Ox Creek Watershed Management Plan

"A Guide for the Protection and Improvement of Water Quality"

"Slow it Down. Spread it Out. Soak it In."

OX CREEK WATERSHED

URBAN | RURAL | EXIT 29

November 2018

Ox Creek Watershed Management Plan

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1 Introduction

The Ox Creek Watershed (OCW) is all of the land that drains into Ox Creek (OC), which is located in Berrien County in Southwest Lower Michigan. Wetlands, ponds, streams and other surface water bodies on this land and the groundwater are also part of the watershed. Water is a critical resource for recreation, irrigation, and increasing the value of adjacent real estate. These uses depend on good water quality, but they can also be a threat to it. The Ox Creek Watershed is identified as the highest priority urban area for implementation in the *Paw Paw River Watershed Management Plan* (https://www.swmpc.org/pprw_mgmt_plan.asp).

A watershed is all of the land that drains into a common body of water. Watersheds surpass political boundaries and connect communities with a common resource.

Although there are multiple threats to water quality in the OCW, the two biggest problems are sediment from agricultural operations and stormwater runoff from the hundreds of acres of existing pavement, especially around the Orchards Mall area. While there are additional issues in the watershed, this Plan primarily focuses on these two. The OCW is a priority for improvement among southern Michigan watersheds and appears on Michigan's §303(d) list because it is not meeting the Other Indigenous Aquatic Life and Wildlife (OIALW) designated use, indicated by poor macroinvertebrate community ratings. Sedimentation, siltation, total suspended solids (TSS), and flow regime alterations are causes of the impairment.

The OCW Management Plan is intended to guide individuals, businesses, organizations and governmental units working cooperatively to ensure the water and natural resources necessary for future growth and prosperity are improved and protected. It can be used to educate watershed residents on how they can improve and protect water quality, encourage and direct natural resource protection and preservation, and develop land use planning and zoning that will protect water quality in the future. Implementation of the plan will require stakeholders to work across political boundaries.

Chapters 2 and 3 of the Management Plan provide an overview of the watershed. Chapter 4 outlines the role governmental units play in protecting water quality. Chapter 5 describes the natural features of the watershed. The process used to develop the plan is reviewed in Chapter 6. Chapter 7 summarizes water quality throughout the watershed and Chapter 8 prioritizes the areas, pollutants, and sources impacting it. Chapter 9 offers goals for the watershed and Chapter 10 provides strategies for achieving them. Lastly, Chapter 11 suggests a strategy for evaluating the progress toward the goals of the plan.

Watershed management involves identifying and prioritizing problems, promoting involvement by stakeholders, developing solutions and measuring success through monitoring and data collection.

The State of Michigan protects all water bodies for designated uses such as water supply, fisheries, and for partial and total body contact for recreation. This Management Plan was created as part of the OCW planning project, which was funded through a partnership developed to bring in grant funds to address the pollution issues, including a grant to the Southwest Michigan Planning Commission (SWMPC) received from the Michigan Department of Environmental Quality (MDEQ) Stormwater, Asset Management, and Wastewater (SAW) Program. Development of the OCW Management Plan relied heavily on stakeholder input and agency support, as well as professional services and other partnerships. The overall health of a watershed can be difficult to determine. Characterizations and recommendations in this plan are based on the best available data.

2 Watershed Description

2.1 Geography

The term watershed describes an area of land that drains downslope to the lowest point. It includes all of the land, in which any drop of water falling within it, will leave in the same stream or river. Watersheds can be large or small and can traverse county, state, or national boundaries. Every stream, tributary, or river has an associated watershed and small watersheds join to become larger watersheds. For example, within the Great Lakes watershed, the OCW is a part of the Paw Paw River Watershed, which is part of the St. Joseph River watershed, which is part of the larger Lake Michigan watershed.

Pennsylvania Department of Environmental Protection

The OCW drains an area of 13.4 square miles. Ox Creek originates in predominately agricultural lands east of Benton Harbor. The Yore & Stoeffer Drain, situated to the south of Ox Creek's headwaters, is its largest tributary. This upper portion of the watershed also contains some light industrial areas. Both Ox Creek and the Yore & Stoeffer Drain have been greatly altered and channelized in these upper reaches.

The middle portion of the watershed is dominated by residential and commercial space that includes shopping centers. Ox Creek is influenced by stormwater sources as a result of increased impervious cover in this part of the watershed. Impervious cover refers to any manmade surfaces (e.g., asphalt, concrete, and rooftops), along with compacted soil, that water cannot penetrate. Rain and snow that would otherwise soak into the ground turns into stormwater runoff when it comes into contact with impervious surfaces.

I-94 is a major transportation link between Detroit and Chicago and has increased commercial land use around the Pipestone Avenue interchange and Orchards Mall. Just below the confluence of Ox Creek and the Yore & Stoeffer Drain the stream enters a ravine-type setting. From this area to downtown Benton Harbor, Ox Creek meanders through a riparian wetland located within the ravine.

The lower portion of the watershed is a mix of residential, urban, commercial, and industrial land use. The industrial portion of the lower watershed includes sites that are either in active use, have been abandoned, or are under redevelopment. Ox Creek flows through Harbor Shores, a golf course/residential/business area on redeveloped land that was formerly mixed-use industrial. Ox Creek then flows into the Paw Paw River near downtown Benton Harbor just upstream of its confluence with the St. Joseph River, and then empties into Lake Michigan.

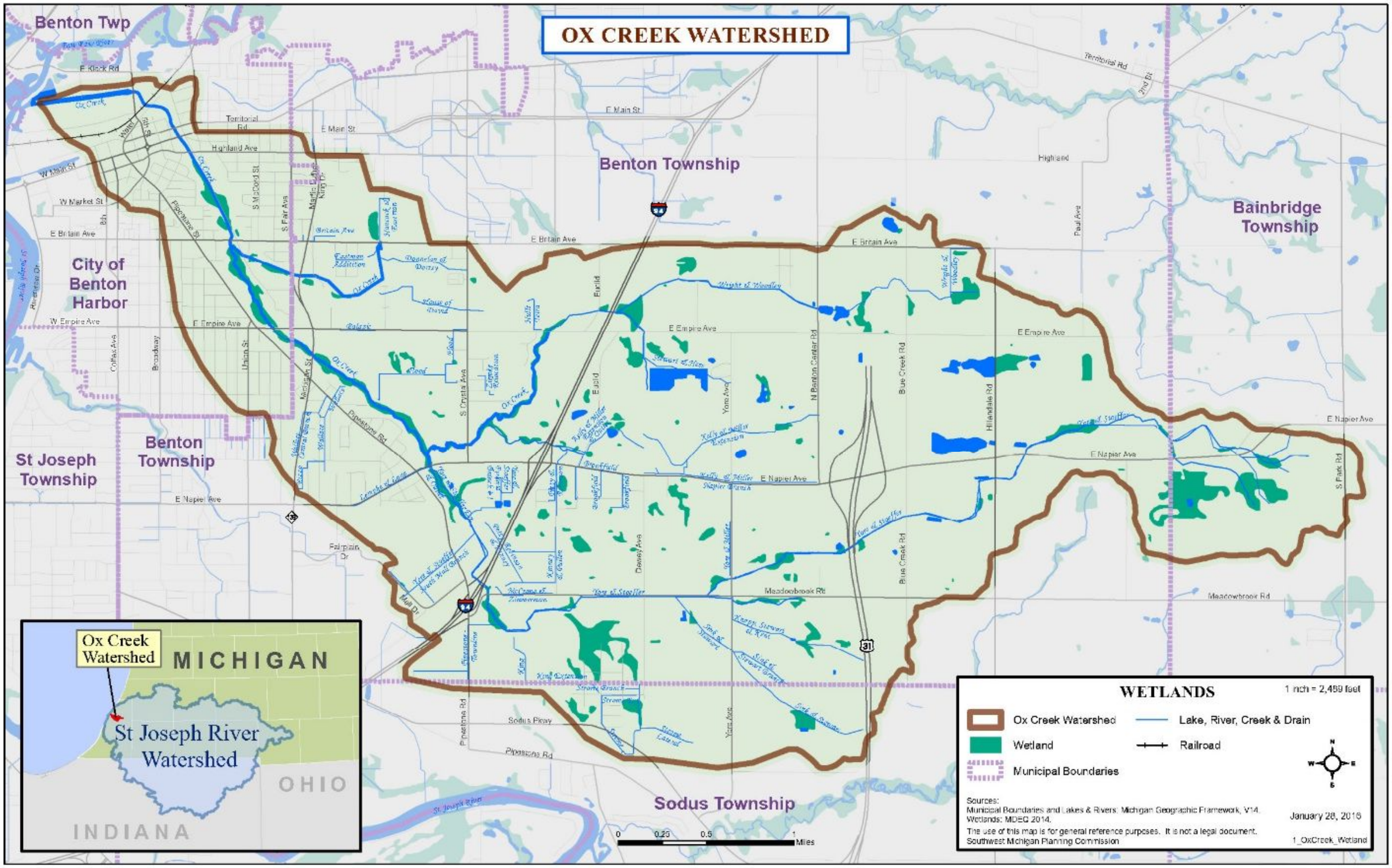
The following Figures show the location of the OCW in progressive detail.

Figure 1. Ox Creek Watershed Locator – State

Figure 2. Ox Creek Watershed Locator – Regional


Van Buren
County
Kalamazoo County
MICHIGAN
Calhoun County
Lake
Michigan
Paw Paw River
Watershed
St Joseph River Watershed
Ox Creek Watershed
Cass County
St. Joseph
County
Branch County
Lenawee County
Berrien
County
Hillsdale County
INDIANA
St Joseph River
OHIO
Pigeon River
Watershed
Elkhart River
Watershed
January 28, 2016
3_OxCreek_Locator

Figure 3. Ox Creek Watershed



Watersheds are typically identified by Hydrologic Unit Codes (HUCs). HUCs were developed by the United States Geologic Society to provide official boundaries for watersheds. HUCs identify a geographic area, which includes part or all of a surface drainage basin. The United States is divided into successively smaller hydrologic units. The units are classified into six levels starting with large areas such as the Great Lakes Region (2-digit) down to small areas like the Ox Creek subwatershed (14-digit). Often, for management purposes, agencies focus on the smaller 14-digit HUC subwatershed level. The OCW – HUC 04050001270090 – covers an area of 8,595 acres and is located in Benton Charter Township (77.11%), Benton Harbor City (10.65%), Sodus Township (5.78%), and Bainbridge Township (5.46%),

2.2 Climate

The proximity of Ox Creek to Lake Michigan and prevailing westerly winds moderate the climate and produce lake-effect precipitation during the fall and winter months. The climate is also influenced by the maritime tropical air mass, which tends to be a relatively warm and humid air mass. The average growing season (consecutive days with low temperatures greater than or equal to 32°F) was 143 days between 1981-2010 (May 14 – Oct. 5). Total annual precipitation is approximately 37.08 inches including approximately 82 inches of snowfall, according to the National Climatic Data Center. At an average temperature of 72°F, July is the hottest month of the year. In January, the average temperature is 24°F (climatedata.org).

Climate change has had an impact on Southwest Lower Michigan, and will continue to do so, with dire effects likely if the causes are to continue unabated. Air temperatures have been much warmer than average and annual precipitation is increasing in the Great Lakes Region. 2017 was the wettest year on record with severe downpours increasing 45%. Moving forward, the area is faced with more winter precipitation as rain, with rain and snow melt happening at the same time leading to earlier peak stream flow. The river flow will be more variable, with more high-flow days in winter and spring and low-flow days in the summer. Summer will also see increased warming with less precipitation, causing lakes and rivers to warm. Warmwater species, such as carp, bluegill, and catfish will thrive, along with harmful algae blooms, and more runoff. Coldwater species, namely sport fish, will be threatened.

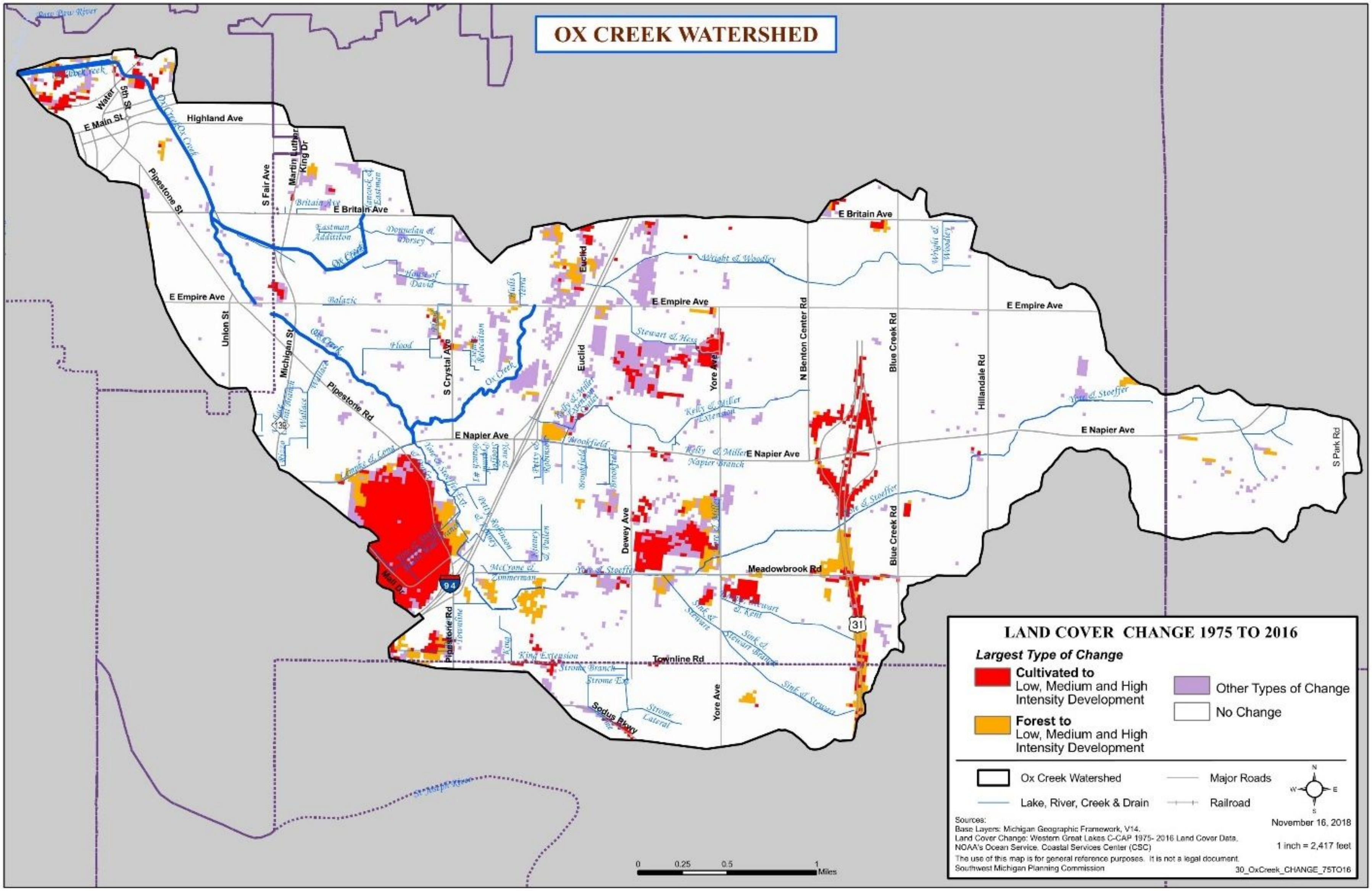
The OCW lies within the Southern Michigan, Northern Indiana Till Plains (SMNITP) ecoregion. Ecoregions are delineated by their climates, soils, vegetation, land slope, and land use. Ditching and channelizing have been used throughout this ecoregion to drain areas that are too wet for settlement and agriculture. The OCW is a priority for improvement due to sediment from agricultural operations and stormwater runoff from the hundreds of acres of existing pavement, especially around the Orchards Mall area.

2.3 Land Cover

Prior to European settlement in the early-to-mid 1800s, much of the OCW was forested. However, today, natural land cover in the OCW has become fragmented by agricultural practices, as well as commercial, and to a lesser degree, residential development. An estimated 74% of wetlands have been lost in the OCW in the last 200 years. Improved stormwater management, as well as proper management of agricultural lands, will be critical to protecting and improving water quality in the OCW.

The past four decades alone have seen marked changes in the OCW. Most notably, the area that is now Orchards Mall/I-94 Exit 29/Pipestone has shifted from cultivated to developed. This area now contains a relatively large number of impervious surfaces, which clearly affects the hydrology of Ox Creek.

Figure 4. Land Cover Change 1975-2016



As seen in the Tables below, 66% of the watershed is in the Rural East area, while 33% is in the Urban West area. However, 65% of the developed space is in the Urban West area, while 87% of the natural space is in the Rural East area. The following Figure maps the OCW land cover.

Figure 5. Urban West /Rural East Demarcation Map for Land Use/Cover

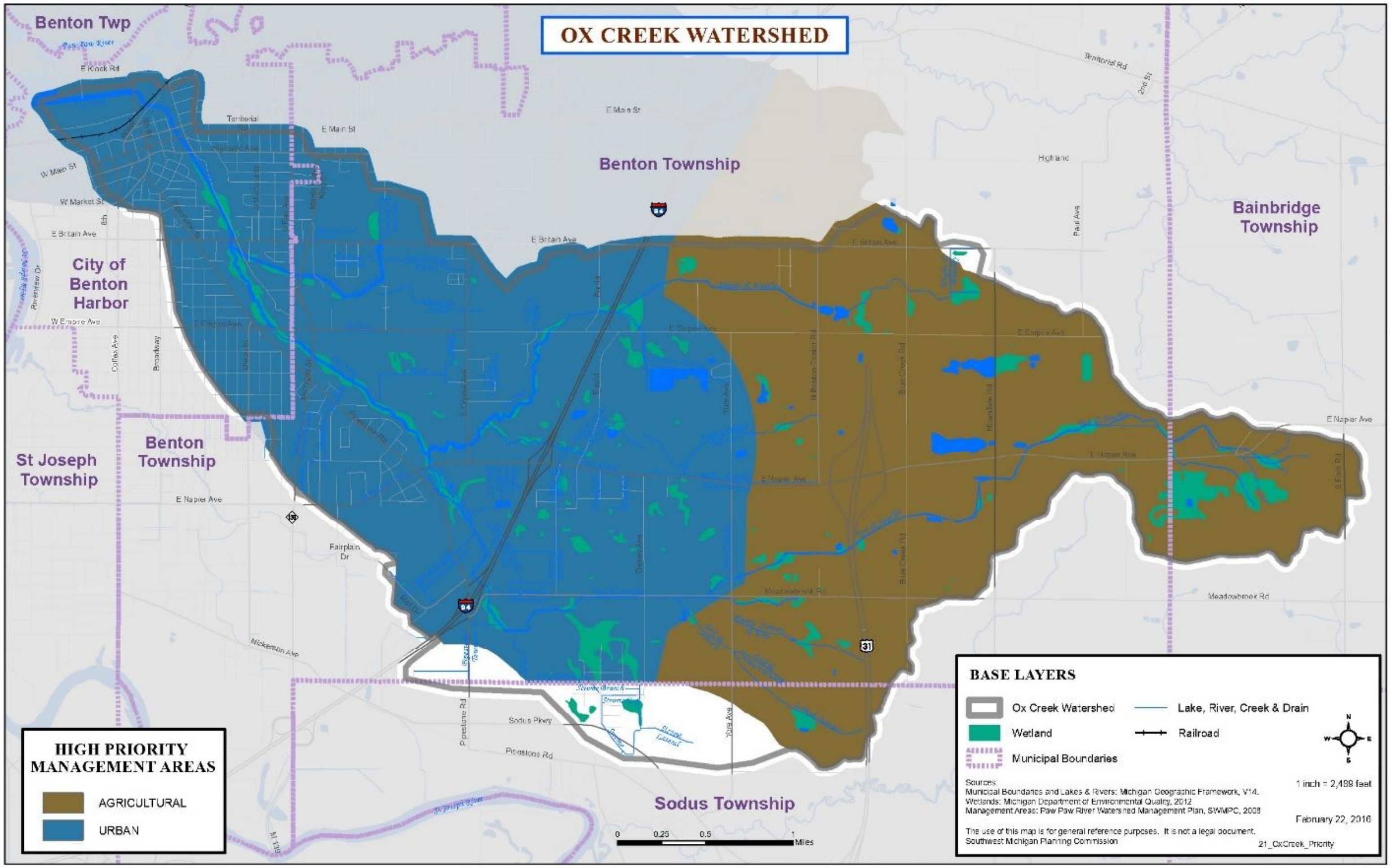


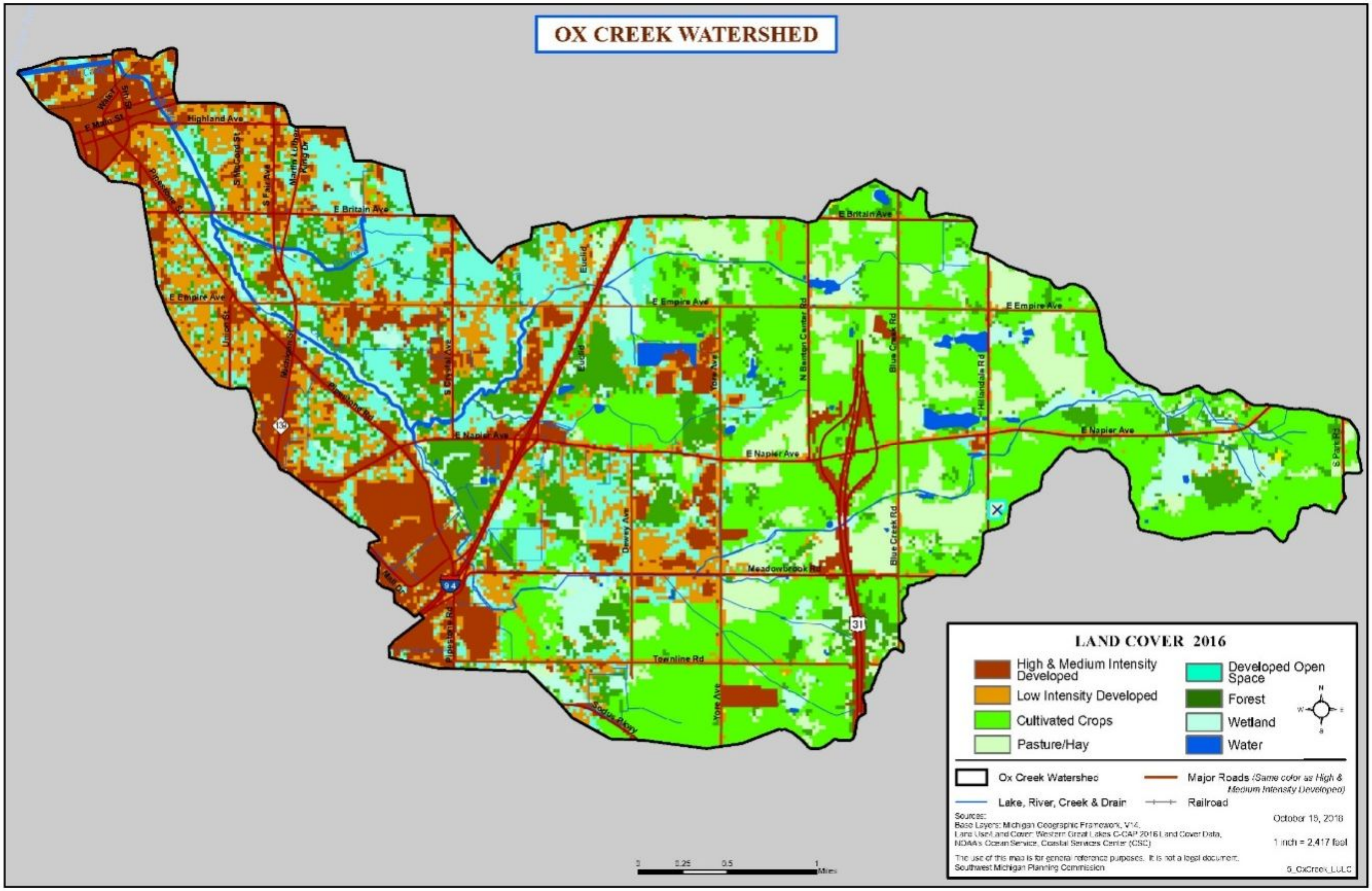
Table 1. Ox Creek Watershed Land Cover – East/West Split, Percentages of Total (2016)

Class	Acres (Total)	% of Total	Urban West	% of Total	Rural East	% of Total
Developed, High Intensity, Medium/Bare Land	1207	14%	788	9%	419	5%
Developed, Low Intensity	1281	15%	782	9%	499	6%
Developed, Open Space	1052	12%	715	8%	337	4%
Total Developed	**3539**	**-**	**2284**	**-**	**1255**	**-**
Cultivated Crops/Hay/Pasture Hay	3258	38%	35	0%	3223	38%
Forest/Shrub	972	11%	407	5%	565	7%
Grassland/Herbaceous	169	2%	16	0%	153	2%
Wetland	642	7%	177	2%	465	5%
Water	14	~0%	1	~0%	13	~0%
Total Natural	**5056**	**-**	**194**	**-**	**632**	**-**
Total	**8595**	**100%**	**2919**	**34%**	**5676**	**66%**

Table 2. Ox Creek Watershed Land Cover – East/West, Percentages of Class (2016)

Class	Acres (Total)	Urban East	% of Class	Rural West	% of Class
Developed, High Intensity, Medium/Bare Land	1207	788	65%	419	35%
Developed, Low Intensity	1281	782	61%	499	39%
Developed, Open Space	1052	715	68%	337	32%
Total Developed	**3539**	**2284**	**65%**	**1255**	**35%**
Cultivated Crops/Hay/Pasture Hay	3258	35	1%	3223	99%
Forest/Shrub	972	407	42%	565	58%
Grassland/Herbaceous	169	16	9%	153	91%
Wetland	642	177	28%	465	72%
Water	14	1	6%	13	94%
Total Natural	**5056**	**635**	**13%**	**4421**	**87%**
Total	**8595**	**2919**	**-**	**5676**	**-**

Figure 6. Ox Creek Watershed Land Cover (2016)



2.4 Geology, Hydrology and Soils

Geology and Hydrology

Virtually all of Michigan's topography and hydrology has been influenced by glacial action. Repeated advances of continental ice sheets eroded the pre-existing rock and soils and then redeposited these materials as sediments as the ice advanced, melted, and retreated during several cycles. These glacial materials were deposited as sands, gravels, silts, and clays, as well as various mixtures, and vary in thickness within the watershed area from approximately 130 feet to over 400 feet. Ice movement and its meltwater influenced the patterns and distributions of various landforms, such as moraines and stream valleys. The meltwater created large rivers, which deposited glacial materials throughout the region. These glacial deposits and their associated landforms provide a foundation for the hydrology, soil types, and land cover that exist today.

Hydrology plays an important role in water quality. The hydrology of a watershed is driven by local climate conditions, land use, and soils. In Ox Creek, altered drainage patterns and land use has resulted in flashy flows, where the stream responds to and recovers from precipitation events relatively quickly.

Several segments of Ox Creek and its tributaries have been channelized or relocated to facilitate agricultural or commercial and industrial development. A common practice for improving drainage is to install subsurface tile drains and ditches to lower the water table beneath agricultural fields. Subsurface drains (e.g., corrugated plastic tile or pipe) installed beneath the ground surface serve as conduits to collect and/or convey drainage water, either to a stream channel or to a surface field drainage ditch. While these drainage improvements increase the amount of land available for cultivation and reduce flooding, they also influence the hydrology, the aquatic habitat, and water quality of area streams.

Drains intercept precipitation and snowmelt as it infiltrates the subsurface soil layer. This intercepted water would normally reach the water table where it would be stored as groundwater. Instead, the subsurface flow is quickly conveyed through the network of drains and ditches to nearby waterbodies. This process can increase the volume of water that reaches local streams during rainfall and snowmelt events, which leads to a rapid rise in stream levels during runoff events. Extensive tiling can also alter the quality of drainage water exiting the fields to receiving waters because shorter delivery times to a stream often reduce the benefits associated with longer filtration through soil layers.

Soils

The National Cooperative Soil Survey publishes soil surveys for each county within the U.S. These soil surveys contain predictions of soil behavior for selected land uses and also highlight limitations and hazards inherent in the soil, general improvements needed to overcome the limitations, and the impact of selected land uses on the environment. The soil surveys are designed for many different users. Planners, community officials, engineers, developers, builders, etc., use the surveys to help plan land use, select sites for construction, and identify special practices needed to ensure proper performance.

Hydrologic soil groups can help determine which portions of the watershed are more important for groundwater recharge; groundwater inputs are important for maintaining stream temperatures and flow throughout the system.

Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups (HSGs) based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D. Where A soils generally have the smallest runoff potential and D soils the greatest.

Details of this classification can be found in *'Urban Hydrology for Small Watersheds'* published by the Engineering Division of the Natural Resource Conservation Service, United States Department of Agriculture, Technical Release–55.

Group A is sand, loamy sand, or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly or moderately deep to deep, moderately well- to well-drained soils with moderately fine to moderately coarse textures.

Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, and soils with moderately fine to fine structure.

Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

The following Figures show the soils in the OCW.

Figure 7. Ox Creek Hydrologic Soil Groups

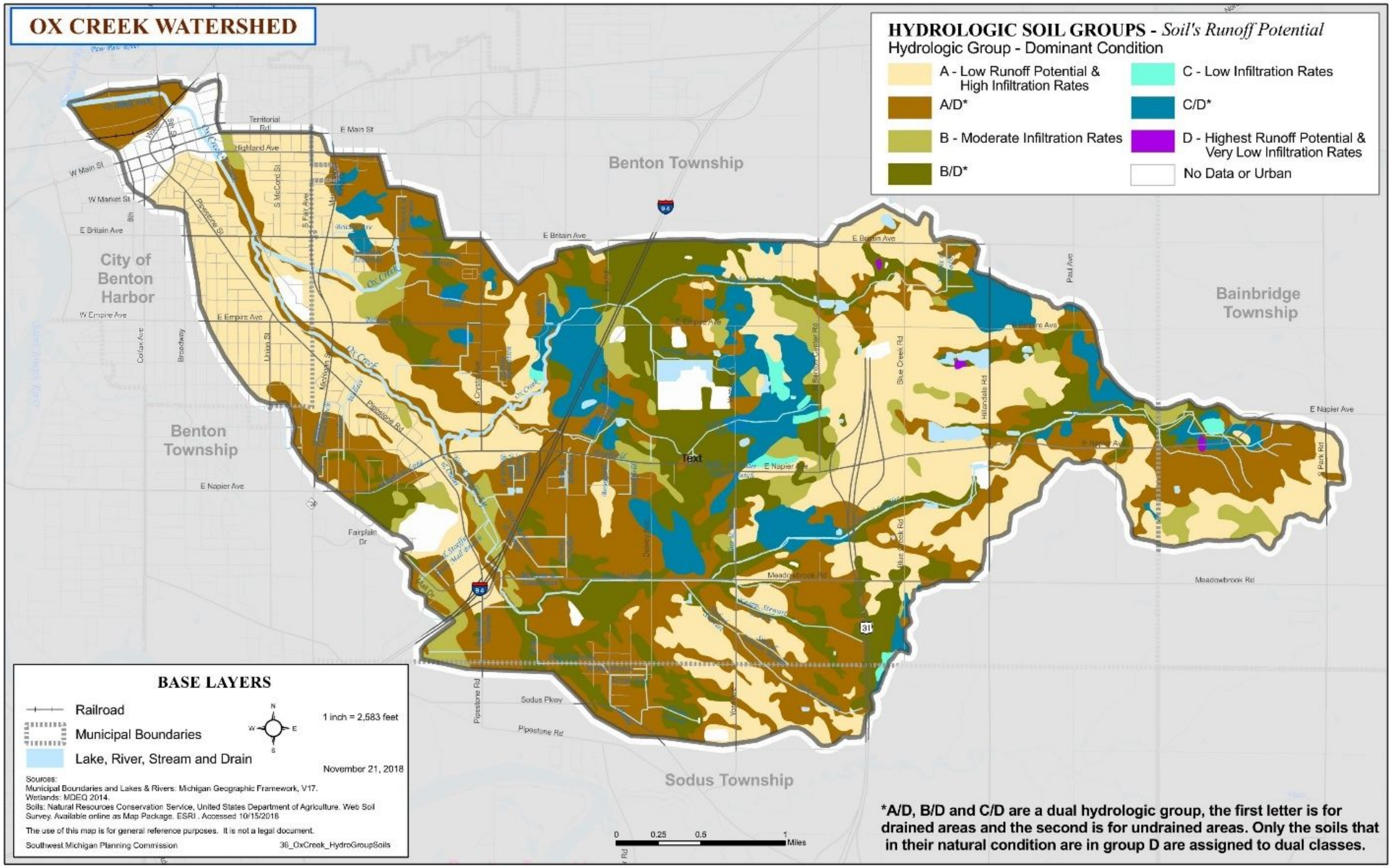
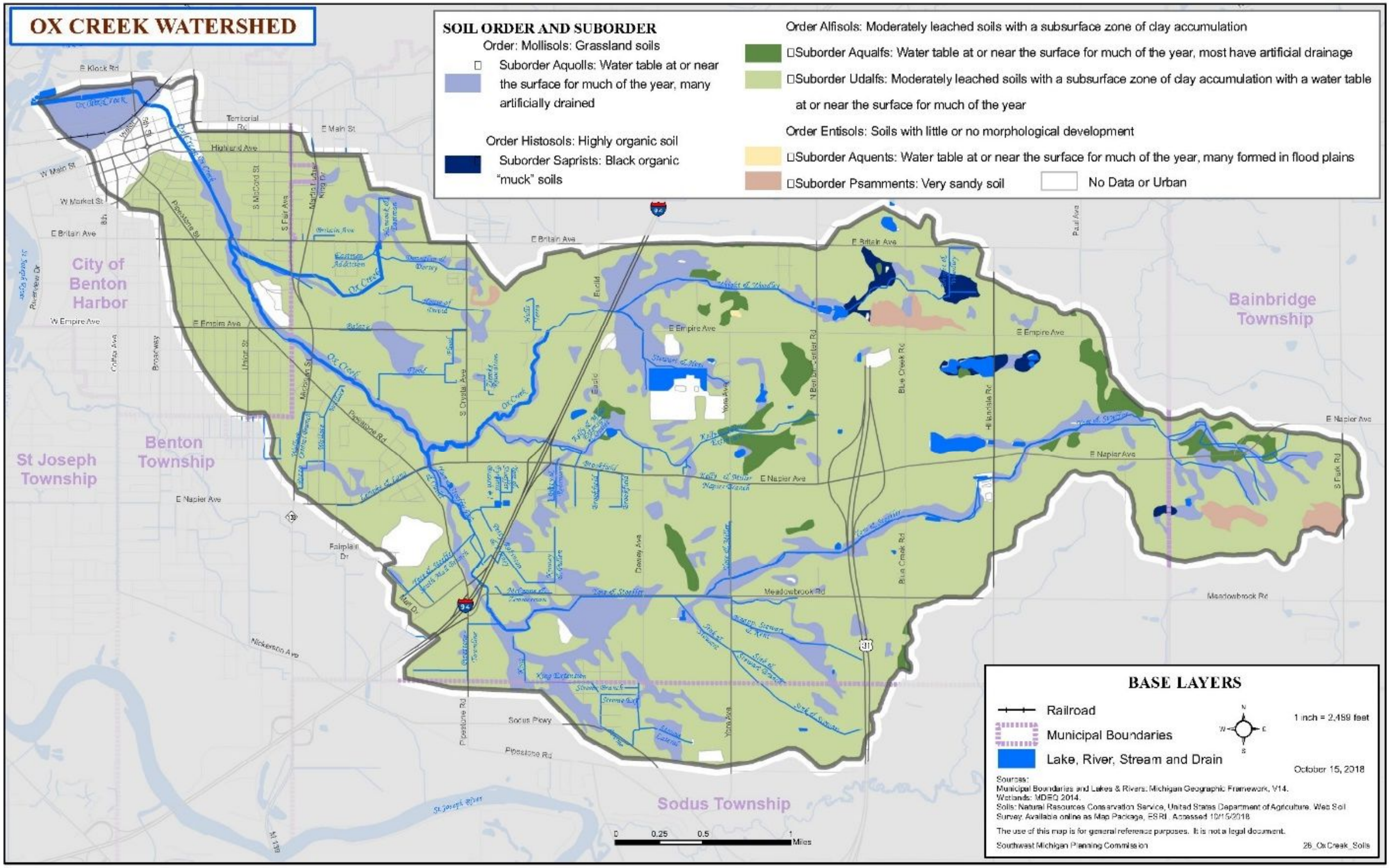


Figure 8. Ox Creek Watershed Soil Order and Suborder



The soils in the Orchards Mall/I-94 Exit 29/Pipestone area are an area of focus. Soil data was downloaded from the U.S. Department of Agriculture (USDA) portal and loaded to geographic information system (GIS) software. The data was symbolized in GIS software by the soil name and displayed on the map over the study area.

Soil classifications found in the Orchards Mall/I-94 Exit 29/Pipestone are as follows:

Brady sandy loam: Nearly level, somewhat poorly drained soil is on flat plains. Permeability is moderately rapid to very rapid and surface runoff is low. The available water capacity is moderate.

Cohoctah-Abscota sandy loams: Nearly level, poorly drained Cohoctah soil and the moderately well drained Abscota soil on flood plains and bottom lands of streams and rivers. Most areas are narrow, elongated flood plains in deeply dissected, upload drainageways. These soils are subject to flooding something during most years. Permeability is moderately rapid in the Cohoctah soil and rapid in the Abscota soil. The available water capacity is high for the Cohoctah soil and low for the Abscota soil. Surface runoff is slow for the Abscota soil and very slow or ponded for the Cohoctah soil.

Gilford sandy loam: Nearly level, very poorly drained soil is in low flat areas. It is subject to frequent flooding. Permeability is moderately rapid and surface runoff is very slow. The available water capacity is moderate.

Kibbie loam: Nearly level, somewhat poorly drained, sloping soils on convex areas or in drainageways. Permeability is moderate and surface runoff is slow. The available water capacity is high.

Martinsville fine sandy loam: Well-drained soil. Permeability is moderate and surface runoff is slow. The water capacity is moderate.

Metea loamy sand: Well-drained soil. Permeability is very rapid to moderately slow and surface runoff is slow. The available water capacity is moderate.

Oshtemo sandy loam: Well-drained soil. Permeability is moderately rapid and surface runoff is slow. The available water capacity is moderate.

Oshtemo-Urban land complex: Consists of nearly level and gently sloping, well-drained soils and urban land. Urban land is covered by streets, parking lots, driveways, buildings, sidewalks, and other structures that obscure or alter the soil so that identification is not suitable. Permeability of the Oshtemo soil is moderately to very rapid and surface runoff is slow. The available water capacity is moderate.

Sebewa loam: Nearly level, poorly drained soil is in broad, flat, low areas. It is subject to frequent ponding. Permeability is moderately rapid and surface runoff is very low. The available water capacity is moderate.

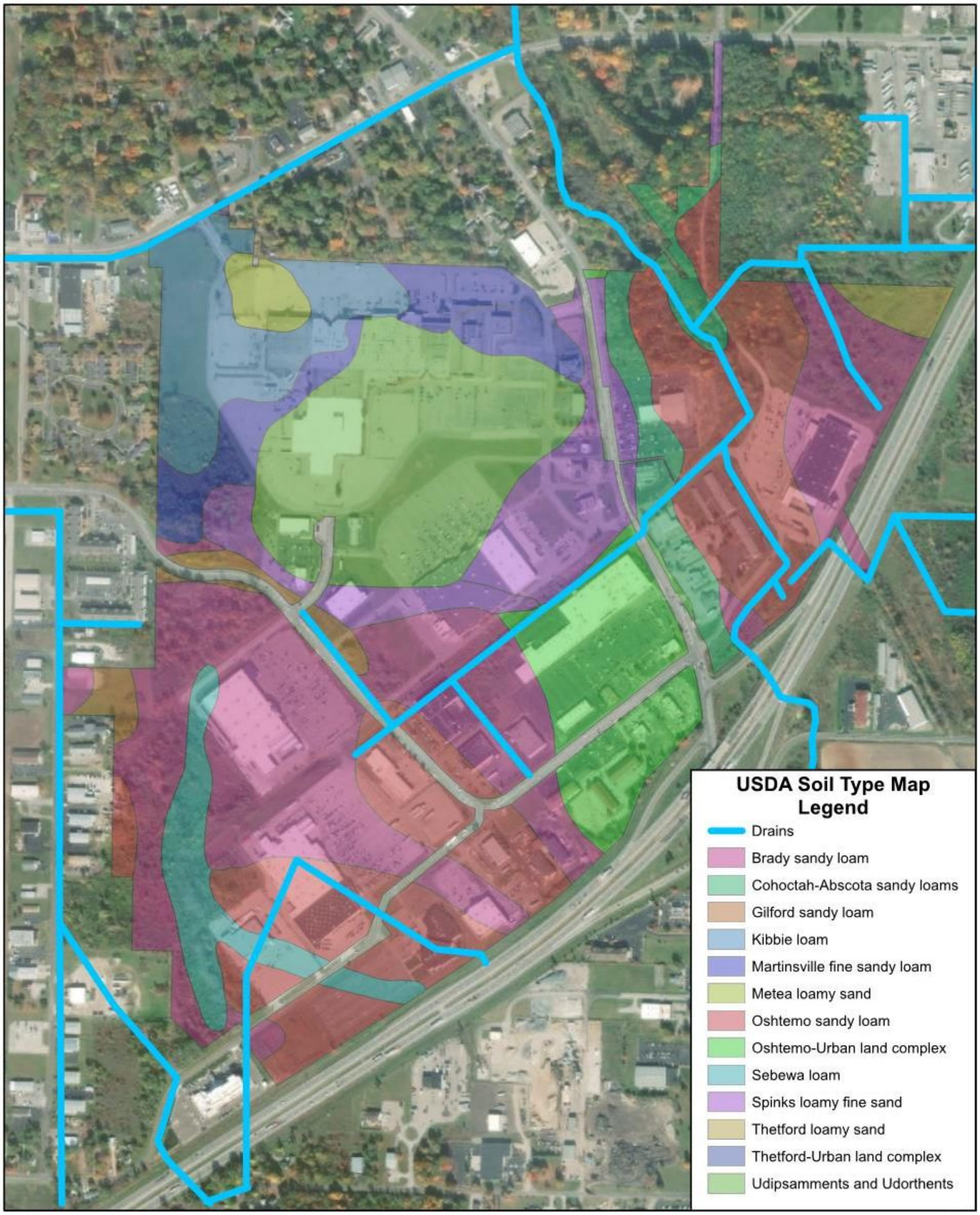
Spinks loamy fine sand: Well-drained soil. Permeability is moderately rapid or rapid and surface runoff is slow. The available water capacity is low.

Thetford loamy sand: Nearly level, somewhat poorly drained soil is on plains. Permeability is moderately rapid and surface runoff is slow. The water capacity is low.

Thetford-Urban land complex: Nearly level, somewhat poorly drained soils and urban land. Some areas are artificially drained by sewer systems, gutters, drainage tiles, and surfaces ditches. If the Thetford soil is not drained, it has a water table at a depth of 1 foot during the wet season. Some low-lying areas are ponded because of runoff from adjacent, higher areas or because of high water table. Urban land is covered by streets, parking lots, driveways, buildings, sidewalks, and other structures that obscure or alter the soil so that identification is not suitable. Permeability is moderately rapid and surface runoff is slow. The available water capacity is low.

Udipsamments and Udorthents: The soil ranges from clay to sand and surface runoff is very rapid.

Figure 9. Orchards Mall/I-94 Exit 29/Pipestone Area Soils



3 Community Profile

3.1 History of Region

Throughout history, water resources have been important for the culture and economy of southwest Michigan. The Hopewell inhabited the area from 500 BC to 900 AD, followed by the Algonquin groups and the Miami tribe. By the early 1700s the Potawatomi tribe was the predominant Native American people in this area. The French were the first European explorers to come to Southwest Michigan; they were interested in the fur trade in this area. The French explorer, LaSalle, is known to have wintered near the City of St Joseph in 1680-81.

The Erie canal was opened in 1825 and settlers poured into Southwest Michigan from the east. Most settlements were located on streams or rivers and soon major water- and steam-driven mills were erected in every settlement. Until railroads were installed, flour and other products were transported by water to Lake Michigan.

Benton Harbor was mainly swampland bordered by the Paw Paw River, through which a canal was built, hence the "harbor" in the city's name. Southwest Michigan is known for its fruit and vegetable production, and the name “Orchards Mall” certainly represents the land cover that preceded that development.

3.2 Governmental Units

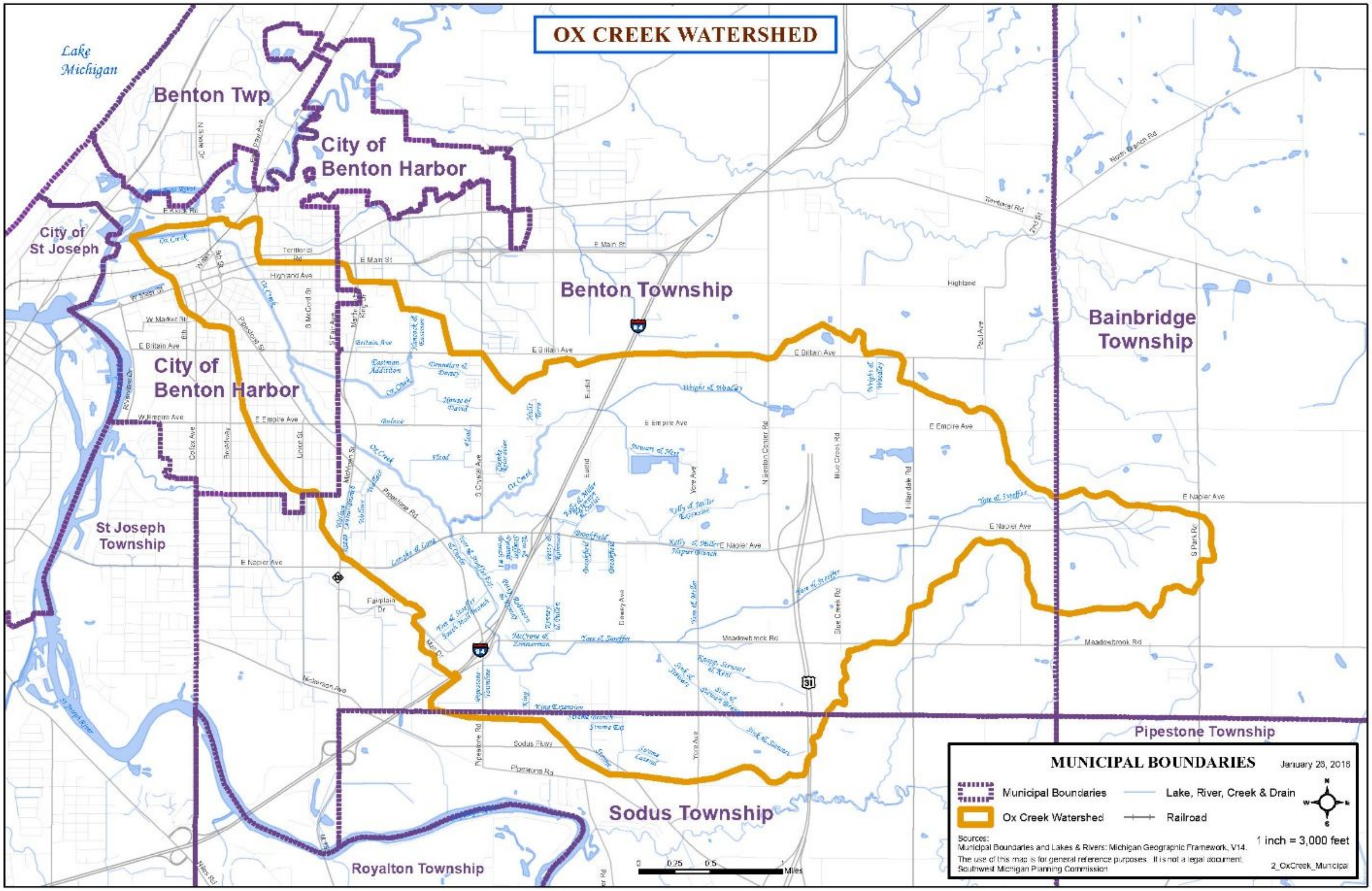
In the OCW, there are five (5) governmental units including three (3) townships (Benton, Bainbridge, and Sodus, one (1) city (Benton Harbor), one (1) county (Berrien). Benton Charter Township has by far the largest percentage of land in the OCW at 77.11%. Figure 9 shows the municipal boundaries in the OCW.

The following Table lists all of the governmental units located in the OCW along with its approximate: 1.) number of acres of OCW, 2.) total miles of OCW streams/drain, 3.) total stream miles, and 4.) total drain miles. Benton Charter Township has the most water length in the OCW (43.32 miles).

Table 3. Ox Creek Watershed Area, Total Miles of Streams and Drains, by Municipality

Municipality	Watershed Area (Acres)	Total Miles of Stream/Drains	Total Stream Miles	Total Drain Miles
Benton Charter Township	6,713.08	43.32	12.38	30.95
Benton Harbor, City of	914.95	3.25	2.72	.53
Sodus Township	496.75	3.18	–	3.18
Bainbridge Township	469.18	3.05	1.62	1.43
Total	**8,593.96**	**52.80**	**16.72**	**36.09**

Figure 10. Municipal Boundaries in Ox Creek Watershed



3.3 **Demographics**

The OCW is an important resource for its human population, including parts of the metropolitan areas of Benton Harbor at the mouth. It is important to understand the characteristics of the population in the watershed. By having a better understanding of the people, water quality related management and outreach efforts can be tailored to be more effective for the intended audience(s).

All of the demographic information presented here is from the 2010 U.S. Census and American Community Survey (ACS) estimates and is detailed in the Tables and Figures below. According to 2010 U.S. Census data, there were 9,632 people living in the OCW. The average population density in the watershed was 717 people per square mile. In 2010, the watershed contained about 3,431 households with 1,409 (41%) of these being owner occupied. The average household contained 2.75 persons. The most densely populated areas of the watershed are located in the Urban West (Benton Harbor area), while the Rural East is more agricultural, and thus, less densely populated. For the race breakdown of the population living in the watershed, 71.1% were black or African American, 23.2% were white only and 5.7% were Hispanic or Latino.

When looking at OCW demographic data relative to Berrien County and the State of Michigan, as well as the Urban West/Rural East split, clear distinctions emerge.
Figure 13 illustrates trends for population, households, number of families, and median household income. There is higher median household income in the Rural East portion of the watershed versus the Urban West. Disparities are also evident in educational attainment, employment status, income, and poverty status.

Watersheds cross socioeconomic boundaries, and the OCW exemplifies this. Chapter 9 details key plans for sections of the OCW that are aimed at revitalization, including the Orchards Mall/I-94 Exit 29/Pipestone Area, an improvement focus area for this Watershed Management Plan.

Figure 11. Ox Creek Watershed Urban West/Rural East Demarcation

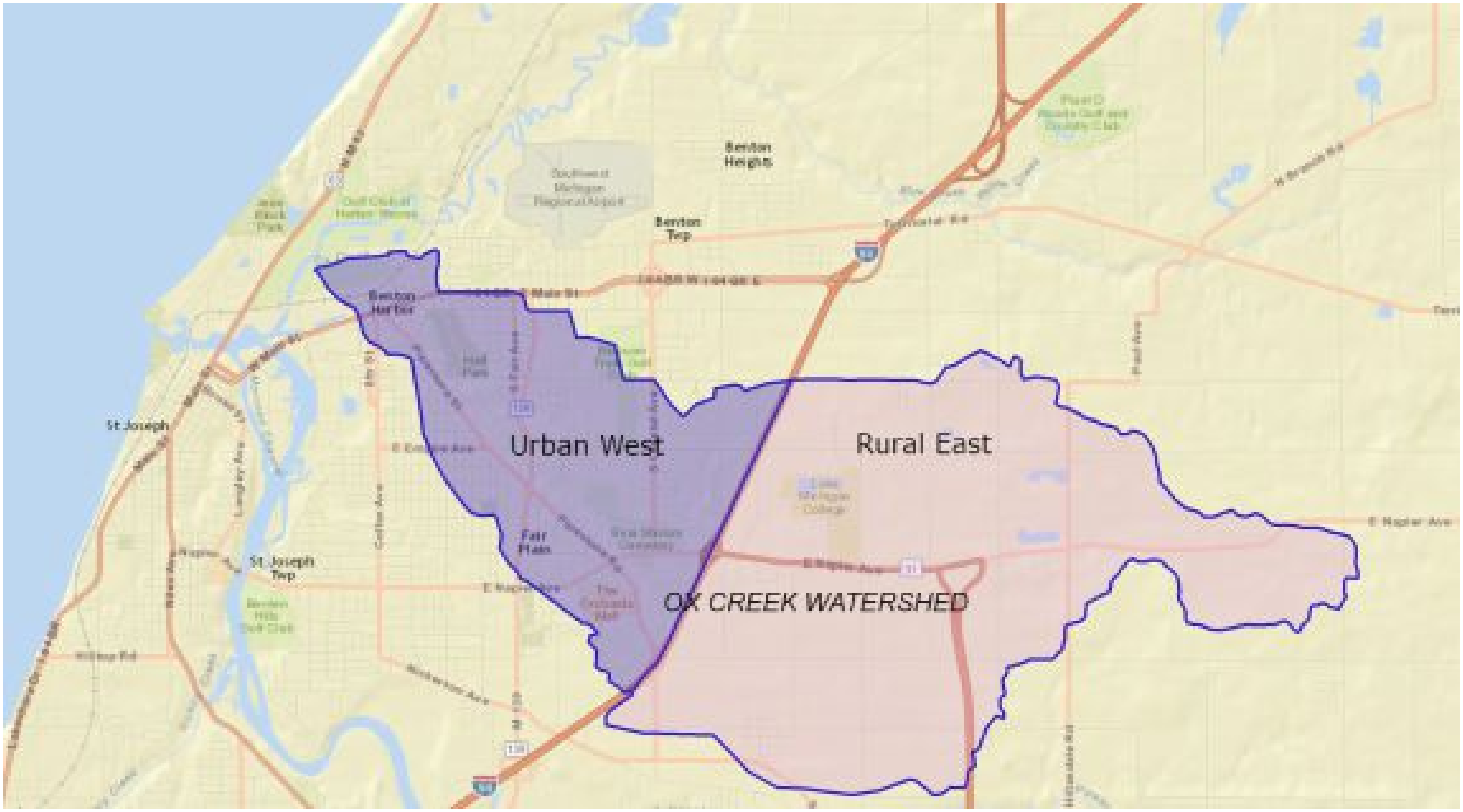


Figure 12. Ox Creek Watershed Population Density (2010)

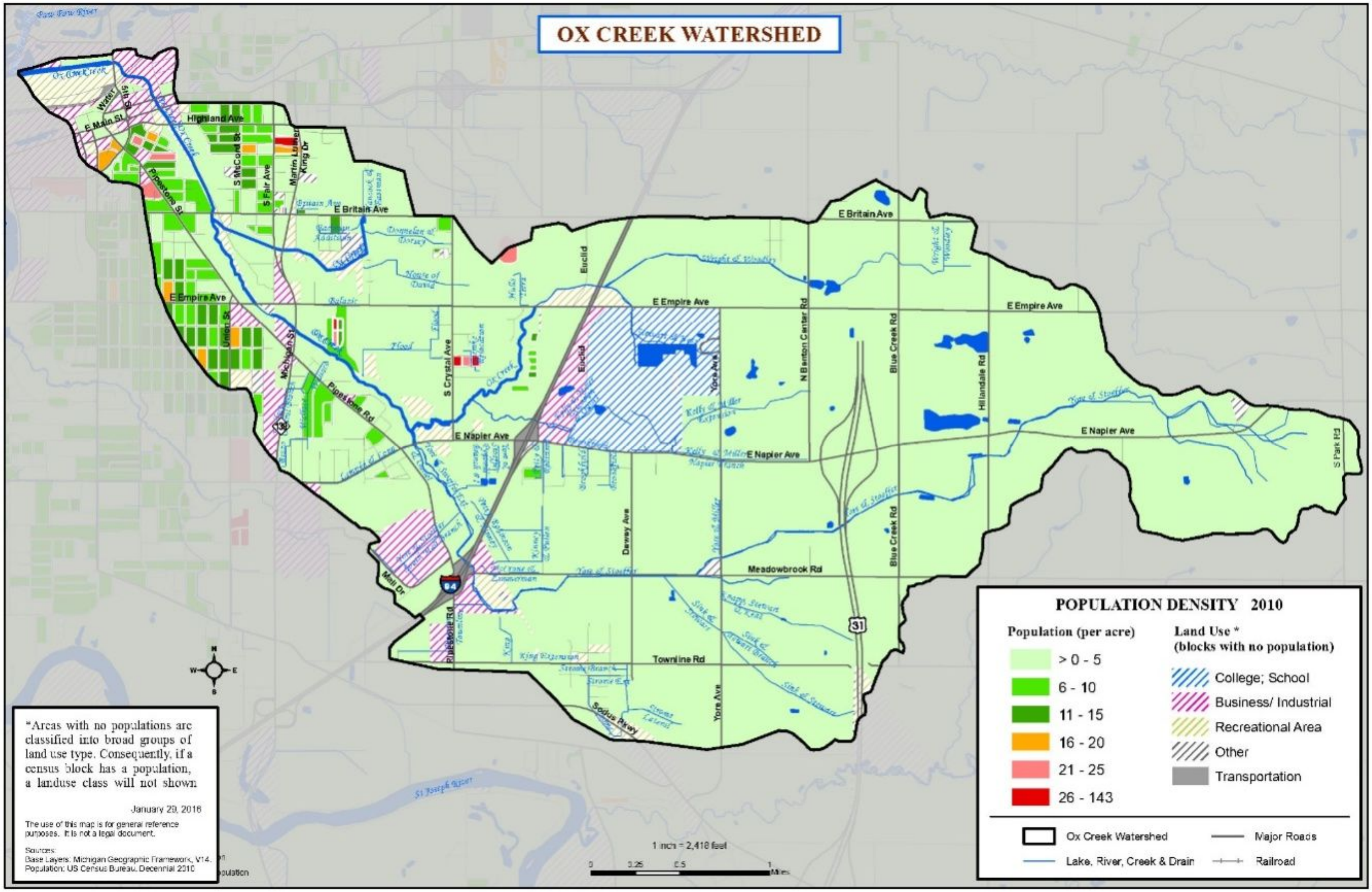
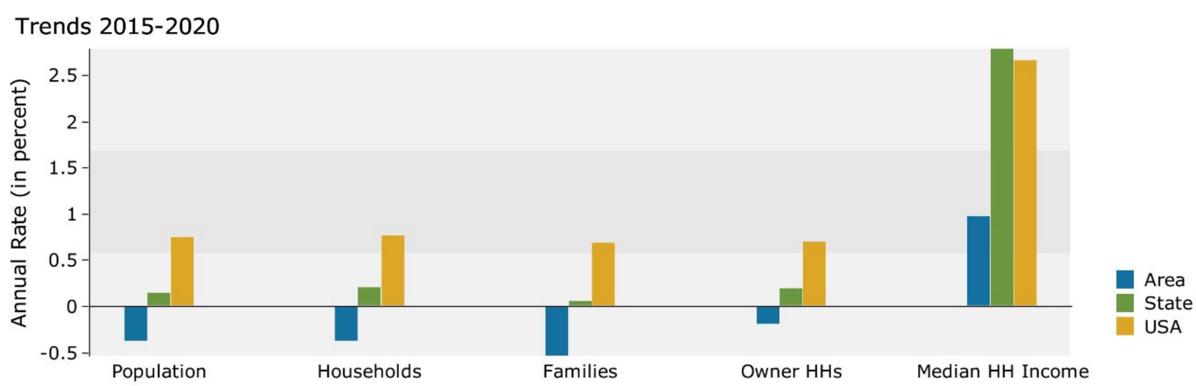


Table 4. Race by Census Block (2010)

Population by Race	Number	Percent
Total	9,632	100.0%
Population Reporting One Race	9,406	97.7%
White	2,234	23.2%
Black	6,848	71.1%
American Indian	40	0.4%
Asian	26	0.3%
Pacific Islander	1	0.0%
Some Other Race	257	2.7%
Population Reporting Two or More Races	226	2.3%
Total Hispanic Population	551	5.7%

Figure 13. Demographic Trends, 2015-2020 (est.)



Note: Area=Ox Creek Watershed

Figure 14. Median Household Income (2012-2016)

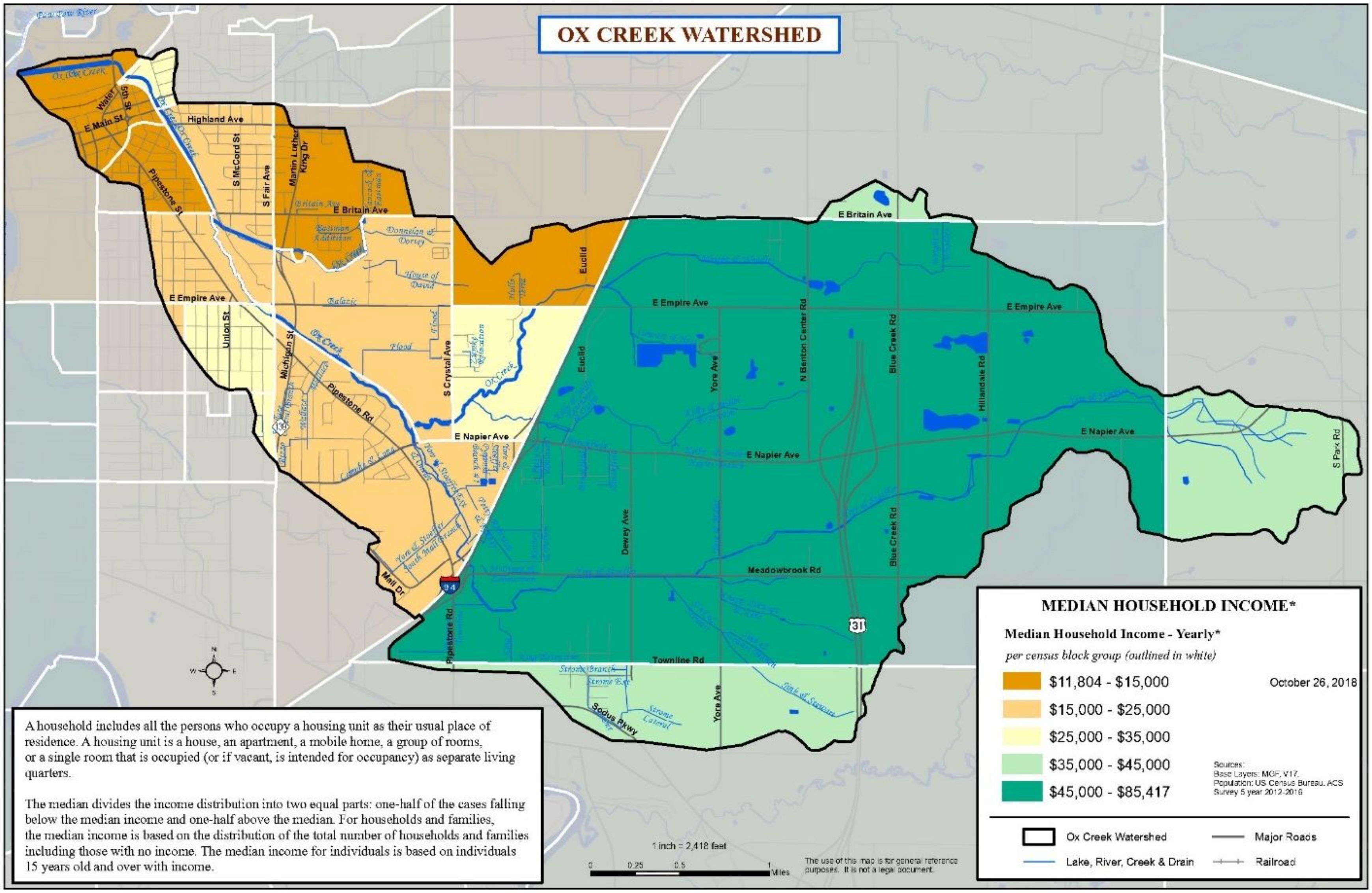


Table 5. Educational Attainment, 2015 (est.)

2015 Population Age 25+: Educational Attainment (%)			
	Ox Creek WS	Berrien County	Michigan
Less than 9th Grade	11.39%	4.15%	3.25%
9-12th Grade/No Diploma	22.25%	7.66%	7.08%
High School Diploma	29.1%	26.1%	25.24%
GED/Alternative Credential	6.44%	4.03%	4%
Some College/No Degree	21.48%	22.79%	23.87%
Associate Degree	4.42%	9.57%	9.07%
Bachelor's Degree	2.51%	15.13%	16.69%
Graduate/Professional Degree	2.42%	10.58%	10.79%

Table 6. Employment Status, 2015 (est.)

	Ox Creek WS	Berrien County	Michigan
2015 Employed Civilian Population Age 16+ (%)	85.12%	93.52%	91.19%
2015 Unemployed Population Age 16+ (%)	14.85%	6.48%	8.81%
2015 Unemployment Rate (%)	14.90%	6.50%	8.80%

Table 7. Income, 2015 (est.)

	Ox Creek WS	Urban West	Rural East	Berrien County	Michigan
2015 Per Capita Income	$11,052	$9,298	$25,297	$24,251	$26,523
2015 Median Household Income	$17,686	$15,102	$46,250	$43,003	$49,402
2015 Average Household Income	$29,484	$25,155	$59,110	$59,139	$66,492

Table 8. Poverty Status, 2015 (est.)

	Ox Creek WS	Urban West	Rural East	Berrien County	Michigan
Households with Income Below Poverty Level (%)	43.53%	48.28%	6.56%	15.94%	15.31%

3.4 Future Growth and Development

The OCW has the potential to be a part of key resources that attract businesses, residents, and tourists to the area. Over the next few decades, the OCW is expected to see population growth and land use change, especially in the central part of the watershed along the I-94 corridor. A key component of the future planning for the OCW includes a vision to revitalize the Orchards Mall/I-94 Exit 29/Pipestone area with mixed-use development and public gathering spaces as a gateway to Benton Harbor and St. Joseph and the regional commercial/retail hub of Southwest Michigan. With these projects, population growth and major land use changes are expected to occur rapidly throughout the watershed. This is an improvement focus area for this Watershed Management Plan.

For the long-term prosperity and health of these communities, the water quality and natural resources need to be recognized for their important role in the current and future economic development of the region. It will be imperative to have thoughtful and sensitive planning of these and other developments to ensure that the water quality and natural resources and the services they provide are protected. For more information on economic development and natural resources visit http://www.swmpc.org/growgreen.asp.

4 Resource Management

Federal, state, county, and local governmental units and their agencies have exclusive, or share, responsibility for the management and protection of water, land, and other natural resources. Local entities are obligated to comply with federal and state environmental statutes, county-level ordinances, and local ordinances. In the case of surface water protection, the federal and state laws generally provide a national or statewide strategy for water quality protection. Because of their broad-scale nature there are often gaps in protection efforts. This presents opportunities for county and local governmental units to enact ordinances or standards that will support a more comprehensive water quality protection strategy.

> For more information on opportunities for local government to protect water and other natural resources consult the “Filling the Gaps” documents at www.swmpc.org/gaps.asp.

4.1 Land Use and Water Quality

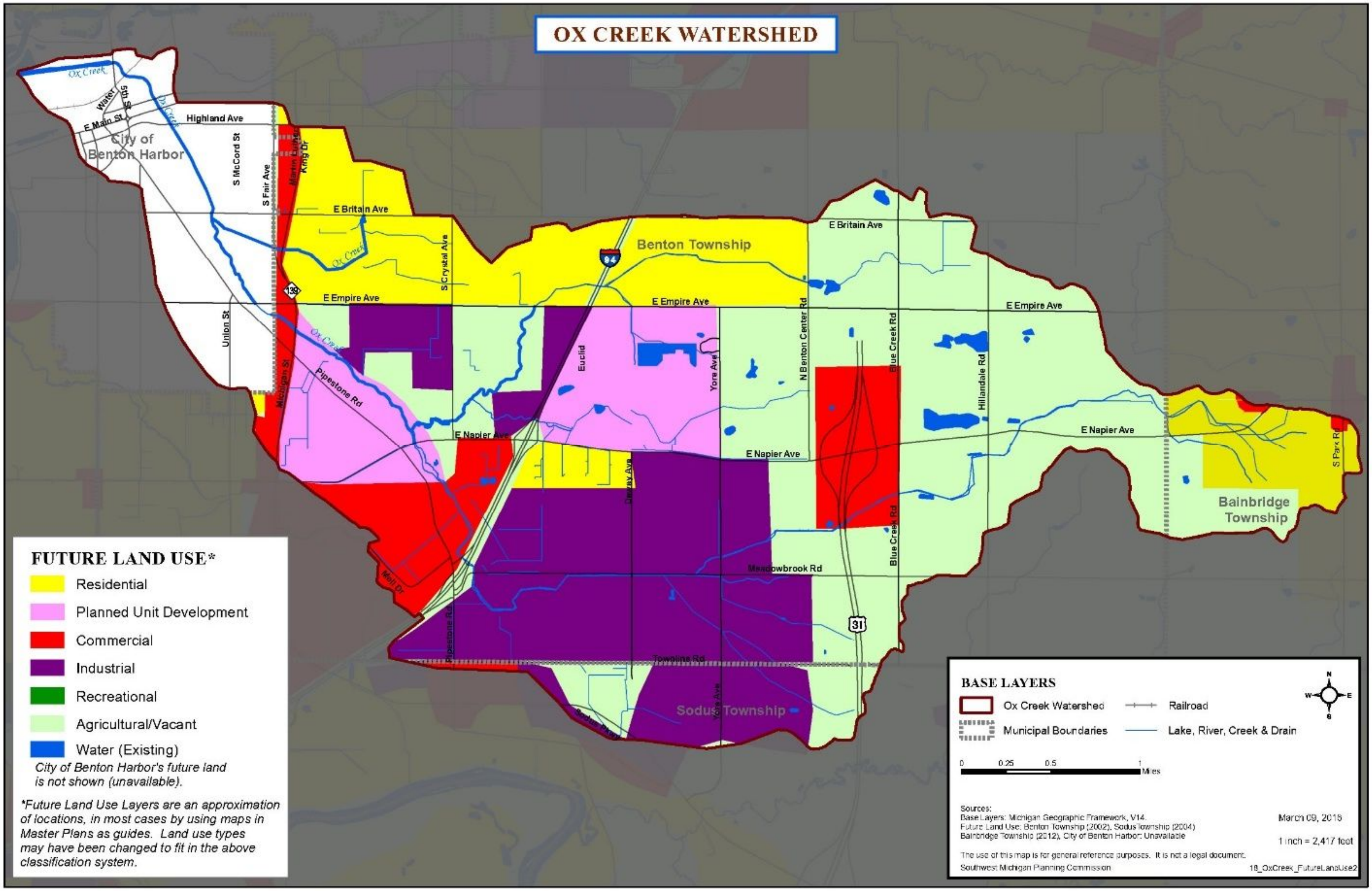
The way land is managed, patterns of land use in relation to natural resources, and especially the way water is managed on a site to support the land use has a large impact on the quality of water and the ecology of lakes, rivers, streams, and shorelands.

The authority to regulate land use rests primarily with local governments, largely through master plans and zoning ordinances. In addition, counties have the authority to enact ordinances that could affect the management of land. For example, several counties in Michigan have adopted point of sale ordinances for septic systems. As a result, city, village, and township governments have a significant role to play in protecting water resources. This role presents itself where federal and state statutes and county ordinances leave off.

> The authority to regulate land use rests primarily with local governments. This gives cities, villages, and townships a significant role in protecting water resources.

It is essential to plan for land uses with respect to existing natural features, soils, and drainage patterns to lessen the impacts to water quality. Certain uses and activities should be located in areas where their impacts to water will be minimized. From a watershed perspective, land use will not only affect the immediate area, but also downstream areas and water bodies. The Figure below is a composite map of future land use in the watershed. The future land use map was created from each governmental unit’s master plan. The future land use map is a vision that is supposed to guide future development. Most of the land in the OCW is planned for agriculture, industrial, and rural or low-density residential use.

Figure 15. Composite Future Land Use



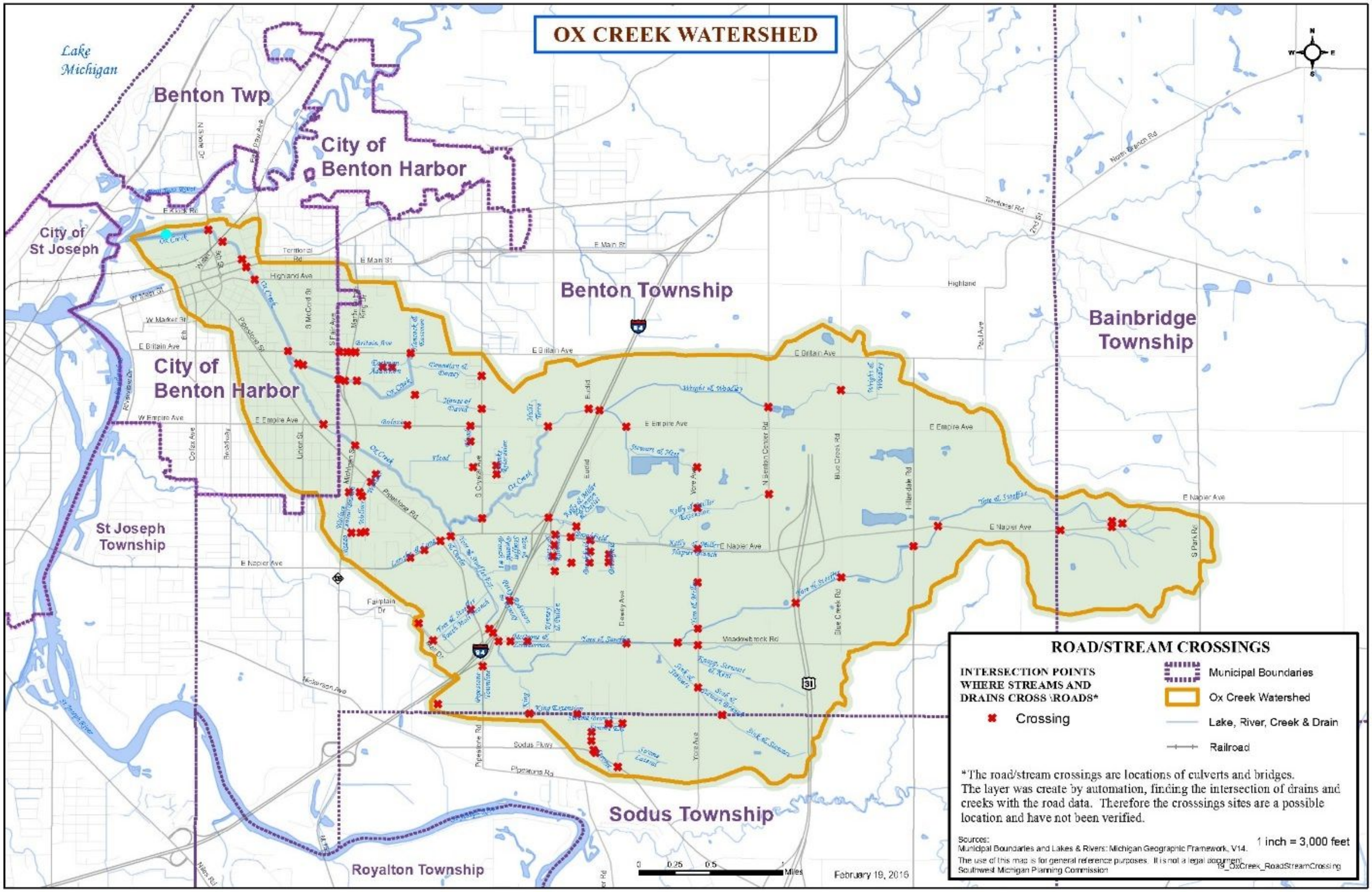
Once the placement of different future land uses (high-density residential, low-density residential, commercial, industrial, etc.) are located with respect to soils, natural features, water bodies, and drainage patterns there should be great attention to how the land is developed. Land development can have a significant impact on water quality. The impacts to water quality that commonly result directly from development activity and increased drainage to support land development can be minimized through the use of smart growth and low-impact development techniques. For more information on low-impact development techniques visit www.swmpc.org/lid.asp.

Roads and Water Quality

Roads are a land use that can have substantial impacts on water quality. Controlling roadway-related pollution during project planning, construction, and ongoing maintenance is important. For example, the salting and sanding of roads during the winter can be a major pollution concern. Figure 16 shows the extent of the road/stream crossings in the OCW, of which there are 111. Chapter 10 details the plan for surveys and assessments. Poorly designed and maintained road crossings across creeks and streams can lead to damaging erosion and may block fish movement. Michigan Department of Transportation (MDOT) and County Road Commissions are responsible for the construction and maintenance of most roads in the OCW. However, the management of local roads is often shared with townships, cities, and villages. In addition, many cities and villages have their own road systems, which they maintain. The Southeast Michigan Council of Governments (SEMCOG) published a guidance document designed to promote good planning practices and endorse consideration and integration of environmental issues into transportation projects. This guidance document is available online at www.swmpc.org/downloads/enviro_transpo_guidance.pdf.

Roads are a land use that can have substantial impacts on water quality. Controlling roadway-related pollution during project planning, construction and ongoing maintenance is important.

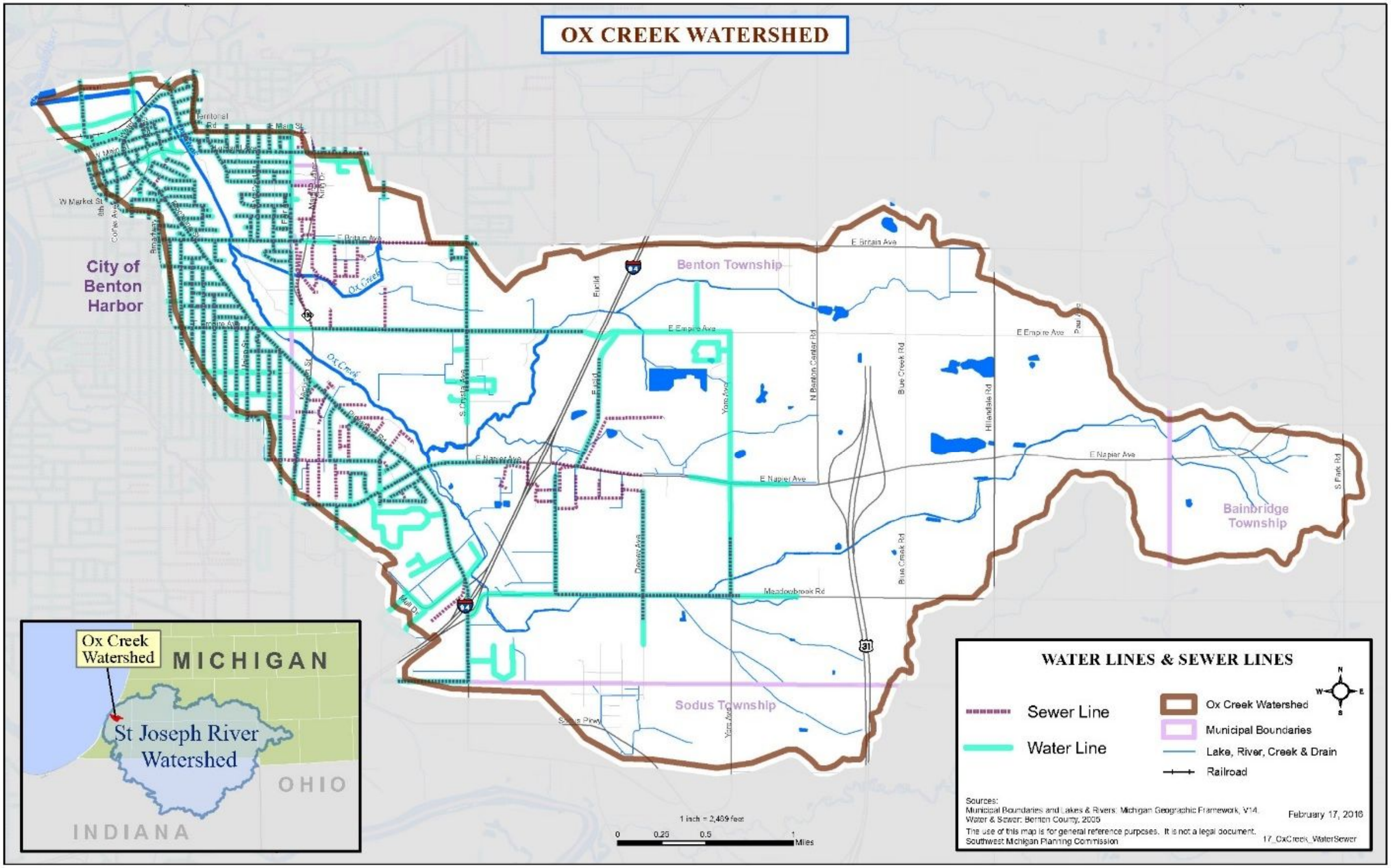
Figure 16. Road/Stream Crossings



Water and Sewer Lines

The more urbanized areas of the watershed are served by municipal drinking water and sanitary sewer which are maintained by the municipalities. Potential problems exist with the infiltration of stormwater into the sewer system during rain events, putting a strain on a system developed to deal with only wastewater. For the priority area of Orchards Mall/I-94 Exit 29/Pipestone, the excessive flashy flows could also potentially cause exfiltration of sewage into waterbodies. Wherever those overtaxed sewer lines come in contact with streams or groundwater there is contamination risk.

Figure 17. Municipal Drinking Water and Sanitary Sewer Lines



4.2 Regulatory Authority and Water Resources

Water Bodies (rivers, drains, streams, lakes)

MDEQ regulates water bodies in the watershed based on the Natural Resources and Environmental Protection Act, PA 451, part 301 Inland Lakes and Streams. This program oversees activities including dredging, filling, constructing or placement of a structure on bottomlands, constructing reconfiguring, or expanding a marina, interfering with the natural flow of water or connecting a ditch or canal to an inland lake or stream. It also requires a permit from the Water Resources Division of MDEQ for certain construction activities on inland lakes and streams. Cities, villages, and townships should enact ordinances that further protect the water quality of lakes and streams. Model ordinances to protect water quality can be found at www.swmpc.org/ordinances.asp.

MDEQ also regulates any discharges to lakes or streams such as those from industrial operations or municipal wastewater treatment plants through the National Pollutant Discharge Elimination System (NPDES) program. The Figure below shows the NPDES Permits, leaking underground storage tanks, Part 201, and brownfields in the watershed. The following Tables list the NPDES permits in the watershed, the leaking underground storage tanks in the watershed, and Part 201 of the Natural Resources and Environmental Protection Act (NREPA). NREPA is Michigan’s primary environmental cleanup program and provides the regulatory framework for the majority of contaminated sites in Michigan.

Figure 18. NPDES Permits, Underground Storage Tanks, Part 201, Brownfields

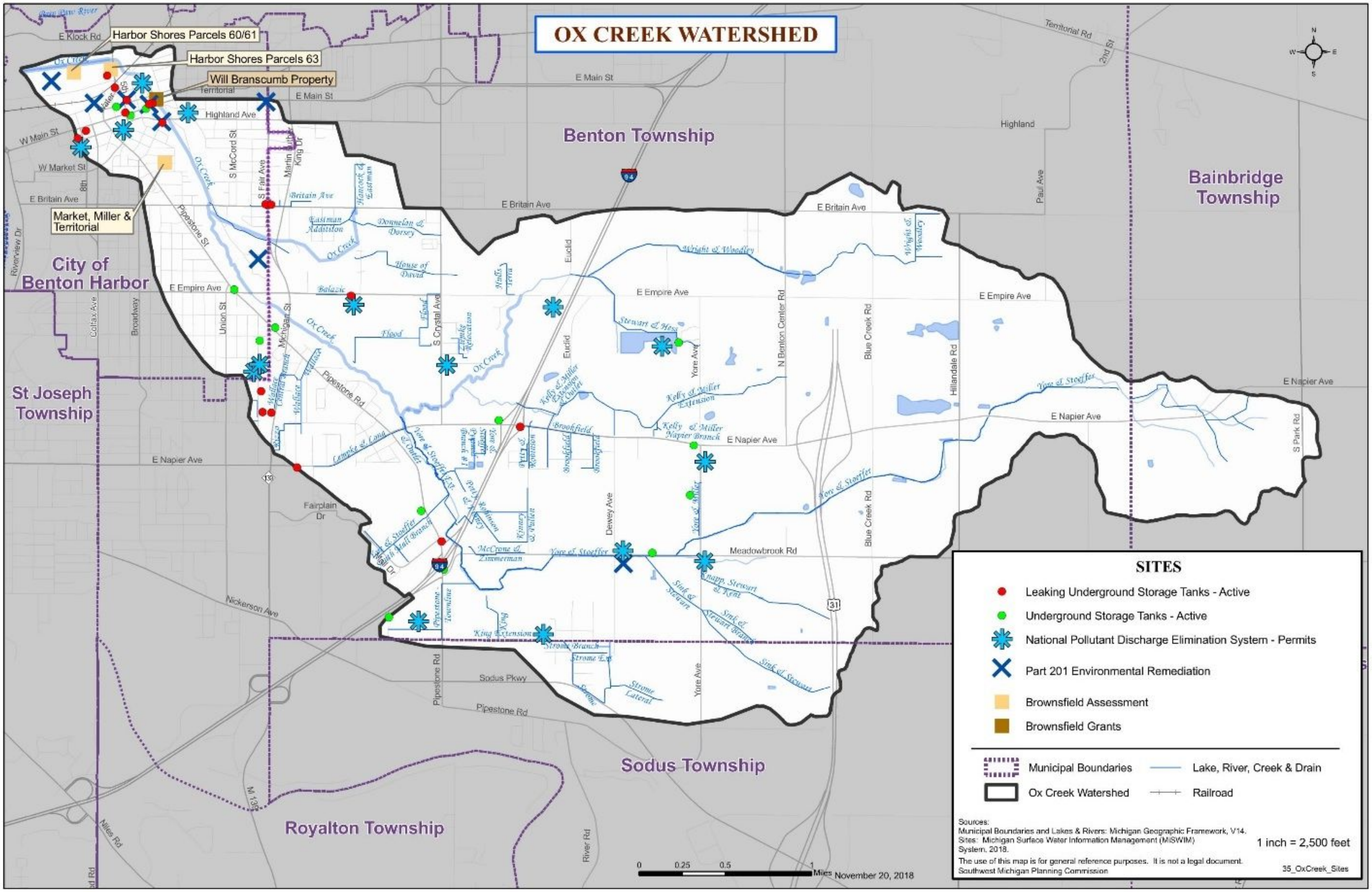


Table 9. NPDES Permits in the Ox Creek Watershed

Facility Name	Address	City
M46115 - Benton Harbor Garage	1435 Milton St	Benton Harbor
Utilicorp United Inc	352 Highland Ave	Benton Harbor
Franks Pro Mart	1478 South M-139	Benton Harbor
Goodyear Asc #6145	1927 Pipestone Rd	Benton Harbor
355 East Main Street	355 E Main St	Benton Harbor
Flying J Travel Plaza #666	1860 E Napier Ave	Benton Harbor
Donna LeBeau	174 W Main St	Benton Harbor
Lakeshore Motors Inc	1074 E Napier Rd	Benton Harbor
Benton Harbor American Laundry	227 Territorial Rd	Benton Harbor
Former Schroeder Buick Facility	204 W Main St	Benton Harbor
Abandoned Building	230 Water St	Benton Harbor
Sunoco Station	480 S Fair Ave	Benton Harbor
Juluis Kolesar Inc	1359 Milton St	Benton Harbor
U-Know Barber Shop	225 E Main St	Benton Harbor
Old Europe Cheese	1330 E Empire Ave	Benton Harbor
Spence Technology	121 Graham Ave	Benton Harbor
Cities Service Oil Co	481 S Fair Ave	Benton Harbor
Ron Gaynor	327 E Main St	Benton Harbor

Table 10. Leaking Underground Storage Tanks

Facility Name	Address	City
M46115 - Benton Harbor Garage	1435 Milton St	Benton Harbor
Utilicorp United Inc	352 Highland Ave	Benton Harbor
Franks Pro Mart	1478 South M-139	Benton Harbor
Goodyear Asc #6145	1927 Pipestone Rd	Benton Harbor
355 East Main Street	355 E Main St	Benton Harbor
Flying J Travel Plaza #666	1860 E Napier Ave	Benton Harbor
Donna LeBeau	174 W Main St	Benton Harbor
Lakeshore Motors Inc	1074 E Napier Rd	Benton Harbor
Benton Harbor American Laundry	227 Territorial Rd	Benton Harbor
Former Schroeder Buick Facility	204 W Main St	Benton Harbor
Abandoned Building	230 Water St	Benton Harbor
Sunoco Station	480 S Fair Ave	Benton Harbor
Juluis Kolesar Inc	1359 Milton St	Benton Harbor
U-Know Barber Shop	225 E Main St	Benton Harbor
Old Europe Cheese	1330 E Empire Ave	Benton Harbor
Spence Technology	121 Graham Ave	Benton Harbor
Cities Service Oil Co	481 S Fair Ave	Benton Harbor
Ron Gaynor	327 E Main St	Benton Harbor

Table 11. Part 201 Sites

Site Name	Address	City
MGP - Benton Harbor - MGU	SW corner of Highland and Jefferson	Benton Harbor
East Main & Third	327 E Main St	Benton Harbor
American Laundry - Benton Harbor	227 Territorial Rd	Benton Harbor
Main & Fair, SW Corner	890 East Main St	Benton Harbor
Harbor Graphics (Vomela Specialties)	123 Hinkley Street	Benton Harbor
Harbor Plating	724 South Fair Avenue	Benton Harbor
Gast ReMark Facility	2550 Meadowbrook Rd	Benton Harbor
Harbor Shores - Edgewater Development	Graham Avenue	Benton Harbor

Further, the MDEQ administers the Phase II Stormwater Program, which requires owners or operators of municipal separate storm sewer systems (MS4) in urbanized areas to implement programs and practices to control polluted stormwater runoff. Benton Harbor City, Berrien County Road Department, and Berrien County Drain Commissioner and Administration participate in the Phase II Stormwater Program and have MS4 stormwater permit coverage. More information on this program is available at www.swmpc.org/lsjr.asp.

The County Drain Commissioner is responsible for the administration of the Drain Code of 1956, as amended. The duties of the Drain Commissioner include the construction and maintenance of drains, determining drainage districts, apportioning costs of drains among property owners, and receiving bids and awarding contracts for drain construction. The following Tables show the length of designated drain in each municipality. The Drain Commissioner also approves drainage in new developments and subdivisions and maintains lake levels. The Soil Erosion and Sedimentation Control Program (SESC) is housed in the Drain Commissioner’s office. The County Enforcement Agent for the SESC has the responsibility of ensuring earth change activities that are one or more acres in area and/or within 500 feet of a watercourse or lake do not contribute soil to water bodies.

Table 12. Benton Charter Township Drains, by Length (Miles)

Drain Name	Length (Miles)
Yore & Stoeffer	7.77
Wright & Woodley	3.25
Yore & Stoeffer Extension & Outlet	2.83
Kinney Consolidated	1.19
Knapp, Stewart & Kent	1.07
Brookfield	1.03
Kelly & Miller	0.92
Flood	0.91
Stewart & Hess	0.91
Kelly & Milller Extension & Outlet	0.83
Pipestone – Townline	0.76
Sink & Stewart	0.70
House of David	0.69
Lempke & Long	0.59
Donnelan & Dorsey	0.56

Drain Name	Length (Miles)
Yore & Stoeffer South Mall Branch	0.55
Wallace	0.54
Hancock & Eastman	0.45
Wallace Central Branch	0.37
Sink & Stewart Branch	0.36
McCrone & Zimmerman	0.36
Yore & Miller	0.32
Rizzo	0.30
Petty & Robinson	0.28
Britain Avenue	0.28
Hulls Terra	0.26
Yore & Stoeffer Pyramid Branch	0.24
Kelly & Miller Extension	0.23
Ziemke Relocation	0.20
Yore & Stoeffer Pyramid Branch #1	0.20
Pleasant Gardens	0.20
Balazic	0.19
Eastman Addition	0.18
Rosedale & Lynch	0.17
Yore & Stoeffer Mall Place Branch	0.16
Handcock & Eastmen	0.14
Petty, Robinson & Kinney	0.14
Yore & Stoeffer South Mall Branch Lateral	0.14
Kelly & Miller Branch	0.13
Flood - Industrial Court Branch	0.12
Brookfield South Branch	0.12
Yore & Stoeffer Pyramid Branch 1984	0.11
Yore & Stoeffer Pyramid Branch	0.08
Pipestone - Townline Branch	0.06
Britain Avenue Lateral	0.04
Yore & Stoeffer Pyramid Branch #2	0.01
Total	**30.95**

Table 13. Sodus Township Drains, by Length (Miles)

Drain Name	Length (Miles)
King	1.12
Sink & Stewart	0.67
Strome Extension	0.56
Strome	0.42
Strome Lateral	0.32
Strome Branch	0.08
Total	**3.18**

Table 14. Bainbridge Township Drains, by Length (Miles)

Drain Name	Length (Miles)
Yore & Stoeffer Extension	0.96
Yore & Stoeffer Extension Branch	0.48
Total	**1.43**

Table 15. City of Benton Harbor Drains, by Length (Miles)

Drain Name	Length (Miles)
Handcock & Eastmen	0.38
Britain Avenue	0.11
Handcock & Eastmen	0.04
Total	**.53**

Wetlands

Michigan is one of two states that has the authority to administer section 404 of the Clean Water Act dealing with wetland protection. The MDEQ regulates wetlands; however, MDEQ does not regulate all wetlands. Wetlands are regulated by MDEQ if they meet any of the following criteria:

- Connected to one of the Great Lakes.
- Located within 1,000 feet of one of the Great Lakes.
- Connected to an inland lake, pond, river, or stream.
- Located within 500 feet of an inland lake, pond, river, or stream.
- Not connected to one of the Great Lakes or an inland lake, pond, stream, or river, but are more than 5 acres in size.
- Not connected to one of the Great Lakes, or an inland lake, pond, stream, or river, and less than 5 acres in size, but the DEQ has determined that these wetlands are essential to the preservation of the state's natural resources and has notified the property owner.

Since there are gaps in state protection of wetlands, a local unit of government (city, township, village, county) has the authority to create wetland regulations. A local wetland ordinance must be at least as restrictive as state regulations and the MDEQ must be notified if there is a local wetland ordinance in effect. Approximately 50 communities in Michigan have adopted local wetland ordinances. None of these are in the OCW; however, jurisdictions can also require building setbacks and a no-disturb zone around wetlands, which can be just as effective as a wetland ordinance. For more information on wetland ordinances see www.swmpc.org/wetlandworkshop.asp.

> Local governmental units can enact building setbacks and a no disturb zone around wetlands to help protect water quality.

Floodplains

The MDEQ requires that a permit be obtained prior to any alteration or occupation of the 100-year floodplain of a river, stream, or drain to ensure that development is reasonably safe from flooding and does not increase flood damage potential. Local ordinances restricting development in floodplains can be more restrictive than MDEQ regulations.

All of the communities in the OCW participate in the Federal Emergency Management Agency's (FEMA) National Flood Insurance Program (NFIP) (see the Table below). The NFIP is a federal program enabling property owners in participating communities to purchase insurance protection against losses from flooding. The program is designed to provide an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods. The overall intent of NFIP is to reduce future flood damage through community floodplain management ordinances and provide protection for property owners against potential losses through an insurance mechanism that requires a premium to be paid for the protection.

Groundwater

Locally, the health department plays a role in groundwater protection with the regulation of the installation and design of septic systems. Local units of government have the authority to require the maintenance of septic systems through a septic system maintenance district ordinance. Another local groundwater protection option is a point of sale inspection ordinance for septic systems. With this ordinance, when property is sold there is a requirement to inspect the septic system. In the OCW there are no septic system-related ordinances.

At the state level, the MDEQ and the Michigan Department of Agriculture and Rural Development (MDARD) monitor groundwater use. All large quantity withdrawals, defined as having the capacity to withdraw more than 100,000 gallons of water per day average over any 30-day period, equivalent to 70 gallons per minute pumping, must be registered and water use must be reported annually. The Comprehensive State Groundwater Protection Program is a statewide program that looks at groundwater uses, including drinking water, and its role in sustaining the health of surface water bodies (rivers, streams, wetlands, marshes). The City of Benton Harbor and Benton Township get water from Lake Michigan. The remaining townships in the OCW do not have municipal water, but private wells. The Wellhead Protection Program (WHPP) is intended to protect the drinking water supply. The program minimizes the potential for contamination by identifying and protecting the area that contributes water to municipal water supply wells and avoids costly groundwater cleanups. Currently, small portions of the OCW have a WHPP in place (see Chapter 5).

4.3 Local Water Quality Protection Policies

Local governments regulate land use mostly through master plans and zoning ordinances. The Table below presents a list of governmental units in the OCW that possess master plans and zoning ordinances as well as participation in the FEMA NFIP. Community participation in the NFIP is voluntary and based on an agreement between local governmental units and the federal government that states if a governmental unit will adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction in Special Flood Hazard Areas, the federal government will make flood insurance available within the community as a financial protection against flood losses.

It is crucial that master plans and zoning ordinances be living documents and are updated regularly. It is also essential that these documents relate water quality and natural resource protection to the safety and welfare of the residents and community and address the connection between land use and water quality. Further, the plans should discuss the negative impacts of increased impervious surfaces and the need for stormwater management and low-impact development techniques to protect water quality. Lastly, the plans should include language on natural resources (lakes, wetlands, streams, riparian buffers, woodlands, open space, etc.) and their value to the community and their role in protecting water quality. The following provides provision guidelines for zoning ordinances:

1. Waterbody Protection

- require adequate building setbacks along rivers/drains and wetlands
- require naturally vegetated buffers along streams, rivers, lakes, and wetlands
- floodplain protection regulations

2. Site Plan Review Process

- show the location of natural features, such as lakes, ponds, streams, floodplains, floodways, wetlands, woodlands, steep slopes, and natural drainage patterns on site plans
- show and label all stormwater best management practices on the site plan (rain gardens, swales, etc.)
- site plan review criteria – require the preservation of natural features, such as lakes, ponds, streams, floodplains, floodways, wetlands, woodlands, steep slopes, and natural drainage patterns to the fullest extent possible and minimize site disturbance as much as possible
- require Drain Commissioner review of stormwater management during the site plan review process
- require the use of native plants in all landscaping plans and vegetative stormwater best management practices (BMPs) (to help reduce stormwater velocities, filter runoff and provide additional opportunities for wildlife habitat)
- require the use of low-impact development techniques whenever feasible (see *Low Impact Development for Michigan: A Design Guide for Implementers and Reviewers* at www.swmpc.org/downloads/lidmanual.pdf

3. Open Space and Agricultural Land Preservation

- use bonus densities or other incentives to encourage open space developments
- require all Planned Unit Developments to provide 25-50% open space
- require open space areas to be contiguous and restrict uses of open space area to low-impact uses
- in agricultural zoning districts, utilize methods, such as sliding scale, to limit fragmentation of farmland and to lessen conflicts between farming and residential uses
- require buffers between agricultural operations and residential uses
- allow for clustering/open-space developments in agricultural districts to protect natural features

4. Parking Lots and Roads – Reducing Impervious Surfaces

- allow for more flexibility in parking standards and encourage shared parking
- require a portion of large paved parking lots to be planted with trees/vegetation
- require treatment of stormwater parking-lot runoff in landscaped areas
- require 30% of the parking area to have compact-car spaces (9x18 ft or less)
- require space for bicycle parking in parking lots
- allow driveways and overflow parking to be pervious or porous pavement
- use maximum spaces instead of minimums for parking space numbers
- require landscaped areas in cul-de-sacs and allow hammerheads
- allow swales instead of curb and gutter (if curbs are used, require perforated or invisible curbs, which allow for water to flow into swales

5. Stormwater BMPs (refer to *Low Impact Development for Michigan: A Design Guide for Implementers and Reviewers* at www.swmpc.org/downloads/lidmanual.pdf or see model stormwater ordinance at www.swmpc.org/ordinances.asp)

- allow the location of bioretention areas (rain gardens, filter strips, swales) in required setback areas and common areas
- encourage the use of BMPs that improve a site's infiltration and have BMPs labeled and shown on site plans
- require use of native plants for landscaping plans and for runoff/stormwater controls (prohibit invasive and exotics species)

- require use of BMPs and encourage use of above-ground BMPs instead of below-ground stormwater conveyance systems
- prohibit direct discharge of stormwater into wetlands, streams, or other surface waters without pre-treatment
- require periodic monitoring of BMPs to ensure they are working properly and require that all stormwater BMPs be maintained

Table 16. Zoning, Master Plans and NFIP Participation by Governmental Unit

Governmental Unit	Zoning?	Master Plan Date*	FEMA NFIP Participation
Bainbridge Twp.	Yes	2003	Yes
Benton Harbor, City of	Yes	2011	Yes
Benton Twp.	Yes	2002 (update in progress)	Yes
Sodus Twp.	Yes	2008	Yes

*on file at SWMPC

4.4 **Private Land Management**

Beyond, federal, state, and local laws protecting water quality, the greatest opportunity to protect and preserve water quality and natural resources rests with the landowner in how they manage their lands. Most of the land in the watershed is in private ownership. Many organizations are willing to provide technical assistance to landowners on how to better manage their lands to protect natural resources and water quality. These organizations include Michigan State University (MSU) County Extension Offices, Conservation Districts, Natural Resources Conservation Service, Southwest Michigan Land Conservancy, The Nature Conservancy, Department of Natural Resources and United States Fish and Wildlife Service (Partners for Wildlife Program).

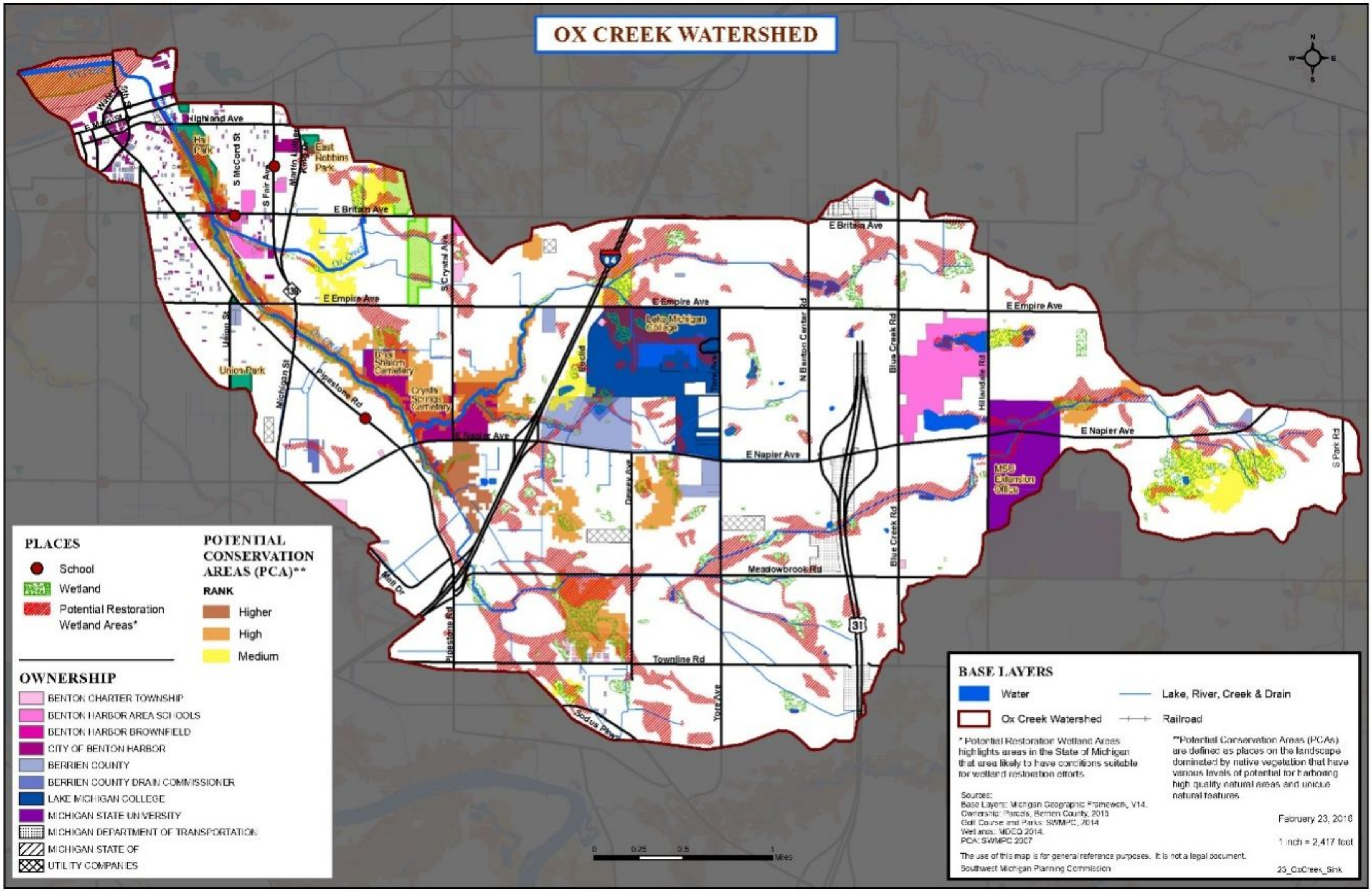
5 Natural Features

The natural features of the OCW provide ecosystem services that benefit humans, such as recharging groundwater, cleansing air, and filtering water.

5.1 Protected Lands

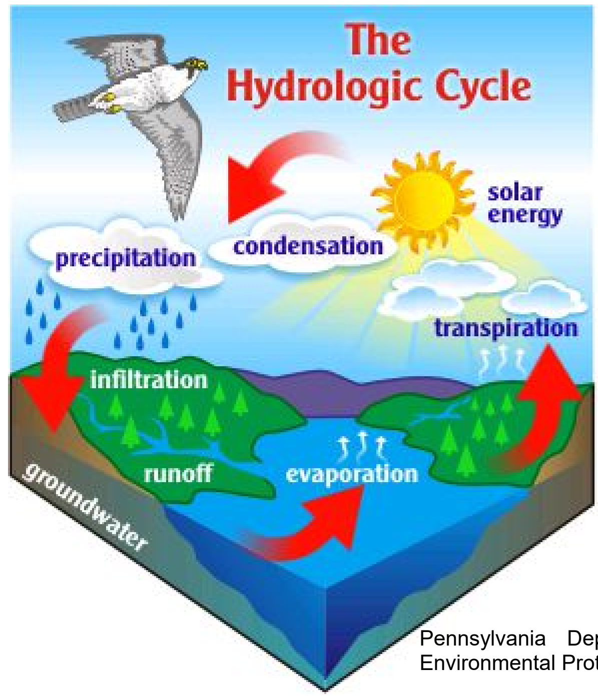
The following Figure shows municipal land ownership in the OCW along with existing wetlands and potential restoration wetland areas, and potential conservation areas (PCA).

Figure 19. Conservation and Recreation Lands



5.2 Generalized Hydrologic Cycle

The earth's water is one large, continuous feature that exists within a complex and dynamic cycle and is commonly categorized as distinct features such as surface water, groundwater, and wetlands. Although the cycle has no beginning or end, it is convenient to describe the generalized cycle with a starting point of surface water. Water evaporates from oceans, lakes, and other surface waters to the atmosphere and is carried over land surfaces, where it condenses and is precipitated onto the land surfaces as rain, snow, etc. Some water will drain across the land as runoff into a water body. The land cover will affect how this water moves across the land. If the surface soil is permeable, some water will infiltrate to the subsurface under the influence of gravity and will saturate the soil and/or rock. This zone of saturation is recognized as groundwater. Due to gravity, groundwater generally moves from areas of higher elevations to lower elevations to locations where it discharges to wetlands and/or surface water (lakes, streams, rivers). Wetlands may be viewed as a transition of groundwater to surface water, and vice versa.

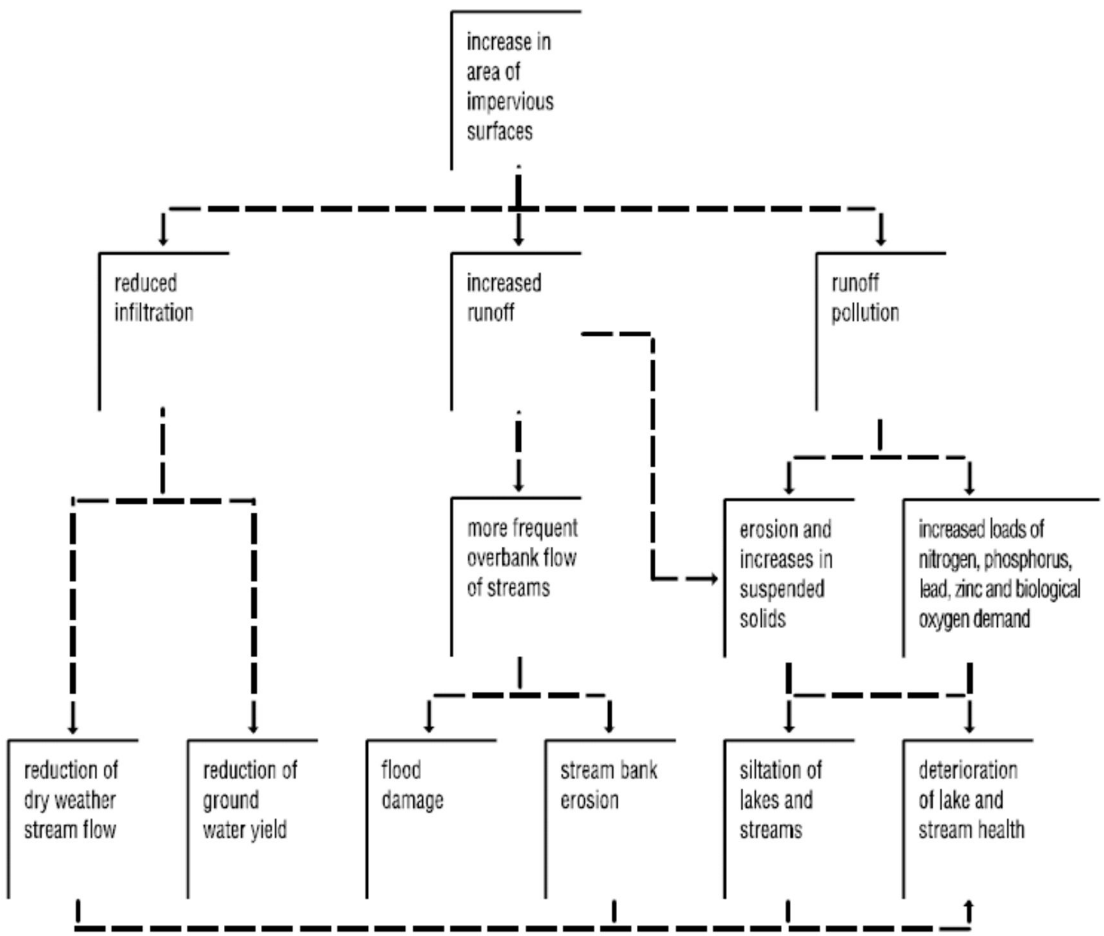


Pennsylvania Department of Environmental Protection

A properly functioning hydrologic cycle is greatly dependent upon the land cover and natural features in the watershed. Natural vegetation, such as forested land cover, usually has high infiltration capacity and low runoff rates. Whereas urbanized land cover has impervious areas (buildings, parking lots, and roads) and networks of ditches, pipes, and storm sewers, which augment natural stream channels. Impervious surfaces in urban areas reduce infiltration and the recharge of groundwater while increasing the amount of runoff. This runoff carries pollutants contributing to poor water quality. Agricultural lands, including row crops, orchards, vineyards, rangelands, and animal farms can also have a significant impact on runoff and groundwater resources. Agricultural lands are often heavily compacted by farm equipment, which lessens their ability to infiltrate water. In addition, many agricultural lands are extensively ditched to move water off of the land as quickly as possible. Further, irrigation can alter the groundwater resources. These activities disrupt the natural hydrologic cycle and negatively impact the functioning of the remaining natural features in the watershed.

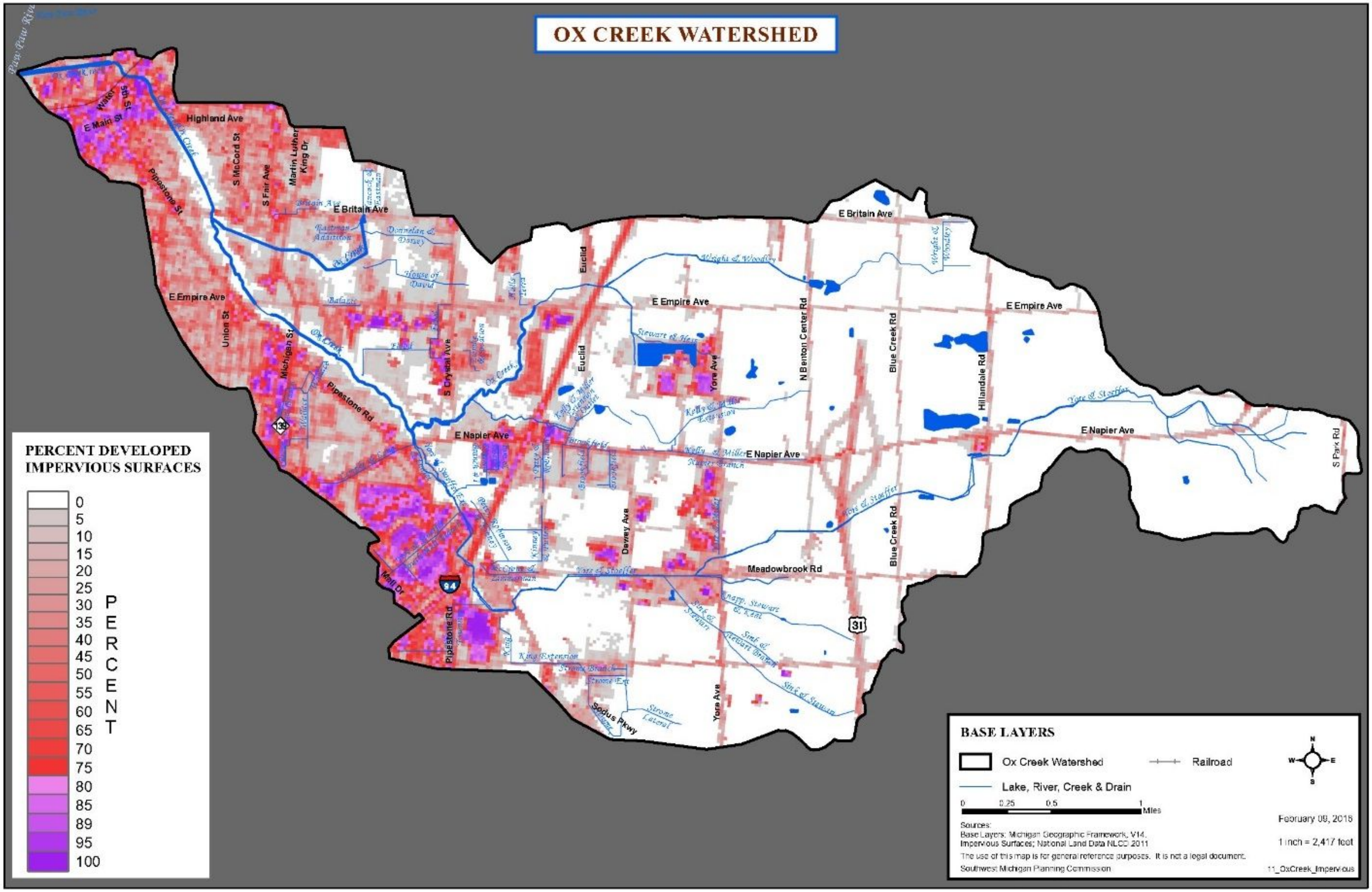
The following Figure illustrates the many impacts of the loss of natural lands and an increase in impervious surfaces on water quality and quantity. The impacts resulting from land-use change also negatively impact the fragmented natural areas left in the watershed. Following is a discussion of the different natural communities found in the OCW and the major threats to their existence and quality. The interdependent natural systems and communities discussed in this chapter include rivers, wetlands, groundwater, and floodplains.

Figure 20. Impacts of Impervious Surfaces



The Figure below shows the widely varied percentages of impervious surfaces across the OCW, demonstrating the concentration of high-percentage impervious surfaces in the Urban West region of the watershed, particularly downtown in the City of Benton Harbor and the vicinity of commercial/retail development along Pipestone Road and I-94 interchange.

Figure 21. Impervious Surfaces



5.3 Streams/Drains

Ox Creek is a warmwater stream. The Yore & Stoeffer Drain, situated to the south of Ox Creek's headwaters, is its largest tributary.

Warmwater streams typically have higher surface water inputs than groundwater inputs and as a result these streams have higher flow variability. Species richness is typically higher in southern Michigan streams, like Ox Creek; however, OCW appears on Michigan's §303(d) list (Goodwin, et. al., 2012) as not meeting the OIALW designated use as a result of biological impairments. The listing includes Ox Creek, Yore & Stoeffer Drain, and its tributaries which is 16.72 miles.

The OCW contains only 16.72 miles of stream that are not a designated drain. Out of the 52.8 miles of stream and drains, 36.09 miles (68%) of the total length are designated drains. The following table lists the county drains in the OCW.

Table 17. Ox Creek Drains, Length (Miles)

Drain Name	Municipality	Length (Miles)
Eastman Addition	Benton Charter Township	0.18
Britain Avenue	Benton Charter Township	0.28
Britain Avenue Lateral	Benton Charter Township	0.04
Hancock & Eastman	Benton Charter Township	0.45
Donnelan & Dorsey	Benton Charter Township	0.56
House of David	Benton Charter Township	0.69
Hulls Terra	Benton Charter Township	0.26
Stewart & Hess	Benton Charter Township	0.91
Kelly & Miller Extension	Benton Charter Township	0.23
Kelly & Miller	Benton Charter Township	0.92
Kelly & Milller Extension & Outlet	Benton Charter Township	0.83
Kelly & Miller Branch	Benton Charter Township	0.13
Brookfield South Branch	Benton Charter Township	0.12
Brookfield	Benton Charter Township	1.03
Petty & Robinson	Benton Charter Township	0.28
Pleasant Gardens	Benton Charter Township	0.20
Yore & Stoeffer Pyramid Branch	Benton Charter Township	0.08
Yore & Stoeffer Pyramid Branch	Benton Charter Township	0.24
Yore & Stoeffer Pyramid Branch #2	Benton Charter Township	0.01
Yore & Stoeffer Pyramid Branch #1	Benton Charter Township	0.20
Yore & Stoeffer Pyramid Branch 1984	Benton Charter Township	0.11
Ziemke Relocation	Benton Charter Township	0.20
Balazic	Benton Charter Township	0.19
Flood	Benton Charter Township	0.91
Lempke & Long	Benton Charter Township	0.59
Flood - Industrial Court Branch	Benton Charter Township	0.12
Wallace	Benton Charter Township	0.54
Wallace Central Branch	Benton Charter Township	0.37
Rizzo	Benton Charter Township	0.30

Drain Name	Municipality	Length (Miles)
Rosedale & Lynch	Benton Charter Township	0.17
Yore & Stoeffer Mall Place Branch	Benton Charter Township	0.16
Yore & Stoeffer South Mall Branch	Benton Charter Township	0.55
Yore & Stoeffer South Mall Branch Lateral	Benton Charter Township	0.14
Pipestone - Townline	Benton Charter Township	0.76
Pipestone - Townline Branch	Benton Charter Township	0.06
Petty, Robinson & Kinney	Benton Charter Township	0.14
Kinney Consolidated	Benton Charter Township	1.19
McCrone & Zimmerman	Benton Charter Township	0.36
Yore & Miller	Benton Charter Township	0.32
Sink & Stewart	Benton Charter Township	0.70
Sink & Stewart Branch	Benton Charter Township	0.36
Wright & Woodley	Benton Charter Township	3.25
Knapp, Stewart & Kent	Benton Charter Township	1.07
Yore & Stoeffer	Benton Charter Township	7.77
Yore & Stoeffer Extension & Outlet	Benton Charter Township	2.83
Handcock & Eastmen	Benton Charter Township	0.14
Sink & Stewart	Sodus Township	0.67
Strome Lateral	Sodus Township	0.32
Strome	Sodus Township	0.42
Strome Branch	Sodus Township	0.08
Strome Extension	Sodus Township	0.56
King	Sodus Township	1.12
Handcock & Eastmen	Benton Harbor, City of	0.38
Handcock & Eastmen	Benton Harbor, City of	0.04
Britain Avenue	Benton Harbor, City of	0.11
Yore & Stoeffer Extension	Bainbridge Township	0.96
Yore & Stoeffer Extension Branch	Bainbridge Township	0.48
Total		**36.09**

Threats

This Mangement Plan is intended to address the major threats to surface water, including flow regime alterations, sedimentation/siltation, and solids (suspended/bedload) from stream bank modifications/destabilization, impervious surface/parking lot runoff, and urban runoff/storm sewers.

Water pollution comes from all land uses in the watershed including residential, commercial, industrial, and agricultural.

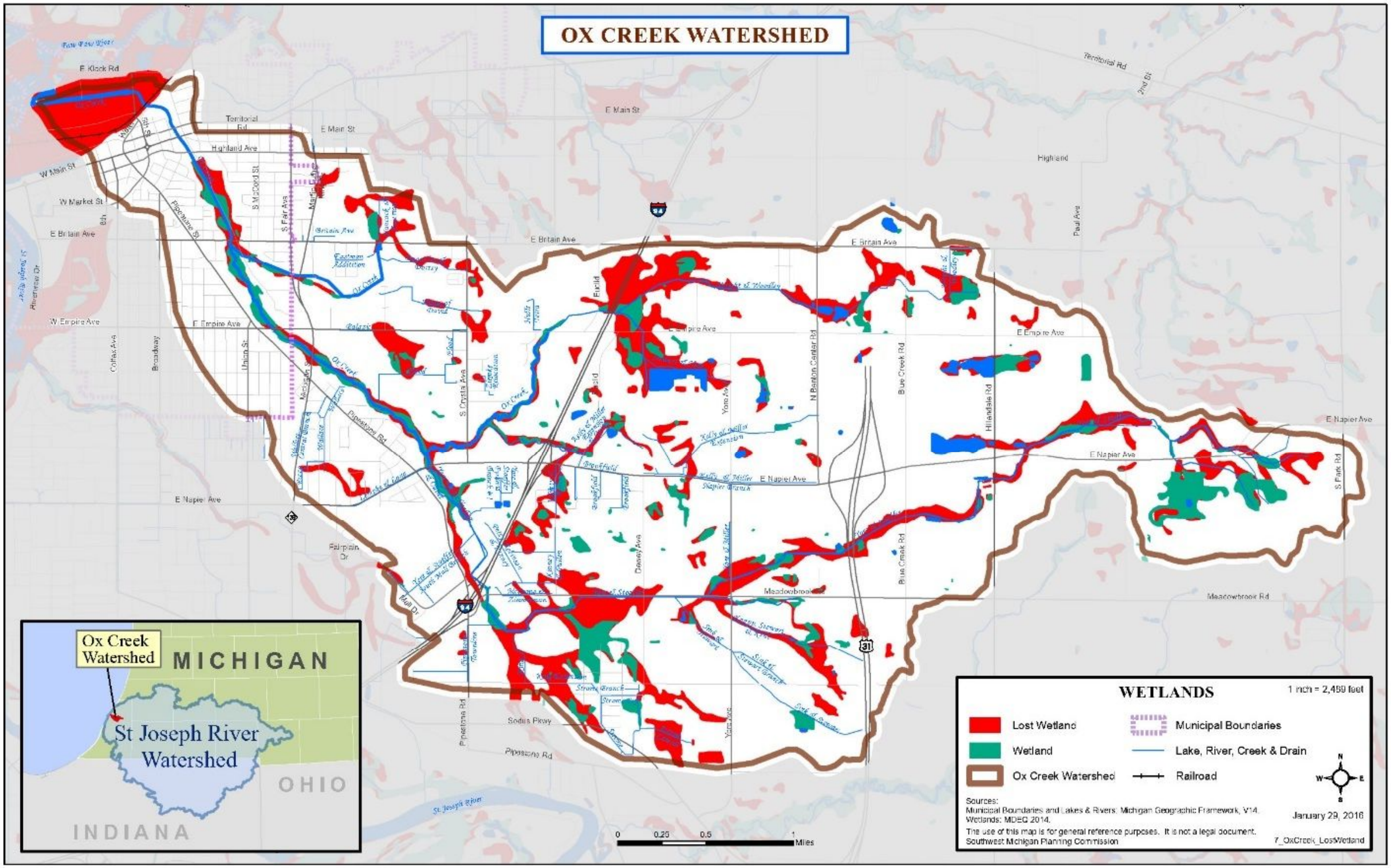
5.4 Wetlands

Wetlands provide critical ecosystem services such as cleansing water, storing water, and providing wildlife habitat. They provide a number of benefits by storing water following rain and snow melt. By keeping the water in place, wetlands recharge groundwater instead of the water being discharged through field tiles and drains. Wetlands help reduce the magnitude and frequency of flooding events. Sediment and chemicals in water held in wetlands have time to be filtered out before the water enters lakes and streams. They also provide excellent wildlife habitat.

The wetland resource base in the OCW has undergone significant disruption in the 200 years since Michigan was settled, losing approximately 74% of its total wetland area. The watershed itself has been extensively ditched since pre-settlement, and this has resulted in the destruction, degradation, and vegetative conversion of many of the wetlands and waterways that originally existed. By losing such a significant portion of the total wetland area other functions have been impacted, with streamflow maintenance, nutrient transformation, and other wildlife habitat all estimated to have lost 44-45% of their original capacity. No wetland functions have increased in the last 200 years. The loss of wetlands and riparian buffers in the upper Ox Creek and Yore & Stoeffer Drain units has reduced the ability of the watershed to retain sediment and store floodwaters.

There is potential to restore up to 1000 acres of wetlands in this watershed.

Figure 22. Wetlands in the Ox Creek Watershed



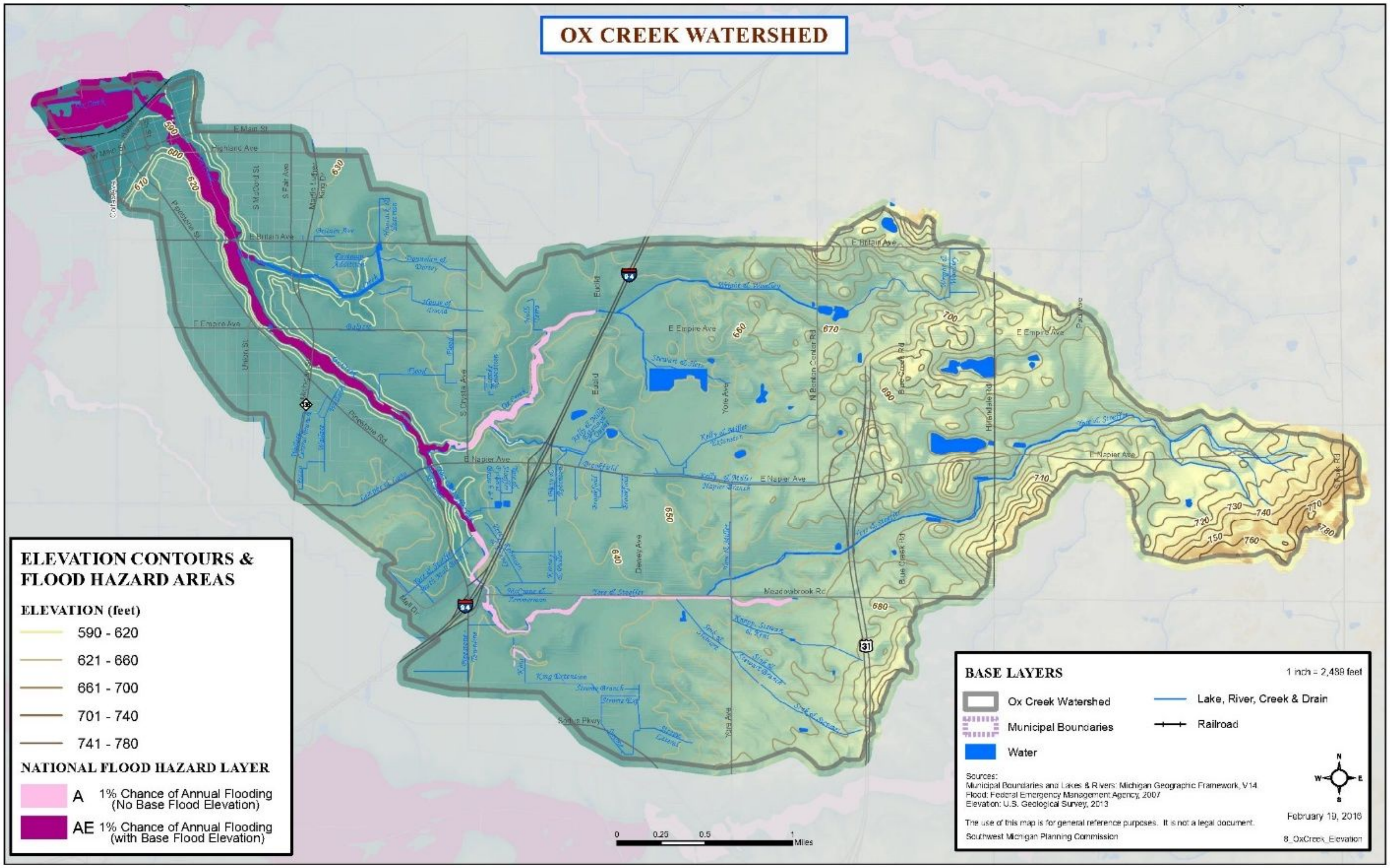
Threats

In the OCW there are 403 existing acres of wetlands; 1,060 acres have been lost since pre-settlement. Current threats to wetlands include filling or draining to accommodate industrial, residential, agricultural, or recreational land uses. Altered hydrology is a significant threat to most wetland types, whether it is due to a change in groundwater contributions to a fen or diversion of the water that feeds a swamp or marsh due to new road construction. While a number of threats generally threaten wetlands, in the OCW polluted runoff with sediment, nutrients, and chemicals are primary threats. Because wetlands are so critical to water quality and hydrology, with the significant 74% loss, conservation and protection of the limited remaining wetlands is essential.

5.5 Floodplains

A river, stream, lake, or drain may on occasion overflow their banks and inundate adjacent land areas. The land that is inundated by water is defined as a floodplain. In Michigan, and nationally, the term floodplain has come to mean the land area that will be inundated by the overflow of water resulting from a 100-year flood (a flood which has a 1% chance of occurring any given year).

Figure 23. Floodplains in the Ox Creek Watershed



Threats

Current threats to floodplains include conversion to industrial, residential, or recreational uses, wetland or floodplain fill or drainage, chemical pollution, sedimentation, and nutrient loading from agriculture and other land uses. Almost all rivers and their floodplains are subject to multiple hydrologic alterations, such as changes in land use, human-made levees, impoundments, channelization, and dams.

5.6 Groundwater

Groundwater is the water that saturates the tiny spaces between soil and rock. Most groundwater is found in aquifers, which are underground layers of porous rock that are saturated from above or from structures sloping toward it. For water to reach the aquifer, it must be able to infiltrate through the soil.

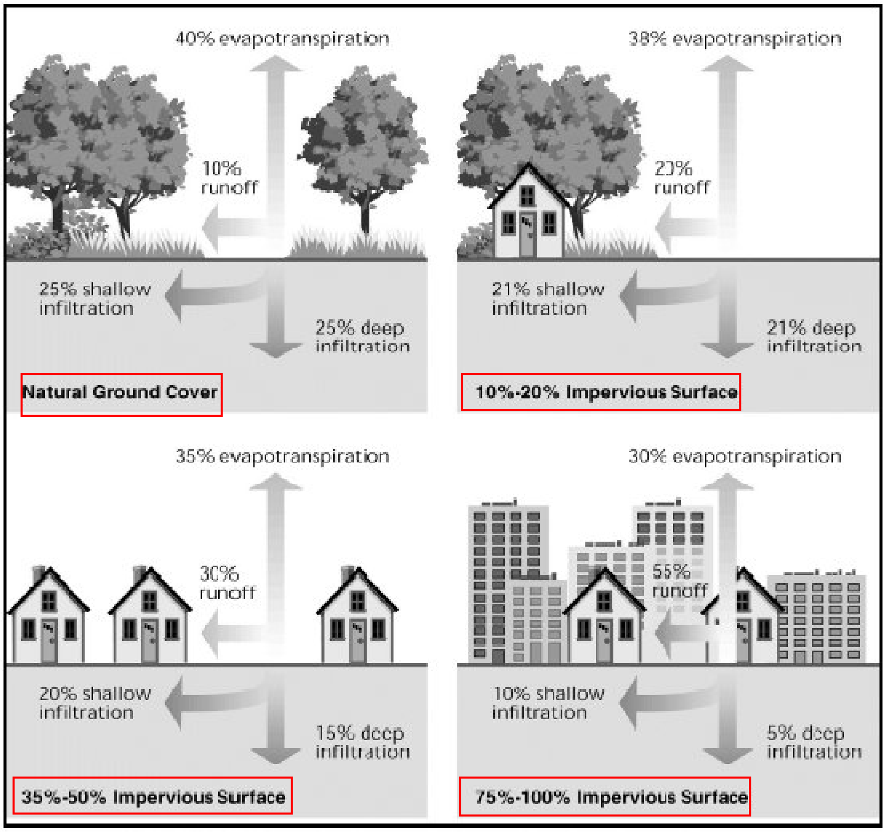
Groundwater and surface water are fundamentally interconnected. In fact, it is often difficult to separate the two because they "feed" each other. Aquifers feed streams and provide a stream's baseflow. Often, groundwater can be responsible for maintaining the hydrologic balance of streams, springs, lakes, and wetlands.

Threats

Increased groundwater withdrawal to meet the demands of a growing population is a threat. Despite a general abundance of groundwater in the OCW, there is growing concern about the availability of good-quality groundwater for industrial, agricultural, and domestic use, and for adequate baseflow to streams and wetlands. Increased withdrawal can cause groundwater overdraft, which occurs when water removal rates exceed recharge rates. This depletes water supplies and may even cause land subsidence (the gradual settling or sudden sinking of the land surface from changes that take place underground).

In addition to groundwater withdrawals, increases in impervious surface and soil compaction limit infiltration and reduce groundwater recharge. These land-use changes, along with improvements in drainage efficiency (adding drain tiles, storm drains, and ditches), further reduce groundwater recharge. The reduction in infiltration alters the hydrology of surface water causing increased flooding and streambank erosion.

Figure 24. Effects of Impervious Cover



Groundwater contamination can often be linked to land use. What goes on the ground can seep through the soil and turn up in drinking water, lakes, rivers, streams, and wetlands. Activities in urban areas that pose significant threats to groundwater quality include industrial and municipal waste disposal, road salting, and the storage of petroleum products and other hazardous materials. In rural areas, different threats to groundwater quality exist such as animal waste, septic systems, fertilizers and pesticides. The following Tables lists common groundwater contaminant sources and known areas of groundwater contamination in the OCW.

Table 18. Common Groundwater Contaminant Sources

Source	Contaminant	Source	Contaminant
Salting practices & storage	Chlorides	Solid waste landfills	Hazardous materials, Metals
Snow dumping	Chlorides	Industrial uses	Hazardous materials
Agricultural fertilizers	Nitrates	Households	Hazardous materials
Manure handling	Nitrates, pathogens	Gas stations	Hydrocarbons, Solvents
Home fertilizer	Nitrates	Auto repair shops	Hydrocarbons, Solvents

Source	Contaminant	Source	Contaminant
Septic systems	Nitrates, pathogens	Recycling facilities	Hydrocarbons, Solvents
Urban landscapes	Hydrocarbons, pesticides, pathogens	Auto salvage yards/junk yards	Hydrocarbons, Solvents
Agricultural dealers	Hydrocarbons, pesticides, nitrates	Underground storage tanks	Hydrocarbons
Agricultural feedlots	Nitrates, pathogens	Industrial floor drains	Hydrocarbons, Solvents

Table 19. Known Groundwater Contamination Areas

Area	Contaminant	Source
Benton Harbor	VOCs trichloroethene (TCE) and tetrachloroethene (PCE) and their breakdown products: 1,1-dichloroethene (1,1-DCE), vinyl chloride, and cis-1,2-dichloroethene (cis-1,2-DCE)	Aircraft Components Superfund Site

A wellhead protection area is a surface and subsurface land area regulated to prevent contamination of a well or well field supplying a public water system. This program, established under the Safe Drinking Water Act (42 U.S.C. 330f-300j), is implemented through state governments.

Overall, groundwater in Southwest Michigan is very vulnerable to groundwater pollution.

The purpose of Michigan's WHPP is to protect public water supply systems (PWSS) which use groundwater, from potential sources of contamination. Protection is provided by identifying, through hydrogeologic study, the area within a 10-year time of travel which contributes groundwater to PWSS wells, identifying potential sources of contamination within the area, and developing methods to cooperatively manage the area and minimize the threat to the PWSS.

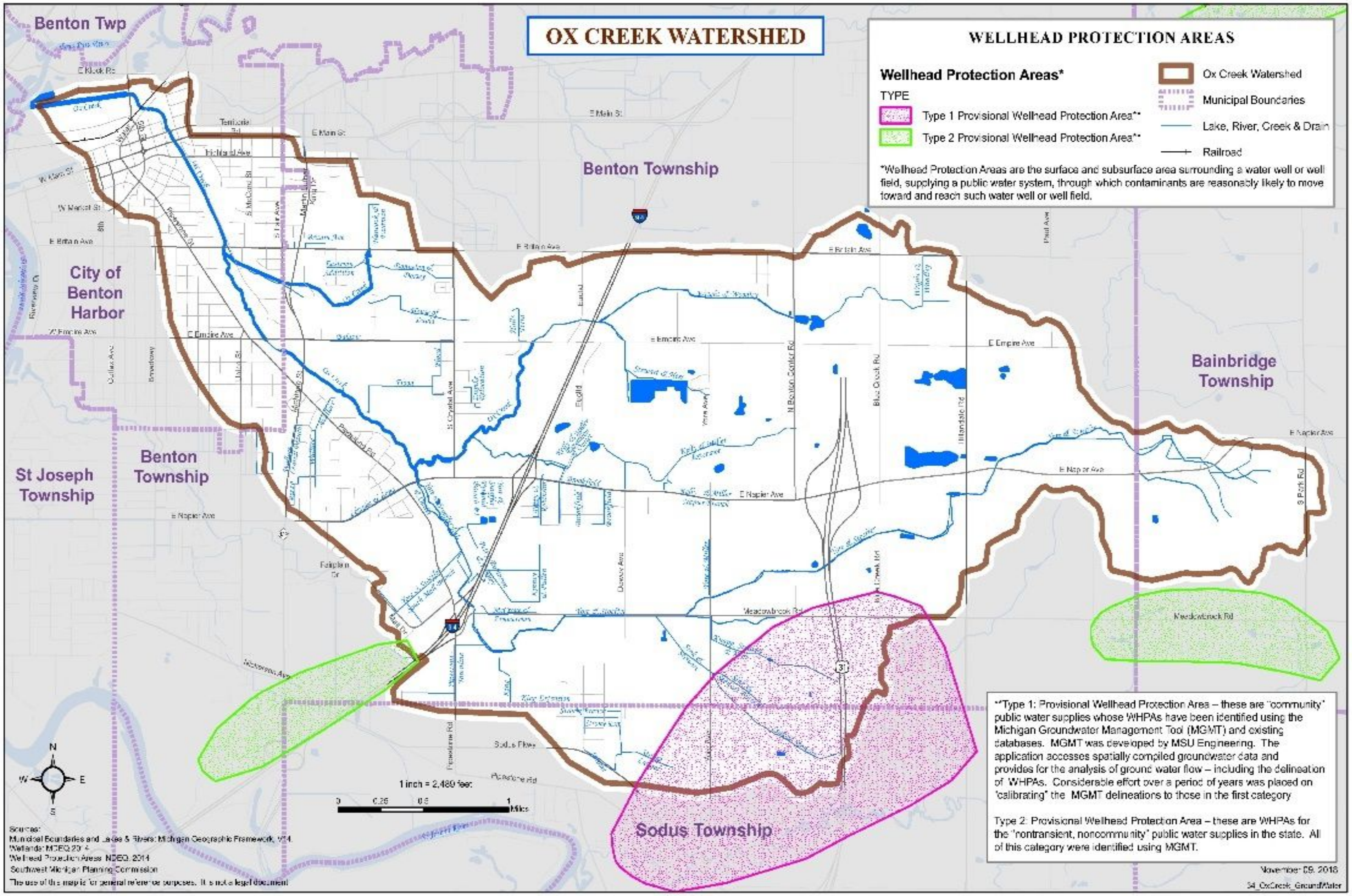
In the OCW there is limited area that is considered a Wellhead Protection Area (WHPA). These WHPAs were identified via a groundwater study conducted in and around the well or well field. The work generally included the conducting of an aquifer test, collection of static water elevations to confirm the direction of groundwater flow and groundwater flow modeling. In essence, they are those that have been done using field verified information.

The Figure below shows the two types of WHPAs in the OCW.

- Type 1 Provisional Wellhead Protection Area – these are "community" public water supplies whose WHPAs have been identified using the Michigan Groundwater Management Tool (MGMT) and existing databases. MGMT was developed by MSU Engineering. The application accesses spatially compiled groundwater data and provides for the analysis of groundwater flow – including the delineation of WHPAs. Considerable effort over a period of years was placed on “calibrating” the MGMT delineations to those in the first category.

- Type 2 Provisional Wellhead Protection Area – these are WHPAs for the “nontransient, noncommunity” public water supplies in the state. All in this category were identified using MGMT.

Figure 25. Wellhead Protections Areas in the OCW



6 Plan Development Process

This OCW Management Plan was developed utilizing the best available data along with input from stakeholders. The planning process included:

- soliciting public input
- reviewing previous studies and reports
- conducting research on topics of concern such as wetland functions, floodplains, agricultural concerns, and hydrology
- Total Maximum Daily Load (TMDL) analysis to determine priority areas

Project partners include the Berrien County Drain Commission, Cornerstone Alliance, Benton Charter Township, Southwest Michigan Planning Commission, Two Rivers Coalition, and the Berrien Conservation District, with technical assistance from Wightman.

6.1 Public Input

The Ox Creek Watershed Study incorporated public engagement throughout the planning process in a three-tiered approach: steering committee, business stakeholders, and targeted meetings with local officials and staff from agencies. The steering committee is a group of volunteers with environmental, economic development, and municipal perspectives who guided the over-arching metrics for success while providing review periodically throughout the project. Once the project team with the steering committee's input selected the project planning area, business stakeholders within the OCW and Orchards Mall commercial area were engaged to provide feedback on areas that need improvement, what those areas should look like, and which areas should be preserved.

The following vision statement was developed from the identified objectives, advantages and opportunities laid out:

"Envision a revitalized Orchards Mall area with mixed use development and public gathering spaces as a gateway to Benton Harbor and St. Joseph and the regional commercial/retail hub of SW Michigan."

A web site, along with coordinated graphics, was developed at https://sustainoxcreek.org/ to inform the public of the Ox Creek project, offering visitors the opportunity to:

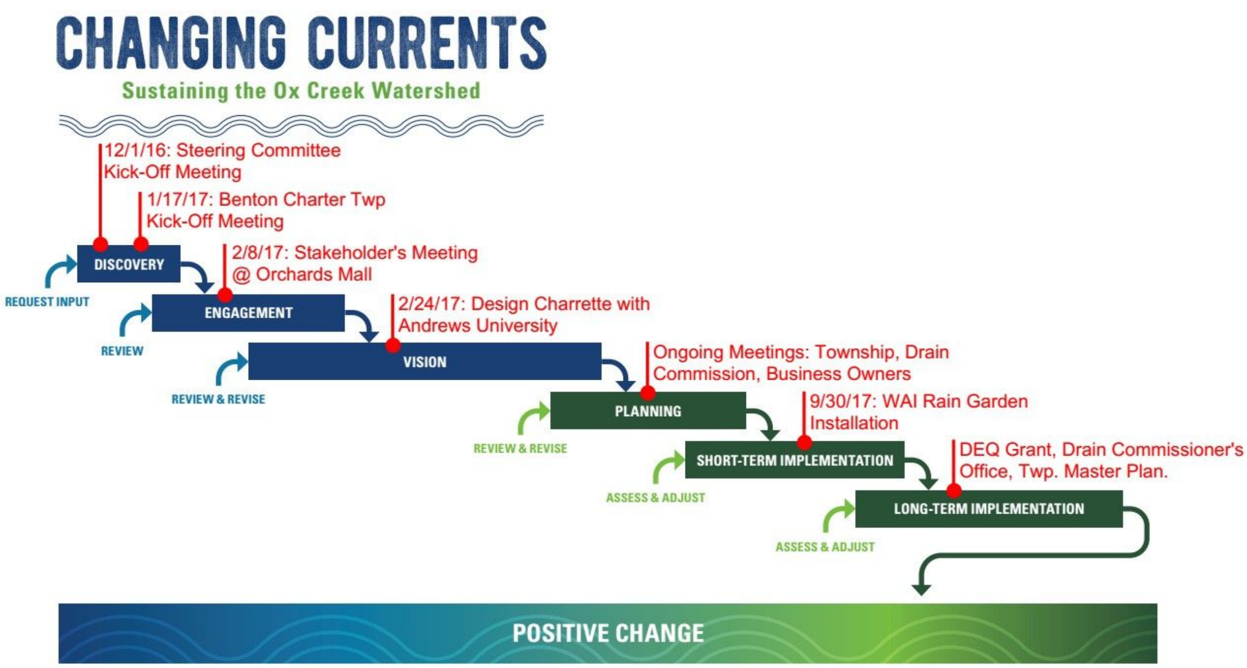
- Learn more about the OCW and how sustaining it is key to a healthy environment and economy.
- See plans for what is possible for the future development of the area through renderings and detailed maps.
- Read the latest articles and updates as plans progress. Also dive deeper with information about watersheds and BMPs for urban stormwater management and agriculture.

- Find a listing of who the best choice is to contact for information specific to their interest or questions.

OX CREEK WATERSHED
URBAN | RURAL | EXIT 29

Andrews University architecture students, with Wightman staff, led a charrette-based design approach where municipal officials, County officials, MDOT, and commercial and economic developers worked directly with the students as they proposed and drew improvements. Once developed, these drawings were used for targeted meetings throughout the region to discuss issues/opportunities with the County Drain Commissioner, MDOT's planning department, and Benton Charter Township staff to determine the feasibility and effectiveness of the proposed designs.

Figure 26. Changing Currents: The Road to a Sustainable Ox Creek



6.2 Previous Studies/Reports

Several studies and reports pertaining to the OCW were reviewed during the development of this Management Plan. The information contained in these reports provided much of the background information and also helped to prioritize protection and management areas. These reports include: *The Paw Paw River Watershed*

Management Plan, the *Ox Creek Technical Plan Update*, and the *Total Maximum Daily Load for Biota in Ox Creek*.

6.3 Watershed Research and Modeling

The poor macroinvertebrate community in the OCW could be attributed to a lack of suitable habitat for colonization (due to past channel alterations). High stormwater flows likely bring additional pollutant and sediment loads to the stream that further degrades the habitat. The complexity of water quality concerns in the OCW has resulted in several investigations that have included biological assessments, sediment sampling, TSS and flow monitoring, and water chemistry sampling. Further, the following studies have been used to better understand the pollutants, sources and causes and to prioritize them in Chapter 8.

TMDL Analysis

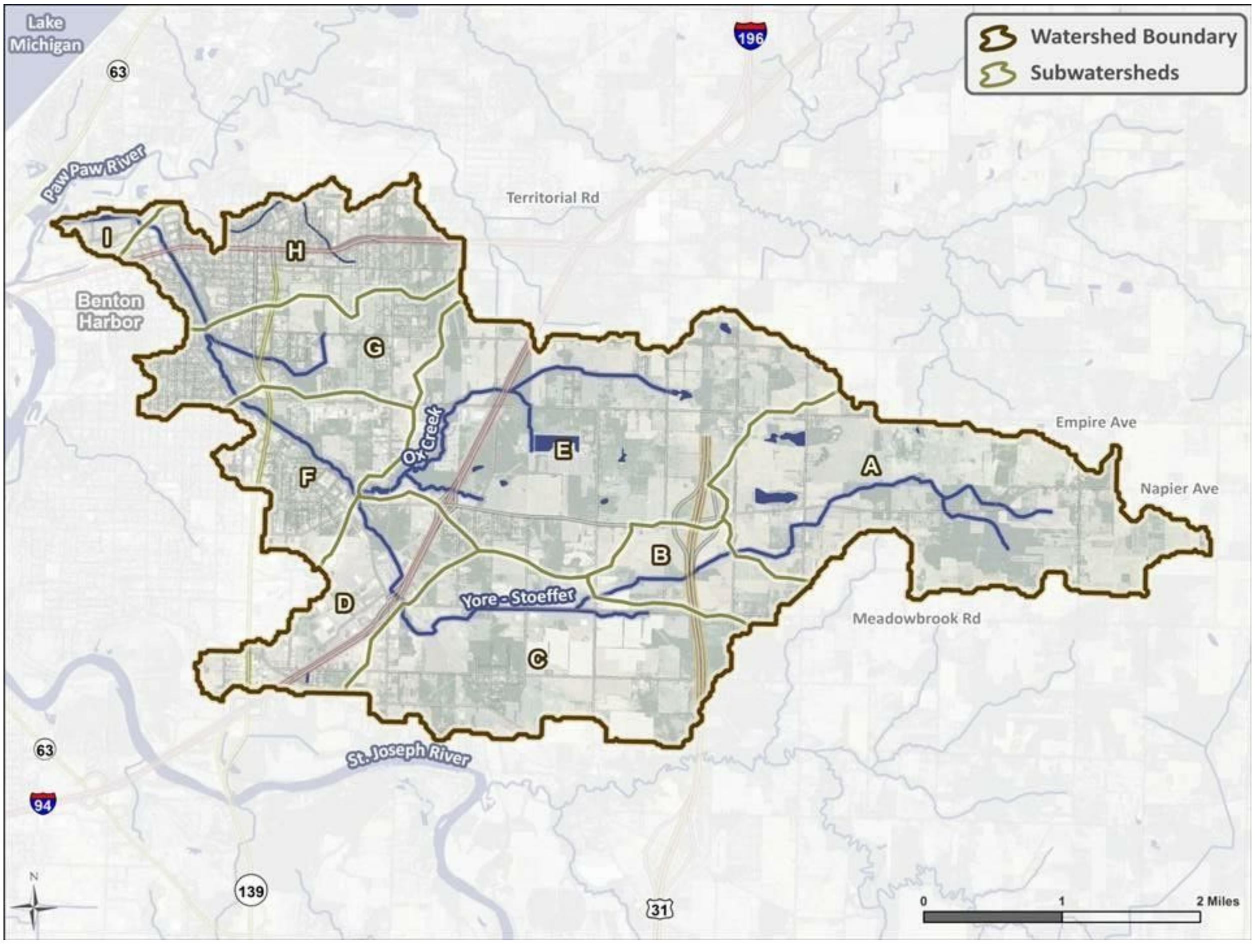
There have been extensive analyses done for *Total Maximun Daily Load for Biota in Ox Creek*, which can be found as an Appendix; the following summarizes that study.

These studies recognize that different land use patterns and source areas across the watershed contribute to spatial variation of pollutant loading. A subwatershed framework is needed because different factors (e.g., land use, sources of sediment, amount of impervious cover, etc.) appear to influence the biological integrity, hydrology, and water quality patterns at each location. The use of subwatersheds enhances the source assessment by grouping information; it also sets the stage for the TMDL linkage analysis. The use of subwatersheds creates an opportunity to relate source information to water quality monitoring results. Subwatersheds can help connect potential cause information to documented effects on a reach-by-reach basis. Ox Creek drainage has been partitioned into subwatershed units to facilitate the source assessment. These subwatershed units used for the source assessment are identified in the following Table and Figure. These subwatershed boundaries are defined in a way that builds on locations sampled by MDEQ.

Table 20. Ox Creek subwatersheds listed from upstream to downstream

Subbasin ID	Name
Unit A	Yore & Stoeffer Headwaters
Unit B	Upper Yore & Stoeffer
Unit C	Middle Yore & Stoeffer
Unit D	Lower Yore & Stoeffer
Unit E	Ox Headwaters
Unit F	Upper Ox
Unit G	Middle Ox
Unit H	Lower Ox
Unit I	Ox Outlet

Figure 27. Ox Creek Watershed Units



The following Table summarizes the major considerations and concerns based on information regarding this linkage analysis. Specific concerns in the Ox Creek watershed vary by location. For example, the daily maximum TSS target is exceeded in the Yore & Stoeffer Drain (Units B,C) and the headwater area of Ox Creek (Unit E). A number of factors may contribute to elevated TSS loads in the upper watershed including erosion from cropland and loss of wetlands, as well as the straightening and deepening of drainage ditches.

Flashy flows, which disrupt macroinvertebrate community structure, exert a much greater adverse effect on the lower portions of Ox Creek (Units F,G,H,I). Flashy flows also transport elevated TSS loads from the upper portion of the watershed, causing excess siltation in the downstream reaches of Ox Creek.

Table 21. Ox Creek Watershed Loading Considerations and Concerns

Unit	Cumulative Land Use (acres)	Cumulative Land Use Estimated % Impervious Cover	Biology*** *(dominant taxa)*	Total Suspended Solids	Hydrology
Yore & Stoeffer Drain					
A	2,150	1%	n.a.	---	*see Note*[1]
B	2,615	1%	n.a.	TSS Targets exceeded	
C	4,370	4%	*Physidae (Gastropods)*		
D	5,175	9%	n.a.	n.a.	*see Note*[2]
Ox Creek					
E	2,600	7%	*Amphipoda (scuds)*	TSS Targets exceeded	---
F	8,500	10%	n.a.	Siltation due to excess TSS loads	*"Flashy"* flows
G	9,395	10%	*Oligochaeta (worms)*		
H	10,455	11%	*Oligochaeta (worms)*		
I	10,559	12%	n.a.		

Notes:
- ***: Dominant taxa used as an example indicator to illustrate the variation in biological stressors that exist across the Ox Creek watershed.
- ---: no identified concern
- Note[1]: Loss of wetlands reducing floodwater storage; effect of agricultural drainage ditches
- Note[2]: Highest percentage of impervious cover in Ox Creek watershed
- n.a.: Not assessed

Cumulative land use. Land use (and specifically impervious cover) is one characteristic that clearly affects all aspects of watershed loading and response, particularly hydrology, water quality, and biology. It is a major controlling factor that determines the amount of stormwater runoff. The estimated percentage of impervious cover in the lower portions of Ox Creek (Units D, E, F, G, H, I) is significantly greater than in the upper subwatersheds (Units A, B, C). The increased percentage of impervious surfaces subsequently cause flashy flows and generate excess stormwater volume.

Land use is also a major factor in generating elevated TSS loads in the upper subwatershed. In addition to surface erosion from cropland (see High Impact Tageting [HIT] model), the loss of wetlands and riparian buffers in the upper Ox Creek and Yore & Stoeffer Drain units has reduced the ability of the watershed to retain sediment and store floodwaters (see LLWFA [Landscape Level Watershed Functional Analysis] maps). The straightening and deepening of ditches in the upper watershed also results in increased flow rates and stream velocities during storm events that contribute to increased channel scour and bank erosion.

Biology changes across the watershed. The variation in dominant taxa (shown in the above Table) is one way to illustrate the effect of different stressors at each location.

For example, Physidae (or freshwater snails) are dominant in subwatershed Unit C. This particular subwatershed is an area where TSS targets, as well as water quality criteria and PECs for several PAHs, are all exceeded. MDEQ's Procedure 51 specifically uses the percentage of isopods, snails, and leeches as a metric. These organisms show a high tolerance to a variety of both physical and chemical parameters. High percentages of these organisms at a sample site are strong evidence of stream degradation.

Total Suspended Solids targets are exceeded in upper portions of the watershed, notably the Yore & Stoeffer Drain (Units B,C) and the headwater area of Ox Creek (Unit E). An important part of the linkage analysis is to examine the effect of these TSS exceedances across the entire watershed, particularly their role in causing downstream siltation problems. This closer examination is best accomplished through a loading analysis.

TSS exceedances were gauged during two storm events (August 19, 2007 and April 9, 2008) in the two primary upstream tributaries: Yore & Stoeffer Drain (Units B,C) and the Ox Creek headwater area (Unit E). The individual tributary loads form the total TSS load to the mainstem of Ox Creek below their confluence. In both storm events, the sum of the tributary TSS loads either exceeded or comprised a significant majority of the TSS loads that were monitored downstream. This indicates that TMDL implementation efforts to meet the TSS targets in the upper subwatershed units should address sediment sources in these areas (see Chapter 10).

Hydrology and flow rates affect TSS concentrations. Stable flow regimes also support the establishment of healthy macroinvertebrate populations. The primary concern regarding hydrology in Ox Creek is flashy flows in the lower subwatersheds (Units F,G,H,I). Flashy flows disrupt aquatic community structure and increase the transport of TSS loads that cause downstream siltation problems. The R-B Flashiness Index score for lower Ox Creek at Britain Avenue is 0.52, which places it in the highest quartile for Michigan watersheds of comparable size.

The R-B Flashiness Index score for lower Ox Creek at Britain Avenue is 0.52, which places it in the highest quartile for Michigan watersheds of comparable size.

During storm events, rain falling on impervious surfaces produces higher volumes of runoff (due to the decreased ability of the subwatershed to infiltrate water). These higher volumes occur in shorter "bursts," resulting in flashy flows. Not surprisingly, the problems with flashy flows in Ox Creek appear to coincide with those subwatershed units that have higher amounts of impervious surfaces. Another important part of the linkage analysis is to use the data to examine where significant amounts of water are being delivered to Ox Creek. Flow information collected during the TSS survey can be used to develop a water volume analysis (somewhat analogous to the loading analysis for TSS). In the case of both storm events, a significant volume of water is added to Ox Creek downstream from the Yore & Stoeffer Drain at Meadowbrook and Ox Creek at Crystal. In the case of both storm events, a significant volume of water is added to Ox

Creek downstream from these two sites. This is not surprising given the increased levels of impervious surfaces that occur in subwatersheds D, F, G, H, and I. This highlights the need to also focus on reducing flow volumes (i.e., quantity) when addressing biological impairments in Ox Creek.

In addition, management practices in the upper subwatershed have contributed to altered hydrology. The loss of wetlands for floodwater storage coupled with the straightening and deepening of ditches also increase the overall “flashiness” of flows in Ox Creek.

The net effect of altered hydrology in the Ox Creek watershed is that concentration targets alone will not solve water quality problems associated with excess siltation. Siltation causing the biological impairments in Ox Creek is the result of excess TSS loads. These loads are the product of the TSS concentrations times the corresponding flow times a conversion factor. Through this relationship, the flow regime directly affects the total maximum allowable daily load.

TMDL Development

The TMDL represents the maximum loading that can be assimilated by a waterbody while still achieving the applicable water quality standard. The applicable designated use for the Ox Creek TMDL is the protection of OIALW. The primary narrative target is the restoration of biological communities to achieve an “acceptable” score using Procedure 51 (i.e., a score greater than -4). Based on an evaluation of macroinvertebrate and sediment data for other southern Michigan streams that attain the OIALW designated use, a daily maximum of 300 mg/L TSS has been identified as a numeric target that will protect aquatic life uses in Ox Creek.

Based on an evaluation of macroinvertebrate and sediment data for other southern Michigan streams that attain the OIALW designated use, a daily maximum of 300 mg/L TSS has been identified as a numeric target that will protect aquatic life uses in Ox Creek.

Under the regulatory framework for development of TMDLs, calculation of the loading capacity for impaired segments identified on the §303(d) list is an important first step. EPA’s regulation defines loading capacity as *“the greatest amount of loading that a water can receive without violating water quality standards.”* The loading capacity is the basis of the TMDL and provides a measure against which attainment with water quality standards (WQS) will be evaluated. The loading capacity also guides pollutant reduction efforts needed to bring a water into compliance with standards.

Typically, loads are expressed as mass per time, such as pounds per day. The loading capacity of a stream is determined using:

- the water quality criterion or target value; and
- a design flow for the receiving water, which represents a secondary target that reflects critical conditions.

Critical conditions used for TMDL development in Michigan are established with an acceptably low frequency of occurrence that, if protected for, should also be protective of other more frequent occurrences (Goodwin, 2007). Critical conditions are typically defined as an exceedance flow. An exceedance flow is a statistically determined flow that is exceeded a specific percentage of time using a flow duration curve. For example, the 95% exceedance flow is the flow expected to be exceeded 95% of the time; this reflects low flow conditions. Similarly, the 1-day exceedance flow represents the daily average flow expected to be exceeded one day each year (i.e., the one divided by 365 days, or 0.274% of the time), which reflects high flow conditions.

Critical conditions for the applicability of WQS are given in MDEQ's Rule 90 (R 323.1090). For water quality problems associated with low flow conditions, R323.1090(2)(a) defines this as the 95% exceedance flow. However, Rule 90 also provides that *"alternate design flows may be used for intermittent wet weather discharges as necessary to protect the designated uses of the receiving water"* [R 323.1090(4)]. The poor biological communities and habitat degradation are the result of excessive sediment loads often associated with high flow conditions, as described in development of the 300 mg/L TSS target.

The TSS target is a daily maximum value, which recognizes that sediment concentrations vary as a function of flow. Because of the direct relationship between TSS and flow, the 1-day maximum exceedance flow is used to represent critical conditions that determine Ox Creek watershed TMDL loading capacities. In addition to reducing TSS concentrations, a reduction in stormwater volume should help address aquatic life impairments.

In addition to reducing TSS concentrations, a reduction in stormwater volume should help address aquatic life impairments.

The Table below presents the TSS loading capacity at the outlet of each subwatershed. The 1-day exceedance design flow for each subwatershed is determined using the Galien River gage as a representative site based on a drainage area weighting factor (i.e., each subwatershed area divided by the Galien River drainage area). The Galien River had the highest coefficient of determination for observed flow data between other US Geological Survey sites examined and Ox Creek. In addition, macroinvertebrate scores for the Galien River were rated as acceptable using Michigan's Procedure 51.

Table 22. Ox Creek Watershed TSS Loading Capacity Summary

Total Suspended Solids Loading Capacity Summary					
Subwatershed		Cumulative Drainage Area *(sq.mi.)*	1-day Maximum Exceedance Flow *(cfs)*	TSS Loading Capacity *(tons/day)*	
				Subwatershed	*Cumulative*
A	*Yore & Stoeffer Headwaters*	3.36	46.2	37.4	37.4
B	*Upper Yore & Stoeffer*	4.09	56.3	8.1	45.5
C	*Middle Yore & Stoeffer*	6.83	93.9	30.5	76.0
D	*Lower Yore & Stoeffer*	8.09	111.3	14.0	90.0
E	*Ox Headwaters*	4.06	55.8	45.2	45.2
F	*Upper Ox*	13.28	182.7	12.6	147.8
G	*Middle Ox*	14.68	201.9	15.6	163.4
H	*Lower Ox*	16.34	224.8	18.4	181.8
I	*Ox Outlet*	16.50	227.0	1.8	183.6

Individual components for the OCW TMDL are summarized in the Figure below of Total Maximum Daily Load for Biota in Ox Creek. Allocations fall into two categories: NPDES stormwater wasteload allocation (WLA) (which includes both MS4 and industrial stormwater) and load allocation (LA) (which accounts for both nonpoint sources and background).

Table 23. Ox Creek TMDL Summary

Subwatershed		Area *(acres)*	TSS Cumulative Loading Capacity *(tons/day)*	TSS Subwatershed Allocations *(tons/day)*		Margin of Safety
				NPDES Stormwater WLA	LA	
A	*Yore & Stoeffer HW*	2,150	37.4	0.00	37.40	*Implicit*
B	*Upper Yore & Stoeffer*	465	45.5	0.15	7.95	
C	*Middle Yore & Stoeffer*	1,755	76.0	6.18	24.32	
D	*Lower Yore & Stoeffer*	805	90.0	11.60	2.40	
E	*Ox Headwaters*	2,600	45.2	6.88	38.32	
F	*Upper Ox*	725	147.8	11.10	1.50	
G	*Middle Ox*	895	163.4	11.32	4.28	
H	*Lower Ox*	1,060	181.8	13.68	4.72	
I	*Ox Outlet*	104	183.6	1.80	0.00	
	TOTAL	10,559	183.6	62.71	120.89	*Implicit*

For additional information on TMDL development please see Appendix: *Total Maximum Daily Load for Biota in Ox Creek*.

<u>L-THIA Model of Urban BMPs</u>
Long Term Hydrologic Impact Analysis (L-THIA) models were run to simulate possible development changes in the Orchards Mall area of the OCW. L-THIA is a spreadsheet developed by Purdue University that estimates changes in recharge, runoff, and nonpoint source pollution resulting from past or proposed development. This model shows that if a commercial area in the mall area is redeveloped as commercial and impervious surfacing is reduced by 5%, runoff is reduced by 1.75" or over 11%. Suspended solids are reduced by over 11% as well. Other nonpoint pollutants such as nitrogen, phosphorus, copper, lead and other heavy metals, oil and grease are also reduced.

This modeling also allows for lot level Low Impact Development (LID) calculations to be run. Many of the development plans suggested for the OCW utilize rain gardens/bioretention and swales. When these options were chosen on a hypothetical 10-acre commercial site being redeveloped, annual runoff reduced by 2.86" and over 19%. These BMPs also reduce suspend solids by over 19%. Nitrogen, phosphorus, oil and grease, and heavy metals are reduced as well.

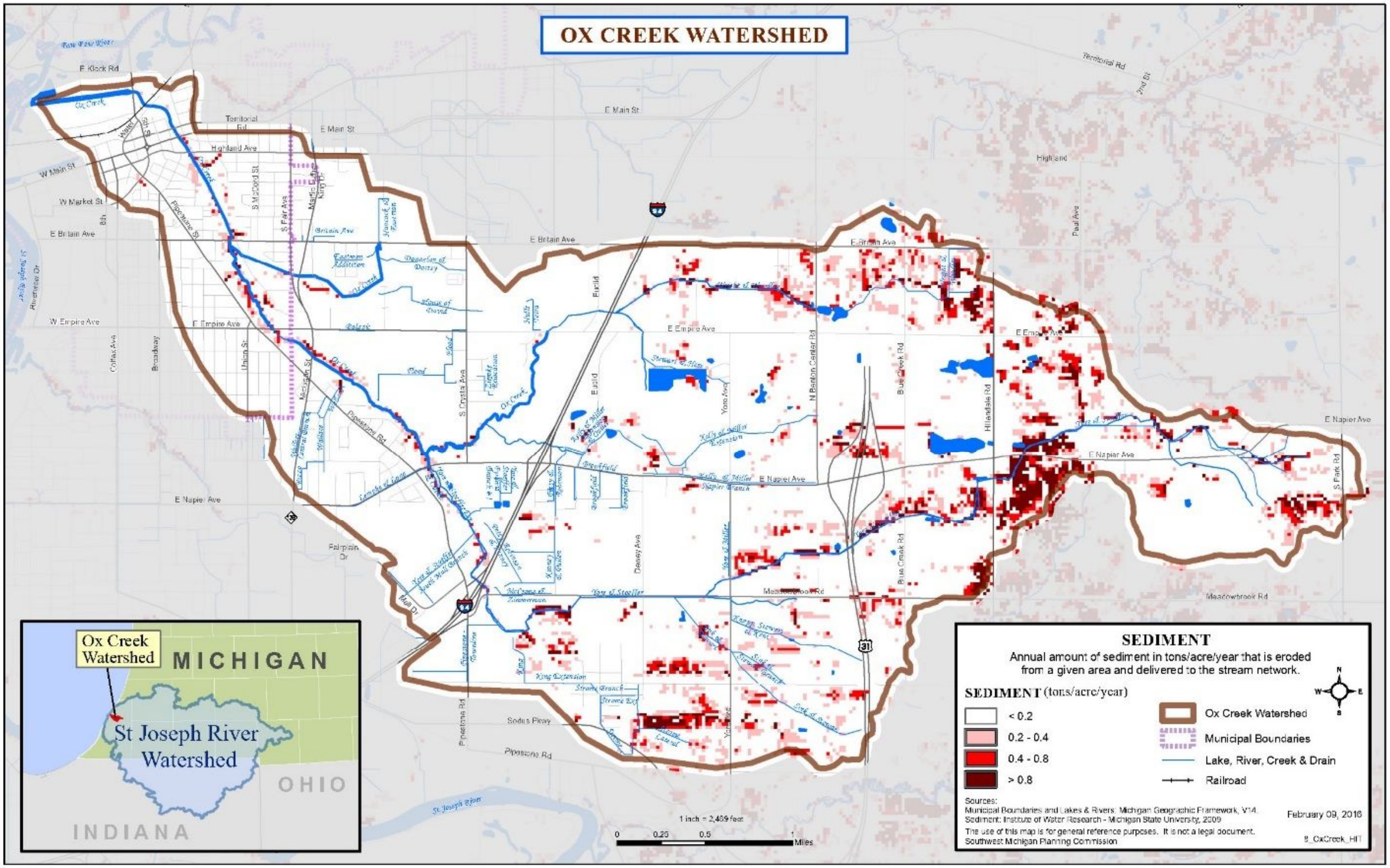
These preliminary modeling efforts show the impact both LID, and reduction in pervious surfaces can have on development. See Appendix: *LTHIA Model Results* for LTHIA output result details.

Sediment Loading

The High Impact Targeting or HIT system, is an online decision support tool for prioritizing agricultural areas contributing sediment to the Great Lakes and their tributaries. HIT produces field-scale maps identifying areas at risk for erosion and sediment loading and tonnage estimates for erosion and sediment loading at watershed scales. This online tool allows users to interact with this data spatially and evaluate the potential impacts of BMPs on selected watersheds. HIT data, along with detailed metadata, is downloadable for users in desktop GIS format for more in-depth spatial analysis. HIT combines an erosion model (RUSLE – Revised Universal Soil Loss Equation) and a sediment delivery model (SEDMOD – Spatially Explicit Delivery Model) to calculate annual erosion and sediment loading to streams. Development for HIT was funded by the U.S. Army Corps of Engineers and the USDA Natural Resources Conservation Service.

The following Figure shows the areas in the OCW that are expected to have the most erosion and cause sedimentation of waterbodies. This analysis focuses primarily on agricultural lands and on sheet erosion (RUSLE), not gully, bank, or wind erosion. The estimates produced with HIT for rates of erosion and sediment loadings are for relative comparisons of watersheds and are not precise.

Figure 28. Annual Sediment Loads



MDEQ Landscape-Level Wetland Functional Assessment

Wetlands are critical for providing diverse wildlife habitat, improving water quality and stabilizing stream flows throughout the watershed. In 2007, the MDEQ completed a landscape-level analysis to better understand the functions of existing and lost wetlands in the Paw Paw River Watershed, which included the OCW. The results from this analysis can be utilized to locate wetlands with important functions such as protecting water quality, providing habitat, and reducing flood impacts in the watershed. The results can help pinpoint potential restoration, enhancement, and protection activities to appropriate areas of the watershed that are most in need of a particular wetland function. These most important functions for the OCW are sediment retention and nutrient transformation and floodwater retention, as demonstrated in the Figures below.

Figure 29. Landscape Level Wetland Functional Assessment, Sediment Retention and Nutrient Transformation

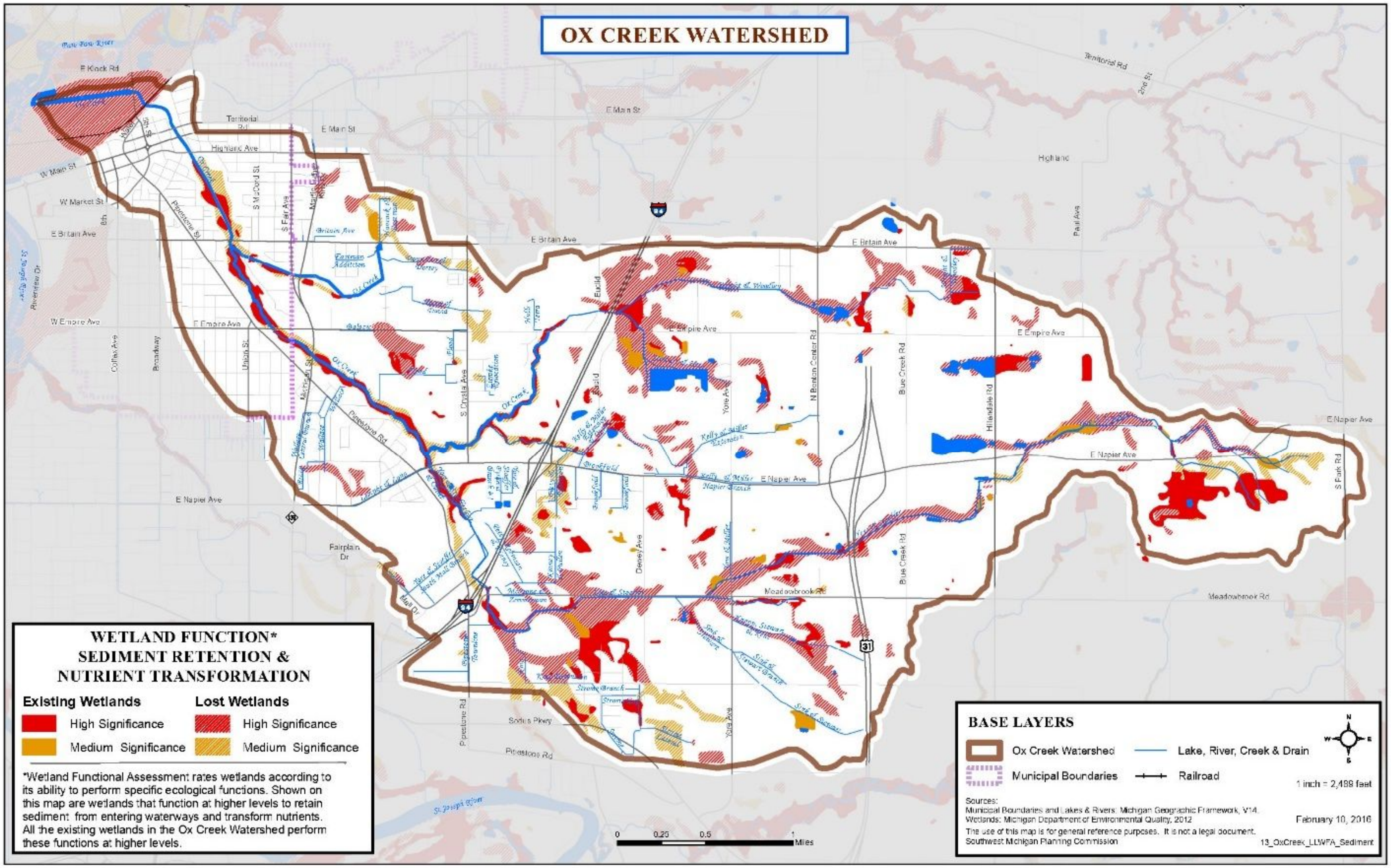
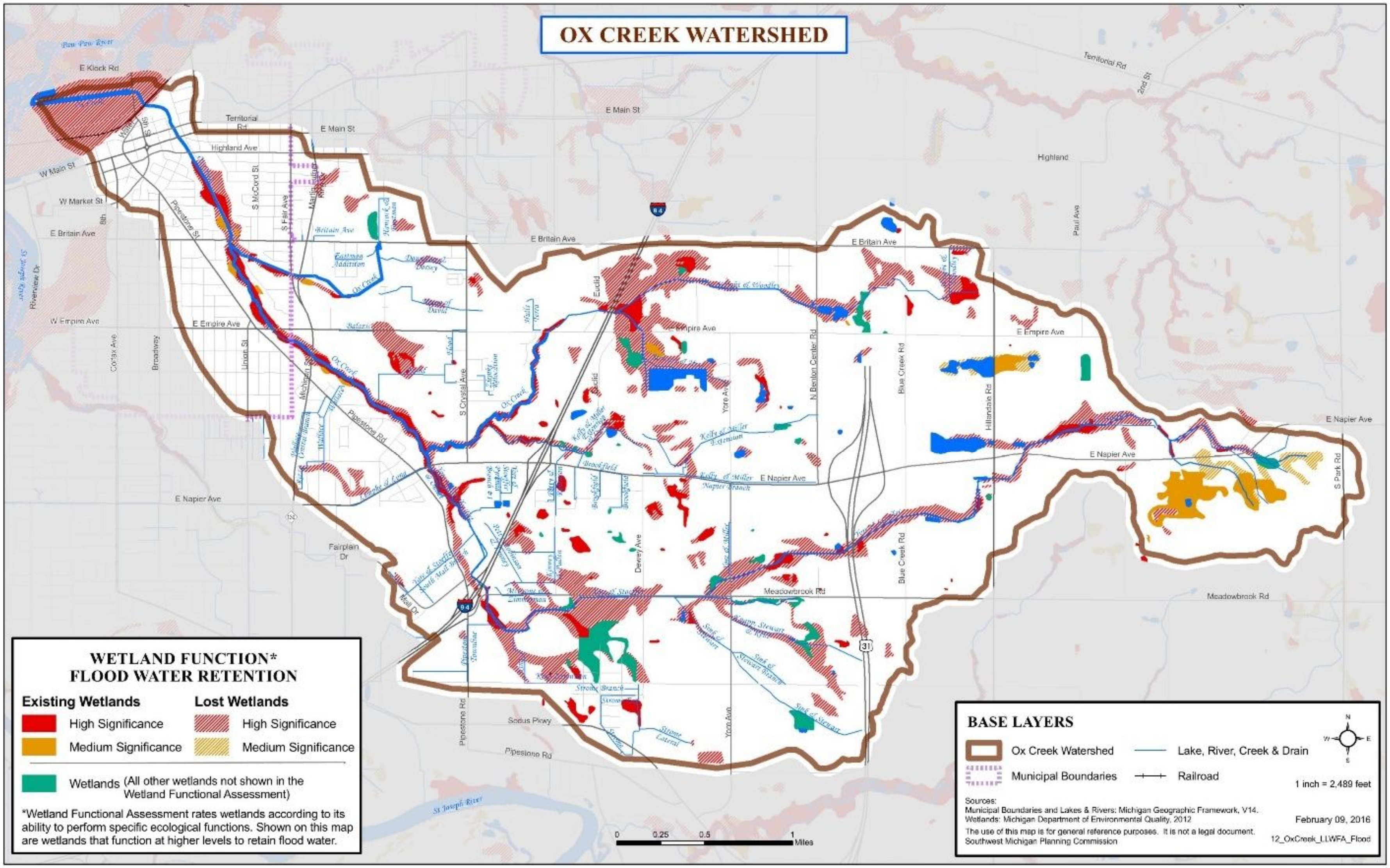


Figure 30. Landscape Level Wetland Functional Assessment, Floodwater Retention

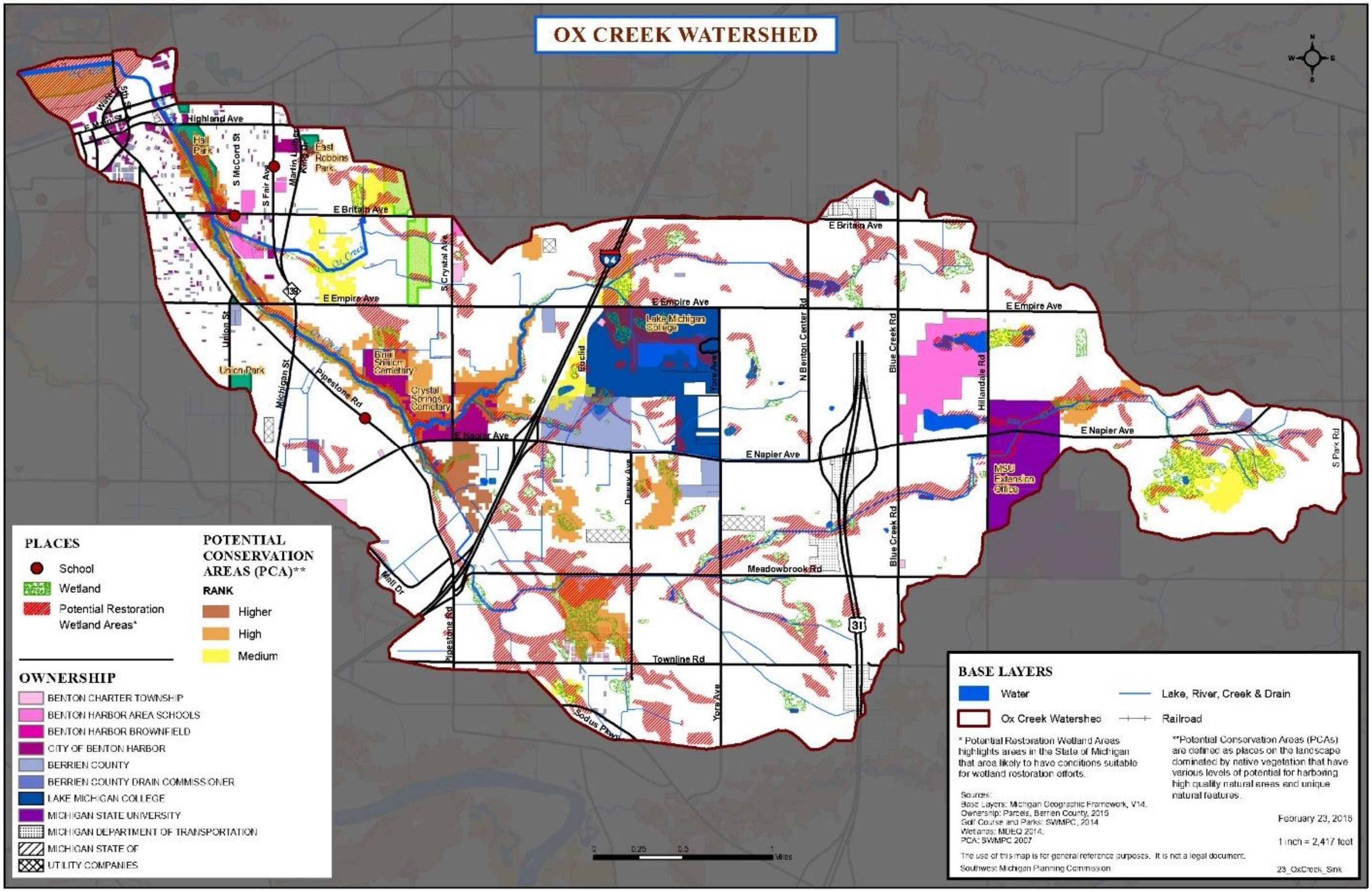


Potential Conservation Areas

PCAs have been identified with assistance from the Michigan Natural Features Inventory (MNFI). These maps can help guide and target conservation and recreation efforts in Southwest Michigan. The criteria used to prioritize the lands for conservation include total size of natural area, size of core area, stream length, landscape connectivity, restorability of surrounding lands, vegetation quality and bio-rarity score.

The goal is to protect these identified high-quality natural lands through conservation easements and fee-simple purchases to ensure a connected green infrastructure system in Southwest Michigan. These maps can be used by local and state governments, local and county parks departments, land conservancies and others to identify high-priority lands for preservation. For more information on the MNFI study visit www.swmpc.org/swmi.asp.

Figure 31. Potential Conservation Area



7 Water Quality Summary

7.1 Designated Uses

According to the MDEQ, the primary criterion for water quality is whether the water body meets designated uses. Designated uses are recognized uses of water established by state and federal water quality programs. All surface waters of the state of Michigan are designated for and shall be protected for the uses listed in Table 24 below. (Citation: R323.1100 of Part 4, Part 31 of PA 451, 1994, revised 4/2/99). A watershed management plan provides direction for protecting and restoring designated uses.

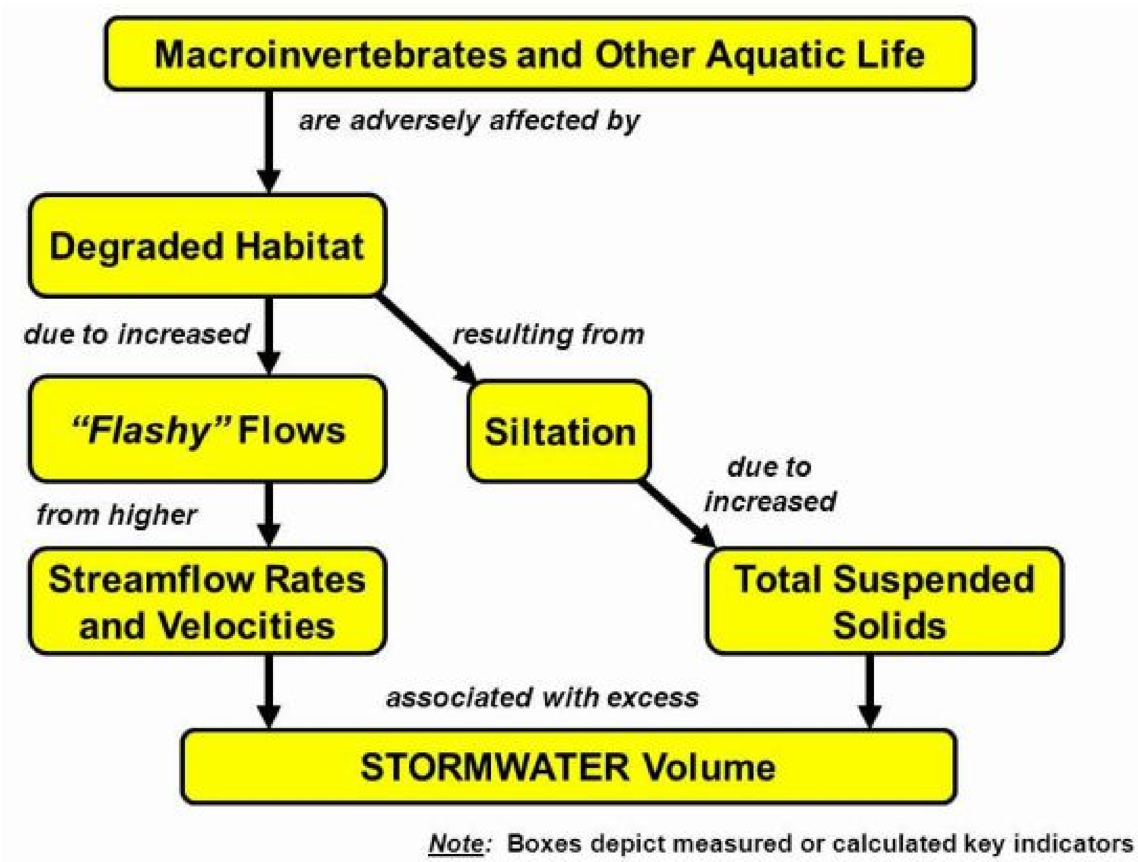
Table 24. Definitions of Designated Uses

Designated Use	General Definition
Agriculture	Water supply for cropland irrigation and livestock watering
Industrial Water Supply	Water utilized in industrial processes
Public Water Supply	Public drinking water source
Navigation	Waters capable of being used for shipping, travel, or other transport by private, military, or commercial vessels
Warmwater Fishery	Supports reproduction of warmwater fish
Coldwater Fishery	Supports reproduction of coldwater fish
Other Indigenous Aquatic Life and Wildlife	Supports reproduction of indigenous animals, plants, and insects
Partial Body Contact	Water quality standards are maintained for water skiing, canoeing, and wading
Total Body Contact	Water quality standards are maintained for swimming

7.2 General Water Quality Statement

The OCW appears on Michigan's §303(d) list (Goodwin, et. al., 2012) as not meeting the OIALW designated use as a result of biological impairments. A TMDL has been developed to address this, as summarized in the previous chapter. The following Figure exhibits the OCW major issues of flashy flows and TSS on the OIALW designated use.

Figure 32. Relationship between key indicators in Ox Creek linkage analysis



The public water supply use is not applicable to the OCW because no communities withdraw water from Ox Creek for drinking water. The designated uses of coldwater fishery and navigation are also not applicable. The designated uses of agriculture and industrial water supply are being met. There is not enough data to determine if the following uses are being met: warmwater fishery and partial and total body contact.

The State of Michigan also considers Fish Consumption a designated use for all water bodies. For Ox Creek, the Fish Consumption designated use is considered non-attaining due to elevated levels of PCB's found in several locations.

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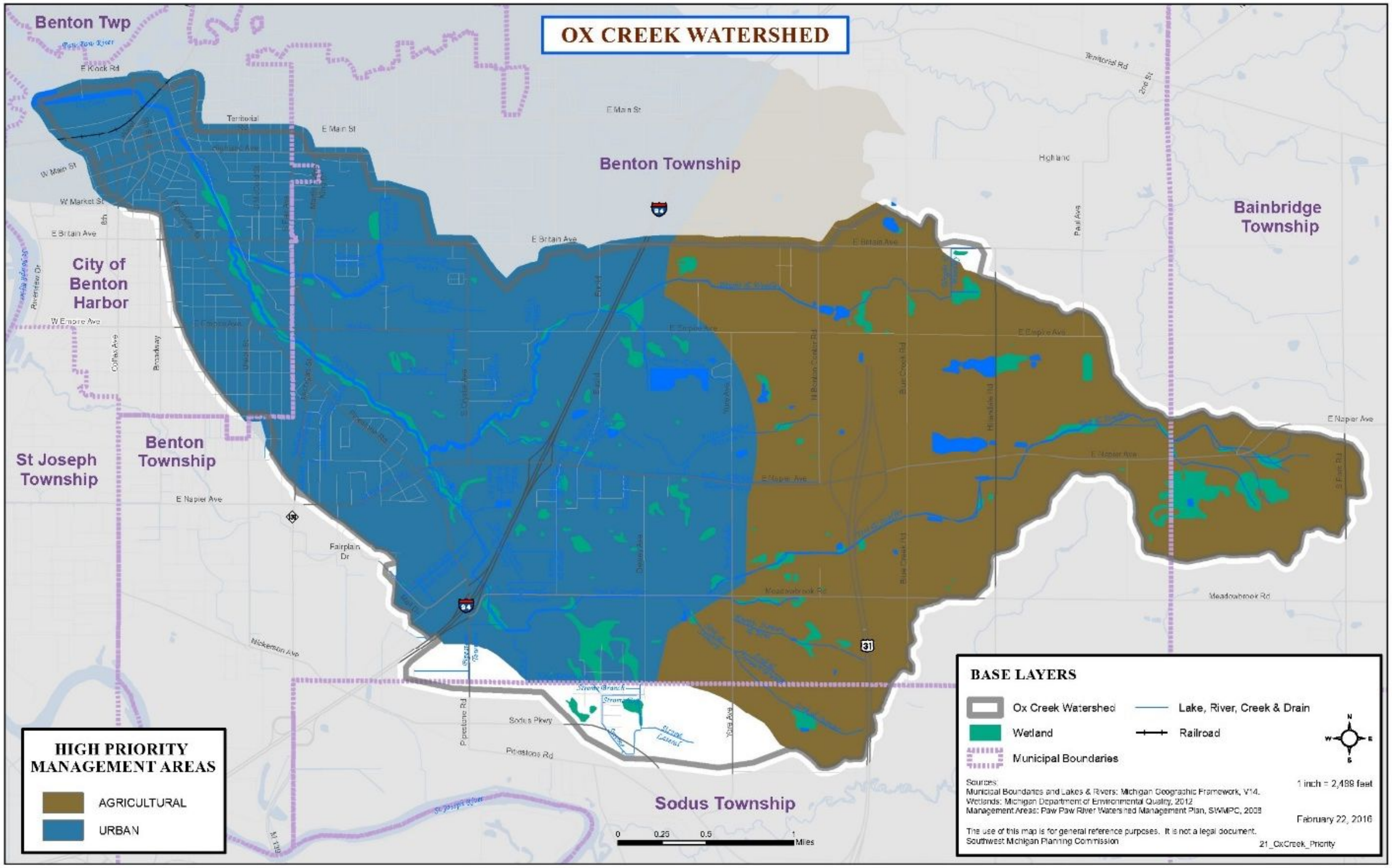
8 Prioritization – Areas, Pollutants, Sources

Lands that are contributing, or have the potential to contribute, a majority of the pollutants impacting water quality are deemed highest priority. Priority areas were identified based on best available data. By identifying priority areas, implementation can be targeted to the places where the most benefit can be achieved. Three different types of areas were prioritized in the OCW – urban management areas, agricultural management areas, and potential conservation/wetland restoration areas. The urban and agricultural management areas are split generally as shown in the Figure below while the potential conservation/wetland restoration areas are scattered throughout the entire watershed. For the urban areas, the Orchards Mall/I-94 Exit 29/Pipestone zone is a featured improvement focus area. Pollutants and sources of pollutants were also prioritized for each of the three areas.

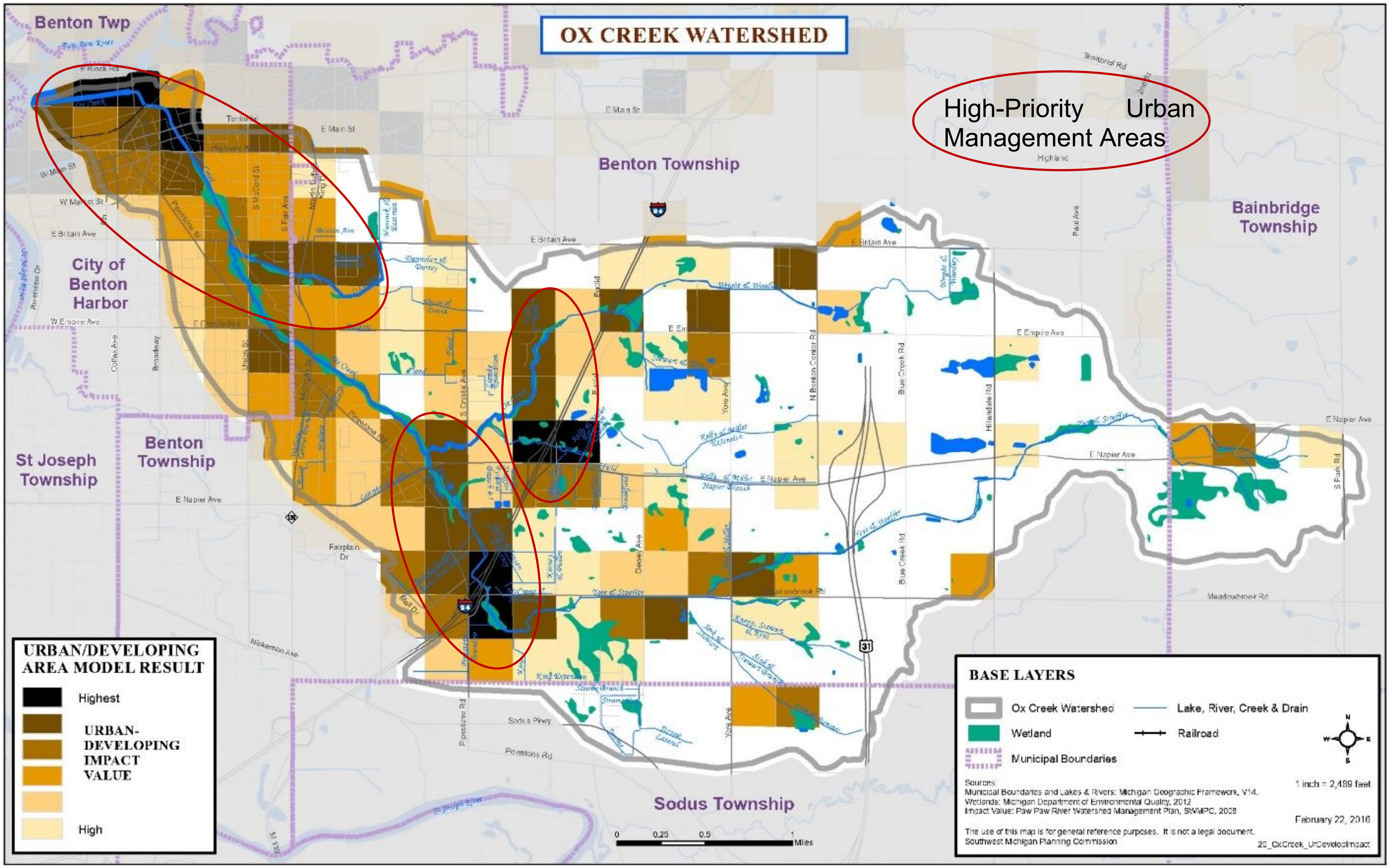
Figure 33. High-Priority Urban and Agricultural Management Areas



8.1 Urban Management Areas

The prioritization of urban management areas is based on significant water body impairments and amount of urban land cover. The downstream portion of the Ox Creek watershed (west of I-94) is considered a high-priority urban management area of the *Paw Paw River Watershed Management Plan*. The below Figure shows the higher prioritized urban management areas as identified in the *Paw Paw River Watershed Management Plan*.

Figure 34. High-Priority Urban Management Areas



Urban Management Area Pollutants and Sources

In the urban management areas, the prioritization of pollutants and sources is based on their known significance to impaired water quality in these areas. The priority pollutants are sediment and flashy flows. In the urban management areas, the priority pollutant sources are:

1. **Polluted runoff/Altered hydrology –** A majority of pollutants impairing designated uses in urban areas are found in polluted (stormwater) runoff, which largely results from impervious surfaces and the lack of stormwater treatment. Altered hydrology in urban areas usually entails reconfiguring natural drainage patterns with grading, using of storm drains and piping and channelizing, re-routing watercourses, and loss of wetlands.
2. **Streambanks –** Impervious surfaces in urban areas can alter hydrology, which causes streambank erosion.

Improvement Focus Area

This focus is an area referred to as Orchards Mall/I-94 Exit 29/Pipestone, also known as the Lower Yore & Stoeffer unit, and as subwatershed unit D in the approved TMDL for Ox Creek. This area consists of the land area draining to the Yore & Stoeffer Drain between Meadowbrook Road and the confluence with Ox Creek near Napier Avenue. Features of interest in this unit include the development around the I-94 interchange at Pipestone Road and the Orchards Mall area. This subwatershed unit contains a relatively large number of impervious surfaces, which clearly affects the hydrology of Ox Creek. More specifically, this focuses prioritization for the Orchards Mall area which is 315 acres total, of which 100 acres (32%) where the stormwater is treated and 215 acres (68%) where stormwater is not treated.

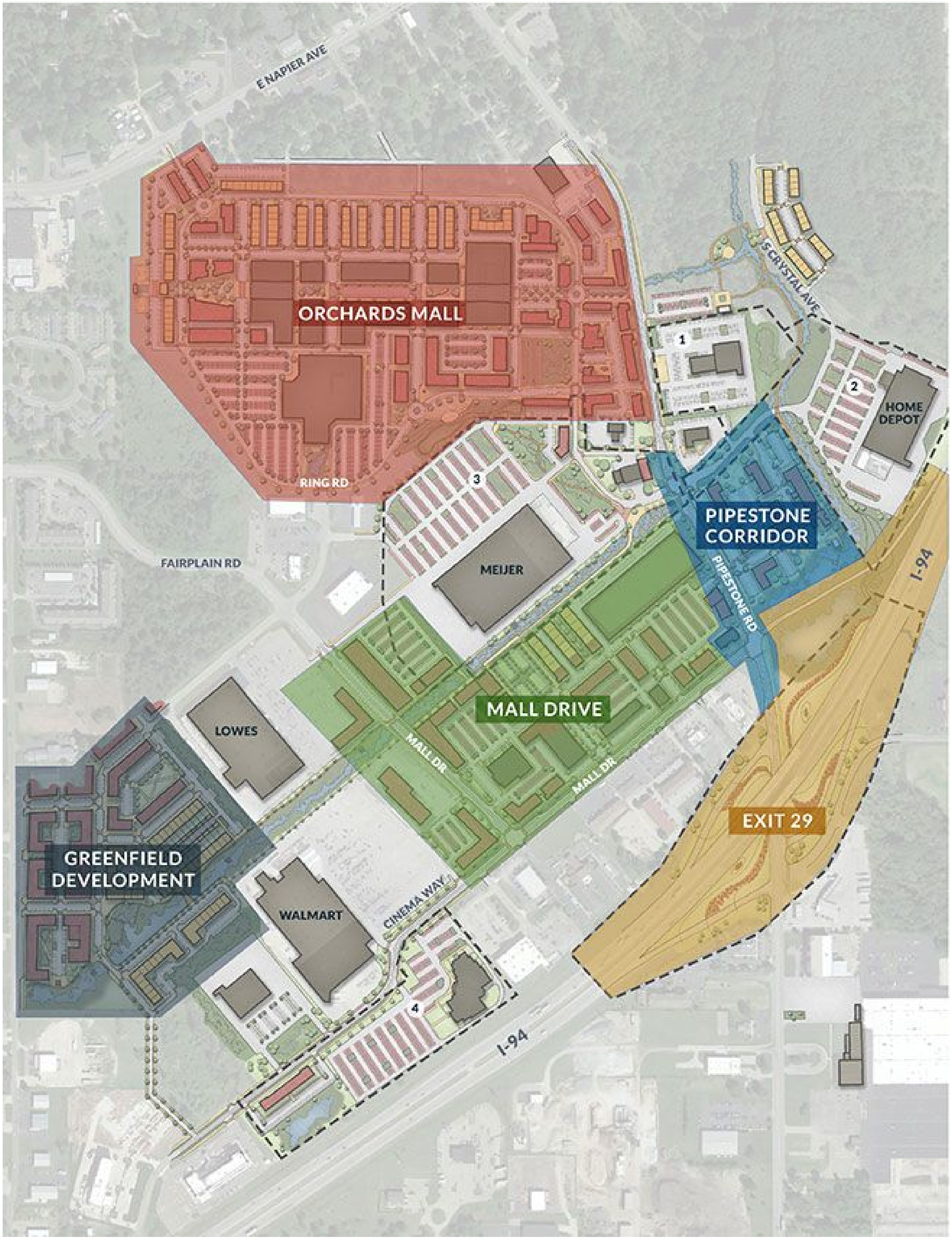
Improvement plans for this area are the focus of the document "*Ox Creek Technical Update: An Addendum to the Paw Paw River Watershed Management Plan"* which can be found in the Appendix to this OCW Management Plan.

The plans were developed in five conceptual development zones: The Orchards Mall for redevelopment, the Greenfield Development for new development, Pipestone Corridor for safety and sense of arrival, the Mall Drive Corridor for suburban retrofit and infill development, and the I-94/Pipestone Exit for improved water quality and non-motorized travel. The five planning areas depict how high-quality development and better multi-modal access can be a driving force for cleaner water through sustainable property management.

Identification of BMP locations were identified based on the following criteria:

- sites lacking treatment
- sites with a high site percent imperviousness
- close proximity to the Yore & Stoeffer Drain

Figure 35. Five Conceptual Development Zones for Orchards Mall Area



Highest Priority Sites

The Brookfield Dodge and Orchards Mall sites are the highest priority for implementation.

Brookfield Dodge is located at 1845 Pipestone Road in Benton Harbor. The site is approximately 14 acres in size with approximately 290 parking stalls. The site is 64% impervious and 36% pervious.

The Orchards Mall site is located at 1800 Pipestone Road in Benton Harbor. The site is approximately 30 acres in size with approximately 624 parking stalls. The site is 92% impervious and 8% pervious.

Second Highest Priority Sites

The I-94/Pipestone Interchange is located at between the I-94 westbound off-ramp and Pipestone Road in Benton Harbor, the site is approximately 3 acres in size.

Meijer is located at 1920 Pipestone Road in Benton Harbor, the site is approximately 27 acres in size with approximately 940 parking stalls. The site is 67% impervious and 33% pervious.

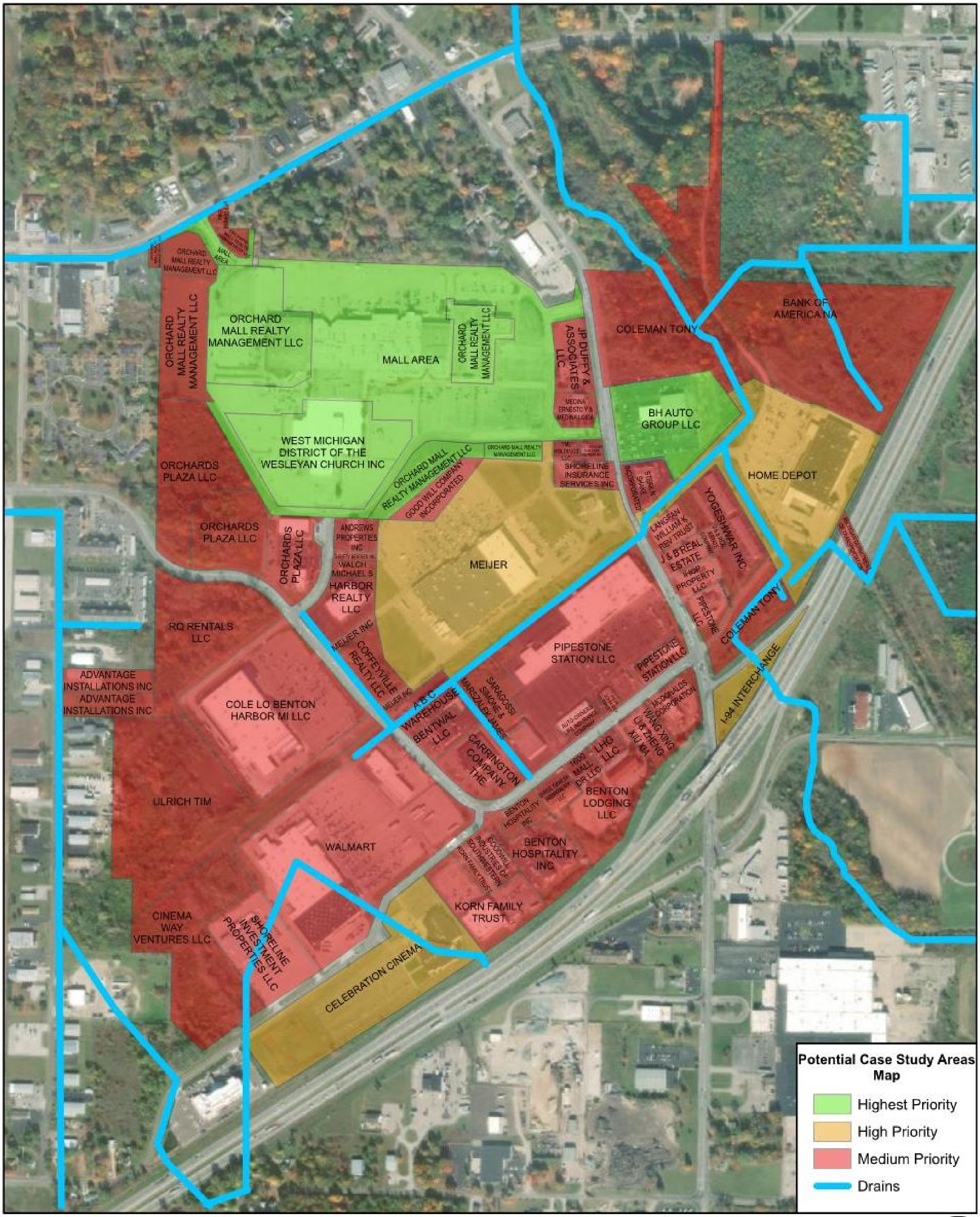
Home Depot is located at 2075 Pipestone Road in Benton Harbor, the site is 12 acres in size with approximately 475 parking stalls. The site is 79% impervious and 21% pervious.

Celebration Cinema is located at 1468 Cinema Way in Benton Harbor, the site is approximately 13 acres in size with approximately 650 parking stalls. The site is 48% impervious and 52% pervious.

The structural BMPs targeted for these areas (shown in the Figure below) will focus on the following:

- bioretention (rain garden)
- capture reuse (rain barrel, cistern, manufactured product)
- pervious pavement with infiltration
- riparian buffer restoration
- vegetated roof
- vegetated swale

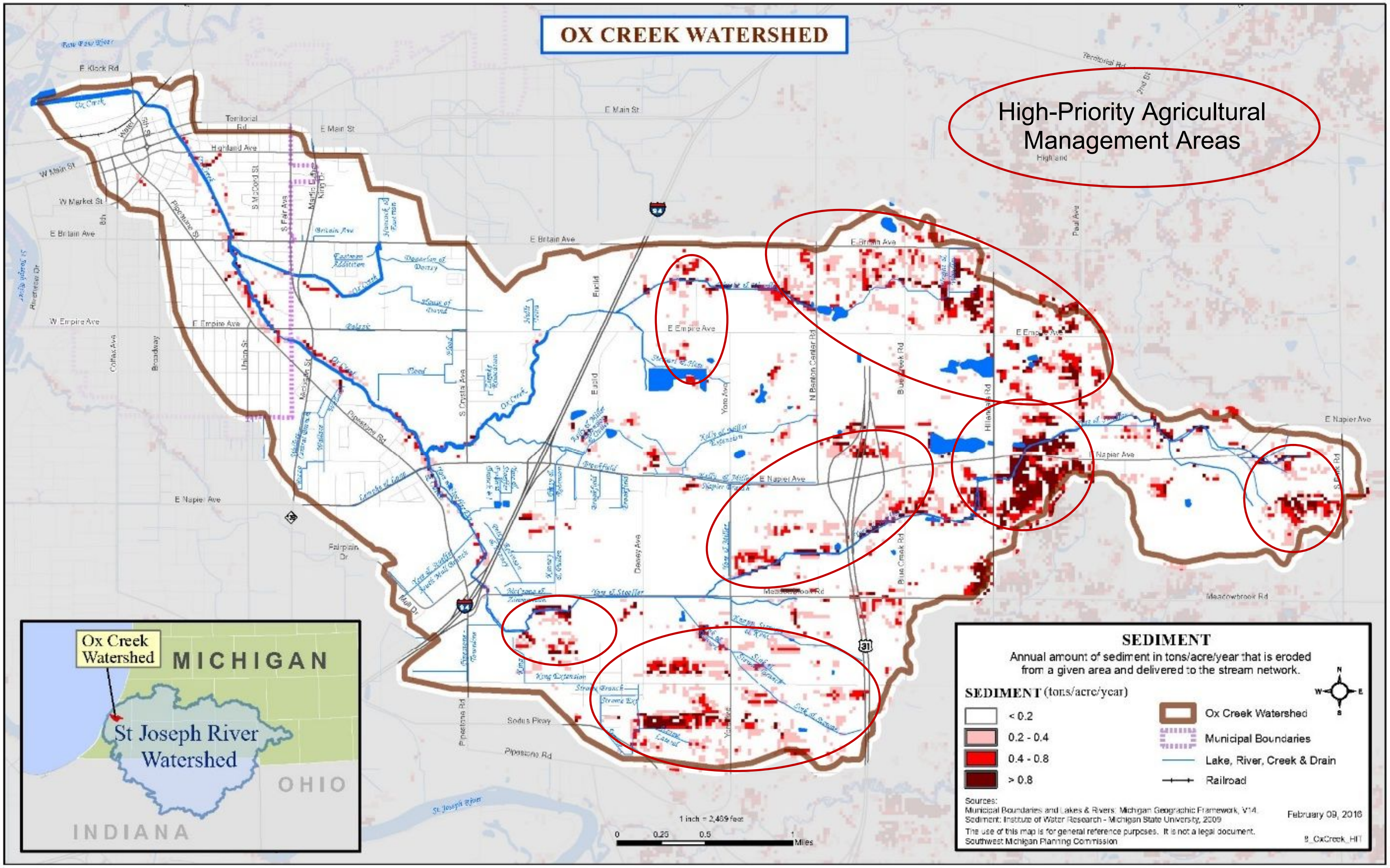
Figure 36. Priority Sites for Orchards Mall Area



8.2 Agricultural Management Areas

The prioritization of agricultural management areas is based on significant water body impairments, estimated pollutant loadings (HIT model), and amount of agriculture land cover. The Figure below shows the areas that are contributing the most sediment to the OCW.

Figure 37. High-Priority Agricultural Management Areas



Agricultural Management Area Pollutants and Sources

In the agricultural management areas, the prioritization of pollutants and sources is based on their suspected significance to impaired water quality in these areas. The priority pollutants are:

1. **Sediment** is a known pollutant throughout the watershed, especially in the agricultural areas. Sediment from agricultural runoff also carries nutrients like phosphorus and nitrogen. Biosurveys found sediment impairment occurring in the agricultural management area.
2. **Polluted runoff/altered hydrology** is a known pollutant throughout the watershed including the agricultural areas. In agricultural areas polluted (stormwater) runoff carries sediment and other pollutants such as nutrients and pathogens directly to surface water bodies. Altered hydrology is the result of the channelization of waterbodies, deepening of drains, loss of wetland and the construction of new drains and installation of drainage tile.

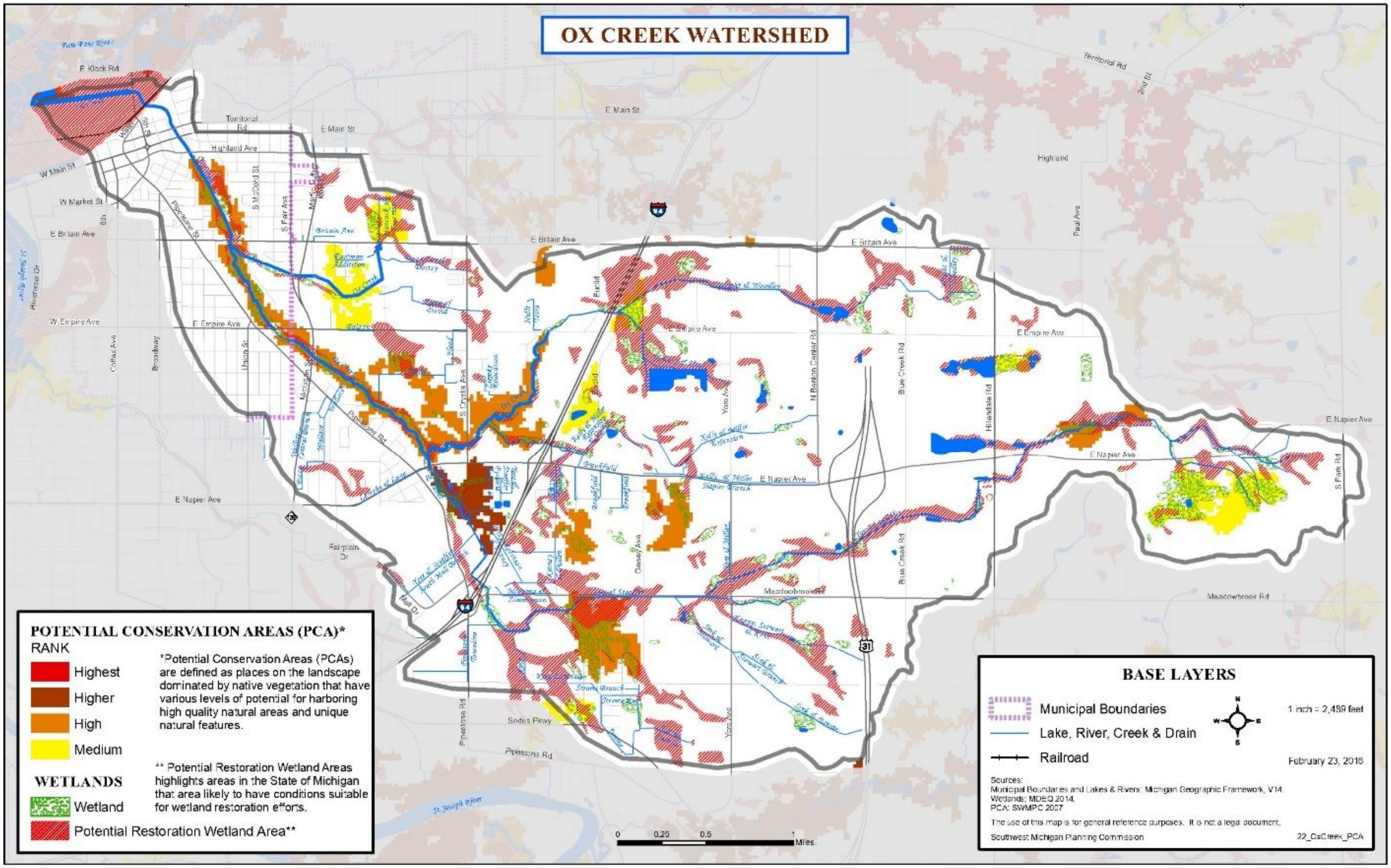
In the agricultural management areas, the priority pollutant sources are:

1. **Streambanks –** Streambank erosion is a significant source of the highest priority pollutant (sediment).
2. **Stormwater runoff –** Unmanaged runoff from agricultural lands can carry the priority pollutant, sediment, and also nutrients, bacteria and pathogens directly to surface water.
3. **Altered hydrology –** Tile drains and straightening and deepening of drainage ditches contribute to flashy flows and sedimentation.

8.3 Potential Conservation/Wetland Restoration Areas

The prioritization of potential conservation areas is based on the MNFI analysis of intact high-quality natural lands and existing wetlands. The wetland restoration areas are based on the LLWFA and include all potential restoration wetlands. The high-priority areas, if not preserved or at least managed properly, have the potential to contribute large amounts of pollution, as well as disrupt hydrologic patterns in the watershed. With the significant wetland loss in the OCW (74%) all remaining wetlands are a priority for protection. The remainder of the watershed is lower in priority for protection efforts, but since this analysis is at a landscape level, specific sites in the lower priority area may need just as much attention as the high-priority areas for maintaining long-term water quality in the watershed. The Figure below shows the potential conservation and wetland restoration areas.

Figure 38. High-Priority Potential Conservation/Wetland Restoration Areas



Potential Conservation/Wetland Restoration Area Pollutants and Sources

In the PCAs, the prioritization of pollutants and sources is based on their potential to threaten or impair water quality as development increases in these areas.

In the PCAs, the high-priority pollutants are flashy flows and sediment. In the PCAs, the pollutant sources are prioritized as follows:

1. **Streambanks –** Increasing impervious surface in potential conservation areas could alter hydrology and cause streambank erosion if runoff is not managed properly. Removal of the riparian corridor in protection areas could cause additional streambank erosion.
2. **Polluted (stormwater) runoff/altered hydrology –** Priority pollutants could increase with new development, stormwater runoff from construction sites and additional impervious surfaces. Loss of wetland in the OCW are of utmost concern since 74% of the pre-settlement wetlands have been lost already. Any additional wetland loss is a concern.

9 Goals and Objectives

Successful implementation of a watershed management plan is more likely to occur when the objectives are based on clearly defined goals. Goals can represent a long-term vision and also serve as guideposts established to keep everyone moving in the same direction and assess progress. Objectives are more specific actions that need to occur to achieve the stated goal. The goals and objectives for the OCW address both water quality concerns and desired uses.

Successful implementation of a watershed management plan is more likely to occur when the objectives are based on clearly defined goals.

9.1 Goals for Designated Uses

The following two goals are related to the improvement of the water quality of the OCW. Objectives for these goals are listed in the Action Plan (Table 27) as tasks to be implemented.

1. Reduce sediment impairing water quality in agricultural and urban areas to meet designated uses.

2. Reduce flashy flows impairing water quality in agricultural and urban areas to meet designated uses.

9.2 Goals for Desired Uses

In addition to the Designated Uses established by state and federal water quality programs, stakeholders identified several desired uses for the OCW. Desired Uses are based on factors important to the watershed community. Desired uses may or may not have a direct impact on water quality. The following Table lists the desired uses identified through public meetings, surveys, and discussions with watershed stakeholders. The desired uses listed in the Table all have a direct or indirect impact on water quality.

Table 25. Ox Creek Watershed Desired Uses

OCW Desired Use	General Definition
Coordinated development	Promote and achieve the environmental and economic benefits of planned communities through coordinated land use planning and low-impact development.
Groundwater Resources Protection	Protect groundwater recharge and wellhead areas from contamination and overdrafting.
Appropriate recreational use and infrastructure	Establish water and non-motorized trails on or along appropriate sections of Ox Creek and its tributaries where desired and feasible while protecting natural features.
Watershed monitoring efforts	Continue and increase monitoring efforts to better understand issues in the OCW and to create baselines for future reference.

The following goals were developed to address the desired uses identified by stakeholders. Objectives for these goals are listed below.

1. Coordinated land use planning in the OCW.

- Review local plans, ordinances and regulations addressing stormwater management, non-point source pollution, and related water quality and natural resource issues.
- Promote uniform set back requirements along creeks, drains and wetlands.
- Gain local commitments to consider the watershed context in planning efforts and to recognize stormwater planning early in site planning and evaluation.

2. Protected groundwater resources

- Continue to close abandoned wells.
- Determine current and future amount of groundwater withdrawal and its potential impacts.
- Develop strategies to prevent increased impervious surfaces in high recharge areas and to restore areas with high recharge potential, as appropriate.

3. Improved recreation infrastructure along river while respecting natural features

- Build and maintain a non-motorized trail along Ox Creek that follows a former railroad corridor that would connect the Orchards Mall/I-94 Exit 29/Pipestone focus area and downtown Benton Harbor.
- Explore options for development of a water trail along Ox Creek east of I-94 for non-motorized boating.

4. Continued/increased watershed monitoring efforts

- Partner with Drain Commissioners, MDEQ, and MDNR, to develop and implement a monitoring strategy.

10 Implementation Strategies

This chapter provides a management strategy to protect and improve water quality in the OCW. The management strategy prioritizes tasks to be implemented, identifies specific problem sites and lays out a detailed action plan for implementation. The strategy also includes an information and education plan and describes current efforts.

10.1 Action Plan by Priority Area

The following Table is a detailed action plan with structural, vegetative, and managerial tasks, which address priority pollutants and their sources. This action plan should serve as a starting point for effective implementation. The items in the action plan should be reviewed annually and updated as conditions change in the watershed.

The Table is divided into three priority areas (potential conservation/wetland restoration areas, agricultural, and urban – with a focus on the Orchards Mall/I-94 Exit 29/Pipestone area). For each priority area, specific tasks are listed. Each task addresses specific pollutants and sources as indicated. Since resources will probably not be available to implement all of the tasks at once, the Table provides a suggested timeframe for beginning implementation of each task. The implementation timeframe was based on the ranking of pollutants and sources for each priority area in Chapter 8. Prioritizing the tasks will allow resources to be allocated to the tasks that address the most important pollutants and sources first. The timeframe may be changed if resources or opportunities become available for earlier implementation. The Table also provides a cost estimate for each task and identifies the potential lead agency or individuals that need to take action. Potential partners, funding sources, and programs are listed, which could assist with task implementation. Lastly, milestones and proposed evaluation methods are listed for each task.

Below is a list of structural, vegetative and managerial tasks to be implemented in the OCW by priority area. The priority areas are meant to target implementation efforts where the most benefit can be achieved. However, implementing these tasks in other parts of the watershed may be necessary to achieve long-term water quality improvement and protection. The priority areas are based on the watershed protection and management area maps described in Chapter 8.

Urban Area Tasks

The following tasks should be focused in the urban priority areas. Where appropriate, milestones are described to accomplish the overall task.

Tasks to begin within 1-5 years:

- Implement stormwater BMPs (road/parking lot sweeping, stormceptors, rain gardens, constructed wetlands, vegetated swales, etc.)
    - Milestones: Implement BMPs on Brookfield Dodge and Orchards Mall site within 3 years.

        - Work wth MDOT and Berrien County Road Department on I-94/Pipestone exit reconfiguration and Pipestone improvements for water quality within 2 years.
        - Approach second-priority landowners (Meijer, Celebration Cinema, Home Depot, etc.) within 2 years.
- Develop ordinances to reduce parking lot size and require LID
    - Milestones: Review Benton Charter Township parking ordinances and offer recommendations within 2 years.
- Implement improved county stormwater standards that encourage/require low-impact development techniques.
    - Milestones: Develop committee and meet to determine improvements to current stormwater standards within 2 years.

<u>Agricultural Area Tasks</u>
The following tasks should be focused in the agricultural priority areas. There are no milestones for these tasks as they are ongoing. (See additional efforts in the Information and Education Plan section of this Plan that serve as milestone activities.)
Tasks to begin within 1-5 years:
- Utilize alternative drain maintenance/construction techniques (such as two-stage ditch design, natural river restoration techniques – j-hooks, cross vanes, etc.).
- Restore riparian buffers and stabilize eroding streambanks.
- Install agricultural BMPs (drain tile management, filter strips, no-till, cover crops, grassed waterways, etc.).

<u>Potential Conservation/Wetland Restoration Areas Tasks</u>
The following tasks should be focused in the priority conservation areas as indicated in Chapter 6. The priority areas for these tasks are throughout the entire watershed encompassing the urban and agricultural management areas. These tasks are ongoing with limited milestone activities. Again, see the Information and Education section for activities that serve as milestones for these tasks.
Tasks to begin within 1-5 years:
- Enact/improve water quality protection related ordinances (see Chapter 4.3 of this Plan for recommendations on ordinances).
    - Milestone: Draft ordinances available within 2 years.
- Restore lost wetlands (see LLWFA maps to determine priority sites for protection).
    - Milestone: 40 acres within 5 years.
- Protect existing wetlands (see LLWFA maps to determine priority sites for protection).
    - Milestone: 40 acres within 5 years.

Tasks to begin within 6-10 years:
- Protect potential conservation area lands.
- Identify and correct problem road/stream crossing sites.
    - Milestone: Inventory and assess road stream crossings within 3 years.

10.2 Information and Education

Introduction

The purpose of the Information and Education (I&E) plan is to provide a framework to inform and motivate the various stakeholders, residents, and other decision makers within the OCW to take appropriate actions to protect water quality. This plan will also provide a starting point for organizations within the watershed looking to provide educational opportunities or outreach efforts

Information & Education Goal

The I&E plan will help to achieve the watershed management goals by increasing the involvement of the community in watershed protection efforts through awareness, education, and action. The watershed community can become involved only if they are informed of the issues and are provided information and opportunities to participate.

Target Audiences

The level of understanding of watershed concepts and management, the concerns, values, and level of enthusiasm can all vary between different audience groups. Recognizing differences between groups of target audiences is critical to achieving success through education and outreach efforts. Educational messages may need to be tailored to effectively reach different audiences. It is important to understand key motivators of each target audience to establish messages that will persuade them to adopt behaviors or practices to protect and improve water quality. The Table below lists and describes the major target audiences for the OCW and specific messages and activities that could be used to reach each audience.

Table 26. Information & Education Target Audiences

Target Audiences	Description of Audience	General Message Ideas	Potential Activities
Businesses	This audience includes businesses in the improvement focus area that can make low-impact development improvements.	Clean water helps to ensure a high quality of life that attracts workers and other businesses.	Workshops and presentations Brochures/flyers/fact sheets/website/social media/ One-on-one contact
Developers/ Builders/ Engineers	This audience includes developers, builders, and engineers.	Water quality impacts property values.	Newsletter articles Workshops and presentations Watershed tours Brochures/flyers/fact sheets Trainings/one-on-one contact
Farmers	This audience includes both agricultural landowners and those renting agricultural lands and farming them.	Protecting water quality is a long-term investment by saving money by decreasing inputs (fuel, fertilizer).	Workshops and presentations Brochures/flyers/fact sheets One-on-one contact Watershed tours Newsletter articles

Target Audiences	Description of Audience	General Message Ideas	Potential Activities
Government Officials and Employees	This audience includes elected (board and council members) and appointed (planning commissions and zoning board of appeals) officials of cities, townships, and the county. This audience also includes the drain commission and road department staff. It also includes state and federal elected officials.	Water quality impacts economic growth potential. Water quality impacts property values and the tax revenue generated in my community to support essential services. Clean drinking water protects public health.	One-on-one contact Trainings Workshops and presentations Brochures/flyers/fact sheets/website/social media Watershed tours Educational videos
Property Owners	This audience includes any property owner in the watershed.	Water quality impacts my property value and my health.	Public service announcements (PSA) and press releases Display/materials at festivals Workshops and presentations Watershed tours Tax/utility bill inserts Website/YouTube video/social media Workshops and presentations Brochures/flyers/fact sheets One-on-one contact

Watershed Issues

To begin formulating education and outreach strategies, it is important to identify the major issues, which need to be addressed to improve and protect water quality. The priority issues for the OCW are urban and agricultural BMPs and the protection and restoration of wetlands. Each issue is tied to pollutants of concern in the watershed. For each issue, the audience(s) will need to not only understand the issue, but also the solutions or actions needed to protect or improve water quality.

1. Watershed Awareness

All watershed audiences need to be made aware of the priority pollutants and their sources and causes in each of the watersheds. Education efforts should, whenever possible, offer audiences solutions to improve and protect water quality.

2.Urban BMPs: Land change and the protection of natural resources, and stormwater management are a key component of the Ox Creek BMPs. Urbanized land cover has impervious areas (buildings, parking lots, roads) and networks of ditches, pipes, and storm sewer, which augment natural drainage patterns. Stormwater runoff is caused when rain, snowmelt, or wind carries pollutants off the land and into water bodies. Preservation and management of open space, wetlands, and other natural features helps to reduce the amount of stormwater runoff and the pollutants it carries entering water bodies.

Businesses in the focus improvement area of Orchards Mall/I-94 Exit 29/Pipestone are the primary target for these efforts. Educational efforts can also promote municipal operations and maintenance best practices, which are important for reducing polluted runoff. Local government activities impacting stormwater runoff include land-use planning, road and parking lot maintenance and construction, lawn-care practices, oversight of construction sites and identification and correction of illicit discharges and connections. These include best practices for road and parking lot construction and maintenance. Local governmental officials and builders/developers need to understand the water quality benefits of smart growth, low-impact development (better stormwater management), and protection of wetlands, floodplains, and riparian areas. Additionally, education efforts should increase awareness of stormwater pollutants, sources and causes, especially the impacts of impervious (paved or built) surfaces and their role in delivering water and pollutants to water bodies.

3. Agricultural Runoff
Agricultural lands cover 38% of the OCW, all of which are in the Rural East section. If not properly managed, runoff from agricultural lands can impact the watershed by delivering pollutants such as sediment and nutrients. Education efforts should seek to help audiences understand the impacts of agricultural runoff. A key concept is the need to reduce soil erosion from agricultural lands. It is also important to understand that soil particles also carry nutrients and chemicals to water bodies. There are many BMPs for addressing soil erosion from agricultural lands. BMPs include conservation tillage, filter strips, cover crops, grassed waterways, ditch naturalization, drain tile management, and wetland restoration. Cost share and technical assistance programs are available to assist agricultural landowners in implementing many of these practices.

> Erosion is an intrinsic natural process, but in many places, it is increased by human land use. A certain amount of erosion is natural and, in fact, healthy. Excessive erosion, however, does cause problems, such as sedimentation of streams and lakes, ecosystem damage and outright loss of soil. Soil erosion on agricultural fields can be caused by water, wind and tillage practices. Soil loss, and its associated impacts, is of great concern to farmers.

Drain maintenance activities, which often remove vegetation from riparian areas, contribute to soil erosion problems in agricultural areas. Drain maintenance projects should ensure as much riparian vegetation is left intact as possible and replace the vegetation with native grasses, shrubs, and trees if it needs to be removed. Also, natural stream channel design concepts should be used instead of deepening of ditches.

Distribution Formats
Because of the differences between target audiences, it will sometimes be necessary to utilize multiple formats to successfully get the intended message across. Distribution methods include social media, print media, websites, newsletters, and direct mailings, email lists, and passive distribution of printed materials

10.3 Current Efforts

It is important to understand current efforts being offered or resources that are available for use or adaptation in the OCW.

A web site, along with coordinated graphics, was developed at https://sustainoxcreek.org/ to inform the public of the Ox Creek project, offering visitors the opportunity to:

- Learn more about the OCW and how sustaining it is key to a healthy environment and economy.
- See plans for what is possible for the future development of the area through renderings and detailed maps.
- Read the latest articles and updates as plans progress. Also dive deeper with information about watersheds and urban development and agricultural BMPs.
- Find a listing of who the best choice is to contact for information specific to their interest or questions.

MSU Extension periodically sponsors a Citizen Planner Course in Southwest Michigan. The target audiences for this course are municipal and planning officials as well as citizens. Topics presented during each course include various land use planning topics and techniques.

Sarett Nature Center, Conservation Districts, SWMPC, MSUE, garden clubs and lake associations periodically host educational workshops related to watershed and water quality topics.

The SWMPC provides educational resources about stormwater and water quality to Berrien County Phase II communities. These resources are available on the Internet at www.swmpc.org/pep_materials.asp and could easily be adapted for use in the OCW.

The Berrien County Drain Commission and Berrien County Road Department have partnered with the SWMPC to update the County's stormwater standards to encourage/require more low-impact development techniques.

The OCW project partners are currently working from a number of funding/grant sources:

- The Southwest Michigan Land Conservancy received a $600,000 grant from the MDEQ. The conservancy received the grant during the summer of 2015. Local sources contributed another $400,000 to match the state grant. This grant had funds to develop a technical update to the *Paw Paw River Watershed Management Plan* focused on the OCW (see Appendix).

- The Berrien County Drain Commission has been awarded a $743,000 grant from the MDEQ with $528,000 in local matching funds for the project. This project will implement urban stormwater BMPs in the highest priority urban management areas.

- The development of this OCW Management Plan is funded with MDEQ's SAW program.

Additionally, there are several opportunities to coordinate with and build upon existing local programs and projects. One key local initiative that has developed during the planning phase of the OCW project is the location of the first stormwater BMP near the study area, located at Wightman's Benton Harbor Office, which is just southeast of the Orchards Mall/I-94 Exit 29/Pipestone study area. For additional information see the *Ox Creek Technical Plan Update*.

10.4 Planning and Studies

In some areas, further study and investigation may be needed before more specific recommendations can be made.

Wetland restoration and protection activities are listed for both urban and agricultural management areas; therefore, the implementation of these tasks could have a substantial effect on the long-term improvement and protection of water quality in the watershed. A targeted wetland restoration and protection project based on the LLWFA in conjunction with an educational campaign to landowners and municipal officials would be extremely helpful in advancing the wetland-related tasks in the action plan. A few demonstration projects would be beneficial even in lower priority areas, because there has not been much wetland restoration work in the watershed.

The University of Michigan has begun a project in OCW called Evaluating Infrastructure Performance and Sediment Loadings in Ox Creek. The project lead is Branko Kerkez (bkerkez@umich.edu) and more information about his project can be found at http://Open-Storm.org. The University of Michigan, in collaboration with the Berrien County Drain Commission and *SustainOxCreek.org* has been working to build a real-time water information system for Ox Creek. The goal of the project is to provide measurements that will be used by watershed managers to measure performance of infrastructure and environmental management projects.

Completed work: Eight stream-level sensors have been deployed in the basin.This data is now reporting live on the Internet and is available to local watershed managers. Two more sensor nodes have been constructed, which will be deployed to measure soil moisture. A hydrologic model is also being calibrated.

Proposed Work: With water-level data in place, calibrate rating curves to obtain actual flow. Additionally, collect sediment data to evaluate if current stormwater projects are reducing stream erosion and the transport of sediments into the St. Joseph River. This will be accomplished by deploying two ultrasonic flow sensors, which also measure sediments loads. Also, deploy one optical sediment meter, which will measure a depth profile of turbidity and sediment. These sensors will be deployed on Ox Creek before and after the Orchards Mall. This will help to calculate a sediment balance for the watershed and will provide before-and-after measurements for infrastructure projects. Given the novelty of these sensors, it is believed that this dataset will be unprecedented in spatial and temporal resolution.

Table 27. Ox Creek Watershed Action Plan

Task	Pollutant	Source	Cause	Begin Implementation	Potential Lead (Partners)	Estimated Cost	Potential Funding or Partner Programs	Milestones (after implementation begins)	Proposed Evaluation Method
Urban Management Areas (downstream portion of OCW)									
Implement stormwater best management practices (road/parking lot sweeping, stormceptors, rain gardens, vegetated swales, constructed wetlands, wet/dry ponds, etc.).	Sediment/ Flashy Flows	Stormwater runoff – impervious surfaces and storm drains/ Streambanks	Lack of stormwater management/ increased flow fluctuations	2019-2024	Landowners, Municipalities, Drain Commissioner, Road Department, SWMPC	See *Ox Creek Technical Update* in the Appendix for specific cost estimates	Landowners, Municipalities, MDEQ 319, Drain Assessments	Implement BMPs on Brookfield Dodge and Orchards Mall site within 3 years. Work with MDOT and Berrien County Road Department on I-94/Pipestone exit reconfiguration and Pipestone improvements for water quality within 2 years. Approach second priority landowners (Meijer, Celebration Cinema, Home Depot, etc.) within 2 years.	Number of landowners or municipalities implementing practices; Estimate pollutant loading reduction
Develop ordinances to reduce parking lot size and require LID.	Sediment/ Flashy Flows	Stormwater runoff – impervious surfaces and storm drains/ Streambanks	Lack of stormwater management/ increased flow fluctuations	2019-2024	Municipalities, SWMPC	$3,500/municipality	Municipalities, MDEQ 319	Review Benton Charter Township parking ordinances and offer recommendations within 2 years.	Number of municipalities with adopted parking ordinance
Implement improved county stormwater standards that encourage/require low-impact development techniques.	Sediment/ Flashy Flows	Stormwater runoff – impervious surfaces and storm drains/ Streambanks	Lack of stormwater management/ increased flow fluctuations	2019-2024	Berrien County Drain Commissioner, Berrien County Road Dept., SWMPC, Consultant	$18,000	Berrien County Drain Commissioner, Berrien County Road Dept, SWMPC	Develop committee and meet to determine improvements to current stormwater standards within 2 years.	Adopted County Stormwater Guidelines
Agricultural Management Areas (upstream portion of Ox Creek)									
Task	**Pollutant**	**Source**	**Cause**	**Begin Implementation**	**Potential Lead (Partners)**	**Estimated Cost**	**Potential Funding or Partner Programs**	**Milestones (after implementation begins)**	**Proposed Evaluation Method**
Utilize alternative drain maintenance/ construction techniques.	Sediment/ Flashy Flows	Streambanks	Increased flow fluctuations	2019-2024	Drain Commissioner	$40/linear foot for tree revetments $15/lineal foot for woody debris mgt. $80/linear foot for 2-stage ditch $500-1,000/linear foot for j-hooks and cross vanes	Drain Assessments, MDEQ 319	Complete drain construction on upper Yore & Stoeffer Drain within 3 years.	Number of miles of drain maintained or constructed with alternative techniques
Install agricultural BMPs (drain tile management, filter strips, no-till, cover crops, grassed waterways, nutrient mgt., etc.).	Sediment/ flashy flows	Streambanks/ Stormwater runoff -agricultural lands	Increased flow fluctuations/lack of BMPs	2019-2024	Landowners (NRCS, Berrien Conservation District)	~$30/acre for cover crop – 10% of the agricultural land (325 acres) would be $9,775	Farm Bill Programs, MDEQ 319	See Education Plan	Number of acres/linear feet; Estimate sediment/nutrient loading reduction; Number of landowners
Restore riparian buffers and stabilize eroding streambanks.	Sediment	Streambanks	Lack of riparian buffers	2019-2024	Landowners (Drain Commissioner, Conservation District, NRCS)	$500-1,000/acre for restoration $400/ft for stabilization	Drain Assessments, MDEQ 319, Farm Bill Programs	See Education Plan	Linear feet of restoration/stabilization; Estimate pollutant loading reduction
Potential Conservation/Wetland Restoration Areas (throughout out watershed)									

Task	Priority Pollutant	Source	Cause	Begin Implementation	Potential Lead (Partners)	Estimated Cost	Potential Funding or Partner Programs	Milestones (after implementation begins)	Proposed Evaluation Method
Enact/improve water quality protection related ordinances.	Sediment/ Flashy Flows	Streambanks/ Stormwater runoff – impervious surfaces and storm drains	Increased flow fluctuations Insufficient land use planning	2019-2024	Municipalities (SWMPC)	$10,000/municipality	Municipalities, MDEQ 319	Draft ordinances available within 2 years.	Number of ordinances enacted; Number of municipalities with ordinances
Restore wetlands	Sediment/ Flashy Flows	Wetland loss	Increased flow fluctuations	2019-2024	Landowners (Southwest Michigan Land Conservancy, Sarett Nature Center, Ducks Unlimited)	$1,000-5,000/acre	USDA Farm Bill, Partners for Wildlife, DU, National Fish and Wildlife Foundation, MDEQ 319	40 acres within 5 years	Number of acres restored; Number of landowners restoring wetlands; Estimate loading reduction
Protect potential conservation lands and existing wetlands.	Sediment/ Flashy Flows	Stormwater runoff – impervious surfaces and storm drains	Insufficient land use planning	2019-2024	SWMLC, Sarett Nature Center	$3,000-6,000/acre for purchase ~$3,000/conservation easement	Land Trusts, MDEQ 319, private foundations	40 acres within 5 years	Number of acres protected; Estimate pollutant loading reduction
Identify and correct problem road/stream crossing sites.	Sediment	Streambanks	Improper design or maintenance of road/stream crossings	2025-2030	Road Department	$5,000-100,000/site	Road Dept, MDEQ 319, MDNR Aquatic Habitat Grant	Inventory and assess road stream crossings within 3 years.	Number of sites corrected; Estimate sediment loading reduction

11 Evaluation

An evaluation process will determine if the plan implementation is effective and if improvements in water quality are being achieved. Measuring improvements and sharing results will increase community support for plan implementation. Since watersheds are extremely dynamic systems influenced by many factors, evaluation can be a difficult and expensive endeavor. As a result, different levels of evaluation are proposed to illustrate levels of success in the watershed. The level of evaluation and the methods utilized will largely be dependent on the amount of resources and funding available. This Watershed Management Plan should be reviewed and updated periodically.

The overall goal is to remove the Ox Creek and its tributaries from the 303(d) list by reducing sediment (TSS) and flashy flows. The implementation efforts will be evaluated by calculating pollutant loads and comparing to the target loads in the approved TMDL. Further, MDEQ will continue to do benthic macroinvertebrate sampling to see if assessment scores improve over time. Lastly, TSS sampling may be conducted in the future to see if TSS targets are being met after BMP implementation.

Evaluation measures will also include the number of landowners implementing BMPs, the acres or linear feet of BMPs installed, the pollutants (sediment, nutrients, flow) reduced, and ultimately the de-listing of the Ox Creek from the 303(d) list. The MDEQ spreadsheets will be used to document pollutant load reductions for urban BMPs at the site level. All I&E activities will be evaluated by recording the number of participants, number of one-on-one visits and increased interest in BMP implementation.

11.1 Knowledge and Awareness

The first level of evaluation is documenting a change in knowledge or increase in awareness. Measures and data collection for this level can take place in three specific ways:

1. A pre- and post-test of individuals at workshops focused on specific water quality issues in the OCW. This should be an ongoing activity.
2. The tracking of involvement in a local watershed group or increases in attendance at water quality workshops or other events. This should be an ongoing activity.
3. A large-scale social survey effort of the OCW population to understand individual watershed awareness and behaviors impacting water quality. Surveys are expensive, so this level of evaluation will not be able to happen until funding is secured. This evaluation may happen in coordination with the Phase II Public Education Plan implementation.

11.2 Documenting Implementation

The second level of evaluation is BMP adoption or implementation. The measurement is mostly a documentation of successful implementation. The evaluation will involve identifying and tracking individuals, organizations, and governmental units involved in implementing and adopting BMPs whether they be structural, vegetative, or managerial.

Data about the BMP implementation can be gathered simply through tracking the number of BMPs installed or adopted. This evaluation should be done annually.

Table 27 above has milestones and specific evaluation methods proposed for measuring the progress of BMP implementation and improvements to water quality for each task in the OCW action plan. The action plan should be reviewed at least annually to ensure progress is being made to meet the milestones. During the annual review, the action plan should be updated as tasks are completed, and as new tasks are identified.

11.3 Monitoring Water Quality

Another level of evaluation is documenting changes in water quality through monitoring. The monitoring of water quality is a very complex task, which involves gathering data from a number of sources. Periodic assessments of the water quality in the OCW are conducted as part of federal and state water quality monitoring programs. Local efforts to monitor water quality include those of the Berrien County Drain Commission in coordination with the University of Michigan. Combining data gathered under these programs, with other periodic water quality assessments will provide a picture of water quality in the watershed.

11.4 Estimating Pollutant Load Reductions

The last level of evaluation is to estimate a reduction in pollutant loadings. A pollutant loading is a quantifiable amount of pollution that is being delivered to a water body. Pollutant load reductions can be calculated based on the ability of an installed BMP to reduce the targeted pollutant. Pollutant loading calculations are best used at specific sites where structural BMPs are installed and detailed data about the reduction of pollutants can be gathered. Specific pollutant load reduction calculations should be completed for structural BMPs when they are proposed and installed.

In Table 27, under the last column (proposed evaluation methods), pollutant loading reduction calculations are suggested for evaluating several tasks in the action plan. Specifically these tasks include: restoring wetlands and protecting existing wetlands and potential conservation lands, installing agricultural BMPs (filter strips, no-till, cover crops, grassed waterways, nutrient management, etc.), restoring riparian buffers and stabilizing streambanks, utilizing urban stormwater BMPs (road/parking lot sweeping, stormceptors, rain gardens, vegetated swales, constructed wetlands, wet/dry ponds, etc.), and correcting road/stream crossing problem sites. The other items in the action plan either deal with hydrological modifications or they are proactive and preventative measures. Estimating pollutant loads and load reductions for these types of practices is not feasible.

11.5 Evaluating Cost Effectiveness

In the *Paw Paw River Watershed Management Plan*, cost estimates were done for Ox Creek BMPs, as follows (for more information see *Urban Build-out and Stormwater BMP Analysis in the Paw Paw River Watershed*.

Table 28. Wet retention pond pollutant treatment costs with a 50% treatment coverage of urban lands

	Pond Volume	Pond Area[1]	TP Load Reduction	TSS Load Reduction	Capital Cost[2]	30-year Annualized Cost	TP Load Reduction Cost[3]	TSS Load Reduction Cost
Urban Center	ft^3	acre	lbs/yr	lbs/yr	$	$/yr	$/lbs/yr	$/lbs/yr
Ox Creek Area (Benton Harbor)	749,559	3.4	1,086	358,988	730,820	64,147	59	0.18

[1]Ponds are assumed to have an average depth of 5 feet.
[2]Construction cost + design and permits.
[3]Assuming a 5% interest rate and including a $4,152/acre/year maintenance cost.

Table 29. Dry retention pond pollutant treatment costs with a 50% treatment coverage of urban lands

	Pond Volume	Pond Area[1]	TP Load Reduction	TSS Load Reduction	Capital Cost[2]	30-year Annualized Cost	TP Load Reduction Cost[3]	TSS Load Reduction Cost
Urban Center	ft^3	acre	lbs/yr	lbs/yr	$	$/yr	$/lbs/yr	$/lbs/yr
Ox Creek Area (Benton Harbor)	749,559	3.4	362	199,438	584,656	38,033	151	0.27

[1]Ponds are assumed to have an average depth of 5 feet.
[2]Construction cost + design and permits.
[3]Assuming a 5% interest rate and including a $4,825/acre/year maintenance cost.

Table 30. Vegetated swale pollutant treatment costs with a 50% treatment coverage of urban lands

	Area[1]	TP Load Reduction	TSS Load Reduction	Capital Cost[2]	30-year Annualized Cost	TP Load Reduction Cost[3]	TSS Load Reduction Cost
Urban Center	acre	lbs/yr	lbs/yr	$	$/yr	$/lbs/yr	$/lbs/yr
Ox Creek Area (Benton Harbor)	15	483	319,101	196,498	25,882	54	0.08

[1]Total area of vegetated swales in the subwatershed. Assuming for every 5 acre of drainage area, an 8x200 sq ft swale is needed.
[2]Construction cost.
[3]Assuming a 5% interest rate and including a $0.02/acre/year maintenance cost.

Table 31. Rain garden pollutant treatment costs with a 15% treatment coverage of urban lands

	Area[1]	TP Load Reduction	TSS Load Reduction	Capital Cost[2]	30-year Annualized Cost	TP Load Reduction Cost[3]	TSS Load Reduction Cost
Urban Center	acre	lbs/yr	lbs/yr	$	$/yr	$/lbs/yr	$/lbs/yr
Ox Creek Area (Benton Harbor)	80.9	362	119,663	38,758,220	2,521,270	6,967	21.07

[1]Total area of rain gardens in the subwatershed. Assuming rain garden area of 19% of the drainage area, which in turn is assumed to be 15% of impervious urban lands.
[2]Construction cost.
[3]Assuming a 5% interest rate.

Table 32. Constructed wetland treatment costs with a 50% treatment coverage of urban lands

	Area[1]	TP Load Reduction	TSS Load Reduction	Capital Cost[2]	30-year Annualized Cost	TP Load Reduction Cost[3]	TSS Load Reduction Cost
Urban Center	acre	lbs/yr	lbs/yr	$	$/yr	$/lbs/yr	$/lbs/yr
Ox Creek Area (Benton Harbor)	141.9	1,086	358,988	7,237,334	591,420	545	1.65

[1]Total area of constructed wetland in the subwatershed. Assuming constructed wetlands area of have 10% of the impervious drainage area.
[2]Construction cost.
[3]Assuming a 5% interest rate and including a $850/acre/year maintenance cost.

Also see the Appendix for the *Ox Creek Technical Update* which has specific cost estimates for urban BMP implementation.

11.6 Evaluating the Watershed Management Plan

The Watershed Management Plan should be reviewed and updated as needed. The Berrien County Conservation District should take the lead in the management and action plan review process. As general guidance, the review should at a minimum include the following updates:

- Land Cover (Chapter 2.4) – every 10 years
- Demographics (Chapter 3.3) – with every new US Census
- Future Growth and Development (Chapter 3.4) – every 5-10 years
- Local Water Quality Protection Policies (Chapter 4.3 and 4.4) – every 5 years
- Water Quality Summary (Chapter 7) – every two years with the release of MDEQ Integrated Reports
- Scheduled TMDLs – every two years with the release of MDEQ Integrated Reports or when a TMDL is completed
- Prioritization of areas, pollutants and sources (Chapter 8) – every 5-10 years

- Goals and Objectives (Chapter 9) – every 5-10 years
- Implementation Strategy (Chapter 10) – review annually and update as needed

Appendix – Ox Creek Watershed Management Plan Acronyms/Abbreviations

ACS	American Community Survey
BMP	Best management practices
FEMA	Federal Emergency Management Agency
GIS	Geographic information system
HIT	High Impact Tageting
HSG	Hydrologic Soil Group
HUC	Hydrologic Unit Code
I&E	Information and Education
LA	Load allocation
LID	Low Impact Development
LLWFA	Landscape Level Watershed Functional Analysis
L-THIA	Long Term Hydrologic Impact Analysis
MDARD	Michigan Department of Agriculture and Rural Development
MDEQ	Michigan Department of Environmental Quality
MDOT	Michigan Department of Transportation
MGMT	Michigan Groundwater Management Tool
MNFI	Michigan Natural Features Inventory
MS4	Municipal separate storm sewer system
MSU	Michigan State University
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
NREPA	Natural Resources and Environmental Protection Act
OC	Ox Creek
OCW	Ox Creek Watershed
OIALW	Other Indigenous Aquatic Life and Wildlife
PCA	Potential conservation area
PSA	Public service announcement
PWSS	Public water supply system
RUSLE	Revised Universal Soil Loss Equation
SAW	Stormwater, Asset Management, and Wastewater Program
SEDMOD	Spatially Explicit Delivery Model
SEMCOG	Southeast Michigan Council of Governments
SESC	Soil Erosion and Sedimentation Control Program
SMNITP	Southern Michigan, Northern Indiana Till Plains
SWMPC	Southwestern Michigan Planning Commission
TMDL	Total Maximum Daily Load
TSS	Total suspended solids
USDA	U.S. Department of Agriculture
WHPA	Wellhead Protection Area
WHPP	Wellhead Protection Program
WLA	Wasteload allocation
WQS	Water quality standard

Total Maximum Daily Load for Biota in Ox Creek

Berrien County, Michigan

May 10, 2013

Prepared for

U.S. Environmental Protection Agency -- Region 5
Michigan Department of Environmental Quality

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Acronyms and Abbreviations

AUID	Assessment Unit Identifier
BCDC	Berrien County Drain Commission
BCRC	Berrien County Road Commission
BMPs	Best Management Practices
BMP-DSS	Best Management Practices - Decision Support System
CFR	Code of Federal Regulations
COC	Certificate of Coverage
CPOM	coarse particulate organic material
CWA	Clean Water Act
cfs	cubic feet per second
CV	coefficient of variation
EPT	Ephemeroptera, Plecoptera, and Trichoptera
HIT	High Impact Targeting
HUC	Hydrologic Unit Code
IC	impervious cover
IWR	Institute of Water Research
LA	load allocations
LDC	load duration curve
LTA	long term average
MDC	maximum daily concentration
MDEQ	Michigan Department of Environmental Quality
MDOT	Michigan Department of Transportation
MOS	margin of safety
MS4	municipal separate storm sewer system
NCDC	National Climatic Data Center
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
OIALW	other indigenous aquatic life and wildlife
P51	Biological Survey Procedure 51
PPRW	Paw Paw River watershed
PPRWMP	Paw Paw River Watershed Management Plan
RA	reasonable assurance
SWAS	Surface Water Assessment Section
TMDL	Total Maximum Daily Load
TSS	total suspended solids
SSC	suspended sediment concentration
SUSTAIN	System for Urban Stormwater Treatment and Analysis Integration
SWAT	Soil and Water Assessment Tool
SWMPC	Southwest Michigan Planning Commission
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	waste load allocations
WQS	water quality standards
WQv	water quality volume

Executive Summary

A Total Maximum Daily Load (TMDL) has been developed for Ox Creek to address biological impairments in the watershed. The macroinvertebrate community structure data coupled with qualitative habitat observations (Lipsey, 2007) indicate that siltation due to excess total suspended solids (TSS) loads is causing these impairments. This TMDL establishes the allowable loadings for TSS through waste load allocations for point sources and load allocations for nonpoint sources (NPS). Based on these allocations, the TMDL process identifies appropriate actions to achieve biological community targets that will result in attainment of Michigan's water quality standards for Ox Creek.

Key parts of the technical analysis used to support development of the Ox Creek TMDL include:

- Identifying 300 mg/L as a daily maximum TSS target, which will protect aquatic life uses in Ox Creek based on an evaluation of macroinvertebrate and sediment data for other southern Michigan streams that attain the Michigan Department of Environmental Quality's bioassessment criteria **[Section 3]**.

- Using a subwatershed analysis framework to evaluate land use data coupled with information on permitted National Pollutant Discharge Elimination System facilities to assess sources of TSS in the Ox Creek watershed **[Section 4]**.

- Linking available water quality and flow data with source assessment information to analyze watershed loading and response patterns, highlighting key areas in the Ox Creek watershed where TSS and flow reductions are needed to address siltation problems **[Section 5.1]**.

- Determining appropriate hydrology-based objectives needed to minimize stream flashiness and avoid excess siltation, which contributes to aquatic life use impairments **[Section 5.2]**.

- Calculating the TSS loading capacity (i.e., the greatest amount of a pollutant that a water body can receive and still meet water quality standards) based on the 300 mg/L target and design flow derived from development of hydrology-based objectives **[Section 6.1]**.

- Establishing load and waste load allocations **[Section 6.2]**.

Finally, the U.S. Environmental Protection Agency recommends that a reasonable assurance assessment be a key part of the TMDL process. Reasonable assurance activities are programs that are in place to assist in meeting the Ox Creek watershed TMDL allocations and applicable water quality standards. The reasonable assurance evaluation provides documentation that the nonpoint source reduction required to achieve proposed load allocations developed in point source / NPS (or mixed-source) TMDLs can and will occur over time **[Section 7]**.

1. Introduction

Section 303(d) of the federal Clean Water Act and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations [CFR], Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are not meeting water quality standards (WQS). The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. TMDLs provide a basis for determining the pollutant reductions necessary from both point and nonpoint sources to restore and maintain the quality of water resources. The purpose of this TMDL is to identify the appropriate actions to achieve the biological (macroinvertebrate) community targets that will result in WQS attainment, specifically through reduction in total suspended solids (TSS) loadings from sources in the Ox Creek watershed.

2. Problem Statement

The Ox Creek watershed is a warm water system located in southwest Michigan. The creek flows through Benton Harbor where it joins the Paw Paw River *(Figure 2-1)*. The Ox Creek watershed appears on Michigan's §303(d) list (Goodwin, et. al., 2012*)* as not meeting the Other Indigenous Aquatic Life and Wildlife (OIALW) designated use as a result of biological impairments. The reaches and possible causes and sources of non-attainment are listed as follows.

Water body name: Ox Creek **AUID**: 040500012509-02
Impaired designated use: Other Indigenous Aquatic Life and Wildlife
Cause: other flow regime alterations, sedimentation / siltation, and solids (suspended / bedload).
Source: stream bank modifications / destabilization, impervious surface / parking lot runoff, and urban runoff / storm sewers.
Size: 16.8 Miles
Location Description: Ox Creek, Yore-Stoeffer Drain, and tributaries
TMDL Year(s): 2013

AUID stands for Assessment Unit Identifier. Michigan uses the National Hydrography Database coding scheme (1:24,000 resolution) to georeference water bodies when generating the Sections 305(b) and 303(d) lists. The 12-digit Hydrologic Unit Code (HUC) is used as a default when listing streams and rivers to facilitate record keeping and mapping. Each 12-digit HUC base assessment unit may be split into multiple assessment units if site-specific information supports a smaller assessment unit. These smaller assessment units are identified by a dash and number (i.e., -06) after the 12-digit HUC. An assessment unit may consist of all water bodies in a 12-digit HUC (as a maximum) or specific stream segments or lakes in a 12-digit HUC (Goodwin et al., 2012).

The poor macroinvertebrate community could be attributed to a lack of suitable habitat for colonization (due to past channel alterations). High storm water flows likely bring additional pollutant and sediment loads to the stream that further degrades the habitat. The complexity of water quality concerns in the Ox Creek watershed has resulted in several investigations that have included biological assessments, sediment sampling, total suspended solids and flow monitoring, and water chemistry sampling.

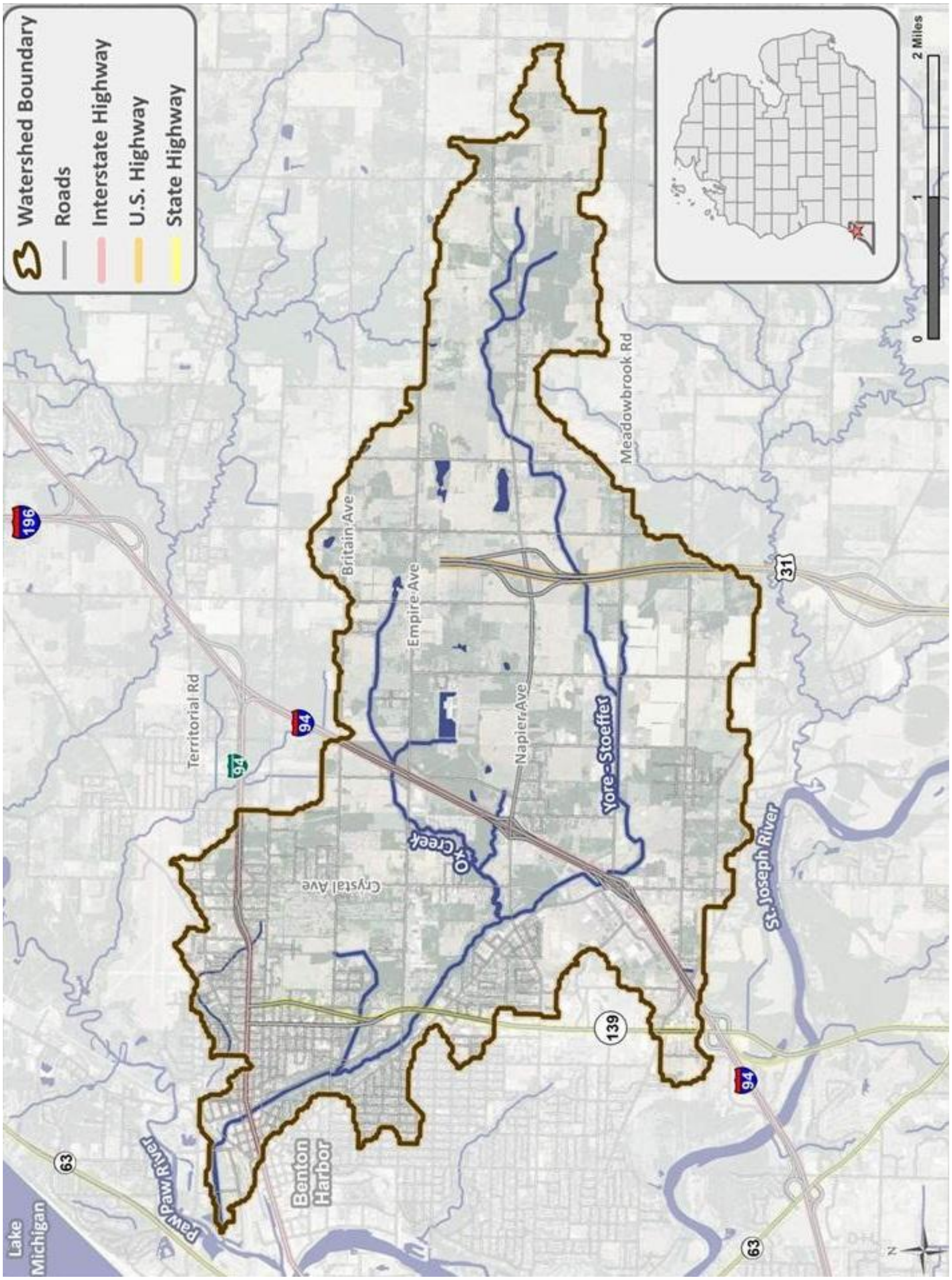


Figure 2-1. Ox Creek project area.

2.1 Setting

The watershed drains an area of 16.5 square miles. Ox Creek originates in predominately agricultural lands east of Benton Harbor *(Figure 2-2)*. The Yore – Stoeffer Drain, situated to the south of Ox Creek's headwaters, is its largest tributary. This upper portion of the watershed also contains some light industrial areas. Both Ox Creek and the Yore – Stoeffer Drain have been greatly altered and channelized in these upper reaches.

The middle portion of the watershed is dominated by residential and commercial space that includes shopping centers. Ox Creek is influenced by storm water sources as a result of increased impervious cover in this part of the watershed. Impervious cover refers to any man made surfaces (e.g. asphalt, concrete, and rooftops), along with compacted soil, that water cannot penetrate. Rain and snow that would otherwise soak into the ground turns into stormwater runoff when it comes into contact with impervious surfaces.

I-94 is a major transportation link between Detroit and Chicago, and has increased commercial land use around the Pipestone Avenue interchange and Orchard Mall. Just below the confluence of Ox Creek and the Yore – Stoeffer Drain, the stream enters a ravine-type setting. From this area to downtown Benton Harbor, Ox Creek meanders through a riparian wetland located within the ravine.

The lower portion of the watershed is a mix of residential, urban, commercial, and industrial land use. The industrial portion of the lower watershed includes sites that are either in active use, have been abandoned, or are under redevelopment. Ox Creek flows into the Paw Paw River near downtown Benton Harbor just upstream of its confluence with the St. Joseph River, which then empties into Lake Michigan.

Overall land use for the Ox Creek watershed is summarized in Table 2-1.

Table 2-1. Ox Creek land use summary.

Land Use / Land Cover Category	Acreage	Percentage
Open Water	3	0.0%
Developed, Open	2,396	22.7%
Developed, Low-Intensity	1,621	15.4%
Developed, Medium-Intensity	842	8.0%
Developed, High Intensity	372	3.5%
Barren Land	38	0.4%
Deciduous Forest	672	6.4%
Evergreen Forest	52	0.5%
Mixed forest	20	0.2%
Shrub/Scrub	11	0.1%
Grassland/Herbaceous	277	2.6%
Pasture/Hay	828	7.8%
Cultivated Crops	2,974	28.1%
Woody Wetlands	437	4.1%
Emergent Herbaceous Wetlands	16	0.2%
TOTAL	10,559	100.0%

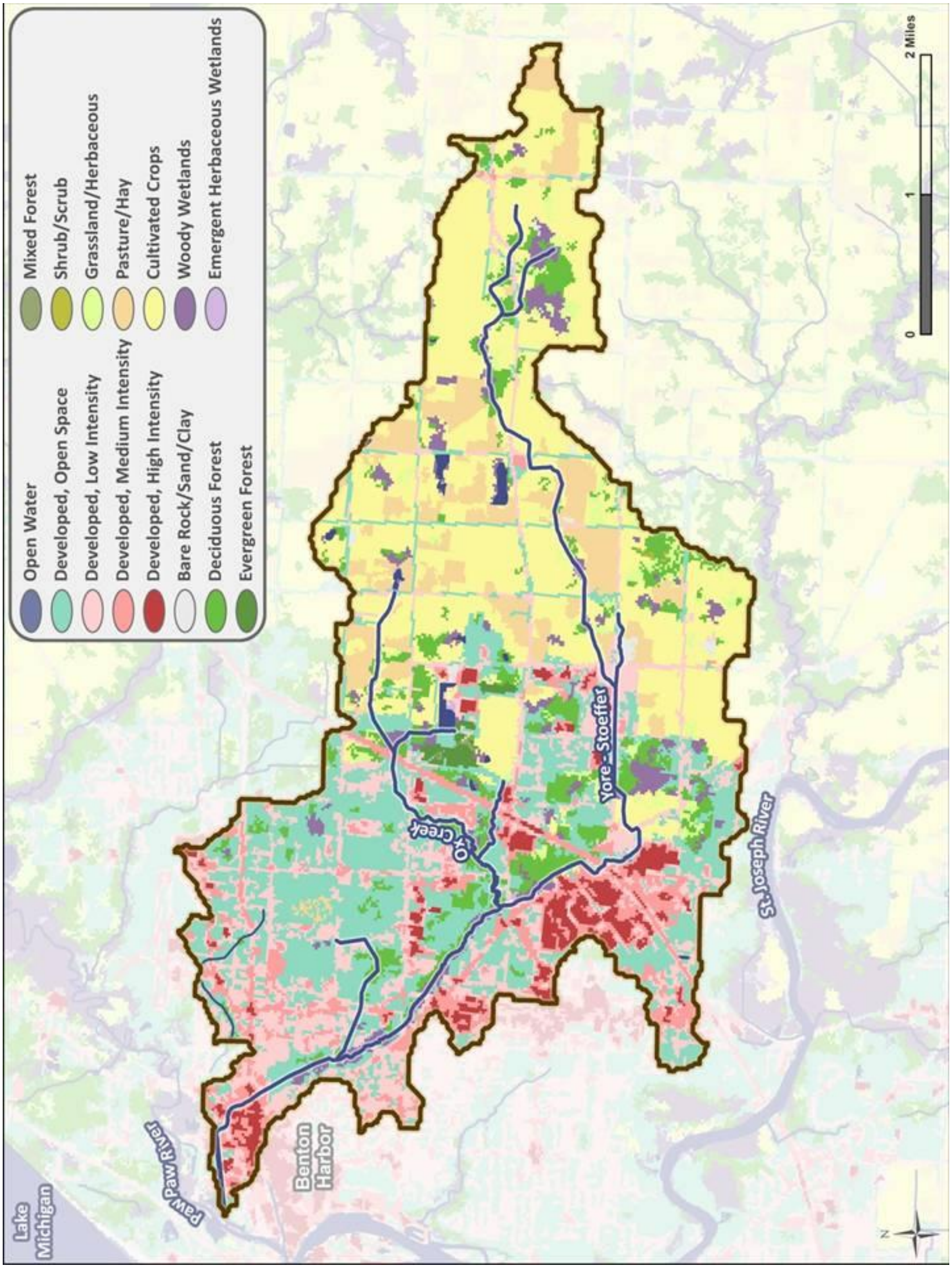


Figure 2-2. Ox Creek watershed land use.

2.2 Hydrology

Hydrology plays an important role in water quality. The hydrology of a watershed is driven by local climate conditions, land use, and soils. In Ox Creek, altered drainage patterns and land use has resulted in flashy flows, where the stream responds to and recovers from precipitation events relatively quickly.

Several segments of Ox Creek and its tributaries have been channelized or relocated to facilitate agricultural or commercial development. A common practice for improving drainage is to install subsurface tile drains and ditches to lower the water table beneath agricultural fields. Subsurface drains (e.g., corrugated plastic tile or pipe) installed beneath the ground surface serve as conduits to collect and / or convey drainage water, either to a stream channel or to a surface field drainage ditch. While these drainage improvements increase the amount of land available for cultivation and reduce flooding, they also influence the hydrology, the aquatic habitat, and water quality of area streams.

Drains intercept precipitation and snowmelt as it infiltrates the subsurface soil layer. This intercepted water would normally reach the water table where it would be stored as groundwater. Instead, the subsurface flow is quickly conveyed through the network of drains and ditches to nearby waterbodies. This process can increase the volume of water that reaches local streams during rainfall and snowmelt events, which leads to a rapid rise in stream levels during runoff events. Extensive tiling can also alter the quality of drainage water exiting the fields to receiving waters because shorter delivery times to a stream often reduce the benefits associated with longer filtration through soil layers.

Recorders that report water levels at short time intervals (i.e., 15 minutes) can be used to examine the flashiness of a stream. These devices, often referred to as level loggers, were deployed on Ox Creek at Britain Avenue in 2007 by the Michigan Department of Environmental Quality (MDEQ) *(Figure 2-3)*. This information shows that during storm events over the Ox Creek watershed, water levels can rise over four feet in a very short period of time. Similar patterns were also observed in 2008 *(Figure 2-4)*.

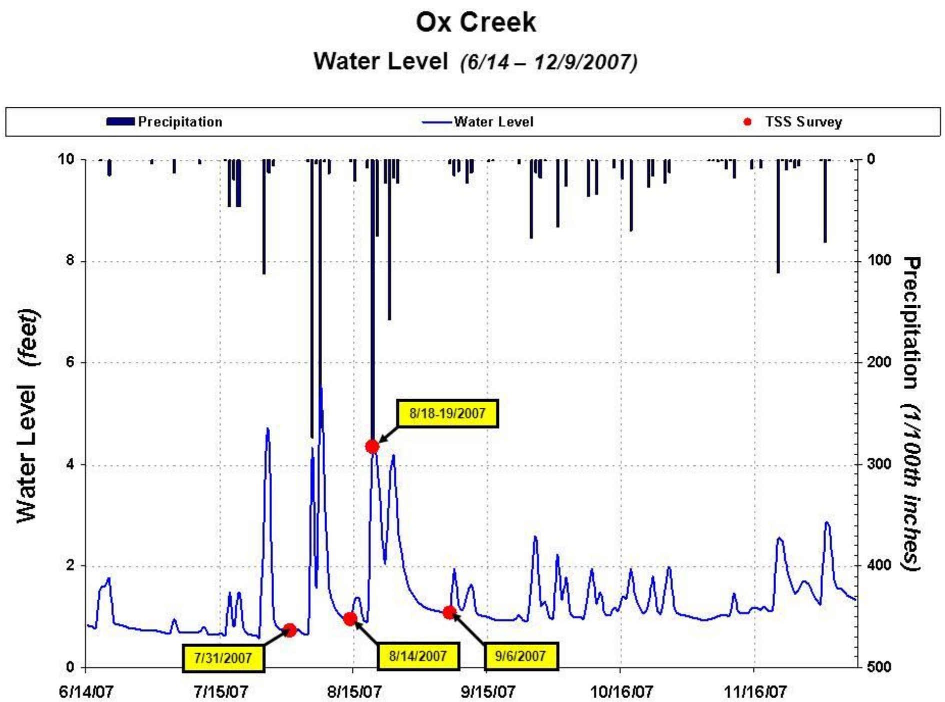


Figure 2-3. Water level data collected in Ox Creek at Britain Avenue -- 2007.

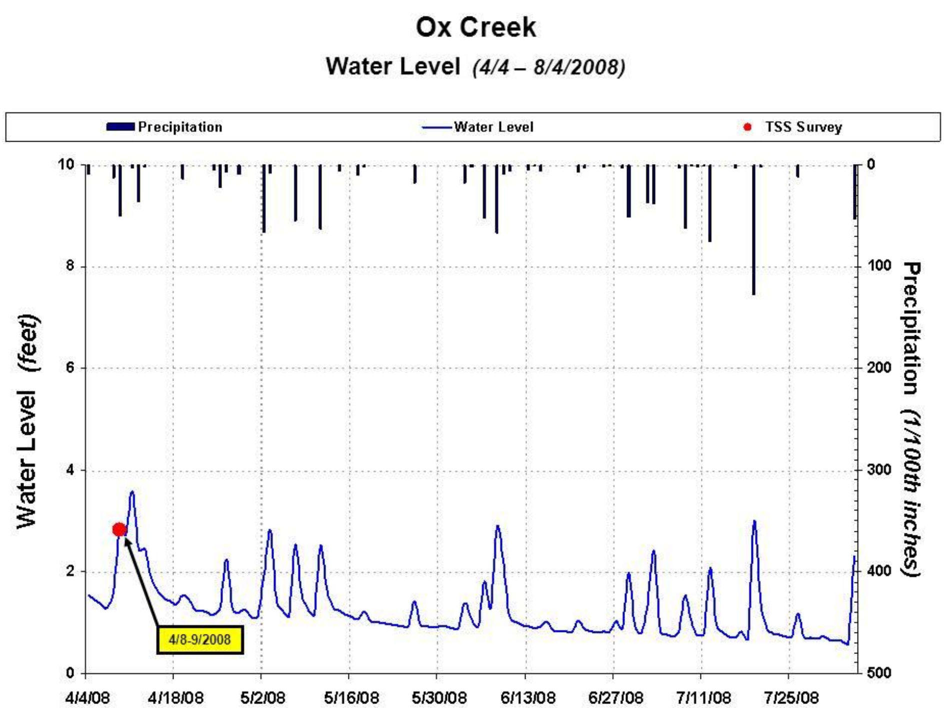


Figure 2-4. Water level data collected in Ox Creek at Britain Avenue -- 2008.

2.3 Bioassessment Information

Ox Creek contains a mix of pools, runs, and riffles that were targeted for biological assessment with a focus on benthic macroinvertebrates. Benthic macroinvertebrates live throughout the stream bed, attaching to rocks and woody debris and burrowing in sandy stream bottoms and among the debris, roots, and plants that collect and grow in and along the water's edge. Biologists have been studying the health and composition of benthic macroinvertebrate communities in streams for decades. As a result, benthic macroinvertebrates are widely used to determine biological condition. These organisms are naturally found in all streams, even in the smallest streams that cannot support fish.

Macroinvertebrate community data provide the most significant basis for identifying non-attainment of the OIALW designated use in Ox Creek. Because they are relatively stationary and cannot escape pollution, macroinvertebrate communities integrate the effects of stressors over time (i.e., pollution-tolerant species will survive in degraded conditions, and pollution-sensitive species will die). These communities are also critically important to fish because most species require a good supply of benthic macroinvertebrates as food. Studies in Ox Creek indicate that impairment of the macroinvertebrate community is due to a loss of sensitive taxa and a compositional shift toward more tolerant generalist taxa. The end result is a very simplified community structure.

The Surface Water Assessment Section (SWAS) biological survey Procedure 51 (P51) for wadeable streams was used to evaluate conditions in Ox Creek *(MDEQ, 1990; Creal et al, 1996)*. P51 uses metrics that rate macroinvertebrate communities from excellent (+5 to +9) to poor (-5 to -9). Scores from +4 to -4 are rated acceptable. Negative scores in the acceptable range are considered trending towards a poor rating, while positive scores in the acceptable range are tending towards an excellent rating. The individual P51 metrics are described in Table 2-2 along with their expected response to declining stream conditions. In this section, the question "*What aspects of Procedure 51 can be used to help identify potential stressors?"* is explored.

Table 2-2. Procedure 51 macroinvertebrate metrics.

	Metric	Description	Expected Response to Disturbance
1	Total Number of Taxa.	Taxa richness has historically been a key component in most all evaluations of a macroinvertebrate subsample. The underlying reason is the basic ecological principle that healthy, stable biological communities have high species diversity. Increases in number of taxa are well documented to correspond with increasing water quality and habitat suitability. Small, pristine headwater streams may, however, be exceptions and show low taxa richness.	Decrease
2	Total Number of Mayfly Taxa.	Mayflies are an important component of a high quality stream biota. As a group, they are decidedly pollution sensitive and are often the first group to disappear with the onset of perturbation. Thus, the number of taxa present is a good indicator of environmental conditions.	Decrease
3	Total Number of Caddisfly Taxa.	Caddisflies are often a predominant component of the macroinvertebrate fauna in larger, relatively unimpacted streams and rivers but are also important in small headwater streams. Through tending to be slightly more pollution tolerant as a group than mayflies, caddisflies display a wide range of tolerance and habitat selection among species. However, few species are extremely pollution tolerant and, as such, the number of taxa present can be a good indicator of environmental conditions.	Decrease
4	Total Number of Stonefly Taxa.	Stoneflies are one of the most sensitive groups of aquatic insects. The presence of one or more taxa is often used to indicate very good environmental quality. Small increases or small declines in overall numbers of different stonefly taxa is thus very critical for correct evaluation of stream quality.	Decrease
5	Percent Mayfly Composition.	As with the number of mayfly taxa, the percent abundance of mayflies in the total invertebrate sample can change dramatically and rapidly to minor environmental disturbances or fluctuations.	Decrease
6	Percent Caddisfly Composition.	As with the number of caddisfly taxa, percent abundance of caddisflies is strongly related to stream size with greater proportions found in larger order streams. Optimal habitat and availability of appropriate food type seem to be the main constraints for large populations of caddisflies.	Decrease
7	Percent Contribution of the Dominant Taxon.	The abundance of the numerically dominant taxon is an indication of community balance. A community dominated by relatively few taxa for example, would indicate environmental stress, as would a community composed of several taxa but numerically dominated by only one or two taxa.	Increase
8	Percent Isopods, Snails, and Leeches.	These three taxa, when compared as a combined percentage of the invertebrate community, can give an indication of the severity of environmental perturbation present. These organisms show a high tolerance to a variety of physical and chemical parameters. High percentages of these organisms at a sample site are very good evidence for stream degradation.	Increase
9	Percent Surface Dependent.	This metric is the ratio of the number of macroinvertebrates which obtain oxygen via a generally direct atmospheric exchange, usually at the air/water interface, to the total number of organisms collected. High numbers or percentages of surface breathers may indicate large diurnal dissolved oxygen shifts or other biological or chemical oxygen demanding constraints. Areas subject to elevated temperatures, low or erratic flows may also show disproportionately high percentages of surface dependent macroinvertebrates.	Increase

Biological assessment scores for Ox Creek were reported by Lipsey (2007) and Rockafellow (2002), and have been summarized in the *"Ox Creek TMDL Development -- Watershed Characterization and Source Assessment Report" (Tetra Tech, 2010)*. Overall bioassessment scores were poor. Macroinvertebrate scores for Blue Creek, Pipestone Creek, and Hickory Creek were also examined. These creeks are in the Benton Harbor area, had acceptable macroinvertebrate scores, and offer a potential opportunity to serve as reference streams for evaluating Ox Creek data.

Figure 2-5 through Figure 2-8 present a graphic display of key individual P51 metrics, notably the relative percentages of mayflies, caddisflies, dominant taxa, and tolerant taxa (i.e., isopods, snails, and leeches). The *"above average"* on each graph corresponds to an individual metric score of +1. This means that the community based on that metric is performing better than the average condition at excellent sites in that ecoregion *(Creal, et al, 1996)*. Conversely, the *"below average"* corresponds to an individual metric score of -1; meaning that the site is outside of (minus) two standard deviations from the average condition at excellent sites *(Creal, et al, 1996)*.

Generally, all Ox Creek stations scored below average for P51 metrics 2 through 6 due to insufficient numbers of mayfly, stonefly, and caddisfly taxa (one exception was the 2006 bioassessment at Crystal Avenue, where metric 2 scored *"Acceptable"*). These taxa are relatively intolerant (i.e., typically the first organisms to disappear). In addition, most sites scored below average for P51 metrics 7 and 8. Metric 7 (percent contribution of dominant taxa) reflects community balance.

The mayfly and caddisfly composition in Ox Creek is virtually non-existent compared to Blue, Pipestone, and Hickory Creeks (Figure 2-5 and Figure 2-6). The absence of these pollution intolerant organisms clearly suggests several potential stressors including increased sedimentation, impaired in-stream habitat, and high storm water flows.

The relatively high percentage of dominant taxa at all Ox Creek sites (Figure 2-7) is also indicative of degraded conditions. A community dominated by relatively few taxa typically indicates environmental stress. The dominant taxa vary between sites as shown in Table 2-3. Similarly, metric 8 (percent isopods, snails, and leeches; Figure 2-8) reflect the presence of a high number of pollution tolerant organisms in Ox Creek.

Table 2-3. Dominant taxa at Ox Creek 2006 macroinvertebrate sites.

Site	Dominant Taxa	Percentage
Yore-Stoeffer Drain at Meadowbrook Road	Physidae (Gastropods)	50.0
Ox Creek at Crystal Avenue	Amphipoda (scuds)	44.5
Ox Creek at Britain Avenue	Oligochaeta (worms)	48.0
Ox Creek at Water Street	Oligochaeta (worms)	52.2

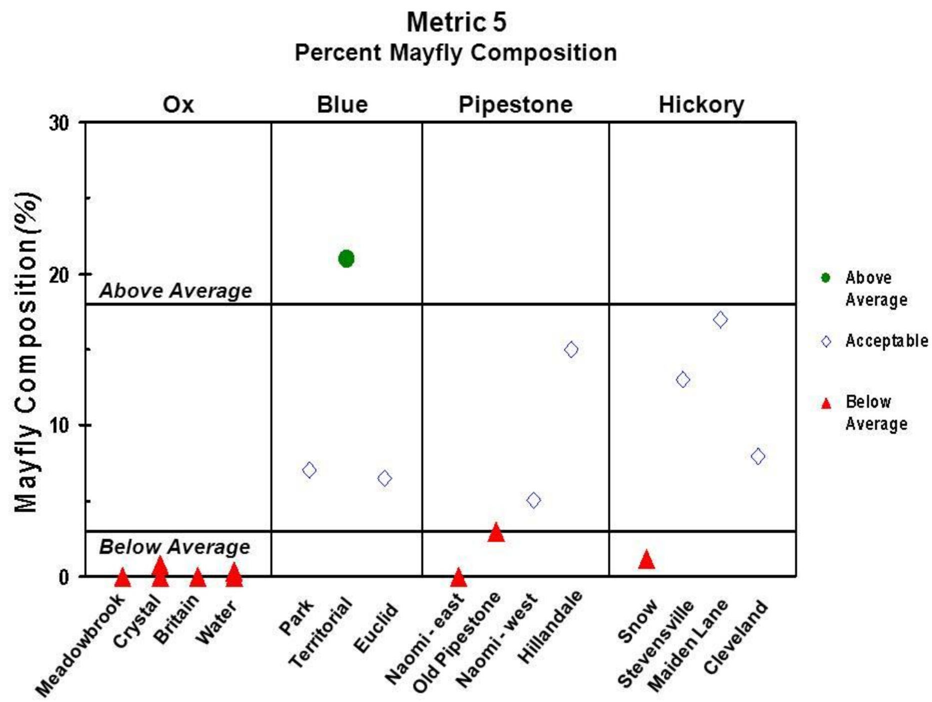


Figure 2-5. Mayfly composition in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

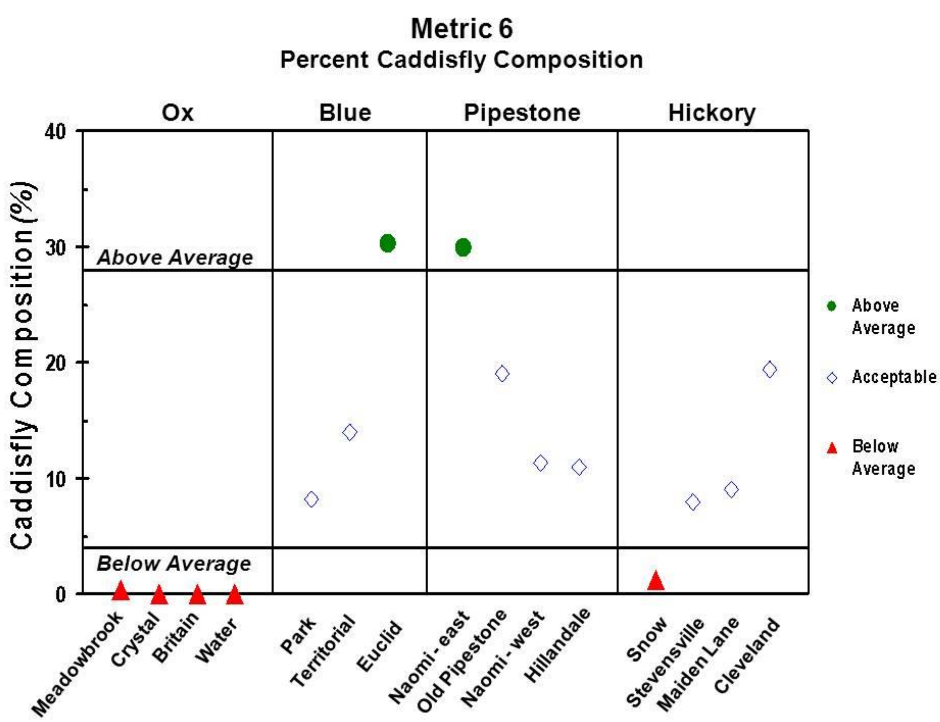


Figure 2-6. Caddisfly composition in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

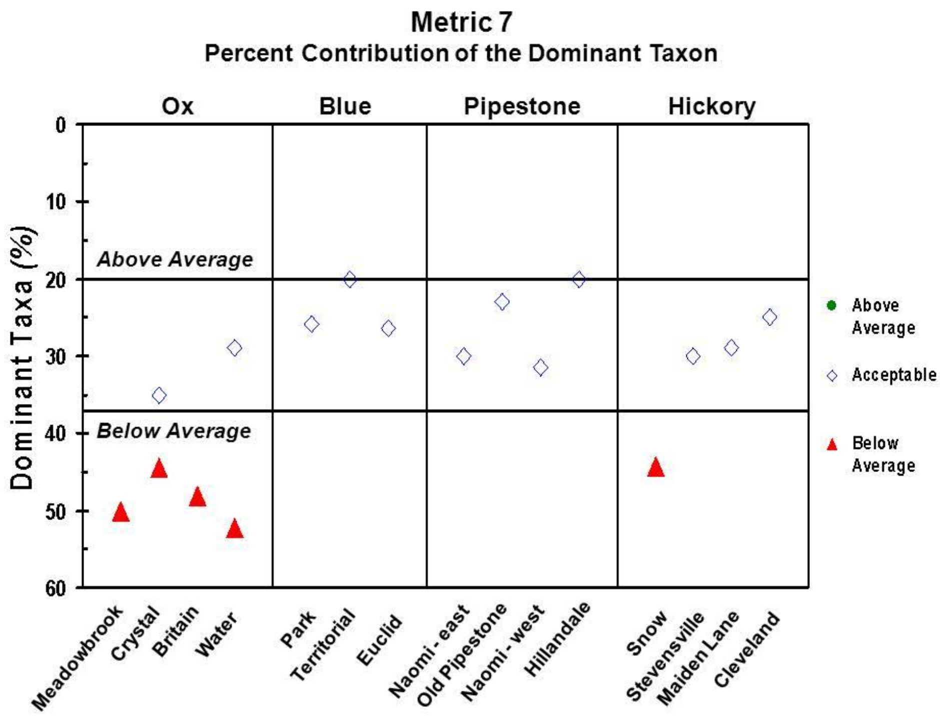


Figure 2-7. Dominant taxa in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

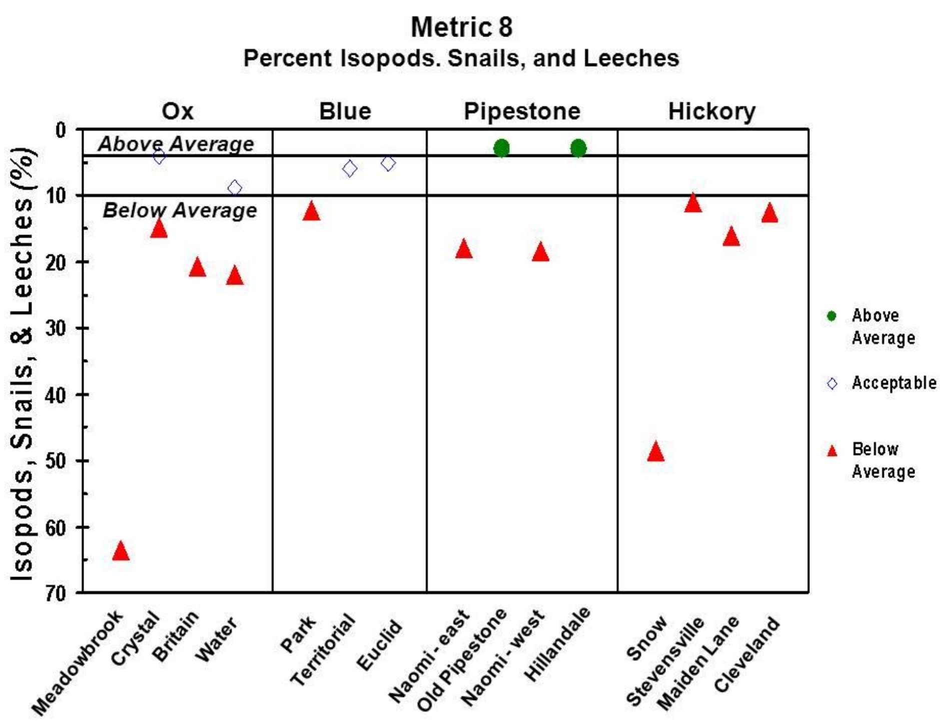


Figure 2-8. Isopod, snails, and leeches in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

2.4 Total Suspended Solids Sampling

Studies to investigate potential causes of biological impairments included water column measurements. MDEQ qualitative habitat surveys noted heavy siltation at several stations in Ox Creek. For this reason, an emphasis was placed on collecting total suspended solids data, both under dry conditions and during wet-weather events. This section summarizes those results

A study was initiated by MDEQ in 2007 and continued in 2008 that focused on total suspended solids monitoring at seven sites (Limno Tech, 2008). These sites are listed in Table 2-4 with locations shown in Figure 2-9. Sampling included both wet and dry weather. Water level recorders were deployed at the Britain Avenue site to enable development of stream flow estimates. Flow measurements were taken at this station to develop a flow rating curve to be used to convert water level to an estimate of flow. In addition, *"tape down"* measurements (i.e., the distance from an identified reference point at each monitoring location to the water surface) were recorded at each station at the time of sample collection to be used in conjunction with the flow rating curve to estimate flow at all other stations.

Table 2-4. Ox Creek TSS sampling sites listed from upstream to downstream.

Location	MDEQ Site ID
Yore – Stoeffer Drain at Blue Creek Road	#05
Yore – Stoeffer Drain at Yore Avenue	#06
Yore – Stoeffer Drain at Meadowbrook Road	#01
Ox Creek at Crystal Avenue	#02
Ox Creek at Empire Avenue	#03
Ox Creek at Britain Avenue	#07
Ox Creek at Water Street	#04

Table 2-5 summarizes the dates sampled for each type of event (wet or dry). In addition, the 24-hour precipitation reported by the National Weather Service for the Benton Harbor airport is included for each wet weather sampling event. Because hydrology plays an important role in evaluating water quality, Ox Creek flows associated with TSS sample events are shown in Figure 2-10. This graph provides a context for TSS sampling events relative to hydrologic conditions.

Figure 2-11 presents a summary of the TSS monitoring data. Information is depicted in the longitudinal direction moving from upstream to downstream (left to right). Two horizontal lines are included to put TSS concentrations into some perspective. These are drawn at 25 mg/L and 300 mg/L, which will be discussed under *"Targets Development"* (Section 3).

The highest TSS values were reported for the Yore-Stoeffer Drain at the Yore Avenue site (the largest occurred during the second wet weather sampling event in April 2008). This particular site, located in the upper reaches of the Yore-Stoeffer Drain, is in the agricultural portion of the watershed. This site, along with the Blue Creek Road site, also exhibited a high degree of variability, as evidenced by the range of sample values shown in Figure 2-11.

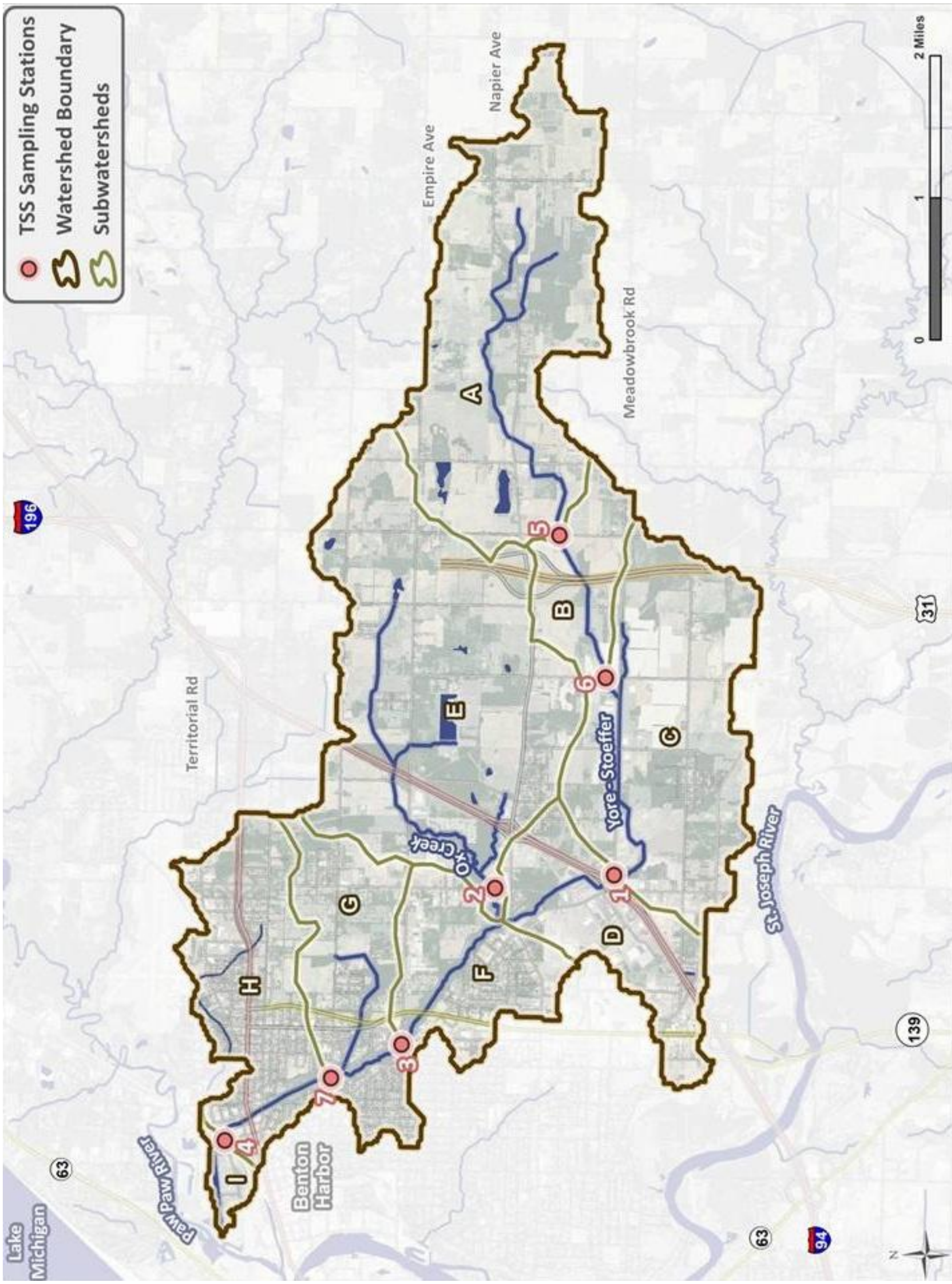


Figure 2-9. Location of Ox Creek 2007 and 2008 TSS monitoring sites.

Table 2-5. TSS sampling event dates.

Sample Date	Event	24-hour Precipitation (inches)
7/31/2007	Dry	0
8/14/2007	Dry	0
8/18-19/2007	Wet	2.52
9/6/2007	Dry	0
4/8-9/2008	Wet	0.69

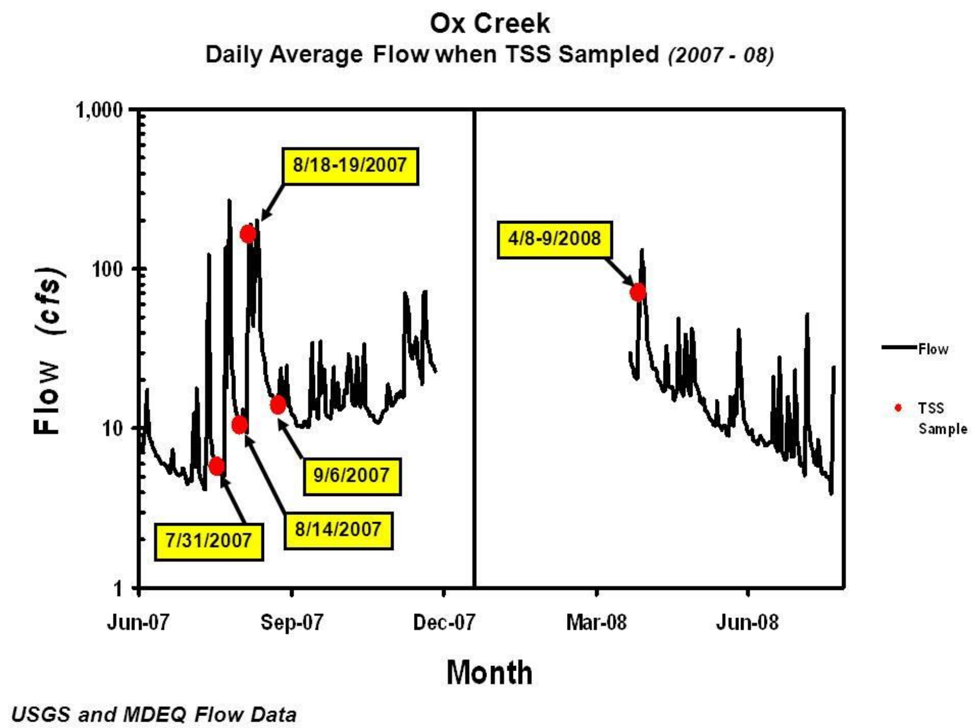


Figure 2-10. Ox Creek flow and TSS sample dates.

Figure 2-12 depicts TSS data for the Yore Avenue site as a function of water level. The general pattern indicates that TSS concentrations increase with rising water level (and flow). However, two areas of the graph are highlighted where exceptions to the general pattern occur. First, the two largest TSS values (noted by the upper circle) did not correspond to the highest water levels. Second, the smallest TSS values did not necessarily occur at the lowest water level (noted by the lower circle). These anomalies may be related to several factors such as the intensity of the precipitation event, the season of occurrence, and the timing of the individual TSS sample relative to the onset of the storm as well as the timing of the previous storm.

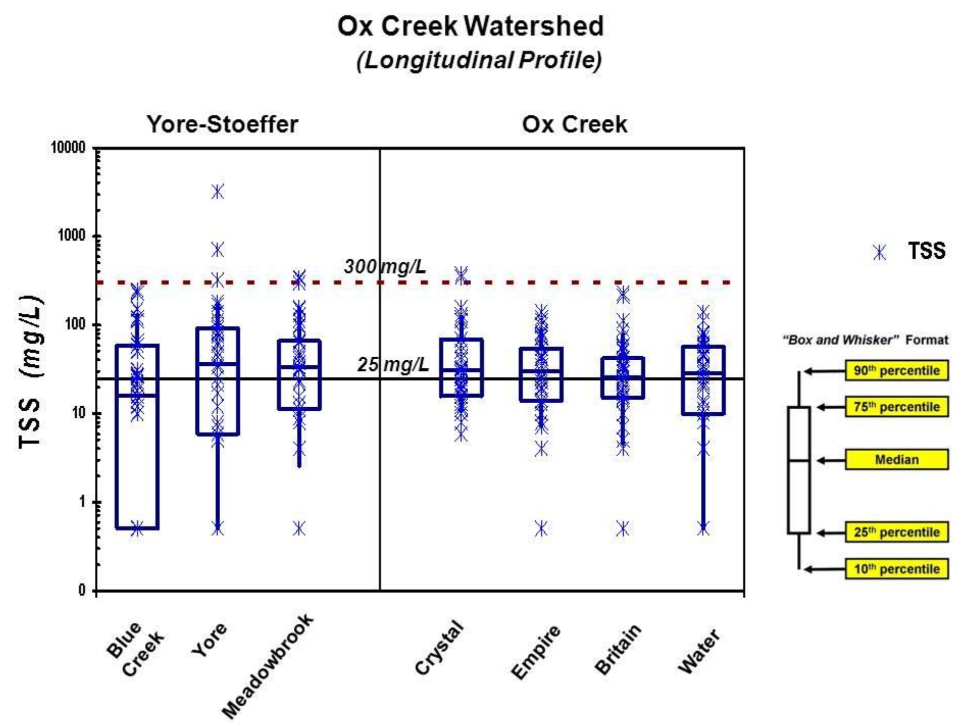


Figure 2-11. Longitudinal profile of TSS monitoring data.

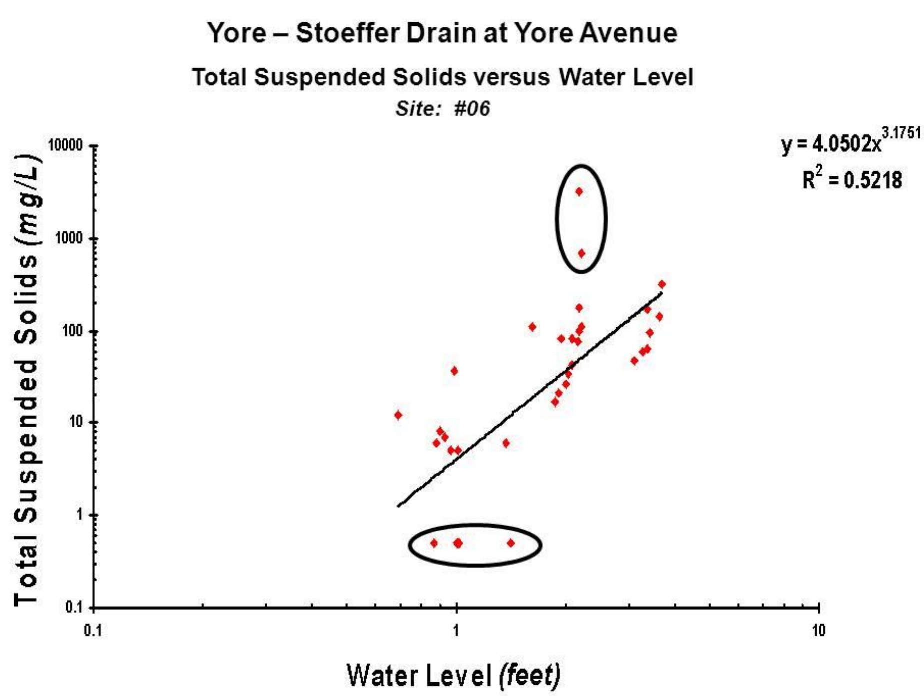


Figure 2-12. TSS as a function of water level -- Yore Avenue site.

3. Targets

3.1 Applicable Water Quality Standards

The authority to designate uses and adopt Water Quality Standards (WQS) is granted through Part 31 (Water Resources Protection) of Michigan's Natural Resources and Environmental Protection Act (1994 PA 451, as amended). Pursuant to this statute, MDEQ promulgated its WQS as Michigan Administrative Code R 323.1041 – 323.1117, Part 4 Rules. Designated uses to be protected in surface waters of the state are defined under R323.1100, and include *"other indigenous aquatic life and wildlife"*.

The narrative target for the Ox Creek TMDL is based on the P51 biological assessment protocol (MDEQ, 1990). This biota TMDL target is the reestablishment of fish and macroinvertebrate communities that result in a consistent *"acceptable"* or *"excellent"* rating. Future macroinvertebrate and fish surveys will be conducted in successive years, following the implementation of efforts like Best Management Practices (BMPs) to stabilize runoff discharges, extremes in stream flow conditions, and minimize sediment loadings to the creek.

While the primary target is the restoration of acceptable biological communities, the Part 4 Rules contain provisions that may be used to develop secondary targets that address documented impairments. For example, R 323.1050 (Rule 50) states that *"surface waters of the state shall not have any of the following physical properties in unnatural quantities which are or may become injurious to any designated use: turbidity, color, oil films, floating solids, foams, settleable solids, suspended solids, deposits"*. Several TMDLs developed by the MDEQ used TSS as a numeric target to address aquatic life impairments (e.g.Goodwin, 2007; Wuycheck, 2004).

3.2 Total Suspended Solids

Use of TSS as a numeric target is intended to help guide proper control of excessive sediment loads from runoff. This indicator can also address problems associated with runoff discharge rates and volumes that lead to channel instability, stream bank erosion, and thus increased TSS concentrations. In addition, the use of TSS as a numeric target connects a measurable in-stream parameter to hydrologic changes in the watershed, which can result in habitat changes that are adversely affecting biological communities.

The numeric value used in past MDEQ TMDLs has been a mean annual TSS concentration of 80 mg/L for wet weather events. This TSS target was based on a review of existing conditions and published literature on the effects of TSS to aquatic life. The past use of numeric TSS targets helped create a TMDL framework that can identify possible steps to restore biological communities to an acceptable condition. However, the way in which this target is expressed (i.e., a mean annual TSS concentration for wet weather events) presents several practical challenges in terms of evaluating progress towards meeting numeric TMDL objectives. For example, what constitutes a wet-weather event is not defined. In addition, monitoring efforts are not typically conducted in a way that allows data to be compared to a *"mean annual concentration for wet weather events"*.

An innovative approach used by MDEQ provides information that relates to development of TSS targets, particularly identifying a daily maximum value. Specifically, the Sediment Erosion Transport Predictor (SETP) method represents functions of watershed characteristics, soils, and flow regimes. The technique is simply a graph showing the relationship between suspended solids and flow *(Figure 3-1)*.

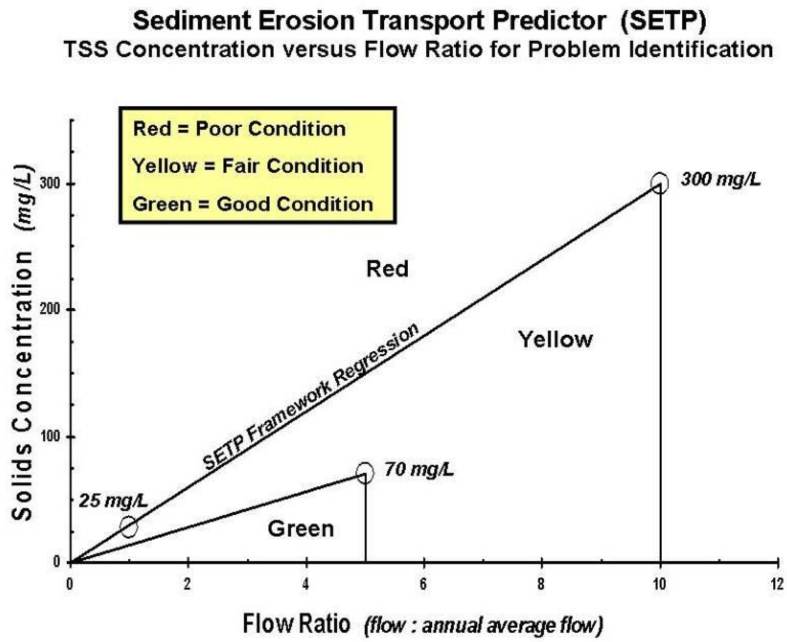


Figure 3-1. Sediment Erosion Transport Predictor *(SETP)* framework overview.

These values are combined with multiple averaging period methods to provide a greater level of clarity that describes how the targets are to be interpreted (TetraTech, 2011; TetraTech, 2012). EPA's *Technical Support Document for Water Quality-Based Toxics Control"* (USEPA, 1991) describes a multiple averaging period method, which has been used to define the Ox Creek TMDL TSS targets. The approach is based on achieving a maximum daily target that considers patterns and variability in a consistent manner. Multiple averaging periods provide a way to achieve both long-term program objectives and focus implementation efforts while avoiding short term problems.

Based on available information for suspended solids in southern Michigan, the following TSS target is used to develop the Ox Creek TMDL:

- 300 mg/L maximum daily TSS

This target is supported by multiple lines of evidence. The 300 mg/L maximum daily TSS is based on MDEQ studies supporting development of SETP. The SETP effort included a qualitative analysis of information from 12 different Lower Michigan streams and rivers. The analysis identified 300 mg/L TSS as a general level above which the stream sedimentation condition was degraded.

The appropriateness of this target was validated by applying the framework to sites with both bioassessment information and either TSS or suspended sediment concentration (SSC) data. Validation involved ensuring that sites meeting the TSS targets were also in either acceptable or excellent condition based on bioassessment data. Using the best available information, the validation process demonstrates that these TMDL targets should lead to attainment of Michigan's water quality standards. Following validation, the targets and methodology were applied to Ox Creek flow and TSS data. The analysis showed that Ox Creek generally exceeded threshold levels; consistent with bioassessment scores.

4. Source Assessment

Source assessments are an important component of water quality management plans and TMDL development. These analyses are generally used to evaluate the type, magnitude, timing, and location of pollutant loading to a waterbody (USEPA, 1999). Source assessment methods vary widely with respect to their applicability, ease of use, and acceptability. TSS can originate from an array of sources including point source discharges (e.g., industrial pipes) and surface runoff, particularly storm water. The purpose of this section is to provide a summary of sources that contribute TSS to Ox Creek.

4.1 Subwatersheds

To facilitate the source assessment, the Ox Creek drainage has been partitioned into subwatershed units. The use of subwatersheds creates an opportunity to relate source information to water quality monitoring results. The use of subwatersheds enhances the source assessment by grouping information; it also sets the stage for the TMDL linkage analysis. Subwatersheds can help connect potential cause information to documented effects on a reach-by-reach basis. The ability to summarize information at different spatial scales strengthens the overall TMDL development process and will also enable more effective targeting of implementation efforts.

Subwatershed units used for the source assessment are identified in Table 4-1 and Figure 4-1. These subwatershed boundaries are defined in a way that builds on locations sampled by MDEQ. The sections that follow first describe point sources in the Ox Creek watershed. The source assessment concludes with a discussion of nonpoint sources, summarizing basic characteristics for each subwatershed group. This includes size, nonpoint source areas located within the subwatershed, and land use / land cover.

Table 4-1. Ox Creek subwatersheds listed from upstream to downstream.

Subbasin ID	**Name**	**Area**	
		(acres)	***(sq.mi.)***
Unit A	Yore – Stoeffer Headwaters	2,150	3.36
Unit B	Upper Yore – Stoeffer	465	0.73
Unit C	Middle Yore – Stoeffer	1,755	2.74
Unit D	Lower Yore – Stoeffer	805	1.26
Unit E	Ox Headwaters	2,600	4.06
Unit F	Upper Ox	725	1.13
Unit G	Middle Ox	895	1.40
Unit H	Lower Ox	1,060	1.66
Unit I	Ox Outlet	104	0.16
TOTAL		10,559	16.50

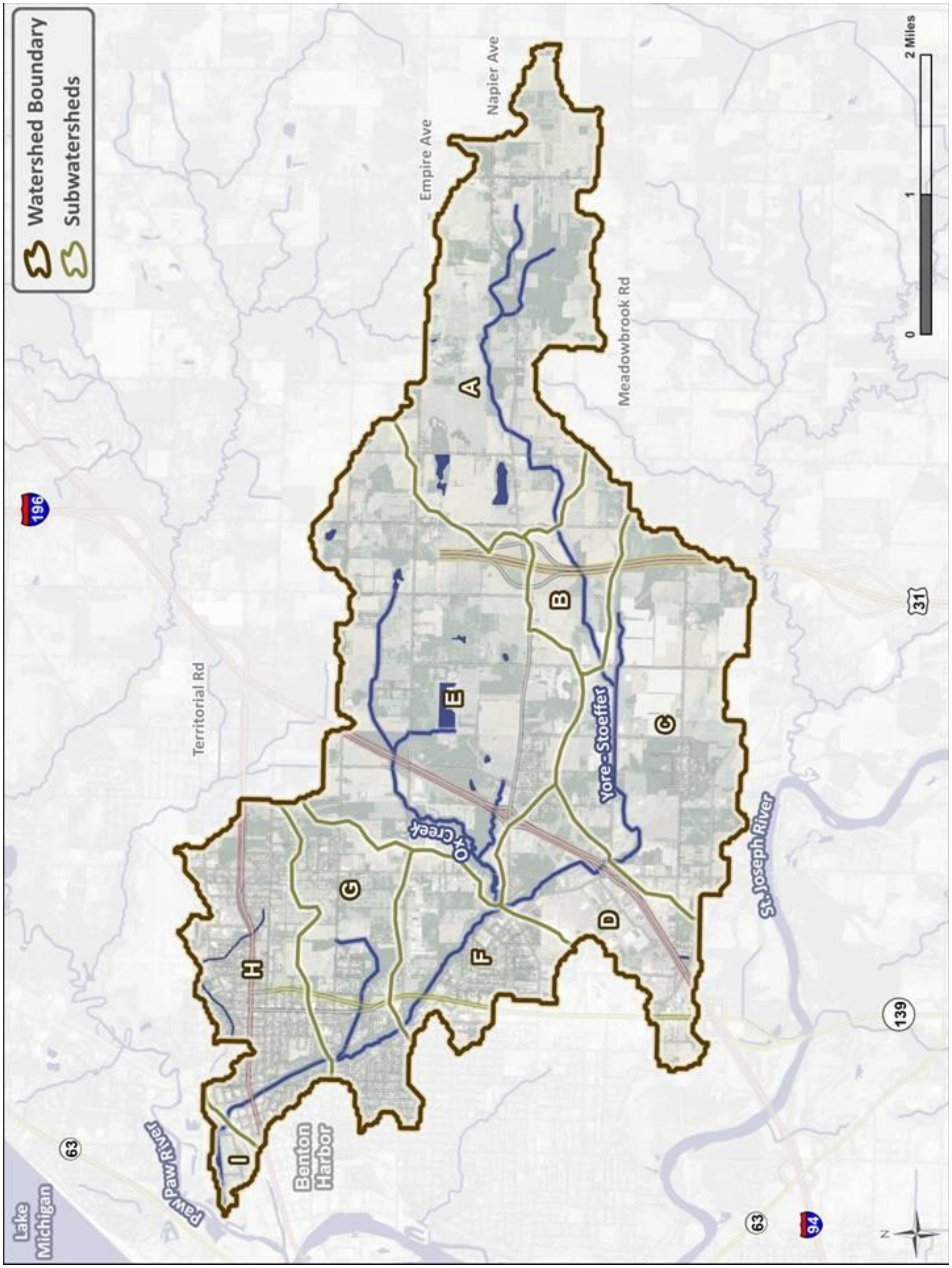


Figure 4-1. Ox Creek watershed units.

4.2 Source Data Review

Historic development revolving around the growth and urbanization of Benton Harbor has created a wide array of potential sources that could deliver TSS to Ox Creek. The subsections that follow review major source categories of concern in the watershed.

4.2.1 Point Sources

Point sources are those originating from a single, identifiable source in the watershed. Point source discharges are regulated through the National Pollutant Discharge Elimination System (NPDES) permits. In Michigan, MDEQ may utilize an individual permit, general permit, or *"permit by rule"* for NPDES authorizations. MDEQ determines the appropriate permit type for each surface water discharge.

An individual NPDES permit is site-specific. The limitations and requirements are based on the permittee's wastewater discharge, the volume of discharge, facility operations, and receiving stream characteristics. Examples of individual NPDES permits include municipal waste water treatment plants or an industry with process wastewater containing pollutants, such as a paper mill. There are currently no facilities in the Ox Creek watershed that have been issued an individual NPDES permit.

A general permit is designed to cover permittees with similar operations and / or type of discharges. General permits may contain effluent limitations protective of most surface waters statewide. Locations where more stringent requirements are necessary require an individual permit. Facilities that are determined to be eligible to be covered under a general permit receive a Certificate of Coverage (COC). Currently, there are four facilities in the Ox Creek watershed covered under the general permit for "Non Contact Cooling Water" *(Table 4-2)*. The location of these facilities is shown in Figure 4-2.

Construction activities in Michigan are regulated under the *"permit-by-rule"*. *"Permit-by-rule"* denotes that permit requirements are stated in a formally promulgated administrative rule. A facility requiring coverage under a *"permit-by-rule"* must abide by the provisions written in the rule. The facility submits a form called a Notice of Coverage (NOC). In the Ox Creek watershed, there is one operation that has submitted an NOC form based on construction activities that are covered by administrative rule *(Table 4-3)*.

Table 4-2. Facilities in Ox Creek watershed with COCs for non-contact cooling water.

Permit ID	Name	Flow	Subwatershed
MIG250480	Lake Michigan College	1.95 mgd	E
MIG250393	National Zinc Processors	0.001 mgd	F
MIG250362	Siemens VAI Services	0.03 mgd	H
MIG250368	New Products Corporation	0.112 mgd	I

Table 4-3. Facilities with construction storm water permit coverage.

Permit ID	Name	Permit Type	Subwatersheds
MIR111668	Whirlpool Corporation	Construction NOC	H,I

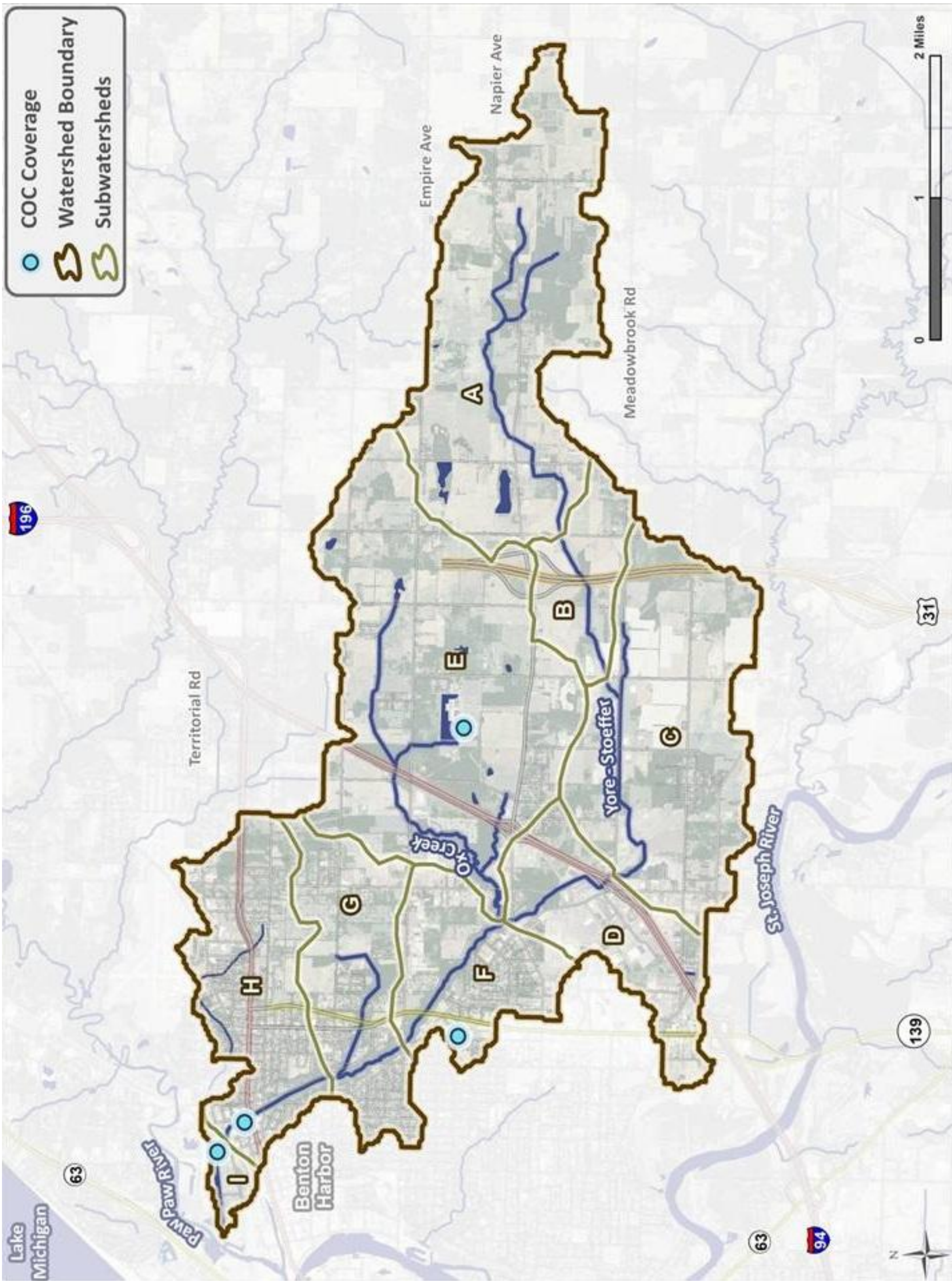


Figure 4-2. Location of facilities with COCs for non-contact cooling water.

Storm water runoff is generated in a watershed from precipitation events, such as rainfall or snowmelt. Certain types of storm water runoff are covered under NPDES permits based on where the stormwater originates. One category of sources is referred to as Municipal Separate Storm Sewer Systems, or MS4. MS4s which service a population greater than 100,000 must obtain a permit as part of the Phase I NPDES Storm Water Program. MS4s that service a population in the defined urbanized areas of Michigan and are not covered under a Phase I permit must obtain a Phase II NPDES permit. MS4 permits are focused on reducing impacts to surface waters from the effects of urbanization. Table 4-4 identifies those jurisdictions in the Ox Creek watershed that have been issued a COC by MDEQ under the MS4 program. As part of its Storm Water Management Program (SWMP), the city of Benton Harbor has identified the location of its MS4 storm water outfalls. These are shown in Figure 4-3.

Table 4-4. Jurisdictions with MS4 storm water permit coverage.

Permit ID	Name	Permit Type	Subwatershed(s)
MIG610243	City of Benton Harbor	MS4 COC	F,G,H,I
MIG610228	Berrien Co. – Road Commission	MS4 COC	C,D,E,F,G,H
MIG610229	Berrien Co. – Drain Commission	MS4 COC	C,D,E,F,G,H
MI0057364	Michigan Dept. of Transportation	NPDES MS4	C,D,E,F,G,H

An industry must apply for a storm water permit if storm water associated with industrial activity at the facility discharges to a surface water. Michigan's Industrial Storm Water Discharge permit requires that facilities develop and implement a Storm Water Pollution Prevention Plan for the facility and eliminate any unauthorized non-storm water discharges. The applicant must also obtain a certified operator who supervises the control structures at the facility. Facilities in the Ox Creek watershed covered under the industrial storm water permit are listed in Table 4-5 and shown in Figure 4-4.

Table 4-5. Facilities with industrial storm water permit coverage.

Permit ID	Name	Permit Type	Subwatershed(s)
MIS310027	Rieth-Riley Cons-Benton Harbor	Industrial COC	C
MIS310109	ABC Precision Machining	Industrial COC	C
MIS310114	Mono Ceramics-Benton Harbor	Industrial COC	C
MIS310255	Sandvik Materials Tech	Industrial COC	C
MIS310333	Ausco Products-St Joseph	Industrial COC	C
MIS310062	Leco-Michigan Ceramics Div	Industrial COC	E
MIS310009	Brutsche Concrete-Benton Harbor	Industrial COC	F
MIS310069	National Zinc Processors	Industrial COC	F
MIS310131	K-O Products Co	Industrial COC	F
MIS310204	Old Europe Cheese Inc	Industrial COC	F
MIS310119	JVIS Mfg – Ox Creek Facility	Industrial COC	H
MIS310396	Siemens VAI	Industrial COC	H
MIS310611	New Products Corp	Industrial COC	I

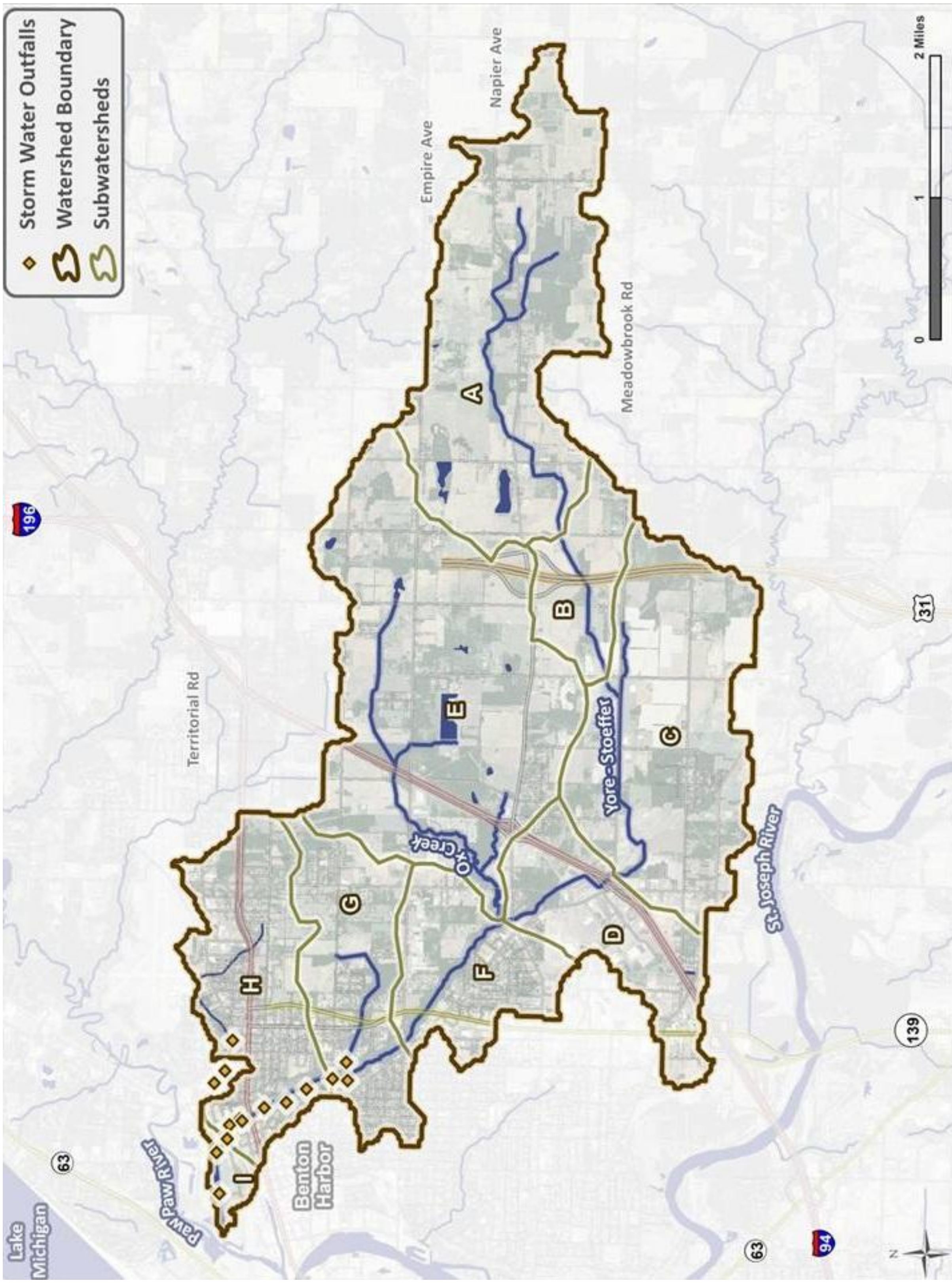


Figure 4-3. Location of outfalls under Benton Harbor MS4 storm water permit.

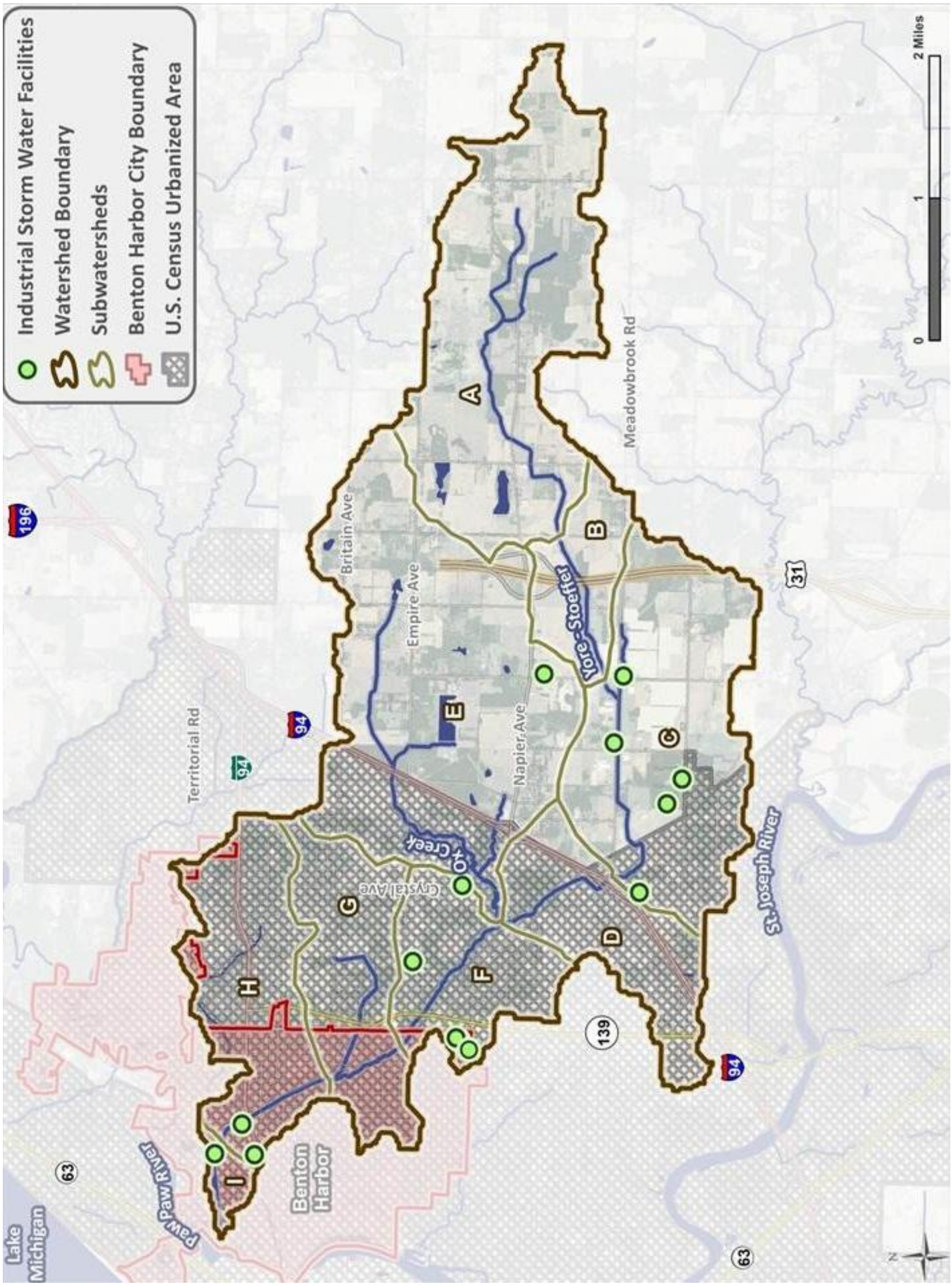


Figure 4-4. Location of facilities with industrial storm water permit coverage.

4.2.2 Nonpoint Sources

Nonpoint storm water sources play a significant role in affecting water quality in Ox Creek. For that reason, an understanding of factors that affect storm water runoff within each subwatershed unit is an important part of the source assessment. This section presents information on land use from areas that potentially deliver nonpoint source pollutants to the stream. This builds a foundation for the TMDL linkage analysis.

Subwatershed unit boundaries have been identified to coincide with MDEQ monitoring sites, to the extent possible. Subwatershed unit boundaries also take into account the location of the confluence between Ox Creek and its largest tributary the Yore – Stoeffer Drain. The type of land use in each subwatershed unit affects nonpoint source pollutants that potentially reach Ox Creek and its major tributaries. Examples include sediment from agricultural land or stormwater runoff from other areas not covered under MS4 permits.

Table 4-6 presents a summary of land use information for the Ox Creek watershed by subwatershed unit in terms of acreage. Table 4-7 presents the same information on a percentage basis.

Table 4-6. Ox Creek watershed land use summary (acreage).

Land Use / Land Cover	Subwatershed Unit ID								
	A	B	C	D	E	F	G	H	I
Open Water	2	0	0	0	1	0	0	0	0
Developed, Open	64	26	332	201	628	240	475	410	20
Developed, Low-Intensity	77	20	290	137	256	183	260	370	28
Developed, Medium-Intensity	8	1	67	217	114	145	72	185	33
Developed, High Intensity	0	0	49	137	40	75	1	49	21
Barren Land	4	2	17	0	15	0	0	0	0
Deciduous Forest	152	15	145	61	200	46	32	21	0
Evergreen Forest	3	0	0	1	48	0	0	0	0
Mixed forest	1	0	2	4	10	1	1	1	0
Shrub/Scrub	0	1	8	1	0	0	0	1	0
Grassland/Herbaceous	74	36	110	10	45	0	0	2	0
Pasture/Hay	329	128	63	0	292	0	11	5	0
Cultivated Crops	1,301	220	590	12	847	0	4	0	0
Woody Wetlands	134	16	80	21	95	35	39	16	1
Emergent Herbaceous Wetlands	1	0	2	3	9	0	0	0	1
TOTAL	2,150	465	1,755	805	2,600	725	895	1,060	104

Table 4-7. Ox Creek watershed land use summary (percentage).

Land Use / Land Cover	Subwatershed Unit ID								
	A	B	C	D	E	F	G	H	I
Open Water	0%	--	--	--	0%	--	--	--	--
Developed, Open	3%	6%	19%	25%	24%	34%	54%	39%	19%
Developed, Low-Intensity	4%	4%	17%	17%	10%	25%	29%	35%	27%
Developed, Medium-Intensity	0%	0%	4%	28%	4%	20%	8%	17%	32%
Developed, High Intensity	--	--	3%	17%	2%	10%	0%	5%	20%
Barren Land	0%	0%	1%	--	1%	--	--	--	--
Deciduous Forest	7%	3%	8%	8%	8%	6%	4%	2%	--
Evergreen Forest	0%	--	--	0%	2%	--	--	--	--
Mixed forest	0%	--	0%	0%	0%	0%	0%	0%	--
Shrub/Scrub	--	0%	0%	0%	--	--	--	0%	--
Grassland/Herbaceous	3%	8%	6%	1%	2%	--	--	0%	--
Pasture/Hay	16%	28%	4%	--	11%	--	1%	0%	--
Cultivated Crops	61%	48%	33%	1%	32%	--	0%	--	--
Woody Wetlands	6%	3%	5%	3%	4%	5%	4%	2%	1%
Emergent Herbaceous Wetlands	0%	--	0%	0%	0%	--	--	--	1%

Note: "--" means that land use not present in the subwatershed unit
"0%" means land use present in subwatershed unit, but in amount less than 0.5%

The following paragraphs provide a brief overview of each unit. More detailed information is presented in the separate *"Ox Creek TMDL Development -- Linkage Analysis"* (Tetra Tech, 2012). This document contains ground views of each subwatershed outlet at MDEQ monitoring sites, as well as maps showing point source locations and land use. This document also concluded that the highest TSS concentrations observed during wet-weather events coincide with upper portions of the drainage that have a relatively lower percentage of urban development. Dominant sources include areas where soils are disturbed (e.g., construction activities including transportation projects, poorly managed agricultural fields).

Unit A. The *Yore – Stoeffer Headwaters* unit consists of the land area draining to the Yore – Stoeffer Drain upstream of Blue Creek Road. There are no point source facilities in this unit. Land use is dominated by cultivated crops (61%) with a noticeable amount as pasture / hay (16%). This particular subwatershed unit is largely agricultural and contains relatively little developed land within its drainage area. Water quality data collected at the outlet of unit A (Blue Creek Road) was limited to TSS sampling. With the exception of storm events, sampling results at this location indicate relatively low TSS levels compared to other Ox Creek sites.

Unit B. The *Upper Yore – Stoeffer* unit consists of the land area draining to the Yore – Stoeffer Drain between Blue Creek Road and Yore Avenue. There are no point source facilities in this unit. Land use is dominated by cultivated crops (48%) with a noticeable amount as pasture / hay (28%). This particular subwatershed unit is largely agricultural and contains relatively little developed land within its drainage area. The construction of US-31, located within this unit, was also occurring during our study time period. Water quality data collected at the outlet of unit B (Yore Avenue) consisted of water column TSS sampling. Sample results for TSS included several of the highest wet-weather levels in the entire Ox Creek watershed.

<u>Unit C</u>. The <u>*Middle Yore – Stoeffer*</u> unit consists of the land area draining to the Yore – Stoeffer Drain between Yore Avenue and Meadowbrook Road. There are five industrial facilities located in unit C that are covered under storm water permits, while two MS4 jurisdictions include lands in this unit *(Table 4-4)*. Major land uses include cultivated crops (33%), as well as low, medium, and high intensity development (24%). Subwatershed unit C is a transition area in terms of sources and land use. This is reflected in the water quality data collected at the outlet of unit C (Meadowbrook Road). Sample results for TSS show elevated levels during storm events indicating the potential for sediment and siltation to influence biological communities at this site.

<u>Unit D</u>. The <u>*Lower Yore – Stoeffer*</u> unit consists of the land area draining to the Yore – Stoeffer Drain between Meadowbrook Road and the confluence with Ox Creek. There are no point source facilities located in unit D. Three MS4 jurisdictions include lands in this unit *(Table 4-4)*. Features of interest in this unit include the development around the I-94 interchange at Pipestone Road and the Orchards Mall area. Land use is dominated by low, medium, and high intensity development (62%) followed by developed open land (25%). Subwatershed unit D contains a relatively large amount of impervious surfaces, which likely affects the hydrology and TSS loads in Ox Creek.

<u>Unit E</u>. The <u>*Ox Headwaters*</u> unit consists of the land area draining to Ox Creek from its source to its confluence with the Yore – Stoeffer Drain just below Crystal Avenue. There is one facility located in unit E that is covered under a COC for the discharge of non-contact cooling water and one facility covered under an industrial storm water permit, while three MS4 jurisdictions include lands in this unit *(Table 4-4)*. Land uses include a mix of cultivated crops (32%) and pasture / hay (11%), as well as low, medium, and high intensity development (16%). Subwatershed unit E is a transition area in terms of sources and land use. Water quality data collected above the outlet of unit E (Crystal Avenue) consisted of water column TSS sampling. Sample results for TSS did show elevated levels during storm events indicating the potential for sediment and siltation to influence biological communities at this site.

<u>Unit F</u>. The <u>*Upper Ox*</u> unit consists of the land area draining to Ox Creek from its confluence with the Yore – Stoeffer Drain just below Crystal Avenue to Empire Avenue. There is one facility located in unit F that is covered under a COC for the discharge of non-contact cooling water and four facilities covered under an industrial storm water permit, while one MS4 jurisdiction (Benton Harbor) includes lands in this unit *(Table 4-4)*. Land use is dominated by low, medium, and high intensity development (55%) followed by developed open land (34%). The riparian area along this reach of Ox Creek is largely woody wetlands (5% of the entire subwatershed unit). Subwatershed unit F contains a relatively large amount of impervious surface, which likely affects the hydrology of Ox Creek. Sample results for TSS did show elevated levels during storm events indicating the potential for sediment and siltation to influence biological communities at this site.

<u>Unit G</u>. The <u>*Middle Ox*</u> unit consists of the land area draining to Ox Creek from Empire Avenue to Britain Avenue. There are no point sources located in unit G, although one MS4 jurisdiction (Benton Harbor) includes lands in this unit *(Table 4-4)*. Land use is dominated by low, medium, and high intensity development (37%) and by developed open land (54%). Similar to unit F, the riparian area along this reach of Ox Creek is largely woody wetlands (4% of the entire subwatershed unit). Subwatershed unit G contains a relatively large amount of impervious surface, which likely affects the hydrology and TSS loads in Ox Creek.

<u>Unit H</u>. The *<u>Lower Ox</u>* unit consists of the land area draining to Ox Creek from Britain Avenue to Water Street. There is one facility located in unit H that is covered under a COC for the discharge of non-contact cooling water and two facilities covered under an industrial storm water permit, while one MS4 jurisdiction (Benton Harbor) includes lands in this unit *(Table 4-4)*. Features of interest include the high intensity development in downtown Benton Harbor at the lower end of this subwatershed unit. Land use is dominated by low, medium, and high intensity development (57%) and by developed open land (39%). Subwatershed unit H contains a relatively large amount of impervious surface, which likely affects the hydrology of Ox Creek. Sample results for TSS did show elevated levels during storm events indicating the potential for sediment and siltation to influence biological communities at this site.

<u>Unit I</u>. The *<u>Ox Outlet</u>* unit consists of the land area draining to Ox Creek from Water Street to North 8th Street. There is one facility located in unit I that is covered under a COC for the discharge of non-contact cooling water and one facility covered under an industrial storm water permit, while one MS4 jurisdiction (Benton Harbor) includes lands in this unit. Land use is dominated by low, medium, and high intensity development (79%) and by developed open land (19%). Subwatershed unit I contains a relatively large amount of impervious surface, which likely affects the hydrology and TSS loads in Ox Creek.

5. Linkage Analysis

Ox Creek is on Michigan's §303(d) list as a result of biological impairments *(Goodwin, et.al., 2012)*, specifically a poor macroinvertebrate community; therefore it is not meeting the OIALW designated use. Possible causes of non-attainment of the designated use have been listed as: other flow regime alterations, sedimentation / siltation, and solids (suspended / bedload). Sources identified by MDEQ for the aforementioned causes are stream bank modifications / destabilization, impervious surface / parking lot runoff, and urban runoff / storm sewers.

TMDL development requires a combination of technical analysis, practical understanding of important watershed processes, and interpretation of watershed loadings and receiving water responses to those loadings. An essential component of TMDL development is establishing a relationship between numeric indicators intended to measure attainment of designated uses and pollutant source loads. The linkage analysis examines connections between water quality targets, available data, and potential sources.

Biological data collected at several sites in the Ox Creek drainage resulted in the stream being placed on MDEQ's §303(d) non-attainment list. Biological assessments indicate the adverse effects of pollution. However, the specific pollutant(s) and source(s) are not known based on biological assessments alone. For this reason, MDEQ collected information on other potential stressors including flow, TSS, and toxic pollutants. The macroinvertebrate community structure data, coupled with qualitative observations, indicate that siltation due to excess sediment loads is a primary reason for biological impairments in Ox Creek. The sediment and water column toxics data were also evaluated as potential stressors. However, results of this analysis were inconclusive relative to identifying toxics as a stressor of macroinvertebrate populations in Ox Creek. As discussed earlier, TSS targets have been identified for use in the Ox Creek TMDL.

5.1 Indicators and Relationships

TMDL development for impaired streams based on biological monitoring data requires identification of one or more pollutants that is adversely affecting the aquatic community (macroinvertebrates in the case of Ox Creek). An important part of the linkage analysis is to examine the relationship between various key indicators (e.g., bioassessment, habitat, flow, TSS, water quality). This is a major consideration in identifying the pollutant(s) that will be the focus of any given TMDL. Figure 5-1 shows the relationship of the biological impairment to major processes of concern in Ox Creek. This diagram provides a framework for connecting information on the biological impairment to other key indicators at a watershed scale.

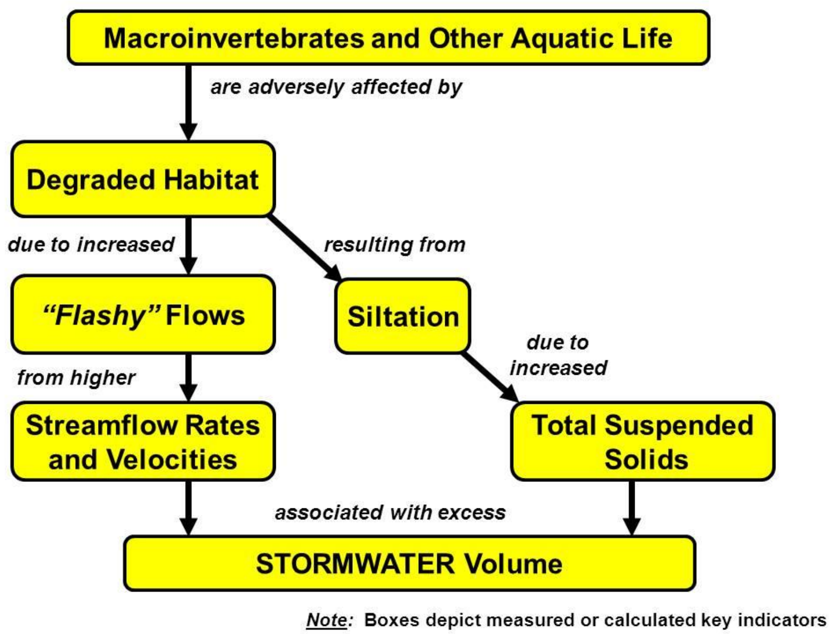


Figure 5-1. Relationship between key indicators in Ox Creek linkage analysis.

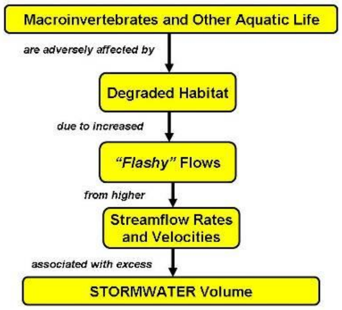
5.2 Total Suspended Solids Targets

The relationship between macroinvertebrates and key indicators shown in Figure 5-1 revolves around two critical paths. The first critical path (represented by the right side of the diagram) proceeds through total suspended solids. The macroinvertebrate community structure data coupled with qualitative habitat observations indicate that siltation due to excess total suspended solids loads is a cause of biological impairments in Ox Creek.

Because of this critical relationship and because total suspended solids is a pollutant, a 300 mg/L maximum daily TSS target is used for the Ox Creek TMDL. This target is supported by multiple lines of evidence. Following validation, this target and supporting methodology were applied to Ox Creek flow and TSS data. The analysis showed that Ox Creek generally exceeded threshold levels, consistent with bioassessment scores (See Section 3).

5.3 Flashiness and Stormwater Volume

The second critical path (represented by the left side of the diagram) emphasizes the need to also consider storm water volume. Flow rates affect TSS concentrations and loads. Hydrology can also be a major factor that affects aquatic communities (thus influencing bioassessment scores). Stable flow regimes support the establishment of healthy macroinvertebrate populations. *"Flashy"* flows (e.g., due to urban runoff) disrupt aquatic community structure and increase the transport of TSS loads that cause downstream siltation problems.



Morse (2001) and USEPA (2007) summarize a number of studies that describe the adverse effect of urbanization and altered hydrology on macroinvertebrate populations. For example, predator taxa are typically *"washed out"* from *"flashy"* systems due to increased stream velocities and flow volumes. Predator taxa tend to be more long-lived, with longer reproductive cycles than other taxa and may not be able to recover as quickly from increased frequency or magnitude of disturbance (Cassin et.al., 2005). Shredder taxa are also sensitive to *"flashiness"* and greatly increased frequencies of high pulses, which may increase export rates of coarse particulate organic material (CPOM) and decrease residence times of CPOM, both of which may reduce food availability and quality (Cassin et.al., 2005).

"Flashiness" is an indicator of the frequency and rapidity of short-term changes in stream flow, particularly during runoff events (Baker, et.al, 2004). Increased *"flashiness"* is typically associated with unstable watersheds and degraded habitat that adversely affects aquatic life. Fongers, et. al. (2007) provides a context to incorporate *"flashiness"* into the stormwater assessment process based on an examination of gaged streams and rivers across Michigan. Their study included a summary of R-B Flashiness Index quartile rankings by drainage area size for Michigan watersheds *(Figure 5-2)*. The R-B Flashiness Index score for lower Ox Creek is 0.52, which places it in the highest quartile for Michigan watersheds of comparable size.

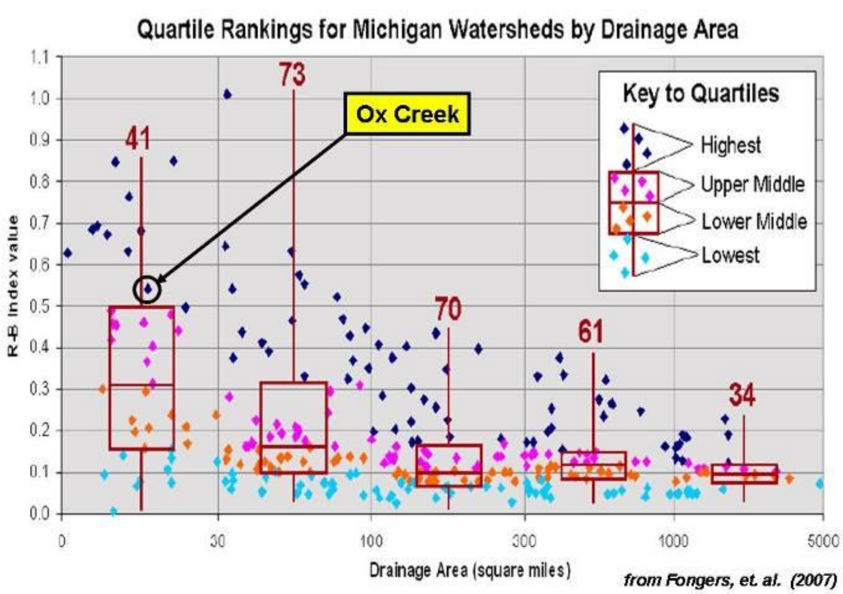


Figure 5-2. R-B flashiness index quartile rankings for Michigan rivers and streams.

5.4 Spatial Patterns

An examination of Ox Creek's overall response to watershed loading is a key part of the linkage analysis. This evaluation recognizes the varied nature of the drainage. Different land use patterns and source areas across the watershed contribute to the spatial variation. The subwatershed framework explained above is needed because different factors (e.g., land use, sources of sediment, amount of impervious cover, etc.) appear to influence the biological integrity, hydrology, and water quality patterns at each location.

Table 5-1 summarizes the major considerations and concerns based on information presented in the preceding sections of this linkage analysis. Specific concerns in the Ox Creek watershed vary by location. For example, the daily maximum TSS target is exceeded in the Yore-Stoeffer Drain (Units B,C) and the headwater area of Ox Creek (Unit E). A number of factors may contribute to elevated TSS loads in the upper watershed including erosion from cropland and loss of wetlands, as well as the straightening and deepening of drainage ditches.

"Flashy" flows, which disrupt macroinvertebrate community structure, exert a much greater adverse effect on the lower portions of Ox Creek (Units F,G,H,I). *"Flashy"* flows also transport elevated TSS loads from the upper portion of the watershed, causing excess siltation in the downstream reaches of Ox Creek. The following paragraphs provide a brief synopsis of information in this table.

Table 5-1. Ox Creek watershed loading considerations and concerns.

Unit	Cumulative Land Use		Biology *** (dominant taxa)	Total Suspended Solids	Hydrology
	(acres)	Estimated % Impervious Cover			
Yore – Stoeffer Drain					
A	2,150	1%	n.a.	---	*see Note*[1]
B	2,615	1%	n.a.	TSS Targets exceeded	
C	4,370	4%	*Physidae (Gastropods)*		
D	5,175	9%	n.a.	n.a.	*see Note*[2]
Ox Creek					
E	2,600	7%	*Amphipoda (scuds)*	TSS Targets exceeded	---
F	8,500	10%	n.a.	Siltation due to excess TSS loads	*"Flashy"* flows
G	9,395	10%	*Oligochaeta (worms)*		
H	10,455	11%	*Oligochaeta (worms)*		
I	10,559	12%	n.a.		

Notes:
- ***: Dominant taxa used as an example indicator to illustrate the variation in biological stressors that exist across the Ox Creek watershed.
- ---: no identified concern
- Note[1]: Loss of wetlands reducing floodwater storage; effect of agricultural drainage ditches
- Note[2]: Highest percentage of impervious cover in Ox Creek watershed
- n.a.: Not assessed

***Cumulative land use*.** Land use (and specifically impervious cover, or IC) is one characteristic that clearly affects all aspects of watershed loading and response; particularly hydrology, water quality, and biology. It is a major controlling factor that determines the amount of storm water runoff. The estimated percentage of impervious cover in the lower portions of Ox Creek (Units D, E, F, G, H, I) is significantly greater than in the upper subwatersheds (Units A, B, C). The increased percentage impervious surfaces subsequently cause *"flashy"* flows and generate excess stormwater volume.

Land use is also a major factor in generating elevated TSS loads in the upper subwatersheds. In addition to surface erosion from crop land, the loss of wetlands and riparian buffers in the upper Ox Creek and Yore –Stoeffer Drain units has reduced the ability of the watershed to retain sediment and store floodwaters. The straightening and deepening of ditches in the upper watershed also results in increased flow rates and stream velocities during storm events that contribute to increased channel scour and bank erosion.

Biology changes across the watershed. The variation in dominant taxa, shown in Table 5-1, is one way to illustrate the effect of different stressors at each location. For example, Physidae (or freshwater snails) are dominant in subwatershed unit C. This particular subwatershed is an area where TSS targets, as well as water quality criteria and PECs for several PAHs, are all exceeded. MDEQ's Procedure 51 specifically uses the percentage of isopods, snails, and leeches as a metric. These organisms show a high tolerance to a variety of both physical and chemical parameters. High percentages of these organisms at a sample site are strong evidence of stream degradation.

Total Suspended Solids targets are exceeded in upper portions of the watershed; notably the Yore-Stoeffer Drain (Units B,C) and the headwater area of Ox Creek (Unit E). An important part of the linkage analysis is to examine the effect of these TSS exceedances across the entire watershed, particularly their role in causing downstream siltation problems. This closer examination is best accomplished through a loading analysis.

Figure 5-3 and Figure 5-4 depict the loading of TSS in the Ox Creek watershed for two wet-weather surveys as a longitudinal profile. These graphs integrate information presented in the analysis of individual subwatersheds (Tetra Tech, 2012). The TSS exceedances occur in the two primary upstream tributaries: Yore-Stoeffer Drain (Units B,C) and the Ox Creek headwater area (Unit E). The individual tributary loads form the total TSS load to the mainstem of Ox Creek below their confluence. Each tributary load is shown separately. The shaded box is the Yore-Stoeffer TSS load (represented by data collected at the Meadowbrook Road site); the empty box is the Ox Creek headwaters TSS load (represented by data collected at the Crystal Avenue site). To depict the sum of these loads, the Yore-Stoeffer Drain TSS load is also shown on top of the Ox Creek headwaters TSS load in each figure.

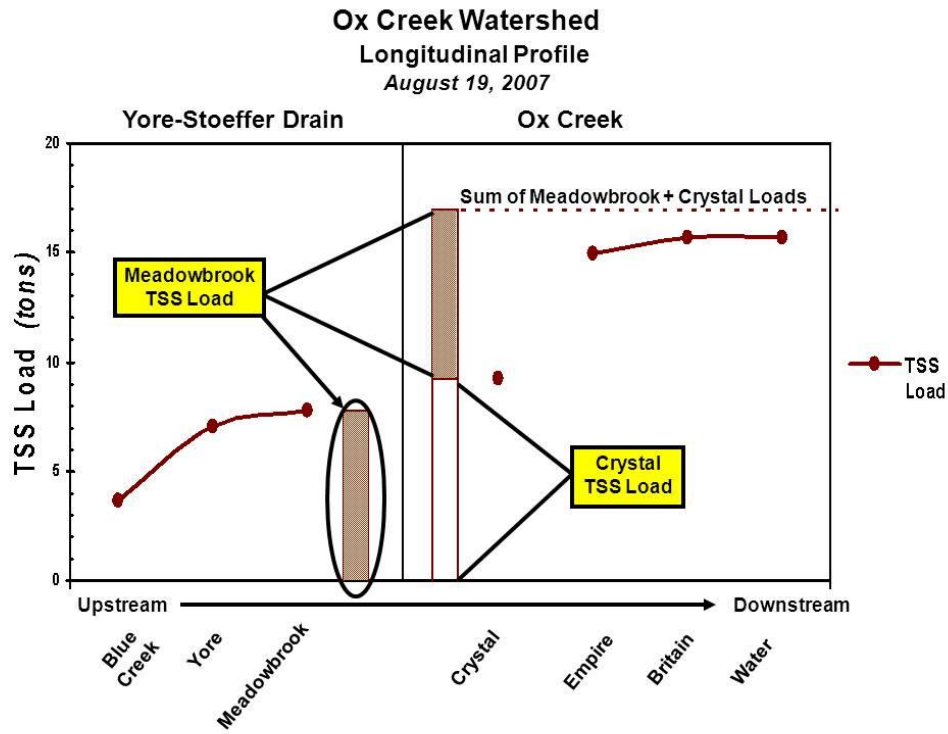


Figure 5-3. TSS loads in the Ox Creek watershed for wet weather event #1.

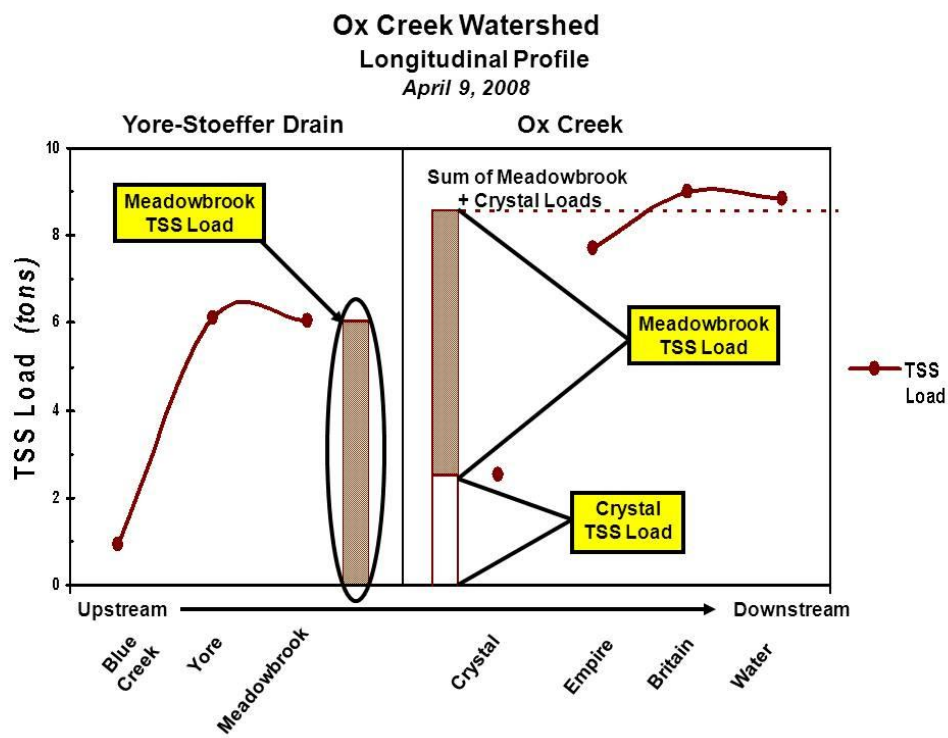


Figure 5-4. TSS loads in the Ox Creek watershed for wet weather event #2.

In both storm events, the sum of the tributary TSS loads either exceeded or comprised a significant majority of the TSS loads that were monitored downstream. This indicates that TMDL implementation efforts to meet the TSS targets in the upper subwatershed units should address sediment sources in these areas. This includes erosion from land surfaces where soil has been disturbed. Potential areas to be examined in this source category include:

- construction sites
- poorly managed agricultural fields
- riparian corridors in a degraded condition
- commercial areas with accumulated sediment on impervious surfaces that can be delivered to the stream (which could also be a source of PAHs and heavy metals)

In addition to these potential source areas, the role of ditches or gullies should also be evaluated as contributors of sediment and TSS to Ox Creek. Implementation efforts to meet the TSS targets in the upper subwatershed units will also reduce downstream loads and siltation problems.

Hydrology and flow rates affect TSS concentrations. Stable flow regimes also support the establishment of healthy macroinvertebrate populations. As indicated in Table 5-1, the primary concern regarding hydrology in Ox Creek is *"flashy"* flows in the lower subwatersheds (Units F,G,H,I). *"Flashy"* flows disrupt aquatic community structure and increase the transport of TSS loads that cause downstream siltation problems. As discussed earlier, the R-B Flashiness Index score for lower Ox Creek at Britain Avenue is 0.52, which places it in the highest quartile for Michigan watersheds of comparable size.

Table 5-1 provides an estimate the cumulative level of impervious surfaces at the outlet of each subwatershed unit. During storm events, rain falling on impervious surfaces produces higher volumes of runoff (due to the decreased ability of the subwatershed to infiltrate water). These higher volumes occur in shorter *"bursts"*, resulting in *"flashy"* flows. Not surprisingly, the problems with *"flashy"* flows in Ox Creek appear to coincide with those subwatershed units that have higher amounts of impervious surfaces.

Another important part of the linkage analysis is to use the data to examine where significant amounts of water are being delivered to Ox Creek. Flow information collected during the TSS survey can be used to develop a water volume analysis (somewhat analogous to the loading analysis for TSS). Figure 5-5 and Figure 5-6 depict the water volume in Ox Creek for the first two wet-weather surveys. These graphs integrate information on flow and in the analysis of individual subwatersheds (Tetra Tech, 2012).

Individual tributary flow volumes are shown separately. To depict the sum of the volumes, the Yore-Stoeffer Drain at Meadowbrook volume is also shown on top of the Ox Creek at Crystal volume. In the case of both storm events, a significant volume of water is added to Ox Creek downstream from these two sites. This is not surprising given the increased levels of impervious surfaces that occur in subwatersheds D, F, G, H, and I. This highlights the need to also focus on reducing flow volumes (i.e, quantity) when addressing biological impairments in Ox Creek.

In addition, management practices in the upper subwatershed have contributed to altered hydrology. The loss of wetlands for floodwater storage coupled with the straightening and deepening of ditches also increase the overall "flashiness" of flows in Ox Creek.

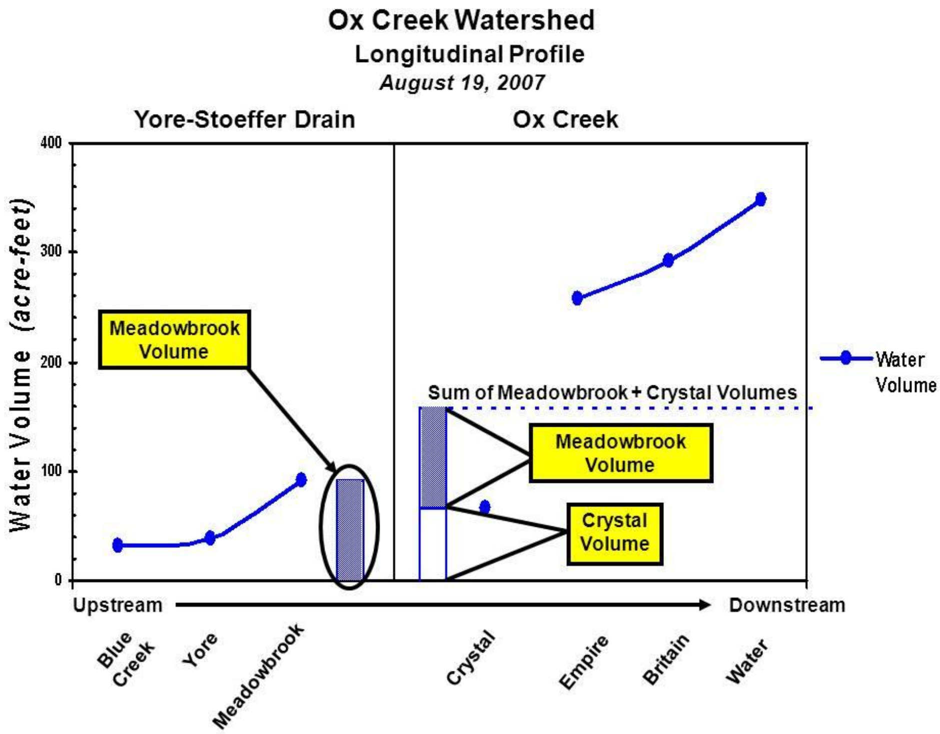


Figure 5-5. Water volume in the Ox Creek watershed for wet weather event #1.

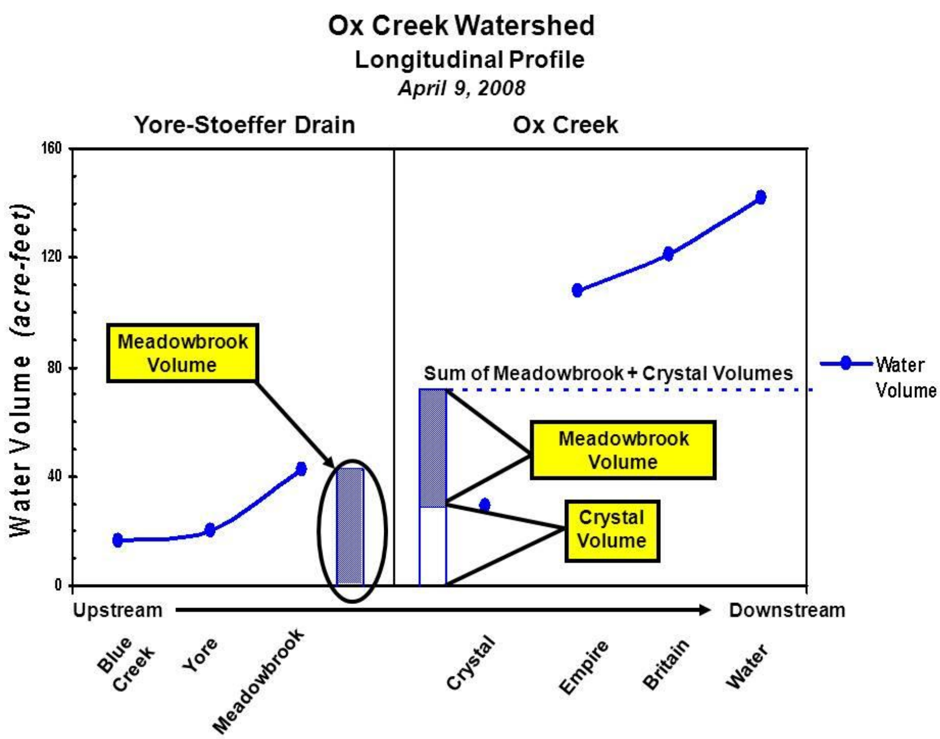


Figure 5-6. Water volume in the Ox Creek watershed for wet weather event #2.

The net effect of altered hydrology in the Ox Creek watershed is that concentration targets alone will not solve water quality problems associated with excess siltation. Siltation causing the biological impairments in Ox Creek is the result of excess TSS loads. These loads are the product of the TSS concentrations times the corresponding flow times a conversion factor. Through this relationship, the flow regime directly affects the total maximum allowable daily load, as illustrated in Figure 5-7.

The connection between the TSS loads and flow is shown using the duration curve framework. The two unit area load duration curves depicted in Figure 5-7 use flow data from Ox Creek and from the Galien River. It should be noted that the Galien River had the highest coefficient of determination for observed flow data between other USGS sites examined and Ox Creek. The coefficient of determination provides a measure of how useful each gaged location may be in estimating flows in Ox Creek. In addition, macroinvertebrate scores for the Galien River were rated as acceptable using Michigan's Procedure 51.

The graph shown in Figure 5-7 is developed by simply dividing all TSS load values along each duration curve by the corresponding watershed drainage area. Unit area load duration curves enable a meaningful comparison of characteristics between watersheds of different size (a technique that normalizes the information).

As shown in Figure 5-7, the daily maximum loading capacity for the Galien River is 6.2 tons/square mile per day, based on the 300 mg/L TSS concentration target. This compares to a value of 10.4 tons/square mile per day using the same 300 mg/L TSS target and the existing Ox Creek flow duration curve measured at Britain Avenue.

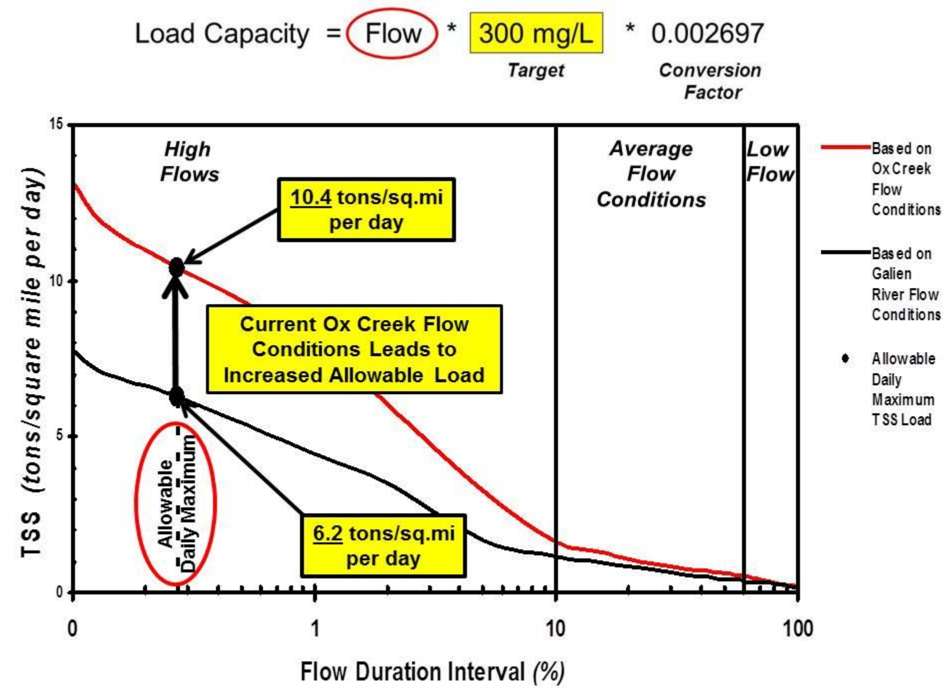


Figure 5-7. Relative effect of flow on increased maximum daily TSS loads contributing to siltation.

(using 300 mg/L as the concentration target).

5.5 Summary

The linkages described in Figure 5-1 and Table 5-1 reiterate the importance of TSS and flow to address biological impairments in Ox Creek. The linkages and the array of concerns point to the need for a range of different management strategies to address problems causing non-attainment of Michigan's OIALW designated use in the Ox Creek watershed.

The watershed scale analysis of TSS loads highlights the need for erosion control in the upper portions of the watershed. The highest TSS concentrations observed during wet-weather events coincide with upper portions of the drainage that have a relatively lower percentage of urban development. Dominant sources include areas where soils are disturbed (e.g., construction activities including transportation projects, poorly managed agricultural fields). The major concern is where sediment accumulated on surfaces and exposed soils, in gullies or other areas susceptible to erosion and is quickly washed away. Sediment from these source areas can be transported to the stream through erosion processes. Areas adjacent to the stream provide the most direct delivery path of sediment to Ox Creek receiving waters. As a result, riparian management is typically associated with erosion control efforts.

Sediment loads originating in the upper portions of the Ox Creek watershed are transported to the lower reaches. This contributes to siltation problems downstream that degrade habitat. Thus, implementation of erosion control practices will also reduce TSS loads that contribute to downstream siltation problems. In addition, the loss of wetlands in the upper watershed reduces the ability of the Ox Creek drainage system to retain eroded sediment. This loss of wetlands in turn increases TSS loads that contribute to downstream problems.

Finally, *"flashy"* flows that can disrupt macroinvertebrate community structure are also a problem in the lower reaches of Ox Creek. These *"flashy"* flows are associated with urban runoff. The watershed scale analysis of flow volumes *(Figure 5-5 and Figure 5-6)* further describes the concern. This assessment highlights the need for storm water management, particularly strategies that reduce flow volumes.

6. TMDL Development

The TMDL represents the maximum loading that can be assimilated by a waterbody while still achieving the applicable water quality standard. The applicable designated use for the Ox Creek TMDL is the protection of *"other indigenous aquatic life and wildlife"*. The primary narrative target is the restoration of biological communities to achieve an *"acceptable"* score using Procedure 51 (i.e., a score greater than -4). Based on an evaluation of macroinvertebrate and sediment data for other southern Michigan streams that attain the OIALW designated use, a daily maximum of 300 mg/L TSS has been identified as a numeric target that will protect aquatic life uses in Ox Creek.

6.1 Loading Capacity

Under the regulatory framework for development of TMDLs, calculation of the loading capacity for impaired segments identified on the §303(d) list is an important first step. EPA's regulation defines loading capacity as *"the greatest amount of loading that a water can receive without violating water quality standards"*. The loading capacity is the basis of the TMDL and provides a measure against which attainment with WQS will be evaluated. The loading capacity also guides pollutant reduction efforts needed to bring a water into compliance with standards.

Typically, loads are expressed as mass per time, such as pounds per day. The loading capacity of a stream is determined using:

- ♦ the water quality criterion or target value; and
- ♦ a design flow for the receiving water, which represents a secondary target that reflects critical conditions.

Critical conditions used for TMDL development in Michigan are established with an acceptably low frequency of occurrence that, if protected for, should also be protective of other more frequent occurrences (Goodwin, 2007). Critical conditions are typically defined as an exceedance flow. An exceedance flow is a statistically determined flow that is exceeded a specific percentage of time using a flow duration curve. For example, the 95% exceedance flow is the flow expected to be exceeded 95% of the time; this reflects low flow conditions. Similarly, the 1-day exceedance flow represents the daily average flow expected to be exceeded one day each year (i.e., the one divided by 365 days, or 0.274% of the time), which reflects high flow conditions.

Critical conditions for the applicability of WQS are given in MDEQ's Rule 90 (R 323.1090). For water quality problems associated with low flow conditions, R323.1090(2)(a) defines this as the 95% exceedance flow. However, Rule 90 also provides that *"alternate design flows may be used for intermittent wet weather discharges as necessary to protect the designated uses of the receiving water"* [R 323.1090(4)]. The poor biological communities and habitat degradation are the result of excessive sediment loads often associated with high flow conditions, as described in development of the 300 mg/L TSS target.

The TSS target is a daily maximum value, which recognizes that sediment concentrations vary as a function of flow. Because of the direct relationship between TSS and flow, the 1-day maximum exceedance flow is used to represent critical conditions that determine Ox Creek watershed TMDL loading capacities. In addition to reducing TSS concentrations, a reduction in stormwater volume should help address aquatic life impairments.

The TSS loading capacity, expressed as tons per day, is determined by using the following equation:

$$\text{Load Capacity} = \text{Flow} * \text{TSS Target} * 0.002697$$

where:

Load Capacity = maximum daily load *(tons / day)*
Flow = design flow *(cubic feet per second)* = 1-day exceedance flow
TSS Target = 300 mg/L
0.002697 = conversion factor

Table 6-1 presents the TSS loading capacity at the outlet of each subwatershed. The 1-day exceedance design flow for each subwatershed is determined using the Galien River gage as a representative site based on a drainage area weighting factor (i.e., each subwatershed area divided by the Galien River drainage area). As stated earlier (Section 5.4), the Galien River had the highest coefficient of determination for observed flow data between other USGS sites examined and Ox Creek. In addition, macroinvertebrate scores for the Galien River were rated as acceptable using Michigan's Procedure 51.

Table 6-1. Ox Creek watershed TSS loading capacities.

Total Suspended Solids Loading Capacity Summary					
Subwatershed		Cumulative Drainage Area *(sq.mi.)*	1-day Maximum Exceedance Flow *(cfs)*	TSS Loading Capacity *(tons/day)*	
				Subwatershed	*Cumulative*
A	***Yore – Stoeffer Headwaters***	3.36	46.2	37.4	37.4
B	***Upper Yore - Stoeffer***	4.09	56.3	8.1	45.5
C	***Middle Yore - Stoeffer***	6.83	93.9	30.5	76.0
D	***Lower Yore - Stoeffer***	8.09	111.3	14.0	90.0
E	***Ox Headwaters***	4.06	55.8	45.2	45.2
F	***Upper Ox***	13.28	182.7	12.6	147.8
G	***Middle Ox***	14.68	201.9	15.6	163.4
H	***Lower Ox***	16.34	224.8	18.4	181.8
I	***Ox Outlet***	16.50	227.0	1.8	183.6

6.2 Allocations

TMDLs (also referred to as Loading Capacities) are comprised of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a Margin of Safety (MOS), either implicitly or explicitly, that accounts for uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

$$\text{TMDL(or LC)} = \Sigma\text{WLAs} + \Sigma\text{LAs} + \text{MOS}$$

6.2.1 Waste Load Allocations

As previously mentioned in Section 4.2.1, there are currently no facilities in the Ox Creek watershed that have been issued an individual NPDES permit. Currently, there are four facilities in the Ox Creek watershed covered under the general permit for *"Non Contact Cooling Water" (Table 4-2)*. Effluent limits in the general permit for *"Non Contact Cooling Water"* states: *"The receiving water shall contain no turbidity, color, oil films, floating solids, foams, settleable solids, suspended solids, or deposits as a result of this discharge in unnatural quantities which are or may become injurious to any designated use"*. Therefore, no WLA is needed for these facilities.

Municipal and Transportation Stormwater. Individual WLAs must be established for each MS4 permittee. In this TMDL, the WLA is determined by the amount of area in the Ox Creek watershed for which each permittee is responsible. Figure 6-1 provides an overview of locational information, which includes the U.S. Census Urbanized area (2010), Benton Harbor city limits, roads maintained by the Michigan Department of Transportation (MDOT), and roads maintained by the Berrien County Road Commission (BCRC). In addition, the Berrien County Drain Commission (BCDC) is given a WLA to cover MS4 responsibilities for county drains under its jurisdiction.

For the incorporated area of Benton Harbor, the percentage of its jurisdictional area relative to that of the entire subwatershed unit was used to apportion the load. The city's lands are included in four subwatersheds (F, G, H, I). Table 6-2 summarizes information used to determine Benton Harbor's MS4 WLA. This includes the loading capacity for each individual subwatershed unit, subwatershed unit size, and the amount of Benton Harbor's incorporated area in each subwatershed unit. For example:

MS4 WLA for Unit F = (46 acres / 725 acres) * 12.6 tons / day = 0.80 tons/day

Table 6-2. Ox Creek MS4 waste load allocation for Benton Harbor.

Subwatershed Unit		Loading Capacity *(tons/day)*	Area *(acres)*		MS4 TSS Wasteload Allocation *(tons/day)*
			Total	*Benton Harbor*	
F	***Upper Ox***	12.6	725	46	0.80
G	***Middle Ox***	15.6	895	283	4.93
H	***Lower Ox***	18.4	1,060	419	7.27
I	***Ox Outlet***	1.8	104	104	1.55 ***
				TOTAL	14.80

Note: *** Adjusted to account for industrial stormwater WLA *(see Table 6-6, Column 5)*.

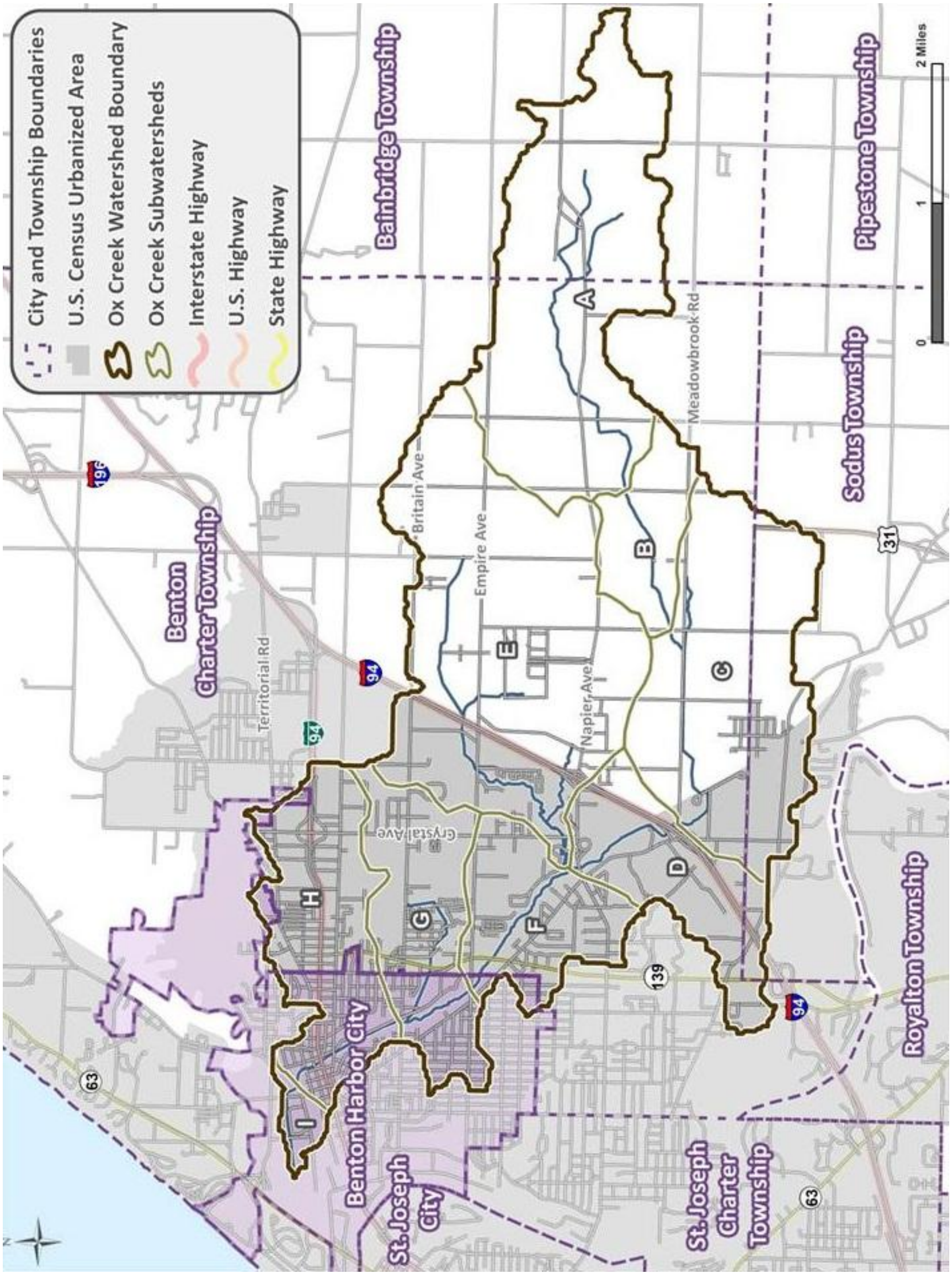


Figure 6-1. MS4 urbanized area in Ox Creek watershed.

Unincorporated Berrien County includes three permittees: the MDOT, the Road Commission, and the Drain Commission. The WLA for MDOT is determined based on the transportation right-of-way under its jurisdiction (a 50-foot right-of-way on either side of the road centerline is assumed). Table 6-3 summarizes information used to calculate MDOT's WLA. Similarly, the MS4 WLA for BCRC is determined based on the transportation right-of-way under its jurisdiction that also lies within the U.S. Census Bureau Urbanized Area (a 30-foot right-of-way on either side of the road centerline is assumed). Table 6-4 summarizes information used to calculate BCRC's WLA. For example:

MDOT WLA for Unit B = (8.48 acres / 465 acres) * 8.1 tons / day = 0.15 tons/day

Table 6-3. Ox Creek MDOT waste load allocation.

Subwatershed Unit		Loading Capacity *(tons/day)*	Area *(acres)*		Road Length *(miles)*	NPDES TSS Wasteload Allocation *(tons/day)*
			Total	*MDOT (100 ft. width)*	*MDOT*	
B	***Upper Yore - Stoeffer***	8.1	465	8.48	0.70	0.15
C	***Middle Yore - Stoeffer***	30.5	1,755	8.12	0.67	0.14
D	***Lower Yore - Stoeffer***	14.0	805	93.45	7.71	1.63
E	***Ox Headwaters***	45.2	2,600	70.67	5.83	1.23
F	***Upper Ox***	12.6	725	9.33	0.77	0.16
G	***Middle Ox***	15.6	895	7.52	0.62	0.13
H	***Lower Ox***	18.4	1,060	45.58	3.76	0.79
					TOTAL	4.23

Table 6-4. Ox Creek MS4 waste load allocation for Berrien County Road Commission.

Subwatershed Unit		Loading Capacity *(tons/day)*	Area *(acres)*		Road Length *(miles)*	MS4 TSS Wasteload Allocation *(tons/day)*
			Total	*BCRC (60 ft. width)*	*BCRC*	
C	***Middle Yore - Stoeffer***	30.5	1,755	45.82	6.30	0.80
D	***Lower Yore - Stoeffer***	14.0	805	65.09	8.95	1.13
E	***Ox Headwaters***	45.2	2,600	44.80	6.16	0.78
F	***Upper Ox***	12.6	725	91.93	12.64	1.60
G	***Middle Ox***	15.6	895	82.47	11.34	1.44
H	***Lower Ox***	18.4	1,060	126.04	17.33	2.19
					TOTAL	7.94

The MS4 WLA for BCDC is determined based on the amount of developed land under its jurisdiction that also lies within the U.S. Census Bureau Urbanized Area, which is not part of an open drain. The amount of developed land is based on 2006 National Land Cover Dataset (NLCD) data. Information describing the developed land that flows to an open drain was provided by BCDC. Table 6-5 summarizes information used to calculate BCDC's WLA. For example:

BCDC WLA for Unit D = (508 acres / 805 acres) * 14.0 tons / day = 8.84 tons/day

Table 6-5. Ox Creek MS4 waste load allocation for Berrien County Drain Commission.

Subwatershed		Loading Capacity (tons/day)	Area (acres)		MS4 TSS Wasteload Allocation (tons/day)
			Total	*Berrien County MS4 Area Developed Land*	
C	***Middle Yore - Stoeffer***	30.5	1,755	230	3.99
D	***Lower Yore - Stoeffer***	14.0	805	508	8.84
E	***Ox Headwaters***	45.2	2,600	266	4.62
F	***Upper Ox***	12.6	725	434	7.54
G	***Middle Ox***	15.6	895	276	4.82
H	***Lower Ox***	18.4	1,060	169	2.93
				TOTAL	32.74

Industrial Stormwater. As noted in the Source Assessment (Section 4), several facilities located in the Ox Creek watershed have industrial storm water permits *(Table 4-5)*. These facilities also require WLAs. Using the same methodology to develop MS4 stormwater and transportation WLAs, allocations have been calculated based on facility area. Exact areas were not available for industrial facilities listed in Table 4-5. A subset of these facilities was reviewed using air photos and GIS software to develop an average estimate of 14.4 acres for each site. This acreage value was divided by the entire watershed area (10,559 acres from Table 2-1), then multiplied by the loading capacity for the entire watershed (183.6 pounds per day from Table 6-1), or:

Industrial Facility WLA= (14.4 acres / 10,559 acres) * 183.6 tons / day = 0.25 tons/day

Stormwater WLA Summary. MS4 and transportation WLAs are summarized by individual subwatershed unit in Table 6-6. This table also provides information that enables the translation of those subwatershed allocation values into permittee group MS 4 WLAs. It identifies the percentage of the subwatershed unit MS4 WLA that is allocated to each permittee group.

Table 6-6. Individual NPDES stormwater WLAs in Ox Creek watershed.

Subwatershed		NPDES Stormwater TSS WLA *(tons/day)*	NPDES Stormwater Permittee Subwatershed Unit WLA				
			1	2	3	4	5
A	***Yore – Stoeffer HW***	---	---	---	---	---	---
B	***Upper Yore - Stoeffer***	0.15	---	0.15	---	---	---
C	***Middle Yore - Stoeffer***	6.18	---	0.14	0.80	3.99	1.25
D	***Lower Yore - Stoeffer***	11.60	---	1.63	1.13	8.84	---
E	***Ox Headwaters***	6.88	---	1.23	0.78	4.62	0.25
F	***Upper Ox***	11.10	0.80	0.16	1.60	7.54	1.00
G	***Middle Ox***	11.32	4.93	0.13	1.44	4.82	---
H	***Lower Ox***	13.68	7.27	0.79	2.19	2.93	0.50
I	***Ox Outlet***	1.80	1.55	---	---	---	0.25
	TOTAL	62.71	14.55	4.23	7.94	32.74	3.25

NPDES Stormwater Permittees:

1	MIG610243	City of Benton Harbor MS4
2	MI0057364	Michigan DOT MS4
3	MIG610228	Berrien Co. – Road Commission MS4
4	MIG610229	Berrien Co. – Drain Commission MS4
5	Listed in Table 4-5	Industrial stormwater *(0.25 tons / day per facility)*

6.2.2 Load Allocations

Load allocations were calculated by subtracting the WLA *(Table 6-6)* from the TMDL *(Table 6-1)*. Individual LAs were not assigned to specific potential nonpoint source categories (ex. row crop agriculture, orchards, etc.). Instead, load allocations were assigned to each township based on jurisdictional area. Jurisdictional areas for the Ox Creek watershed are summarized in Table 6-7. Individual LAs assigned to each township is based on percentage of its jurisdictional area. Benton Harbor is not given a LA because it is assumed that very little land is not included in their MS4 WLA. Table 6-8 summarizes load allocations by subwatershed unit and by township. For example, the load allocation for Benton Township in subwatershed unit A is calculated by deriving the percent area in unit A *(Table 6-7)* and multiplying by the total load allocation for subwatershed unit A *(Table 6-8)*, or:

Benton Unit A LA= (1,097 acres / 2,150 acres) * 37.4 tons / day = 19.08 tons/day

Table 6-7. Ox Creek watershed jurisdictional area summary.

Subwatershed Unit		Area *(acres)*				
		Subwatershed Unit	Township			*Benton Harbor*
			Benton	*Bainbridge*	*Sodus*	
A	***Yore – Stoeffer HW***	2,150	1,097	1,053	---	---
B	***Upper Yore - Stoeffer***	465	465	---	---	---
C	***Middle Yore - Stoeffer***	1,755	1,099	---	656	---
D	***Lower Yore - Stoeffer***	805	725	---	80	---
E	***Ox Headwaters***	2,600	2,600	---	---	---
F	***Upper Ox***	725	679	---	---	46
G	***Middle Ox***	895	612	---	---	283
H	***Lower Ox***	1,060	641	---	---	419
I	***Ox Outlet***	104	---	---	---	104
	TOTAL	10,559	7,918	1,053	736	852

Table 6-8. Load allocations for total suspended solids in Ox Creek watershed.

Subwatershed Unit		Area *(acres)*	TSS Load Allocation *(tons/day)*				
			Township			Subwatershed	Cumulative
			Benton	*Bainbridge*	*Sodus*		
A	***Yore – Stoeffer HW***	2,150	19.08	18.32	---	37.40	37.40
B	***Upper Yore - Stoeffer***	465	7.95	---	---	7.95	45.35
C	***Middle Yore - Stoeffer***	1,755	15.23	---	9.09	24.32	69.67
D	***Lower Yore - Stoeffer***	805	2.16	---	0.24	2.40	72.07
E	***Ox Headwaters***	2,600	38.32	---	---	38.32	38.32
F	***Upper Ox***	725	1.50	---	---	1.50	111.89
G	***Middle Ox***	895	4.28	---	---	4.28	116.17
H	***Lower Ox***	1,060	4.72	---	---	4.72	120.89
	TOTAL	10,559	93.24	18.32	9.33	120.89	

6.3 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations at 40 CFR 130.7 require that *"TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety (MOS) which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality."* The margin of safety (MOS) can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991).

A MOS is implicit in a biota TMDL because the quality of the biological community, its integrity, and overall composition represent an integration of the effects of spatial and temporal variability in sediment loads to the aquatic environment. Ultimately it is the reflection by the biological community, signified by an acceptable or higher rating using Procedure 51, which is the goal of this TMDL thereby providing a MOS for the secondary numeric TSS target. Follow-up biological and habitat quality assessments will be conducted to determine the progress in attaining the TMDL goals.

6.4 Seasonal Variation

TMDLs are required to consider critical conditions and seasonal variation for streamflow, loading, and water quality parameters. The critical condition is the set of environmental conditions for which controls designed to protect water quality will ensure attainment of water quality standards for all other conditions. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable.

This TMDL utilized the Load Duration Curve (LDC) methodology to evaluate Ox Creek monitoring data under different flow conditions, which is described in the *"Watershed Characterization and Source Assessment"* (Tetra Tech, 2010) and the *"Linkage Analysis"* (Tetra Tech, 2012). This approach demonstrated that TSS concentrations and loads exert the greatest adverse effect on aquatic life under high flow conditions. The duration curve methodology considers both seasonal and flow variation; it was used to help develop TSS and hydrology-based targets. This, in turn, defined 1-day maximum loading capacities in the Ox Creek watershed. The LDC methodology provides an excellent way to graphically present the instantaneous load and evaluate seasonal flow variations. Utilizing the load duration method ensures seasonal variability is taken into consideration in the calculation of the TMDL.

6.5 TMDL Summary

Individual components for the Ox Creek watershed TMDL are summarized in Table 6-9. Allocations fall into two categories: NPDES stormwater WLA (which includes both MS4 and industrial stormwater) and LA (which accounts for both NPS and background).

Table 6-9. Ox Creek watershed total suspended solids TMDL summary.

Subwatershed		Area *(acres)*	TSS Cumulative Loading Capacity *(tons/day)*	TSS Subwatershed Allocations *(tons/day)*		Margin of Safety
				NPDES Stormwater WLA	LA	
A	***Yore – Stoeffer HW***	2,150	37.4	0.00	37.40	***Implicit***
B	***Upper Yore - Stoeffer***	465	45.5	0.15	7.95	
C	***Middle Yore - Stoeffer***	1,755	76.0	6.18	24.32	
D	***Lower Yore - Stoeffer***	805	90.0	11.60	2.40	
E	***Ox Headwaters***	2,600	45.2	6.88	38.32	
F	***Upper Ox***	725	147.8	11.10	1.50	
G	***Middle Ox***	895	163.4	11.32	4.28	
H	***Lower Ox***	1,060	181.8	13.68	4.72	
I	***Ox Outlet***	104	183.6	1.80	0.00	
	TOTAL	10,559	183.6	62.71	120.89	***Implicit***

7. Reasonable Assurance

Reasonable assurance (RA) activities are programs that are in place to assist in meeting the Ox Creek watershed TMDL allocations and applicable water quality standards. The RA evaluation provides documentation that the nonpoint source reduction required to achieve proposed load allocations developed in point source / NPS (or mixed-source) TMDLs can and will occur over time. A reasonable assurance evaluation typically describes the load allocation in the context of implementation activities, links the WLA to the LA, examines any implementation schedules, milestones, and tracking systems, as well as lists potential follow-up actions.

7.1 Reduction Estimates

The technical analysis used to develop TSS targets included an assessment of existing conditions in Ox Creek based on information from MDEQ survey data. The daily maximum TSS values from the MDEQ 2007-2008 survey data *(Table 7-1)* are the starting point used to develop estimates of the existing maximum daily TSS load at each site. Load reduction estimates are derived from this survey data using the multiple averaging period method used to define TSS targets (see Section 3.2; also TetraTech, 2011and TetraTech, 2012).

The multiple averaging period method is used because the MDEQ survey values reflect two “snapshot” wet-weather events, which may not represent the maximum TSS value expected at each site over a longer time period. The MDEQ flow estimates from the water level recorder information are used to estimate maximum daily flows at each site based on drainage area weighting, similar to development of the loading capacities (see Section 6.1).

Table 7-2 summarizes load reduction estimates. As discussed in the linkage analysis, implementation efforts should focus on erosion control in the upper portions of the Ox Creek watershed. Load reduction efforts in the lower portion of Ox Creek should focus on reducing storm water volumes delivered to the stream.

Table 7-1. Maximum TSS values by subwatershed from DEQ sampling.

Subwatershed			**Maximum MDEQ TSS Survey Value** *(mg/L)*	**Date Maximum MDEQ TSS Survey Value Observed**
Unit	**Name**	**Outlet Location**		
A	Yore –Stoeffer Headwaters	Blue Creek Road	250	8/19/2007
B	Yore –Stoeffer Headwaters	Yore Avenue	3,200	4/9/2008
C	Yore –Stoeffer Headwaters	Meadowbrook Road	350	4/9/2008
E	Ox Headwaters	Crystal Avenue	370	4/9/2008
F	Upper Ox	Empire Avenue	140	8/19/2007
G	Middle Ox	Britain Avenue	230	4/9/2008
H	Lower Ox	Water Street	140	8/19/2007

Table 7-2. Total suspended solids reduction estimates at key points in Ox Creek watershed.

Subwatershed		Load (tons/day)		Load Reduction
		Capacity	Existing	
A	***Yore – Stoeffer HW***	37.4	57	35%
B	***Upper Yore - Stoeffer***	45.5	518	91%
C	***Middle Yore - Stoeffer***	76.0	157	52%
D	***Lower Yore - Stoeffer***	90.0	180	50%
E	***Ox Headwaters***	45.2	87	48%
F	***Upper Ox***	147.8	160	8%
G	***Middle Ox***	163.4	266	38%
H	***Lower Ox***	181.8	197	7%
I	***Ox Outlet***	183.6	199	7%

7.2 Current Reasonable Assurance Activities

7.2.1 NPDES

Industrial Storm Water. Federal regulations require certain industries to apply for an NPDES permit if storm water associated with industrial activity at the facility discharges into a separate storm sewer system or directly into a surface water. A storm water permit is not required if storm water does not discharge from the facility or is discharged into a sewer system that leads to a Wastewater Treatment Plant.

The COCs for the general industrial storm water permit (MIS310000) listed in Table 4-5, specify that facilities need to obtain a certified operator who will have supervision and control over the control structures at the facility, eliminate any unauthorized non-storm water discharges, and develop and implement the Storm Water Pollution Prevention Plan for the facility. The permittee shall determine whether its facility discharges storm water to a water body for which the MDEQ has established a TMDL. If so, the permittee shall assess whether the TMDL requirements for the facility's discharge are being met through the existing Storm Water Pollution Prevention Plan controls or whether additional control measures are necessary. The permittee's assessment of whether the TMDL requirements are being met shall focus on the effectiveness, adequacy, and implementation of the permittee's Storm Water Pollution Prevention Plan controls. The applicable TMDLs will be identified in the COC issued under this permit.

Municipal Separate Storm Sewer Systems. The TMDL watershed receives storm water discharges from Phase II community MS4s (City of Benton Harbor, Berrien County Road Commission, and Berrien County Drain Commission). These regulated MS4s have obtained permit coverage under Michigan's NPDES MS4 Watershed-Based (MIG610000) Storm Water General Permit (effective 2003). In addition, the MDOT has a statewide NPDES Individual Storm Water Permit (MI0057364) to cover storm water discharges from its MS4. This statewide permit requires the permittee to reduce the discharge of pollutants to the maximum extent practicable and employ Best Management Practices to meet the permittee's responsibilities established by the TMDL.

Under Watershed-Based MS4 permits, permittees are required to reduce the discharge of pollutants (including TSS) from their MS4 to the maximum extent practicable through the development and implementation of a Public Involvement and Participation Process, a storm water-related Public Education Plan, an Illicit Discharge Elimination Program (IDEP), a post-construction Storm Water Control Program for new development and redevelopment project, and a Pollution Prevention/Good Housekeeping Program for municipal operations.

Soil Erosion and Sedimentation Control. Construction activities covered under a Permit-by-Rule (Table 4.3) have soil erosion and sedimentation control (SESC) explicitly built into the process, thereby addressing TSS loadings from wet weather runoff. Under this permit the site must have an SESC permit or plan, properly maintained and operated soil erosion control measures, and the owner or easement holder is required to provide for weekly inspections of the SESC practices identified in their SESC permit. In addition, the site should be inspected after major rain events that cause a discharge from the site. These inspections should be conducted by a storm water operator who is trained and certified by the MDEQ.

Future Point Source Reasonable Assurance Activities. NPDES individual permits, COCs, and general permits are reissued every five years on a rotating schedule, and the requirements within the permits (outlined above) may also change at reissuance. Pursuant to R 323.1207(1)(b)(ii) of the Part 8 rules, and 40 CFR, Part 130.7, NPDES permits issued or reissued after the approval of this TMDL are required to be consistent with the goals of this TMDL (described in the WLA Section [2.1.a]).

MS4 permits for facilities in the Ox Creek watershed will be reissued in 2018. A new application for MS4 permittees will be available at that time. The current cycle year application includes questions that address discharges to impaired waters with a USEPA approved TMDL that includes a pollutant load allocation assigned to the permittee's MS4. The application notes that "BMPs shall be implemented to reduce the discharge of the TMDL pollutant from the MS4 to make progress in meeting Water Quality Standards.

The applicant is to describe the current and proposed BMPs to meet the minimum requirements for the applicant's TMDL Implementation Plan, which shall be incorporated into the SWMP. A measurable goal with an assessment of the effectiveness of the BMPs and a schedule of implementation will need to be included for each BMP. Monitoring shall be specifically for the pollutant identified in the TMDL and may include, but is not limited to, outfall monitoring, in-stream monitoring, or modeling. At a minimum the monitoring will be conducted twice during the 5 year permit cycle. This type of information will be included in the MS4 application and permits issued in 2018.

It is the responsibility of MDEQ staff to inspect and audit NPDES permitted facilities once every five years on a rotating basis. At the time of these audits, MDEQ staff review permits, permittee actions, submittals, and records to ensure that each permittee is fulfilling the requirements of its permit. Consistency of the permit with the TMDL, and any potential deficiencies will be reviewed and addressed as part of the audit and permit reissuance processes.

7.2.2 Nonpoint Sources

NPDES permit-related point source discharges are regulated as determined by the language contained within each permit, and they must be consistent with the goals and assumptions of this TMDL (see Section 5.1). The implementation of nonpoint source activities to reach the goal of attaining the WQS is largely voluntary. Funding is available on a competitive basis through Clean Michigan Initiative and federal Clean Water Act Section 319 grants for TMDL implementation and watershed planning and management activities.

The Michigan Agriculture Environmental Assurance Program is a voluntary program established by Michigan law (Section 324.3109d of Part 31) to minimize the environmental risk of farms, and to promote the adherence to Right-to-Farm Generally Accepted Agricultural Management Practices, also known as GAAMPs. For a farm to earn Michigan Agriculture Environmental Assurance Program verification, the operator must demonstrate that they are meeting the requirements geared toward reducing contamination of ground and surface water, as well as the air.

7.2.3 Public Involvement

The Paw Paw River watershed has an active citizen based watershed group, the Two Rivers Coalition, whose mission is to protect the health of the Black River and Paw Paw River Watersheds through conservation, education, and advocacy. Its vision is clean rivers and lakes. They have a very well-run web site which provides information pertaining to the Paw Paw River watershed. They have organized several campaigns including educating homeowners on the importance of riparian buffers, wetland protection, and septic system maintenance. Several workshops and events such as creek clean ups and stream bank improvements are organized by this group on an annual basis.

7.2.4 Watershed Management Plan

The Paw Paw River Watershed Management Plan (PPRWMP) was developed in 2008 (Southwest Michigan Planning Commission, 2008). The PPRWMP "is intended to guide individuals, businesses, organizations and governmental units working cooperatively to ensure the water and natural resources necessary for future growth and prosperity are improved and protected. It can be used to educate watershed residents on how they can improve and protect water quality, encourage and direct natural resource protection and preservation, and develop land use planning and zoning that will protect water quality in the future". The management plan and follow up activities will be important in the implementation of this TMDL.

7.3 Future Implementation Activity Recommendations

Implementation activities in the Paw Paw River watershed, which includes Ox Creek, are guided by the PPRWMP. Priority areas in the PPRW watershed were identified based on lands that are contributing, or have the potential to contribute, a majority of the pollutants adversely affecting water quality. By identifying priority areas, PPRWMP implementation is targeted to the places where the most benefit can be achieved. Three different types of areas were prioritized in the PPRWMP – protection areas, agricultural management areas, and urban management areas. The PPRWMP identifies the upstream portion of Ox Creek as medium priority for agricultural management and the downstream portion as high priority for urban management.

Medium priority agricultural management pollutants are prioritized based on their suspected significance to impaired water quality in these areas. Preparation of the PPRWMP included a review of bioassessment reports available from MDEQ. As a result of this review, the PPRWMP noted that excess sediment and siltation is occurring in all impaired streams located in agricultural management areas within the Paw Paw River watershed. For this reason, the PPRWMP prioritized the following pollutant sources in agricultural management areas:

- ***Stream banks –*** Stream bank erosion is a significant source of the highest priority pollutant (sediment). Stream bank erosion was identified in biosurveys throughout the agricultural areas.
- ***Stormwater runoff –*** Unmanaged runoff from agricultural lands can carry sediment, nutrients, bacteria and pathogens directly to surface water.

High priority urban management areas are suspected to contain a majority of the urban related pollutant sources impairing or threatening water quality in the Paw Paw River watershed . The PPRWMP prioritized sediment as a known pollutant causing impairments in urban areas, especially in Benton Harbor (Ox Creek). In urban management areas, the PPRWMP prioritized the following pollutant sources:

- ***Stormwater runoff –*** A majority of pollutants impairing or threatening designated uses in urban areas are found in stormwater runoff; largely resulting from impervious surfaces.
- ***Stream banks –*** Impervious surfaces in urban areas can alter hydrology, which causes stream bank erosion.

The PPRWMP represents a starting point for future Ox Creek TMDL implementation activities, as it integrates BMP planning efforts. An important aspect of the transition from a watershed plan to actual implementation projects is effective targeting of BMPs. One recommended activity is the use of a multi-scale analysis, which can help the targeting process. A multi-scale analysis that evaluates GIS data is used to identify high priority catchments for BMP implementation within the Ox Creek watershed. High priority catchments are critical areas that have a disproportionate effect on water quality. This approach is consistent with a focus advocated by USEPA and a number of states; one that recognizes BMPs placed in critical locations can help treat small areas that produce disproportionate amounts of pollution. First and second order streams represent areas within an overall drainage network where the benefits of implementing BMPs are often most noticeable.

The following sections build on information in the PPRWMP and describe either methods being explored by the Southwest Michigan Planning Commission (SWMPC) or tools being used in other Great Lakes watersheds to promote effective BMP targeting.

7.3.1 Agricultural Areas

Implementation activities for agricultural management areas identified in the PPRWMP include:

- Install agricultural BMPs (e.g., filter strips, no-till, cover crops, grassed waterways)
- Restore riparian buffers and stabilize eroding stream banks
- Utilize alternative drain maintenance/ construction techniques (e.g., two stage ditch design, natural river restoration techniques - j-hooks, cross vanes, etc.)
- Protect and / or restore wetlands
- Prevent/limit livestock access (fencing, crossings structures, alternative water sources)

Table 7-3 describes PPRWMP tasks, sources, causes, and proposed evaluation methods that could work towards reducing sediment loads from agricultural lands in the upper Ox Creek watershed. Table 7-3 includes "Estimate pollutant loading reduction" as a proposed evaluation method to address sediment in agricultural areas. The Soil and Water Assessment Tool (SWAT) was utilized in the PPRWMP to estimate pollutant reductions for sediment with the installation of agricultural BMPs (e.g., conservation tillage, filter strips, cover crops).

Table 7-3. PPRWMP agricultural management tasks to address sediment *(SWMPC, 2008)*.

Task	Source	Cause	Proposed Evaluation Method
Restore riparian buffers and stabilize eroding streambanks	Streambanks	Lack of riparian buffers	Linear feet of restoration/stabilization; Estimate pollutant loading reduction
Install agricultural BMPs (filter strips, no-till, cover crops, grassed waterways, etc)	Stormwater runoff - agricultural lands	Lack of BMPs	Number of acres; Estimate sediment loading reduction; Number of landowners
	Streambanks	Increased flow fluctuations	
Restore wetlands	Streambanks	Increased flow fluctuations	Number of acres restored; Number of landowners restoring wetlands; Estimate loading reduction
Protect wetlands	Stormwater runoff -agricultural lands	Loss of wetlands	Number of acres protected; Number of landowners protecting wetlands; Estimate pollutant loading reduction
Utilize alternative drain maintenance / construction techniques	Streambanks	Increased flow fluctuations	Number of miles of drain maintained or constructed with alternative techniques

SWMPC is exploring the use of the High Impact Targeting (HIT) approach to guide and prioritize the installation of agricultural BMPs. The HIT method was developed by the Institute of Water Research (IWR) at Michigan State University (http://www.iwr.msu.edu/hit2). HIT is an on-line tool that allows users to prioritize erosion control and sediment reduction efforts in the Great Lakes Basin. The SWMPC and The Nature Conservancy (TNC) have partnered to use the HIT approach in developing the Sediment Calculator for the PPRW (http://35.8.121.111/sedcalc/). Figure 7-1 presents visual results of the HIT analysis for a portion of the Ox Creek drainage where loads are highest. This area coincides with the high levels reported from the MDEQ TSS sampling *(Table 7-1)*. The Sediment Calculator compares initial erosion and sediment production estimates based on NLCD land use to increases or reductions for several management practices including conventional tillage, mulch till, no-till, cover crop, buffer strips, and grass waterways.

The information from the HIT analysis can be combined with land use information and TMDL TSS reduction estimates necessary for each subwatershed unit in the Ox Creek watershed. As an example, subwatershed unit B between Blue Creek Road and Yore Avenue has areas along the Yore-Stoeffer Drain with annual erosion rates greater than 4 tons / acre per year *(Figure 7-1)*. Figure 7-2 provides a closer view of NLCD land use in subwatershed unit B including an air photo of the area. Table 7-4 summarizes preliminary erosion and sediment delivery estimates for subwatershed unit B using the HIT analysis of land use data and estimates of sediment reduction as a result of BMP implementation.

Estimates from the Sediment Calculator are expressed as annual average sediment production values, which are higher than actual in-stream TSS measurements used to establish TMDL load allocations and reduction targets. However, the Sediment Calculator is a useful tool that allows comparison of different BMPs and implementation strategies. The use of other tools, such as watershed models, should be explored as a way to complement Sediment Calculator results such that load reductions are maximized at minimal costs.

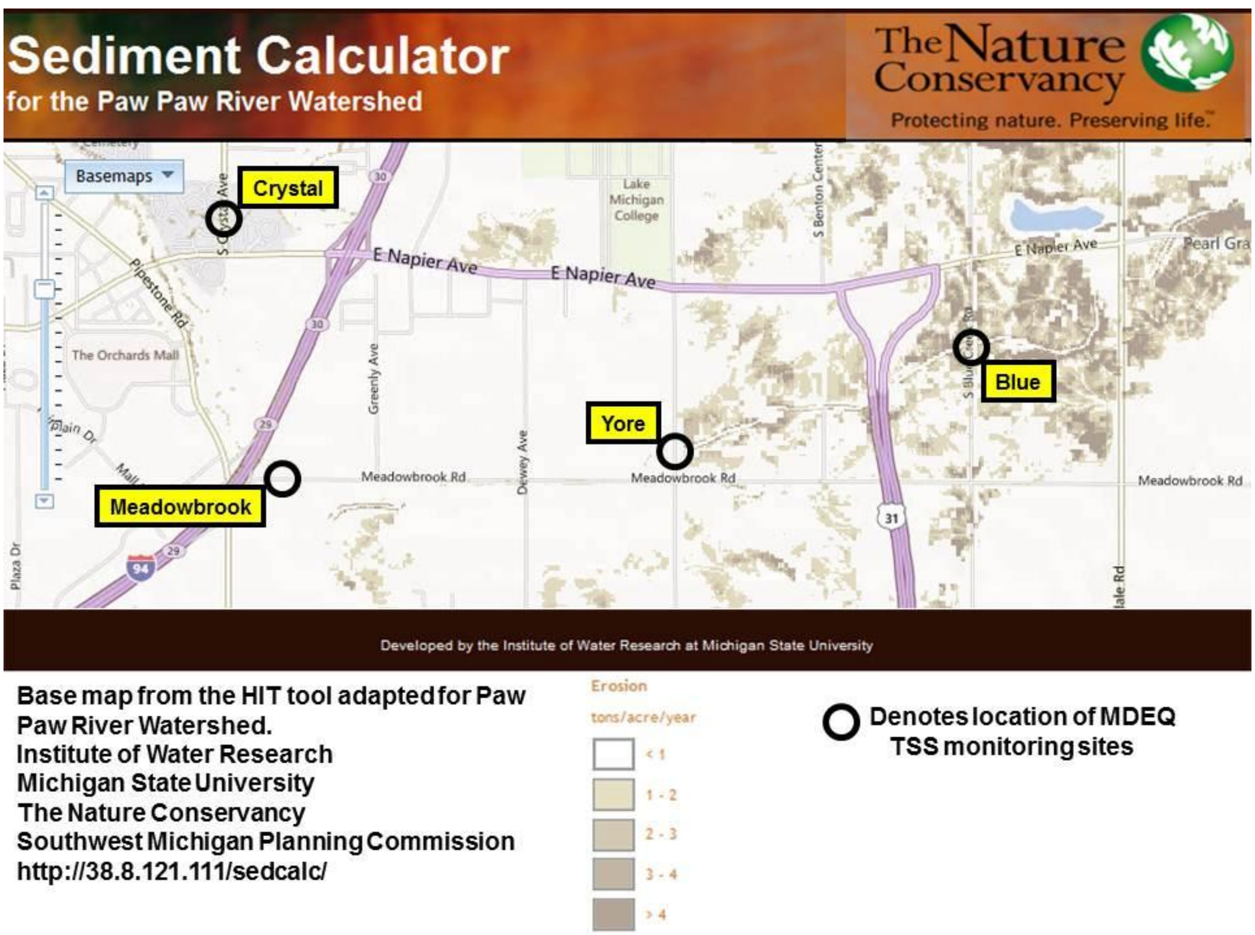


Figure 7-1. HIT sediment load estimates for upper Ox Creek watershed.

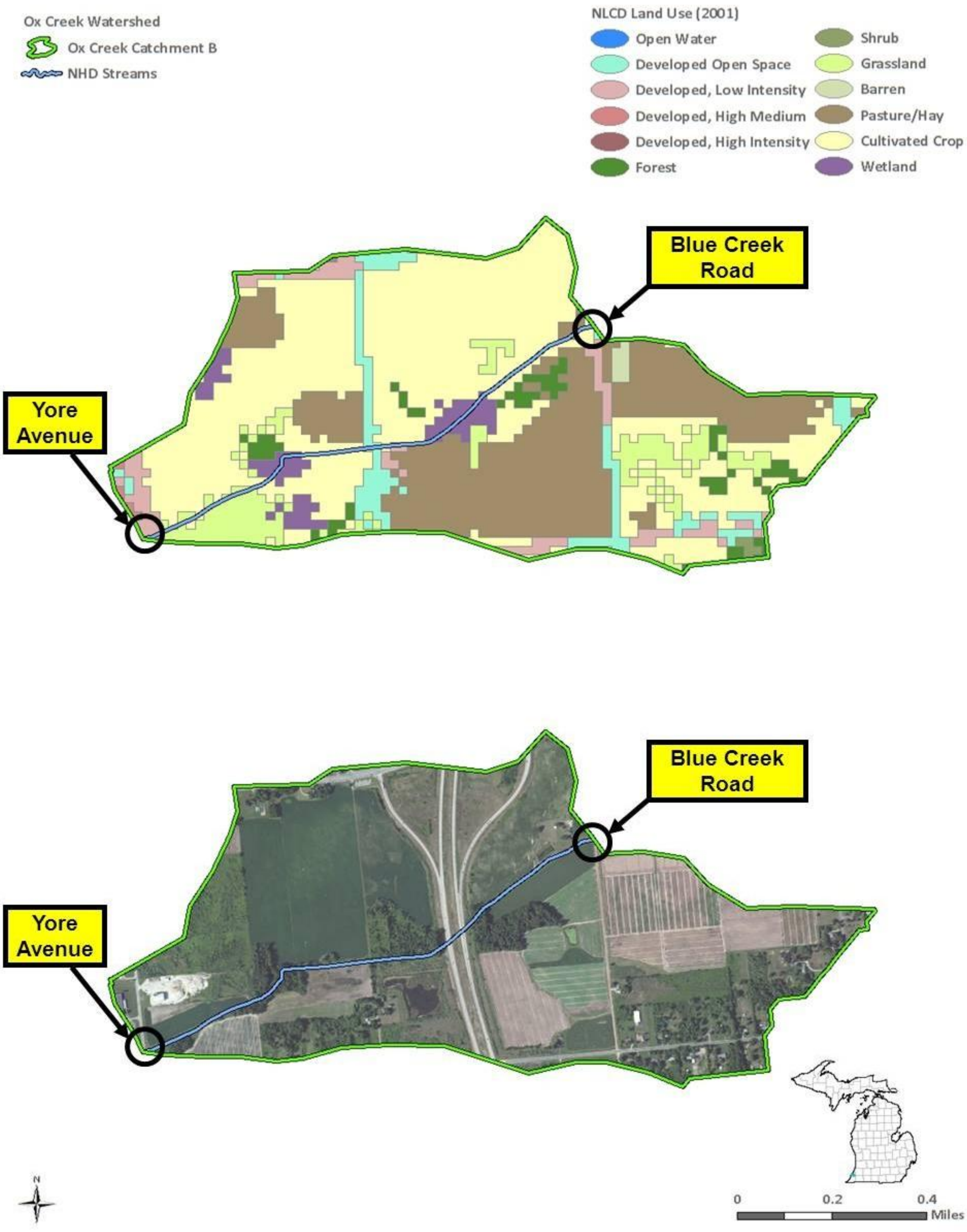


Figure 7-2. Land use and air photo of subwatershed unit B.

Table 7-4. Sediment Calculator – HIT tool estimates for subwatershed unit B.

Condition or Practice	Erosion *(tons/acre per year)*	Sediment *(tons/acre per year)*
Conventional tillage	2.263	0.500
Conventional tillage with cover crop	1.851	0.370
Mulch-till	1.358	0.197
Mulch-till with cover crop	1.440	0.187
No-till	0.782	0.073
No-till with cover crop	0.617	0.043
Buffer strips	0.371	0.032
Grass waterways	0.330	0.016

The following paragraphs briefly describe agricultural BMPs described in the PPRWMP that could be implemented in the Ox Creek watershed.

Conservation Tillage. Conservation tillage practices and residue management are commonly used to control erosion and surface transport of pollutants from fields used for crop production. Crop residues not only provide erosion control, but also provide a nutrient source to growing plants. Continued use of conservation tillage results in a more productive soil with higher organic and nutrient content. Using some form of conservation tillage will reduce sediment loading from fields. Tillage practices leaving 20 to 30 percent residue cover after planting reduce erosion by approximately 50 percent compared to bare soil. Practices that result in 70 percent residue cover reduce erosion by approximately 90 percent (University of Illinois Extension, 2002). USEPA reports the findings of several studies regarding the benefits of tillage practices describing that no-till reduced runoff loss by 69 percent, which protects stream banks from erosion and loss of canopy cover (USEPA, 2003).

Riparian Buffers. Riparian corridors, including both the stream channel and adjacent land areas, are important components of watershed ecology. Preserving natural vegetation along stream corridors can effectively reduce the water quality degradation associated with human disturbances. The root structure of the buffer vegetation enhances infiltration of runoff and subsequent trapping of nonpoint source pollutants. However, the buffers are effective in this manner only when the runoff enters the buffer as a slow-moving, shallow *sheet*; concentrated flow in a ditch or gully quickly passes through the buffer, offering minimal opportunity for retention of pollutants.

Even more important than the filtering capacity of the buffers is the protection they provide to stream banks. The root systems of the vegetation serve as reinforcements in stream bank soils, which help to hold stream bank material in place and minimize erosion. Because of the increase in stormwater runoff volume and peak rates of runoff associated with agriculture and development, stream channels are subject to greater erosional forces during storm flow events. Preserving natural vegetation along stream channels minimizes the potential for water quality and habitat degradation due to stream bank erosion and enhances the pollutant removal of sheet flow runoff from developed areas that pass through the buffer.

Filter strips. Filter strips are areas that are generally placed adjacent to watercourses and planted with perennial grasses, legumes and forbs. Such areas provide a setback between watercourses and agricultural activities, reduce erosion, trap pollutants, improve water quality and provide habitat. If topography allows, filter strips / areas can be used to treat flow from tile drain outlets. SWAT provides an algorithm for estimating the trapping efficiency of filter strips for reducing sediment based on width. As noted, the greatest incremental reductions occur in the first two meters of filter strip width (Figure 7-3).

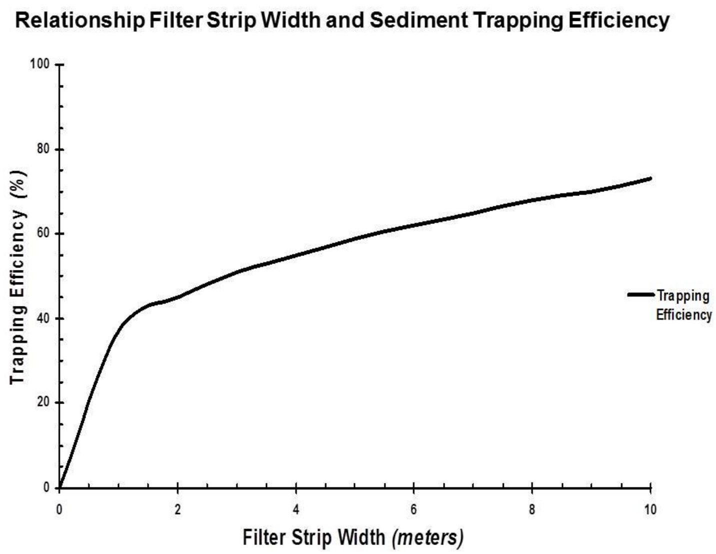


Figure 7-3. Relationship between filter strip width and pollutant trapping efficiency.

Grassed Waterways. Grassed waterways are grass-lined stormwater conveyances that prevent erosion of the transport channel. The grassed channel can reduce runoff velocities, allow for some infiltration, and filter out some particulate pollutants. The objectives of grassed waterways are to convey runoff from water concentrations without causing erosion or flooding, reduce gully erosion, and protect / improve water quality. The primary purpose of a grassed waterway is to transport surface runoff and reduce channel erosion. As such, they are often components of multi-practice systems, rather than a standalone practice for water quality.

Ditch Management. Drainage patterns throughout the Ox Creek watershed has been altered with subsurface tile drain networks, straightened surface flow channels, and removal of riparian vegetation. Portions of the project area are characterized by poorly infiltrating soils. Clay soils result in heavy, and at times deep, mud. Such conditions historically limited crop production until the area was drained by the construction of ditches. Ditches and channels can be managed in such a way to reduce sediment transport while removing excess surface and subsurface flows. One example of this type of management is the construction of two stage ditches. A two-stage channel system incorporates benches that function as flood plains and attempts to restore or create some natural channel processes. In a traditional agricultural drainage channel, the more frequent lower flow discharges may not flow at a depth and velocity sufficient to move sediment through the reach and deposition results. With a two stage design the channel-forming discharge channel provides the necessary sediment conveyance, while the flood plain channel provides for the design flood conveyance, which results in a more stable waterway (USDA, August 2007).

Outlet Control Devices. A conventional tile drain system collects infiltrated water below the root zone and transports the water quickly to a down-gradient surface outlet. Placing a water-level-control structure at the outlet allows for storage of the collected water to a predefined elevation. The stored water becomes a source of moisture for plants during dry conditions and undergoes biological, chemical, and physical processes that result in lower nutrient concentrations in the final effluent. Similar structures can be installed at the outlets of surface drainage systems to store water and allow for infiltration and pollutant removal before discharge to a receiving stream.

Wetlands restoration and protection. Wetlands are critical for stabilizing stream flows and improving water quality throughout the watershed (PPRWMP, 2008). MDEQ completed a landscape level analysis to better understand the functions of existing and lost wetlands in the PPRW. Analysis results can help pinpoint potential restoration and protection activities toward appropriate areas of the watershed that are in most need of a particular wetland function. Important functions related to the Ox Creek TMDL include sediment retention (beneficial for removing TSS from runoff) and floodwater storage (which reduce peak flows that transport high TSS loads).

Table 7-5 provides an estimate of current and pre-settlement wetlands in the Ox Creek watershed by subwatershed unit, including the functional value lost for sediment retention and floodwater storage in the Ox Creek watershed. The results from this analysis *(graphically displayed in Figure 7-4 and Figure 7-5)* can be used to locate wetlands with these important functions, which have been lost and could be potential restoration sites. Results of the landscape level wetlands analysis can be combined with available GIS information, as illustrated in Figure 7-6, to identify potential restoration locations that could help reduce TSS loads in the upper Ox Creek watershed.

Table 7-5. Ox Creek wetlands status and functional loss.

Subwatershed	Current Wetlands *(acres)*	Pre-Settlement Wetlands *(acres)*	Wetland Loss	Sediment Retention Functional Loss	Floodwater Functional Loss
A	115	252	55%	76%	69%
B	15	63	76%	97%	83%
C	84	246	66%	86%	90%
D	20	57	65%	58%	55%
E	129	382	66%	79%	74%
F	35	90	61%	60%	59%
G	42	122	66%	52%	51%
H	24	105	77%	95%	79%
I	0	90	100%	100%	100%

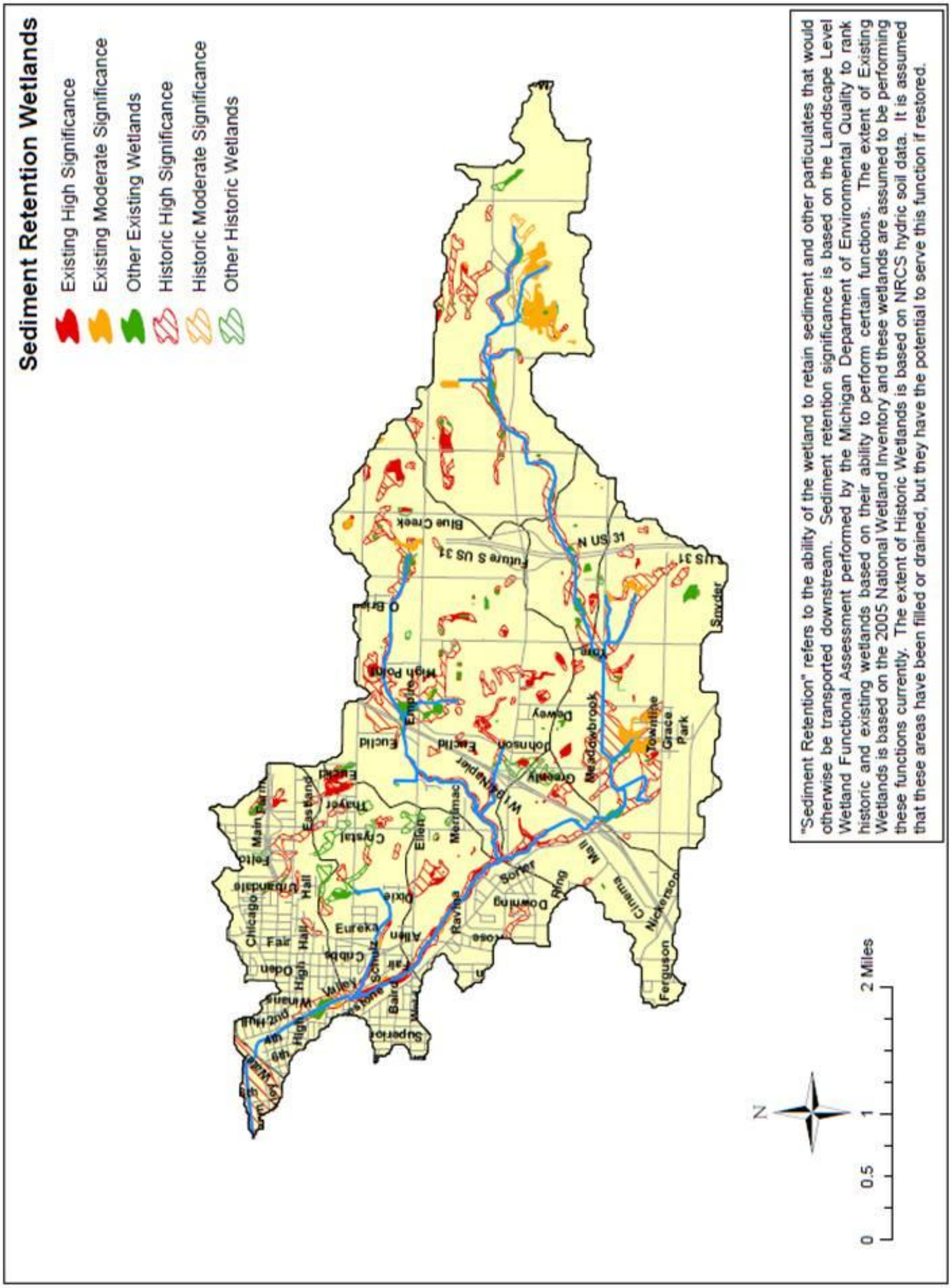


Figure 7-4. Ox Creek sediment retention wetland summary.

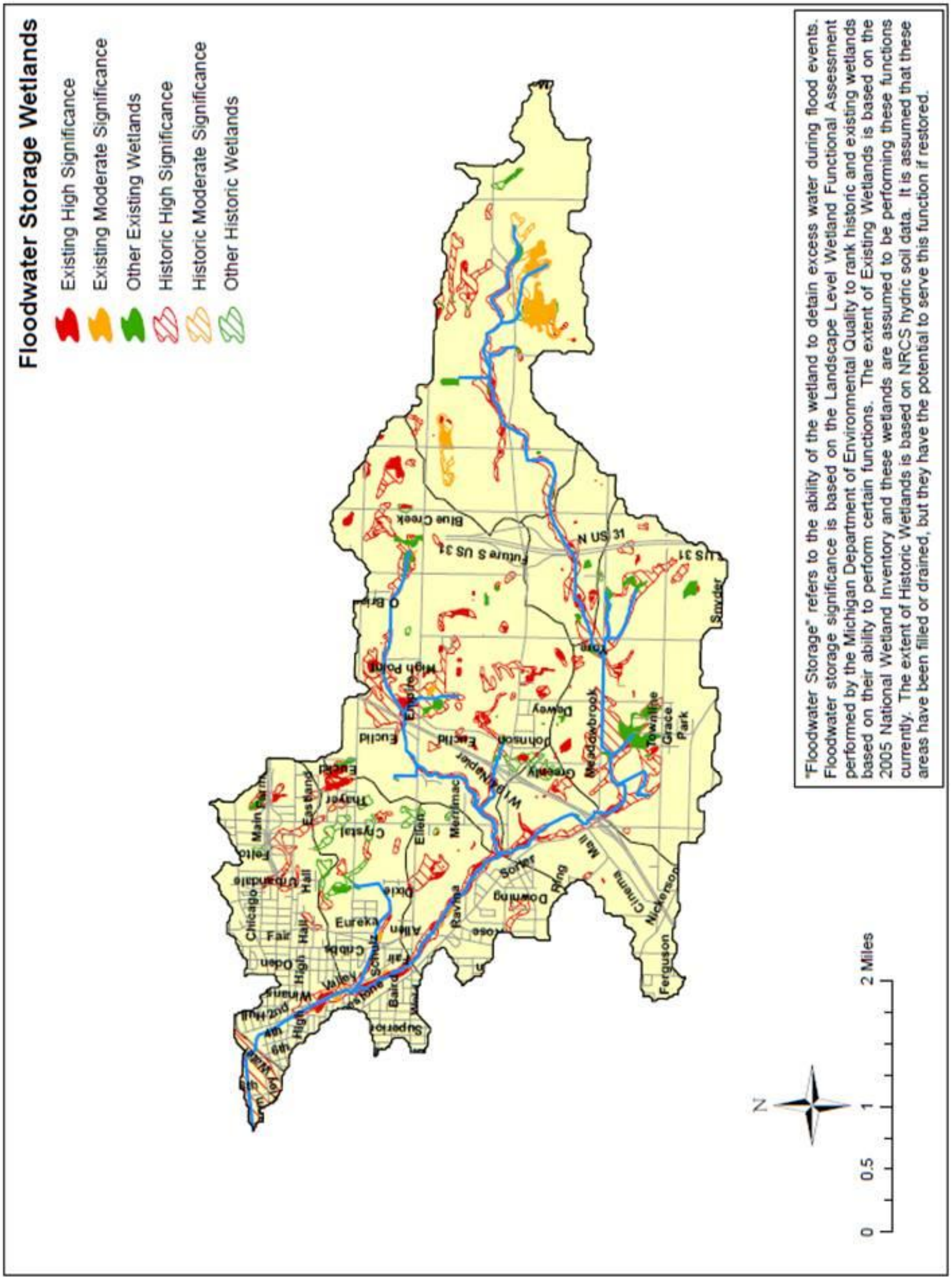


Figure 7-5. Ox Creek floodwater storage wetland summary.

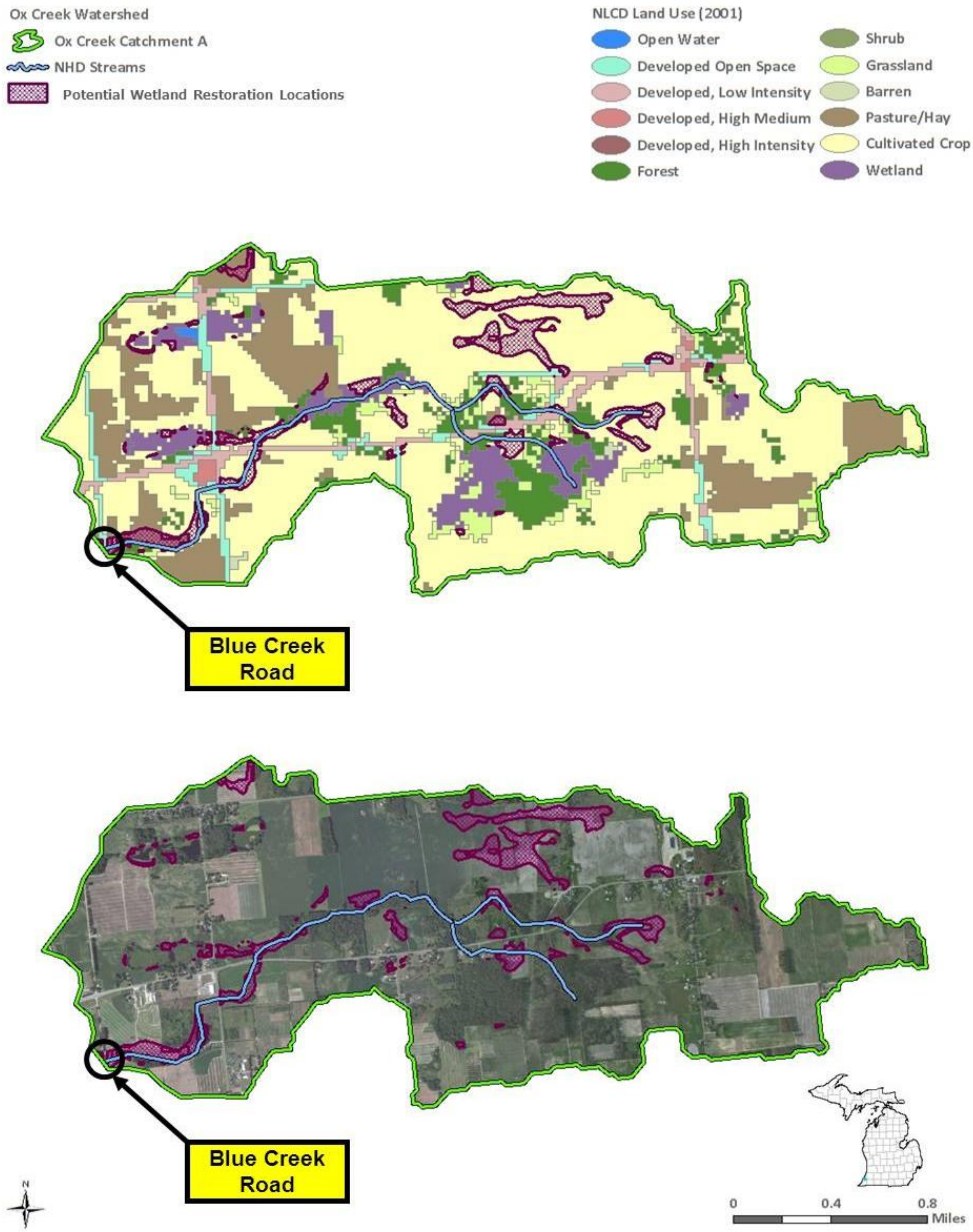


Figure 7-6. Land use and air photo of subwatershed unit A.

7.3.2 Urban Stormwater

Implementation activities for urban management areas identified in the Paw Paw River Watershed Management Plan include:

- Utilize stormwater best management practices (road/parking lot sweeping, stormceptors, rain gardens, constructed wetlands, vegetated swales, etc)
- Enact stormwater and post construction control ordinances
- Identify and correct illicit connections or discharges to stormwater system
- Utilize best management practices for road maintenance

Table 7-6 describes PPRWMP tasks, sources, causes, and proposed evaluation methods that could work towards reducing sediment loads from urban lands in the upper Ox Creek watershed.

Table 7-6. PPRWMP urban management tasks to address sediment *(SWMPC, 2008)*.

Task	Source	Cause	Proposed Evaluation Method
Utilize stormwater BMPs (road / parking lot sweeping, stormceptors, rain gardens, vegetated swales, constructed wetlands, wet / dry ponds, etc)	Stormwater runoff – impervious surfaces and storm drains	Lack of stormwater management	Number of municipalities sweeping streets/parking lots and using other practices; Estimate pollutant loading Reduction
	Streambanks	Increased flow fluctuations	
Enact stormwater and post construction control ordinances	Stormwater runoff – impervious surfaces and storm drains	Lack of stormwater management	Number of municipalities with ordinances enacted
Utilize BMPs for road maintenance	Stormwater runoff – roads and parking lots	Improper road sand application and snow disposal	Number of road agencies adopting improved practices; Estimate sediment loading reduction
Identify and correct illicit discharges or connections	Stormwater runoff – impervious surfaces and storm drains	Illicit connections or discharges	Number of connections or discharges identified and corrected

A recommended approach to guide the next phase of stormwater BMP planning efforts is to construct a multi-scale analysis framework from available land use information. Development in the Ox Creek watershed has led to an increase in impervious surface area. In turn, the conversion of pervious land to impervious surfaces results in additional stormwater draining into Ox Creek and its tributaries. NLCD provides a summary of land use information; the highest development intensities occur in subwatersheds D and I (Table 7-7).

Table 7-7. Ox Creek subwatershed developed land and impervious cover summary *(2006 NLCD)*.

Subwatershed		Area *(acres)*	Development Intensity				Estimated Impervious Cover
			High	*Med*	*Low*	*Open*	
A	***Yore – Stoeffer HW***	2,150	0%	0%	4%	3%	1%
B	***Upper Yore - Stoeffer***	465	0%	0%	4%	6%	1%
C	***Middle Yore - Stoeffer***	1,755	3%	4%	17%	19%	9%
D	***Lower Yore - Stoeffer***	805	17%	27%	17%	25%	34%
E	***Ox Headwaters***	2,600	2%	4%	10%	24%	7%
F	***Upper Ox***	725	10%	20%	25%	33%	26%
G	***Middle Ox***	895	0%	8%	29%	53%	13%
H	***Lower Ox***	1,060	5%	17%	35%	39%	22%
I	***Ox Outlet***	104	20%	32%	27%	19%	41%

The Lower Yore-Stoeffer (Unit D) represents an interesting subwatershed in terms of stormwater management; it has a range of different development intensities and is an area that has faced growth pressure due to its proximity to I-94. Unit D serves as an example subwatershed to demonstrate how Ox Creek TMDL targets can be connected to stormwater management program implementation. The first step is to target potential priority stormwater source areas. Using GIS tools, locations with high levels of impervious cover can be identified. Figure 7-7 shows the 2006 NLCD GIS data layer for the Lower Yore-Stoeffer subwatershed. This information is used to estimate the development intensity, which can be used to estimate the corresponding impervious area *(Table 7-8)*. This provides a method to identify priority locations that warrant a detailed assessment of potential BMP implementation opportunities based on impervious surface area estimates.

Table 7-8. NLCD developed land class impervious cover estimates.

NLCD Development Category	Typical Land Uses	Impervious Cover Estimate *(percent)*	
		Average	*Range*
High Intensity	Commercial *(retail, office)* Institutional *(school, hospital),* Apartments	85	*(80-90)*
Medium Intensity	Residential	55	*(50-60)*
Low Intensity	Residential, Recreational	20	*(15-25)*
Developed Open Space		5	*(0-10)*

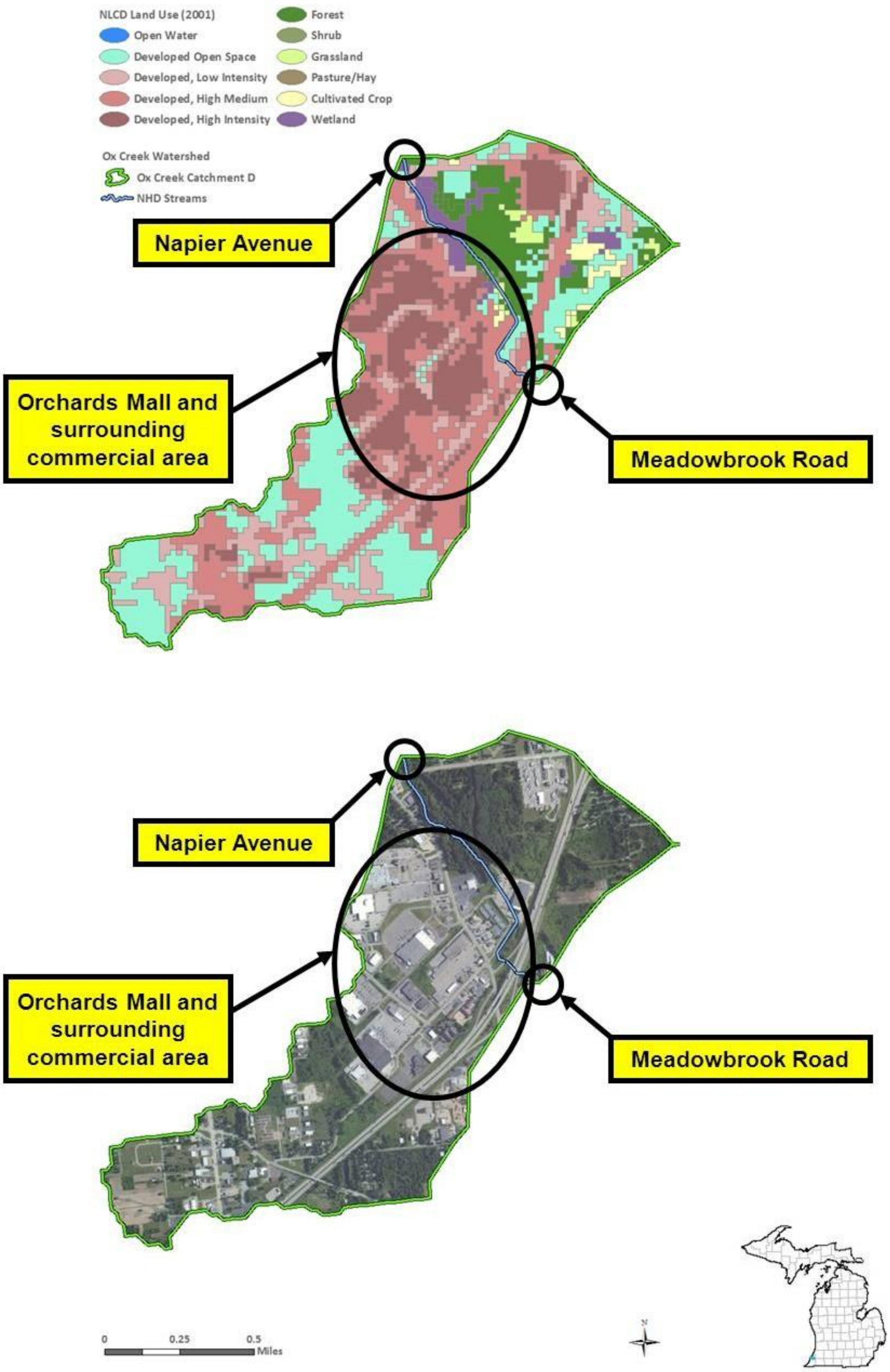


Figure 7-7. Land use and air photo of subwatershed unit D.

Once catchments within each subwatershed unit are identified, more detailed information on impervious cover types can be inventoried. Example inventory data at this catchment scale includes: size of parking lots, street lengths and widths, number of homes, average driveway size, average roof size, sidewalk presence and size, etc. This type of analysis allows better targeting of impervious areas that will lead to measurable results.

By examining the type of development and impervious cover present, stormwater volume estimates produced by various source areas (e.g., commercial parking, roads, residential roof) can be developed. Estimates that describe the maximum extent to which BMPs could be applied for each impervious surface type can also be made through field reconnaissance, a review of aerial imagery, or combination of both. Potential locations for BMP installation can be identified according to available land, as well as proximity to sources of runoff and TSS.

Figure 7-8 shows an example schematic that serves as an organizational tool for determining where certain categories of BMPs could actually be implemented (e.g., bioswales along streets; porous pavement for parking and driveways; rain barrels coupled with rain gardens for residential roofs). In addition to assessing individual practices, options also include the potential use of treatment trains (e.g., rain barrels followed by rain gardens, flow from porous pavement systems to bioswales, etc.), as illustrated in Figure 7-8.

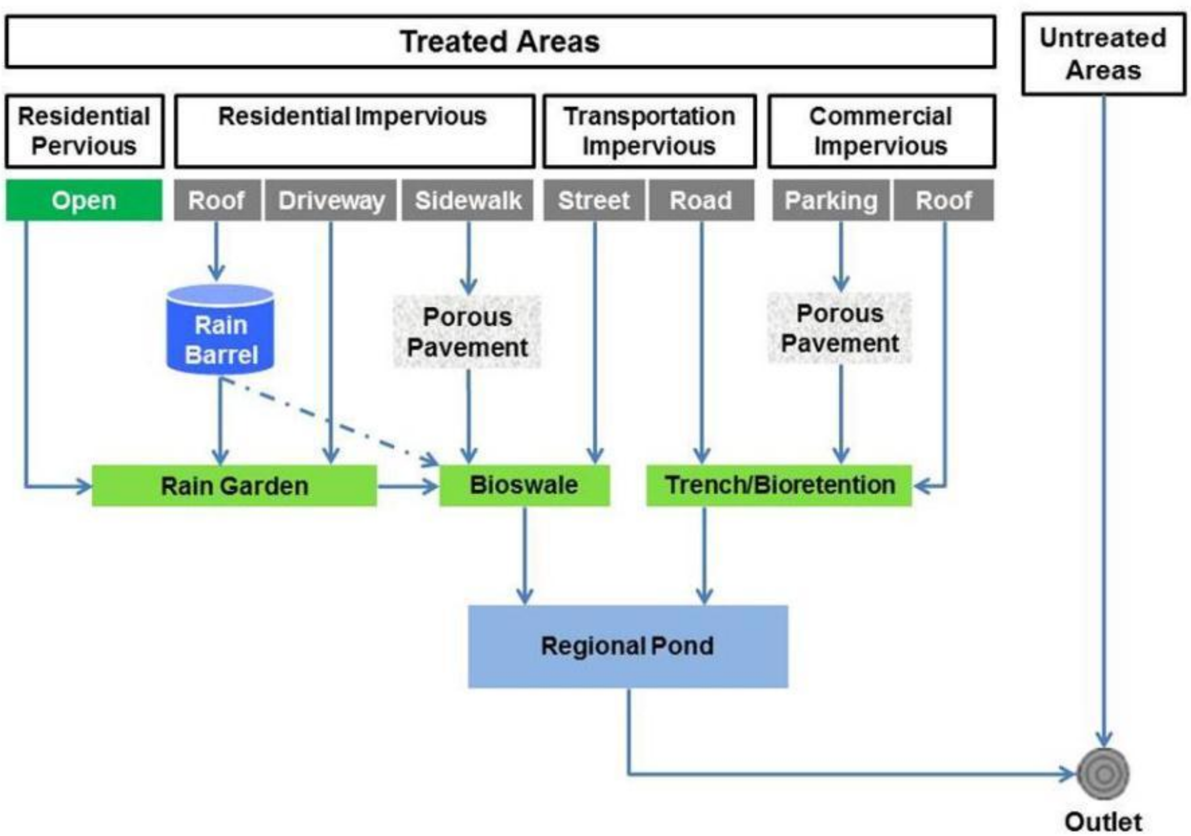


Figure 7-8. Schematic identifying BMP treatment train options for impervious surface types.

BMP assessment tools can be used to develop curves that describe TSS or stormwater volume reductions associated with different management strategies. These curves can be used to examine the potential range of TSS or stormwater volume reductions achieved under various BMP design assumptions (e.g., size, background infiltration rates) and at different levels of implementation (e.g., BMP installation on five percent of available area, ten percent of available area, fifteen percent, and so on). These level of implementation curves serve as a screening analysis that can be used to enhance the PPRMWP for reducing the effect of stormwater on sediment loads in Ox Creek.

The results of an example screening analysis for bioswales applied to streets and roads with Benton Harbor climate and soils data are presented in
Figure 7-9. These curves were developed using the BMP assessment tool available in the low-impact development management evaluation computer program (known as the BMP - Decision Support System, or BMP-DSS) developed for Prince George's County, Maryland (TetraTech, 2001 and 2003). The BMP assessment tool is also available in the System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN), which has been pilot tested in several Great Lakes area watersheds (TetraTech, 2012). This particular example graph depicts volume reduction as a function of the percentage of total residential street length where bioswales are installed (addressing a key question related *"level of implementation"*). The screening analysis is constructed in a way that shows the sensitivity major design variables (e.g., media depth, native soil infiltration rate).

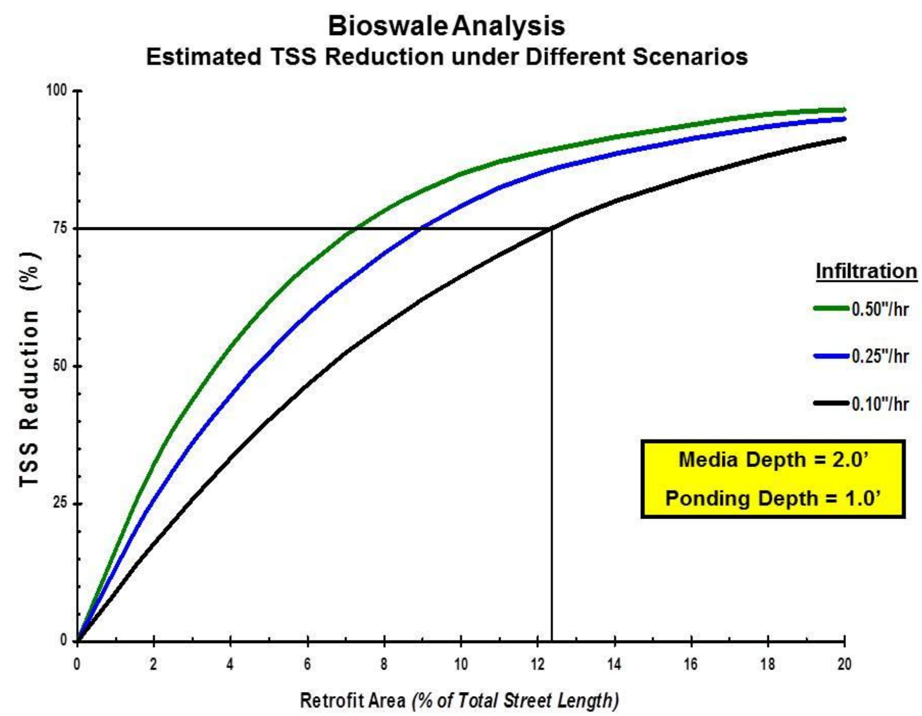


Figure 7-9. Bioswale TSS reduction estimates at background infiltration rates.

7.3.3 Summary of Implementation Recommendations

The following source-specific activities are recommended to make progress in meeting the goal of this TMDL:

Agricultural Areas.

- Apply and / or install agricultural BMPs identified in the PPRWMP that would reduce TSS loads being delivered to streams in the Ox Creek watershed. Practices on cropland include filter strips, no-till, cover crops, and grassed waterways.
- Identify areas where restoration activities would be beneficial for removing TSS from runoff. This includes riparian buffers to stabilize eroding stream banks, as well as wetland restoration in areas where historic high functional value wetlands have been lost.
- Use tools such as the HIT model to identify and prioritize sources areas in greatest need of sediment reduction BMPs and restoration efforts.
- Continue outreach to the agricultural community to encourage participation in the Michigan Agriculture Environmental Assurance Program promoting adherence to Right-to-Farm Generally Accepted Agricultural Management Practices.
- Pursue funding opportunities to implement agricultural BMPs through Clean Michigan Initiative and federal CWA 319 grants.

Urban Areas.

- Apply and / or install urban BMPs identified in the PPRWMP that would reduce stormwater runoff and TSS loads from being delivered to streams in the Ox Creek watershed. Practices in urban areas include road / parking lot sweeping, stormceptors, rain gardens, constructed wetlands, and vegetated swales, as well as BMPs for road maintenance.
- Use recent stormwater BMP assessment tools (e.g., BMP-DSS, SUSTAIN) being applied in other Great Lakes watersheds to identify and prioritize sources areas in greatest need stormwater and sediment reduction efforts.
- Continue outreach to the urban community to encourage installation of BMPs in priority areas.
- Pursue funding opportunities to implement urban BMPs through state and federal assistance grants to local communities. An example is the Clean Michigan Initiative grant program.

All Areas.

- Identify opportunities to monitor water quality and collect data that measures the effectiveness of implementation efforts towards reducing TSS loads in the Ox Creek watershed.

7.4 Implementation Partners

The Watershed Management Plan also includes a list of potential leads (e.g., Drain Commission, land owners) and potential partners (e.g., SWMPC, NRCS, the Berrien County Conservation District, The Nature Conservancy), which summarized in Table 7-9.

Table 7-9. PPRWMP potential partners *(SWMPC, 2008)*.

Task	Potential Lead *(Partners)*	Potential Funding or Partner Programs
Agricultural Management		
Restore riparian buffers and stabilize eroding stream banks	Landowners *(Drain Comm., Conservation Districts, NRCS)*	Drain Assessments, MDEQ 319, Farm Bill Programs, Carbon Credit Program, Clean Michigan Initiative
Install agricultural BMPs (filter strips, no-till, cover crops, grassed waterways, etc)	Landowners *(NRCS, Conservation Districts, TNC)*	Farm Bill Programs, MDEQ 319, Carbon Credit Program, Clean Michigan Initiative
Restore wetlands	Landowners *(NRCS, USFWS)*	WRP. Partners for Wildlife, NAWCA, DU, National Fish and Wildlife Foundation, MDEQ 319, Continuous CRP, Clean Michigan Initiative
Protect wetlands	Landowners *(NRCS, USFWS, SWMLC, TNC)*	MDEQ 319, NAWCA grant, Ducks Unlimited, Wetland Reserve Program. Partners for Wildlife, Continuous CRP
Utilize alternative drain maintenance / construction techniques	Drain Commissioner *(TNC)*	Drain Assessments, MDEQ 319, Clean Michigan Initiative
Urban Management		
Utilize stormwater best management practices (road/parking lot sweeping, stormceptors, rain gardens, vegetated swales, constructed wetlands, wet/dry ponds, etc)	Municipalities, Drain Commissioner, Road Commission *(SWMPC, MTA, MML)*	Municipalities, MDEQ 319, Clean Michigan Initiative
Enact stormwater and post construction control ordinances	Municipalities, Drain Commissioner, Road Commission *(SWMPC, MTA, MML)*	Municipalities, MDEQ 319
Utilize best management practices for road maintenance	Road Commission, Municipalities	Road Commission, Municipalities, Clean Michigan Initiative
Identify and correct illicit discharges or connections	Drain Commissioner, Municipalities, Road Commission	Drain Commissioner, Municipalities, Road Commission, Clean Michigan Initiative

8. Future Monitoring

Monitoring will be conducted by the MDEQ to assess progress toward meeting the biota TMDL target following implementation of applicable BMPs and control measures. Additionally, the Paw Paw River watershed will continue to be monitored on a five-year rotating basis, regardless of TMDL activity, and the information from those surveys will be available to assess the condition of the biological communities as well.

Follow-up biological assessments will be conducted from June through September under stable, low flow conditions, following Procedure 51. Future in-stream monitoring of TSS concentrations may be conducted by the MDEQ if necessary and as resources allow, once actions have occurred to address sources of TSS, as described in this document. When the results of these actions indicate that the water body may have improved sufficiently to meet WQS, sampling may be conducted at the appropriate frequency to determine if the loading targets are being met.

9. Public Participation

Public meetings to present, discuss, and gather comments on the TMDL were held on March 7, 2013, in Benton Charter Township, and Benton Harbor Michigan. Individual meeting invitation letters were sent to stakeholders who were determined by identifying municipalities (i.e., counties, townships, and cities) and NPDES permitted facilities in the TMDL watershed. Approximately 29 stakeholders attended the public meetings. The availability of the draft TMDL and public meeting details were announced on the MDEQ Calendar. The TMDL was public noticed from February 25 to March 26, 2013. Copies of the draft TMDL were available upon request and posted on the MDEQ's web site.

10. References

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Appendix – Ox Creek Watershed Plan: Public Engagement Framework

The Southwest Michigan Planning Commission has contracted with Wightman and Rb Strategy to develop and implement a broad-based public engagement framework as a part of the Education & Information plan for the Ox Creek Watershed Management Plan. Education and outreach are essential components of successful plan implementation; it is crucial that the businesses, local residents, and municipal representatives be made fully aware of the issues that exist in the watershed and what needs to be done to remediate them, and to protect what they have. This framework focuses on the Orchards Mall/I-94 Exit 29/Pipestone redevelopment initiative.

The public outreach component of the Ox Creek Watershed Management Plan has the foundation of the website http://www.sustainoxcreek.org.Based on the theme “Sustain Ox Creek” the next-phrase framework includes meetings, workshops, direct mailers, emails, posters, and a Facebook page, all incorporating a cohesive visual theme with the goal of educating the public about the importance of addressing sediment from agricultural operations and storm water runoff from the hundreds of acres of existing pavement, especially around the Orchards Mall area.

Details of the initiatives along with examples of collateral materials follow.

Sustain Ox Creek

Amy Home Create

OX CREEK WATERSHED

@sustainoxcreek.org

- Home
- About
- Photos
- Reviews
- Events
- Videos
- Posts
- Community
- Info and Ads

ADDITIONAL CONTACT INFO

http://www.sustainoxcreek.org

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skissack@cstonealliance.org

AREA RESIDENTS
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269-925-1137 x1525
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FARMER/AGRICULTURAL
Nancy Carpenter, Berrien Conservation District
269-471-9111 x3
nancy.carpenter@macd.org

MORE INFO

About

The Southwest Michigan Planning Commission (SWMPC) serves Berrien, Cass and Van Buren Counties. Its mission is to promote a sustainable, high quality of life through facilitating sound planning and decision making. It is coordinating a $1.2 million project to clean up Ox Creek with partners: Berrien County Drain Commission (the grant recipient), Cornerstone Alliance, Benton Charter Township, Two Rivers Coalition and Berrien Conservation District. The project's technical consultant is Wightman.

Environmental Conservation Organization

STORY

Our Story

Ox Creek Watershed is in the far west part of the larger St. Joseph River Watershed. Ox Creek flows into the Paw Paw River, then to the St. Joseph River, and out to Lake Michigan. "It doesn't take too long for the pollution to get to Lake Michigan where our beaches are... We are all part of a bigger picture. We know that what happens upstream will affect downstream areas." says Marcy Hamilton, SWMPC deputy executive director/senior planner.

See More

When studies by the Michigan Department of Environmental Quality listed Ox Creek as a water body not meeting water quality standards due to storm water run-off from both agricultural fields and a Benton Harbor retail hub at Orchards Mall, the Southwest Michigan Planning Commission (SWMPC) went into action to secure funding and convene partners, launching what would become the Ox Creek Watershed Initiative.

The goal is to restore 1,060 acres of wetlands while improving water quality by reducing the amount of sediment and pollutants running into Ox Creek. Another project goal is to improve aesthetics and creative placemaking opportunities that will attract development and encourage investment.

Ox Creek Watershed Plan Video Storyboard

Three Minute Video with 30 sec clips
(Interviews, Ox Creek, St. Joseph River and Lake Michigan)
Heavy use of maps, stock, and Wightman renderings

PART 1: **Clean Water Creates Opportunities** Have public figure introduce "Sustain Ox Creek" initiative

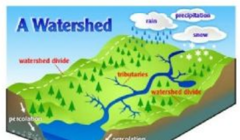
Mission
Show flowing Water with Logo and Title
"A sustainable Ox Creek Watershed will enhance the quality of life in Benton Township by improving environmental vitality and supporting regional economic growth."

List Advantages & Benefits
Show Image montage of lifestyle stock w/ voiceover

What Areas Are Included?
Show regional maps from big picture down to targeted area maps
Ox Creek Watershed is in the far west part of the larger St. Joseph River Watershed.
Ox Creek flows into the Paw Paw River, then to the St. Joseph River, and out to Lake Mi.

What locations are the focus?
Show video of current conditions **(possibly drone)**

PART 2: **Why Ox Creek?** Q&A with Marcy about Watersheds in outdoor setting



Watershed Explanation:
Watershed onsite, then diagram
"A Watershed is an area of land that drains rain water or snow into one location such as a stream, lake or wetland. These water bodies supply our drinking water, water for agriculture…"

Challenge:
Show images of pollution types w/ voiceover
"Unfortunately various forms of pollution, including runoff and erosion, can interfere with the health of the watershed...

Tools:
Show images of Toolkit w/ voiceover
"Development planning and improvements to control stormwater runoff are key… runoff needs to be slowed down, spread out, and soaked in."

PART 3: **What is the Plan for the Area?** Voiceover about area and show B&A from Wightman renderings

Plan Goal/ Imagine:
Show renderings of plans, panning in on details

Ending: Have public figure summarize the "Sustain Ox Creek" initiative

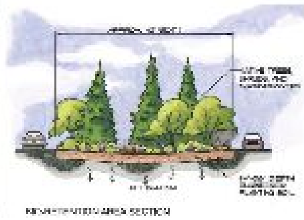
Take away:
Show flowing Water with Logos and web address
"The plan focuses on a revitalized Orchards Mall area with mixed use development and public gathering spaces as a gateway to Benton Harbor and St. Joseph and the regional commercial/retail hub of SW Michigan, with sustaining the health of Ox Creek as the mission of these efforts."

OX CREEK WATERSHED
URBAN | RURAL | EXIT 29

Featured Case Study—Brookfield Dodge

Small Business Support of Sustaining Ox Creek

Don Brookfield Dealership is utilizing several types of techniques to help improve the health and water quality of Ox Creek Watershed. The investments also are ways of beautifying the curb appeal of the business, and creating a nicer experience for local customers.



Examples of Structural Best Management Practices

The goals of these practices are to improve water quality issues caused by stormwater volume, thereby reducing contaminant and sediment run-off that degrade the habitat and flow to other water sources

"Water – slow it down, spread it out, soak it in!"

NEAR TERM IMPLEMENTATION

BIORETENTION (Rain Garden)

A shallow surface depression planted with specially selected native vegetation to capture and treat storm water runoff from rooftops, streets, and parking lots.

BENEFITS:
Volume control and groundwater recharge, moderate peak rate control, filtration, versatile with broad applicability, enhance site aesthetics and habitat, and potential air quality and climate benefits.

COST: Low/Med
Adds less than 1% or up to 5% to total project cost; requires maintenance one—several times/yr.

VEGETATED SWALE

A shallow storm water channel that is densely planted with a variety of grasses, shrubs, and/or trees designed to slow, filter, and infiltrate storm water runoff.

BENEFITS:
Can replace curb and gutter for site drainage and provide significant cost savings, water quality, and peak and volume control with infiltration.

COST: Low/Med
Adds less than 1% or up to 5% to total project cost; requires maintenance one—several times/yr.

LONG TERM SUGGESTED OPTIONS

RIPARIAN BUFFER RESTORATION

An area of land that exists between low, aquatic areas such as rivers, streams, lakes, and wetlands, and higher, dry upland areas such as forests, farms, cities, and suburbs.

BENEFITS:
Water quality, ecological and aesthetic value, and low cost.

COST: Low to Low/Med
Adds less than 1% or up to 5% to total project cost; requires maintenance one time/yr.

PERVIOUS PAVEMENT WITH INFILTRATION

A combination of storm water infiltration, storage, and structural pavement consisting of a permeable surface underdrain by a storage reservoir.

BENEFITS:
Volume control and groundwater recharge, moderate peak rate control, and dual use for pavement and storm water management.

COST: Med to High
Adds 1-5% to total project cost; requires extensive maintenance (i.e., year-round maintenance).

OUR PARTNERS

BE PART OF THE FUTURE DEVELOPMENT!

www.sustainoxcreek.org

Figure 1. Example Case Study Document: Brookfield Dodge

OX CREEK WATERSHED URBAN | RURAL | EXIT 29

Featured Case Study—Brookfield Dodge

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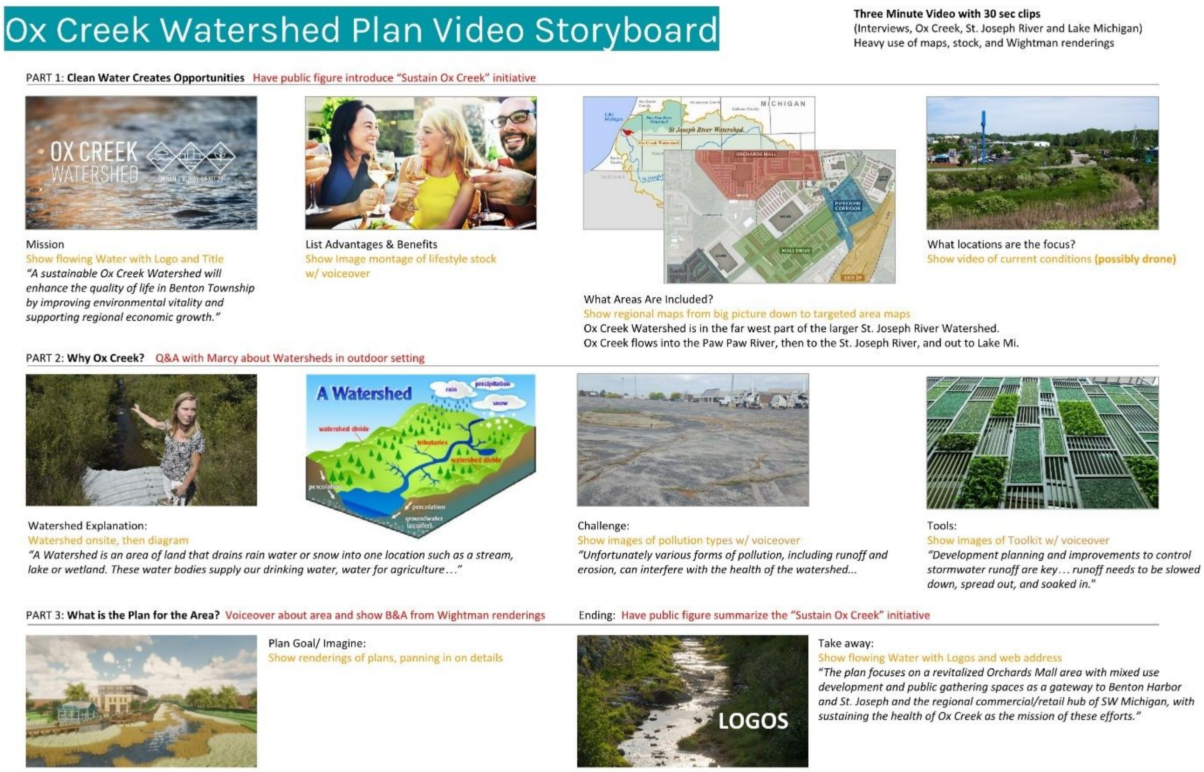
Figure 2. Example Ox Creek Watershed Plan Video Storyboard



SUMMARY OF SCENARIOS
State: Michigan
County: Berrien

Land Use	Hydrologic Soil Group	Pre-Developed	acres Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	1	1	1

PERCENTAGE IMPERVIOUS		
Land Use	Default	Adjusted
Residential 1/4 acre	38	
Residential 1/8 acre	65	
Residential 2 acre	12	
Residential 1 acre	20	
Residential 1/2 acre	25	
Commercial	85	80
Industrial	72	

COMPOSITE CURVE NUMBER		
Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
94	94	93

Curve Number View as:

Land Use	Hydrologic Soil group	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	94	94	93

RUNOFF RESULTS
Avg. Annual Runoff Volume (acre-ft)

Land Use	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	1.24	1.24	1.10
Total Annual Volume (acre-ft)	1.24	1.24	1.10

Also view Annual Variation and Probability of Exceedence

Avg. Annual Runoff Depth (in) View as: Select

Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
14.97	14.97	13.20

Avg. Runoff Depth by Landuse

Land Use	Hydrologic Soil group	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	15.04	15.04	13.26
Average Annual Rainfall Depth (in)				37.50

NONPOINT SOURCE POLLUTANT RESULTS

Nitrogen (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	4	4	4
Total	4	4	4

Phosphorous (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	1	1	0.959
Total	1	1	0.959

Suspended Solids (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	188	188	166
Total	188	188	166

Lead (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.044	0.044	0.038
Total	0.044	0.044	0.038

Copper (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.049	0.049	0.043
Total	0.049	0.049	0.043

Zinc (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.612	0.612	0.539
Total	0.612	0.612	0.539

Cadmium (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.003	0.003	0.002
Total	0.003	0.003	0.002

Chromium (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.034	0.034	0.029
Total	0.034	0.034	0.029

Nickel (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.040	0.040	0.035
Total	0.04	0.04	0.035

BOD (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	78	78	68
Total	78	78	68

COD (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	394	394	347

Total	394	394	347

Oil & Grease (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	30	30	26
Total	30	30	26

Fecal Coliform (millions of coliform)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	106	106	94
Total	106	106	94

Fecal Strep (millions of coliform)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	278	278	245
Total	278	278	245

These results were generated by the L-THIA (Long-Term Hydrologic Impact Assessment) model at "http://www.ecn.purdue.edu/runoff/lthianew"

SUMMARY OF SCENARIOS
State: Michigan
County: Berrien

Land Use	Hydrologic Soil Group	Pre-Developed	acres Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	10	10	10

PERCENTAGE IMPERVIOUS		
Land Use	Default	Adjusted
Residential 1/4 acre	38	
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COMPOSITE CURVE NUMBER		
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94	94	93

Curve Number View as:

Land Use	Hydrologic Soil group	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	94	94	93

RUNOFF RESULTS
Avg. Annual Runoff Volume (acre-ft)

Land Use	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	12.48	12.48	11.00
Total Annual Volume (acre-ft)	12.48	12.48	11.00

Also view Annual Variation and Probability of Exceedence

Avg. Annual Runoff Depth (in) View as: Select

Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
14.97	14.97	13.20

Avg. Runoff Depth by Landuse

Land Use	Hydrologic Soil group	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	15.04	15.04	13.26
Average Annual Rainfall Depth (in)				37.50

NONPOINT SOURCE POLLUTANT RESULTS

Nitrogen (lbs)

Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	45	45	40
Total	45	45	40

Phosphorous (lbs)

Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	10	10	9
Total	10	10	9

Suspended Solids (lbs)

Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	1887	1887	1664
Total	1887	1887	1664

Lead (lbs)

Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.442	0.442	0.389
Total	0.442	0.442	0.389

Copper (lbs)

Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.493	0.493	0.434
Total	0.493	0.493	0.434

Zinc (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	6	6	5
Total	6	6	5

Cadmium (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.032	0.032	0.028
Total	0.032	0.032	0.028

Chromium (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.340	0.340	0.299
Total	0.34	0.34	0.299

Nickel (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.401	0.401	0.353
Total	0.401	0.401	0.353

BOD (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	782	782	689
Total	782	782	689

COD (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	3945	3945	3478

Total	3945	3945	3478

Oil & Grease (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	306	306	269
Total	306	306	269

Fecal Coliform (millions of coliform)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	1066	1066	940
Total	1066	1066	940

Fecal Strep (millions of coliform)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	2782	2782	2453
Total	2782	2782	2453

These results were generated by the L-THIA (Long-Term Hydrologic Impact Assessment) model at "http://www.ecn.purdue.edu/runoff/lthianew"

SUMMARY OF SCENARIOS State: Michigan County: Berrien				
Land Use	Hydrologic Soil Group	Pre-Developed	acres Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	10	10	10

COMPOSITE CURVE NUMBER

Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
94	94	92

Curve Number View as:

Land Use	Hydrologic Soil group	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	94	94	92

RUNOFF RESULTS
Avg. Annual Runoff Volume (acre-ft)

Land Use	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	12.48	12.48	10.09
Total Annual Volume (acre-ft)	12.48	12.48	10.09

Also view Annual Variation and Probability of Exceedence

Avg. Annual Runoff Depth (in) View as: Select

Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
14.97	14.97	12.11

Avg. Runoff Depth by Landuse

Land Use	Hydrologic Soil group	Current	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	C	15.04	15.04	12.16

Average Annual Rainfall Depth (in) 37.50

NONPOINT SOURCE POLLUTANT RESULTS

Nitrogen (lbs)

Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	45	45	36
Total	45	45	36

Phosphorous (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	10	10	8
Total	10	10	8

Suspended Solids (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	1887	1887	1526
Total	1887	1887	1526

Lead (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.442	0.442	0.357
Total	0.442	0.442	0.357

Copper (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.493	0.493	0.398
Total	0.493	0.493	0.398

Zinc (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	6	6	4
Total	6	6	4

Cadmium (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.032	0.032	0.026
Total	0.032	0.032	0.026

Chromium (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.340	0.340	0.274
Total	0.34	0.34	0.274

Nickel (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	0.401	0.401	0.324
Total	0.401	0.401	0.324

BOD (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	782	782	632
Total	782	782	632

COD (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	3945	3945	3189
Total	3945	3945	3189

Oil & Grease (lbs)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	306	306	247
Total	306	306	247

Fecal Coliform (millions of coliform)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	1066	1066	862
Total	1066	1066	862

Fecal Strep (millions of coliform)			
Land Use	Pre-Developed	Post-Developed W/o LID	Post-Developed With LID As Proposed
Commercial	2782	2782	2249
Total	2782	2782	2249

These results were generated by the L-THIA (Long-Term Hydrologic Impact Assessment) model at "http://www.ecn.purdue.edu/runoff/lthianew"