Total Maximum Daily Load for Biota in Ox Creek

Berrien County, Michigan

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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.

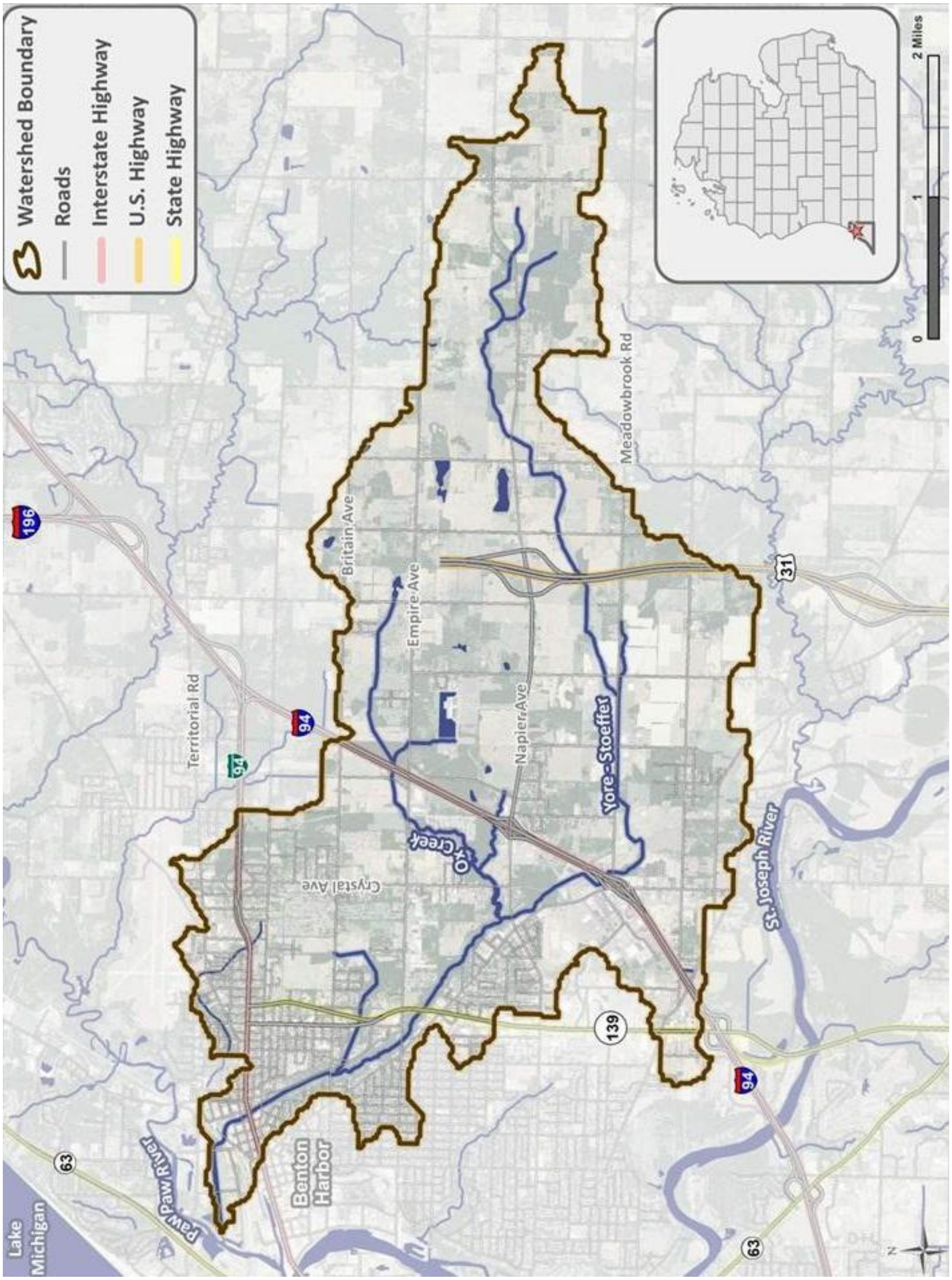


Figure 2-1. Ox Creek project area.

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%

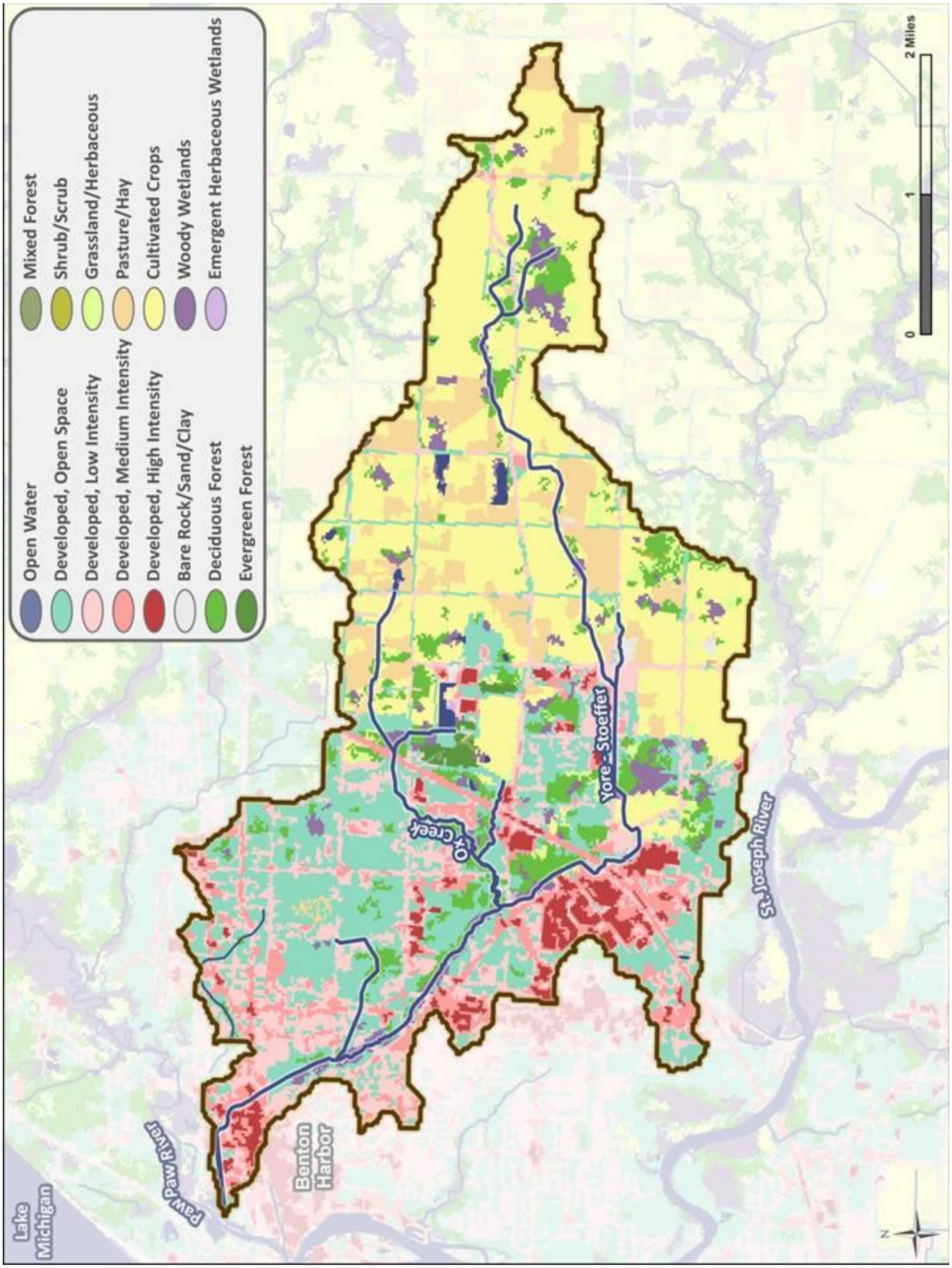


Figure 2-2. Ox Creek watershed land use.

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)*.

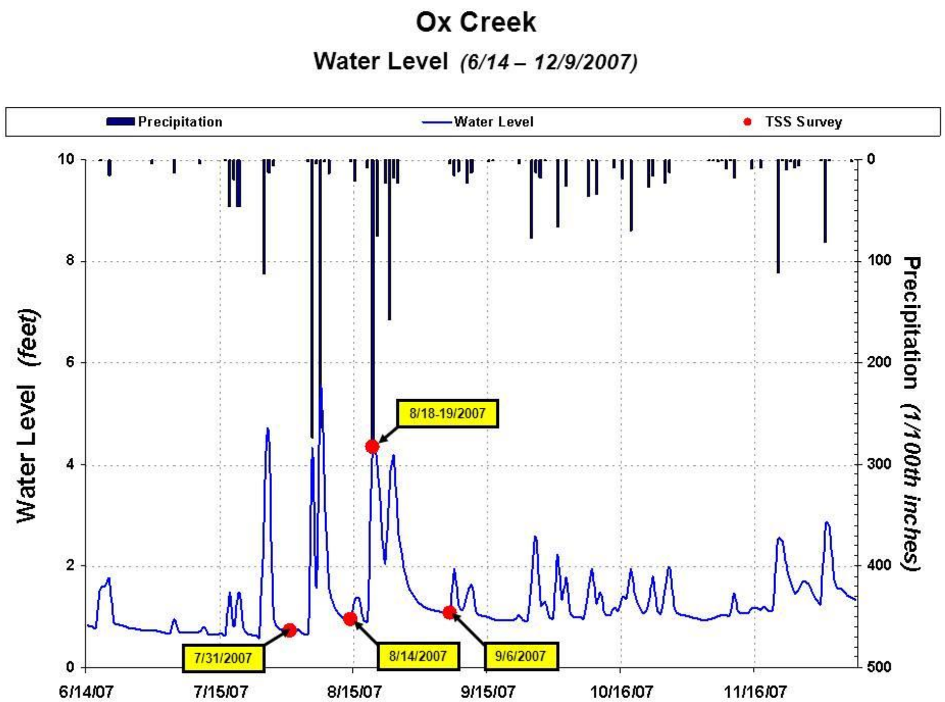


Figure 2-3. Water level data collected in Ox Creek at Britain Avenue -- 2007.

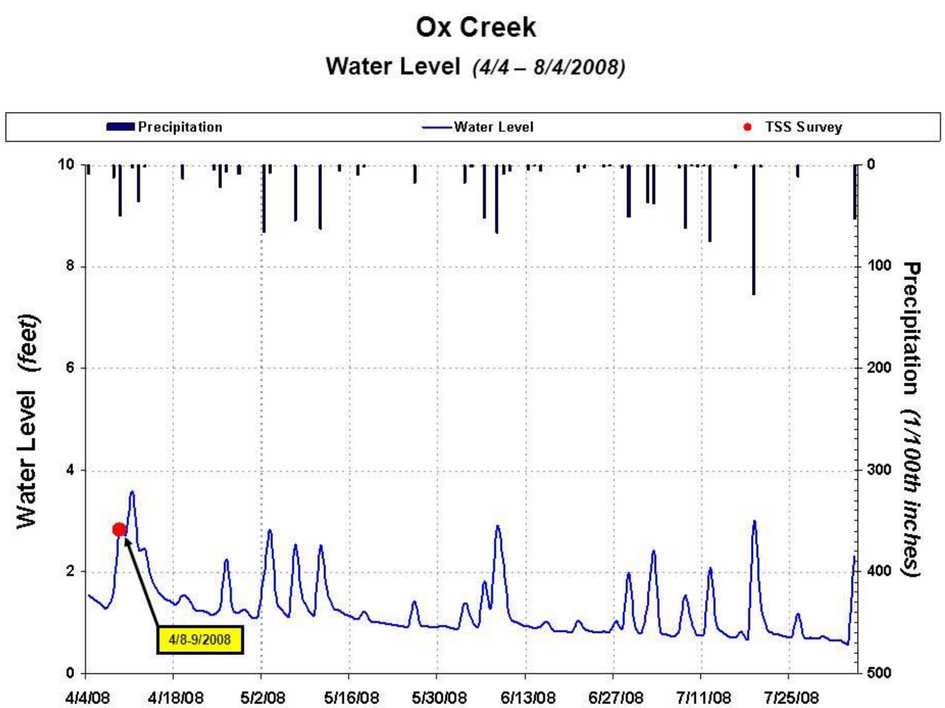


Figure 2-4. Water level data collected in Ox Creek at Britain Avenue -- 2008.

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

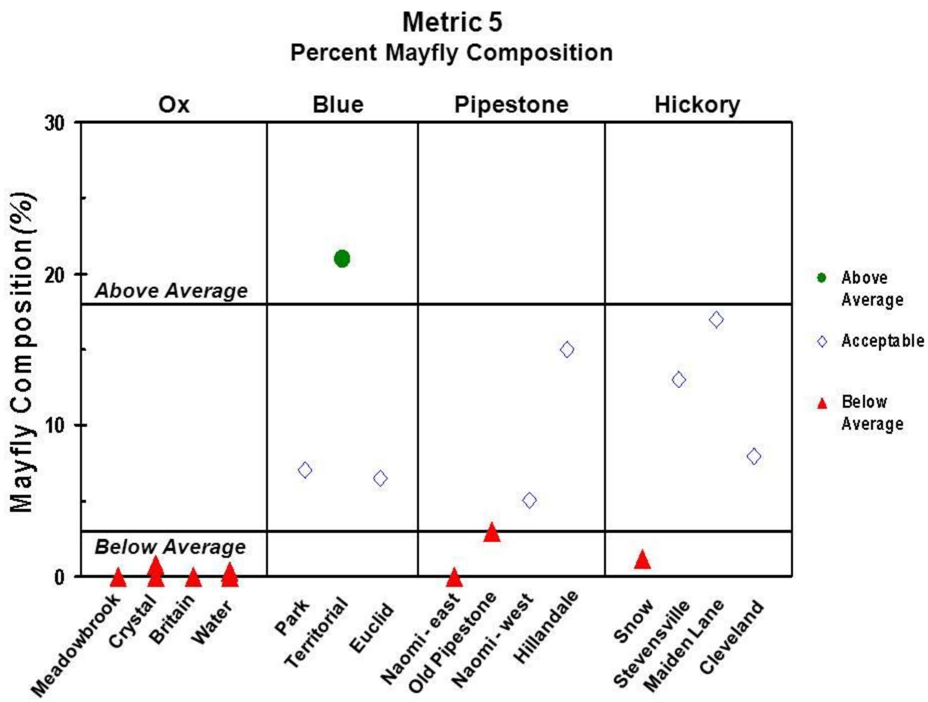


Figure 2-5. Mayfly composition in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

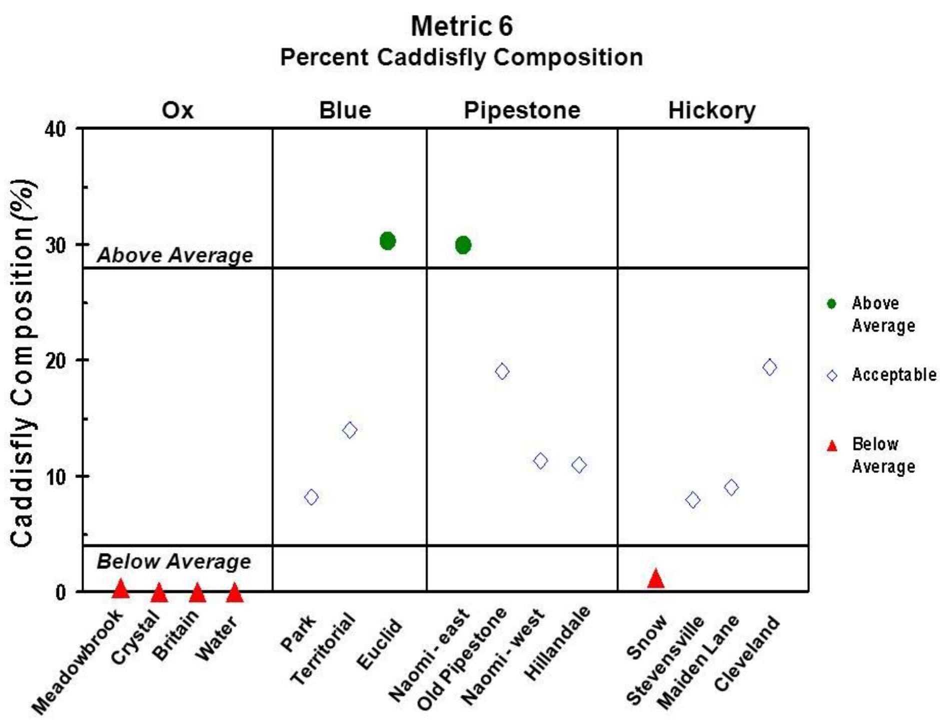


Figure 2-6. Caddisfly composition in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

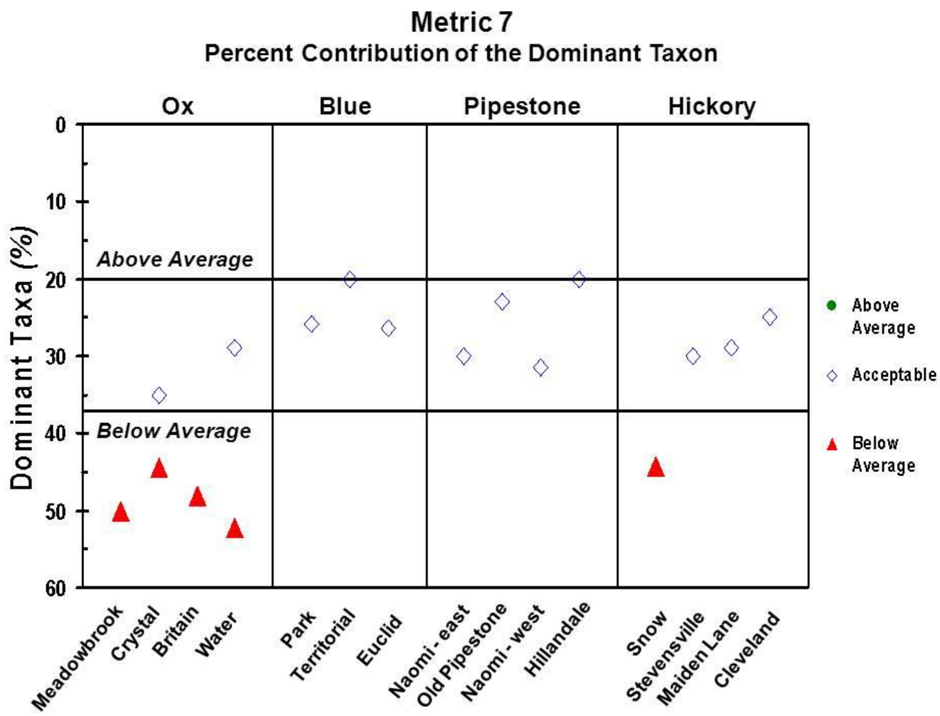


Figure 2-7. Dominant taxa in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

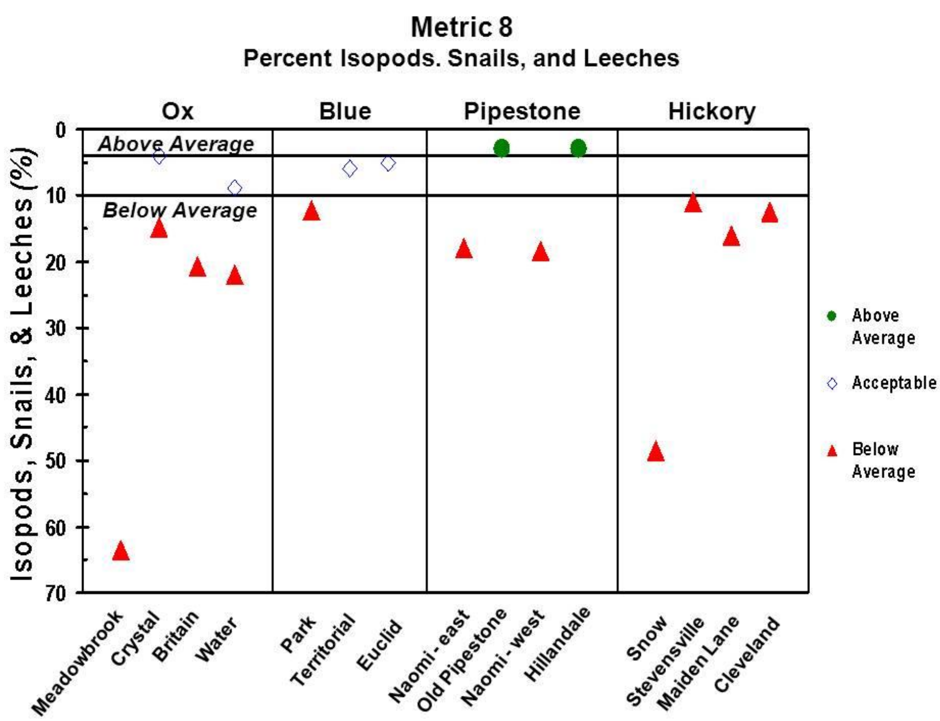


Figure 2-8. Isopod, snails, and leeches in Ox Creek compared to Blue, Pipestone, and Hickory Creeks.

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.

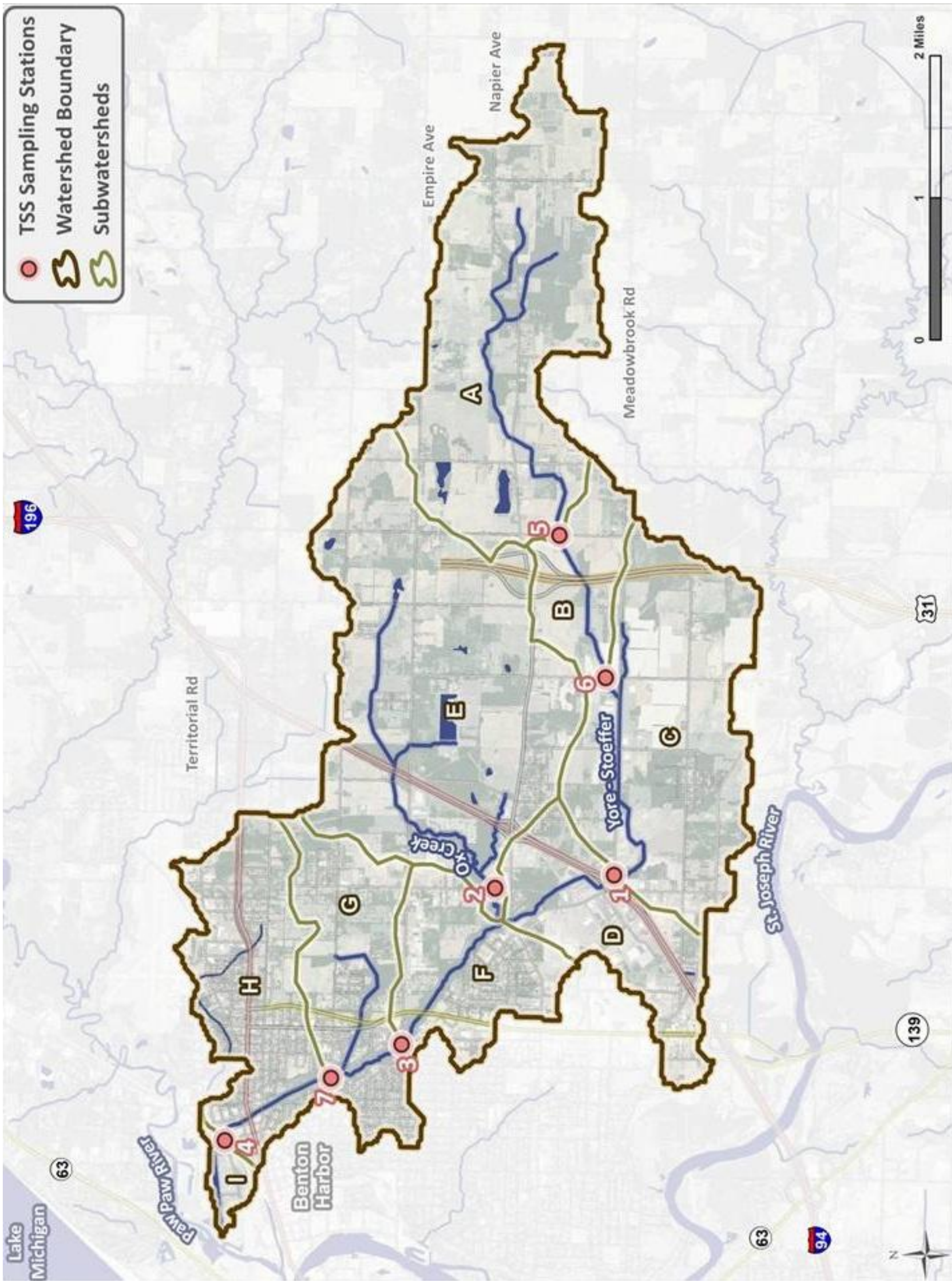


Figure 2-9. Location of Ox Creek 2007 and 2008 TSS monitoring sites.

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

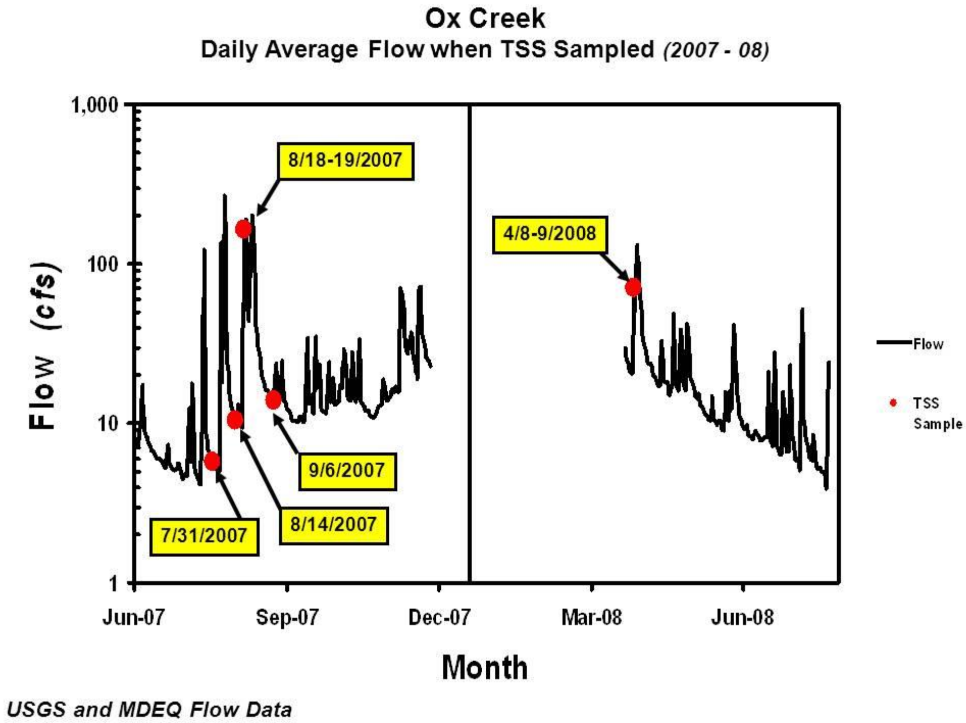


Figure 2-10. Ox Creek flow and TSS sample dates.

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.

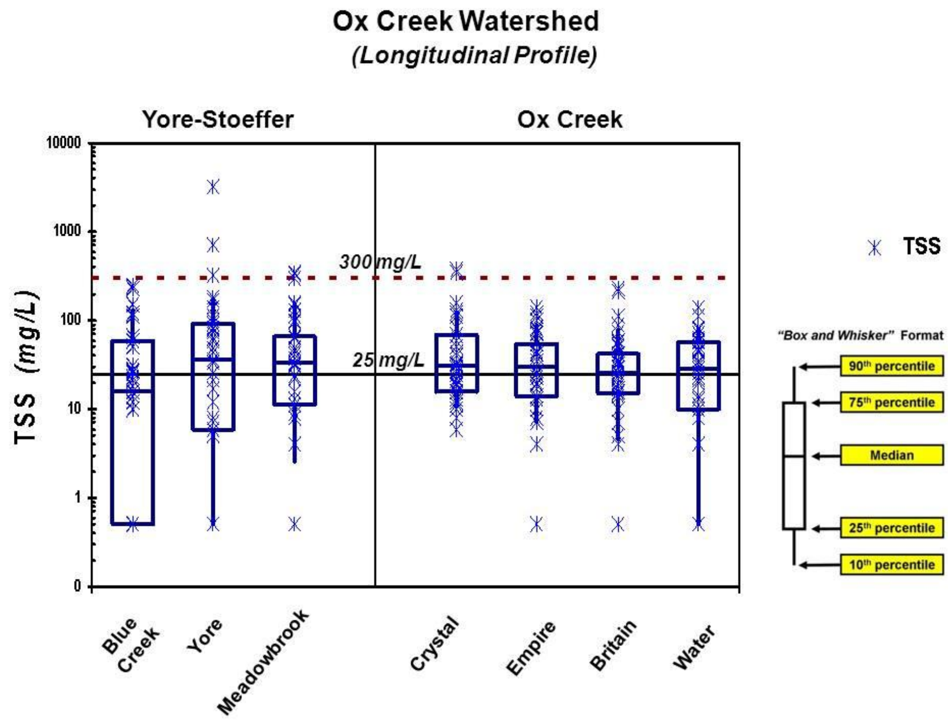


Figure 2-11. Longitudinal profile of TSS monitoring data.

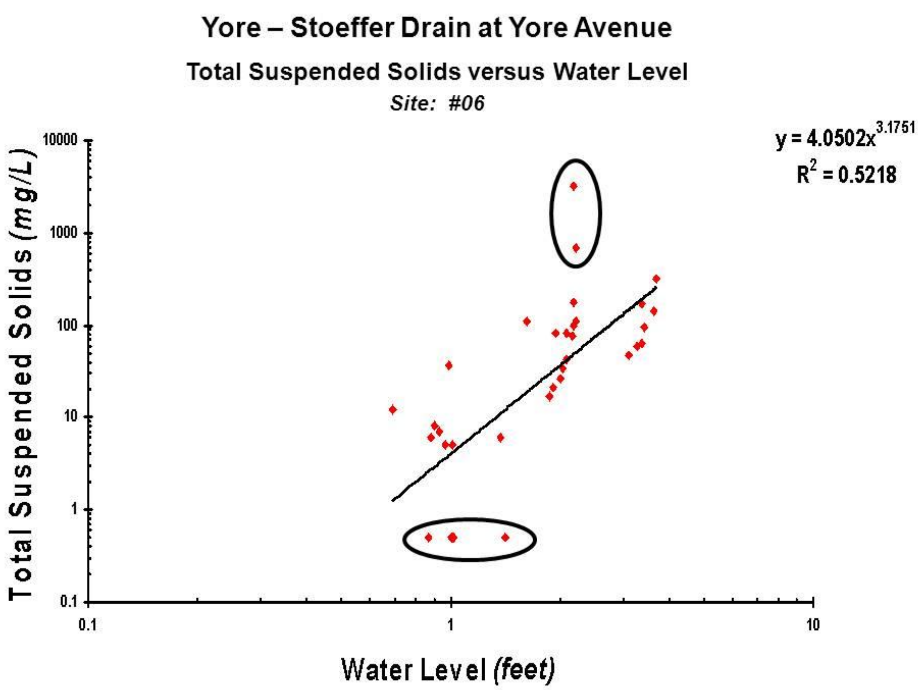


Figure 2-12. TSS as a function of water level -- Yore Avenue site.

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)*.

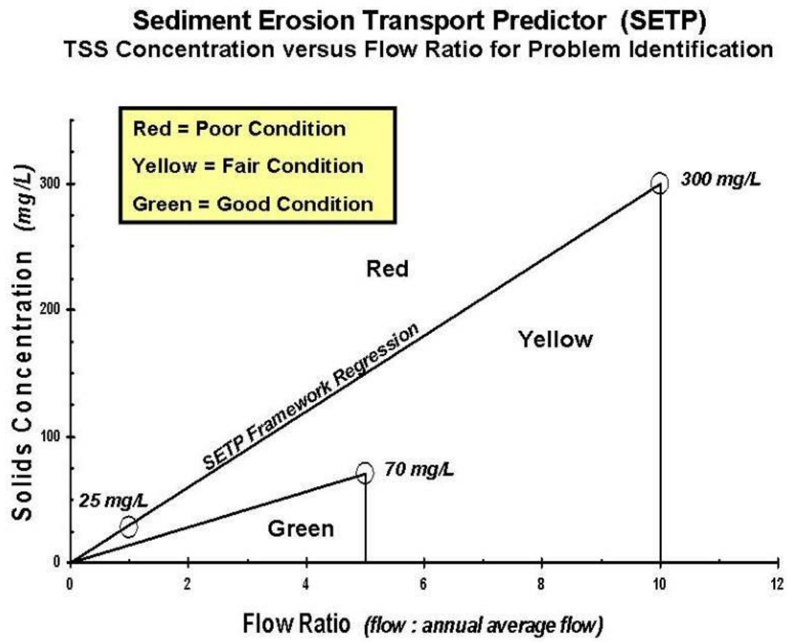


Figure 3-1. Sediment Erosion Transport Predictor *(SETP)* framework overview.

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

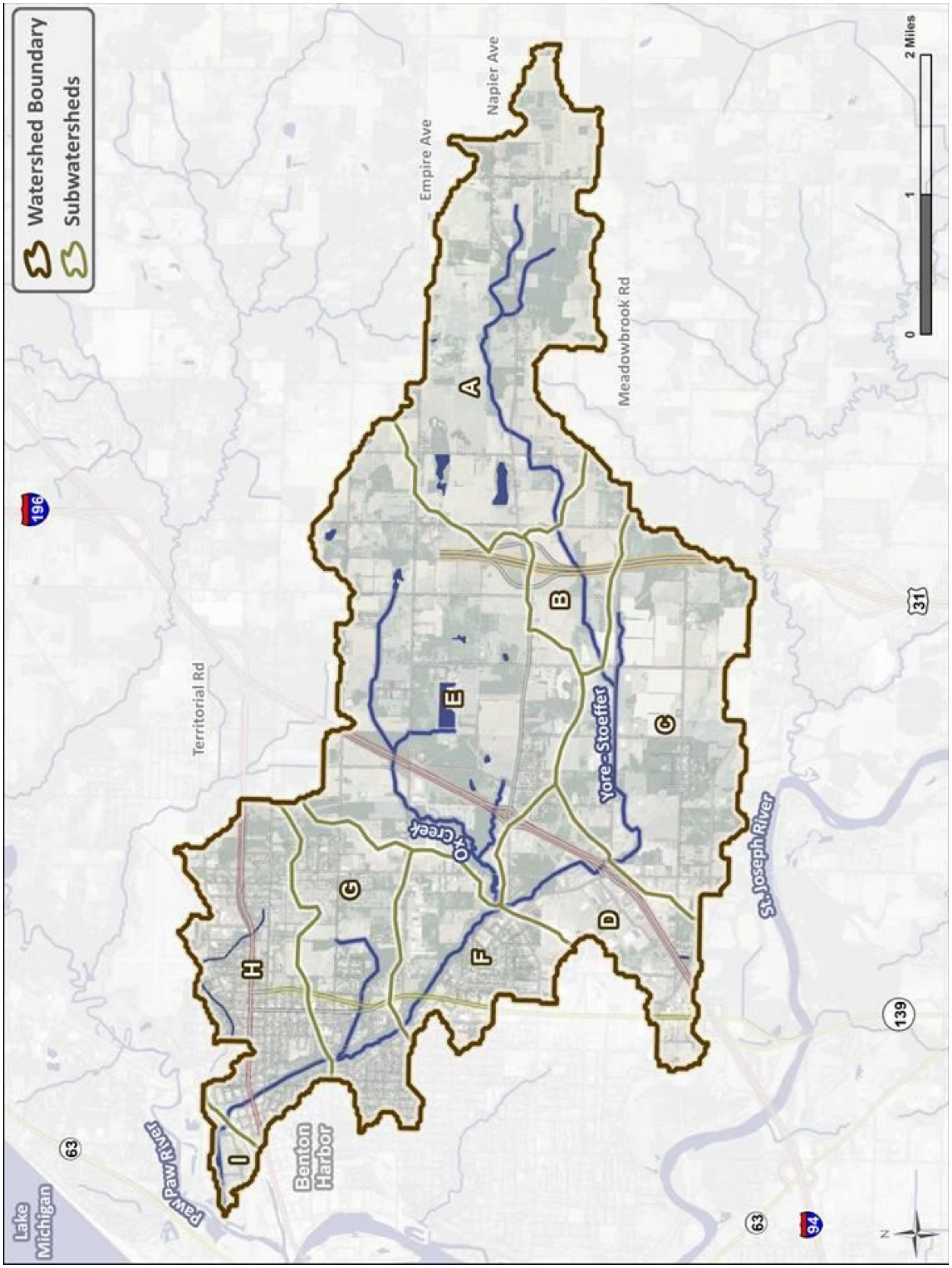


Figure 4-1. Ox Creek watershed units.

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

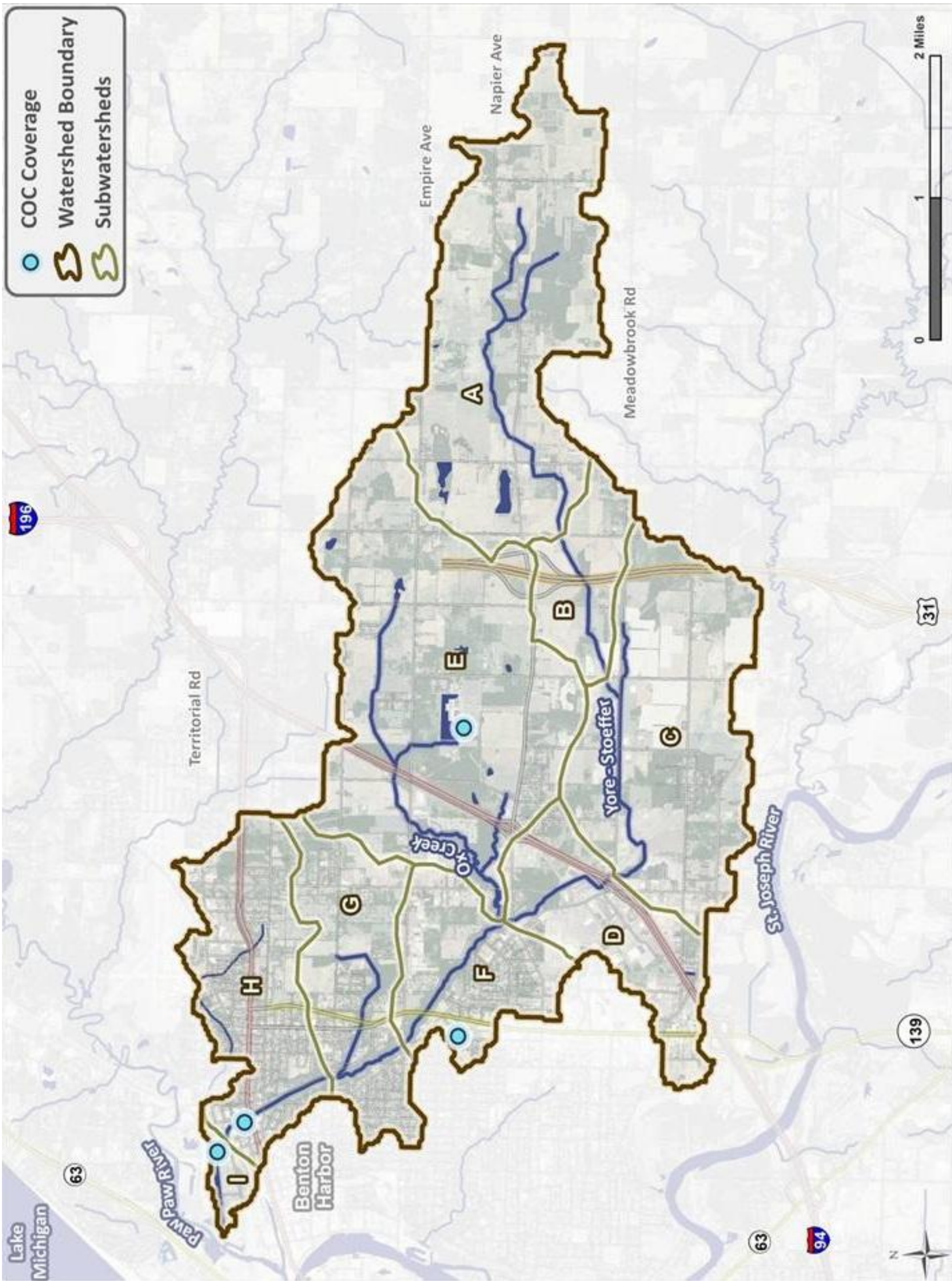


Figure 4-2. Location of facilities with COCs for non-contact cooling water.

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

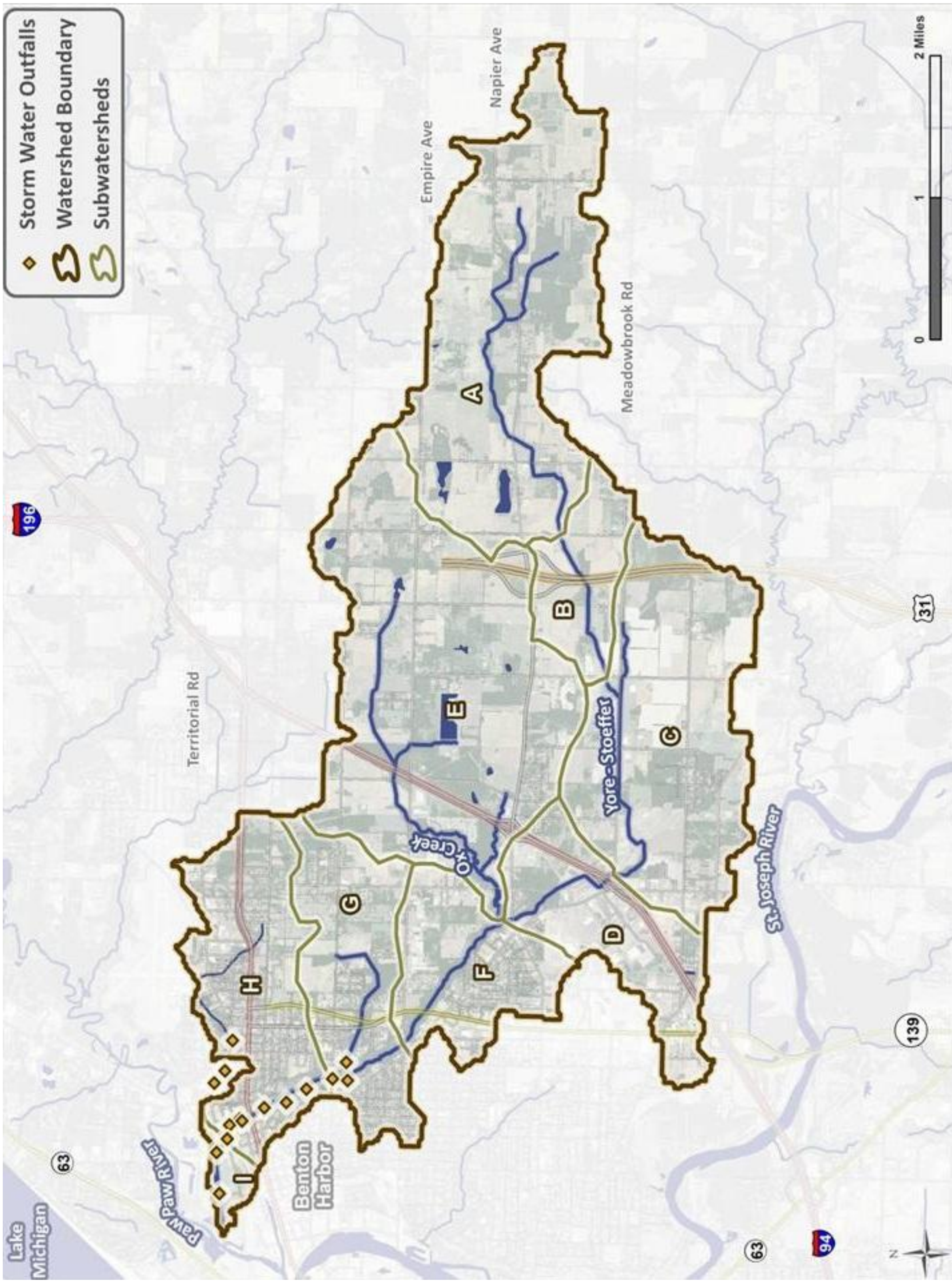


Figure 4-3. Location of outfalls under Benton Harbor MS4 storm water permit.

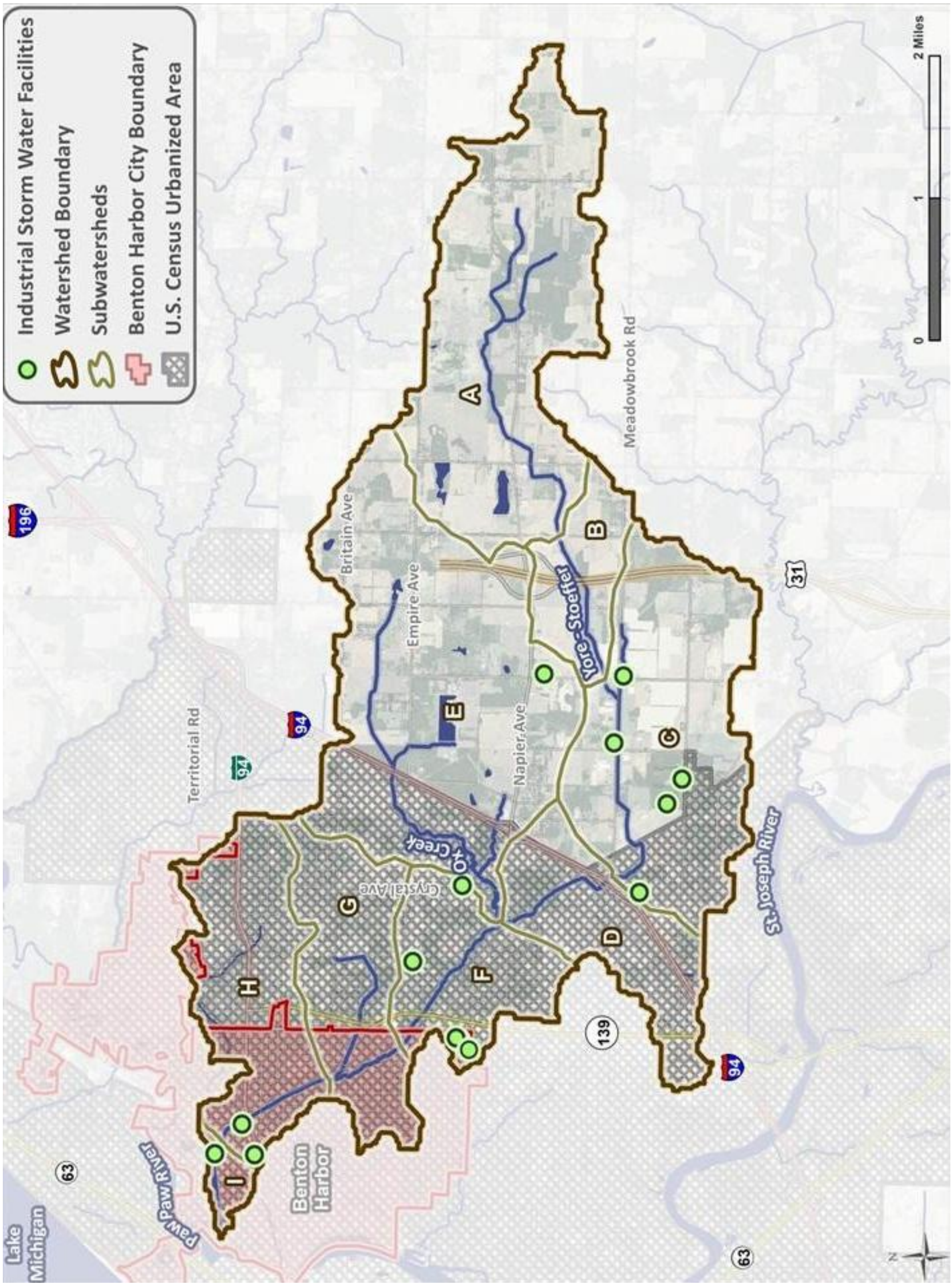


Figure 4-4. Location of facilities with industrial storm water permit coverage.

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.

Unit C. The *Middle Yore – Stoeffer* 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.

Unit D. The *Lower Yore – Stoeffer* 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.

Unit E. The *Ox Headwaters* 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.

Unit F. The *Upper Ox* 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.

Unit G. The *Middle Ox* 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.

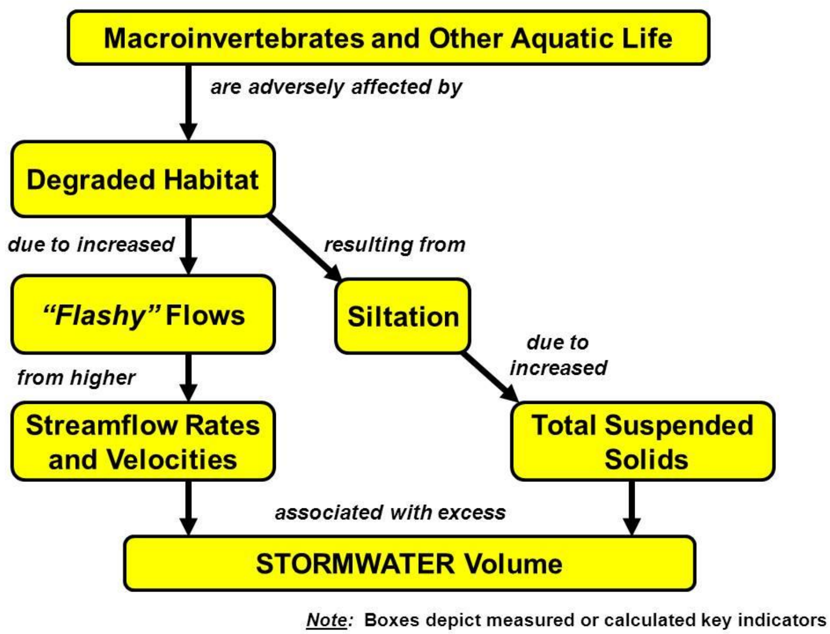


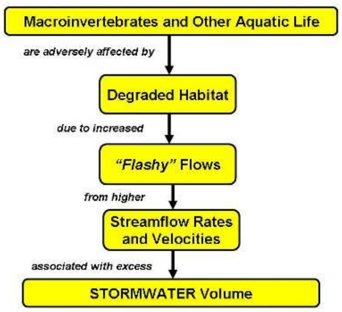
Figure 5-1. Relationship between key indicators in Ox Creek linkage analysis.

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.

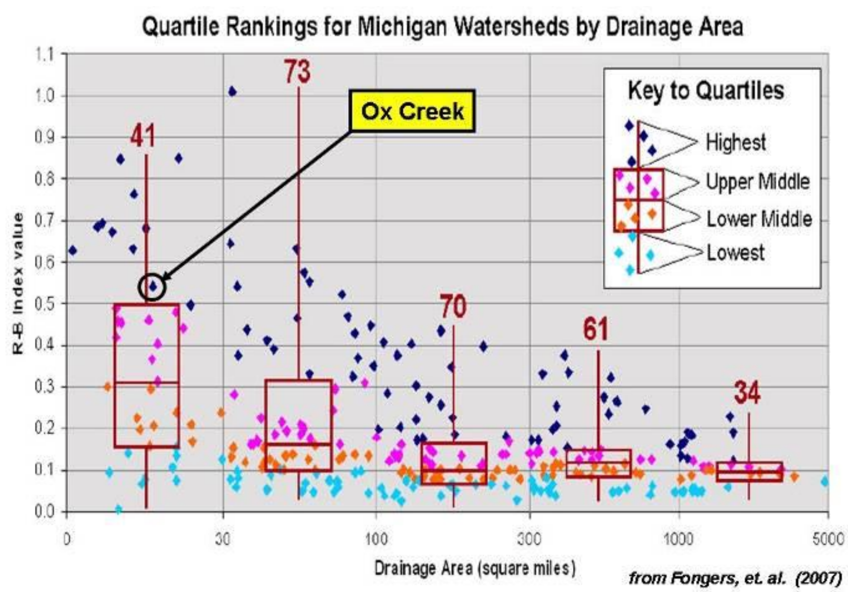


Figure 5-2. R-B flashiness index quartile rankings for Michigan rivers and streams.

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.

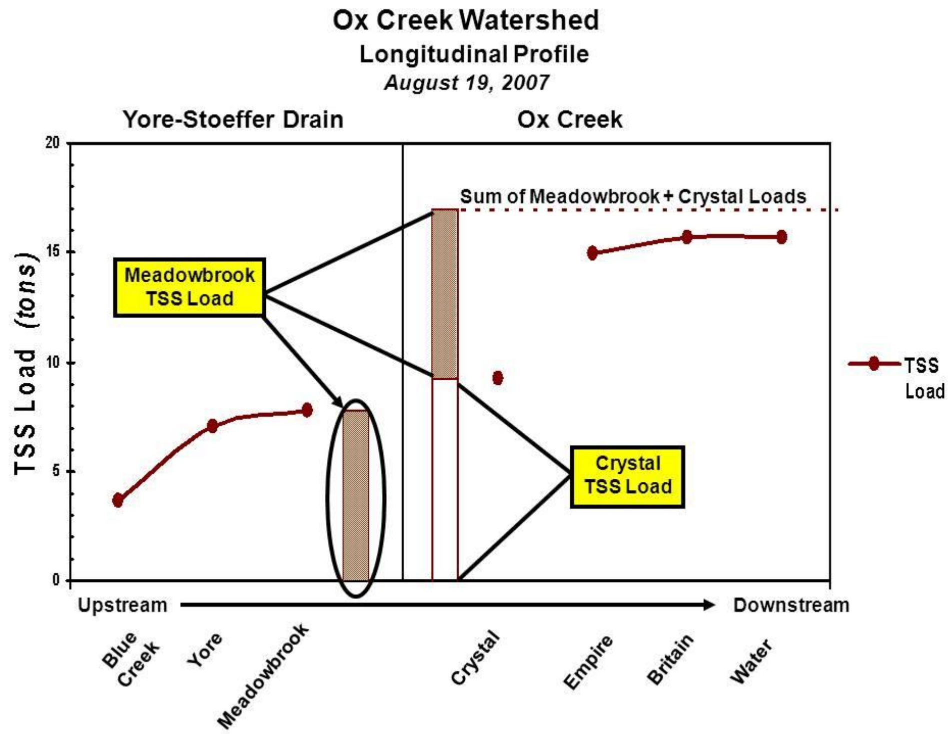


Figure 5-3. TSS loads in the Ox Creek watershed for wet weather event #1.

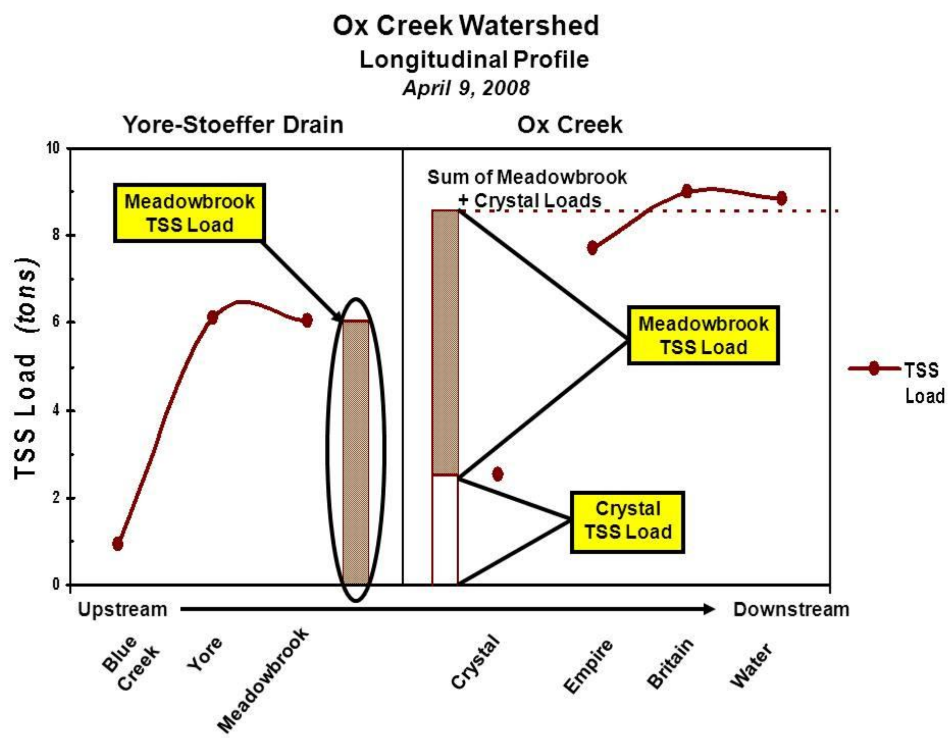


Figure 5-4. TSS loads in the Ox Creek watershed for wet weather event #2.

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.

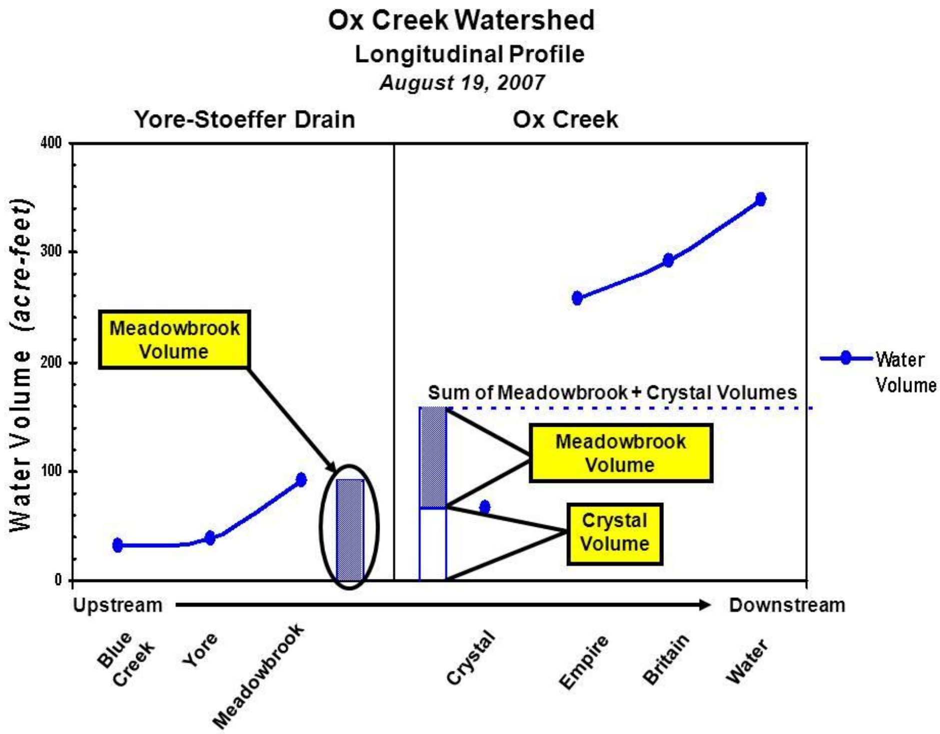


Figure 5-5. Water volume in the Ox Creek watershed for wet weather event #1.

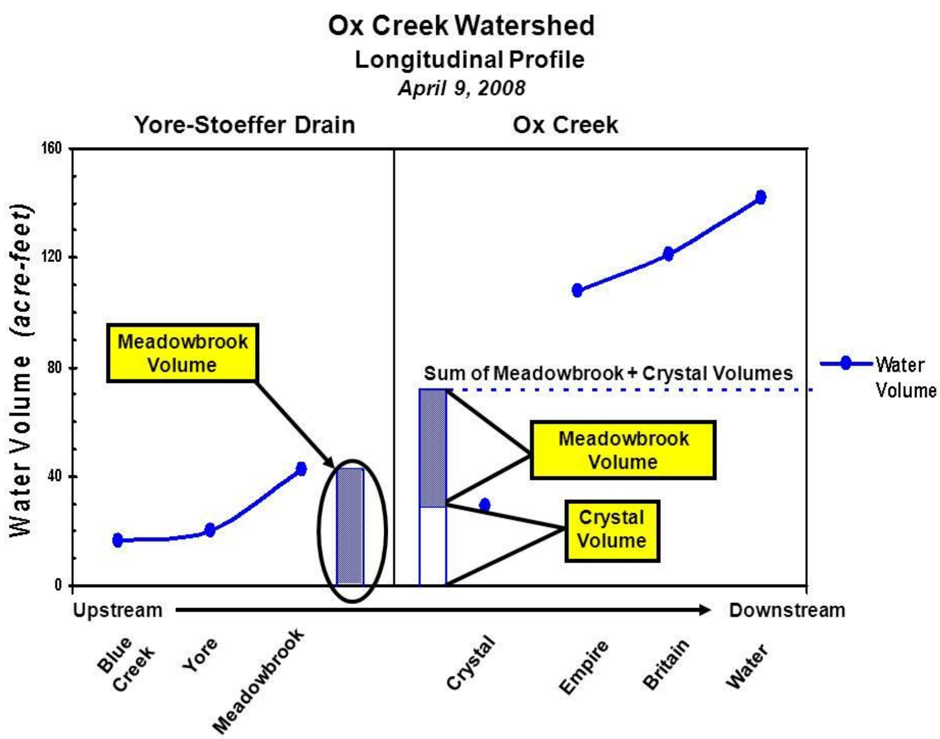


Figure 5-6. Water volume in the Ox Creek watershed for wet weather event #2.

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.

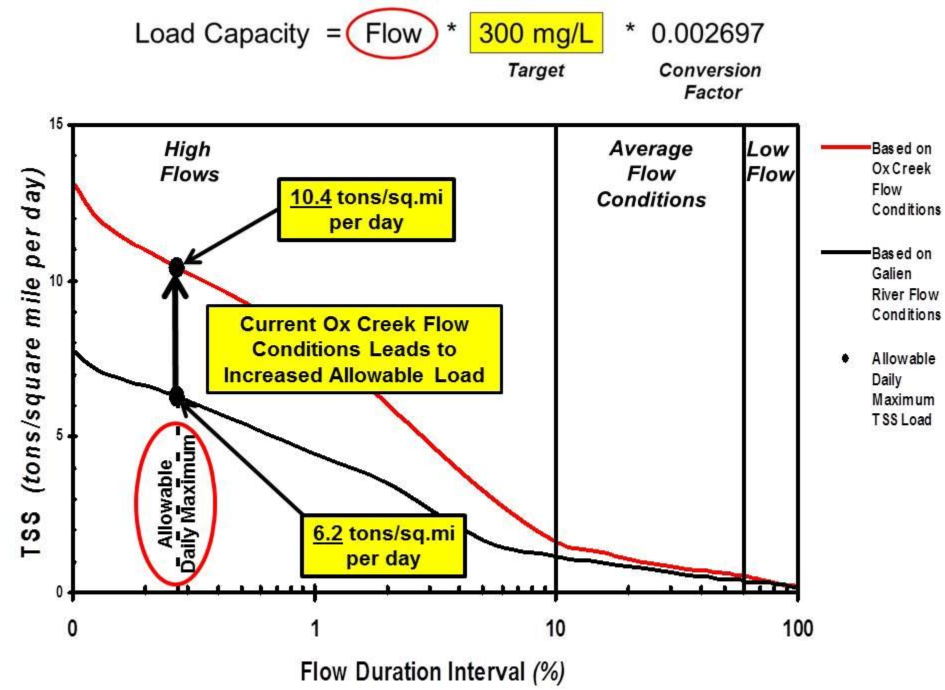


Figure 5-7. Relative effect of flow on increased maximum daily TSS loads contributing to siltation.

(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:

Load Capacity = Flow * 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)*.

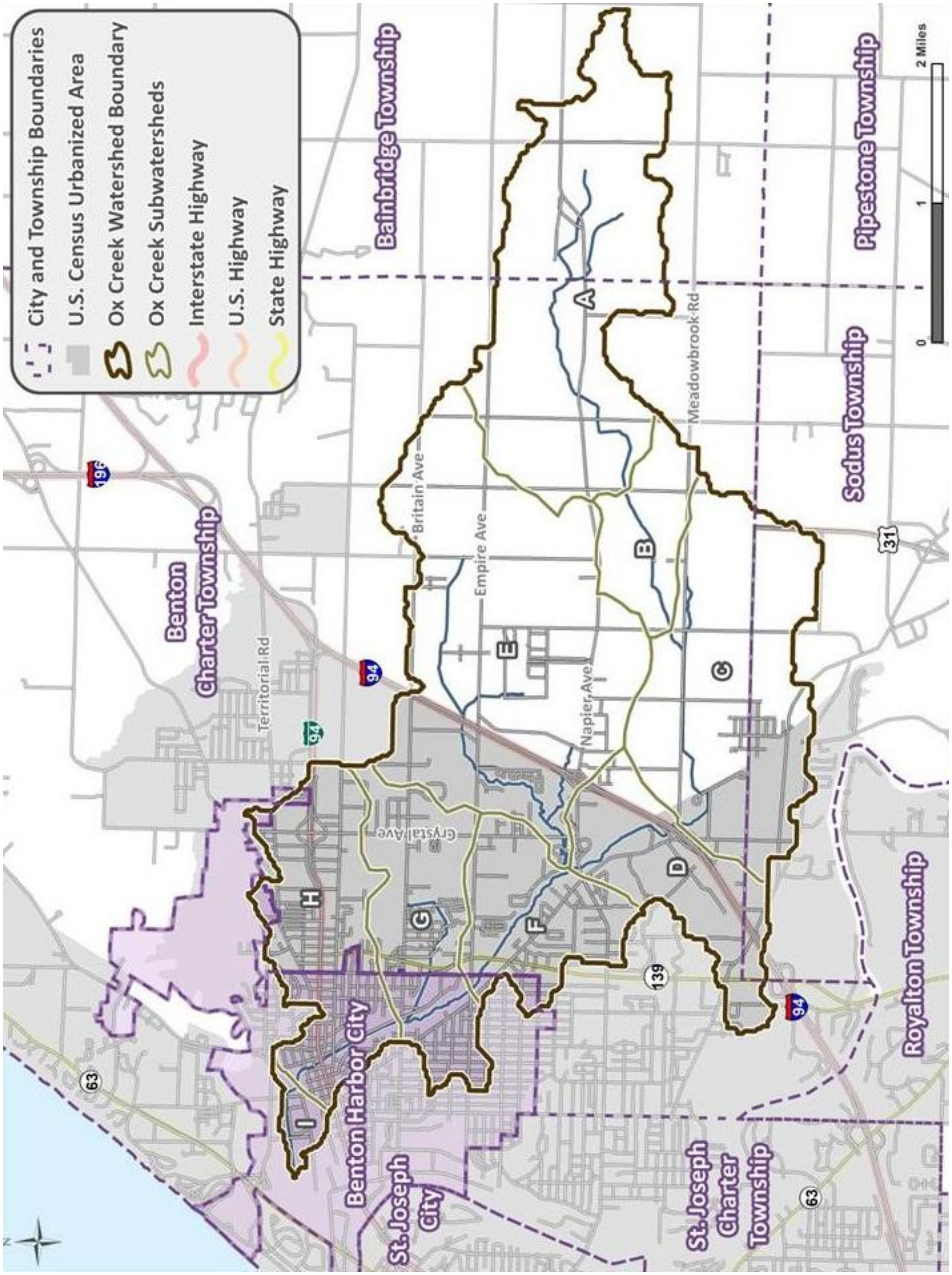


Figure 6-1. MS4 urbanized area in Ox Creek watershed.

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.

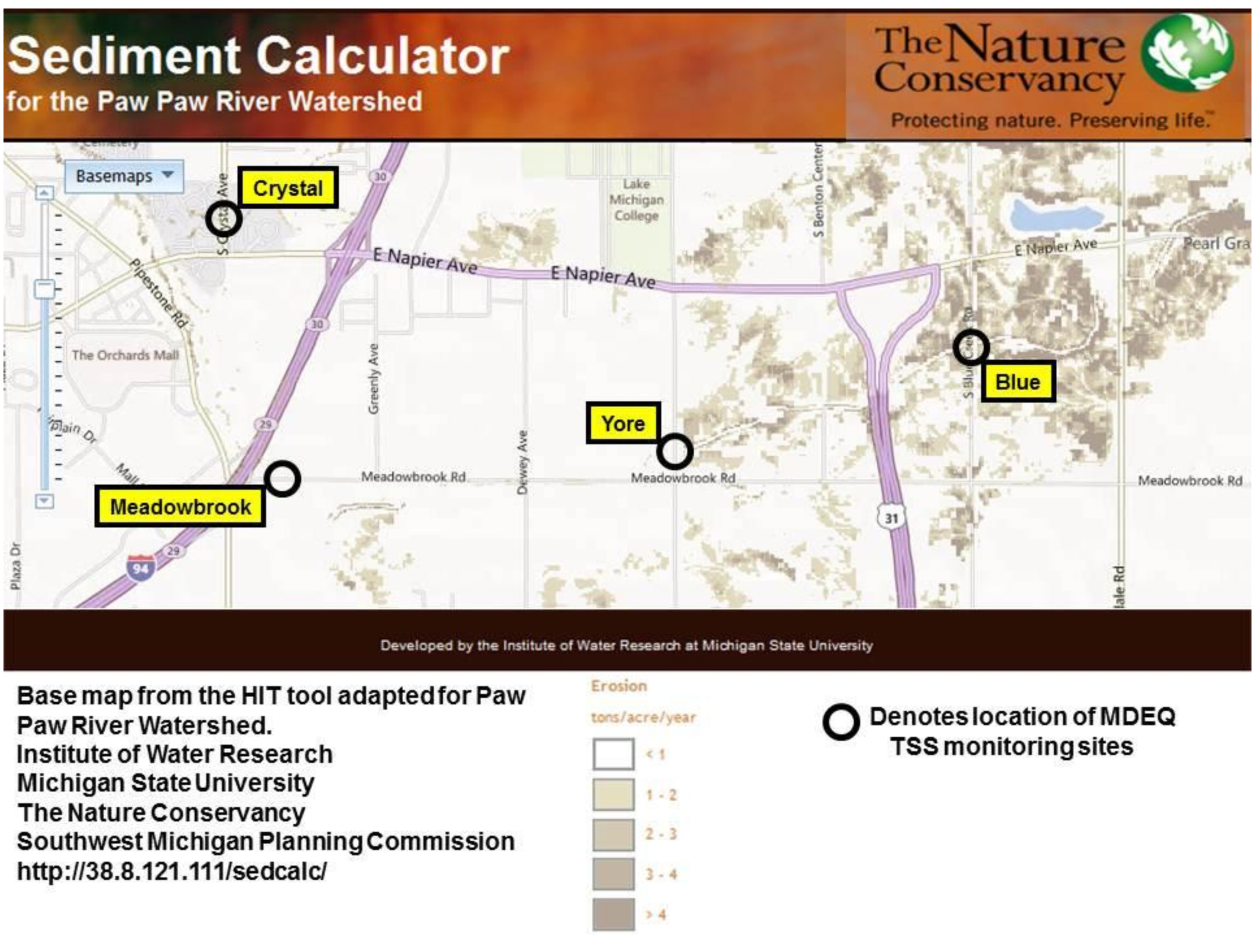


Figure 7-1. HIT sediment load estimates for upper Ox Creek watershed.

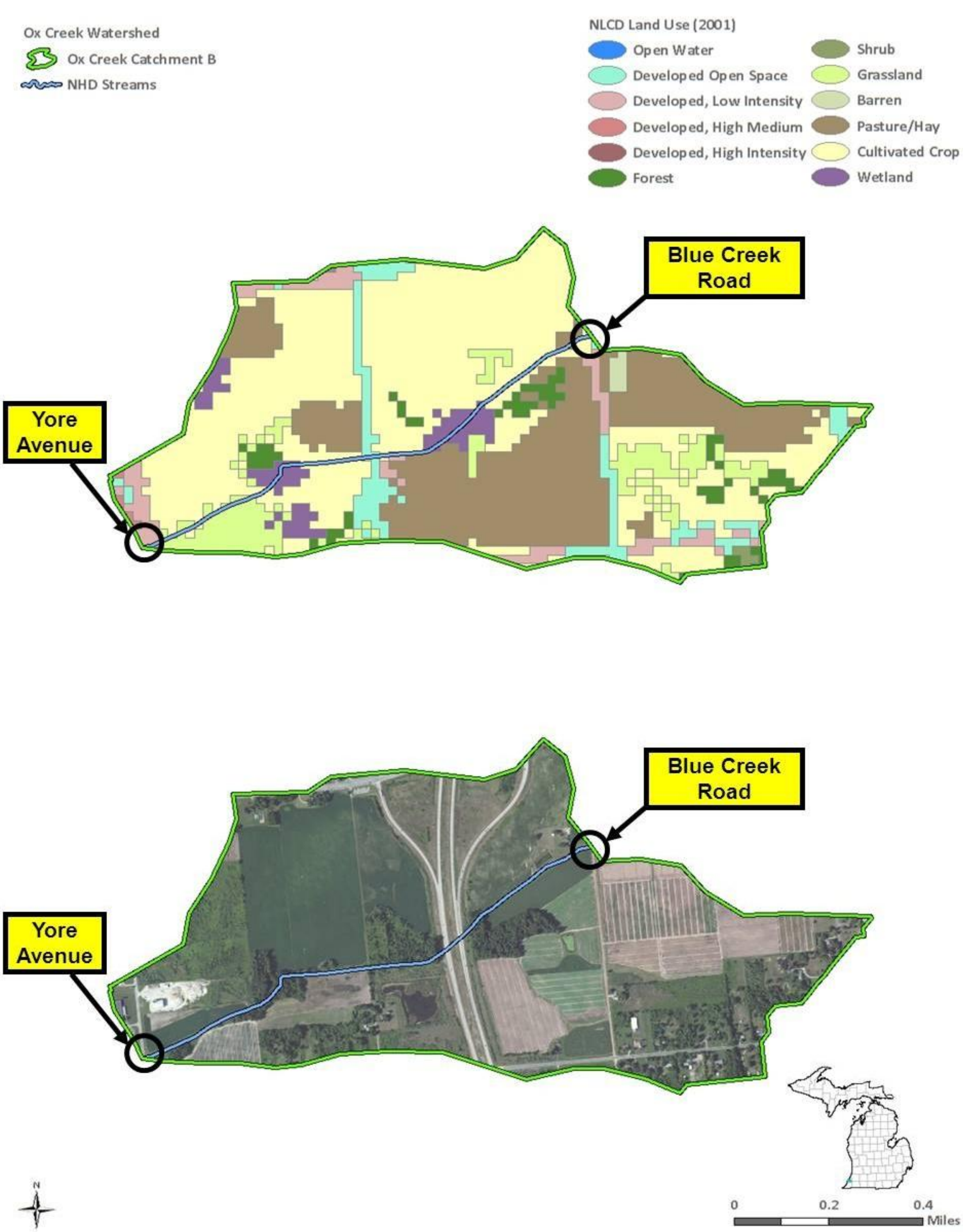


Figure 7-2. Land use and air photo of subwatershed unit B.

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).

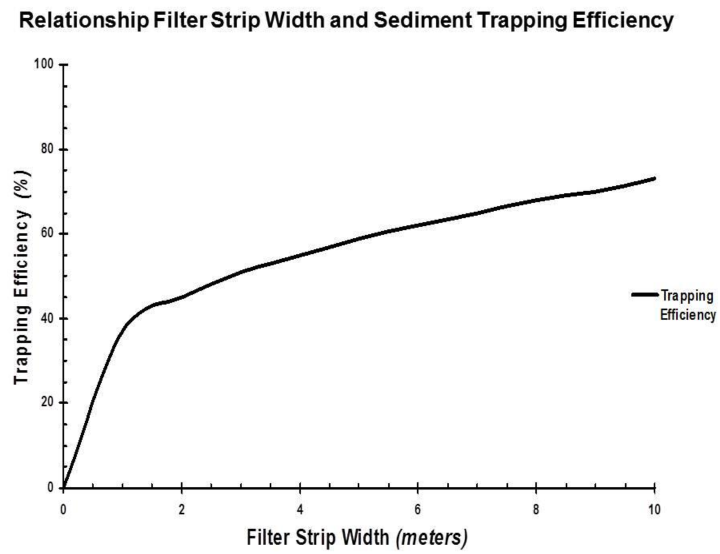


Figure 7-3. Relationship between filter strip width and pollutant trapping efficiency.

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%

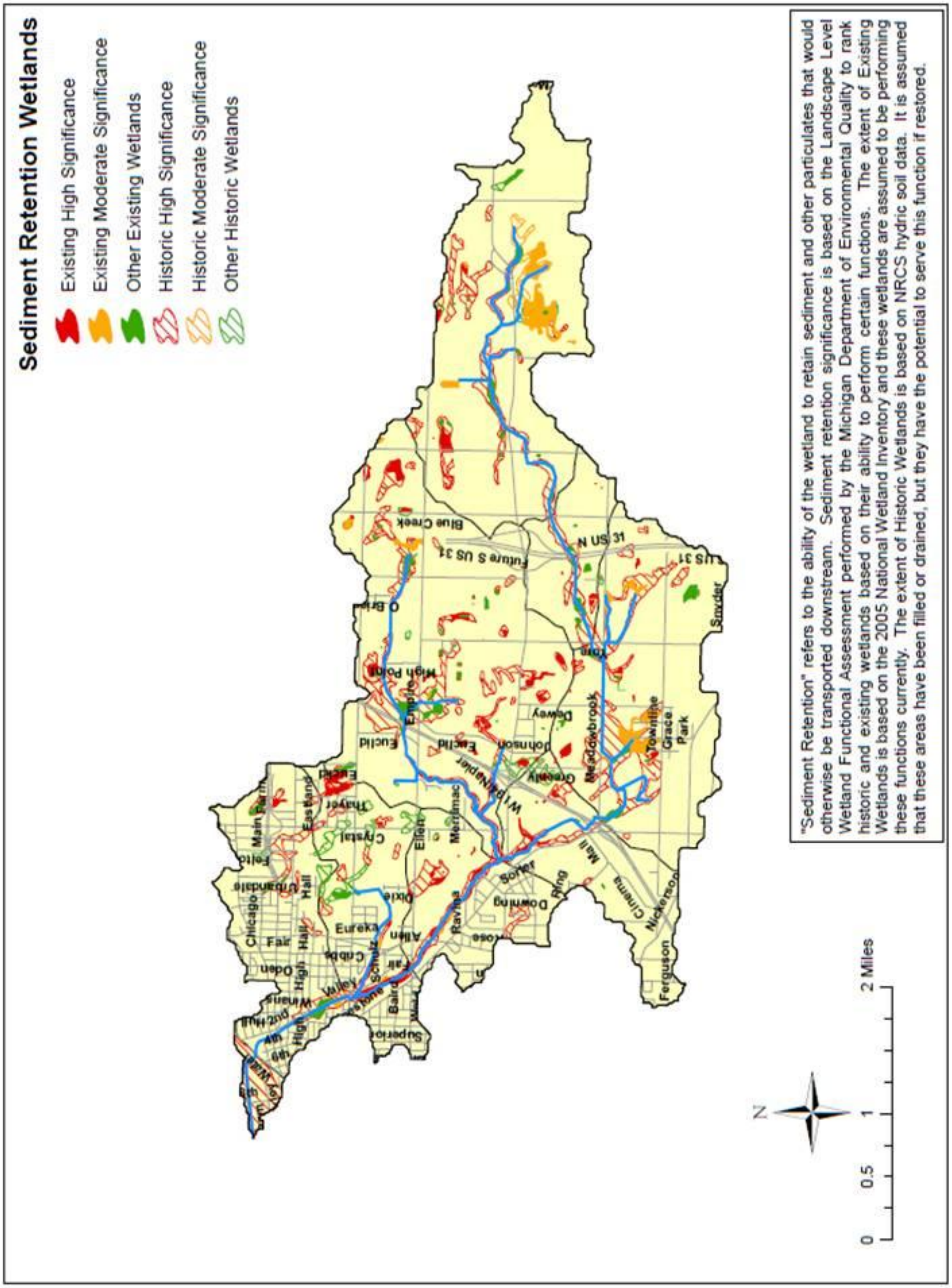


Figure 7-4. Ox Creek sediment retention wetland summary.

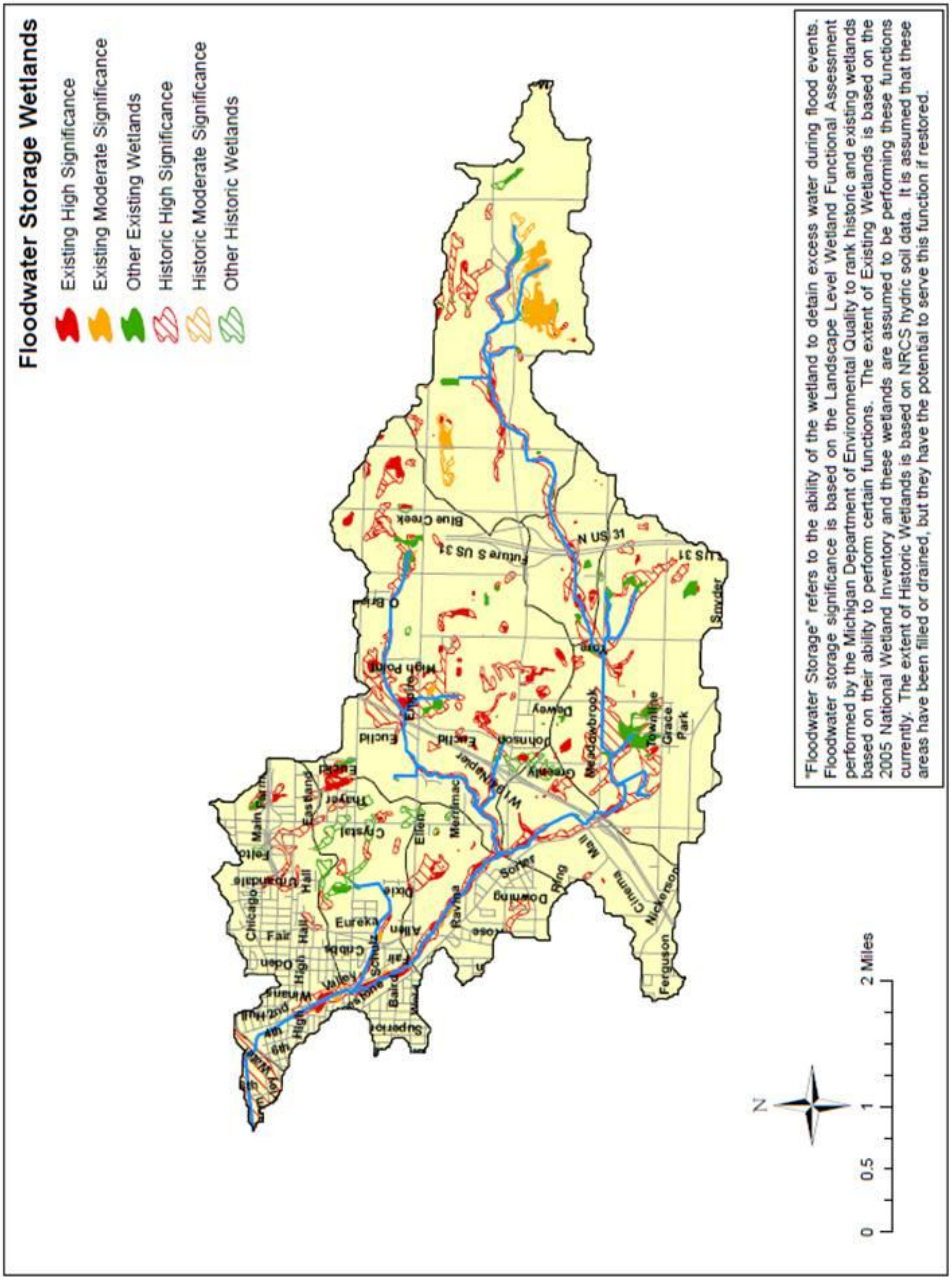


Figure 7-5. Ox Creek floodwater storage wetland summary.

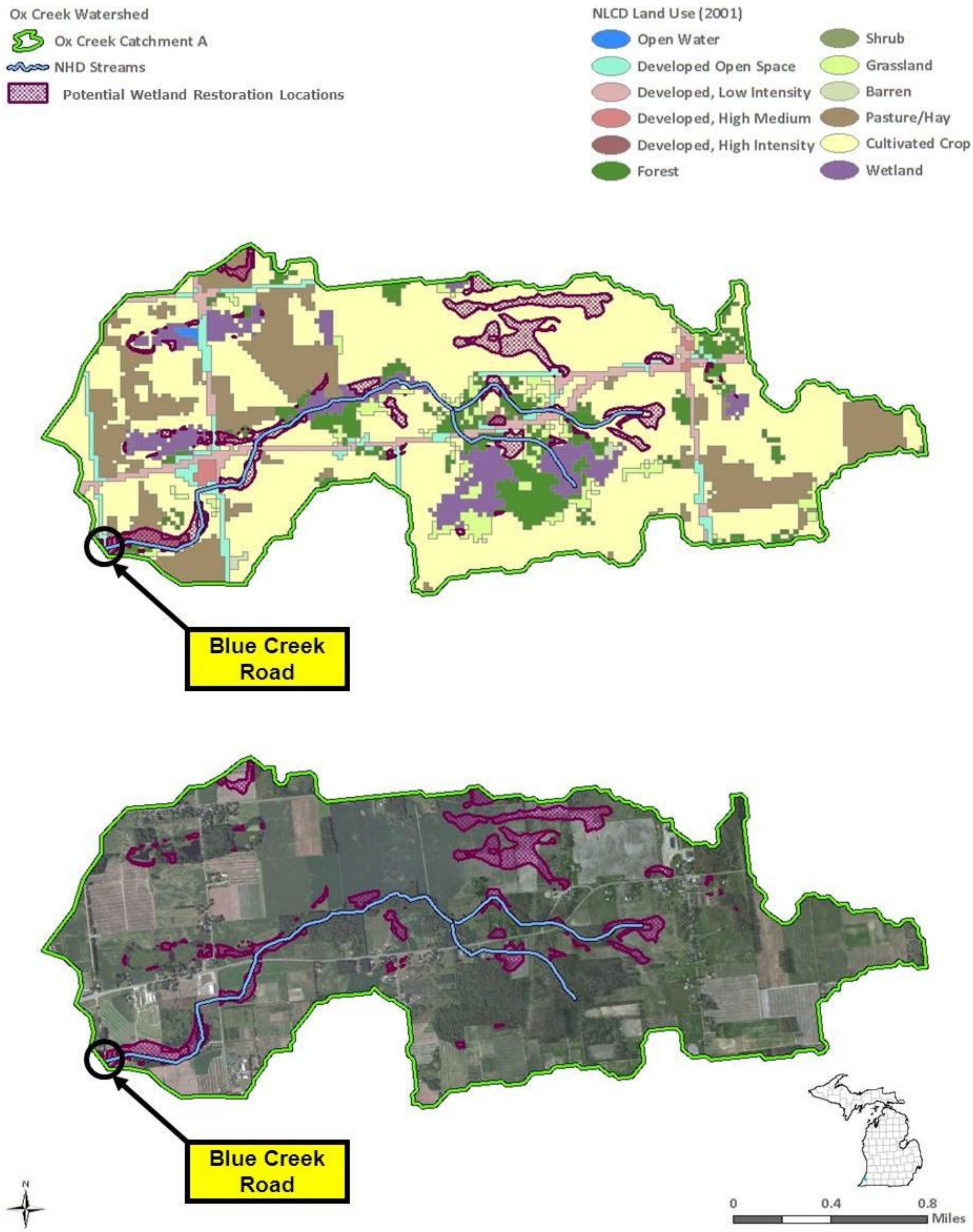


Figure 7-6. Land use and air photo of subwatershed unit A.

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)*

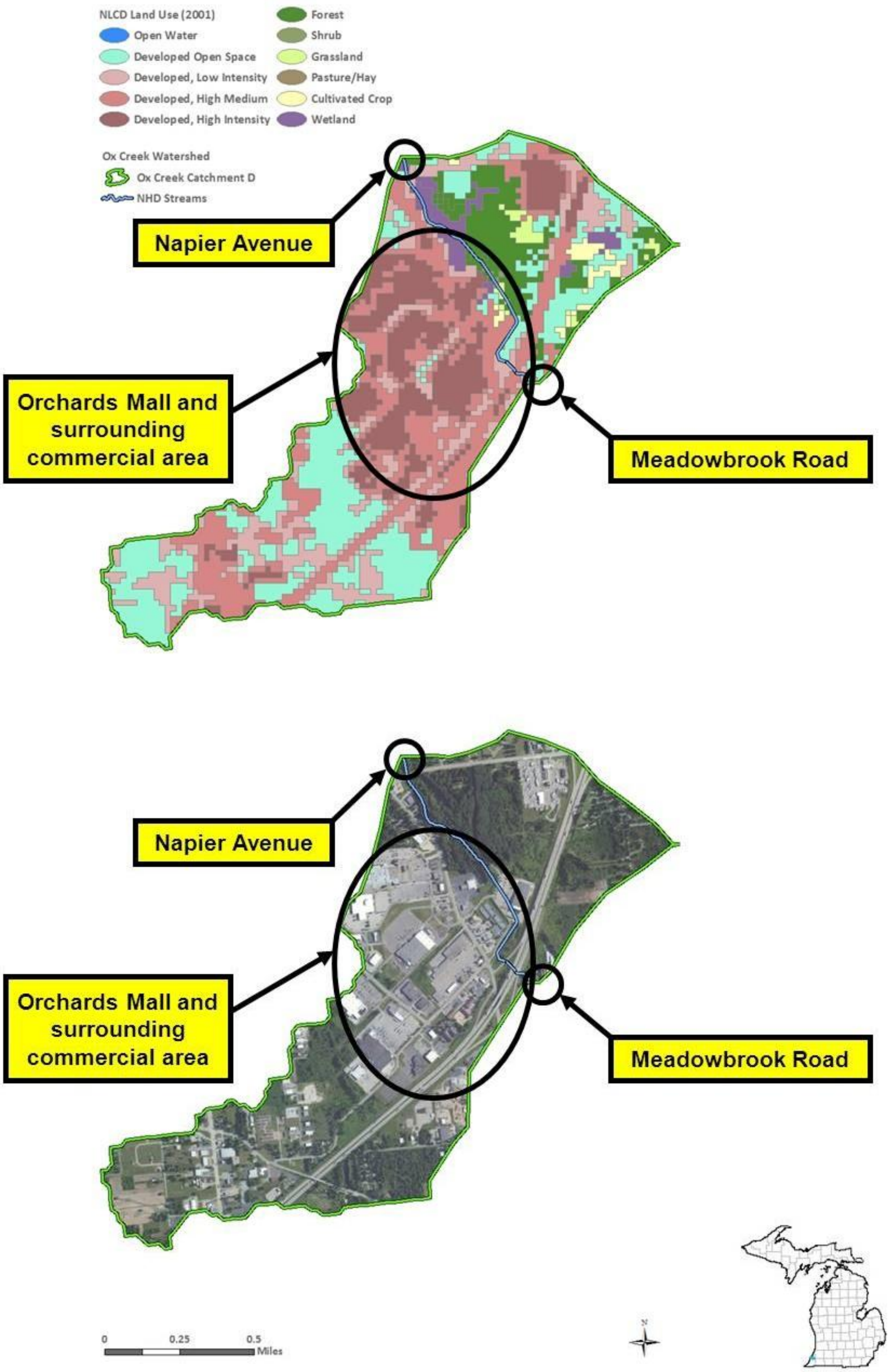


Figure 7-7. Land use and air photo of subwatershed unit D.

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.

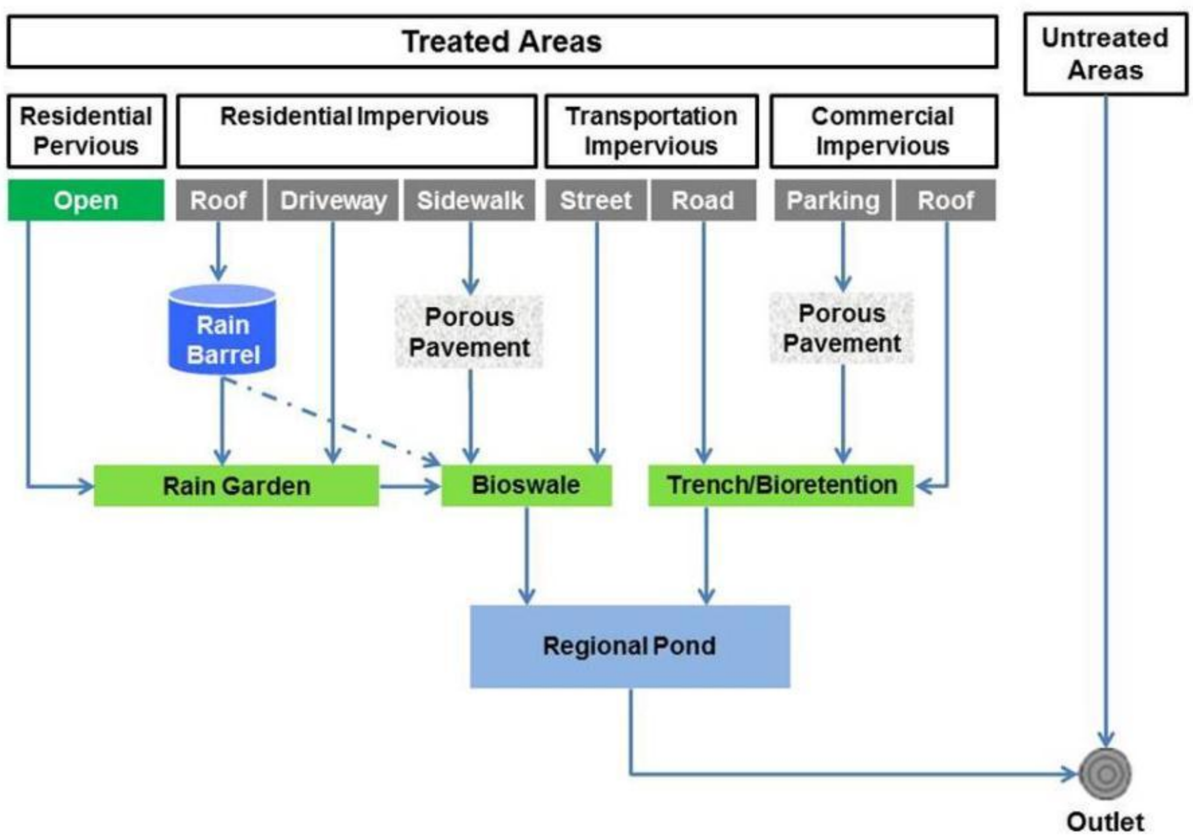


Figure 7-8. Schematic identifying BMP treatment train options for impervious surface types.

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).

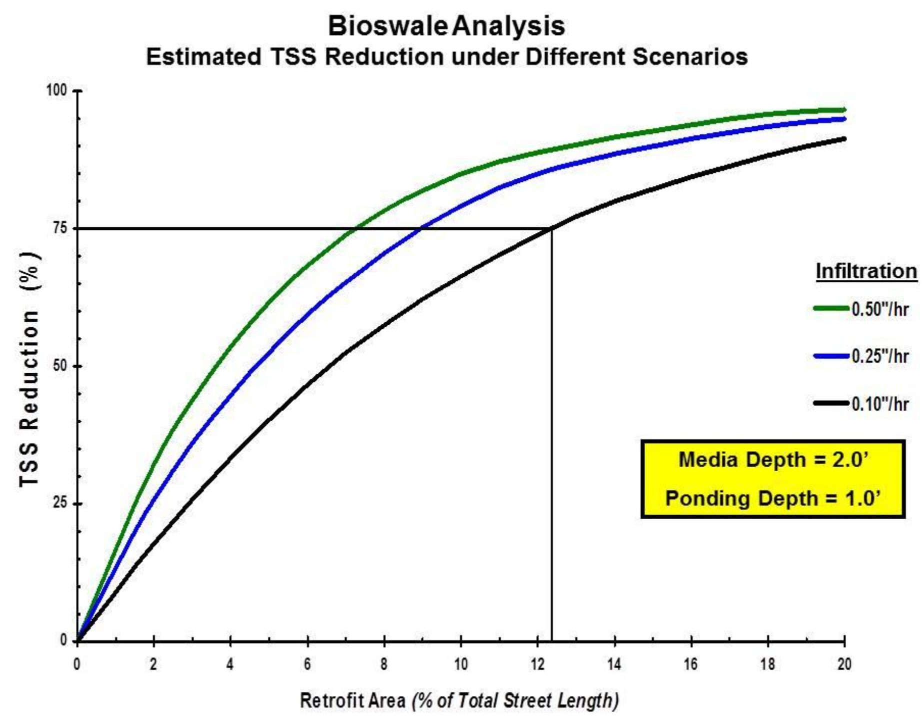


Figure 7-9. Bioswale TSS reduction estimates at background infiltration rates.

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.

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