the lower Muskegon River watershed are its habitat diversity and quality. Habitat diversity is reflected in the variety of upland and wetland environments present in the watershed. Forested and meadow/shrub communities are present in the upland areas while wetland environments including open water marshes, emergents, hydrophytic shrubs, and lowland forests are found in the floodplain. These environments contribute to the diversity of the flora and fauna in the area. Habitat quality is a function of its stability in that the environment can sustain multiple generations over an extended period of time with minimal catastrophic interruptions. High quality environments also contain transition zones that will sustain organisms during various stages in their life cycles and satisfy niche requirements. The flooding and sedimentation in the lower Muskegon River watershed have reduced both habitat diversity and quality. The loss of wetland trees and shrubs significantly impacts the nesting and habitat areas that support many species of birds and small mammals. In addition, this change in vegetation will impact the aquatic environment with respect to a

reduction in woody debris, increased transpiration/evaporation, and an elevation of the temperature.

The Muskegon State Game Reserve is managed primarily for waterfowl (MDNR 1977). Consequently, the elevation of water levels in the floodplain of Zones 1 and 2 would not be considered detrimental for this purpose. In fact, the habitat for waterfowl reproduction and migration has probably been enhanced by the flooding. The absence of biological survey data for the current and historical plant and animal communities makes it difficult to provide any type of qualitative or quantitative assessment of the changes in habitat structure and quality. Similarly, the lack of hydrologic data on the sources and depositional dynamics of the massive influx of sediment in the Muskegon River prohibits the development of predictive models to assess the magnitude and extent of future changes in the watershed. What is certain is that the diversity and quality of the lower Muskegon River watershed have been adversely affected by excessive sedimentation from upstream sources.

4.3 AQUATIC HABITAT

The transport and deposition of sediment is evident in the suspended solids data collected during this evaluation. Figure 4.3.1 shows a comparison of suspended solids data collected in Zones 1, 2, and 4. On a concentration basis, there is a 50% reduction in suspended solids from the samples collected in the main channel in Zone 4 and the samples from the wetland areas of Zones 1 and 2. Most of this change would be related to the deposition of suspended solids in the channel. The small volume of additional water from Cedar Creek and Mosquito Creek would not be sufficient to result in a dilution of the concentration of suspended solids. These results do not contain the bedload sand fraction and therefore underestimate the total amount of sediment moving through the system.

In the Muskegon River, the populations of benthic macroinvertebrates are confined to small areas of stable organic deposition, woody debris jams, and submerged vegetation. In the absence of rock and cobble, backwater areas and woody debris jams are the only environments that have the stability and the food resources present to support the benthic community. Significant numbers of organisms were not found in the sandy sediments that cover a majority of the river bottom. Benthic macroinvertebrates were completely absent at several areas with this type sediment. The combination of the moving and matrix and unstable flow regime results in an environment that will not support these important fish food organisms. Sandy substrates exceeding one foot in depth were common in Zone 4. The depth and quantity of sand present suggests a large supply of moving bedload sand is present in the system that will continue to create unstable conditions for the benthic macroinvertebrates. Any increase in flooding will be deleterious to habitats in the backwater areas that still have organic sediments, woody debris, and macrophytes.

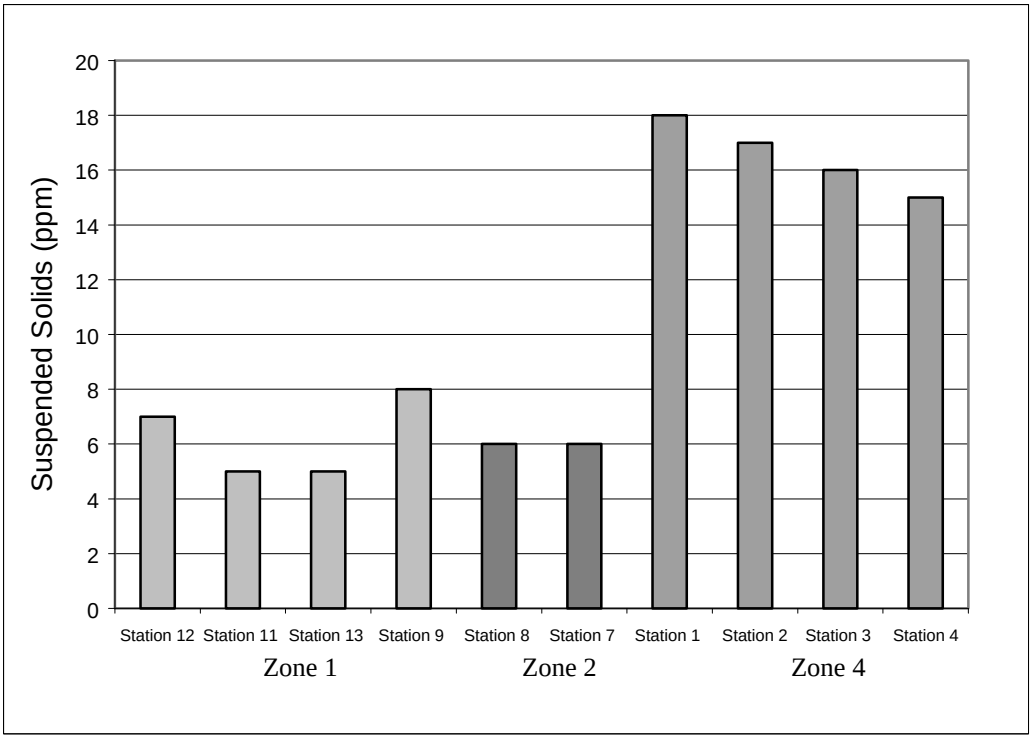


Figure 4.3.1. Suspended Solids Data For Muskegon River Sampling Stations, August 4, 1999.

The benthic community in Cedar Creek reflects a more stable substrate and contains a higher abundance of mayflies and stoneflies. This stream does not have the energy to move bedload sand and consequently provides more favorable conditions for benthic invertebrates. Organic deposits can accumulate in pools, woody debris jams, and around the hydrophytic vegetation. However, deposition from erosional events does result in sand bar deposition and bank scouring. These conditions are not favorable to the benthic invertebrate community. This dichotomy in substrate conditions makes Cedar Creek a very fragile system. The dense riparian areas have provided a stable environment to support a coldwater fishery. The poor soils, sandy substrate, and steep slopes however can disrupt the system if the hydrology is altered or the riparian vegetation is removed. The pressure to develop the area for residential use needs to be balanced with local ordinances that require the preservation of a natural stream corridor and the retention/mitigation of stormwater.

5.0 Recommendations

The results of this preliminary investigation have identified three important areas that need to be addressed for the preservation and enhancement of the natural resources present in the lower Muskegon River watershed:

- critical data gaps exist with respect to the hydrologic and ecological information needed to develop effective management plans,
- a holistic approach must be developed to adequately protect the resource, and
- a public education/outreach program is necessary to foster long term change and build partnerships.

More information is clearly needed in order to develop an understanding of the current biological communities and the physical processes that are involved in supporting and changing their structure. A large scale landcover change has occurred from 1978 to 1997 in the lower Muskegon River watershed. While it is evident the processes of sedimentation and flooding have altered the terrestrial and aquatic communities, the hydrologic factors that have produced this change are not clearly identifiable. The problem of sedimentation appears to be driven by episodic events that deposit coarse sand along the banks, in the wetlands, and in the channel. When the flood waters subside, the flow of Muskegon River has sufficient energy to continue to move bedload sand down the channel and create an unstable habitat for benthic macroinvertebrates and fisheries. The sources of sediment and the dynamics of the transport process are poorly understood and need to be evaluated by a detailed hydrologic modeling study. The hydrologic information and model will be essential to understand the current conditions, evaluate the future of the watershed, and prioritize areas for erosion control. In addition to hydrological data, information on the structure and function of the biological communities is needed to make informed decisions concerning the management of the resource. We know very little about how the current influx of sediment and the elevation in water levels are affecting fisheries and wildlife in the area. Information gleaned from a detailed ecological assessment of the system will drive the decision making process for the lower Muskegon River watershed.

We also need to broaden watershed management plans to holistically embellish the entire resource. The Muskegon State Game Area is currently only managed for waterfowl. The scope of management needs to be expanded to include fisheries, wildlife, and forestry. Land use management is also necessary in the Cedar Creek watershed and the area of the Muskegon River east of Maple Island Road. In the Cedar Creek area, a strong emphasis on preservation of riparian vegetation and maintaining stable stream flow is necessary to preserve the coldwater fisheries. It is also important to continue

the current programs of stream bank stabilization, sand removal, and substrate enhancement to improve fisheries and protect the watershed from flood events. Again, our ability to develop and effectively implement resource management plans for the lower Muskegon River watershed depends on access to detailed hydrologic and ecological information and the formulation of strategies that include these critical variables.

Just as the need for data is critical for the development of watershed management plans, it is also important to disseminate this information to decision makers and the general public. An outreach education program must therefore be developed that identifies the issues and answers, fosters long term stewardship of the resource, and builds effective partnerships that are capable of addressing current and future problems. Public commitment to watershed management depends on understanding the issues and appreciating the value of the resource. Since the problem of sedimentation extends beyond Muskegon County and will require considerable financial resources for analysis and mitigation, the scope of education must include local, regional, state, and national levels. The scope should also span age groups to include children and adults. By focusing education at both age groups, we can address current problems and ensure that future generations have the commitment to preserve the resources of the Muskegon River watershed.

6.0 Conclusions

The Muskegon River is a divergent system of scenic and biologically productive areas that are subject to the adverse impacts of excessive sedimentation and unstable hydrology. While the Muskegon State Game Area acts as a buffer zone around the river and protects it from urban development and local runoff, the export of sediment from upstream locations has resulted in an extensive change in landcover. As part of this project, a study of landcover changes in the lower Muskegon River watershed was performed using aerial imagery from 1978 and 1997. The most significant changes that occurred during this period are summarized below:

- 240 acres of wetland shrubs were lost in the area of the Muskegon River between US-31 and the Causeway from 1978 to 1997. The wetland shrubs were replaced by emergents and aquatic beds more tolerant of elevated water levels.
- 1723 acres of wooded wetland forest were lost in area of the Muskegon River between Mill Iron Road and US-31 from 1978 to 1997. The wooded wetland vegetation was replaced by wetland shrubs, emergents, and aquatic beds. This vegetation is more tolerant of elevated water levels.

The lower Muskegon River watershed contains an extensive marsh/wetland environment that provides critical transitional habitats for fisheries and wildlife. Sedimentation during the last 25 years has filled in the river channels and caused the water to spread laterally across the wetland. Highways and railroad bridges at the western edge of the watershed have created artificial restrictions in the watercourse, resulting in the pooling of flood waters and the subsequent deposition of additional sediment. As a consequence, extensive sand deposition is evident in the eastern end of Muskegon Lake and in the wetlands near the river channels during field surveys performed in 1999. While the wetlands and tributaries of the lower Muskegon River watershed are recognized as natural features significant to the region and to the Great Lakes, very little is known about their ecology and overall function in the system. It is therefore imperative that a detailed assessment of the area fisheries, wetlands, and terrestrial communities be performed. This assessment should document current environmental conditions, define community structure, identify areas of significant change, and determine stress factors. Similarly, the hydrologic variables that have accelerated the export and deposition of sediment in the river from 1978 to 1997 also need to be evaluated in order to develop management plans to mitigate this problem. The lower Muskegon River watershed is a complex system and will require an in depth analysis to obtain the information necessary to develop effective management and restoration plans.

The sedimentation problems of the lower Muskegon River that have developed since 1978 highlight three important paradigms of watershed management:

- knowledge is required to make informed decisions,
- effective resource management must consider the broad range of habitats present, and
- a regional approach is the key to success.

From the above discussion, it is clear that we need more information about the watershed to develop management plans. Without this information, it is impossible to prioritize issues, formulate mitigation strategies, and initiate changes that are beneficial to the system. We must also communicate this information through a public educational process that fosters resource preservation and stewardship. Education will help foster lasting change.

The data from this project also illustrate the importance of a holistic approach to watershed management. The establishment of the Muskegon State Game Area by the Michigan Department of Natural Resources saved a large part of the lower Muskegon River watershed from development. This action however amounts to a large-scale local effort that must be coordinated with other preservation and enhancement activities upstream. Similarly, the current waterfowl management program has been effective in preserving the wetlands for this purpose; however, sedimentation has changed plant communities, altered the hydrology, and impacted fisheries and wildlife. The management of one designated use does not result in the protection of the entire resource. It is important therefore to act on a watershed basis and implement plans to preserve the entire resource.

While the Muskegon River has a large section of protected land that acts as a buffer zone, a majority of the Cedar Creek watershed is privately owned and subject to future development. This stream supports a healthy coldwater fishery that is an important local resource. Cedar Creek is a successful fishery because of its dense riparian vegetation, abundance of woody debris, and ongoing programs to mitigate stream bank erosion and improve benthic habitats. The poor soils and steep slopes characteristic of the upper section of the watershed are very susceptible to erosion by development in riparian areas and the creation of unstable stream hydrology from the introduction of stormwater. These factors underscore a high level of vulnerability in the watershed that will require stewardship and protection of the resources. It is important that stream bank and habitat restoration activities continue to improve vegetative cover and mitigate the sources of siltation. As with the Muskegon River, the future of this important tributary depends on a detailed assessment of the resource, the development of a holistic preservation plan, and a strong public education component.

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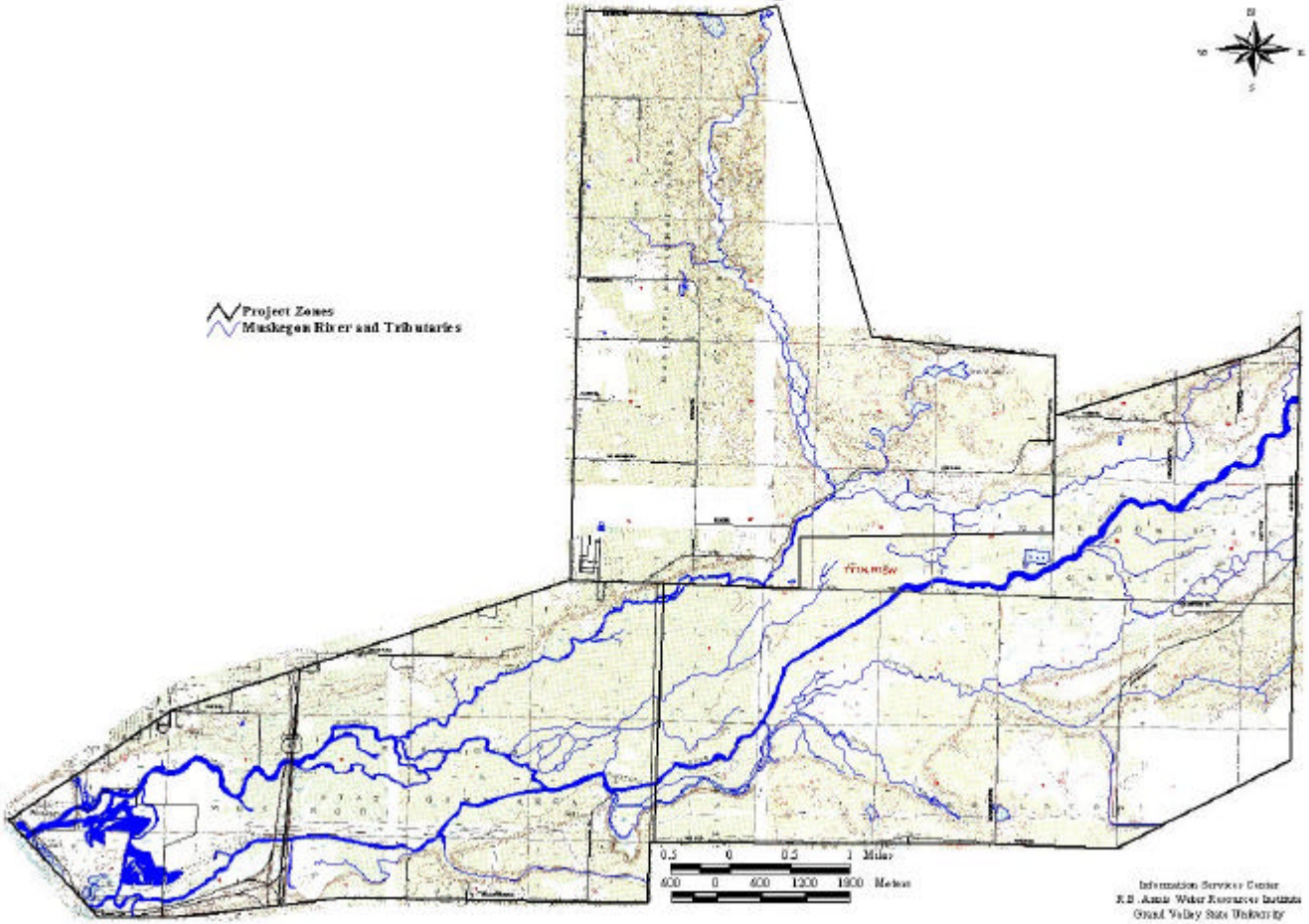
Appendices

APPENDIX A

Figure A-1 Lower Muskegon River Watershed Project Area Contour Map



APPENDIX B

Table B-1. Common Flora Species Found Within The Muskegon State Game Area (MDNR 1977).

american elm	**yellow birch**
sycamore	**cottonwood**
white ash	**pond weeds***
silver maple	**elodea**
sugar maple	**coontail**
red maple	**wild celery**
white willow	**burreed**
weeping willow	**pickeral weed**
black oak	**arrowhead**
red oak	**cordgrass**
yellow water lily	**button bush**
cattail	**alder**
duck weed	**white cedar**
hemlock	**sedge grasses***
red pine	**reeds***
	loosestrife

* Indicates several different species which could not be identified in the field

Table B-2 Common Waterfowl, Amphibian, And Reptile Species Found Within The Muskegon State Game Area (MDNR 1977).

Waterfowl	Amphibians	Reptiles
American widgeon	American toad	Black rat snake
Black duck	Bull frog	Blanding's turtle
Black tern	Central newt	Blue racer
Blue-winged teal	Fowlers toad	Common snapping turtle
Bufflehead	Green frog	Eastern box turtle
Canada goose	Eastern gray tree frog	Eastern garter snake
Canvasback duck	Four-toed salamander	Eastern hognose snake
Common golden eye	Jefferson salamander	Eastern massasauga rattlesnake
Common merganser	Mudpuppy	Eastern milksnake
Greater scaup	Northern cricket frog	Eastern ribbon snake
Green-winged teal	Northern leopord frog	Eastern smooth green snake
Gudwall	Northern spring peeper	Eastern spiny softshell turtle
Hooded merganser	Pickerel frog	Map turtle
Lesser scaup	Red-backed salamander	Midland brown snake
Mallard	Spotted salamander	Midland painted turtle
Mule swan	Western chorus frog	Northern water snake
Red-breasted merganser	Wood frog	Nothern ringneck snake
Redhead Duck		Notrthern brown snake
Pintail duck		Queen snake
Ringneck duck		Spotted turtle
Ruddy duck		Stink pot turtle
Shoveler		Wood turtle
Snow goose		
Tundra swan		
Wood duck		

Table B-3. Common Mammal Species Found Within The Muskegon State Game Area (MDNR 1977).

Badger	Mink
Beaver	Norway rat
Big brown bat	Opossum
Black bear	Pine vole
Cottontail rabbit	Raccoon
Coyote	Red bat
Deer mouse	Red fox
Eastern chipmunk	Red squirrel
Eastern fox squirrel	River otter
Eastern gray squirrel	Short-tail shrew
Eastern mole	Silver haired bat
Gray fox	Southern bog lemming
Hairy bat	Southern flying squirrel
House mouse	Starnose mole
Keen myotis	Striped skunk
Least weasal	Thirteen-lined ground squirrel
Little brown myotis	White tailed deer
Longtail weasel	White-footed deer mouse
Masked shrew	Woodchuck
Meadow jumping mouse	
Mink	
Muskrat	

Table B-4. Common Fish Species Found Within The Muskegon State Game Area (O'Neal 1997).

Northern Brook lamprey	Longnose sucker	Slimy sculpin
Chestnut lamprey	White sucker	White bass
American brook lamprey	Lake chubsucker	White perch
Sea lamprey	Northern hog sucker	Rock bass
Lake sturgeon	Black buffalo	Green sunfish
Longnose gar	Spotted sucker	Pumpkinseed
Shortnose gar	Silver redhorse	Warmouth
Spotted gar	River redhorse	Bluegill
Bowfin	Black redhorse	Longear sunfish
Mooneye	Golden redhorse	Smallmouth bass
American eel	Shorthead redhorse	Largemouth bass
Alewife	Greater redhorse	White crappie
Gizzard shad	Black bullhead	Black crappie
Central stoneroller	Yellow bullhead	Rainbow darter
Goldfish	Brown bullhead	Iowa darter
Lake chub	Channel catfish	Fantail darter
Spotfin shiner	Stonecat	Least darter
Carp	Tadpole madtom	Johnny darter
Brassy minnow	Flathead catfish	Yellow perch
Striped shiner	Grass pickerel	Logperch
Common shiner	Northern pike	Blackside darter
Pearl dace	Muskellunge	Suager
Hornyhead chub	Central mudminnow	Walleye
River chub	Lake herring	Freshwater drum
Golden shiner	Lake whitefish	Pirate perch
Pugnose shiner	Bloater	Banded killifish
Emerald shiner	Coho salmon	Brook silverside
Bigmouth shiner	Rainbow trout	Stickleback
Blackchin shiner	Chinook salmon	Brook stickleback
Blacknose shiner	Round whitefish	Ninespine stickleback
Spottail shinner	Brown trout	Mottled sculpin
Rosyface shiner	Borook trout	Bluntnose minnow
Sand shiner	Lake trout	Fathead minnow
Weed shiner	Arctic grayling	Blacknose dace
Mimic shiner	Trout-perch	Longnose dace
Northern redbelly dace	Pirate perch	Creek chub
Finescale dace	Burbot	Quillback

Table B-5. Common Bird Species Found Within The Muskegon State Game Area

Alder flycatcher	Cowbird	Red-shouldered hawk
American bittern	Crow	Red-tailed hawk
American coot	Eastern bluebird	Red-winged blackbird
American kestrel	Eastern kingbird	Ringed-neck pheasant
Bank swallow	Eastern meadow lark	Robin
Barn swallow	Flycatcher	Rock dove
Barred owl	Great blue heron	Sandpiper
Black capped	Great horned owl	Sharp-shinned hawk
Chickadee	Great-crested sora	Solitary sandpiper
Black-billed cuckoo	Greater yellow leg	Song sparrow
Blackburnian warbler	Green heron	Spotted sandpiper
Black-throated blue warbler	Hairy woodpecker	Starling
Black-throated green warbler	Horned Lark	Swamp sparrow
Blue-jay	House wren	Sharp-shinned hawk
Bobolink	Kingfisher	Solitary sandpiper
Bobwhite	Indigo bunting	Song sparrow
Broad-winged hawk	Killdeer	Starling
Brown creeper	Marsh hawk	Swamp sparrow
Brown thrasher	Mourning dove	Tree swallow
Cardinal	Northern oriole	Tufted titmouse
Catbird	Nuthatch	Turkey vulture
Cedar waxwing	Ovenbird	Veery
Chipping sparrow	Philadelphia vireo	Viginia rail
Cliff swallow	Pied billed grebe	Warbling vireo
Common egret	Pileated woodpecker	White-breasted nuthatch
Common goldfinch	Prothontary warbler	Wilson's snipe
Common snipe	Purple martin	Wood thrush
Cooper's hawk	Red shoulder hawk	Woodcock
	Red-eyed vireo	Yellow warbler
	Red-headed woodpecker	Yellow-throated warbler
		Yellow throated vireo

APPENDIX C

Figure C-1. Middle Branch Muskegon River.

Figure C-2. Zone 2 South Branch Emergent Vegetation

Figure C-3. Zone 2 South Branch Riparian Vegetation

Figure C-4. Zone 2 Sheridan Road Public Access Erosional Effects

Figure C-5. Zone 2 North Branch Riparian Areas

Figure C-6. Zone 2 North Branch Riparian Area

Figure C-7. Zone 2 Mosquito Creek Outlet To The Muskegon River

Figure C-8. Zone 2 Mill Iron Road Public Access Passage To The Marsh Area

Figure C-9. Zone 2 Mill Iron Road Public Access Marsh Area

Figure C-10. Zone 2 Mill Iron Road Public Access Typical Marsh Vegetation And Dead Snags.

Figure C-11. Zone 2 Mosquito Creek Tributary Typical Erosion Problems Within The Area

Figure C-12. Zone 3 Cedar Creek Riparian Slopes And Stabilization Projects

Figure C-13. Cedar Creek Riparian Area North Of Ryerson Road And Out Of The Project Area

Figure C-14. Cedar Creek Riparian Area Near The City Of Twin Lakes, Outside Of The Project Area

Figure C-15. Cedar Creek Watershed Restoration Projects Along Degrading Banks Of The Creek

Figure C-16. Sand Removed From The Sand Traps Within The Cedar Creek

Figure C-17. Zone 4 Typical Riparian And Woody Debris Located In Or Near The Muskegon River

Figure C-18. Zone 4 Typical Herbaceous Areas Located Along The Banks Of The Muskegon River