Ox Creek TMDL Development --

Watershed Characterization and Source Assessment Report

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Prepared for

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1. Executive Summary

Ox Creek is a warm water stream located in southwest Michigan. The creek flows through Benton Harbor where it joins the Paw Paw River. Ox Creek appears on Michigan's §303(d) list due to its impaired biological community (LeSage and Smith, 2008). Possible causes of non-attainment include: sedimentation, siltation, total suspended solids, oil and grease, heavy metals in bottom sediments (e.g., arsenic, chromium, copper, lead, zinc), and polynuclear aromatic hydrocarbons (PAHs) in the water column and sediment (Lipsey, 2007).

The poor macroinvertebrate community could also be attributed to a lack of suitable habitat for colonization (due to past channel alterations and siltation). In addition, 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.

This Watershed Characterization and Source Assessment report presents background information on the setting, climate, soils, hydrology, and other key characteristics that may affect water quality in Ox Creek. Information on Michigan's water quality standards are provided that pertains to the development of a Total Maximum Daily Load (TMDL) for Ox Creek. This includes a discussion of potential indicators and targets that could be used in the TMDL.

This document also describes the biological studies and water quality investigations conducted on Ox Creek. Results are summarized for parameters and factors that could contribute to the impairment of biological communities in Ox Creek. Because source assessments are an important component of water quality management plan and TMDL development, this report concludes with a discussion of potential sources within the Ox Creek watershed. These sources include facilities regulated through National Pollutant Discharge Elimination System (NPDES) permits, facilities regulated through Parts 201 and 213 of Michigan's Natural Resources and Environmental Protection Act, and sources associated with storm water runoff.

2. Background Information

2.1 Setting

Ox Creek is a warm water stream located in southwest Michigan. The creek flows through Benton Harbor where it joins the Paw Paw River *(Figure 2-1)*. The watershed drains an area of 16.5 square miles. Ox Creek originates in predominately agricultural lands east of the city. The Yore – Stouffer 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 – Stouffer 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. Just above the confluence of Ox Creek and the Yore – Stouffer Drain, the stream begins to enter 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.

2.2 Community Profile

Ox Creek played a role in the early history of Benton Harbor. One of the first homesteads in the area to become downtown was located on high ground to the west of Ox Creek (Benton Harbor, 2010). The early settlers planted orchards and prospered from the sale of fruit. As the area's fruit industry grew, a mile long canal was constructed from this location along Ox Creek to the St. Joseph River. This transportation link enabled Benton Harbor to develop as other industries were built along the canal. More recently, Benton Harbor has become the focus of state government attention and been designated as a *"City of Promise"*. Michigan's *"City of Promise"* initiative provides a wide range of assistance and support to those communities in the program (MSHDA, 2010). This has created redevelopment opportunities in the lower Ox Creek watershed.

Major government units with jurisdiction over lands within the Ox Creek watershed include the City of Benton Harbor, Berrien County, and Benton Township. Small portions of the watershed lie within Bainbridge and St. Joseph Townships. Based on 2000 census data, approximately 11,400 people live in the Ox Creek watershed (690 people per square mile). The most densely populated areas of the watershed lie inside the city limits of Benton Harbor *(Figure 2-2)*.

The Berrien County Drain Commission (BCDC) and Berrien County Road Commission each has jurisdictional responsibilities that affect water quality in the Ox Creek watershed. BCDC is responsible for maintaining a network of drains that are tributary to Ox Creek. The Drain Commission is also the enforcing agent for Berrien County's Soil Erosion and Sediment Control Act. In addition, BCDC recently developed guidelines for storm water management in Berrien County. The Road Commission also plays a role in storm water management by virtue of the ditches that eventually convey water to Ox Creek.

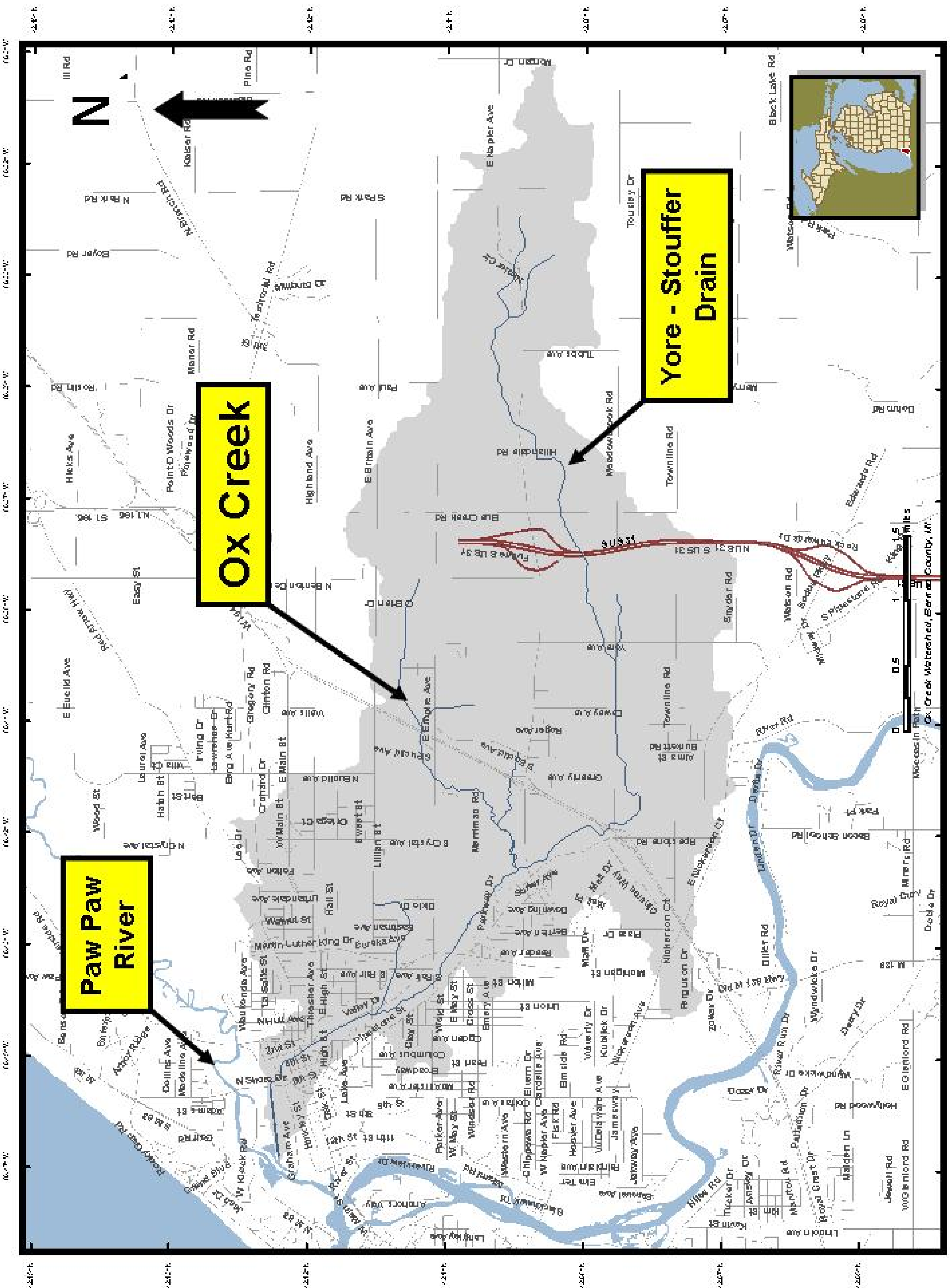

Figure 2-1. Ox Creek project area.

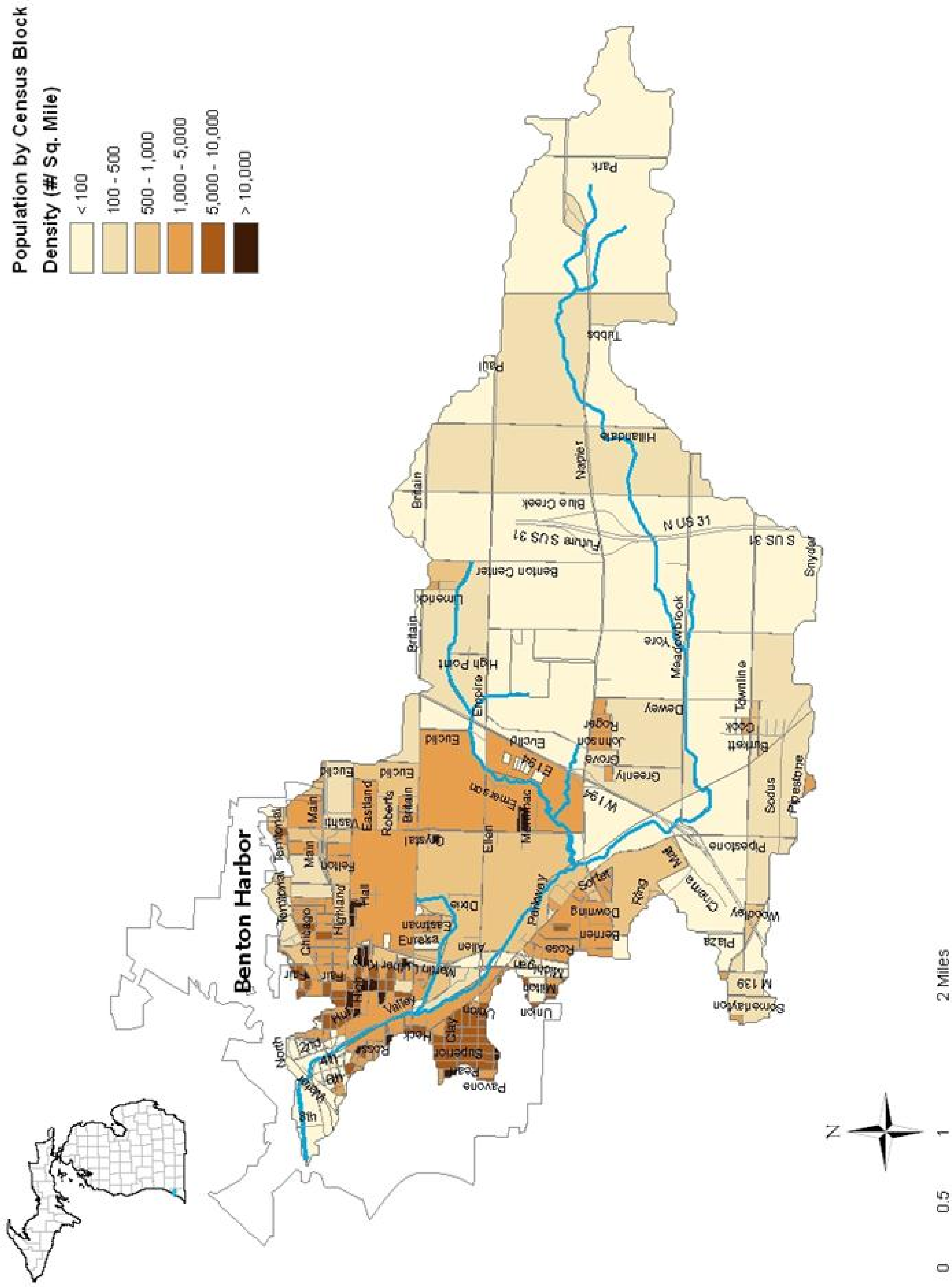

Figure 2-2. Ox Creek population density.

2.3 Climate

The proximity of Ox Creek to Lake Michigan coupled with the prevailing westerly winds moderates the climate of the watershed. This combination tends to produce lake effect precipitation during the fall and winter months. The climate is also influenced by the Maritime Tropical air mass, which tends to be a relatively warm and humid air mass (SWMPC, 2008). According to the National Climatic Data Center (NCDC), from 1971 to 2000 the average winter temperature in Benton Harbor was 26.6 °F and the average summer temperature was 68.9 °F *(Figure 2-3)*. The average growing season (consecutive days with low temperatures greater than or equal to 32 degrees) is 148 days. Total annual precipitation is approximately 38.3 inches including approximately 81 inches of snowfall (USDA, 1980).

Examination of precipitation patterns is a key part of watershed characterization. In particular, rainfall intensity and timing affect watershed response to precipitation. This information is important in evaluating the effects of storm water on Ox Creek. Figure 2-4 presents one way to show rainfall intensity. Using Benton Harbor airport data from 1948 to 2006, 52 percent of the precipitation events were very low intensity (i.e., less that 0.2 inches). On the other hand, seven percent of the measurable precipitation events were greater than one inch.

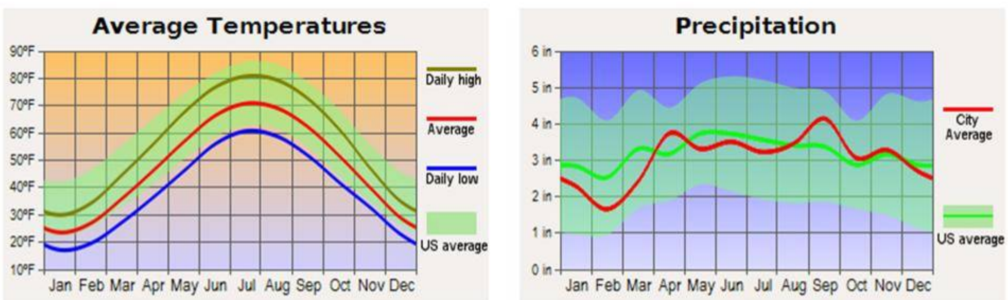

Figure 2-3. Temperature and precipitation summary -- Benton Harbor airport gage.

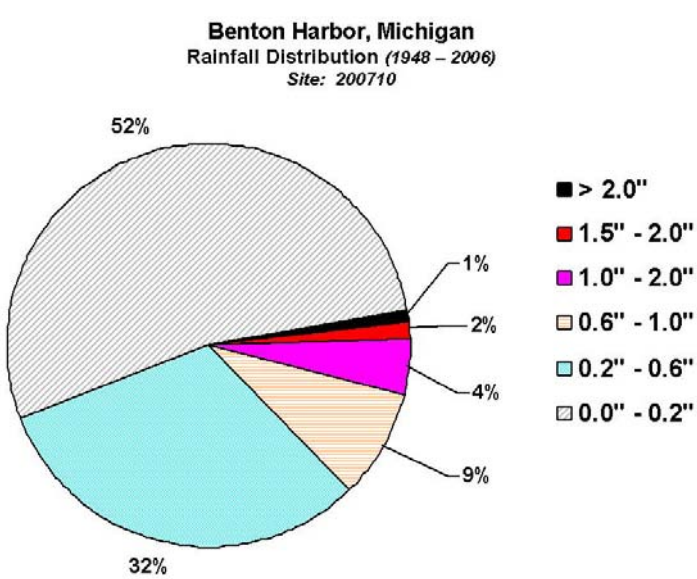

Figure 2-4. Precipitation intensity – Benton Harbor airport gage.

2.4 Land Use / Land Cover

Land use in the Ox Creek watershed is influenced by a combination of agriculture in the upper portion and the urban setting of Benton Harbor in the lower portion. Access to a major transportation link between Detroit and Chicago, specifically I-94, also plays a role in land use within the watershed. This is particularly evident around the Pipestone interchange and Orchard Mall.

Figure 2-5 shows land use within the Ox Creek watershed. The categories associated with each color are described in Table 2-1, which also provides a summary by land use type. The stark difference between agricultural land use in the upper portion of the watershed and development in the lower portion is readily apparent in Figure 2-5.

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%

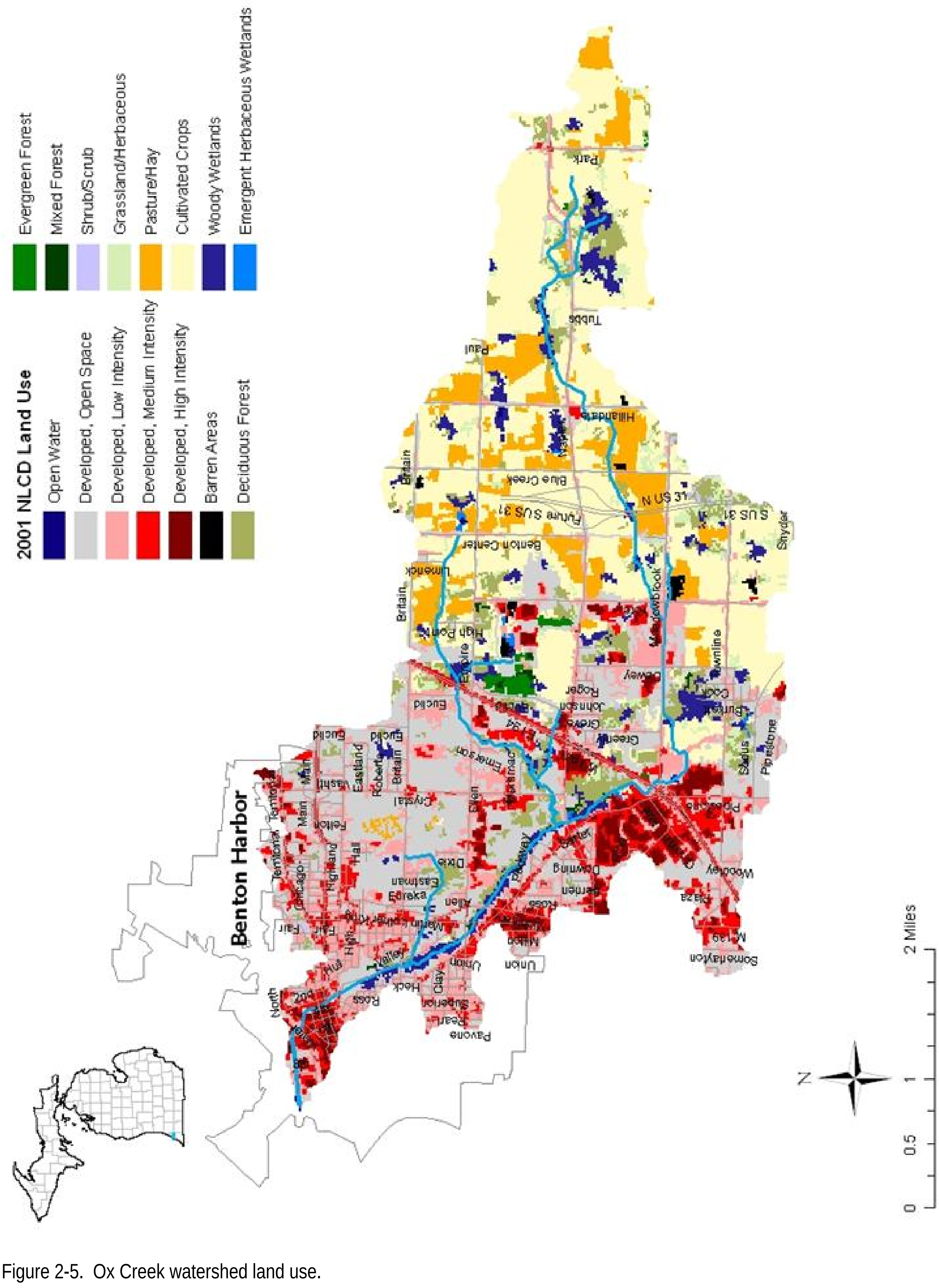

Figure 2-5. Ox Creek watershed land use.

2.5 Geology and Soils

The topography and hydrology of southwest Michigan have been heavily influenced by glacial action (SWMPC, 2008). Pre-existing rocks and soils were eroded repeatedly through continental ice sheet advances. These materials were re-deposited as sediments during several ice advance, melt, and retreat cycles. These glacial materials were deposited as sands, gravels, silts, and clays. The material varied in terms of mixtures and thickness within area watersheds. Ice movement and its melt water influenced the patterns and distribution of various landforms, such as moraines and stream valleys (SWMPC, 2008). The melt water created large rivers, which deposited glacial materials throughout the region. These glacial deposits and associated land forms exerted a major effect that influence present day hydrology, soil types and land cover.

The National Cooperative Soil Survey publishes soil surveys for each county within the U.S. These soil surveys contain predictions of soil behavior for selected land uses. These surveys also highlight limitations and hazards inherent in the soil, general improvements needed to overcome the limitations, and the impact of selected land uses on the environment. The soil surveys are designed for many different uses, including land use planning, the identification of special practices needed to ensure proper performance, and Hydrologic Soil Groups or HSGs (USDA / NRCS, 2007).

Hydrologic Soil Groups can help determine those portions of the watershed that are more important for groundwater recharge. HSGs also show areas where soil types have low infiltration capacity, and thus would be more prone to produce runoff during rain or snowmelt events. Table 2-2 identifies those HSGs found in the Ox Creek watershed and provides a summary description of each group. Figure 2-6 shows the location of different HSGs in the Ox Creek watershed. Generally, soils in this area are typically composed of sandy loams with a high infiltration capacity for absorbing water. The protection of areas with high infiltration capacity (e.g., Group A soils) is important for maintaining hydrology and temperature regimes within the watershed.

Table 2-2. Hydrologic Soil Group (HSG) descriptions.

HSG	Group Description
A	Sand, loamy sand or sandy loam types of soils. Low runoff potential and high infiltration rates even when thoroughly wetted. Consist chiefly of deep, well to excessively drained sands or gravels with a high rate of water transmission.
B	Silt loam or loam. Moderate infiltration rates when thoroughly wetted. Consist chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
C	Soils are sandy clay loam. Low infiltration rates when thoroughly wetted. Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Soils are clay loam, silty clay loam, sandy clay, silty clay or clay. Group D has the highest runoff potential. Low infiltration rates when thoroughly wetted. Consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.
A/D B/D C/D	Dual Hydrologic Soil Groups. Certain wet soils are placed in group D based solely on the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition.

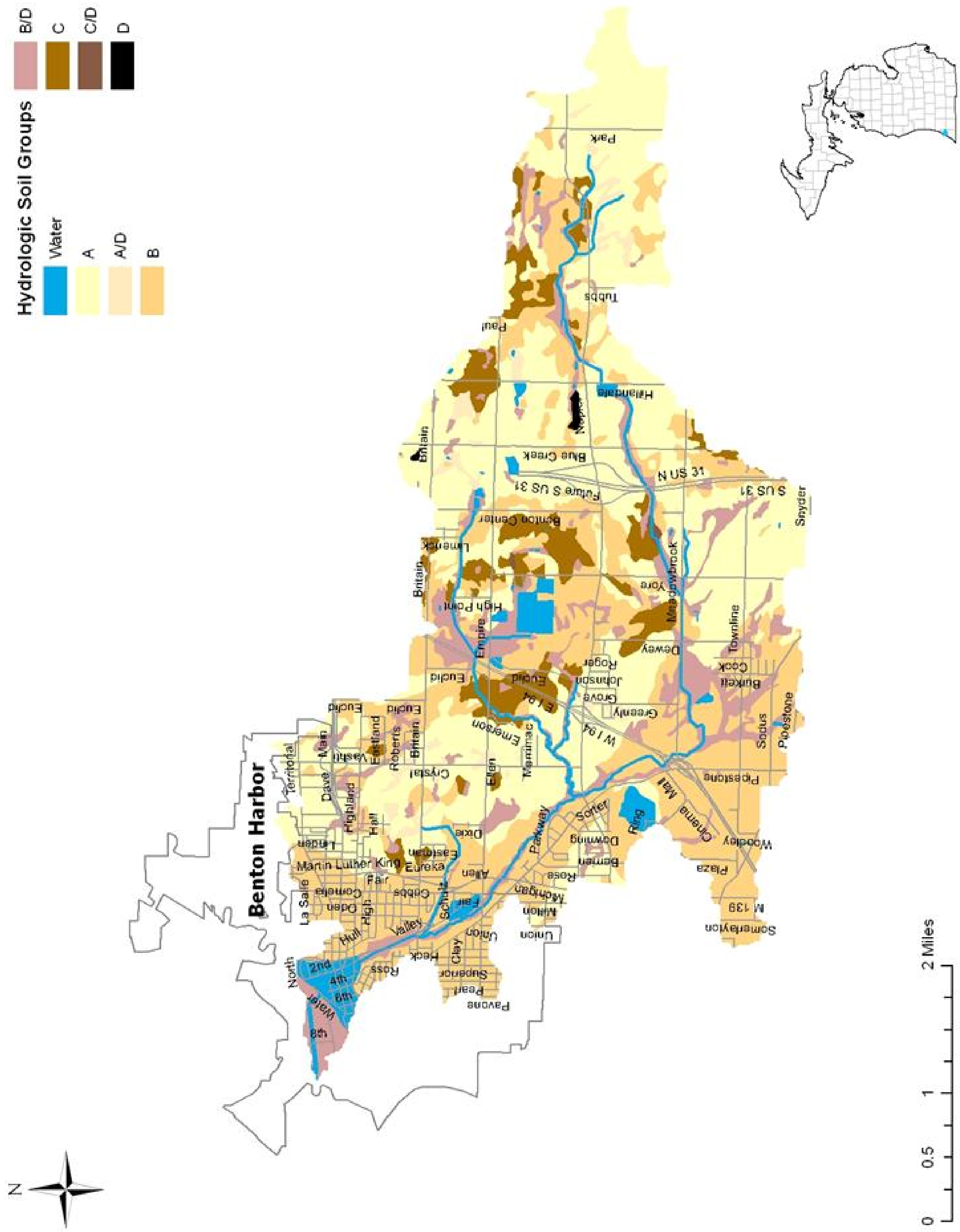

Figure 2-6. Ox Creek watershed Hydrologic Soil Groups.

2.6 Hydrology

Hydrology plays an important role in evaluating water quality. The hydrology of the Ox Creek watershed is driven by local climate conditions. This includes situations that often result in flashy flows, where the stream responds to and recovers from precipitation events relatively quickly. Flooding periodically occurs in areas of the watershed, flowing over roads and encroaching on streamside properties. In addition, ditching and channelizing has been used throughout this region to drain areas where soils are too wet for settlement and agriculture.

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, 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. Often this rapid response is similar to that observed in areas where natural vegetation has been replaced by impervious surfaces. Extensive tiling can also alter the quality of drainage water exiting the fields to receiving waters. For example, 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 Natural Resources and Environment (DNRE) *(Figure 2-7)*. 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 2-8)*. In addition to water volume excesses due to storm water and flooding, natural dry weather periods (e.g., the lack of sufficient water) can make water quantity a factor that affects water quality.

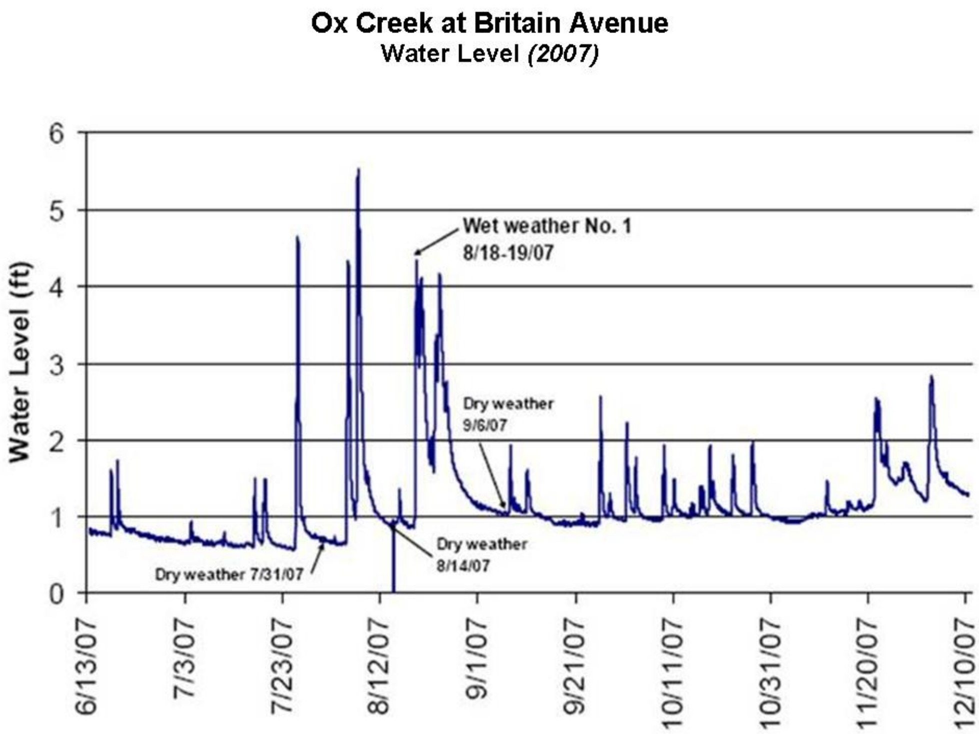

Figure 2-7. Level logger data collected in Ox Creek at Britain Avenue -- 2007.

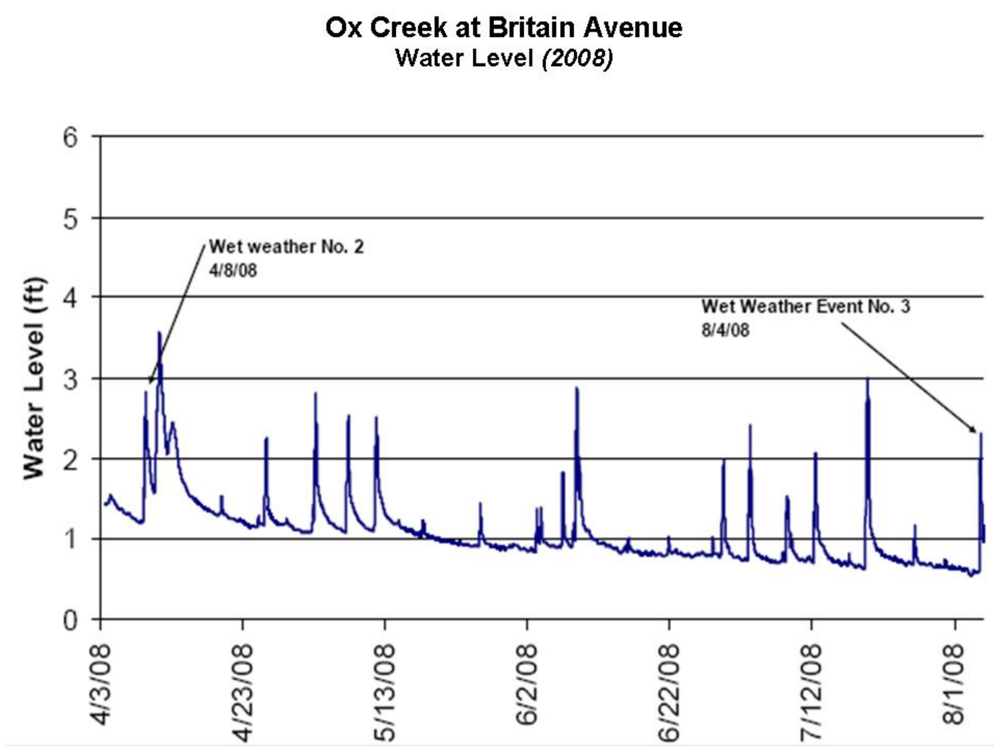

Figure 2-8. Level logger data collected in Ox Creek at Britain Avenue -- 2008.

Limited flow data makes it difficult to describe the full range of hydrologic conditions the Ox Creek watershed may experience. Although long term stream gaging has not been conducted on Ox Creek, the U.S. Geological Survey (USGS) has monitored flow at several locations within 30 miles of the Ox Creek watershed *(Table 2-3 and Figure 2-9)*. Figure 2-10 compares Ox Creek flows in 2007 to those monitored at three of the USGS gages during the same period. This graph also shows daily precipitation measured at the Benton Harbor airport site. Figure 2-11 shows this same information for Ox Creek data collected in 2008.

Table 2-3. USGS stream gaging sites within 30 miles of Ox Creek watershed.

Gage ID	Area (mi.^{2})	Location
04096015	80.7	Galien River near Sawyer
04101800	255	Dowagiac River at Sumnerville
04102500	390	Paw Paw River at Riverside
04102531	14.7	Ox Creek at Benton Harbor *(Britain Avenue)*
04102700	83.6	South Branch Black River near Bangor
04102776	83.0	Middle Branch Black River near South Haven

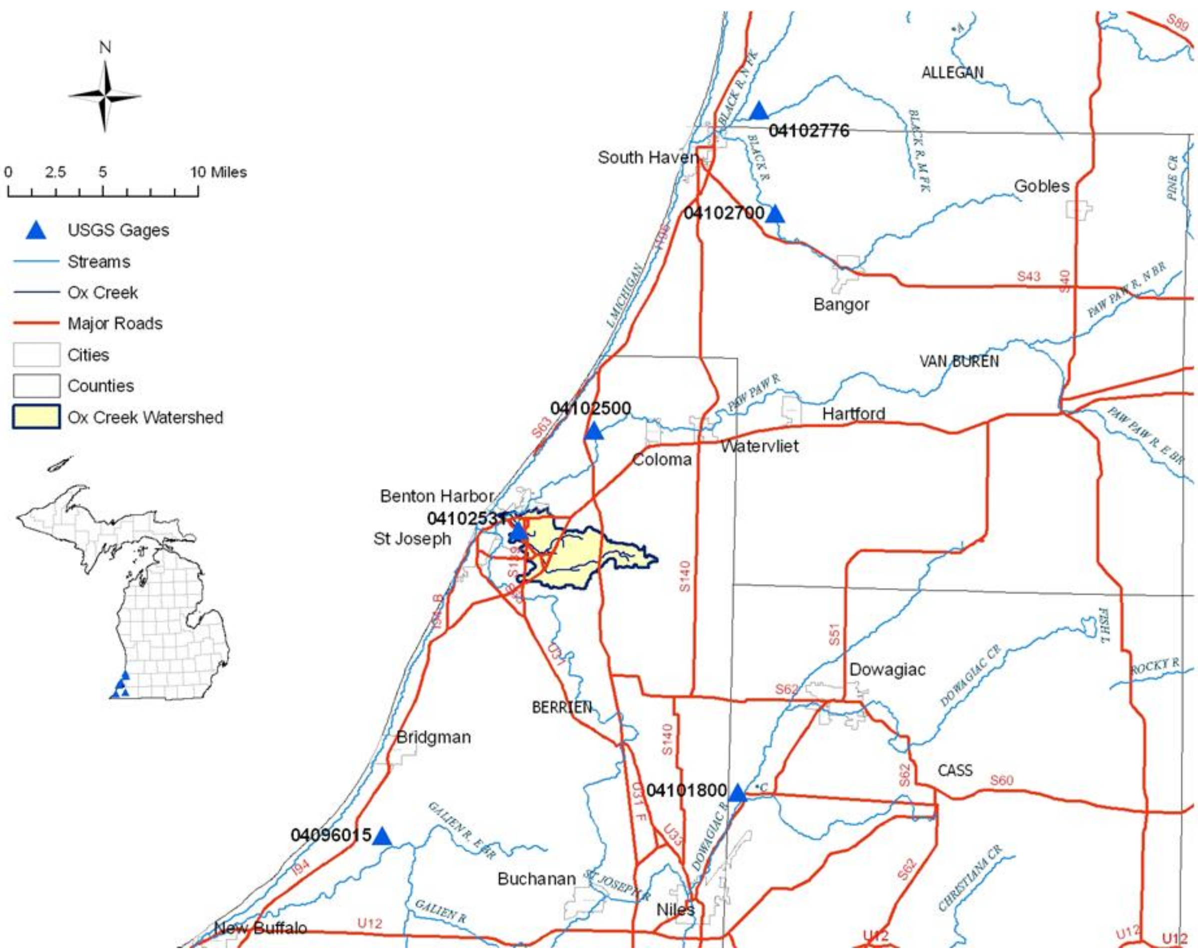

Figure 2-9. Location of USGS stream gaging sites in the general proximity of Ox Creek.

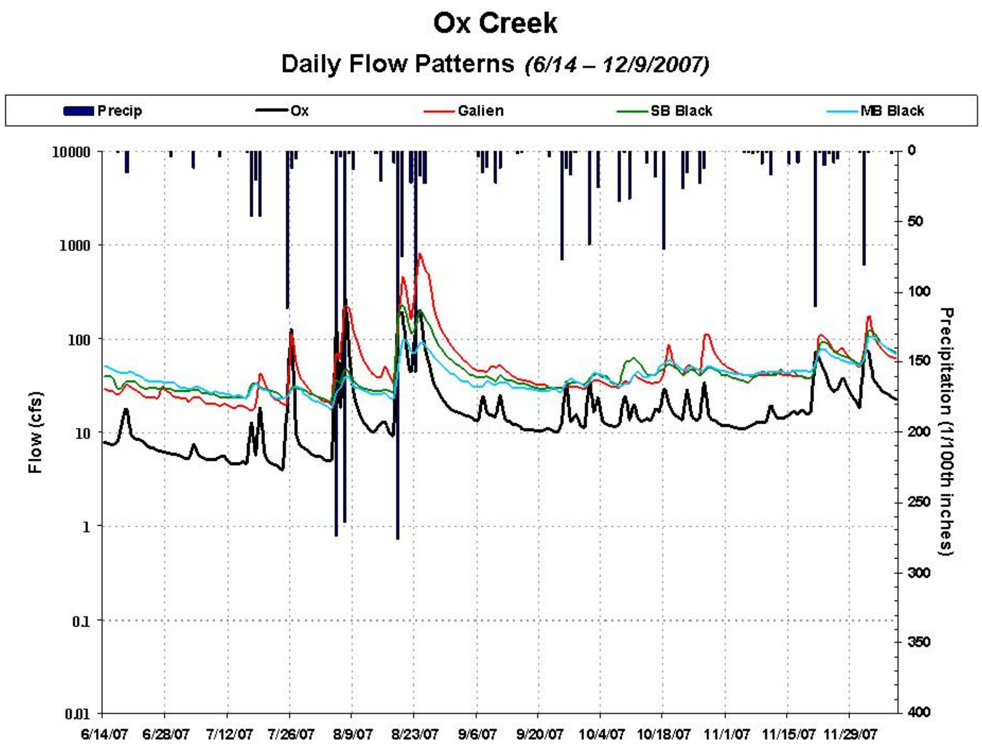

Figure 2-10. Ox Creek flows compared to several USGS sites -- 2007.

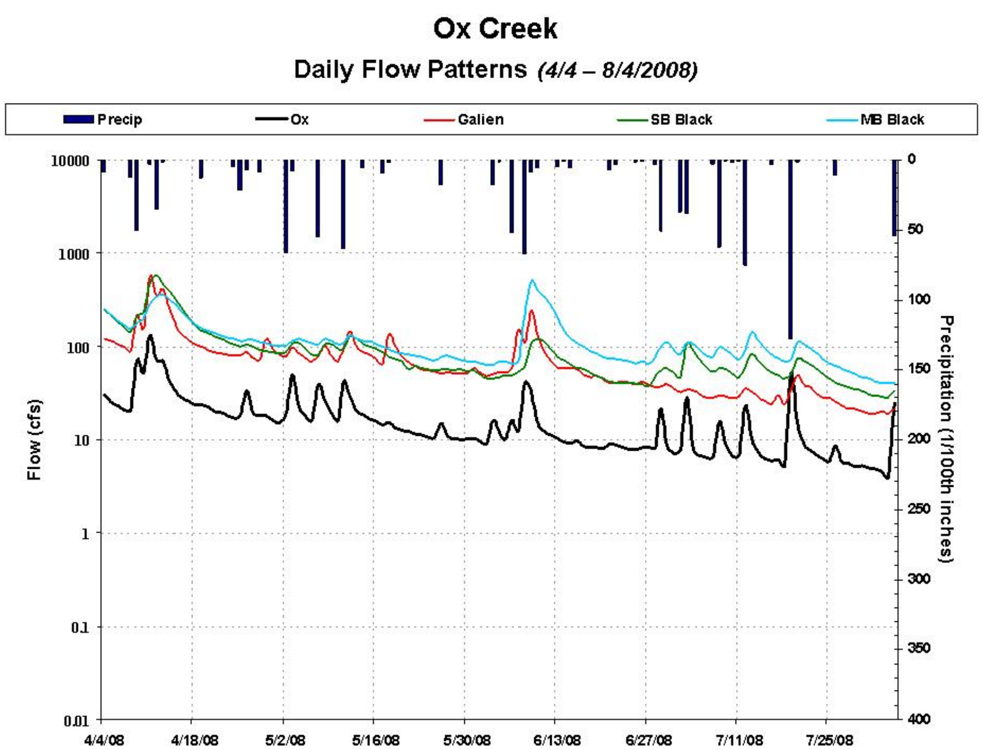

Figure 2-11. Ox Creek flows compared to several USGS sites -- 2008.

Figure 2-10 and Figure 2-11 illustrate that temporal flow patterns in Ox Creek are similar to several sites identified in Table 2-3. For this reason, it is useful to develop a quantitative comparison of flows at these sites to the limited flow data available for Ox Creek. A screening analysis, which correlates flows between sites, is one way to identify a gage that could be used for comparisons. The purpose of this analysis is to identify a site that provides a longer term view of the range of hydrologic conditions that may occur in the Ox Creek watershed. Figure 2-12 shows an example analysis using the Galien River site. Results of the correlation analysis for all of the gages are summarized in Table 2-4.

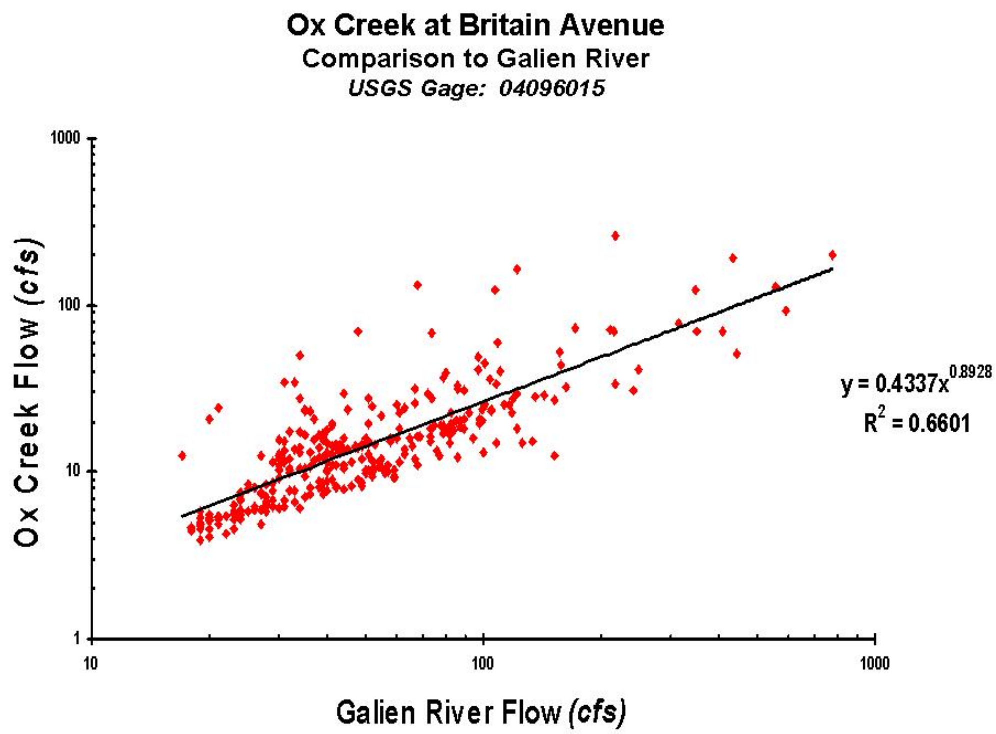

Figure 2-12. Correlation analysis of Ox Creek and Galien River flows.

Table 2-4. Correlation analysis summary of Ox Creek flows with data from area gages.

Gage ID	Area (mi.^{2})	Location	Correlation Coefficent (R^2)
04096015	80.7	Galien River near Sawyer	0.66
04101800	255	Dowagiac River at Sumnerville	0.56
04102500	390	Paw Paw River at Riverside	0.43
04102700	83.6	South Branch Black River near Bangor	0.42
04102766	83.0	Middle Branch Black River near South Haven	0.15

2.6.1 Seasonal Variation

Seasonal variation must be considered in TMDL development. Seasonal variation in flow is a key part of the overall TMDL assessment because water quality parameters are often related to stream flow rates. This is a particularly important component of subsequent analyses linking sources to observed water quality, where the timing of source loads is connected to seasonal water quality patterns.

Flow data collected for Ox Creek (Figure 2-10 and Figure 2-11) does not account for variability over an entire year. Galien River flows were more closely correlated with Ox Creek than the other gages *(Table 2-4)*. For this reason, information at this site can be used to show patterns during the missing periods. Figure 2-13 illustrates the degree to which daily average Galien River flows fluctuated over the course of the two-year Ox Creek level logger study period.

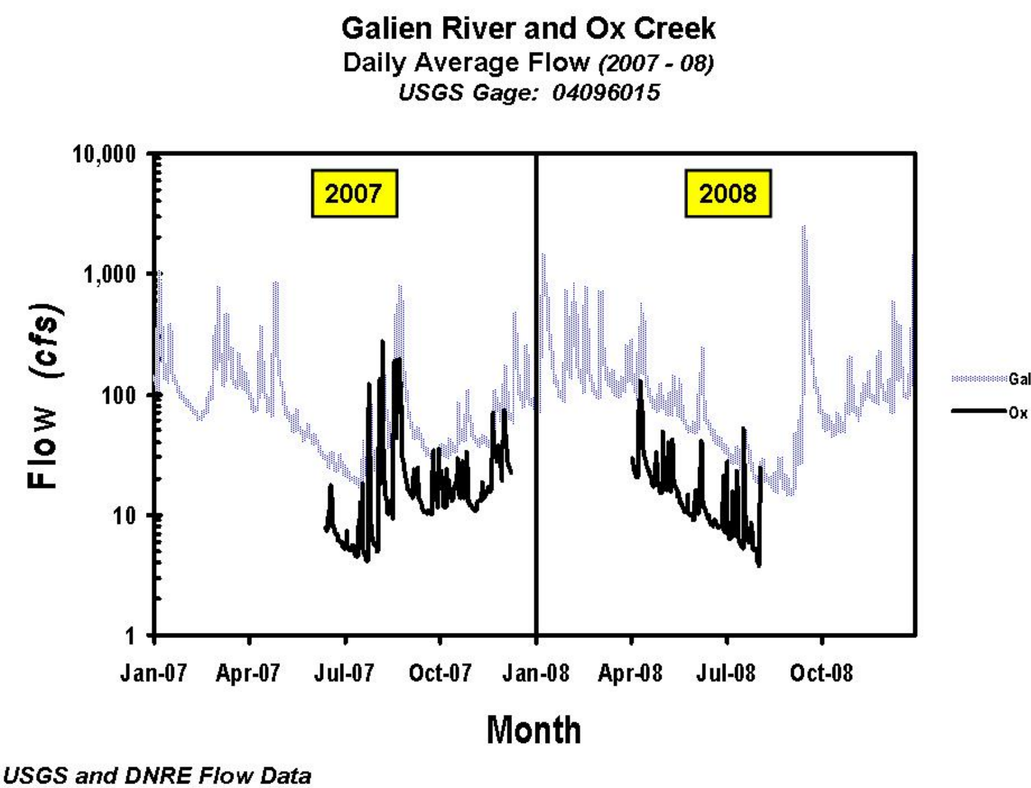

Figure 2-13. Daily average flows in 2007-08 for Galien River.

Figure 2-14 shows the seasonal variation of flow for the Galien River site using the entire period of record (1995 – 2009). In addition to showing general patterns, the *"Box and Whisker"* format used in Figure 2-14 highlights the variability of flows from month to month. For example, the highest flows typically occur between January and March. Flows during these months also tend to vary, reflecting the significant effect that air temperatures exert on hydrology. Periods of heavy snow followed by warmer temperatures can result in major runoff events. Conversely, lower winter flows may coincide with extended periods of below freezing temperatures.

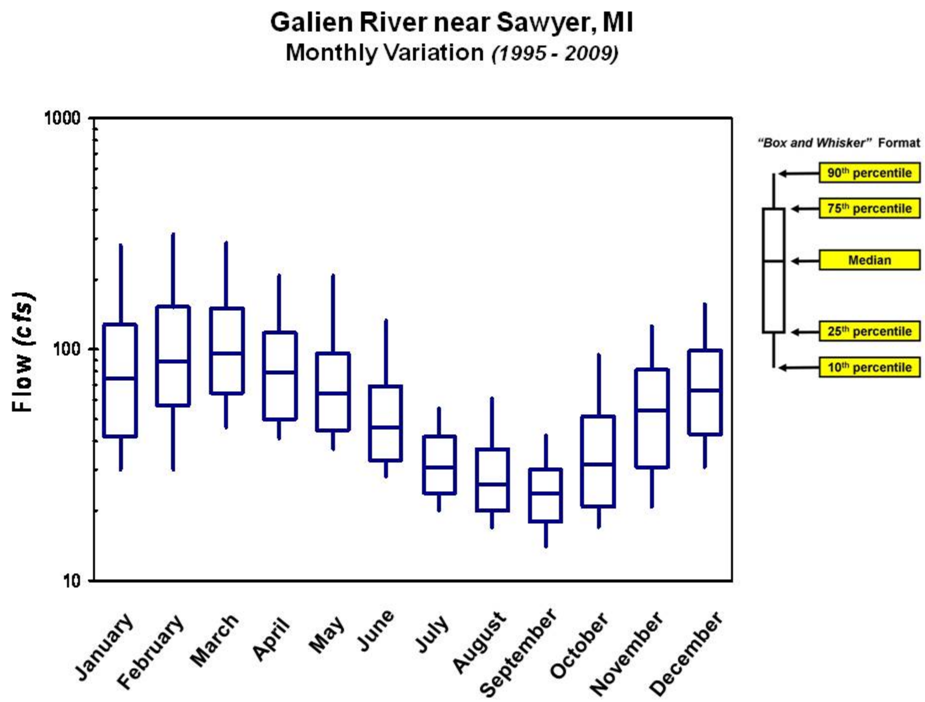

Figure 2-14. Seasonal variation of Galien River flows.

Related to seasonal variation, year-to-year variability is another consideration that affects watershed hydrology. This in turn influences water quality, in particular sediment transport. Peak flow history is one way to view the effect of interannual variation, as shown in Figure 2-15. The figure illustrates that peak flows were similar between 1997 and 2007, but were much higher in 1996 and 2008. Peak flow in 2008 occurred on September 15 after nearly 6.8 inches of rain was measured at Benton Harbor from September 12 to 15; the result of the remnants of Hurricane Ike moving into the upper Midwest.

2.6.2 Flow Duration Curves

The daily average, storm event, peak history, and monthly flow information presented earlier shows the inherent variability associated with hydrology. Flow duration curves provide a way to address that variability. Duration curves describe the percentage of time during which specified flows are equaled or exceeded (Leopold, 1994). Flow duration analysis looks at the cumulative frequency of historic flow data over a specified period, based on measurements taken at uniform intervals (e.g., daily average or 15-minute instantaneous). Duration analysis results in a curve that relates flow values to the percent of time those values have been met or exceeded. Low flows are exceeded a majority of the time, whereas floods are exceeded infrequently.

Duration curves provide the benefit of considering the full range of flow conditions (USEPA, 2007). Development of a flow duration curve is typically based on daily average stream discharge data. A typical curve runs from high flows to low flows along the x-axis, as illustrated in Figure 2-16. Note the flow duration interval of sixty associated with a stream discharge of 40 cfs (i.e., sixty percent of all observed stream discharge values equal or exceed 40 cfs).

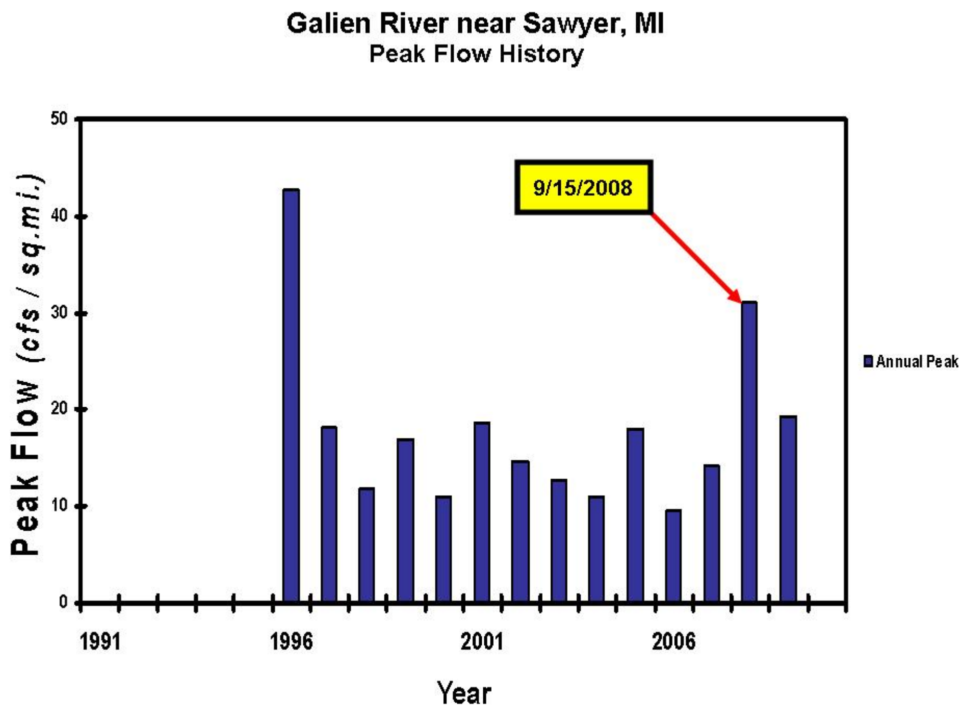

Figure 2-15. Peak flow history for Galien River gage.

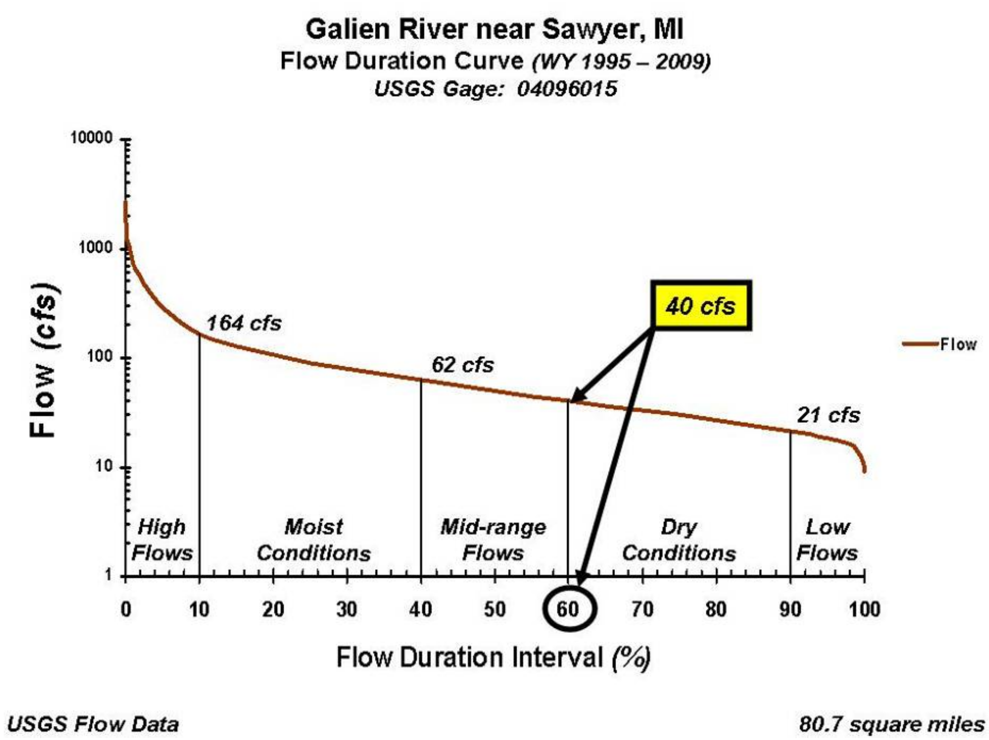

Figure 2-16. Flow duration curve for the Galien River.

Flow duration curve intervals can be grouped into several broad categories or zones. These zones provide additional insight about conditions and patterns associated with water quality impairments where hydrology may play a major role. One common way to look at the duration curve is by dividing it into five zones, as illustrated in Figure 2-16: one representing *high flows (0-10%)*, another for *moist conditions (10-40%)*, one covering *mid-range flows (40-60%)*, another for *dry conditions (60-90%)*, and one representing *low flows (90-100%)*.

This particular approach places the midpoints of the moist, mid-range, and dry zones at the 25th, 50th, and 75th percentiles respectively (i.e., the quartiles). The high zone is centered at the 5th percentile, while the low zone is centered at the 95th percentile. Other schemes can be used, depending on local hydrology, the water quality issues being addressed by assessment efforts, data availability, and the way in which water quality criteria are expressed.

The duration curve framework can enhance the assessment of water quality information collected on Ox Creek. A duration curve can be developed for Ox Creek using the level logger data and flow relationships with the Galien River. Because hydrology tends to exert a major effect on water quality, the duration curve can be used to examine Ox Creek data for patterns relative to flow conditions.

2.6.3 Hydrology and Water Quality Relationships

The primary benefit of flow duration curves in TMDL development is to provide insight regarding patterns associated with hydrology and water quality concerns. The duration curve approach is particularly applicable because water quality is often a function of stream flow. For instance, sediment concentrations typically increase with rising flows as a result of factors such as channel scour from higher velocities. Other parameters, such as chloride, may be more concentrated at low flows and more diluted by increased water volumes at higher flows.

The use of duration curves in water quality assessment creates a framework that enables data to be characterized by flow conditions. The method provides a visual display of the relationship between stream flow and water quality. This concept is illustrated by using sediment data collected at one of the gages identified in Table 2-3: the South Branch Black River near Bangor. In the case of Figure 2-17, sediment concentrations are the greatest under high flow conditions. In addition, the display also shows that the highest levels are generally associated with runoff events (as indicated by the shaded diamonds). A similar analysis to the one shown in Figure 2-17 can be completed using Ox Creek data during development of the TMDL.

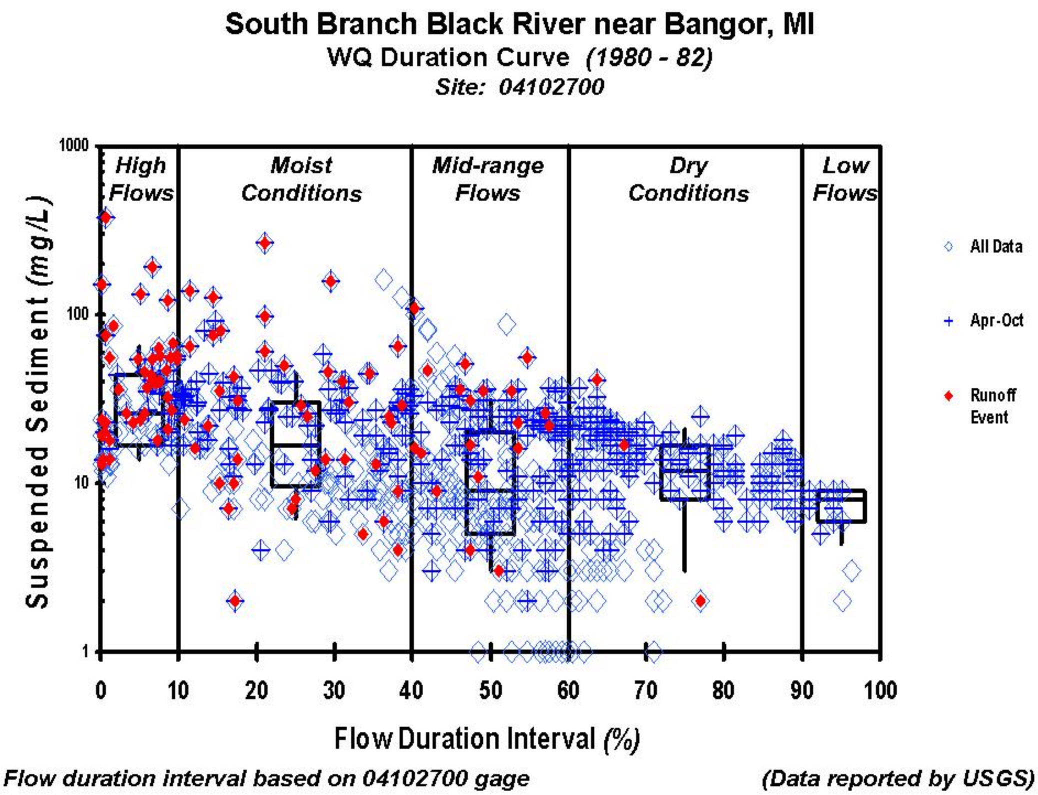

Figure 2-17. Relationship between flow and sediment using duration curve framework.

3. Water Quality Indicators and Potential Targets

This section of the document presents information on the water quality impairments within the Ox Creek watershed and the associated water quality standards.

3.1 Water Quality Impairments

Ox Creek appears on Michigan's §303(d) list due to its impaired biological community. This listing is based on not meeting the *"other indigenous aquatic life and wildlife"* designated use; the result of poor macroinvertebrate community ratings. Possible causes of non-attainment include:

- Sedimentation, siltation, total suspended solids;
- Oil and grease;
- Heavy metals in bottom sediments (e.g., arsenic, chromium, copper, lead, zinc);
- Polynuclear aromatic hydrocarbons (PAHs) in the water column and sediment.

The poor macroinvertebrate community could also be attributed to a lack of suitable habitat for colonization (due to past channel alterations and siltation). In addition, high storm water flows likely bring additional pollutant and sediment loads to the stream that further degrade the habitat.

3.2 Applicable Standards

The authority to designate beneficial 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, DNRE 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"*.

Several portions of the Part 4 Rules contain provisions that may be used to develop numeric targets that will address documented impairments in Ox Creek. 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"*.

To address potential problems related to heavy metals and organic compounds, R 323.1057 (Rule 57) states that *"toxic substances shall not be present in the surface waters of the state at levels that are or may become injurious to the public health, safety, or welfare, plant and animal life, or the designated uses of the waters"*. In addition, subrule 6 states that: *"biological techniques…may be used to assure that acute and chronic aquatic life requirements… are met in the surface waters of the state"*.

Potential numeric targets for metals and PAH parameters are summarized in Table 3-1 that reflect the Rule 57 criteria. Note that Rule 57 describes equations used to determine criteria for several metals, which is based on hardness information. These calculated values result in criteria expressed as dissolved metals. Because monitoring data is typically for total metals, Michigan's Rule 323.1209 of the Part 8 rules specifies translators for converting dissolved to total values.

Table 3-1. Numeric criteria for selected toxic pollutants.

Parameter	Chronic WQS (µg/L)	Acute WQS (µg/L)
Arsenic *(total)*	150	340
Cadmium *(total)*	10.3	28.4
Chromium *(total)*	266	2,037
Lead *(total)*	144	1,286
Zinc *(total)*	612	607
Fluoranthene	1.6	28
Phenanthrene	1.4	9.4

3.3 Bottom Sediment Quality

No numeric bottom sediment quality criteria have been promulgated in Michigan. To evaluate sediment data, several studies and reference papers have been used to identify contaminant levels of concern. One report compiled by DNRE staff examined sediment chemistry in wadeable streams across Michigan (Gerard and Jones, 1999). Reference levels were identified by ecoregion. For Ox Creek, potential targets would be those that apply to the Southern Michigan Northern Indiana Till Plain (SMNITP).

Another study used a consensus based approach to examine lower and upper effect values for contaminants of concern (MacDonald, et.al, 2000). This report identified *"Sediment Quality Guidelines"*, which include a threshold effect concentration (TEC) and probable effect concentration (PEC). The TEC is the concentration below which adverse effects are not expected to occur. The PEC is the concentration above which adverse effects are expected to occur more often than not.

USEPA Region 5 has identified Ecological Screening Levels (ESLs) to evaluate the potential for adverse risk to the environment from chemical contaminants in sediments. These ESLs represent protective benchmarks intended to identify those areas likely to present an unacceptable risk. ESLs include values for sediment. In most cases, the ESL sediment values are equivalent to the TEC.

Table 3-2 provides a summary of potential sediment quality targets for several parameters using information from the SMNITP reference study, the sediment guidelines report, and the Region 5 ESLs. At this point, values presented in Table 3-2 are simply for informational purposes to provide a comparative reference. Development of any sediment targets used in the TMDL will be conducted as part of a subsequent linkage analysis. The linkage analysis will describe the relationship between Michigan's narrative water quality standards and proposed targets.

Table 3-2. Potential bottom sediment quality targets.

Parameter	Units	SMNITP		Sediment Quality Guidelines		R5-ESL
		Average	Range	PEC	TEC	
Arsenic	mg/kg	5.5	na	33	9.79	9.79
Cadmium	mg/kg	1.05	na	4.96	0.99	0.99
Chromium	mg/kg	6.7	2 - 65	111	43.4	43.4
Lead	mg/kg	11	5 - 50	128	35.8	35.8
Zinc	mg/kg	34	6.4 - 170	459	121	121
Benzo(a)anthracene	µg/kg	na	na	1,050	108	108
Benzo(a)pyrene	µg/kg	na	na	1,450	150	150
Chrysene	µg/kg	na	na	1,290	166	166
Fluoranthene	µg/kg	na	na	2,230	423	423
Phenanthrene	µg/kg	na	na	1,170	204	204
Pyrene	µg/kg	na	na	1,520	195	195

Notes

SMNITP: Ecoregion Reference Average *(Southern Michigan Northern Indiana Till Plains)*.
TEC: Threshold Effects Concentration *(below which adverse effects are not expected to occur)*.
PEC: Probable Effects Concentration *(above which adverse effects are expected to occur more often than not)*.
R5-ESL: USEPA Region 5 Ecological Screening Levels
na: not available

3.4 Total Suspended Solids

Several past TMDLs developed by DNRE have used total suspended solids (TSS) as a secondary numeric target to address impaired biological communities. The primary target has been restoration of biological communities to achieve an acceptable score using a biological monitoring protocol. Use of TSS as a secondary 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 increased TSS concentrations. The use of TSS as a secondary numeric target connects a measurable in-stream parameter to hydrologic changes in the watershed, which can result in habitat changes that are heavily impacting biological communities.

The numeric value used in these past TMDLs has been a mean annual TSS concentration of 80 mg/L for wet weather events. This TSS target is based on a review of existing conditions and published literature on the effects of TSS to aquatic life. Vohs et al., (1993) indicated that a chemically inert TSS concentration of 100 mg/L appears to separate those streams with a fish population from those without. Gammon (1970) demonstrated decreases in the standing crop of both fishes and macroinvertebrates in river reaches continuously receiving TSS loadings above 40 mg/L. The European Inland Fisheries Advisory Commission stated that, in the absence of other pollution, a fishery would not be harmed at TSS concentrations less than 25 mg/L (EIFAC, 1980).

Alabaster and Lloyd (1982) provided the following water quality goals for TSS for the protection of fish communities:

Optimum = < 25 mg/L
Good to Moderate = > 25 to 80 mg/L
Less than Moderate = > 80 to 400 mg/L
Poor = > 400 mg/L

In Michigan, the past use of a numeric TSS target has helped create a TMDL framework that can be used to identify possible steps to restore biological communities to an acceptable condition. These TSS values are simply for informational purposes to provide a comparative reference. Development of any TSS targets used in the TMDL will be conducted as part of a subsequent linkage analysis.

4. Data Summary

The complexity of water quality concerns in the Ox Creek watershed has resulted in several investigations. Past studies have included:

- Biological assessments
- Sediment sampling
- Total suspended solids and flow monitoring
- Other water chemistry sampling

Biological assessment information is the basis for placing Ox Creek on Michigan's §303(d) list. Investigations were conducted in 1991, 2001, and 2006 that noted poor macroinvertebrate communities. Concerns vary from the lack of sensitive species (e.g., mayflies, stoneflies, and caddisflies) to the increased presence of pollution tolerant taxa. In conjunction with the biological assessments, an analysis of the physical habitat was also conducted on Ox Creek. The purpose of the habitat evaluation was to identify physical characteristics or factors that may have an adverse effect on macroinvertebrate communities in Ox Creek.

One possible explanation for poor macroinvertebrate community scores is poor sediment quality. Recognizing the potential connection, DNRE collected bottom sediment samples from Ox Creek and analyzed them for toxic pollutants. Laboratory results indicated the presence of several metals and toxic organic compounds. To evaluate potential causes associated with siltation and sediment, DNRE conducted a total suspended solids (TSS) and flow monitoring effort in 2007 and 2008. Samples collected as part of this study were also analyzed for metals and toxic organics in the water column.

A synopsis of these investigations is provided in the following sections.

4.1 Biological Assessments

Michigan DNRE has conducted several biological studies in the Paw Paw River watershed, including sites in Ox Creek (Cooper 1999, Rockafellow 2002, Lipsey 2007). The macroinvertebrate and physical habitat was qualitatively assessed at each site (Table 4-1). The Great Lakes and Environmental Assessment Section (GLEAS) Procedure 51 for wadeable streams was used to evaluate conditions at each site (MDEQ, 1990; Creal et al., 1996). Procedure 51 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 tending towards a poor rating, while positive scores in the acceptable range are tending towards an excellent rating. With two exceptions (Crystal Avenue in 2006 and above mouth in 1991), macroinvertebrate communities within the Ox Creek watershed repeatedly scored poor.

Habitat evaluations are based on 10 metrics, with a possible maximum total score of 200 (MDEQ, 1990; Creal et al., 1996). A station habitat score of >154 is characterized as having excellent habitat, 105 to 154 is good, 56 to 104 is marginal, and <56 is poor. Habitat scores in Ox Creek ranged from 46 to 108 (Table 4-1).

Table 4-1. Biological assessment score summary.

Waterbody	Site Location	Year	Macroinvertebrate Community		Habitat	
			Rating	*Score*	*Rating*	*Score*
Yore – Stouffer Drain	Meadowbrook Road	2006	*Poor*	-6	*Marginal*	96
Ox Creek	Territorial Road	1991	*Poor*	-6	*Poor*	46
	Crystal Avenue	2006	*Acceptable*	-3	*Good*	108
		2001	*Poor*	-5	*Marginal*	63
	Britain Avenue	2006	*Poor*	-6	*Good*	105
	Water Street / 5th Avenue	2006	*Poor*	-5	*Marginal*	98
		2001	*Poor*	-6	*Marginal*	61
	above mouth	1991	*Acceptable*	-4	---	---
Blue Creek [1]	Park Road	2006	*Acceptable*	0	*Excellent*	156
	Territorial Road	2001	*Acceptable*	1	*Marginal*	79
	Benton Center Road	1991	*Acceptable*	0	*Marginal*	76
	Euclid Road	2006	*Acceptable*	4	*Good*	124

Notes: [1] Blue Creek included in table for use as a possible reference site for Ox Creek TMDL.

Biological and habitat survey results for Blue Creek are also included in Table 4-1. Blue Creek is the adjacent watershed located just north Ox Creek's headwaters. Macroinvertebrate scores in Blue Creek were acceptable. Blue Creek offers a potential opportunity to serve as a reference site for evaluating Ox Creek data because it meets Michigan's bioassessment criteria and because of its proximity.

The report developed following the 2006 biological study contains field observation notes. Included is summary information on the habitat at each site, substrate conditions, and the types of biological taxa present or absent. These notes provide useful insights, which describe factors that may influence macroinvertebrate communities at each site. This information is presented in Table 4-2.

Table 4-2. Biological assessment notes (Lipsey, 2007).

Location	Notes
Meadowbrook Road	• Glide / pool habitat rated as marginal. • Epifaunal substrate limited to overhanging vegetation. • Large amount of fine sediment and sand deposits • Little pool variability due to the deposition. • Debris could be found in the shrubs more than three feet above the surface of the water; banks were stable. • Stream has obviously been altered and straightened in the past. • Bank vegetation was limited to grasses. • Only 13 taxa were found. Sixty percent of the individuals found were snails, isopods, and leeches, which are taxa that are more tolerant of degraded conditions. • No mayfly or stonefly taxa were found, and only one individual caddisfly was found. • Poor macroinvertebrate community can most likely be attributed to a lack of suitable habitat for colonization and high storm water flows that bring additional sediment load and silt to further degrade the habitat.
Crystal Avenue	• Glide / pool habitat rated as good. • Station located upstream of old check dam remnants that historically formed a small pond in the cemetery. • Only epifaunal substrate available was aquatic vegetation. • Large amount of sediment deposited in pools and aquatic vegetation. This sediment may be remnants of sediment collected in the pond. The stream water levels rose two feet after a 1.25 inch precipitation event. • Riparian zone has been altered as it is located in a cemetery; however, wetland vegetation was abundant in immediate riparian area. • Macroinvertebrate community scored acceptable.
Britain Avenue	• Glide / pool habitat rated as good. • Station had a large amount of woody debris, but it was unavailable as epifaunal substrate due to large amount of siltation and sediment deposition covering the debris. • Pools also absent due to the sediment deposition. • Bank scour was evident, but the banks were fairly stable. • Only 13 taxa were found and none were taxa that are sensitive to environmental perturbations (i.e., mayflies, stoneflies, or caddisflies). • Poor macroinvertebrate community can most likely be attributed to lack of suitable habitat for colonization and high storm water flows that bring additional silt and sediment load to further degrade the habitat.
Water Street	• Glide / pool habitat rated as marginal. • With exception of some rip-rap that has fallen into stream channel from stream banks and small amount of aquatic vegetation, there was an obvious lack of epifaunal substrate. • Heavy deposits of sand observed throughout stream channel. • Bank scour not evident due to rip rap stabilizing banks; however, more than a two-foot rise in water level was observed after 1.75 inch precipitation event. • Stream channel has been altered dramatically as it enters downtown Benton Harbor area; channel is straight and has little to no riparian area. • Of the more sensitive taxa, only one individual mayfly was found. • Fifty-two percent of the total individuals found were oligochaetes. • Poor macroinvertebrate community can most likely be attributed to a lack of suitable habitat for colonization and high storm water flows that bring additional silt and sediment load to further degrade the habitat.

4.2 Sediment Sampling

Investigations have been conducted to examine sediment quality in Ox Creek. In 2001, several metals and toxic organic compounds were detected in sediments sampled by DNRE at the 5th Avenue site and upstream of Crystal Avenue. DNRE sampled additional locations in 2006. Again, several of the same metals and toxic organic compounds were detected at elevated concentrations in the sediment. A narrative description of both sampling efforts is provided in Table 4-3.

Table 4-3. Sediment assessment summary notes (Lipsey, 2007).

Location	Notes
Meadowbrook Road	• Metals and polynuclear aromatic hydrocarbons (PAHs) results in 2006 sampling indicated several parameters exceeded the range of levels found in SMNITP reference stations and/or exceeded sediment quality guidelines.
Euclid Avenue	• Metals results in 2006 sampling were within range of levels found in SMNITP reference sites
Crystal Avenue	• Metals and PAH results in 2006 sampling indicated several parameters exceeded the range of levels found in SMNITP reference stations and/or exceeded sediment quality guidelines • Several organic compounds and metals in 2001 sampling either exceeded the range of SMNITP reference stations or exceeded sediment quality guidelines.
Britain Avenue	• In 2006, sediment samples taken in unnamed creek at M-139 and at Britain Street. Analyzed for metals and PAHs. • Results indicated that although levels of total chromium were higher than the average for SMNITP reference sites, levels did not exceed sediment quality guidelines. Lead, zinc, and several PAHs exceeded the range of levels found in SMNITP and one or both of the sediment quality guidelines.
Highland Avenue	• In 2006, sediment samples were analyzed for metals and organics. Results indicated several parameters exceeded the range of levels found in SMNITP reference stations and/or exceeded sediment quality guidelines
Water Street / 5th Avenue	• Metals and PAH results in 2006 sampling (Water Street) indicated several parameters exceeded the range of levels found in SMNITP reference stations or exceeded sediment quality guidelines. • Several organic compounds and metals found in 2001 sediment samples (5th Avenue site) that either exceeded the range of found in reference stations in SMNITP or exceeded sediment quality guidelines.
Notes	SMNITP: Ecoregion Reference Average *(Southern Michigan Northern Indiana Till Plains)*

In addition to DNRE surveys, several other studies have assessed the sediment quality of Ox Creek. One investigation evaluated sediment data collected from lower Ox Creek (Earth Tech, 2006). The purpose of the study was to provide information on the severity and distribution of contaminated sediment in Ox Creek between North Shore Drive and the Paw Paw River. Samples were collected from 0 to 6 inches and 18 to 24 inches below the sediment surface using a Russian Sediment Borer.

Most recently, a reach of Ox Creek was examined for the Benton Harbor Brownfield Redevelopment Authority (BHBRA). This study focused on the section between Highland Avenue and Britain Avenue (Prism, 2009). Ten locations were sampled in 2009 along a 3,000 foot reach of Ox Creek using a 3.25 inch diameter stainless steel soil recovery auger. The interval sampled consisted of the upper three feet of sediments. Samples were analyzed for metals, PAHs, PCBs, and pesticides. Sediments consisted of inter-bedded layers and mixtures of sand, silty sand, silt, and soft, organic rich “mucky” silt of varying thicknesses within Ox Creek. Sediments consisted of more coarse-grained material (sand and gravel) in the northern portion and southern end of the study area. Fine-grained (silty sand and silt), soft, and typically “mucky” material was observed in the central portion of the project area.

Sediment data was examined from these sampling efforts. Sediment samples were tested for a number of metals and PAH parameters and several were detected. A preliminary assessment was conducted on those compounds detected most frequently, specifically arsenic, cadmium, chromium, lead, zinc, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene. Results of this evaluation are presented in Figure 4-1 through Figure 4-11. These graphs present a longitudinal profile of the data in order to examine patterns moving from the headwater areas of Ox Creek to the lower reaches (or left to right). Different symbols are used to represent each survey conducted (e.g., DEQ, Prism, Earth Tech 0-6” samples, and Earth Tech 18-24” samples).

Although no criteria have been developed for sediment quality in Michigan, threshold or reference levels identified and discussed in Section 3.3 are shown in each graph. Values shown include the threshold effects concentration (TEC), probable effects concentration (PEC), and the Southern Michigan Northern Indiana Till Plain (SMNITP) reference levels. This information is simply to provide a frame of reference when looking at the data.

In addition to general reference levels, information regarding potential sources of these pollutants is also helpful. For example, the transportation system is a primary source of metals in storm water runoff to streams. Cadmium, lead, and zinc are deposited on surfaces by vehicle exhaust, brake linings, tires, and engine wear. Oil, grease, and other hydrocarbons related to vehicle use are other pollutants associated with urban storm water. Galvanized metal rooftops, gutters and downspouts, and moss killer are also sources of zinc in urban storm water. Outdoor storage of scrap metal can also contribute to metals observed in surface water.

Polycyclic aromatic hydrocarbons (PAHs) such as fluoranthene and phenanthrene are found in the exhaust of motor vehicles and other gasoline and diesel engines, emission from coal-, oil-, and wood burning stoves and furnaces, cigarette smoke, general soot and smoke of industrial, municipal, and domestic origin, in incinerators, coke ovens, and asphalt processing and use (USGS 2005, USDHHS, 1995).

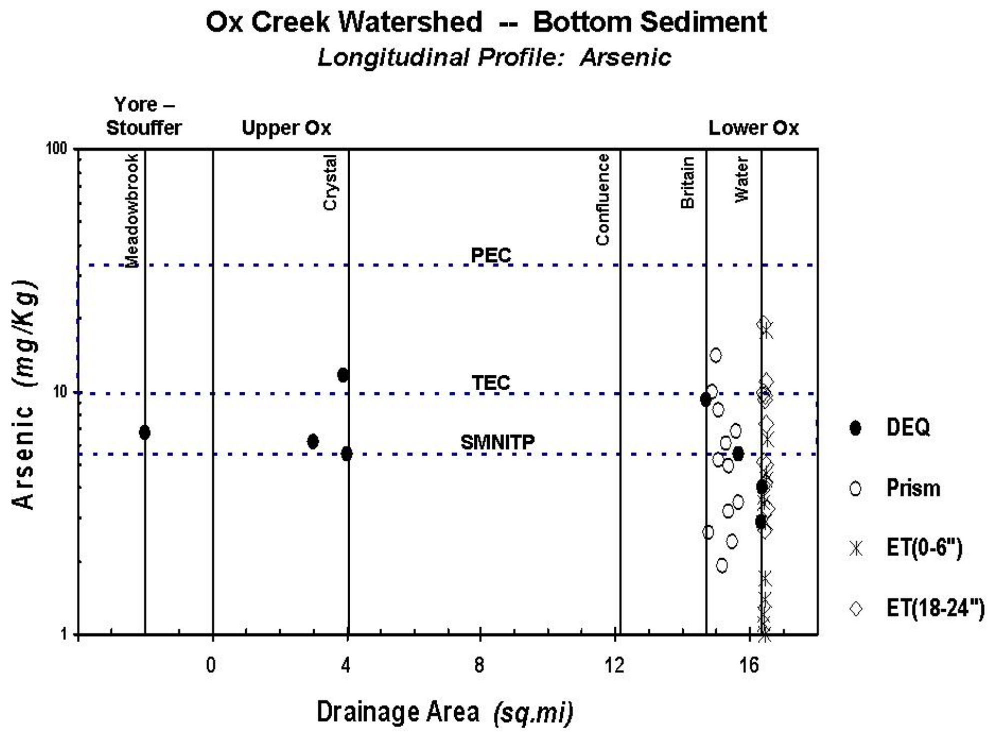

Figure 4-1. Ox Creek sediment sampling results -- arsenic.

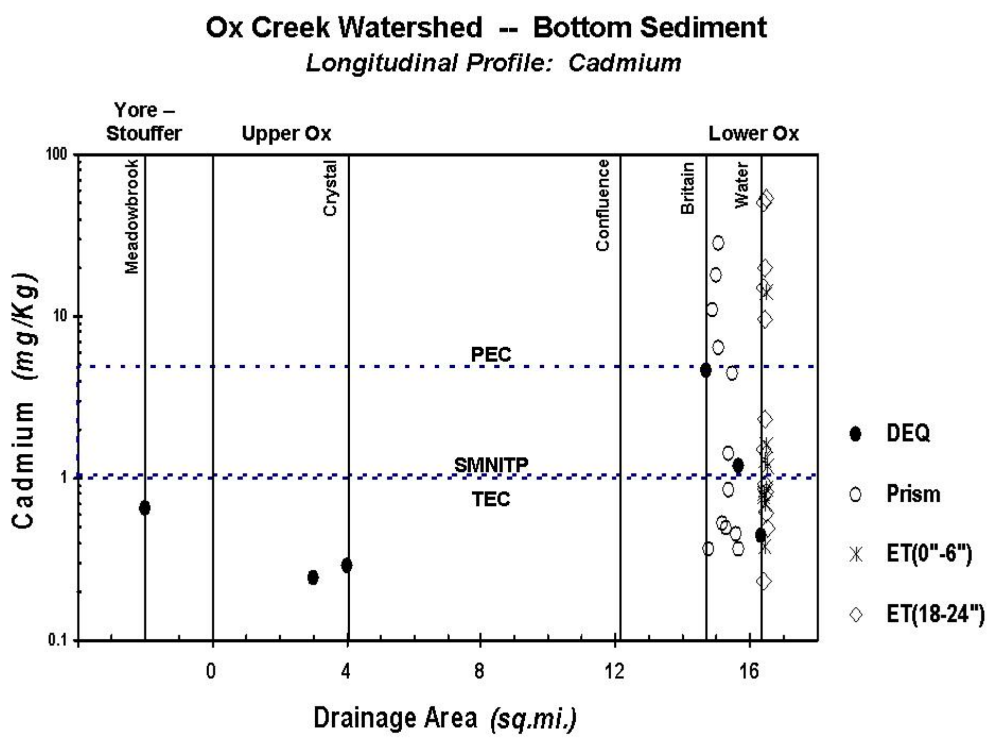

Figure 4-2. Ox Creek sediment sampling results -- cadmium.

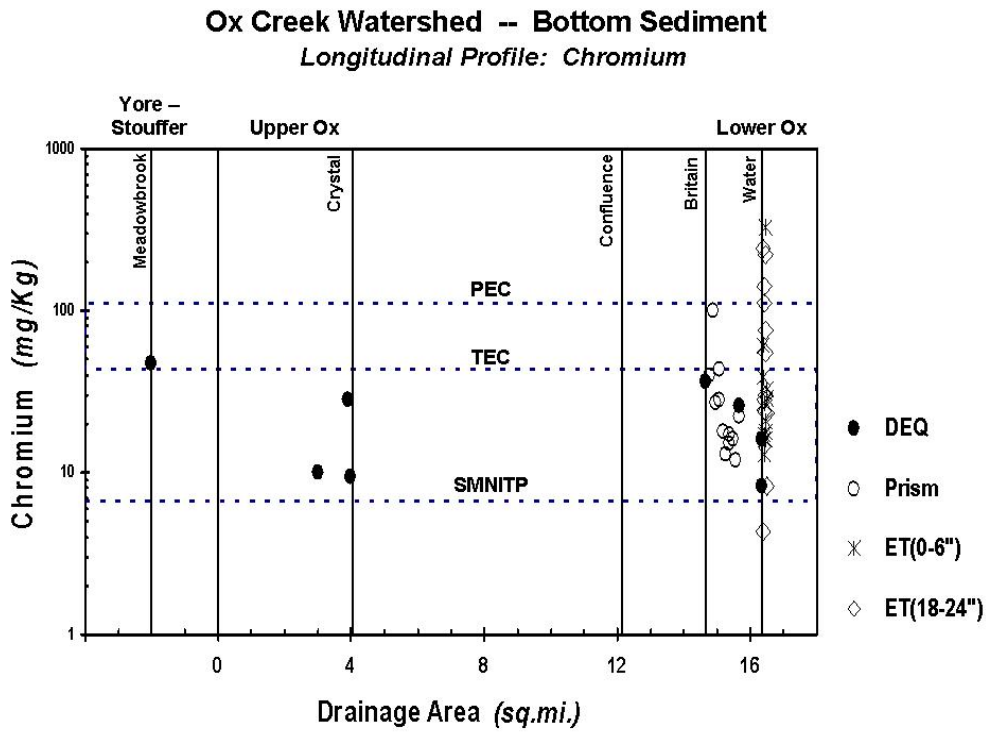

Figure 4-3. Ox Creek sediment sampling results -- chromium.

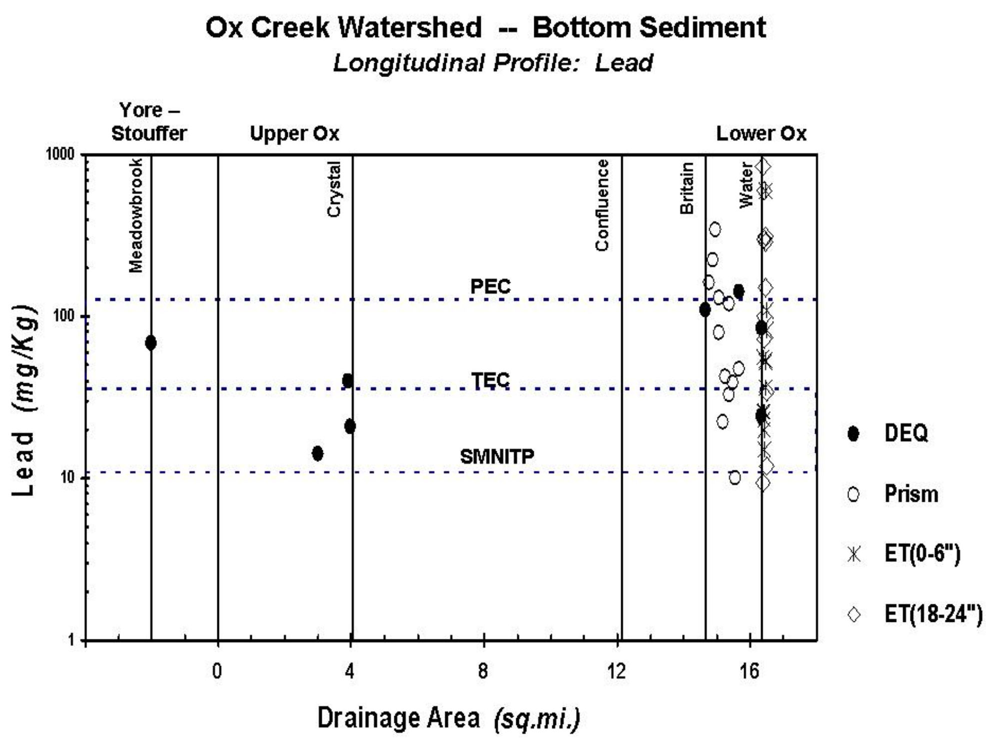

Figure 4-4. Ox Creek sediment sampling results -- lead.

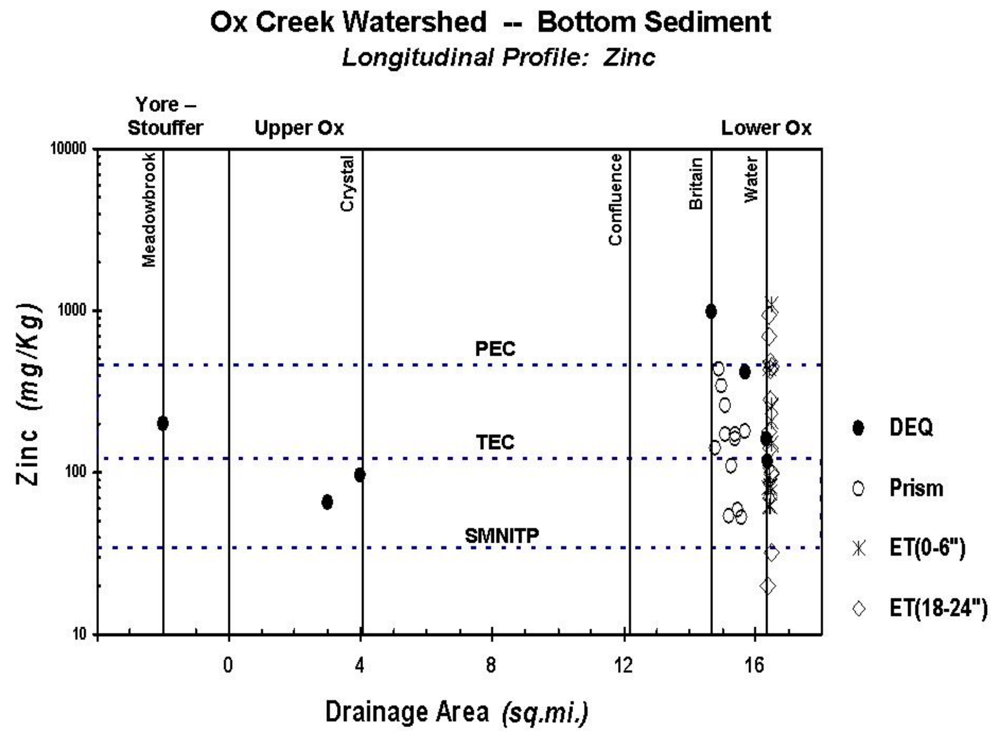

Figure 4-5. Ox Creek sediment sampling results -- zinc.

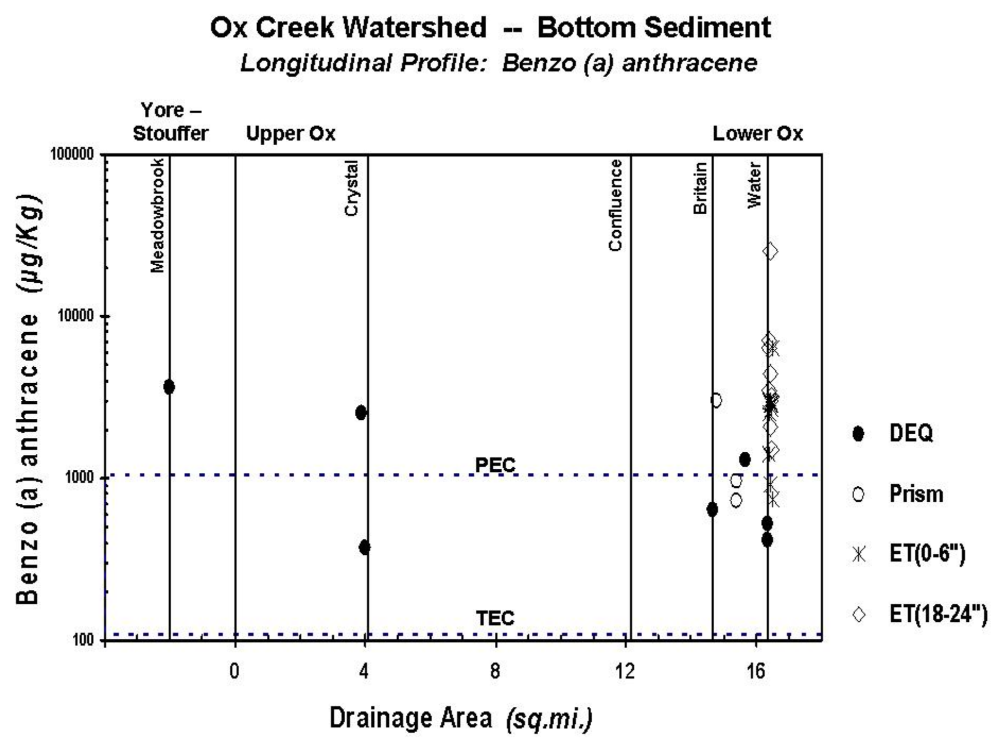

Figure 4-6. Ox Creek sediment sampling results -- benzo(a)anthracene.

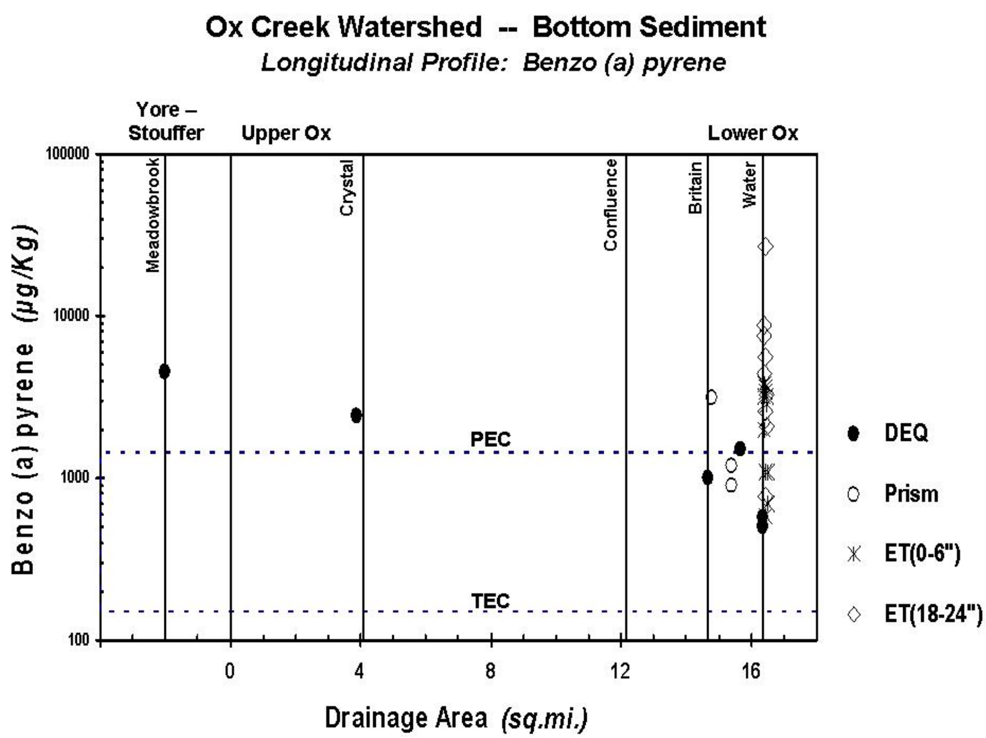

Figure 4-7. Ox Creek sediment sampling results -- benzo(a)pyrene.

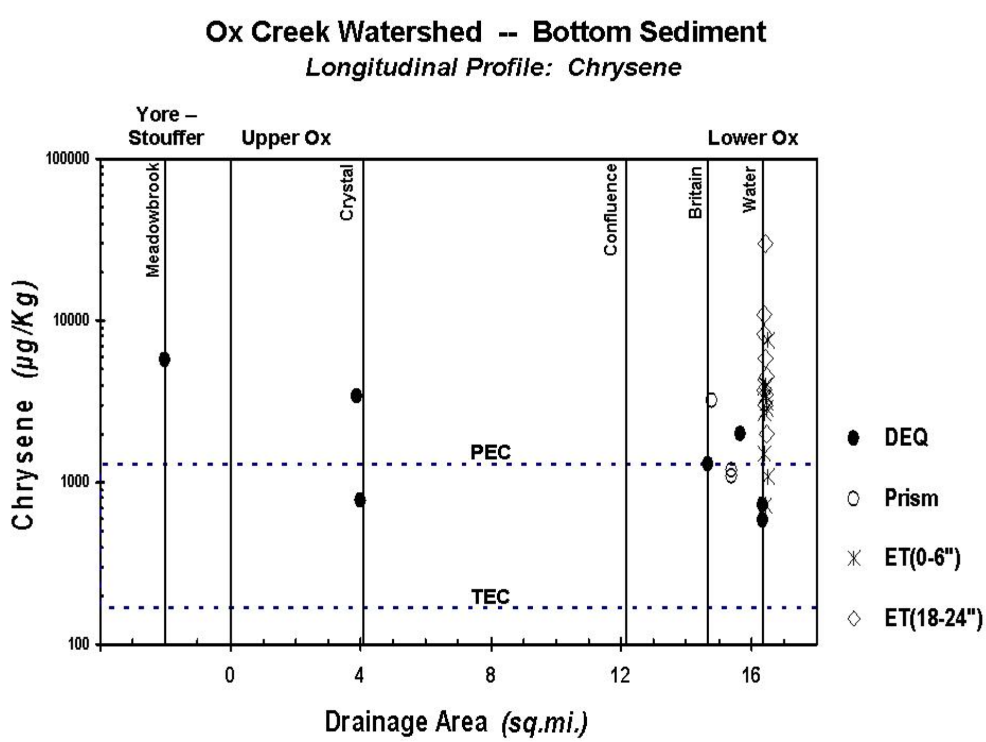

Figure 4-8. Ox Creek sediment sampling results -- chrysene.

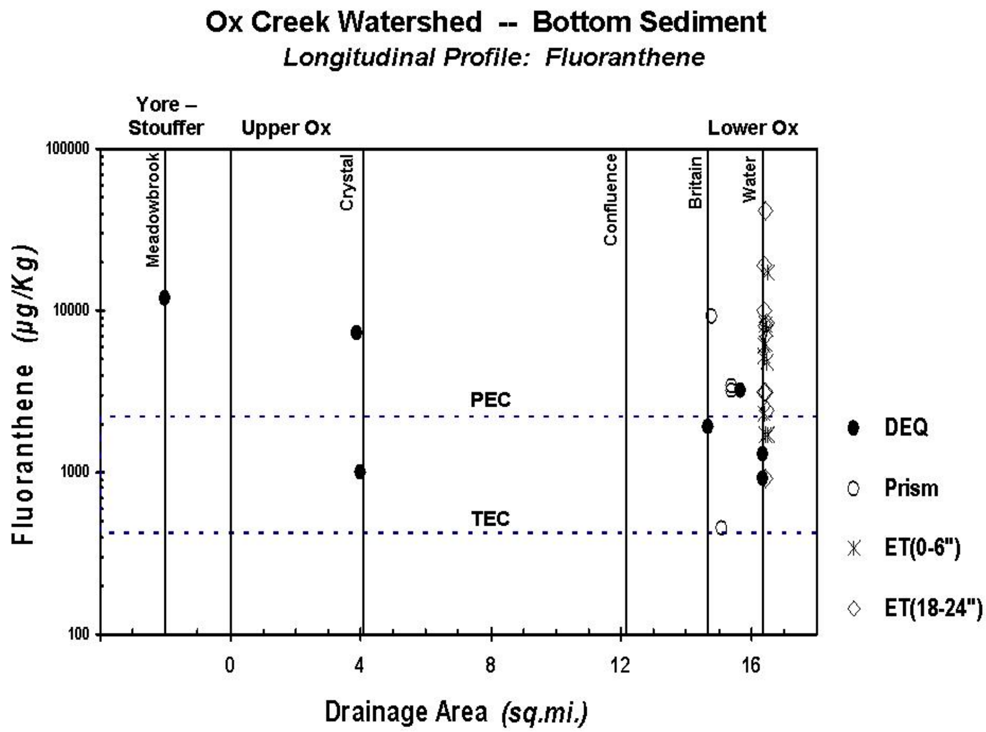

Figure 4-9. Ox Creek sediment sampling results -- fluoranthene.

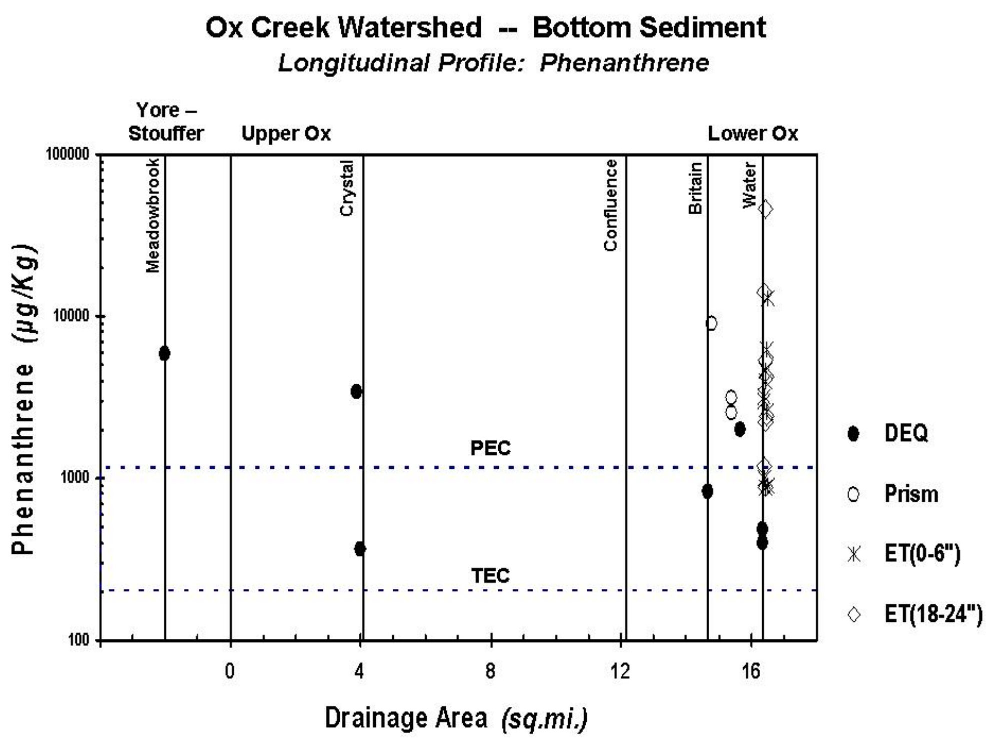

Figure 4-10. Ox Creek sediment sampling results -- phenanthrene.

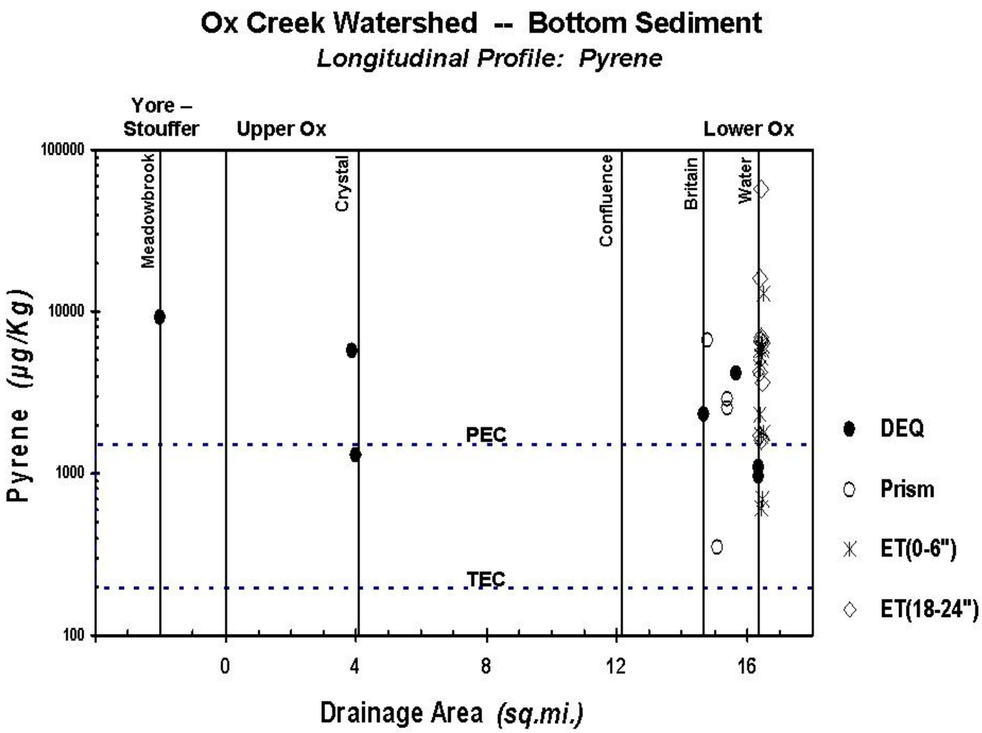

Figure 4-11. Ox Creek sediment sampling results -- pyrene.

4.3 Total Suspended Solids and Flow Monitoring

A study was initiated by DNRE in 2007 that focused on total suspended solids monitoring at seven sites (Limno Tech, 2008). The effort continued into 2008. These sites are listed in Table 4-4; locations are shown in Figure 4-12. Sampling was conducted that consisted of both wet and dry weather events. Water level recorders were deployed at the Britain Avenue site to enable development of stream flow estimates. In addition, the distance from an identified reference point at each monitoring location to the water surface was measured at the time of each sample collection. This distance is referred to as the tape down measurement.

Table 4-4. Ox Creek TSS sampling sites.

Location	Site ID
Yore – Stouffer Drain at Blue Creek Road	#05
Yore – Stouffer Drain at Yore Avenue	#06
Yore – Stouffer 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

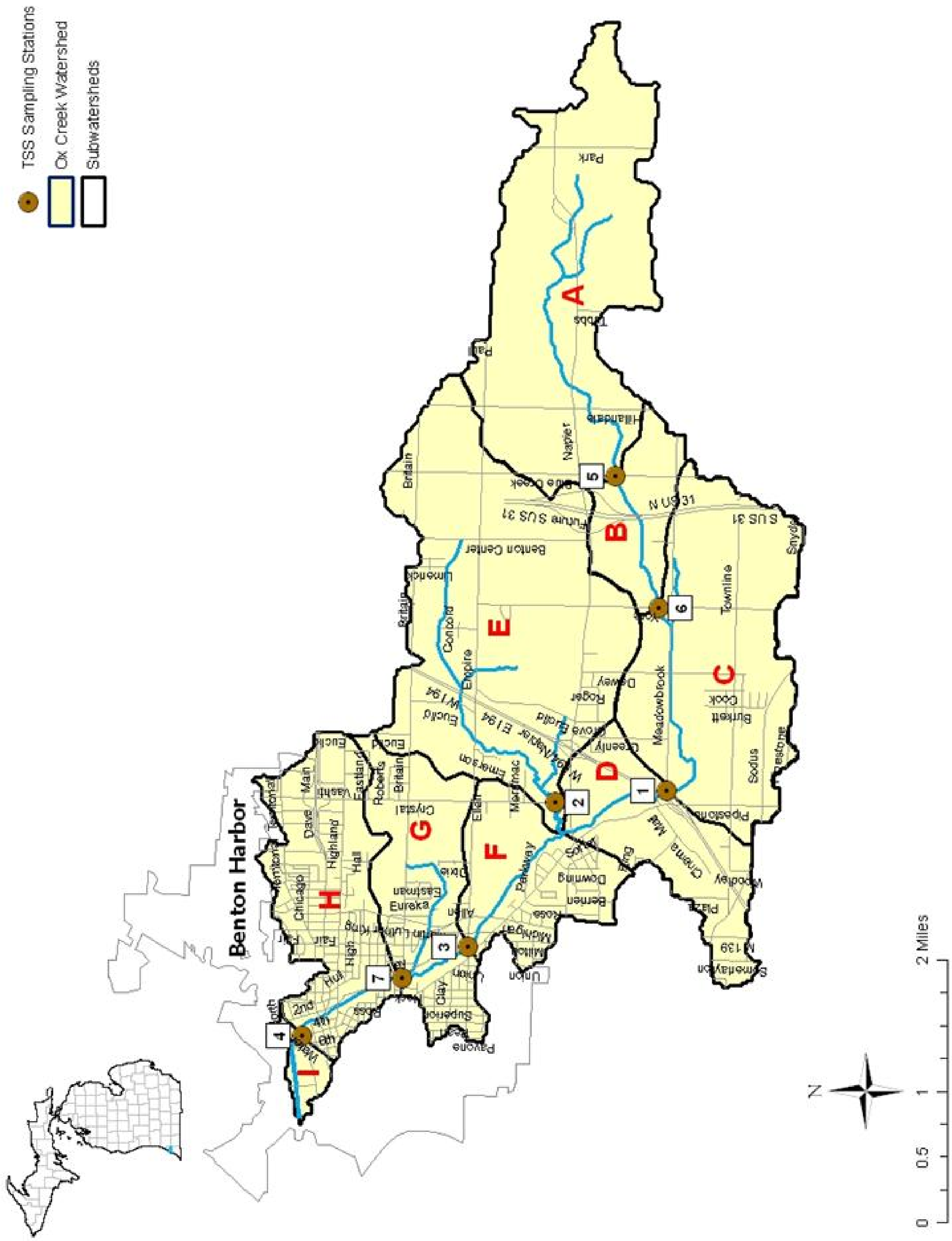

Figure 4-12. Location of Ox Creek TSS monitoring sites.

Table 4-5 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 4-13. This graph provides a context for TSS sampling events relative to hydrologic conditions.

Table 4-5. Dates associated with each TSS sampling event.

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
8/4-5/2008	Wet	0.74

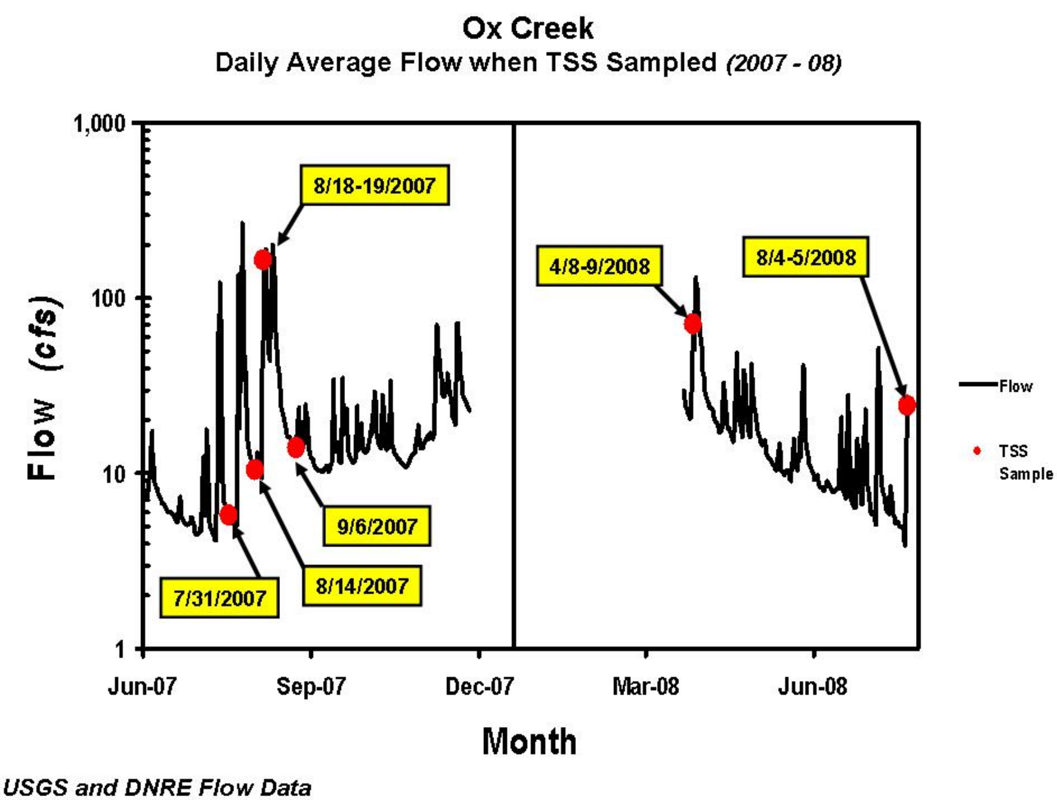

Figure 4-13. Ox Creek flow and TSS sample dates.

Figure 4-14 presents a summary of the TSS monitoring data. Information is depicted in the longitudinal direction moving from upstream to downstream (left to right). The highest TSS values were reported 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-Stouffer 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 4-14.

One way to examine the TSS data is through an analysis of its relationship to flow. Tape down measurements can be expressed as water level, which provides an indication of flow. Figure 4-15 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.

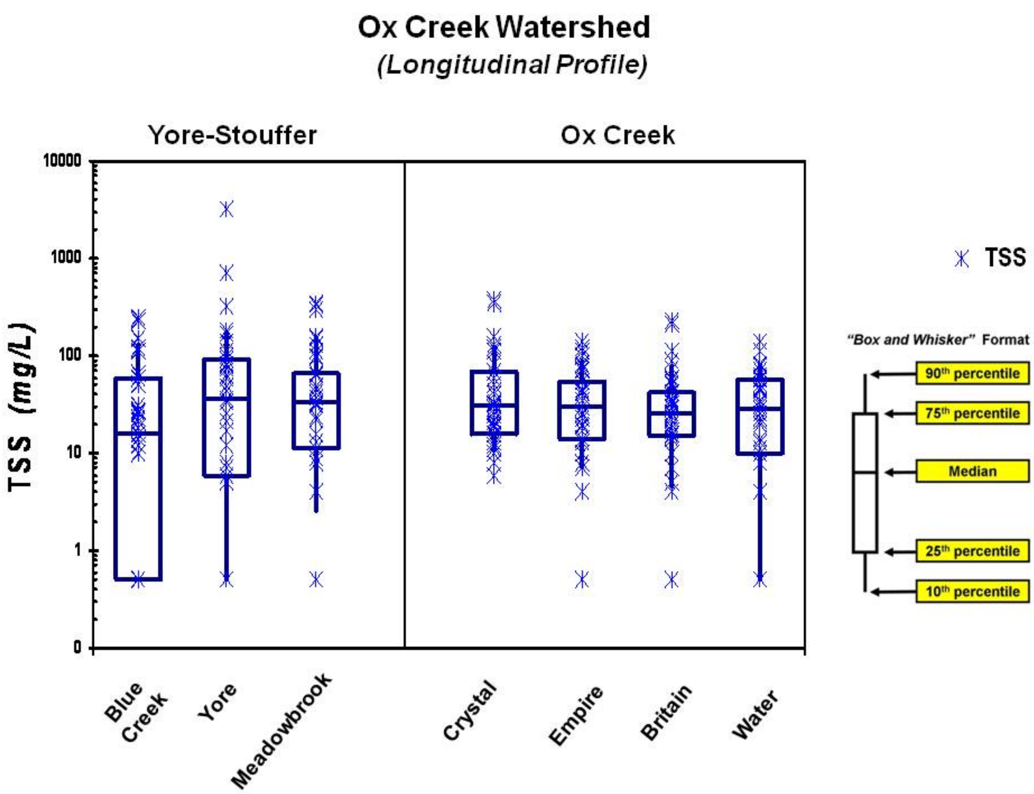

Figure 4-14. Longitudinal profile of TSS monitoring data.

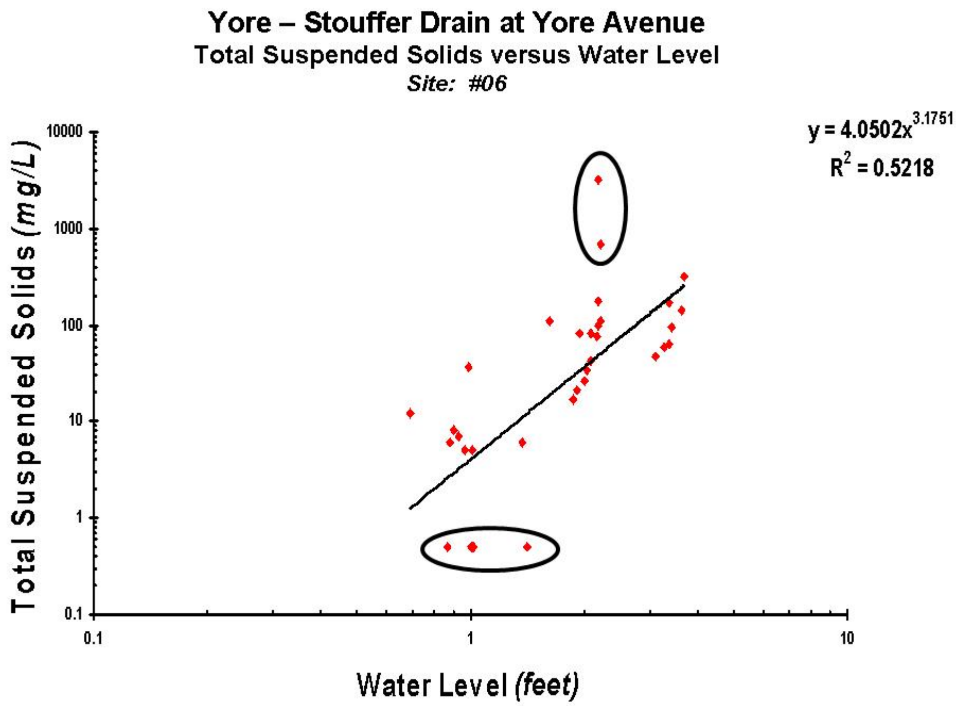

Figure 4-15. TSS as a function of water level -- Yore Avenue site.

Level logger data from the Britain Avenue site provides information that can be used to estimate flows and loads. Using the relationship described in the hydrology discussion between this location and the Galien River gage, a flow duration curve can be developed for Ox Creek at Britain Avenue. This provides a starting point to view TSS loads as they may be related to flows. Figure 4-16 shows a load duration curve for TSS data at Britain Avenue developed from the combined information.

The TSS data in Figure 4-16 is displayed according to the flow duration interval associated with each sample point. In addition, data is separated by each sample event. The first wet weather event occurred in August (summer) as the result of a 2.52 inch storm (noted as Sum-2.52" in Figure 4-16). A significant number of these samples were collected under high flow conditions and included the largest TSS loads. The second wet weather event occurred in the spring and, at 0.69 inches, was the smallest in terms of measured precipitation (noted as Spr-0.69" in Figure 4-16). However, it did result in greater loads than the third event that occurred in the summer as the result of a 0.74 inch storm (noted as Sum-0.74" in Figure 4-16). This may reflect seasonal factors as the second storm occurred in April, prior to the emergence of vegetation on agricultural lands.

The relationship between flow and TSS will be further investigated during the linkage analysis when targets are established for the Ox Creek TMDL.

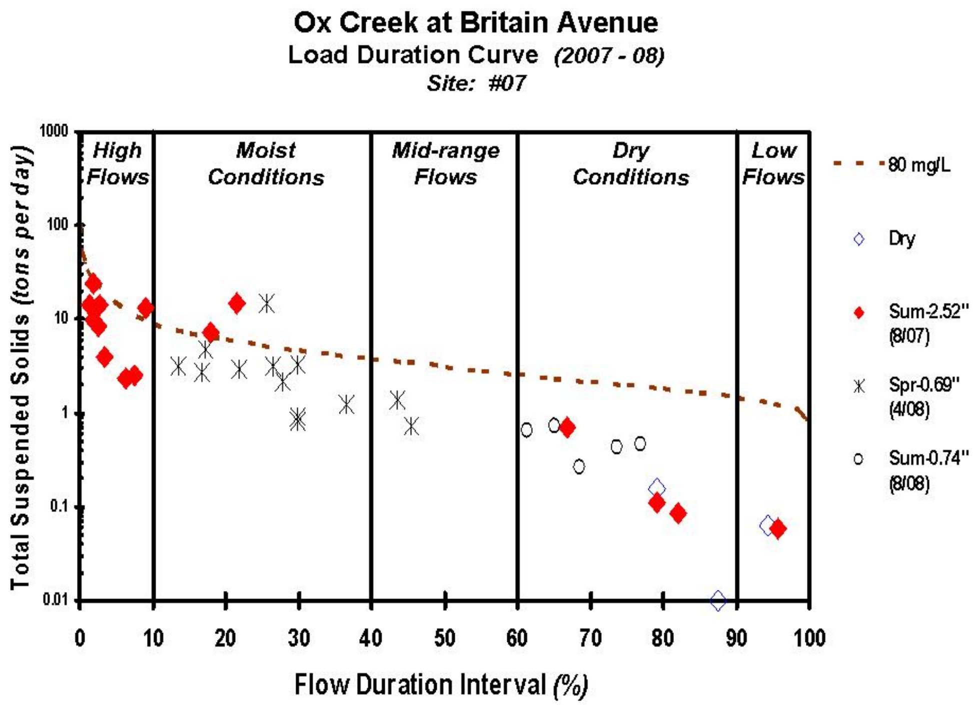

Figure 4-16. Load duration curve for TSS at Britain Avenue.

4.4 Water Chemistry Sampling

Several samples collected as part of the TSS monitoring effort were analyzed for metals and toxic organic compounds in the water column. These analyses were conducted at all locations shown in Table 4-4 except at the Yore – Stouffer Drain at Blue Creek Road (station # 05). Each site was tested six times for toxic pollutants in the water column; once for each of the three dry weather events and once for the first flush of each of the wet weather events.

In many cases, sample results indicated that the pollutant was not detected. Table 4-6 provides an overview of the occurrence for the same compounds shown in the discussion on sediment quality (Section 4.2). These results are presented in terms of the number of times the pollutant was detected. In addition to reporting the frequency of occurrence in the six samples at each site, results were compared to the chronic criteria listed in Table 3-1 (if a value was available for that pollutant). While Table 4-6 presents information on the frequency of occurrence, Table 4-7 provides an indication of magnitude. Table 4-7 summarizes the median of values detected for each compound at the sites sampled.

Some general observations in reviewing the data merit discussion. Although arsenic was detected on all occasions at each site, the levels measured were significantly below the chronic criteria. Zinc, on the other hand, approached the criteria on one sample event at the Empire Road site (#03). The Yore - Stouffer Drain at Meadowbrook Road (#01) exceeded the chronic criteria for two pollutants: fluoranthene and phenanthrene. The Empire Avenue exceeded the chronic criteria for fluoranthene on one occasion.

Table 4-6. Occurrence of toxic pollutants in the water column during TSS survey.

Parameter	Site					
	Yore #06	Meadowbrook #01	Crystal #02	Empire #03	Britain #07	Water #04
Arsenic	6	6	6	6	6	6
Cadmium	---	---	---	---	---	---
Chromium	1	3	1	3	3	2
Lead	---	2	2	2	4	3
Zinc	---	2	1	5	6	5
Benzo(a)anthracene	---	1 **	---	1 **	---	---
Benzo(a)pyrene	---	1 **	---	1 **	---	---
Chrysene	---	2 **	---	1 **	---	---
Fluoranthene	---	2	---	1	1	---
Phenanthrene	---	2	---	1	---	---
Pyrene	---	2 **	---	1 **	---	---

Note: "---" means that parameter was tested for, but was not detected at that site.
Shaded cell indicates at least one sample exceeded the chronic criteria.
** indicates that no criteria available for that parameter *(see Table 3-1)*.

Table 4-7. Median concentration of toxic pollutants in the water column during TSS survey.

Parameter	Units	Site					
		Yore #06	Meadowbrook #01	Crystal #02	Empire #03	Britain #07	Water #04
Arsenic	*(µg/L)*	2.15	2.60	2.30	1.90	1.85	1.60
Cadmium	*(µg/L)*	---	---	---	---	---	---
Chromium	*(µg/L)*	1.20	1.70	1.10	1.50	1.30	1.20
Lead	*(µg/L)*	---	6.95	1.65	7.35	2.40	3.80
Zinc	*(µg/L)*	---	52	14	34	18	20
Benzo(a)anthracene	*(µg/L)*	---	3.90	---	1.00	---	---
Benzo(a)pyrene	*(µg/L)*	---	8.00	---	2.50	---	---
Chrysene	*(µg/L)*	---	7.95	---	1.90	---	---
Fluoranthene	*(µg/L)*	---	15.45	---	3.20	1.00	---
Phenanthrene	*(µg/L)*	---	7.00	---	1.30	---	---
Pyrene	*(µg/L)*	---	99.65	---	2.00	---	---

Note: "---" indicates compound not detected at site

5. 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. The purpose of this section of the document is to identify possible sources within the Ox Creek watershed.

Pollutants of concern in the source assessment include sediment, oil and grease, heavy metals (e.g., chromium, copper, lead), and polynuclear aromatic hydrocarbons (PAHs). These pollutants can originate from an array of sources including point source discharges (e.g., industrial pipes) and surface runoff, particularly storm water. This section provides a summary of potential sources that contribute listed pollutants to Ox Creek.

5.1 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 not only enhances the source assessment by grouping information; it 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 5-1 and Figure 5-1. These subwatershed boundaries are defined in a way that builds on locations sampled by DNRE. The sections that follow first describe point sources in the Ox Creek watershed. The source assessment continues with a discussion of remediation and leaking underground storage tank sites that may affect water quality in Ox Creek. The source assessment concludes with a summary of basic characteristics for each subwatershed group. This includes size, source areas located within the subwatershed, and land use / land cover.

Table 5-1. Ox Creek subwatersheds.

Subbasin ID	Name	Area	
		(acres)	*(sq.mi.)*
Unit A	Yore – Stouffer Headwaters	2,150	3.36
Unit B	Upper Yore – Stouffer	465	0.73
Unit C	Middle Yore – Stouffer	1,755	2.74
Unit D	Lower Yore – Stouffer	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

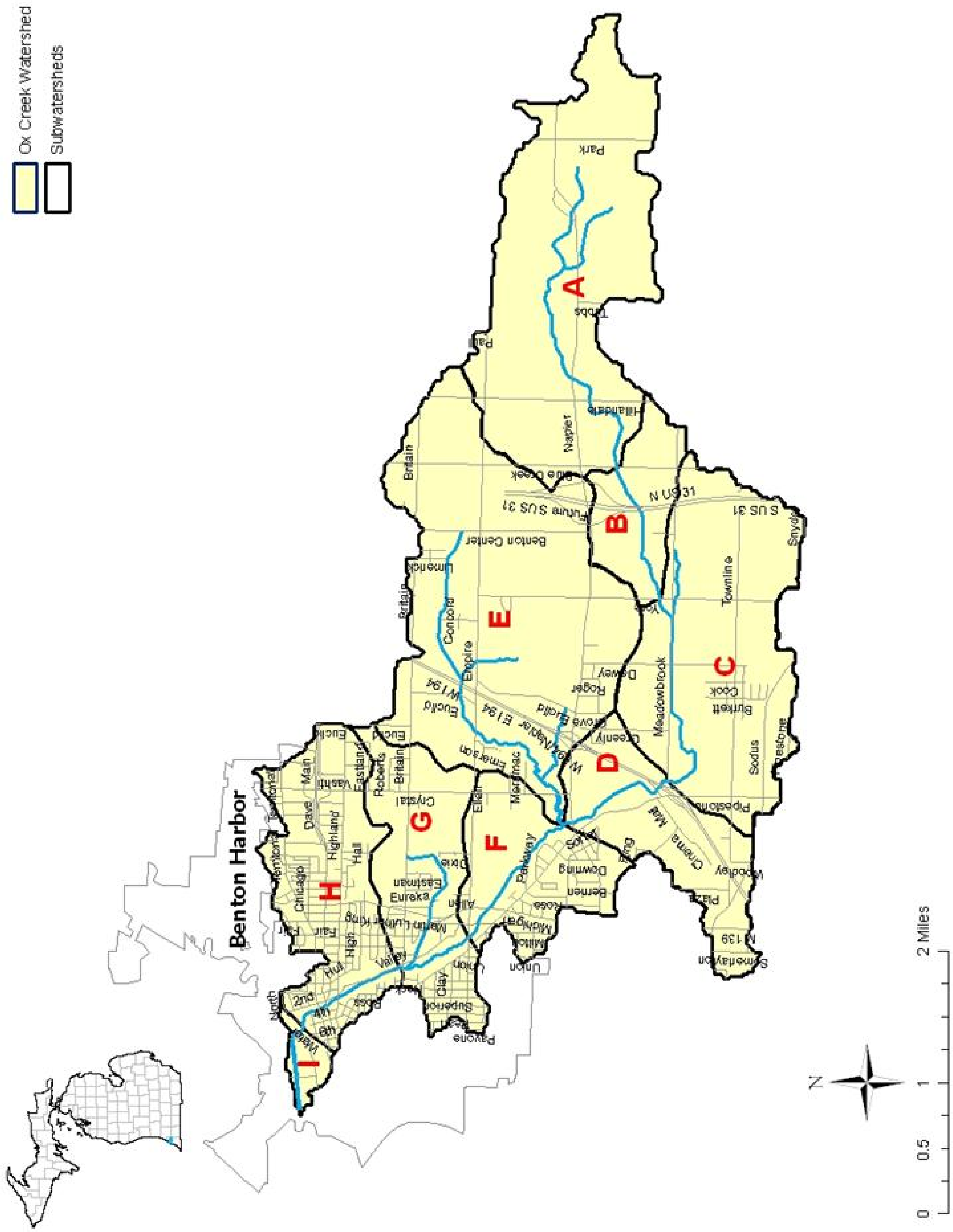

Figure 5-1. Ox Creek watershed units.

5.2 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 contaminants to Ox Creek. The subsections that follow review major source categories of concern in the watershed.

5.2.1 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, DNRE may utilize an individual permit, general permit, or *"permit by rule"* for NPDES authorizations. DNRE 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 where individual NPDES permits are issued 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 5-2)*. The location of these facilities is shown in Figure 5-2.

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 5-3)*.

Table 5-2. 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 5-3. Facilities with construction storm water permit coverage.

Permit ID	Name	Permit Type	Subwatersheds
MIR109897	Harbor Bluffs Contract 2	Construction NOC	H,I

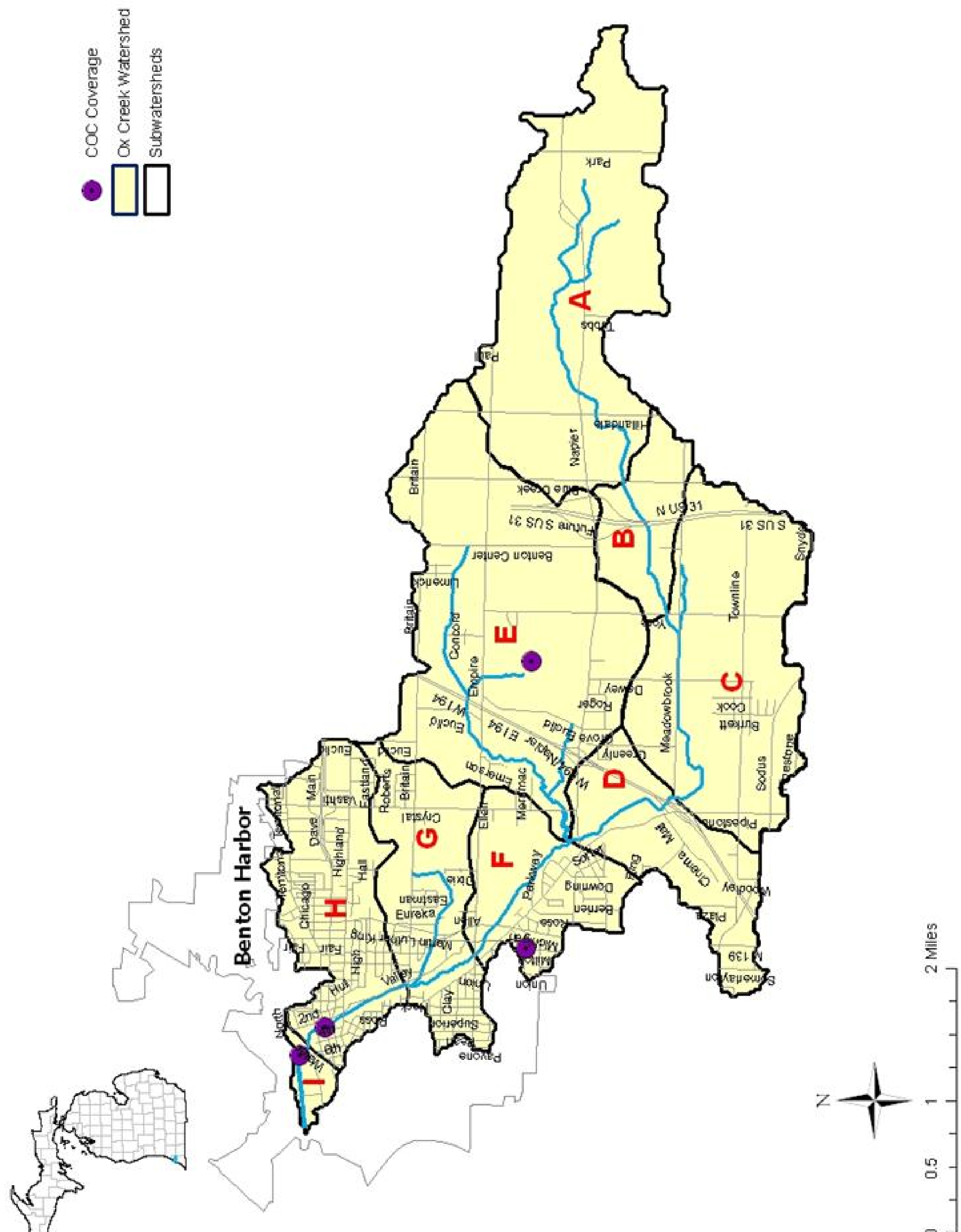

Figure 5-2. Location of facilities with COCs for non-contact cooling water.

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 5-4 identifies those jurisdictions in the Ox Creek watershed that have been issued a COC by DNRE 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 5-3.

Table 5-4. Jurisdictions with MS4 storm water permit coverage.

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

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 obtain a certified operator who supervises control structures at the facility, eliminates any unauthorized non-storm water discharges, and develops and implements a Storm Water Pollution Prevention Plan for the facility. Facilities in the Ox Creek watershed covered under the industrial storm water permit are listed in Table 5-5 and shown in Figure 5-4.

Table 5-5. 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	Atlantic Auto-Territorial	Industrial COC	H
MIS310396	Siemens VAI	Industrial COC	H
MIS310343	Modern Plastics Corp	Industrial COC	I
MIS310611	New Products Corp	Industrial COC	I

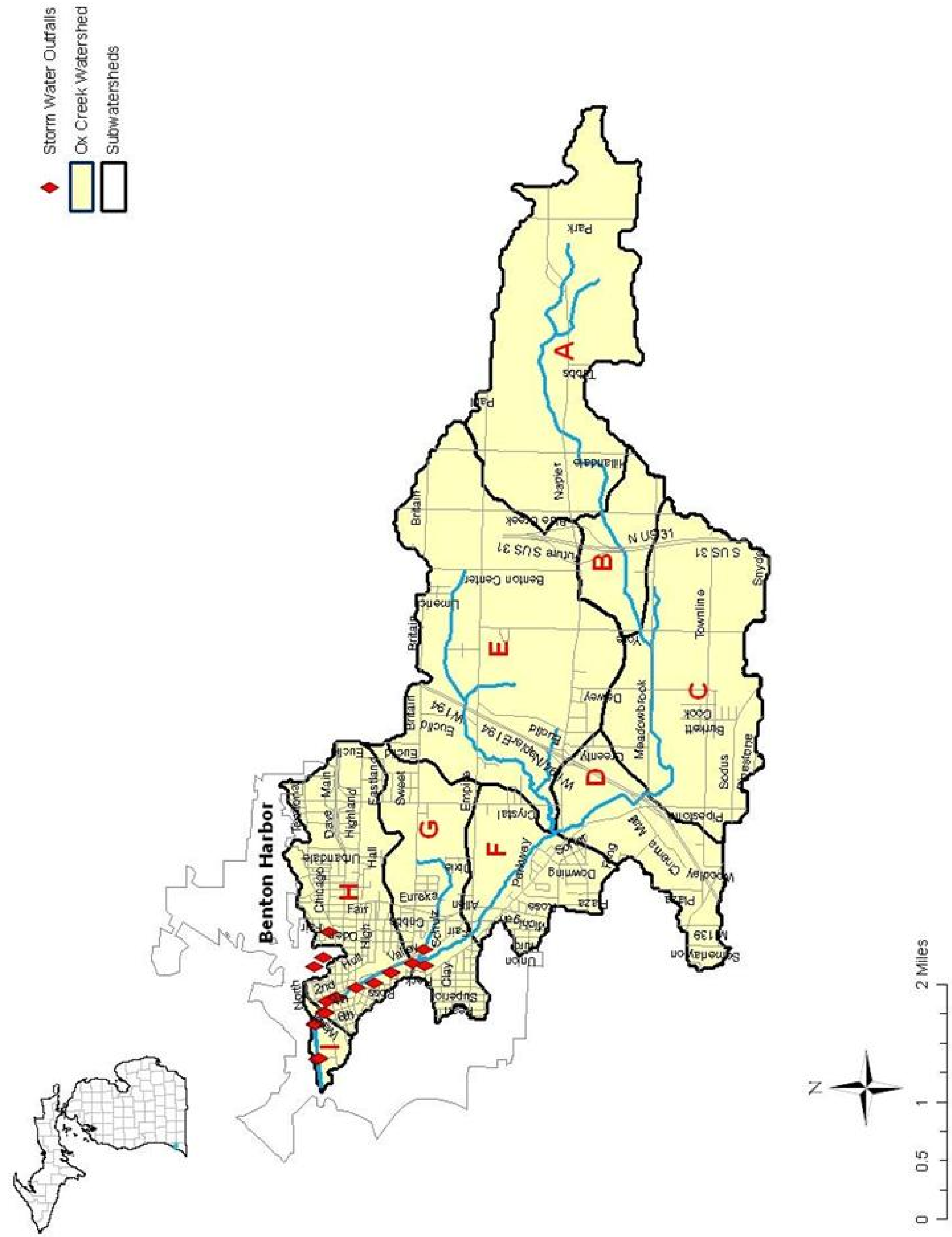

Figure 5-3. Location of outfalls under Benton Harbor MS4 storm water permit.

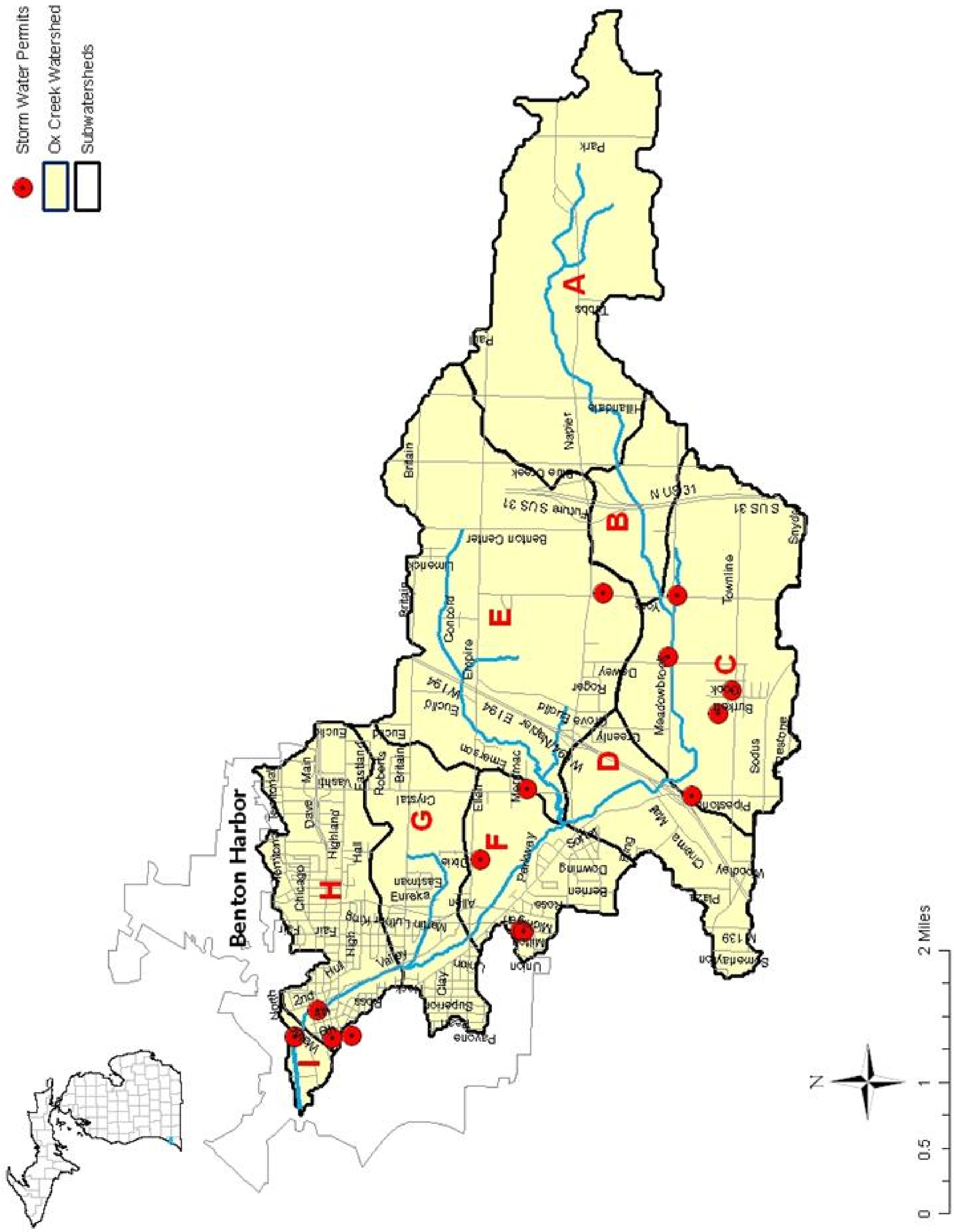

Figure 5-4. Location of facilities with industrial storm water permit coverage.

5.2.2 Remediation Sites

Sites of environmental contamination in Michigan are regulated under Part 201 of the Natural Resources and Environmental Protection Act (1994 PA 451, as amended). The Part 201 cleanup program is administered by DNRE's Remediation and Redevelopment Division (RRD). A Part 201 site or facility is defined as any area, place, or property where hazardous substance in excess of the established state cleanup standard for residential property has been released, deposited, disposed of, or otherwise comes to be located. Property is no longer an active 201 site when actions to remove, reduce, or treat the contamination are completed, lowering the amount of contamination to a level that is below the residential cleanup standards.

Part 201 authorizes the DNRE to set cleanup standards by considering how the contaminated land will be used in the future. This is relevant to the Ox Creek because of the Brownfield redevelopment that is occurring in the lower portion of the watershed. Michigan's cleanup standards are risk-based and reflect the potential for human health risk from exposure to potentially harmful substances at contamination sites based on the property's use.

Environmental remediation under Part 201 requires DNRE to identify and track locations of environmental contamination. Response activity to address sites of environmental contamination generally proceeds in a sequence of steps, which can include initial evaluation, interim response, remedial investigation, remedial action, operation and maintenance, and monitoring.

All Part 201 sites are ranked according to the risk each poses to human health and the environment using a Site Assessment Model. The Site Assessment Model evaluates existing and potential chemical substance exposure to determine a site score reflecting the hazard of the site relative to other sites in Michigan. It is a structured value assessment system based upon the perceived risk and value of the actual and potential affected resources. There are six categories within the model, for which points are assigned to reflect the value of the perceived risks. These categories include:

- Environmental contamination
- Mobility rating
- Sensitive environmental resource
- Population
- Institutional population
- Chemical hazard

Site scores are used by DNRE, along with other criteria, to help determine where limited state funding resources should be utilized.

Several contaminated sites are located in the Ox Creek watershed that are regulated under Part 201, and have been investigated by DNRE-RRD. Examples include the Malleable Industries Site, the Edgewater Development site, the Harbor Plating site, and the former Benton Harbor Manufactured Gas Plant (MGP). Other investigations are being initiated, such as the Harbor Town site in the lower portion of the watershed. This effort is being coordinated with the City of Benton Harbor's Brownfield Redevelopment Program. These sites are identified in Table 5-6 and locations shown in Figure 5-5.

Table 5-6. Sites regulated under Part 201 in the Ox Creek watershed.

Name	Site Type	Status	Subwatershed
Sandalich Grocery & Gas	Interim Response	**Active**	C
Gast ReMark Facility	Remedial Action	**Active**	C
Harbor Plating	Interim Response	**Active**	G
Main & Fair, SW Corner	Evaluation	**Active**	H
Main & Oden, NE Corner	Evaluation	**Active**	H
Territorial Road (1395)	Inactive - no actions taken	Inactive	H
East Main & Third	Interim Response	Inactive	H
Gafill Oil Company	Interim Response	Inactive	H
177 Frederick	Interim Response	**Active**	H
Branscumb Property *(former Benton Harbor Manufactured Gas Plant)*	Interim Response	**Active**	H
North of Main Industrial Area	Interim Response	**Active**	H
American Laundry	Evaluation	**Active**	H
Harbor Graphics *(Vomela Specialty)*	Inactive - no actions taken	Inactive	I
Martin Brothers Mill and Foundry	Inactive - no actions taken	Inactive	I
Malleable Industries Site	Interim Response	Inactive	I
Tile Mart Site	Interim Response	**Active**	I
Modern Plastics	Interim Response	**Active**	I
New Products Production Wells	Evaluation	**Active**	I
Edgewater Development	Interim Response	**Active**	I

5.2.3 Leaking Underground Storage Tanks

Part 213 of the Natural Resources and Environmental Protection Act mandates corrective actions by owners of facilities with Leaking Underground Storage Tanks (LUST). An active (or *"Open"*) LUST site is a location where a release has occurred from an underground storage tank system, and where corrective actions have not been completed to meet the appropriate land use criteria (MDEQ, 2004). At the time of a release, the owner / operator is responsible for the corrective actions. Part 213 requires a facility owner / operator to hire Qualified Underground Storage Tank Consultants (QCs) to perform corrective actions in accordance with Part 213, and to submit specific reports required by the statute. The DNRE-RRD is charged with selectively auditing all aspects of the corrective actions undertaken.

An inactive *("Closed")*, LUST site is a location where a release has occurred from an underground storage tank system and corrective actions have been completed to meet the appropriate land use criteria. A site listed as closed is subject to an audit by the Storage Tank Division within 6 months of the date of receipt of the closure report. If an audit does not confirm that corrective action has been conducted in compliance with Part 213 or that cleanup criteria have not been met, the owner or operator may need to provide additional information or retain a consultant to take additional corrective actions. Until such time as the report indicates that the corrective actions are complete the facility remains *"Open"*.

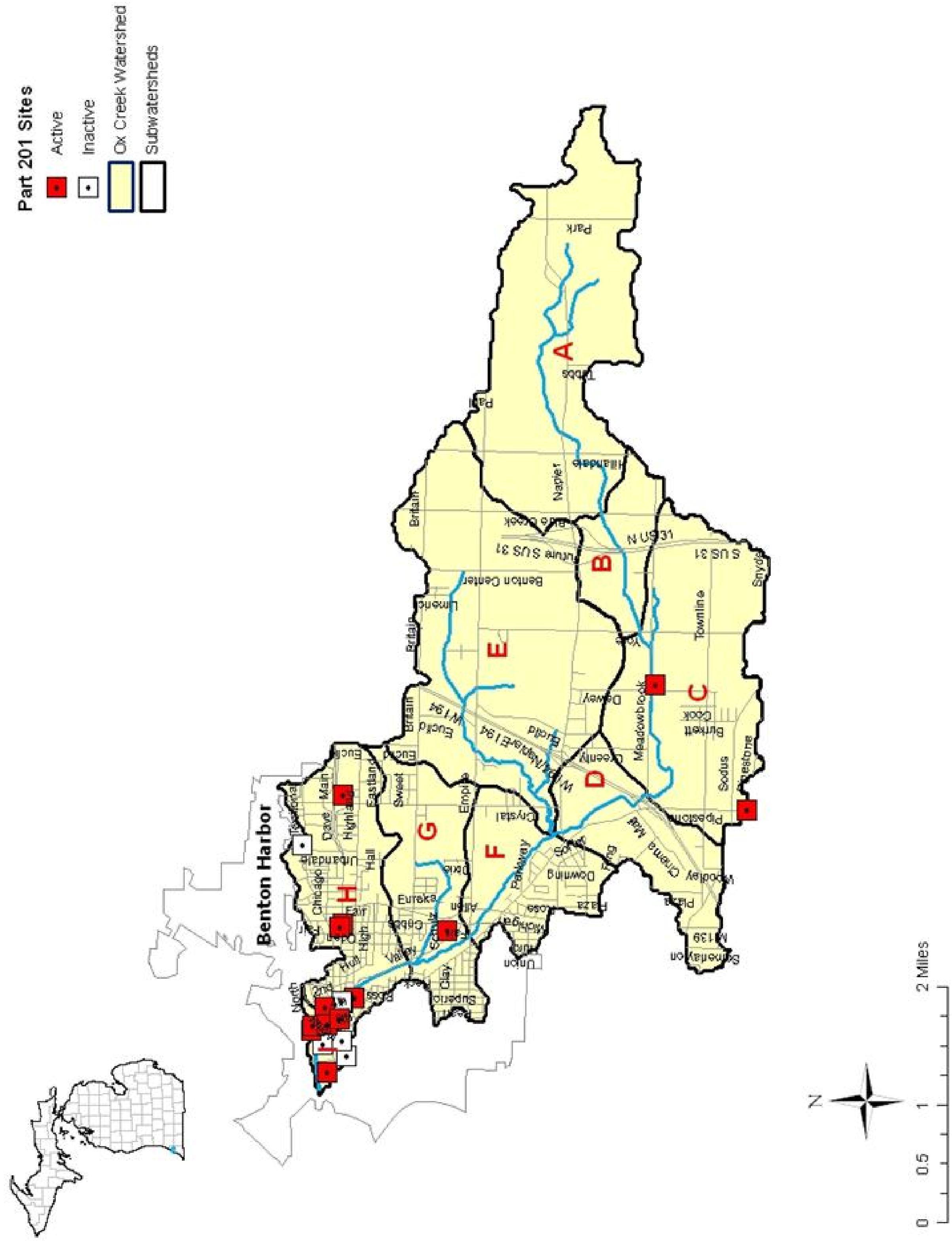

Figure 5-5. Location of Part 201 sites in the Ox Creek watershed.

An *"Open Release"* indicates that chemicals from an underground storage tank have been detected in the groundwater, surface water, or subsurface soils, and reported to DNRE. An *"Open Release"* results in an *"Open"* LUST site. A *"Closed Release"* indicates that corrective actions have been completed to meet the appropriate land use criteria for the specific release that was reported.

A number of Part 213 sites are located in the Ox Creek watershed *(Table 5-7, Table 5-8 and Figure 5-6)*. A number of these sites are *"Closed"*. However, Part 213 recognizes the potential for past contamination to have moved off-site and subsequently pose unacceptable risks to public health and the environment at other locations.

Table 5-7. Sites regulated under Part 213 in the Ox Creek watershed (Units A – G).

Name	Address	Status	Subwatershed
Spinks Super Market	5701 E Napier Ave	Closed	A
United Parcel Service	2755 Meadowbrook Rd	Closed	C
Michigan Gas Utilities	1769 Dewey Ave	Closed	C
Consumers Asphalt	1589 Townline Rd	Closed	C
Lend Lease	1984 Meadowbrook Rd	Closed	C
Pepsi Cola Bottling	2727 Meadowbrook Rd	Closed	C
Pri Mar Maintenance Garage	1533 Townline Rd	Closed	C
Indiana Michigan Power	2425 Meadowbrook Rd	Closed	C
Ausco Products, Inc	1801 Townline & Pipestone	**Active**	C
Former Napier Service Station	2307 Townline Rd	**Active**	C
Sandalich Grocery & Gas	2795 Pipestone Rd	**Active**	C
Goodyear Auto Service Center	1927 Pipestone Rd	Closed	D
Ryder Truck Rental #2641	1455 Townline Rd	Closed	D
Speedway #2378	1981 Pipestone Rd	Closed	D
Meijer Store #41	1920 Pipestone Rd	Closed	D
Goodyear Asc #6145	1927 Pipestone Rd	**Active**	D
Pri Mart Fuel Center #10	2215 Pipestone Rd	**Active**	D
Pri Mart Quik Shop #5	2407 South M-39	**Active**	D
Speedway SuperAmerica	1583 Pipestone Rd	**Active**	D
Lake Michigan College	2755 E Napier Ave	Closed	E
Berrien Co. Road Commission	2860 E Napier Ave	Closed	E
Swan Oil #6 (Total #2752)	2138 E Napier Ave	**Active**	E
Welsh Oil (Petro 2 Truck Stop)	1860 E Napier Ave	**Active**	E
Collins Property	1246 E Empire Ave	Closed	F
Michigan Standard Alloys	1256 Milton St	Closed	F
South End Beverage Inc.	1200 S Crystal Ave	Closed	F
Clark Service Station #738	985 E Napier Ave	**Active**	F
Julius Kolesar Trucking, Inc.	1359 Milton St	**Active**	F
Lakeshore Motors, Inc.	1074 E Napier Rd	**Active**	F
McDonald's Dairy, Inc.	1330 E Empire Ave	**Active**	F
Harbor Metal Treating Co	800 S Fair Ave	Closed	G
Broadway Service Station #2	901 Broadway	**Active**	G
Cities Service Oil Co	481 S Fair Ave	**Active**	G
Empire & Broadway	295 E Empire Ave	**Active**	G
Sunoco Station	480 S Fair Ave	**Active**	G

Table 5-8. Sites regulated under Part 213 in the Ox Creek watershed (Units H – I).

Name	Address	Status	Subwatershed
Emro Marketing - Station #6285	790 E Main St	Closed	H
Benton Charter Township Hall	1725 Territorial Rd	Closed	H
Benton Charter Township	1350 Territorial Rd	Closed	H
Benton Harbor Dpw	350 North St	Closed	H
Northshore Space Group	331 Miller St	Closed	H
Twin Cities Airport	1123 Territorial Rd	Closed	H
Emro Marketing (Cheker #7108)	928 Territorial Rd	Closed	H
Twin Cities Transit Authority	275 E Wall St	Closed	H
BH (Former Dial-A-Ride)	271 Market St	Closed	H
East Main And Third	327 E Main St	Closed	H
Gafill Oil Company	355 E Main ST	Closed	H
B.H. American Laundry	227 Territorial Rd	**Active**	H
Kartar Mobil #3	202 N Fair Ave	**Active**	H
McCoy Memorial COGIC	1960 Highland Ave	**Active**	H
Michigan Gas Utilities	352 Highland Ave	**Active**	H
Phillips 66 Downtown Service	310 E Main St	**Active**	H
U-Know Barber Shop	225 E Main St	**Active**	H
CSX Transportation	247 Northshore Dr	Closed	I
Spence Technology	121 Graham Ave	**Active**	I

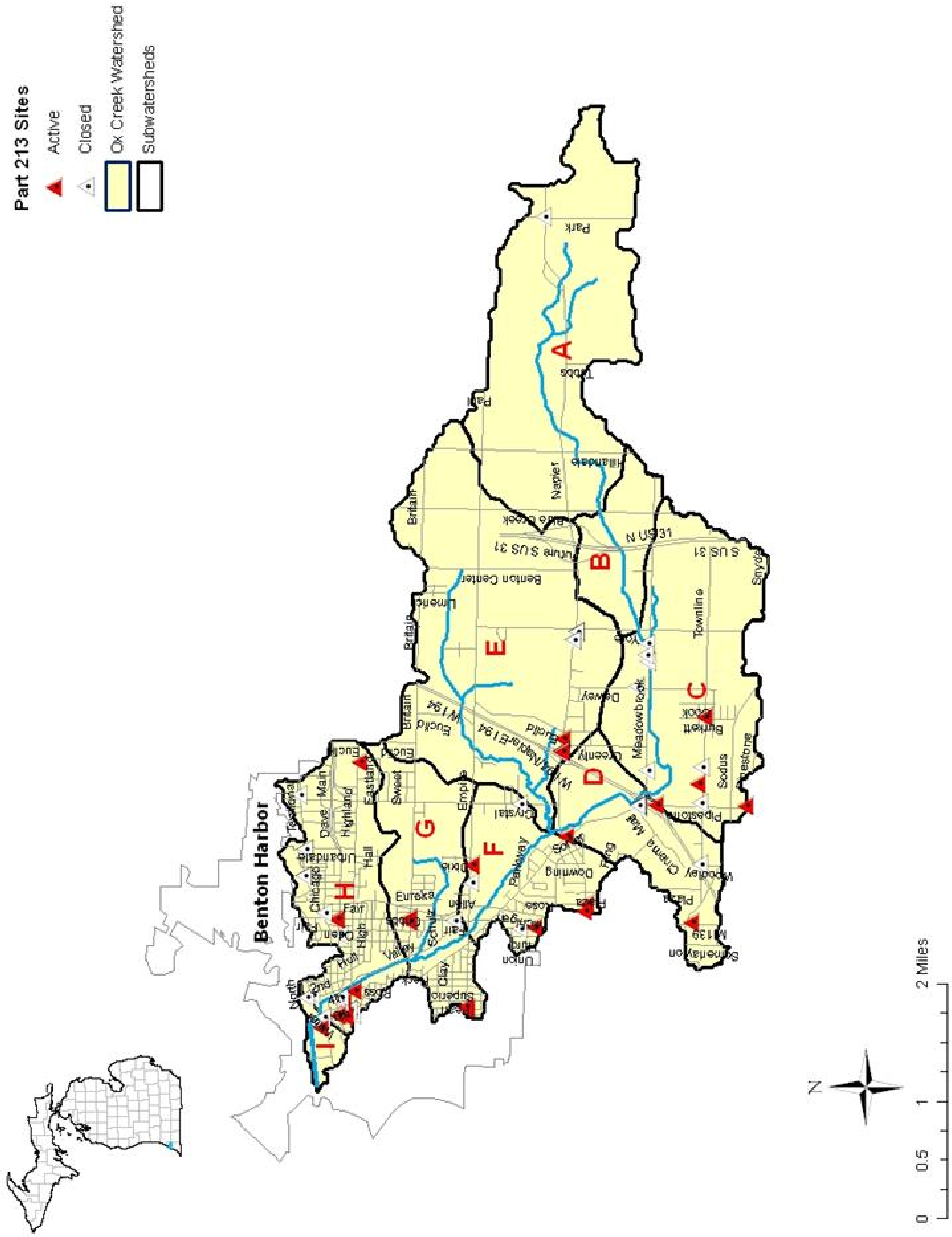

Figure 5-6. Location of Part 213 Leaking Underground Storage Tanks.

5.3 Subwatershed Land Use

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 to help facilitate that process by including a focus on land use from areas that potentially deliver pollutants to the stream. This builds a foundation that sets the stage for the TMDL linkage analysis.

Subwatershed unit boundaries have been identified to coincide with DNRE 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 – Stouffer Drain. The type of land use in each subwatershed unit affects pollutant characteristics that potentially reach Ox Creek and its major tributaries. Examples include sediment from agricultural land or heavy metals and PAHs from roads, commercial, and industrial areas.

Table 5-9 presents a summary of land use information for the Ox Creek watershed by subwatershed unit in terms of acreage. Table 5-10 presents the same information on a percentage basis.

Table 5-9. 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 5-10. 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%

5.3.1 Unit A -- Yore - Stouffer Headwaters

The Yore – Stouffer Headwaters unit consists of the land area draining to the Yore – Stouffer Drain upstream of Blue Creek Road. Figure 5-7 shows a ground view of the unit A outlet taken at the Blue Creek Road monitoring site. There are no point source or Part 201 facilities in this unit *(Figure 5-8)*. One closed Part 213 facility is located in unit A *(Table 5-7)*. Land use in this unit, shown in Figure 5-9, is dominated by cultivated crops (61%) with a noticeable amount as pasture / hay (16%). Table 5-10 presents a summary of land uses in unit A on a percentage basis.

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 because of the lack of point sources or other activities that would likely contribute toxics or heavy metals. With the exception of storm events, sampling results at this location indicate relatively low TSS levels compared to other Ox Creek sites.

Figure 5-7. Yore - Stouffer Drain at Blue Creek Road.

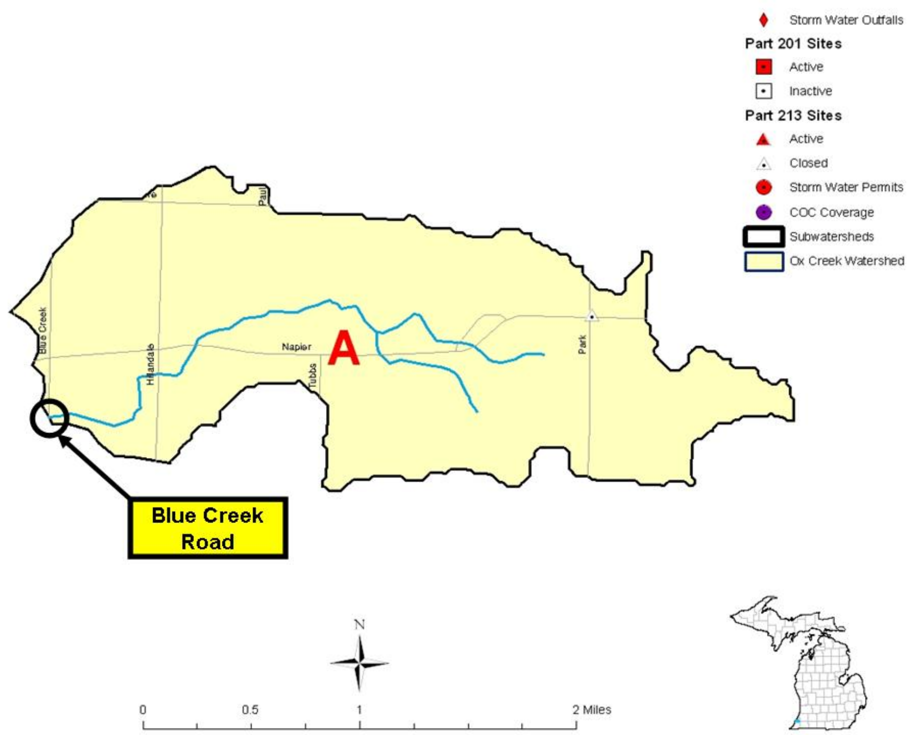

Figure 5-8. Unit A -- Yore - Stouffer Headwaters location.

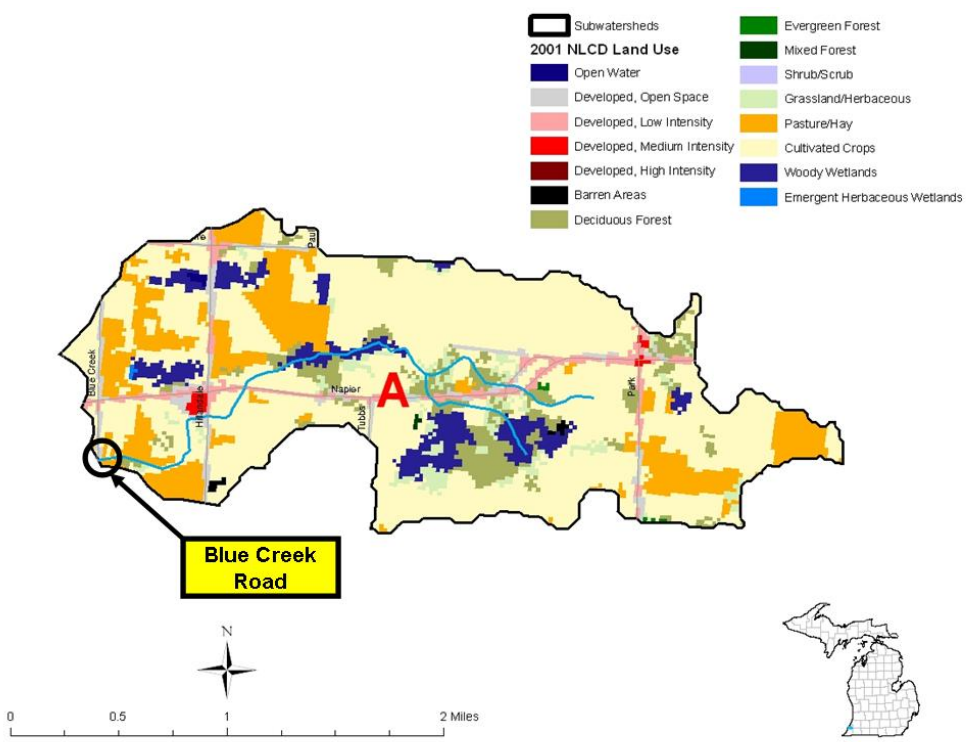

Figure 5-9. Unit A -- Yore - Stouffer Headwaters land use.

5.3.2 Unit B -- Upper Yore - Stouffer

The Upper Yore – Stouffer unit consists of the land area draining to the Yore – Stouffer Drain between Blue Creek Road and Yore Avenue. Figure 5-10 shows a ground view of the unit B outlet taken at the Yore Avenue monitoring site. There are no point source, Part 201, or Part 213 facilities in this unit *(Figure 5-11)*. Land use in this unit, shown in Figure 5-12, is dominated by cultivated crops (48%) with a noticeable amount as pasture / hay (28%). Table 5-10 presents a summary of land uses in unit B on a percentage basis.

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 B (Yore Avenue) consisted of water column TSS and toxics sampling. No heavy metals or toxics were detected at this location. However, sample results for TSS included several of the highest levels in the entire Ox Creek watershed.

Figure 5-10. Yore - Stouffer Drain at Yore Avenue.

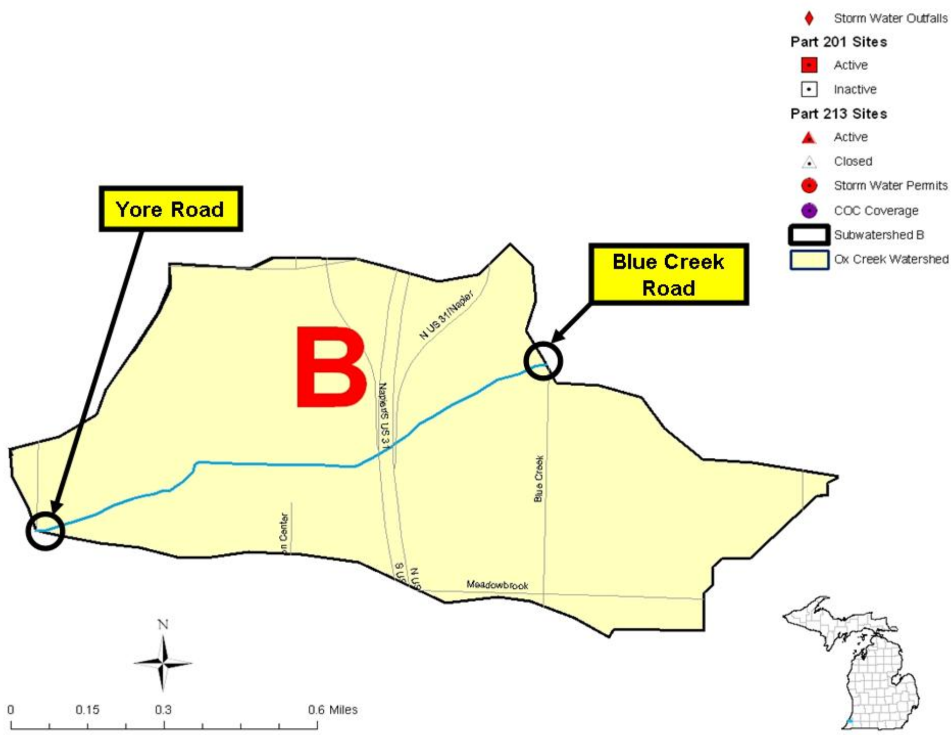

Figure 5-11. Unit B -- Upper Yore - Stouffer location.

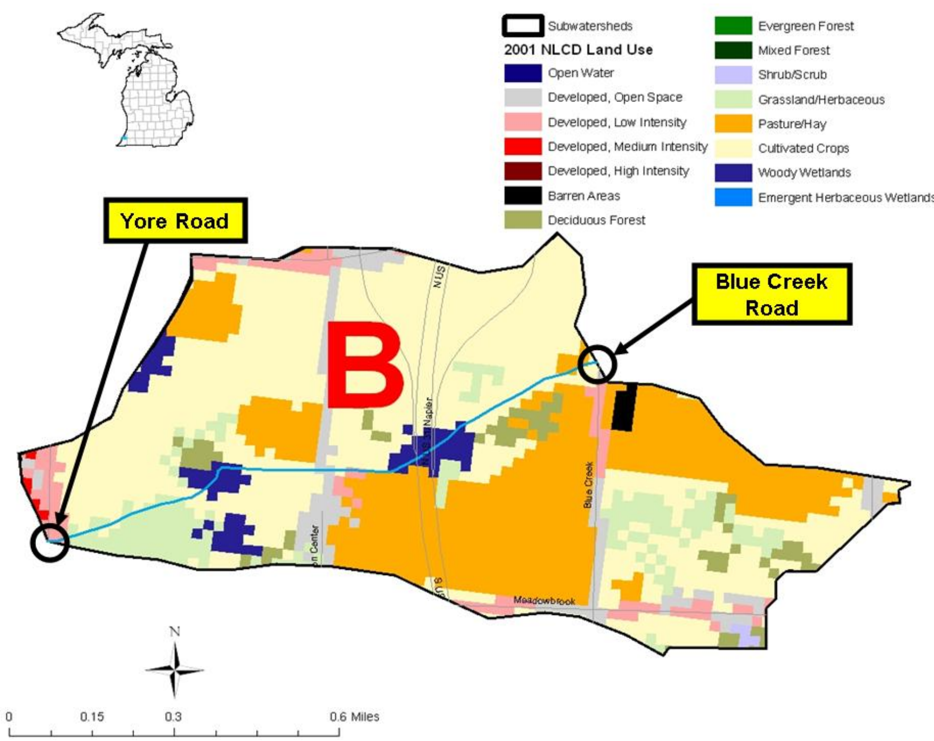

Figure 5-12. Unit B -- Upper Yore - Stouffer land use.

5.3.3 Unit C -- Middle Yore - Stouffer

The Middle Yore – Stouffer unit consists of the land area draining to the Yore – Stouffer Drain between Yore Avenue and Meadowbrook Road. Figure 5-13 shows a ground view of the unit C outlet taken at the Meadowbrook Road monitoring site. 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 *(Figure 5-14 and Table 5-4)*. Two active Part 201 sites are located in unit C *(Table 5-6)*. Three active Part 213 facilities and seven closed sites lie within unit C *(Table 5-7)*. Major land uses in this unit, shown in Figure 5-15, include cultivated crops (33%), as well as low, medium, and high intensity development (24%). Table 5-10 presents a summary of land uses in unit C on a percentage basis.

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. Water column samples also indicate relatively high concentrations of several PAHs, notably fluoranthene and phenanthrene. These compounds were also detected at relatively high levels in bottom sediment samples, as were other PAHs including benzo(a)anthracene, benzo(a)pyrene, chrysene, and pyrene. Potential reasons for these high levels at this site will be investigated in more detail during the linkage analysis.

Figure 5-13. Yore - Stouffer Drain at Meadowbrook Road.

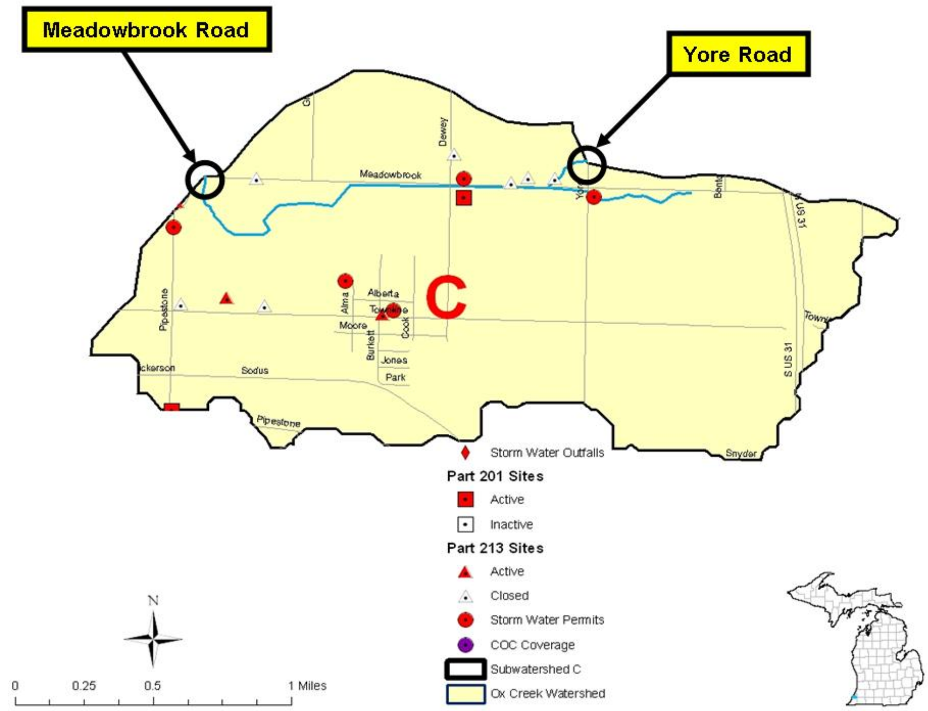

Figure 5-14. Unit C -- Middle Yore - Stouffer location.

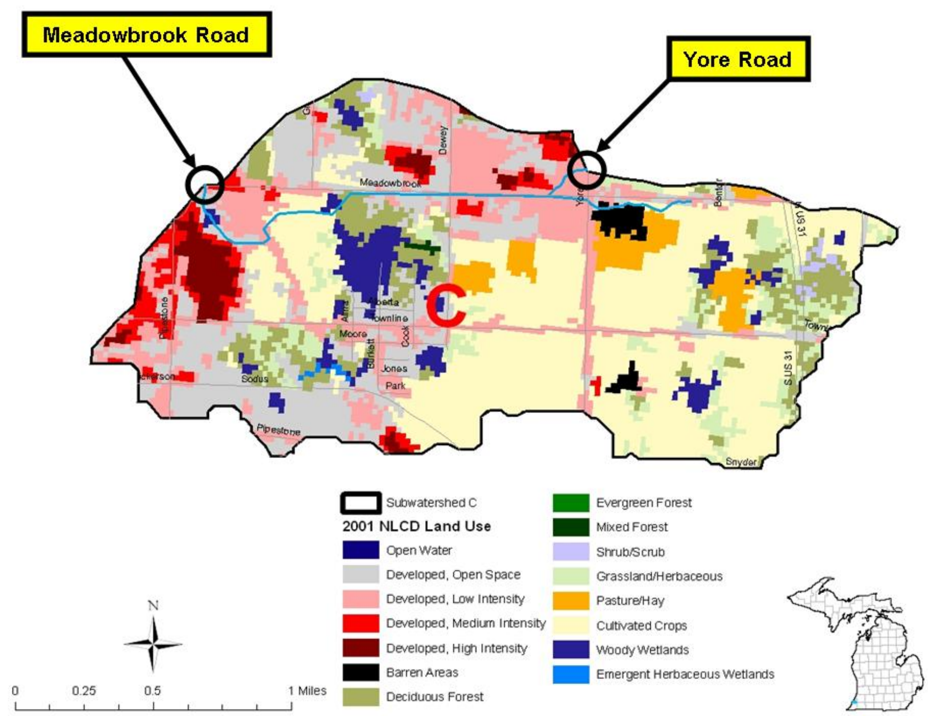

Figure 5-15. Unit C -- Middle Yore - Stouffer land use.

5.3.4 Unit D -- Lower Yore - Stouffer

The Lower Yore – Stouffer unit consists of the land area draining to the Yore – Stouffer Drain between Meadowbrook Road and the confluence with Ox Creek. Figure 5-16 shows a ground view of the unit D outlet taken at the Napier Avenue just above the confluence with Ox Creek. There are no point source or Part 201 facilities located in unit D *(Figure 5-17)*. Three MS4 jurisdictions include lands in this unit *(Table 5-4)*. Four active Part 213 facilities and four closed sites lie within unit D *(Table 5-7)*. Features of interest in this unit include the development around the I-94 interchange at Pipestone Road and the Orchards Mall area. Land use in this unit, shown in Figure 5-18, is dominated by low, medium, and high intensity development (62%) followed by developed open land (25%). Table 5-10 presents a summary of land uses in unit D on a percentage basis.

Subwatershed unit D contains a relatively large amount of impervious surfaces, which likely affects the hydrology of Ox Creek. Although no samples were collected at the outlet of unit D, the linkage analysis will consider the potential effect of land use and source areas in this subwatershed on the water quality of Ox Creek.

Figure 5-16. Yore - Stouffer Drain above Ox Creek.

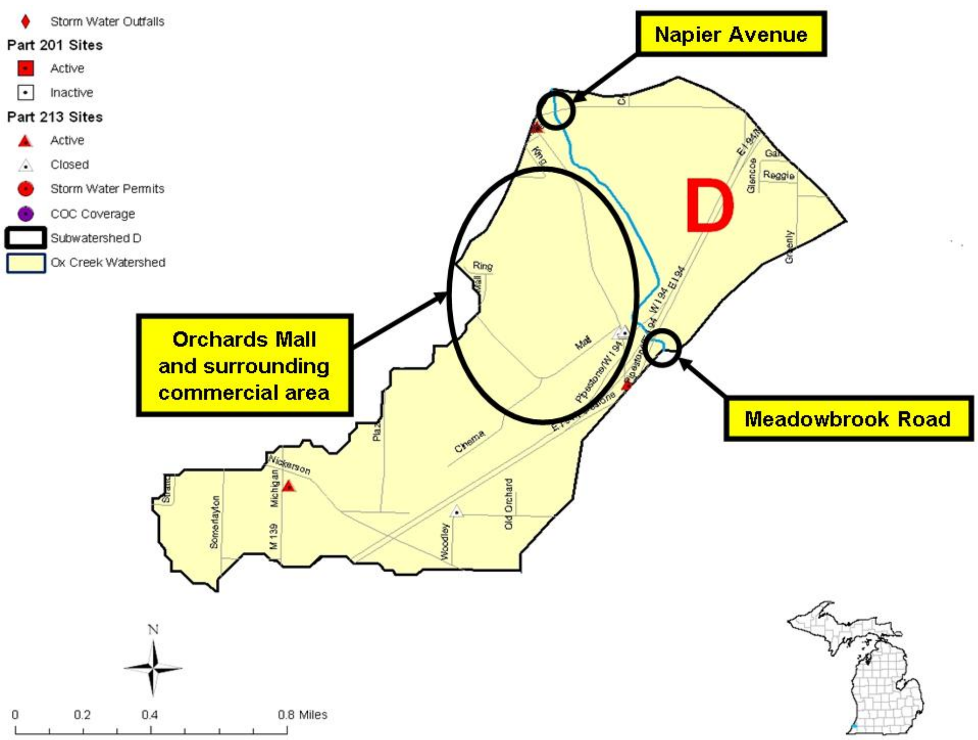

Figure 5-17. Unit D -- Lower Yore - Stouffer location.

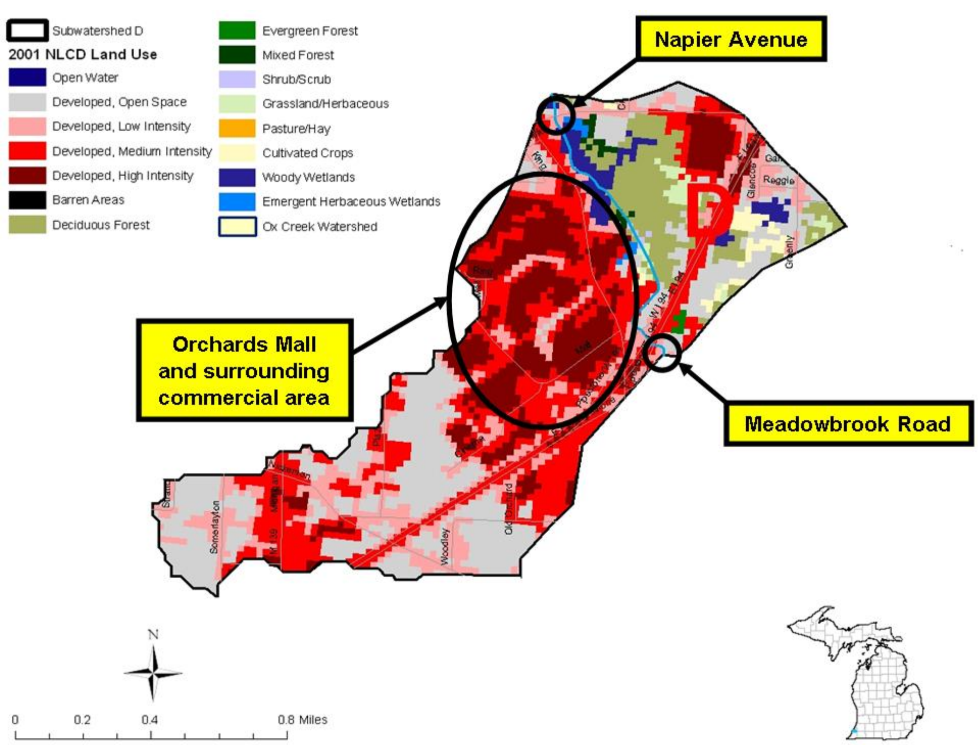

Figure 5-18. Unit D -- Lower Yore - Stouffer land use.

5.3.5 Unit E -- Ox Headwaters

The Ox Headwaters unit consists of the land area draining to Ox Creek from its source to its confluence with the Yore – Stouffer Drain just below Crystal Avenue. Figure 5-19 shows a ground view of the unit E outlet taken at the Crystal Avenue monitoring site. 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 *(Figure 5-20 and Table 5-4)*. No active Part 201 sites are located in unit E *(Table 5-6)*. Two active Part 213 facilities and two closed sites lie within unit E *(Table 5-7)*. Land uses in this unit, shown in Figure 5-21, include a mix of cultivated crops (32%) and pasture / hay (11%), as well as low, medium, and high intensity development (16%). Table 5-10 presents a summary of land uses in unit E on a percentage basis.

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 and toxics sampling, as well as bottom sediment analyses. 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. Although no heavy metals or toxics were detected in the water column at this location, bottom sediment samples indicate that the occurrence of heavy metals and PAHs. This observation will be investigated in more detail during the linkage analysis.

Figure 5-19. Ox Creek at Crystal Avenue.

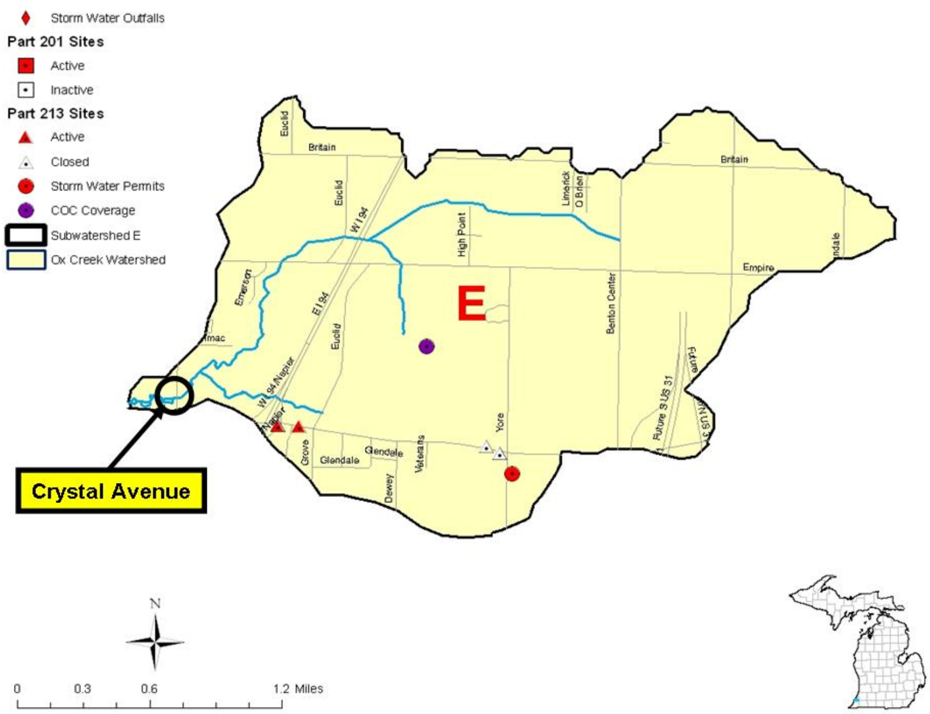

Figure 5-20. Unit E -- Ox Headwaters location.

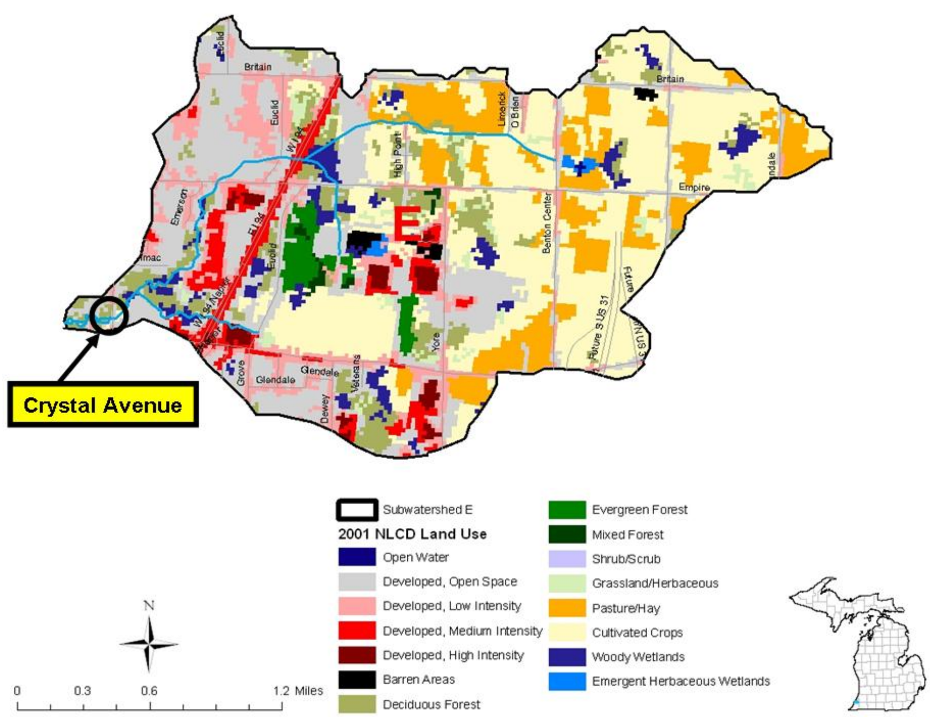

Figure 5-21. Unit E -- Ox Headwaters land use.

5.3.6 Unit F -- Upper Ox

The Upper Ox unit consists of the land area draining to Ox Creek from its confluence with the Yore – Stouffer Drain just below Crystal Avenue to Empire Avenue. Figure 5-22 shows a ground view of the unit F outlet taken at the Empire Avenue monitoring site. 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 *(Figure 5-23 and Table 5-4)*. No active Part 201 sites are located in unit F *(Table 5-6)*. Four active Part 213 facilities and three closed sites lie within unit F *(Table 5-7)*. Land use in this unit, shown in Figure 5-24, 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). Table 5-10 presents a summary of land uses in unit F on a percentage basis.

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. Water column samples indicated relatively high concentrations of several PAHs, notably fluoranthene. Other PAHs and heavy metals were also detected in water column samples. Potential reasons will be investigated in more detail during the linkage analysis. The linkage analysis will also consider the potential effect of land use and source areas in this subwatershed on the water quality of Ox Creek.

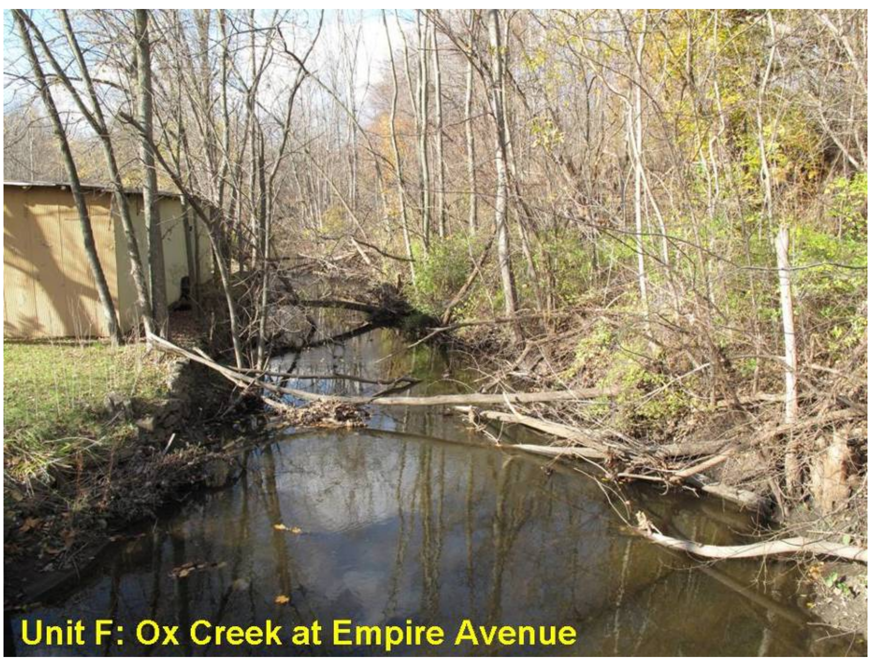

Figure 5-22. Ox Creek at Empire Avenue.

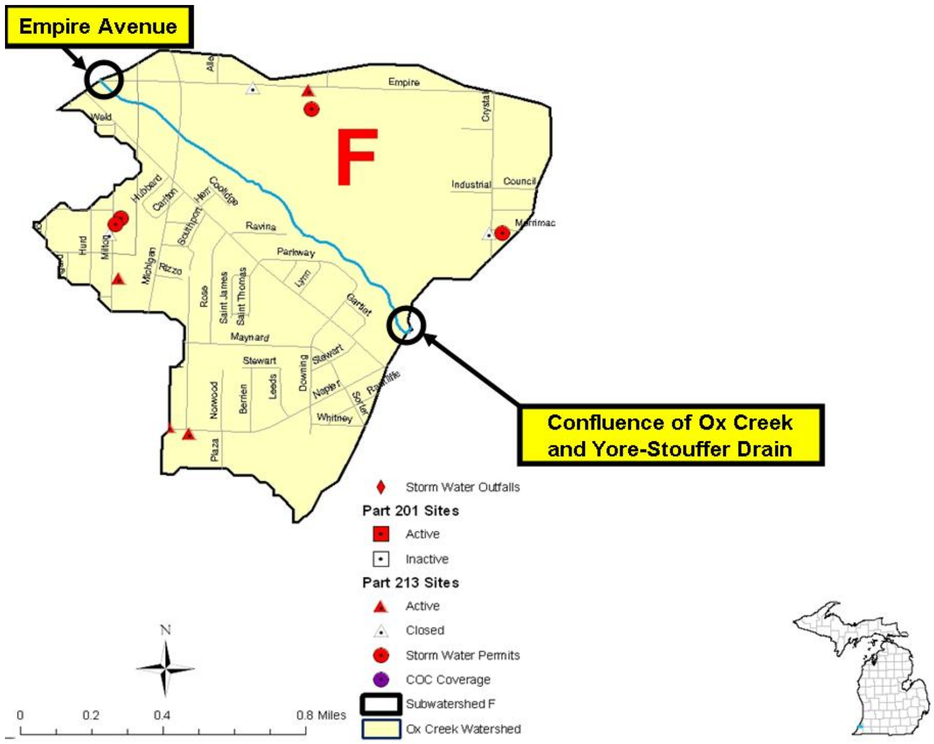

Figure 5-23. Unit F -- Upper Ox location.

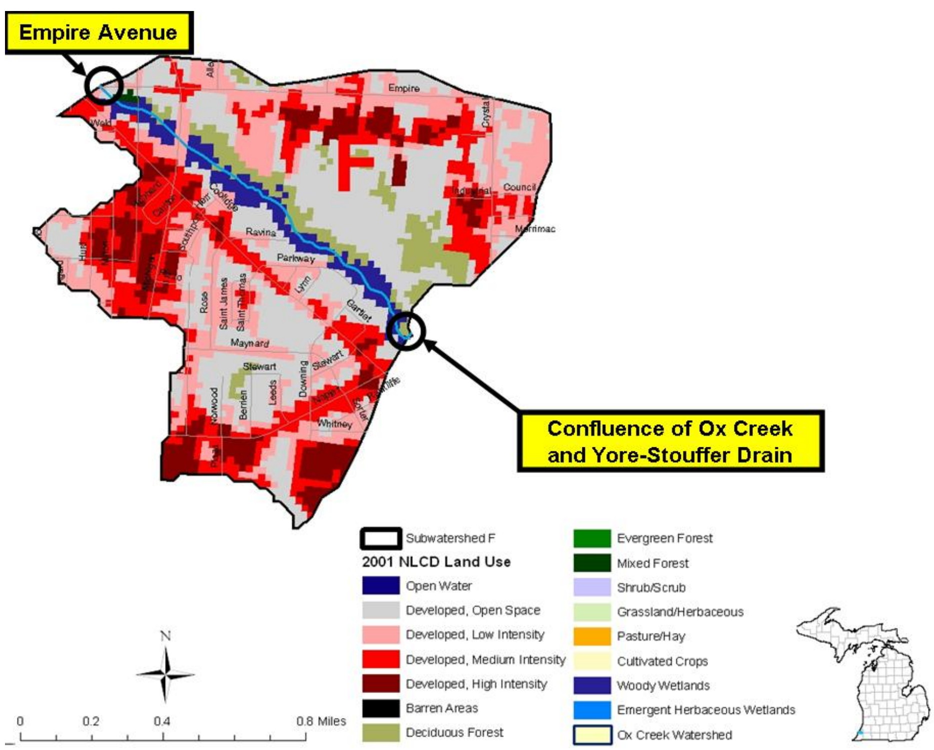

Figure 5-24. Unit F -- Upper Ox land use.

5.3.7 Unit G -- Middle Ox

The Middle Ox unit consists of the land area draining to Ox Creek from Empire Avenue to Britain Avenue. Figure 5-25 shows a ground view of the unit G outlet taken at the Britain Avenue monitoring site. There are no point sources located in unit G, although one MS4 jurisdiction (Benton Harbor) includes lands in this unit *(Figure 5-26 and Table 5-4)*. One active Part 201 sites is located in unit G *(Table 5-6)*. Four active Part 213 facilities and one closed site lie within unit G *(Table 5-7)*. Land use in this unit, shown in Figure 5-27, 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). Table 5-10 presents a summary of land uses in unit G on a percentage basis.

Subwatershed unit G 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. Water column samples did detect several heavy metals and one PAH (fluoranthene). Bottom sediment samples indicated the occurrence of heavy metals and PAHs. Potential reasons will be investigated in more detail during the linkage analysis. The linkage analysis will also consider the potential effect of land use and source areas in this subwatershed on the water quality of Ox Creek.

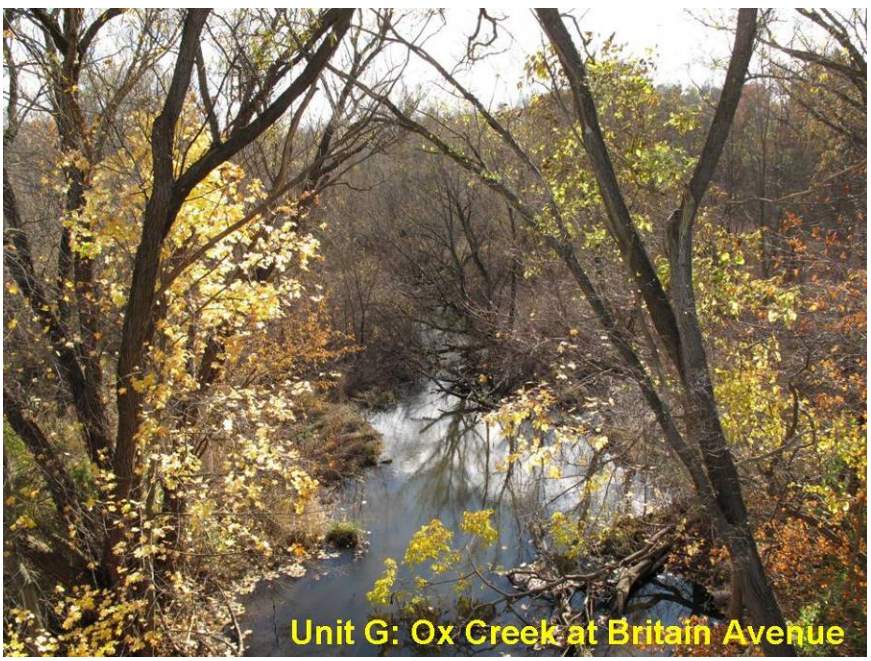

Figure 5-25. Ox Creek at Britain Avenue.

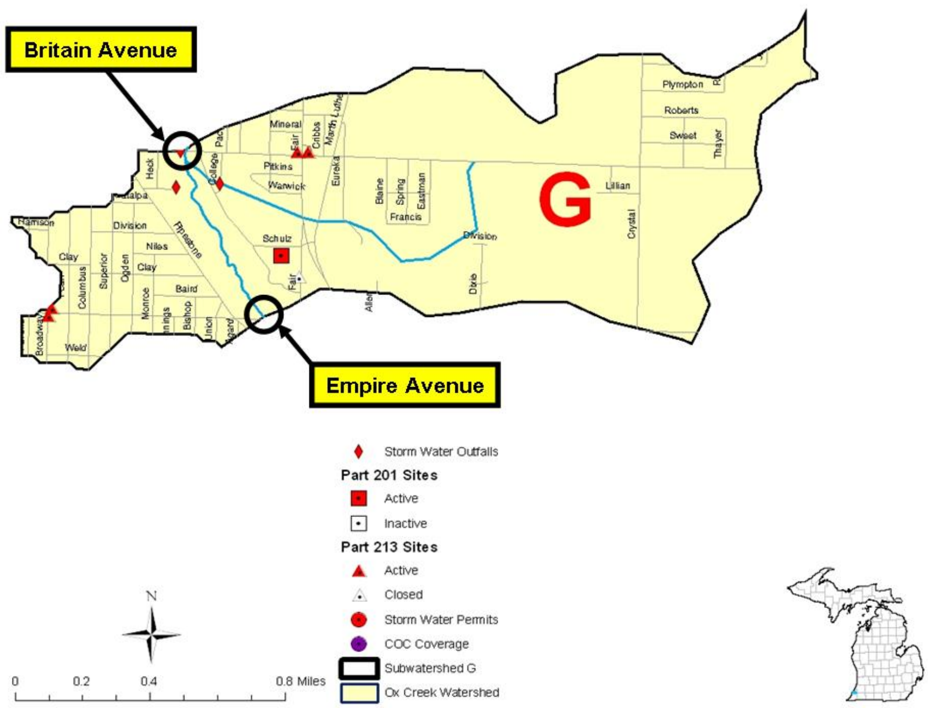

Figure 5-26. Unit G -- Middle Ox location.

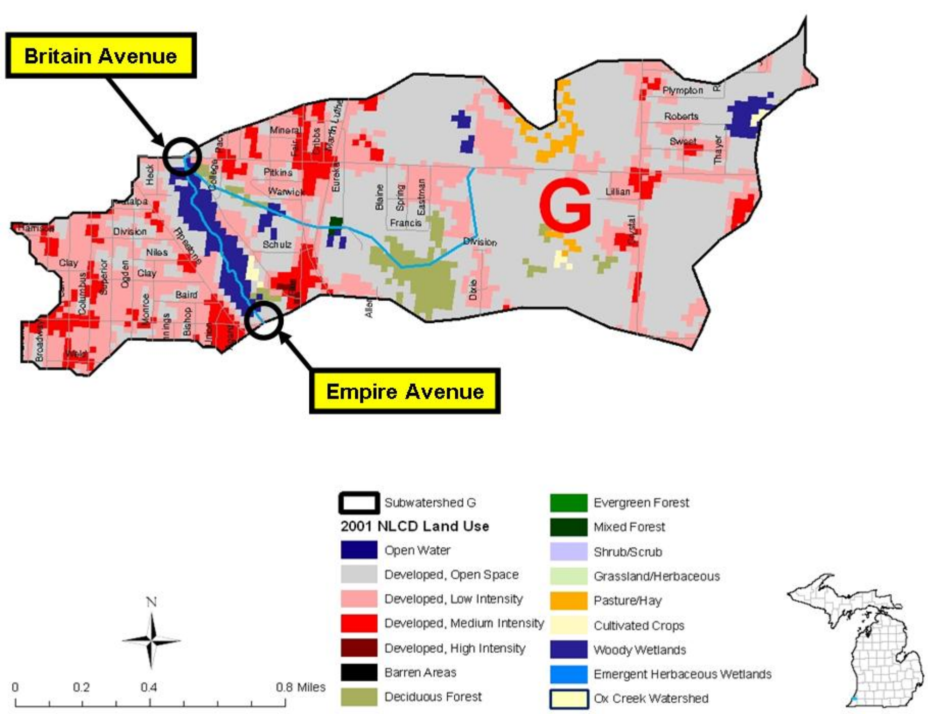

Figure 5-27. Unit G -- Middle Ox land use.

5.3.8 Unit H -- Lower Ox

The Lower Ox unit consists of the land area draining to Ox Creek from Britain Avenue to Water Street. Figure 5-28 shows a ground view of the unit H outlet taken at the Water Street monitoring site. 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 *(Figure 5-29 and Table 5-4)*. Five active Part 201 sites are located in unit H *(Table 5-6)*. Six active Part 213 facilities and eleven closed sites lie within unit H *(Table 5-7)*. Features of interest include the high intensity development in downtown Benton Harbor at the lower end of this subwatershed unit. Land use in this unit, shown in Figure 5-30, is dominated by low, medium, and high intensity development (57%) and by developed open land (39%). Table 5-10 presents a summary of land uses in unit H on a percentage basis.

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. Water column samples did detect several heavy metals. Bottom sediment samples indicated the occurrence of heavy metals and PAHs. Potential reasons will be investigated in more detail during the linkage analysis. The linkage analysis will also consider the potential effect of land use and source areas in this subwatershed on the water quality of Ox Creek.

Figure 5-28. Ox Creek at Water Street.

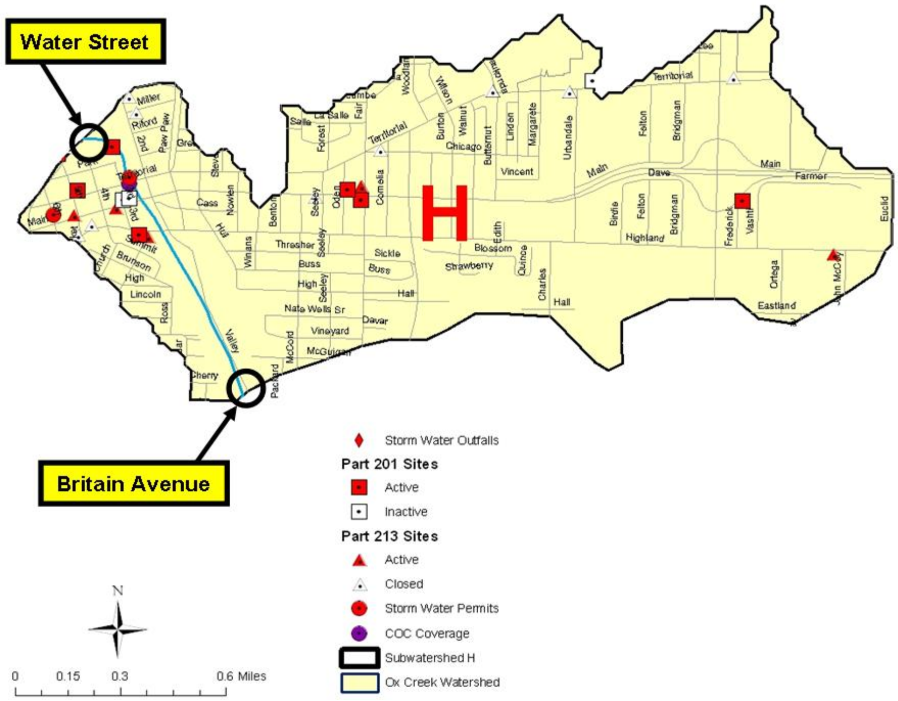

Figure 5-29. Unit H -- Lower Ox location.

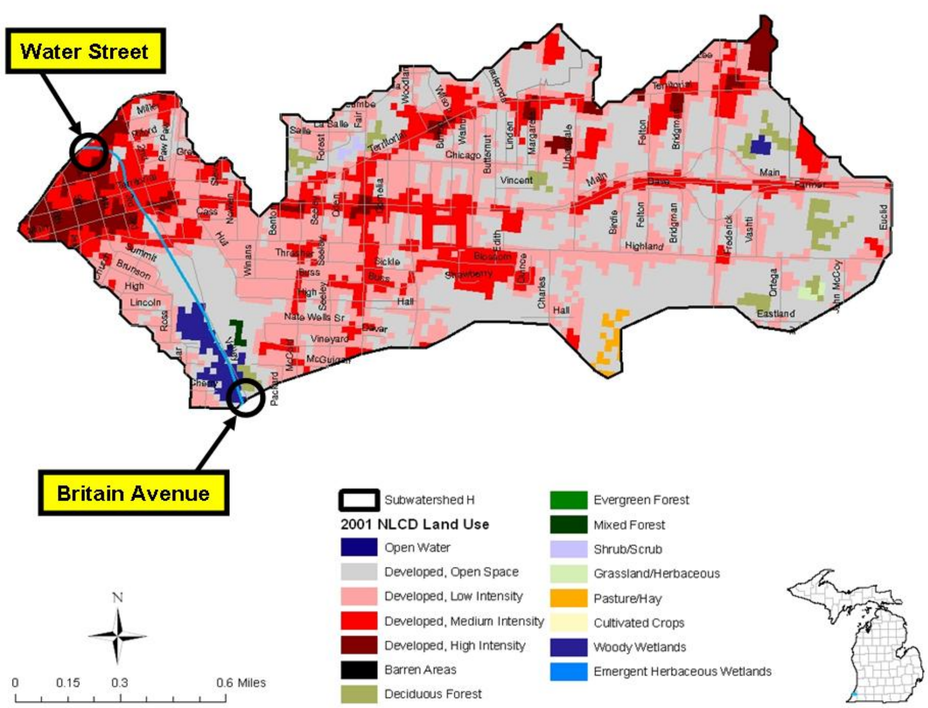

Figure 5-30. Unit H -- Lower Ox land use.

5.3.9 Unit I -- Ox Outlet

The Ox Outlet unit consists of the land area draining to Ox Creek from Water Street to North 8th Street. Figure 5-31 shows a ground view of the unit I outlet taken at 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 two facilities covered under an industrial storm water permit, while one MS4 jurisdiction (Benton Harbor) includes lands in this unit *(Figure 5-32 and Table 5-4)*. Note that in Figure 5-32, the symbol for New Products Corporation does not show up as a non-contact cooling water facility because it also has a storm water permit, which covers the COC marker. One active Part 201 sites is located in unit I *(Table 5-6)*. One active Part 213 facility and one closed site lie within unit I *(Table 5-7)*. Land use in this unit, shown in Figure 5-33, is dominated by low, medium, and high intensity development (79%) and by developed open land (19%). Table 5-10 presents a summary of land uses in unit H on a percentage basis.

Subwatershed unit I contains a relatively large amount of impervious surface, which likely affects the hydrology of Ox Creek. Bottom sediment samples indicated the occurrence of heavy metals and PAHs. Potential reasons will be investigated in more detail during the linkage analysis. The linkage analysis will also consider the potential effect of land use and source areas in this subwatershed on the water quality of Ox Creek.

Figure 5-31. Ox Creek at N. 8th Street.

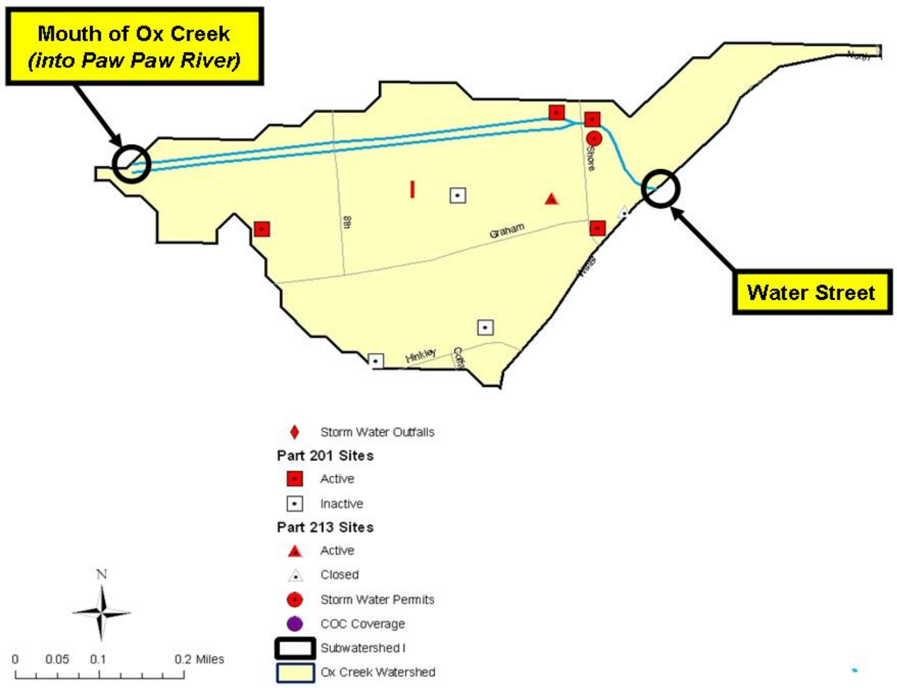

Figure 5-32. Unit I -- Ox Outlet location.

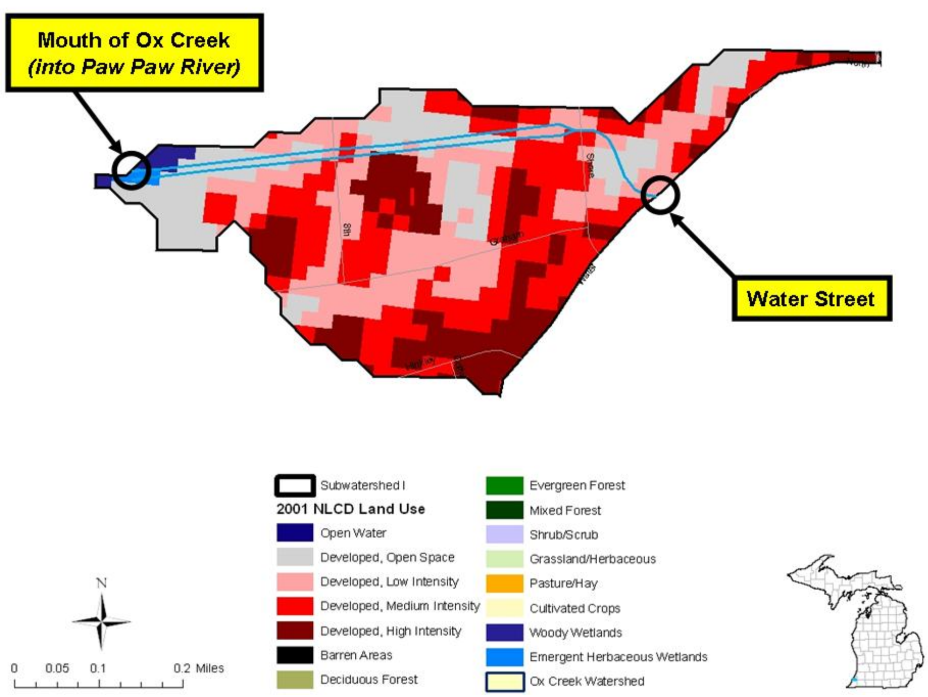

Figure 5-33. Unit I -- Ox Outlet land use.

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