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White River Watershed Preliminary Habitat Assessment

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WHITE RIVER WATERSHED

PRELIMINARY HABITAT ASSESSMENT

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Executive Summary

The White River watershed is the product of the interaction of its unique geologic, hydrologic, and ecologic systems. Glacial geology formed the moraine ridges in the headwaters and produced the outwash plains, soil associations, tributary systems, and pitted areas where kettle lakes and depressional wetlands are found. The coupling with Lake Michigan and the influence of its water level fluctuations carved the deep river valleys and formed the extensive drowned rivermouth complex of White Lake and its wetlands. The hydrologic system in the watershed focuses local groundwater into the stream channel, maintains cold temperature environments that support a significant trout fishery, sustains the regional lakes and wetlands, and provides the vehicle that transports and deposits carbon and nutrients throughout the watershed. Using these geologic and hydrologic resources, a diverse array of biological communities function and interact in the upland forests and prairies of the catchment, the transitional wetland areas, and the aquatic systems present in lakes and streams. In its current state, the White River watershed contains approximately 200,000 acres of forest, 43,000 acres of wetlands, 6,300 acres of open water (lakes and streams), and 38,000 acres of open field. Lands under agricultural production and urban land use cover only 30% of the watershed area. These anthropomorphic systems interact with the geologic, hydrologic, and ecologic framework of the watershed to define the structure and function of the entire basin.

In this project, a preliminary assessment of habitats in the White River watershed was conducted. Land cover and land use were evaluated using available remote sensing data to provide an assessment of current conditions and an analysis of significant change over a 20 year period (1978 to 1992/1997/1998). Investigations of water and habitat quality were also conducted in White Lake, the drowned rivermouth wetland, and selected streams and wetlands in the tributaries and branches of the White River. Significant findings of these assessments include:

✍✍Land cover/use on a watershed basis appeared to be stable with forested and wetland areas showing slight increases in total acreage. With respect to agriculture, row crop usage declined with a corresponding increase in orchards and open fields. ✍✍Areas of significant change were noted on a subwatershed basis. The areas of greatest urban growth were concentrated in the US 31 corridor, the villages, and around larger lakes. ✍✍Mid and lower stream sections and wetlands were located in forested areas with riparian vegetative cover and buffers. Wetlands and streams in several of the headwater areas have poor riparian zones. ✍✍The watershed contains a number of rare and endangered habitats including coastal marshes, bogs, dry sand prairies, barrens, wet

meadows, and mesic prairies. The acreage of Pine/Oak Barrens have decreased by almost 50% over the last 20 years. ✍✍White Lake has remained eutrophic and will require a detailed investigation of nutrient loading and hydrologic modeling to develop a plan to improve water quality. ✍✍The drowned rivermouth was found to be impacted by a combination of agricultural and urban sources. ✍✍Cushman Creek and Heald Creek were found to be impacted by anthropogenic pollution. ✍✍Several wetlands in the upper watershed were impacted by adjacent land use practices (agriculture and road/stream crossings).

Based on the above findings, the following recommendations were made:

✍✍Establish a watershed assembly to promote, prioritize, and coordinate water quality and habitat management/restoration activities throughout the basin. ✍✍Initiate programs involving public education, best management practices, and land acquisition to promote stewardship, improve environmental quality, and preserve rare habitats, respectively. ✍✍Conduct the necessary hydrologic modeling to evaluate nutrient loading to White Lake and identify critical areas to target source control programs in the upper watershed. ✍✍Develop and implement a plan to restore the drowned rivermouth

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This project was an important beginning for future planning and educational activities in the watershed. Preliminary data on the geological, hydrological, and ecological systems were assembled and several areas of concern were identified. In consideration of the size and complexity of the watershed, it is clear that more information will be required to develop effective management plans. Without this information, it is impossible to prioritize issues, formulate mitigation strategies, and initiate changes that are truly 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. It will be impossible to maintain water and habitat quality on a watershed basis if problems in headwater streams and development pressure are not addressed. The future of the White River watershed depends on a detailed assessment of the resource, the development of a holistic preservation plan, and a strong public education component to promote active stewardship. The watershed is a unique and diverse resource with important ecologic and economic value that will require a coordinated and holistic approach for preservation and restoration.

1.0 Introduction

The White River is an important part of the Great Lakes ecosystem. Through its riparian forests, wetlands, and flowing waters, the 344,166 acre (139,279 ha) White River watershed provides the necessary habitat diversity to support fisheries and wildlife resources of regional and national significance. With headwaters in northeastern Newaygo County, the river flows for approximately 83 miles (134 km) before discharging to Lake Michigan. A map of the watershed is presented in Figure 1. Approximately 12,000 years ago, the glacial activity that formed the Great Lakes also created the White River. In its natural state, the White River was a system of dense riparian forests, sprawling wetlands and marshes, inland lakes, and 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. Today, the White River is a somewhat divergent system of scenic and biologically productive areas contrasted with locations that are subject to the adverse impacts of nonpoint source pollution, agriculture, and development. The continued loss of the riparian zone by development and the uncontrolled input of sediment by erosion will ultimately result in significant degradation of this valuable resource.

The White River watershed is located in Muskegon, Newaygo, and Oceana Counties of Michigan (Figure 1.1) and contains an extensive marsh/wetland environment that provides critical transitional habitats for fisheries and wildlife. The river gradient flattens in Muskegon County and forms a freshwater estuary consisting of wooded wetlands, emergent beds, and open water marshes. This estuary is coupled with White Lake, a 2,571 acre drowned-rivermouth system that is connected to Lake Michigan. Approximately 23% of the watershed (76,853 acres) is included in the Manistee National Forest (MDNR 2001) and is managed for the protection of woodland and wildlife habitat (Figure 1.2). The Manistee National Forest acts as a buffer zone around the river and protects it from urban development and local runoff. The White River is divided into two branches, the North Branch and the South Branch. The North Branch has headwaters in central Oceana County while the South Branch originates in eastern Newaygo County. The two branches converge within the Manistee National Forest (southeastern Otto Township) and form the main channel of the river. Many tributaries are also part of this watershed and function as 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 White River watershed are recognized as natural features that are 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 White River watershed that documents current

FIGURE 1.1 THE WHITE RIVER WATERSHED.

FIGURE 1.2 FEDERAL AND STATE LAND IN THE WHITE RIVER WATERSHED.

environmental conditions and identifies areas of significant change. These data will serve as the basis for future assessments of problem areas, educational outreach programs, 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 White River watershed and to identify areas of significant change. In addition, a series of benthic macroinvertebrate and water chemistry samples were collected in wetland environments to further assess the status of the important aquatic habitats and their water quality. Because of the size of the watershed, the aerial data and interpretations from the Michigan Resource Information System (MIRIS) were used (MDNR 1978 and 1992/1997/1998). 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 baseline status; - analyze and summarize MIRIS data for 1992/1997/1998 - conduct a preliminary field survey on major tributaries - conduct assessments of the biological integrity of important wetland systems ?? review 1978 MIRIS data and determine areas that have undergone significant land cover changes from 1978 – 1992/1997/1998 ?? identify significant areas of concern for the lower White River watershed.

This project will provide 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 White River watershed and the significance of problem areas.

2.0 Background

The traditional view of a river is a place with certain recreational and aesthetic qualities associated with the water and stream bank. There is however an alternate perspective that is more attuned to the hydrology and ecology of river systems. Like the fish that lives in it, the river itself is an entity with a unique structure and function, with a specific history, and capable of self-generated dynamic behavior (Wiley and Seelbach 1997). There are four fundamental characteristics, which are essential to understanding the nature of river systems: A river is:

- ✍✍A landscape-scale system because of its connection with its valley, soils, and aquifers.
- ✍✍A hydrologic system because it participates in regional water cycling.
- ✍✍A geomorphic system because it shapes the landscape it occurs on and its own channel.
- ✍✍An ecological system because it supports a diverse and highly adapted biota.

The landscape of the White River watershed extends beyond the water and stream banks to the entire drainage basin (catchment). It is broadly influenced by regional climate and rainfall in addition to local scale events that affect smaller sections. In addition, the landscape scale of a watershed guarantees that every river presents a complex mosaic of interactions and relationships involving the many smaller elements in its catchment. These can include terrestrial ecosystems as well as various human political and economic units. In conjunction with what we see in the current landscape, the historical context of regional and local events also shape the watershed. The history of the White River began with the glacial events that formed the Lake Michigan Basin. Glacial events in the upper part of the Great Lakes caused a drop in Lake Michigan water levels that in turn, affected the landscape of the White River watershed. Anthropogenic events such as logging, agricultural development, and urbanization also have influenced the landscape. Today, the White River watershed reflects a summation of historical landscape changes that will be modified by future events.

A river's hydrologic properties are an inseparable component from its geomorphic, chemical, and biological characteristics. The amount and timing of water transport through a river channel network is the end result of a complex interaction between landscape elements and the climate (Wiley and Seelbach 1997). In order to examine the hydrologic characteristics of a river, we have to understand the key processes that generate stream flow and control its distribution in time and space. These hydrologic processes include: precipitation, evaporation, transpiration, storage, infiltration, overland flow, and groundwater flow. The summation of these processes link the river to its

landscape. The watershed is the basic unit in river hydrology. Every site on a river has a catchment area, that is the source of its water flow. For every watershed there is a balance between inputs, outputs, and storage of water in the landscape. As a result the flow characteristics of a river depend on the nature of its hydrologic source. Rivers supplied primarily by runoff respond dramatically to rain, rapidly generate high peak discharges and then quickly pass water downstream. In between rain events these rivers experience rapid and severe declines in discharge since most excess water in the basin has already been transported away. In contrast, rivers supplied primarily by groundwater respond slowly to precipitation events. Small increases in discharge increases are noted because most precipitation is captured by infiltration. This water slowly makes its way to the channel, and the resultant lag time ensures a continuous supply of groundwater to the river between rain events. Groundwater driven rivers are hydrologically stable systems, with lower peak flows and higher base flows than in runoff-driven rivers of comparable size. The White River watershed contains streams influenced by groundwater and runoff to varying extents. Groundwater influenced streams provide a stable habitat for benthic organisms and support trout based fisheries. Groundwater quality also plays an important role with respect to habitat and fisheries. Runoff driven streams tend to be unstable and more subject to sedimentation and erosion. These streams tend to support warm water fisheries and contain benthic fauna that are more tolerant of sedimentation.

With respect to geomorphology, Davis (1899) described landscapes to be the result of cycles of geologic uplift and erosion. Rivers can be viewed as an agent of continental erosion, and between episodic uplift events, they continually reduce landform elevations towards a base level established by the river mouth. As rivers carry water across the landscape, they also transport sediment and dissolved materials. In this manner, they transform the landscape by erosion, dissolution, and deposition. A simplified but useful model of the overall geomorphic structure of a river (Figure 2.0) divides the system into three types of reaches (Montgomery and Buffington 1993). Each reach is distinctive in terms of material processing. Source reaches are generally small tributaries or headwater streams. Sediment in source reaches is moved intermittently during peak flow or disturbance events. Transport reaches are high gradient areas where channel building occurs. These reaches will rapidly convey increased sediment inputs. In the White River watershed, source reaches are located in the headwaters of the North and South Branches. The transport reach is located in the mid section of the river.

Response reaches are low-gradient transport-limited channels in which significant morphologic adjustment occurs in response to increased sediment supply. Low gradient stream reaches lack the capacity to transport all the sediment that is delivered from the surrounding watershed. Sediment delivered to these reaches is deposited in the reach rather than transported

further downstream. Although response reaches tend to have the greatest stream flow in a watershed, they have the lowest velocity. Transport of

FIGURE 2.0 DIAGRAM OF RIVER ZONES (MONTGOMERY AND BUFFINGTON 1993).

sediments deposited in response reaches usually occur during peak flows events (runoff from snowmelt or seasonal thunderstorms). Sediment deposition in response reaches is a natural process. The sediment may form bars or be stored in stream banks, allowing the reach to retain its function. In the White River watershed, the response reach is located in the lower section where the drowned rivermouth estuary is located. The flattening of the stream gradient plus the reduction in velocity from the discharge into White Lake results in sediment deposition. The highly braided channels in this segment illustrates the historical effects of sediment deposition.

In addition to the physical characteristics of landscape, hydrology, and geomorphology, rivers contain highly diverse ecosystems. Rivers are structurally unique from most other ecosystems because of the following reasons (Wiley and Seelbach 1997):

- ✍✍rivers have a large-scale directional organization (upstream-downstream).
- ✍✍rivers are dominated by advective rather than diffusive material transport.
- ✍✍rivers have high rates of energy and material throughput
- ✍✍rivers always contain many other embedded ecosystems (both terrestrial and aquatic).

Biologists have long recognized that communities in rivers change progressively in a downstream direction. Longitudinal zonation was an early organizing principal in stream ecology that gave rise to the River Continuum Concept (Vannote et al. 1980), which suggested that longitudinal changes in community structure reflect longitudinal changes in the availability of various forms of organic carbon during its transport through the channel system. For example, headwater streams in forested areas are likely to transport large amount of leaf material and have a fauna (shredders) adapted to feeding on this material. In large downstream segments of rivers, fine particulate matter are deposited and the fauna is dominated by animals that feed by collecting these particles (collectors and gatherer*s*).

The physical flow of a river leads to an ecosystem that is based on advective (active) transport. This is true for the transport of sediment, particulate organic matter, nutrients, dissolved gases, pollutants, and even organisms themselves. Advective transport also leads to rapid turnover rates for biological materials. The high turnover rate leads on the one hand to an enhanced sensitivity to changes in inputs. Changes in flow, sediment, nutrients, and organic matter are quickly manifested in the biological community. At the same time, the high turnover rates of water in rivers give them an extraordinary resilience to recover when inputs are returned to normal. The fact that the White River is a high quality stream, despite its legacy of abuse from lumbering, is a testimony to the ecological resilience of river systems.

Ecosystems along the course of a river serve both as regulators of water quantity and water quality. Several types of ecosystems, notably forests and wetlands, are known to act as hydrological buffers, retaining water when it rains and releasing it gradually over several weeks and months. This helps to protect downstream communities from flooding and ensures that water continues to flow during the drier periods of the year. Ecosystems also

regulate water quality. On sloping ground, for example, vegetation anchors soil and prevents it from being washed into the watercourse where it would cause sedimentation and reduce light penetration. This would reduce water quality, the health of aquatic ecosystems, and the suitability of the water for aquaculture and other uses. The physical structure of watercourses and the organisms that inhabit it also regulate water quality. For example, waterfalls, rapids, and aquatic vegetation oxygenate the water, and riverbanks, riverbeds, and vegetation trap sediment. These hydrological and biological processes enable the watercourse to function as a water purification unit providing fresh water. Riverine wetlands also play an important role in regulating water quality. They remove sediments and excessive nutrients from the water by processes of entrainment, decomposition, and uptake by vegetation. As wetlands hold water for long periods of time, decomposition and uptake processes are given enough time to remove nutrients from the water.

The ecosystems in the White River watershed also play a central role in shaping the character of the landscape. The forests, wetlands, lakes, and streams function in synergy to sustain the diverse flora and fauna found in the region. While the system has a large capacity for resiliency, the White River can still be adversely impacted by localized development, erosion, riparian zone modification, and nutrient enrichment. If left uncontrolled, anthropogenic alterations can affect the watershed on a larger scale.

In summary, the White River watershed that we see today is a summation of its glacial history, landscape, hydrology, geomorphic functions, and ecology. On a simple level, it can be enjoyed as a place for observing nature and outdoor recreation. Using a broader perspective, the complexities and interrelationships inherent in the watershed provide the opportunity for study and reflection. The following sections describe the physical and ecological characteristics of the watershed. Section 3 provides a description of the watershed with respect to:

✍✍Glacial History ✍✍Geology
✍✍Soils ✍✍Topography
✍✍Hydrology and Stream
Characteristics ✍✍Terrestrial and
Aquatic Habitats

Section 4 presents the results of the land use change analyses for the entire watershed and the subwatersheds. The results of the assessments conducted for White Lake and wetlands are provided in Sections 5 and 6, respectively. A discussion of the project data is provided in Section 7. Key issues for the watershed are presented along with recommendations in this section. This document is designed to provide a preliminary assessment of the White River watershed. It is structured as an information source for future research and a tool for public education.

3.0 Watershed Description

3.1 GLACIAL HISTORY

The White River watershed lies between two glacial moraines in western

Michigan (Figure 3.1.1). Approximately 12,000 years ago, melt water from the receding glaciers began to carve out the channel of the White River and fill the Lake Michigan Basin (Hough 1958). As a coupled system, water elevations in Lake Michigan have a significant influence on the hydrology of the White River. A summary of Lake Michigan's geologic history and water elevations are presented in Figure 3.1.2 (Larson and Randall 2001). The White River was formed during the stage known as Lake Calumet with a water elevation of 620 ft. A brief period of lower water elevation (Kirkfield Low Water Stage) followed, as a drainage channel from Lake Huron to Lake Ontario was cut. Around 11,500 bp (before present), the climate became colder and the final glacial field advanced across Michigan. The

FIGURE 3.1.1. SATELLITE IMAGE OF THE WHITE RIVER WATERSHED.

Glacial Moraines

White River
Watershed

12000 bp Elevation 620 ft. 11,850 bp Elevation 565 ft.

11,500 bp Elevation 605 ft. 9,500 bp Elevation 230 ft.

4,000 bp Elevation 605 ft. 2,500 bp Elevation 580 ft.

FIGURE 3.1.2. GLACIAL HISTORY AND WATER ELEVATIONS OF LAKE MICHIGAN (LARSON AND RANDALL 2001).

channel to Lake Ontario was frozen and the water level rose back to 605 ft. This stage was called Lake Algonquin and approximately 75% of Lake Michigan was frozen. As the final ice field receded, a large channel was cut across Canada and Lake Michigan levels fell by 373 ft to an elevation of 230 ft. This stage was called Lake Chippewa and low water levels persisted for almost 5,000 years. The dramatic drop in the Lake Michigan's elevation caused the gradient of the White River to correspondingly increase and cut deeply into the landscape. Steep valley segments were formed in the main channel and many of the tributaries. When Lake Michigan levels rose during the Lake Nippising Stage (4000 bp), the valleys in the White River basin began to fill with water and stabilize at 605 ft. A depiction of the White River during this stage is shown in Figure 3.1.3 (M. Wiley personal communication). The river was considerably wider and the rising water table resulted in the formation of many wetlands. A larger version of White Lake was also formed that extended inland to the confluence of the North and South Branches.

Figure 3.1.3. Water Elevation in the White River with Lake Michigan at 605 ft.

Lake Michigan's water elevation began to stabilize near current levels during the Algoma Stage approximately 3,000 years ago. Sediment loads that were formerly deposited in Lake Michigan began to fill in the inland river valley. The large wetland complex near White Lake was gradually formed by this sedimentation process. While sediments were accumulating in the lower White River watershed, the shifting sand dunes along the Lake Michigan shore began to restrict the rivermouth to a narrow channel. The resulting

system is called a drowned rivermouth and contains the transitional environments shown below:

Large lake ? intermediate lake ? estuary ? river ? headwaters

These environments provide a variety of niches that support a diverse flora and fauna. The ecological diversity is enhanced further by the sloping valleys that were cut during the period of low water in Lake Michigan. These valleys focus groundwater into the floodplain and create a full transition of wetland environments from aquatic beds to wooded wetlands. Glacial features such as kettle lakes and depressional lowlands provide the same transitional environments in upland areas. Figure 3.1.4 shows the variety of inland and riverine wetlands associated White River watershed (M. Wiley personal communication). The drowned rivermouth system and estuary, inland lakes, and topography are all the result of regional glacial history and the coupling of the White River watershed to Lake Michigan. These important features define the hydrology, land cover, and ecology of the watershed.

FIGURE 3.1.4 LAKES AND WETLANDS ASSOCIATED WITH THE WHITE RIVER WATERSHED.

3.2 GEOLOGY

The major geologic associations found in the White River watershed are displayed in Figure 3.2.1 (MNFI 1999). Moraine ridges dominate the northern and eastern portions of the watershed. The North Branch begins in a narrow outwash channel between a moraine ridge in Oceana County. The South Branch originates on a broad outwash plain between moraine segments. The river then passes through a pitted outwash plain that contains many kettle lakes and depressional lowlands. South of Hesperia, a broad glacial till plain can be found that also contains a number of small lakes. The area west of Hesperia contains a large and relatively flat outwash plain that forms the upland area for the channel of the White River and its two main branches. The till soils in the outwash plains are of high quality and are extensively used for agriculture (USDA 1995). Poorly drained tills predominate the channel area west of Hesperia and grade into muck and peat associations. The deposits of rich organic materials form the freshwater estuary located near US 31. A second pitted outwash plain borders the south channel of the White River in northern Muskegon County. This area contains many small kettle lakes. This pitted outwash plain also contains many kettle lakes and depressional lowlands. In the area bordering Lake Michigan, sand dunes dominate the landscape. A bisected moraine is located north of Montague. Bisected moraines have flow channels cut on either side of a central ridge. They are visible on Figure 3.2.1 in the region where numerous, parallel stream channels are located.

3.3 SOILS

The soil types found in the watershed can be classified as associations of coarse and fine tills, alluvial materials, and highly organic mucks. The distribution of soil textures is shown in Figure 3.3.1. The distribution of hydric soils is show in Figure 3.3.2. The White River watershed is composed of the following major textures (USDA 1968, 1995, 1996):

?? Sands (Plainfield-Grattan-Brems-Benona associations in Oceana and Newaygo Counties) ?? Sand (Rubicon-Au Gres-Roscommon associations in Muskegon County) ?? Sandy loam (Marlette-Metea-Spinks associations) ?? Mucky sands and peat (Houghton-Kerston-Carlisle-Adrian-Tawas and

Pipestone-Covert-Kingsvill
e

FIGURE 3.2.1 GEOLOGIC ASSOCIATIONS IN THE WHITE RIVER WATERSHED .

FIGURE 3.3.1 SOIL TEXTURES FOUND IN THE WHITE RIVER WATERSHED.

FIGURE 3.3.2 DISTRIBUTION OF HYDRIC SOILS IN THE WHITE RIVER WATERSHED.

Changes in soil type and texture appear to follow county lines rather than geologic features. This is true along the Oceana/Newaygo county line west of Hesperia and the Oceana/Muskegon county line below the confluence of the two branches of the White River. Consequently, the diversity in soil associations within a specific texture reflects more on the individual interpretation of the strata than actual variability. In general, sandy soils have poor water holding capacities, are well drained, and not useful for agriculture. These 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 a high permeability and very low water holding capacity. In addition, the low organic content makes this type of soil a poor medium for plant growth and one that is easily eroded by wind and water action. It is therefore critical that the integrity of the ground cover in areas that contain sandy soils be retained to prevent losses due to runoff and wind erosion.

The sandy loam soil associations found in the moraine areas of the central, eastern, and northwest of the watershed are conducive to agricultural production and have good drainage and water holding capacity characteristics. Upland locations with these soils in Oceana County are used for orchards due to their proximity to Lake Michigan. Sandy loam soils in Newaygo County are generally used for row crops and truck farming. Even though these associations have a lesser potential for wind and water erosion due to increased water holding capacity and improved ability to support ground cover, row cropping can circumvent these characteristics and facilitate soil loss.

The distribution of hydric soils shown in Figure 3.3.2 is associated with the glacial outwash plains (Figure 3.2.1) and stream valley segments. The term hydric refers to soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation typically adapted for life in saturated soil conditions. In most cases, these soils have a high organic content due to the slower breakdown of organic material in the absence of oxygen. They support wetland vegetation and are highly influenced by both groundwater quality and quantity.

3.4 TOPOGRAPHY

The Digital Elevation Model for the White River Watershed is shown in Figure 3.4.1. Geological features are also identified. Topographic slopes are provided in Figure 3.4.2. The glacial moraines and outwash plains are clearly visible in the headwater areas of the North and South Branches on Figure 3.4.1. The elevation at the headwaters in Newaygo County is 298 meters and grades down to 178 meters at White Lake. There are several distinct changes

Glacial Moraine Ridges

Steep Outwash Channel Outwash Channels

Flattened Outwash Plain Outwash Plains **FIGURE 3.4.1 DIGITAL ELEVATION MODEL OF THE WHITE RIVER WATERSHED. ELEVATION IN METERS.**

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FIGURE 3.4.2 TOPOGRAPHIC SLOPES IN THE WHITE RIVER WATERSHED.

in topography throughout the watershed. The flood plain surrounding the lower White River is relatively flat alluvial lowland with 0-6% slopes (Figure 3.4.2). Land with 6-18% slopes is found in the glacial moraine valleys and outwash plains that have features related to pitting (kettle lakes and depressions). The steepest slopes (30-60%) are almost exclusively found in river valleys of the White River and selected tributaries located west of Hesperia. These valleys were carved out during the low water periods the Great Lakes (Section 3.1). The remaining lands with steep slopes are related to moraine remnants in the upper Oceana and Newaygo sections of the watershed.

3.5 HYDROLOGY AND STREAM CHARACTERISTICS

Geomorphic features discussed in the previous sections (geology, soils, and topography) play an integral role in structuring the hydromorphic characteristics (lakes, groundwater, and streams) of the watershed. The White River watershed contains over 253 linear miles of streams and 20 major lakes (MDNR 1975). Figure 3.5.1 shows the major perennial streams, subwatershed boundaries, and lakes found in the drainage basin (MDEQ 1998). Subwatersheds are established based on the catchments of individual tributaries and branches that make up the entire White River watershed. Because they represent distinct drainage basins, subwatersheds are logical units to evaluate water quality and land use issues on a smaller scale. Figures 3.5.2 and 3.5.3 and 3.5.4 provide information on stream gradient, hydrologic status, and temperature respectively (MDNR 1997). The information from these figures is summarized in Table 3.5.1. The watershed contains a mixture of groundwater and

Table 3.5.1. Summary of Stream Characteristics in the White River Watershed by Subwatershed (MDNR 1997).

	Stream	Gradient	Hydrologic Status	Temperature
White Lake and Carlton/Mud Creeks	Carlton Creek	> 10 ft/mi	Runoff Driven Moderate Base Flow	Cool Low Variation
	Silver Creek	< 4 ft/mi	Runoff Driven Moderate Base Flow	Cold Low Variation
SAND CREEK/WOLVERINE LAKE	Sand Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cold Low Variation
	Cleveland Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cold Low Variation
	White River	< 4 ft/mi	Groundwater Driven High Base Flow	Cool Moderate Variation
Middle White River	White River	< 4 ft/mi	Groundwater Driven High Base Flow	Cool Moderate Variation
North Branch	North Branch	4-10 ft/mi	Groundwater Driven High Base Flow	Cold Moderate Variation
	Bear Creek	4-10 ft/mi	Groundwater Driven High Base Flow	Cold Lo w Variation

Table 3.5.1 (continued). Summary of Stream Characteristics in the White River Watershed

	Stream	Gradient	Hydrologic Status	Temperature
North Branch	Knutson Creek	4-10 ft/mi	Groundwater Driven High Base Flow	

Cold Low Variation Swinson Creek 4-10 ft/mi Groundwater High Base Flow Driven Cold Low

Variation **Upper North Branch** North Branch < 4 ft/mi Runoff Driven

Moderate Base Flow

Cool Moderate Variation **Skeel/Cushman/Braton Creeks** Skeel Creek 4-10 ft/mi Runoff Driven

Fair Base Flow

Cool Low Variation Cushman Creek 4-10 ft/mi Runoff Driven Fair Base Flow

Cool Moderate Variation Braton Creek 4-10 ft/mi Runoff Driven Fair Base Flow

Cool Moderate Variation South Branch > 10 ft/mi Groundwater Driven

High Base Flow

Cold Moderate Variation **Martin/Mena/Held Creeks** Martin Creek > 10 ft/mi Groundwater Driven

High Base Flow

Cold Low Variation Mena Creek > 10 ft/mi Groundwater Driven

High Base Flow

Cold Low Variation Held Creek > 10 ft/mi Groundwater Driven

High Base Flow

Cold Low Variation South Branch > 10 ft/mi Groundwater Driven

High Base Flow

Cold Moderate Variation **South Branch/Robinson Lake** South Branch North of

M-20 > 10 ft/mi Groundwater Driven

High Base Flow

Cold Moderate Variation South Branch South of

M-20 < 4 ft/mi Groundwater Driven

High Base Flow

Cold Moderate Variation Robinson Creek 4-10 ft/mi Runoff Driven Fair Base Flow Cool High

Variation **Upper South Branch** South Branch North of

M-20 < 4 ft/mi Groundwater Driven

High Base Flow

Cool Moderate Variation South Branch South of

M-20 < 4 ft/mi Runoff Driven Fair Base Flow

Cold Moderate Variation Flinton Creek 4-10 ft/mi Runoff Driven Fair Base Flow

Cool High Variation Five Mile Creek 4-10 ft/mi Runoff Driven Fair Base Flow

Cool High Variation Mullin Creek < 4 ft/mi Runoff Driven Fair Base Flow Cool Moderate Variation

FIGURE 3.5.1 SUBWATERSHEDS IN THE WHITE RIVER WATERSHED.

FIGURE 3.5.2 STREAM VALLEY SLOPE IN THE WHITE RIVER WATERSHED.

FIGURE 3.5.3 HYDROLOGIC STATUS OF STREAMS IN THE WHITE RIVER WATERSHED.

FIGURE 3.5.4 STREAM TEMPERATURE IN THE WHITE RIVER WATERSHED.

runoff driven streams that are ranked as cold and cool with respect to temperature. Groundwater-fed rivers have deeper channels and faster flows during the summer. Substrates are generally coarse. Stable groundwater temperatures keep the streams cool in the summer and also help warm these rivers during winter. Fishes of stable, groundwater rivers (e.g. trout and sculpin) are habitat specialists, adapted to a rather narrowly defined constant, cold, swift-water environment. Runoff driven rivers are wide and shallow during summer months with temperatures that are influenced by ambient conditions. During summer months, these streams generally have low velocities that allow the accumulation of fine silt and sand substrates. During storm events, discharge increases and transports bedload sediments and the nutrients and soil associated with runoff downstream. Fishes found in flashy, runoff driven rivers are diverse and adapted to warm, slow water, with variable conditions (e.g. many sunfishes, minnows, catfishes, and suckers).

Approximately 20 large lakes ranging in size from ten acres up to several hundred acres, drain into the White River. In addition to the two impoundments on the mainstream at White Cloud (60 acres) and Hesperia (100 acres), five smaller impoundments (3-35 acres) on tributaries, drain into the White River. As part of this project, a field survey of the watershed was conducted of major road/stream crossings and by canoes during August and September 2002. Most of the tributaries in the headwaters of Newaygo County (Flinton, Five Mile, and Mullen Creeks) and the mainstream above White Cloud had a mixture of bottom types composed of sand, silt, and gravel. Some channelization was evident; however, pool and run sequences were common. Between White Cloud and Hesperia, the South Branch passed first through a broad elm swamp where the bottom was mostly sand and contained many deep holes from historical logjams. North of Robinson Lake (Lutes Bridge), the river flowed through glacial moraines and for several miles downstream, the current was moderate and the bottom contained an abundance of gravel with some larger boulders (Figure 3.5.5). The river then slowed and the bottom type changed to sand as the river entered the impoundment at Hesperia. Below Hesperia for eight to ten miles, the river was fairly swift and flowed over a sand and gravel bottom. Below the Pine Point Campground in the Manistee National Forest and extending to White Lake, the river had a moderate current and sandy bottom with many meanders and oxbows. The North Branch begins in McLaren Lake and flows west to Ferry and then south to its junction with the mainstream. Due to the influence of its headwater lakes, the North Branch had warm water temperatures (30 ^{0}C), for the first four or five miles. Below this area, sufficient groundwater entered the stream to reduce the temperatures to a cool water designation. The steam bottom was generally sandy with fair amounts of gravel scattered throughout its length. Sand bar deposition and stream bank erosion sites were more

FIGURE 3.5.5 THE WHITE RIVER WEST OF HESPERIA.

common on the North Branch than the upper South Branch. The USGS operates a gauging station on the White River near Whitehall. Data from 1953-present is available on their web site (www.usgs.org/michigan). Robertson (1997) conducted a hydrological analysis of the White River watershed in order to estimate sediment and total phosphorus loadings to Lake Michigan. His estimates did not include the effects of White 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 White Lake. A summary of Robinson's analyses and USGS data are presented below:

Watershed area 406 mi^2 Long-term daily average flow 450 f^3/sec Long-term daily minimum flow 220 f^3/sec Long-term daily maximum flow 602 f^3/sec Peak flow 1834 f^3/sec Flashiness 4 Suspended Solids Load to Lake Michigan 0.62% (34,000 kg/d) Total Phosphorus Load to Lake Michigan 0.54% (45 kg/d) Stream gradient 1.15 m/km

A loading study of nutrients entering White Lake from the White River was conducted in 1972-1975 (Freedman et al. 1979). The average load of total phosphorus to White Lake during this period was 68 kg/day. White Lake was found to retain approximately 75% of the phosphorus load leaving an average of 20 kg/d discharged to White Lake. These results show the potential for error in the calculations made by Robinson (1977) when the function of White Lake as a nutrient sink is not factored into the estimate. Freedman et al. (1979) also concluded that 94% of the nitrogen and phosphorus loading to White Lake came from the White River. Their study calculated the average phosphorus load upstream of the drowned rivermouth wetland to be 47 kg/d during the same time period. These results suggest that the wetland may be a significant source of the phosphorus load. The drowned rivermouth wetlands have been modified by agricultural producers as shown in Figure 3.5.6. Many of the muck fields have dikes and dewatering systems that discharge into the wetlands. In addition, bridges and elevated roadways have restricted the flow at the rivermouth from the typical wide delta to a narrow channel under the bridge. The extensive physical modifications plus the addition of drainage water may be responsible for turning the wetlands into more of a nutrient source rather than a system of storage and processing. Storm events and seasonal peak flows also may release nutrients from the wetlands by flushing and scouring.

FIGURE 3.5.6 AERIAL VIEW OF THE WHITE RIVER DROWNED RIVERMOUTH WETLANDS.

White Lake is a significant hydromorphic feature of the watershed. It has an area of 10.2 km^2 and a mean depth of 7.3 m. The lake has an estimated volume of $7.6x10^7$ m^3 and a residence time of 56 days. White Lake has a long history of environmental issues related to water quality and the discharge of toxic materials. The lake was impacted in the mid 1800s when saw mills were constructed on the shoreline during the lumbering era. A large portion of the littoral zone was filled with sawdust, wood chips, timber wastes, and bark during this period. Large deposits of lumbering waste can still be found today in the nearshore zone of White Lake. The lumbering era was followed in the 1900s by an era of industrial expansion related to the construction of specialty chemical production facilities and a leather tanning operation. Tannery waste from Whitehall Leather was discharged directly into White Lake from 1890-1973 while effluents from Hooker Chemical's chloralkali and pesticide production were discharged from the 1950s-1986 (Evans 1992 and GLC 2000). One tributary in the local watershed was also used for the discharge of industrial waste effluent from another specialty chemical production facility. As a result, degraded conditions were observed in much of the lake, as well as high sediment concentrations of heavy metals and pesticide related chemicals. Evans (1992) presented a review of studies that described extensive areas of oxygen depletion, high quantities of chromium in the sediments, thermal pollution, the discharge of waste with a high oxygen demand from the tannery (sulfide and organic matter), tainted fish, frequent algal blooms, and high nutrient concentrations. Generally, oligochaetes were the dominant benthic taxa and macroinvertebrate species richness and diversity were low across the lake, indicating eutrophic conditions were prevalent in 1972, especially, the southeastern portion of the lake (Evans 1976). The International Joint Commission designated White Lake as an Area of Concern (AOC) because of severe environmental impairments related to these discharges. The AOC boundary includes the lake and several small subwatersheds. One of these systems, Mill Pond Creek, was used for the discharge of a variety of chlorinated solvent and ether compounds from the Muskegon/Koch Chemical facility. In 1973, a state of the art wastewater treatment facility was constructed and the direct discharge of waste effluents and partially treated municipal sewage to White Lake was eliminated. The new facility was constructed near Silver Creek and utilized aeration, lagoon impoundment, spray irrigation and land treatment to remove nutrients, heavy metals, and organic chemicals. While the system was very effective in reducing the point source load of nutrients to White Lake, nonpoint contributions from upstream sources increased after construction and a net reduction in loading was not observed during 1974 and 1975 (Freedman et al 1979). The same authors used the Vollenweider model (Vollenweider 1975) to examine the amount phosphorus reduction necessary to limit the rate of eutrophication in White Lake. The results of the modeling predicted that external phosphorus loading would have to be reduced by almost 70% before a change in trophic status would be seen.

Considerable progress has been made related to the issue of contaminated sediments in White Lake. Areas of contaminated sediment were delineated (Rediske et al. 1998) and remedial action plans were developed for the sites posing the greatest risk to White Lake. Remediation of the contaminated sediments near the tannery began in the fall of 2002 and will be completed by mid 2003. The area of contaminated sediments near the former Hooker Chemical facility is scheduled for remediation during the latter part of 2003. These remedial actions will address a majority of the issues related to contaminated sediments in White Lake. In contrast, issues of eutrophication and nutrient loading have not been examined in sufficient detail because current hydrologic and water chemistry data are lacking. The hydrology of the White River watershed is complex due to the topography, meander patterns, and the strong influences of the wetlands, Lake Michigan, and White Lake. It will be necessary to develop a detailed hydrologic model for the watershed in order to evaluate solutions for the eutrophication issues in White Lake. Through hydrologic modeling, it will be possible to determine the nutrient contributions of the tributaries and wetlands and to develop an understanding of the transport, storage, and processing dynamics in the watershed.

3.6 TERRESTRIAL AND AQUATIC HABITATS

A diverse assemblage of flora and fauna is found in the White 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 (MNFI 1998, TNC 2002) and are summarized in Appendix A (Tables A-1 through A-5). Species common to upland forests and wetland environments are present.

A map of presettlement vegetation is shown in Figure 3.6.1. The map was developed from historical surveys that were conducted during the late 1700s. The western section of the watershed was dominated by pine and mixed hardwood forests. Beach, sugar maple, and hemlock forests covered much of the mid section. The eastern part of the watershed contained a mixture of hard and softwood species in addition to large conifer swamps in the headwater regions. Dominant forms of land cover are summarized in Table 3.6.1. Approximately 43,500 acres of wetland environments were present in the late 1700s. The current vegetative cover based on aerial photography is shown in

Table 3.6.1 Summary of Presettlement Vegetation in the White River Watershed.

PRESETTLEMENT VEGETATION	ACRES	%
BEACH/RIVERBANK	116	< 0.1
BEECH-SUGAR MAPLE-HEMLOCK FOREST	116,962	34.6
BLACK ASH SWAMP	1,663	0.5
BLACK OAK BARREN	4,824	1.4
CEDAR SWAMP	7,169	2.1
GRASSLAND	83	< 0.1
HEMLOCK-WHITE PINE FOREST	9,802	2.9
JACK PINE-RED PINE FOREST	748	0.2
LAKE/RIVER	7,385	2.2
MIXED CONIFER SWAMP	20,431	6.0
MIXED HARDWOOD SWAMP	9,834	2.9
MUSKEG/BOG	6	< 0.1
OAK/PINE BARRENS	5,684	1.7
SHRUB SWAMP/EMERGENT MARS H	4,435	1.3
WHITE PINE-MIXED HARDWOOD FOREST	79,349	23.4
WHITE PINE-RED PINE FOREST	1,215	0.4
WHITE PINE-WHITE OAK FOREST	68,812	20.3
TOTAL WETLANDS	43,538	12.9

FIGURE 3.6.1 PRESETTLEMENT VEGETATION IN THE WHITE RIVER WATERSHED.

Figure 3.6.2. Land cover and land use types are summarized in Table 3.6.2. An index to these classifications is included in Table 3.6.3. A majority of the watershed is classified as forested (58%) and open field (11%). Approximately 20% of the land use is agricultural while residential and commercial/industrial developments account for 3.25% and 0.5% respectively.

While lumbering, agriculture, and urban development have dramatically altered the watershed, the most noteworthy change has been observed in the reduction of wetland acreage. Presettlement wetlands covered 43,500 acres while the current coverage amounts to about 38,825 acres. A comparison of the two maps reveals that the conversion of wetlands to agricultural production accounts for most of this change. The presettlement wetlands designated as Mixed Conifer Swamps (red color) all contain networks of channelized streams that indicate the wetlands were artificially drained. Areas designated as cedar and hardwood swamps also appear to have been drained for agricultural production. Some of the differences between current and historical wetland acreage also may be due to changes in classification criteria and survey methods.

Table 3.6.2 Summary of Current Land Use and Cover in the White River Watershed (1992, 1997, and 1998).

White River Watershed Land Use/Cover

	Acres	%
Barren/Sand Dune	170	0.049
Commercial/Institutional	1,031	0.295
Confined Feeding	710	0.203
Cropland	65,839	18.837
Northern Hardwoods	48,215	13.795
Central Hardwoods/Oak	84,047	24.046
Aspen-Birch	15,913	4.553
Lowland Hardwoods	26,612	7.614
Pine	23,889	6.835
Other Upland Conifer	12	0.003
Lowland Conifers	2,161	0.618
Managed Christmas Trees	2,621	0.750
Mixed Conifer/Broadleaf	147	0.042
Wooded Wetland	98	0.028
Industrial	713	0.204
Open Field	37,678	10.780
Orchards or Other Specialty Crops	8,009	2.291
Other Agricultural Lands	342	0.098
Other Developed Areas	3,668	1.050
Residential	11,385	3.257
Water	6,300	1.802
Wetland	9,954	2.848
Transitional Land	11	0.003
Total Wetlands	38,825	11.1
Total Forest	203,715	58.2

FIGURE 3.6.2 CURRENT LAND COVER IN THE WHITE RIVER WATERSHED (1992/1997/1998).

Table 3.6.3. MIRIS Classification Definitions For Land Cover Maps

Land Use Descriptions Classification Description

Residential Characterized by land that is covered by multiple and single family structures.

Density is greater than one unit per acre. Crop Land Land used primarily for production of row crops and vegetables.

Water Areas of land that are persistently water covered including lakes, rivers, stream,

and creeks.

Orchard and Specialty Crops

Land used primarily for fruit trees, vineyards, nurseries, seed/sod, and floricultural production.

Barren/Dune Land that has a limited ability to support life and little or on vegetation. Commercial Institutional Areas that are primarily used for the sale of products and services.

Transitional Disturbed land that is transitional to developed areas.
Confined Feeding Areas of land that are used for large livestock and poultry farms.
Other Agricultural Areas of land that are used for greenhouses, out buildings and storage.
Other Developed Areas
Land that is used for mining (extractive), utilities, infrastructure, and recreational areas. Forest Areas that contain at least 10% deciduous and/or conifer species. Open Field Land used for recreational purposes that does not contain heavy structures or

native vegetation, including zoo's, cemeteries, ski areas, and botanical gardens.
Wetland
Wetlands are areas where the water table is at, near, or above the land surface for a significant part of the year. The hydrologic regime supports aquatic and/or hydrophytic vegetation.
Industrial Areas that contain manufacturing facilities that include light and heavy industries, which produce various commercial goods.
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. 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 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.
Lowland Conifer Areas dominated by cedar, spruce, and fir species.
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.

A map of the current wetlands in the White River watershed is shown in Figure 3.6.3. Four types of wetlands classifications are present (Satterlund et al. 1992):

✍✍Aquatic Beds - rooted aquatic plants and water lilies. 6" - 36" water depth ✍✍Emergent Bed - cattails, sedge grass, pickerel weed, and reeds. 0" - 6" water depth ✍✍Shrub – willow, alder, dogwood, and elderberry. 0" - 12" water depth

✍✍Forested - ash, elm, sycamore, cottonwood, oak, and maple. Area prone to seasonal flooding.

Aquatic beds in the drowned rivermouth area 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.

Wetlands develop from a combination of factors including glaciation, climate, agriculture, and hydrologic processes. Each type of wetland is a unique ecosystem with its own inherent values and functions. These ecosystems are among the most productive and threatened ecosystems in the world. Wetlands are classified based upon plant and soil types and the frequency of flooding (Cowardin et al. 1979). Inland wetlands that incorporate a river or stream are called **riverine** wetlands. Wetlands that include a permanently flooded lake or reservoir are called **lacustrine**. Wetlands that are dominated by trees, shrubs, and emergent vegetation are called **palustrine**. Palustrine wetland systems often border riverine and lacustrine systems. The drowned rivermouth wetland at the river mouth near White Lake is a unique system that has both riverine and lacustrine characteristics. While it is similar to a coastal marine estuary in appearance, it does not have the salt gradient that is present in these systems. Each type of wetland is distinguished by its physical and chemical characteristics and by the types of plants and animals that live there. However, many plants and animals may be found in more than one wetland type.

In addition to wetlands, a number of other unique natural communities are present in the White River watershed. The locations and classifications of these communities are presented in Figure 3.6.4 (USFS 2001). The drowned rivermouth wetland near White Lake is classified as a Great Lakes Coastal Marsh (Albert 2001). These systems are influenced by Great Lakes water levels with respect to short-term fluctuations (seiches), seasonal fluctuations from the annual hydrological cycle, and interannual fluctuations from precipitation and evaporation within the basin. They are also characterized by deep accumulations of organic sediment, shallow stream channels, nutrient rich water, and a linear floodplain. The accumulation of organic matter in the

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FIGURE 3.6.3 WETLAND CLASSIFICATIONS IN THE WHITE RIVER WATERSHED.

FIGURE 3.6.4 UNIQUE NATURAL COMMUNITIES IN THE WHITE RIVER WATERSHED.

wetland influences the plant communities found in the emergent and herbaceous zone.

Coastal Plain Marshes are found in eastern Muskegon County, central Newaygo County near Robinson Lake, and northern Newaygo County in the headwaters of the South Branch. These systems are formed in depressions of pitted outwash plains (Chapman 1990) and have concentric bands of vegetation around a center area of open water. A broad range of wetland communities are present in these bands including aquatic beds, emergents, wet prairies, and hardwood swamps (Kost 2000). Given the diversity of plant communities and zonation present, these systems are very sensitive to hydrologic disturbances from draining and shoreline development. With only forty of these systems identified in Michigan, the presence of eight Coastal Marsh Plains in the White River watershed represents a unique concentration of these rare wetlands.

FIGURE 3.6.5 COASTAL PLAIN MARSH IN NEWAYGO COUNTY.

Another rare wetland community, the Northern Wet –Mesic Prairie, is found in Oceana County near the confluence of the North and South Branches. Only 37 of these systems are found in Michigan and they have extreme hydrological regimes ranging from spring flooding to drought conditions in the summer (Albert and Kost 1998). These conditions are due to soil structure (1-3 meters of permeable sand overlaying clay) and the variability in moisture limits the establishment of woody plant species. Northern Wet–Mesic Prairies have very diverse plant communities and are subject to wildfires during the dry season. Wildflower communities are especially diverse in this type of habitat due to seasonal variations in soil moisture. The Northern Wet –Mesic Prairie in Oceana County is shown in Figure 3.6.6.

FIGURE 3.6.6 NORTHERN WET –MESIC PRAIRIE IN OCEANA COUNTY.

Two Northern Wet Meadows are found in central section of the watershed. These wetlands have acidic soils and are dominated by sedges (*Carex*) and forbs (Kost 2001). Northern Wet Meadow systems are formed in depressional, glacial, lowlands and are covered with *Carex* tussocks. The drying of tussocks during drought conditions renders these wetlands very susceptible to fire. Figure 3.6.7 shows a Northern Wet Meadow in Oceana County.

FIGURE 3.6.7 NORTHERN WET MEADOW IN OCEANA COUNTY.

In contrast to wetlands, Dry Sand Prairies are characterized by arid, sandy soils that are very susceptible to fire and wind erosion (Hauser 1953). Figure 3.6.8 shows a Dry Sand Prairie located in Muskegon County. Wildflowers such as Lupine and a variety of grasses and forbs dominate the landscape. The Karner Blue Butterfly is often associated with the lupine species common to these environments. In addition, prickly pear cactus can also be found (Figure 3.6.9). Dry Sand Prairies are very fragile environments and must be isolated from adverse anthropogenic impacts. If natural events such as fire or extreme drought destroys the vegetative cover, the area can often be rehabilitated by seeding with native grasses and wildflowers.

Oak/Pine Barrens are also very dry environments and are characterized by small jack pines (*Pinus banksiana*) mixed with scrubby Hill's oaks and bur oaks interspersed with openings in which shrubs dominate (Cohen 1999). Level topography and soils that are sandy and well drained are characteristic of these environments. Oak/Pine Barrens are maintained by periodic fires and drought conditions. These systems are also rare and only a few hundred acres remain in Michigan. A photograph of the only Oak/Pine Barren in the watershed is shown in Figure 3.6.10.

FIGURE 3.6.8 DRY SAND PRAIRIE IN MUSKEGON COUNTY.

FIGURE 3.6.9 PRICKLY PEAR CACTUS IN A DRY SAND PRAIRIE LOCATED IN MUSKEGON COUNTY.

FIGURE 3.6.10 OAK/PINE BARRENS IN OCEANA COUNTY.

Several bogs are present in Oceana and Newaygo Counties. These wetlands have acidic waters (Bridgham and Richardson. 1993) and are dominated by various combinations of sedges, sphagnum mosses, and insectivorous herbs. Sphagnum moss forms a dense mat that is often floating on the water. This species of moss releases H^+ into the water and creates the acidic environment. Under these conditions, organic matter decays very slowly and large deposits of peat accumulate. A typical bog environment is shown in Figure 3.6.11. While plant diversity is low in bogs, a number of rare and endangered species are usually present. These include the pitcher plant and the marsh five finger (Figure 3.6.12).

The unique wetland and upland environments discussed above add to the ecological diversity found in the White River watershed. They are natural features that are products of the unique set of hydromorphic and geomorphic features present in the watershed and the linkage to the Great Lakes.

FIGURE 3.6.12 PITCHER PLANT AND MARSH FIVE FINGER FROM A BOG IN OCEANA COUNTY.

FIGURE 3.6.11 BOG SYSTEM IN OCEANA COUNTY.

3.7 FISHERIES

The White 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. Currently, 70 fish species are found in the river, with 7 introduced to the region (MDNR 1989). A list of fish species found in the lower White River watershed is presented in Appendix B Table B-4 (MDNR 1989). The MDNR (1975) described the habitats and fisheries found in the White River and its tributaries. Stratton, Flinton, Five Mile and Mullen Creeks were classified as excellent streams for fishing with good populations of brook, brown and rainbow trout. Near White Cloud, the impoundment changed the temperature enough to favor rough fish and suckers. The trout population between White Cloud and Hesperia wasclassified as fair with brown trout in greatest abundance. Several tributaries in the middle section of the White River also contained excellent trout populations. Martin Creek was listed as an excellent brook-brown stream while Mena Creek was listed as good. The lower White was classified as a transitional fishery with strong spring and fall runs of steelhead plus populations of brown trout, smallmouth bass and northern pike. Some of the smaller tributaries in the middle section including Braton, Skeel and Cushman Creeks were listed as having good populations of brooks, browns and rainbows.

Due to the influence of McLaren Lake, a majority of the upper North Branch is a transitional fishery that supports warm water fish. As the stream passes through forested areas and accumulates groundwater, the temperature decreases and reaches a point that will support trout. From the mid point of Newfield Township until it joins with the lower White River, the North Branch was ranked as a good brown trout stream that also supported seasonal runs of steelhead. Several excellent coldwater tributaries enter the North Branch including Robinson Creek, Cobmosa Creek, Newman Creek and Knudsen Creek. All of these streams were reported to contain brooks and browns of respectable size. Downstream from the mouth of the North Branch, several tributaries of the White River were listed as viable brook trout streams. Carlton Creek was ranked as the best of the group, with Silver Creek and Sand Creek ranked above Cleveland Creek. Small impoundments on Sand Creek, Silver Creek and Cleveland Creek alter the temperature regime inundate sufficiently to support suckers and other rough fish. On a watershed basis, the White River supports a variety of coldwater species in addition to providing transitional environments for more tolerant species. The fishery is therefore an ecologically significant feature as well as a factor that adds to the recreational and economic value to the watershed.

4.0 White River Watershed Land Cover

Analysis

Land cover analyses were conducted in each of the subwatersheds using MIRIS data from 1978 and 1992/1997/1998. The most recent data sets were used for each county (Oceana 1992, Newaygo 1997, and Muskegon 1998) and were compared to the 1978 information to determine areas where significant change occurred. The results of the GIS land cover analyses and field surveys are presented in Sections 4.1-4.10 for the individual subwatersheds. Summaries of the current land cover and significant changes from 1978 to 1992/1997/1998 are also presented.

4.1 UPPER SOUTH BRANCH

The Upper South Branch subwatershed covers 60,473 acres and includes sections of eight townships and the City of White Cloud. The land cover data for this area are summarized in Table 4.1.1 and displayed in map format on Figure 4.1.1. The Upper South Branch subwatershed consists primarily of mature forests (68.4%), cropland (13.6%), open fields (11.2%), wetlands (4.25%), open water (0.57%), and developed (0.99% residential, 0.04% commercial/institutional, 0.56% other development). Most of the cropland and open fields are concentrated in the southern and eastern portions of the subwatershed, and the wetlands are mainly found in the northwest portions in Monroe and Merrill Townships. This subwatershed contains nearly 26% of all the wetlands found in the White River watershed, totaling 2,571.2 acres (Table 4.1.1). The majority of these wetlands are located in close proximity to the smaller headwater tributaries and lakes of the Upper South Branch. A large wetland complex is also located in the upper northwest portion of the watershed (Oxford Swamp). The western headwaters of the South Branch and part of Mullen Creek near Van Buren Street, pass through a section of agricultural land where the stream channel lacks a significant riparian zone. This is reflected by a change in water temperature as the streams pass through this area. Diamond Lake is the largest water body in the subwatershed. Approximately 60% of the shoreline is residential and agricultural lands border the home sites in the eastern shore. Since 1978, very little change in land usage has occurred (Table 4.1.1). The most significant change was a shift from cropland and open fields to forested areas. The increase in other developed areas was related to the expansion of an oil and gas field near Four Mile Road and the addition of lands dedicated to utilities and infrastructure in

the White Cloud area. The continued stability of the wetlands and forests in this subwatershed is essential to the local trout fishery and protection of the headwater streams.

Table 4.1.1 Land Cover Analysis of the Upper South Branch Subwatershed.

1992/1997/1998 **Land Use/Cover Classification**

1978 Acreage Acreage
of Percent Total

Acreage Change Net

Percent Change

Residential 576 596 1.0 20 3.5 Commercial/Institutional 19 23 < 0.1 4 23 Industrial 54 75 0.1 20 37 Other Developed Area 125 341 0.6 216 173 Cropland 8,771 8,196 14 -575 -6.6 Confined Feeding and Permanent Pasture 232 8 < 0.1 -223 -96 Orchard or Other Specialty Crop 8 154 0.3 146 1,781 Other Agricultural Land 23 25 < 0.1 2 8.5 Open Field 7,191 6,753 11 -438 -6.1 Forest 40,661 41,372 68 711 1.7 Water 350 347 0.6 -4 -1.1 Wetland 2,464 2,571 4.3 108 4.4 Transitional Land 0 3 < 0.1 3 NA Total Acres 60,464

4.2 SOUTH BRANCH WHITE RIVER/ROBINSON LAKE

The South Branch White River/Robinson Lake subwatershed covers 39,372 acres and includes sections of six townships and the City of White Cloud. GIS land cover data are presented in Table 4.2.1 and displayed in map format on Figure 4.2.1. Approximately 60% of the subwatershed is undeveloped forest, 20% is cropland and 11% is open fields. The forested areas are found in the eastern half of the subwatershed, and the majority of the cropland and open fields are concentrated in the western portion. Riparian corridors have been removed from most of the wetlands and stream channels in the agricultural area. This subwatershed contains 12% of all the wetlands found in the White River watershed, which are concentrated mainly in Dayton and Sherman Townships south of Baseline Road. Developed areas include approximately

FIGURE 4.1.1 LAND COVER MAP OF UPPER SOUTH BRANCH SUBWATERSHED.

2% residential land use, with less than 1% being commercial, institutional or industrial development. Development is concentrated around Robinson Lake (including the resort area of Jugville), on the western side of White Cloud, and in section of the riparian zone near Aetna. Land use changes since 1978 (Table 4.2.1) are similar to the general trend visible throughout the watershed, with a shift in a small amount of cropland to open field, orchard, and forest.

Table 4.2.1 Land Cover Analysis of the South Branch White River / Robinson Lake Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998 Acreage	Percent of Total	Acreage Change	Net Percent Change
Residential	835	900	1.5	65	7.8
Commercial/Institutional	50	67	0.1	17	34
Industrial	56	59	0.1	4	6
Other Developed Area	112	222	0.4	110	99
Cropland	10,040	7,876	13	-2,164	-21.6
Orchard or Other Specialty Crop	146	382	0.6	236	161
Confined Feeding and Permanent Pasture	7	9	< 0.1	2	27
Other Agricultural Land	24	46	0.1	21	88.6
Open Field	2,995	4,368	7	1,372	45.8
Forest	23,446	23,699	39	253	1.1
Water	503	505	0.8	2	0.4
Wetland	1,159	1,233	2.0	74	6.3
Transitional Land	0	7	0.0	7	NA
Total Acres	39,372				

A majority of these land use changes occurred in Denver Township. An important feature of this subwatershed is the wetland / lake system present in Sherman Township, which includes Coonskin Creek, Robinson Lake and Robinson Creek, as well as several other smaller lakes and associated wetlands. Robinson Lake is reported to be eutrophic due to runoff and septic tank leachate from residential and commercial development. Robinson Lake and the developed section of Robinson Creek represent a source of nutrient loading to the South Branch. Crystal Lake is classified as a trout lake and supports a cold water fishery. This lake is unique with respect to this designation in the White River watershed. A majority of the cropland present

FIGURE 4.2.1 LAND COVER MAP OF SOUTH BRANCH WHITE RIVER / ROBINSON LAKE SUBWATERSHED.

Figure 4.2.2 Cattle near Back Creek in the South Branch Subwatershed of the White River.

in this subwatershed is drained by Black Creek in Dayton Township. Figure 4.2.2 shows an area along Black Creek where cattle have access to the water. A bloom of *Cladophora* was observed, which indicates nutrient enrichment. Nutrient loading from these creeks may be significant because of the effects of the impoundment located downstream at Hesperia.

4.3 MARTIN/MENA/HELD CREEKS SUBWATERSHED

The Martin/Mena/Held Creeks subwatershed covers 31,669.8 acres (9.4% of the total watershed area). Land cover data are shown in Table 4.3.1.and displayed in map format on Figure 4.3.1. Undeveloped forested areas account for 68.5% of the subwatershed, followed by open fields (14.7%) and cropland (11.5%). Approximately 10% of all the wetlands present in the White River watershed are located in this subwatershed (965 acres). Less than 1% of the subwatershed land is classified as residential or industrial. Most of the forested areas are found in the eastern portion of the subwatershed north of the main channel of the White River. The western section of the subwatershed contains most of the cropland and open fields. Many of the wetlands and streams in the agricultural area lack riparian zones, which is significant with respect to runoff. A large group of wetlands are located near the headwaters of Martin, Held, and Mena Creeks. These creeks and wetlands are located in forested areas of the subwatershed. There has been significant change in land use within this subwatershed since 1978. Over 3300 acres of cropland

Table 4.3.1 Land Cover Analysis of the Martin/Mena/Held Creeks Subwatershed 1978 - 1992/1997/1998

Land Use/Cover Classification	1978 Acreage	1992/1997/1998 Acreage	Percent of Total	Acreage Change	Net Percent Change
Residential	31	36	0.1	5	15.0
Industrial	0	5	0.0	5	NA
Other Developed Area	0	49	0.2	49	NA
Cropland	6,988	3,654	12	-3,334	-48
Orchard or Other Specialty Crop	161	395	1.2	234	146
Confined Feeding and Permanent Pasture	31	31	0.1	0	-0.6
Other Agricultural Land	10	27	0.1	17	163
Open Field	2,358	4,644	15	2,285	97
Forest	20,945	21,692	68	747	3.6
Water	172	173	0.5	0	0.2
Wetland	976	965	3.0	-11	-1.1
Total Acres	31,670				

changed to open fields, and a large portion of this change was concentrated south of the main channel of the White River's south branch near M-20 and Green Avenue in Dayton Township. Martin, Mena, and Held Creeks are classified as quality trout streams with high gradients and considerable woody debris. It is imperative that the riparian zone and surrounding forests be maintained in their current condition to maintain habitat quality.

4.4 SKEEL/CUSHMAN/BRATON CREEKS SUBWATERSHED

The Skeel/Cushman/Braton Creek subwatershed covers 49,644 acres or 14.8% of the White River watershed. Land cover data are shown in Table 4.4.1.and displayed in map format on Figure 4.4.1. The subwatershed includes seven townships in addition to the City of Hesperia. With respect to land cover, cropland and forested area percentages are nearly equal (38.4% and 44.8%, respectively), followed by open fields (5.9%). Developed areas account for slightly more than 5% of the land area. The undeveloped forested areas are located primarily in the southwestern portions of the subwatershed in the areas surrounding the White River channel. A majority of the residential land use is located in the city of Hesperia and in the surrounding areas, extending

FIGURE 4.3.1 LAND COVER MAP OF THE MARTIN/MENA/HELD

CREEKS SUBWATERSHED.

Table 4.4.1 Land Cover Analysis of the Skeel/Cushman/Braton Creeks Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998 Acreage	Percent of Total	Acreage Change	Net Percent Change
Residential	752	1,682	3.4	929	124
Commercial/Institutional	63	77	0.2	14	23
Industrial	9	9	< 0.1	0	0.1
Other Developed Area	552	920	1.9	368	67
Cropland	21,651	19,068	38	-2582	-12
Orchard or Other Specialty Crop	957	952	1.9	-5	-0.5
Confined Feeding and Permanent Pasture	318	251	0.5	-67	-21
Other Agricultural Land	9	99	0.2	91	1059
Open Field	2,493	2,938	5.9	445	18
Forest	21,457	22,228	45	771	3.6
Water	203	250	0.5	46	23
Wetland	1,167	1,154	2.3	-14	-1.2
Barren/Sand Dune	32	16	< 0.1	-16	-49
Total Acres	49,644				

southward along the Oceana / Newaygo County line. Since 1978 there has been an marked increase in residential land use (124% increase, 929 new acres). Cropland decreased by 2,582 acres with a corresponding increase in developed areas (1,297 acres), forest (771 acres) and open field (368 acres). A majority of the land taken out of agricultural production is located north of Hesperia. A loss of 16 acres of Oak/Pine Barrens was noted in the transition zone of agricultural and forest lands near Braton Creek. Barrens are unique habitats (Section 3.6) and should be preserved to promote diversity. The increase in the other developed area category was related to the expansion of extractive sites. A number of gravel mining sites are located in the subwatershed and constructed in close proximity to streams. Hesperia Dam is also located in this subwatershed. The impoundment was very shallow and was subject to excessive siltation. This impoundment may be a source of nutrients and temperature related problems to the downstream section of the South Branch. As discussed in Section 3.7, Skeel, Cushman, and Braton Creeks were classified as trout streams that support natural reproduction. The headwaters of the three creeks are located in agricultural lands with limited riparian cover. Soil textures and slopes in the headwater areas have the potential for erosion and consequently, these creeks may be subject to

FIGURE 4.4.1 LAND COVER MAP OF THE SKEEL/CUSHMAN/BRATON CREEKS SUBWATERSHED.

sedimentation and nutrient addition. Many of the headwater streams are straight, indicating channelization was performed to enhance drainage. Programs for riparian zone enhancement and best management practices should be initiated in this subwatershed.

4.5 UPPER NORTH BRANCH SUBWATERSHED

The Upper North Branch White River contains 14,800 acres and includes McLaren Lake. Land cover data are shown in Table 4.5.1.and displayed in map format on Figure 4.5.1. The subwatershed is dominated by forested areas

Table 4.5.1 Land Cover Analysis of the Upper North Branch Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998 Acreage	Percent of Total	Acreage Change	Net Percent Change
Residential	285	621	4.2	335	118
Commercial/Institutional	0	4	0.0	4.0	NA
Other Developed Area	2	39	0.3	36	1500
Cropland	3231	2692	18.2	-540	-17
Orchard or Other Specialty Crop	146	299	2.0	153	104
Confined Feeding and Permanent Pasture	15	15	0.1	0.0	< 0.1
Other Agricultural Land	0	4	< 0.1	4.2	NA
Open Field	1556	1287	8.7	-269	-17
Forest	8141	8385	57	244	3
Water	457	462	3.1	5.7	1
Wetland	936	961	6.5	25	3
Barren/Sand Dune	21	33	0.2	11	53
Total Acres		14801			

(8,384.5 acres or 56.7%), followed by cropland (18.2%) and open fields (8.7%). Wetlands (6.5%) and residential land usage (4.2%) also contribute to land cover. A Northern Wet Meadow and bog ecosystems are located within the Upper North Branch White River subwatershed (Figure 3.6.5).

The eastern portion of this subwatershed contains a mixture of croplands, forests, and wetlands. More than half of the wetlands present within the subwatershed are located in agricultural areas with no apparent riparian zone.

FIGURE 4.5.1 LAND COVER MAP OF THE UPPER NORTH BRANCH SUBWATERSHED.

Much of the residential development present in this subwatershed is located around McLaren Lake, with some areas extending to the southwest. The western half is much less developed and contains large tracts of undeveloped forested areas. A few areas of cropland are present, although the majority of cropland is found to the east in the areas surrounding McLaren Lake. Land use changes since 1978 are slightly different than the pattern found throughout the White River watershed. There was a shift from both cropland and open fields to residential and orchard land use types. Forested areas expanded by 244 acres. As discussed in Section 3.7, this subwatershed is the only one that supports a warm water fishery. Drainage from McLaren Lake and several open wetlands form the headwaters of the Upper North Branch and influence the temperature. After passing through the riparian forests and reaches with additional groundwater flows, the temperature decreases to a cold water fishery. Continued residential development in the area surrounding McLaren Lake may be problematic in the future due to increased eutrophication and nutrient loading in the headwaters.

4.6 NORTH BRANCH SUBWATERSHED

The North Branch subwatershed, includes portions of 7 townships and has a area of 53,804 acres (16% of the entire watershed). Land cover data are shown in Table 4.6.1 and displayed in map format on Figure 4.6.1. The subwatershed has a very diverse array of land usage with significant amounts of agricultural, residential, forested and wetland areas. Undeveloped forested areas represent the predominant land cover (27,182 acres or 50.0%) followed by croplands (11,358 or 20.7%). Other significant land covers include 16.3% open fields, 8.9% orchards, 1.5% wetland and 1.4% residential. Agricultural land use is primarily concentrated in Shelby Township, and in Elbridge Township in the northern portions of the subwatershed. On a percentage basis, the North Branch has low amount of wetlands compared to the remainder of the subwatersheds. This is due to the higher elevation and permeable soils found in the moraine ridge that makes up a majority of the area. A notable feature of this catchment area is the high percentage of land cover designated as orchards or specialty crop land. Orchards are found primarily in Shelby Township, however smaller plots are scattered throughout the subwatershed. Land use changes since 1978 involved more acreage in the North Branch than the other subwatersheds. The largest change was the conversion of 3,655 acres of cropland into orchard/specialty crops and open fields. This conversion should enhance water quality by lowering the potential for erosion and reducing the amount of land that is extensively fertilized. Residential growth for the watershed was also high as development increased by 82% (340 acres).

Table 4.6.1 Land Cover Analysis of the North Branch Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998 Acreage	Percent of Total	Acreage Change Net	Percent Change
Residential	416	756	1.4	340	82
Commercial/Institutional	30	27	0.0	-3.2	-10
Industrial	0.0	6.7	0.0	6.6	NA
Other Developed Area	179	259	0.5	80	45
Cropland	15,013	11,358	21	-3,655	-24
Orchard or Other Specialty Crop	2,519	4,903	8.9	2,385	95
Confined Feeding and Permanent Pasture	343	193	0.4	-150	-44
Other Agricultural Land	0.0	25.2	< 0.1	25	NA
Open Field	7,887	8,955	16	1,068	14
Forest	27,362	27,182	50	-180	-0.7
Water	245	252	0.5	6.9	2.8
Wetland	719	842	1.5	123	17
Barren/Sand Dune	44.5	44.9	0.1	0.4	1.0
Total Acres		54,804			

4.7 MIDDLE BRANCH SUBWATERSHED

The Middle Branch is a small subwatershed that is located almost exclusively in the Manistee National Forest. Land cover data are shown in Table 4.7.1 and displayed in map format on Figure 4.7.1. The subwatershed covers 8030 acres with forested and agricultural lands covering 90% and 7.6% of the landscape, respectively. Land cover changes from 1978 were minimal due to the high percentage of federal land. This subwatershed contains the only Northern Wet-Mesic Prairie found in the White River basin.

FIGURE 4.6.1 LAND COVER MAP OF THE NORTH BRANCH SUBWATERSHED.

Table 4.7.1 Land Cover Analysis of the Middle Branch Subwatershed 1978 - 1992/1997/1998.

1992/1997/1998 **Land Use/Cover Classification**

1978 Acreage Acreage
of Percent Total

Acreage Change Net

Percent Change

Residential 26 74 0.9 49 188 Commercial/Institutional 17 18 0.2 0.5 3 Cropland 48 20 0.2 -29 -60 Open Field 568 610 7.6 42 7 Forest 7.269 7.215 90 -54 -1 Water 16 17 0.2 0.0 0.0 Wetland 77 77 1.0 0.0 0.0 Total Acres 8.030

4.8 WHITE LAKE CARLTON/MUD CREEK SUBWATERSHED

The Carlton/Mud Creek subwatershed includes portions of 7 townships and has an area of 53,804 acres. Land cover data are shown in Table 4.8.1 and displayed in map format on Figure 4.8.1. This subwatershed contains the villages of Whitehall, Montague, New Era, and Rothbury. It also contains White Lake and the drowned rivermouth wetland. Land to the east of US 31 is mostly forested below Rothbury. North of the village, land cover changes to agricultural and open field. Forested lands comprise 54% of the area with cropland, open field and residential covering 12%, 10%, and 9.4%, respectively. Significant tributaries of the White River include Silver Creek to the south of the main channel and Carlton and Mud Creeks to the north. The latter two creeks originate in agricultural areas with little riparian cover.

Land cover changes from 1978 included the addition of 1,370 acres of residential development and the conversion of 905 acres of cropland and confined animal feeding operations to open field and other non agricultural uses. This subwatershed was the only one to have a significant amount of forest acreage (564 acres) change to industrial and residential developments. A loss of 46 acres of Pine/Oak Barrens was also recorded. This subwatershed will continue to experience development pressure because of the number of urban centers, good highway access, and the large number of small lakes present. It will be critical to implement the proper zoning measures that encourage the preservation of water quality and greenspace in order to prevent the loss and degradation of important natural resources.

FIGURE 4.7.1 LAND COVER MAP OF THE MIDDLE BRANCH SUBWATERSHED.

Table 4.8.1 Land Cover Analysis of the White Lake/Carlton/Mud Creek Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998 Acreage	Percent of Total	Acreage Change	Net Percent Change
Residential	4004	5375	9.4	1370	34
Commercial/Institutional	505	759	1.3	254	50
Industrial	515	558	1.0	43	8.4
Other Developed Area	1132	1190	2.1	58	5.1
Cropland	7876	6971	12	-905	-11
Orchard or Other Specialty Crop	633	710	1.2	77	12
Confined Feeding and Permanent Pasture	720	178	0.3	-542	-75
Other Agricultural Land	6	53	0.1	47	763
Open Field	5704	5902	10	198	3
Forest	31095	30531	54	-564	-1.8
Water	3400	3413	6.0	12	0.4
Wetland	1374	1364	2.4	-10	-0.7
Barren/Sand Dune	107	61	0.1	-46	-43
Total Acres		57064			

4.9 SAND CREEK/WOLVERINE LAKE SUBWATERSHED

The Sand Creek/Wolverine Lake subwatershed includes portions of 4 townships and has an area of 22,694 acres. Land cover data are shown in Table 4.9.1 and displayed in map format on Figure 4.9.1. This subwatershed includes a large pitted outwash plain that contains a number of small to middle sized lakes, and a variety of wetlands, three Costal Plain Marshes, and two Dry Sand Prairies. Two tributaries of the White River are located within the drainage basin. Sand Creek originates in an agricultural area with a moderate riparian buffer zone. Cleveland Creek originates on Wolverine Lake and passes through forested land before discharging into the White River. Forested lands comprise 78% of the area with cropland, open field and residential covering 3.9%, 3.7%, and 2.6%, respectively. Residential development is concentrated in areas around major lakes and the village of Holton.