OLIVER LAKE DIAGNOSTIC
LAGRANGE COUNTY, INDIANA

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OLIVER LAKE DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

The Oliver Lake Watershed is located in southern Lagrange County, Indiana. The watershed drains 7,270 acres (2,942 ha). The Oliver Lake chain consists of three lakes (Oliver, Olin and Martin). Water flows from Martin Lake to Olin Lake and into Oliver Lake. The water from Oliver Lake's outlet discharges into Hackenburg and Messick lakes before reaching the North Branch of the Elkhart River and flowing south and west to the Elkhart River. The Elkhart River flows northwest before joining the St. Joseph River in Elkhart, Indiana and eventually discharging into Lake Michigan.

The majority (65%) of the watershed is covered by agricultural row crops or pasture. Forested lands, grasslands, and wetlands account for approximately 21% of the watershed land use, while urban land uses, including urban open space and low, medium, and high intensity developed areas, account for 6% of the watershed. Open water, including Oliver, Olin and Martin lakes, covers 7% of the watershed.

For the purpose of this study, the watershed was divided into seven drainage basins. Oliver Lake Watershed receives water from Dove Creek, an unnamed tributary, Bert Hart Ditch and Winling Ditch as well as Olin Lake. Olin Lake receives water from Stoner Ditch as well as Martin Lake. Martin Lake receives water from Truman Flint Ditch and Eshelman Drain. In general, physical and chemical parameter data collected from streams in the Oliver Lake Watershed indicate the potential for water quality degradation when compared with ideal conditions. E. coli, total Kjeldahl nitrogen and total suspended solids concentrations were elevated during base and storm flow conditions. Nitrate-nitrogen concentrations measured relatively normal for Indiana streams. Dove Creek tributary, Bert Hart Ditch, Winling Creek, Winling Creek north tributary, Truman Flint Ditch, Eshelman Drain and Logan Drain exceeded target concentrations under base and storm flow conditions. This suggests that nitrate-nitrogen is loaded to the system under all flow conditions at these sites. Additionally, all sites contained total suspended solids concentrations that exceeded the target concentration during storm flow conditions and in Dove Creek under base flow conditions. This indicates sediment concentrations may be elevated in Oliver Lake Watershed streams, especially under storm flow conditions.

E. coli concentrations exceeded state standards at all sites during base and storm flow conditions except at Oliver Lake outlet. Both the base and storm flow *E. coli* levels met state standards at Site 12. The Dove Creek tributary and Truman Flint Ditch exceeded the maximum laboratory concentration under base flow, while Winling Creek, Eshelman Drain and Logan Drain exceeded the maximum laboratory concentration under storm flow conditions. This suggests the Dove Creek tributary and Truman Flint Ditch have continuous sources of *E. coli* as evidenced by their elevated concentrations under base flow conditions. Conversely, Winling Creek, Eshelman Drain and Logan Drain have *E. coli* sources that occur under storm flow conditions. E. coli is an issue across the Oliver Lake Watershed with 78% of samples exceeding the state standard.

In particular, the Dove Creek tributary generally possessed the poorest water quality when compared to other sites when concentrations are considered. During storm and base flow, Dove Creek tributary possessed elevated orthophosphorus and total phosphorus, nitrate-nitrogen and total Kjeldahl nitrogen, total suspended solids and E. coli. Truman Flint Ditch possessed extremely elevated nitrate-nitrogen and total Kjeldahl nitrogen concentrations under base and storm flow conditions with nitrate-nitrogen approaching the state standard for drinking water under both base and storm flow conditions suggesting that there is always as source of nitrogen within this watershed.

Under base and storm flow conditions, Dove Creek and Oliver Lake outlet generally possessed the greatest loads for all parameters. Dove Creek possesses the highest loading rates for total phosphorus under base and storm flows, the highest orthophosphorus loading rate under storm flow and the second highest loading rates for ammonia and total suspended solids under base and storm flow, the second highest TKN loading rate under storm flow and the second highest loading rate for orthophosphorus under base flow. The Oliver Lake outlet possesses the highest loading rates for TSS, ammonia and total Kjeldahl nitrogen under both base and storm flows, the highest loading rates for nitrate-nitrogen under storm flow and orthophosphorus under base flow as well as the second highest loading rate for total phosphorus under base and storm flow, nitrate under base flow and orthophosphorus under storm flow. Truman Flint Ditch possessed the highest nitrate-nitrogen loading rate under storm flow and the third highest ammonia, total Kjeldahl nitrogen, orthophosphorus and total phosphorus under base flow and the third highest nitrate loading under base flow. Eshelman Drain (Site 10) contained the second highest nitrate and total Kjeldahl nitrogen loading rates under storm flow and the third highest ammonia, orthophosphorus, total phosphorus and total suspended solids under storm flow and the third highest nitrate loading rate under base flow conditions.

Oliver and Olin Lakes generally considered to have low to moderate productivity, while Martin Lake is generally considered moderately to highly productive. Historical data indicates that transparency declined in all three lakes over the last 48 years; however, some change is likely due to differences in when data were collected throughout the year. All three lakes possess worse transparency and higher values of nitrate-nitrogen, ammonia-nitrogen, organic-nitrogen and total phosphorus than most Indiana lakes. Olin and Oliver Lakes are considered oligotrophic to mesotrophic, while Martin Lake is considered mesotrophic to eutrophic. All three lakes have moderate plankton density and chlorophyll a, while possessing nutrient levels to be more productive than was observed.

Continued good water quality in Oliver Lake will require both watershed and in-lake management. Based on modeling results, the watershed is capable of delivering significant amounts of sediment, nutrients, and pathogens. Identified watershed problems include streambank erosion, locations where narrow buffers were observed and locations where livestock impacts streams. In-lake problems include one small erosion area where the shoreline is erodible behind a rock seawall and multiple areas where emergent, native species are present but in lower density than historically. A decrease in water clarity, increased phosphorus concentrations, damage to rooted plants, changes in rooted plant distribution, and increased shoreline erosion are associated with motor boating activity.

Best management practices can be implemented in the watershed, the shoreline, or within the lake. Watershed best management practices include conservation tillage, cover crop manure management planning and livestock access, nutrient/pest management planning, grassed waterway, wetland construction or restoration or depression restoration, water and sediment control basins. Shoreline residents can improve water quality of the lake with pet waste control and planting native plants along the shore. Stormwater entering the lake degrades water quality. The best way to mitigate stormwater impacts is to infiltrate, store, and treat stormwater onsite before it can run off into adjacent waterbodies. Urban best management practices include installation of rain barrels, rain gardens, bioengineered seawalls, and pervious pavement. Many of the homes on Oliver Lake have maintained turf grass lawns that extend to a concrete seawall at the lake's edge. Shoreline landowners should consider re-landscaping lakeside properties to protect their lake. Additionally, all lake and watershed property owners should reduce or eliminate the use of fertilizers and pesticides. These lawn and landscape-care products are a source of nutrients and toxins to the lake. In-lake management practices include restrictions on motor boating and emergent aquatic plant community restoration.

Implementation of best management practices within the Oliver Lake Watershed should be multipronged with focus on the implementation of a soil health program targeting cover crop and conservation tillage in agricultural areas and a rain barrel and rain garden program targeting residential and commercial locations. Filter strip planting, streambank stabilization and urban retrofits should also be targeted; however, due to limited landowner willingness and cost to benefit ratios, these practices should be given lower priority.

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LAGRANGE COUNTY, INDIANA

1.0 INTRODUCTION

The Oliver Lake Watershed is located in southern Lagrange County, Indiana (Figure 1). The watershed drains 7,270 acres (2,942 ha) and is part of the Oliver Lake-Little Elkhart Creek 12-digit hydrologic unit code (HUC 040500011503). The watershed lies within the North Branch Elkhart River HUC (0405000115). The study area lies within Clearspring and Johnson Townships. The Oliver Lake Watershed consists of three lakes, including Oliver, Olin and Martin lakes. Water flows from Martin Lake to Olin Lake and into Oliver Lake. The water from Oliver Lake's outlet discharges into Hackenburg and Messick lakes before reaching the North Branch of the Elkhart River and flowing south and west to the Elkhart River. The Elkhart River flows northwest before joining the St. Joseph River in Elkhart, Indiana and eventually discharging into Lake Michigan.

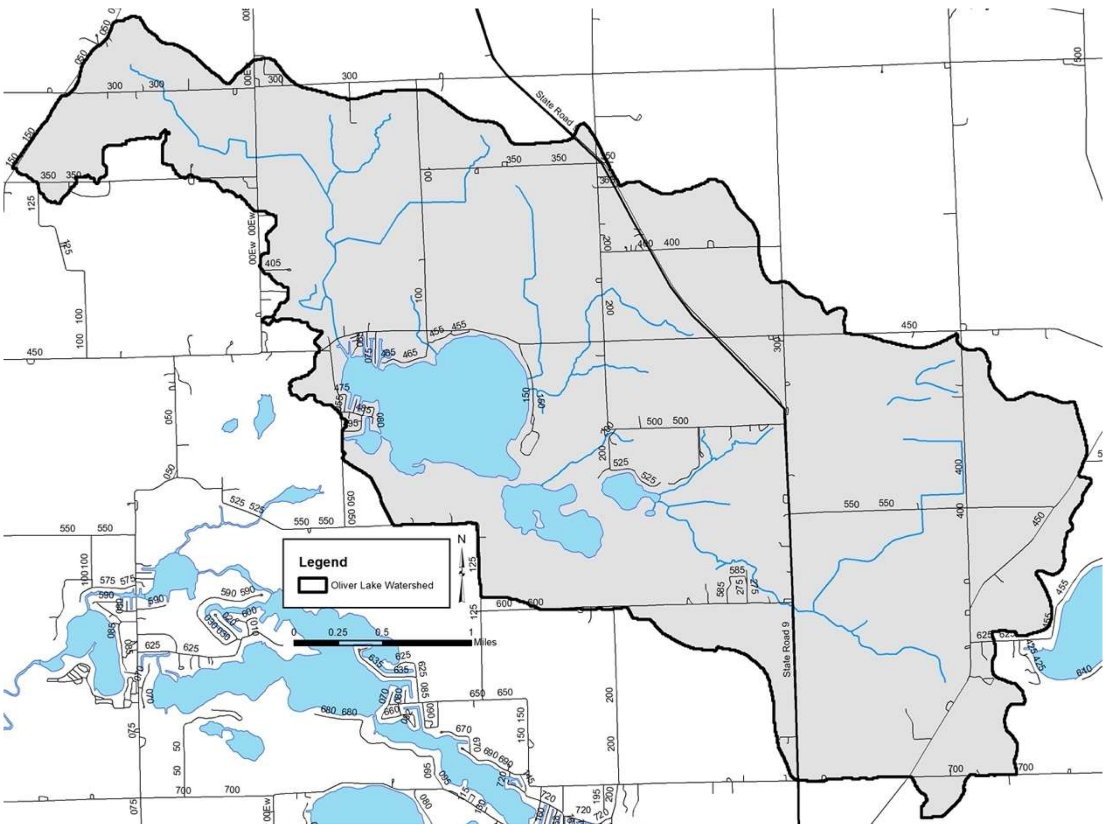


Figure 1. Oliver Lake Watershed Location Map.

Project Purpose

The purpose of the Oliver Lake Watershed Diagnostic Study is to describe historical trends and current conditions found within Oliver Lake and its watershed; identify nonpoint sources of water quality problems; prioritize potential watershed improvement projects; propose specific directions for future work and predict and assess factors for the success of future work.

Objectives

The Oliver Lake Watershed Diagnostic Study follows the Indiana Department of Natural Resources Lake and River Enhancement Program guidelines. The study consisted of four phases:

1. Data review and mapping current conditions: Collection and review of historic studies, water quality, and base mapping of watershed conditions.
2. Public engagement and outreach: Completion of landowner and public meetings, and public information handouts.
3. Watershed assessment: Completion of water quality sampling, biological community, and habitat quality assessment.
4. Analysis and data interpretation: Review of historic and current conditions, assessment of collected water quality data, and compilation of results and recommendations.

2.0 WATERSHED CHARACTERISTICS

2.1 Physical Characteristic

For the purpose of this study, the watershed was divided into seven drainage basins. The Oliver Lake Watershed receives water from Dove Creek, an unnamed tributary, Bert Hart Ditch and Winling Creek as well as Olin Lake. Olin Lake receives water from Stone Ditch as well as Martin Lake. Martin Lake receives water from Truman Flint Ditch and Eshelman Drain. Watershed division allows for the prioritization of portions of watersheds. This division will allow for the identification of both high- and low-quality portions of the watershed, as well as determination of locations where specific management practices may be implemented to generate a change in water quality in the future. Table 1 contains overview data for the Oliver Lake Watershed, including subwatershed areas and boundaries.

Table 1. Watershed areas for the Oliver Lake Watershed.

Subwatershed Name	Total Drainage (Acres/Hectares)	Percent of Watershed (%)
Oliver Lake direct to lake	800.8/324.8	100%
Dove Creek (OL01)	1564.3/633.3	22%
Unnamed (OL04)	47.8/19.4	1%
Bert Hart Ditch (OL05)	371/150.2	5%
Winling Creek (OL06)	691.7/280	10%
Olin Lake direct to lake	400.4/162.1	52%
Stoner Ditch (OL08)	214.9/87	3%
Martin Lake direct to lake	188.3/76.2	44%
Truman Flint Ditch (OL09)	666.3/269.8	9%
Eshelman Drain (OL10)	2325/941.3	32%
Totals	7270.5/2943.5	

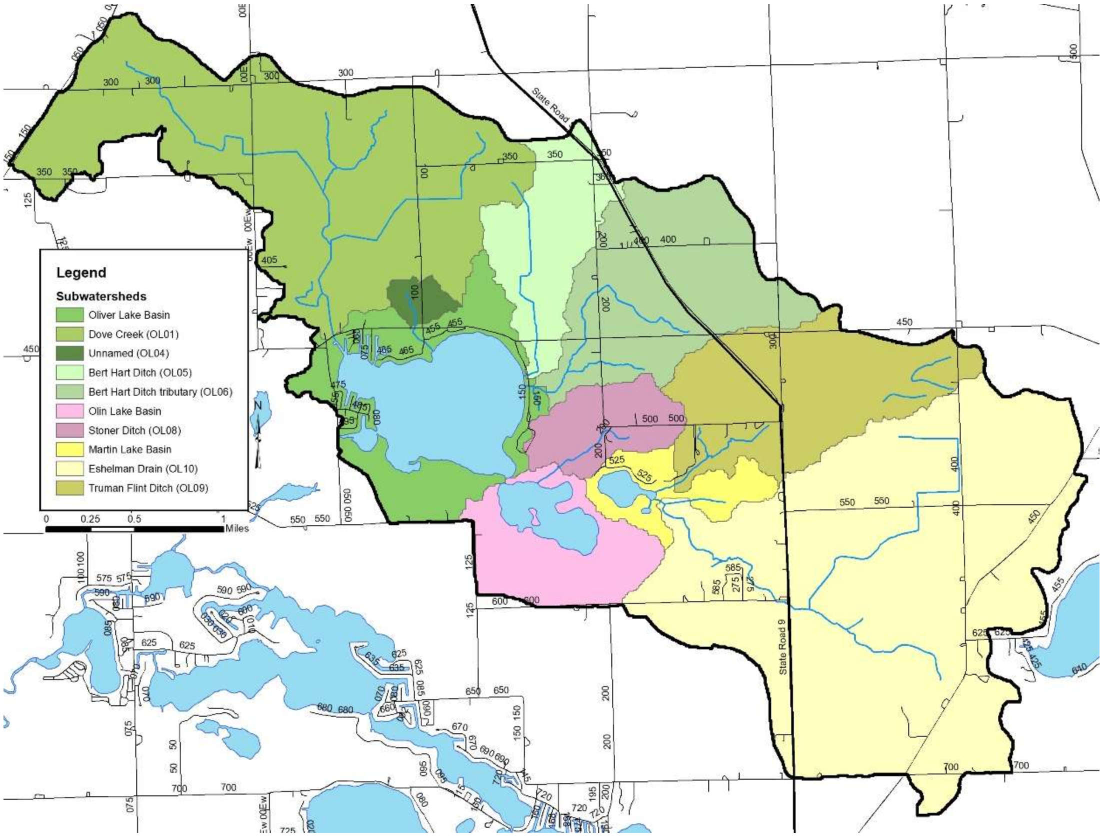


Figure 2. Oliver, Olin and Martin Lake drainage basins and tributary subwatersheds.

2.2 Topography and Physical Setting

The highest elevations of the watershed occur along the northern and eastern edges. Along the eastern boundaries, the watershed nears 1,009 feet (308 m) above mean sea level east of State Road 9. The lowest watershed elevation (899 ft, or 274 m above msl) occurs at the Oliver Lake outlet. Figure 3 details the elevations present in the Oliver Lake Watershed.

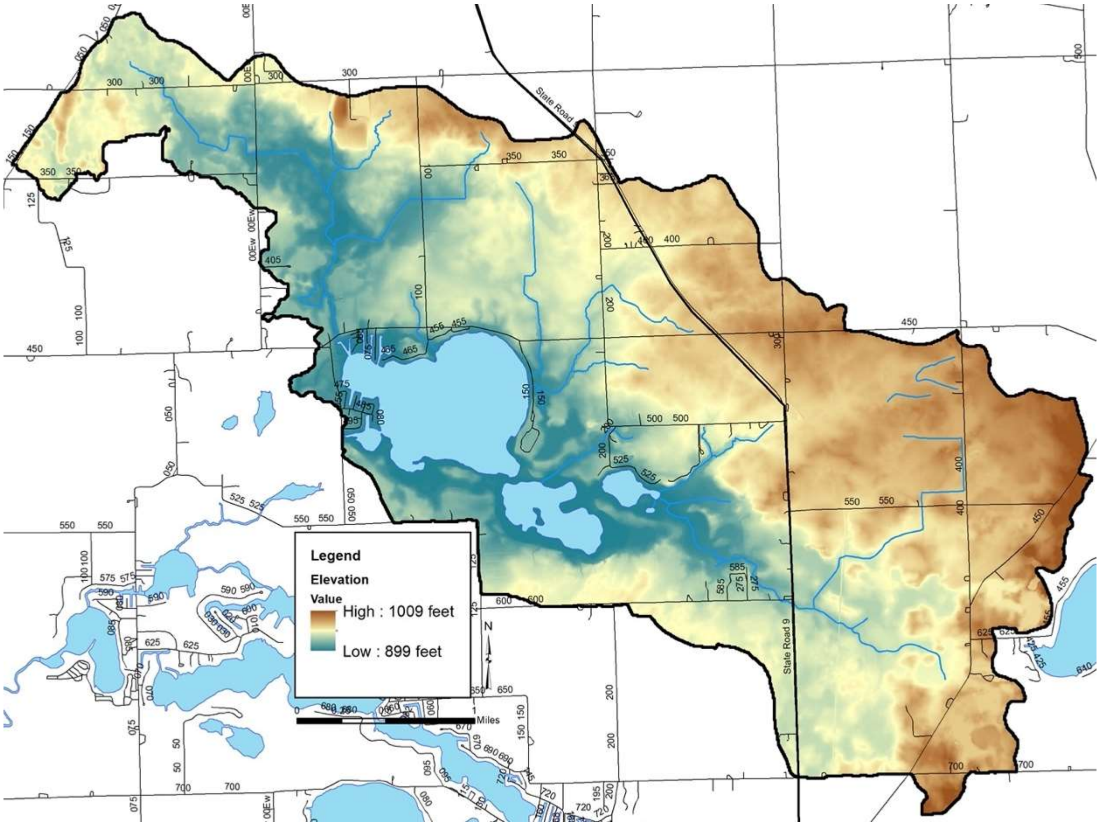


Figure 3. Elevation throughout the Oliver Lake Watershed.

2.3 Climate

In general, Indiana has a temperate climate with warm summers and cool or cold winters. The Oliver Lake Watershed is no different. Climate in this watershed is characterized by four distinct seasons throughout the year. High temperatures measure approximately 83°F (28°C) in July, while low temperatures measure below freezing (16°F/-9°C) in January. The growing season typically extends from early April through the end of September. On average, 37.8 inches (96 cm) of precipitation occurs within the Oliver Lake Watershed with precipitation occurring as small, frequent rain events spread almost evenly throughout the year. Rainfall intensity and timing affect watershed response to precipitation. NOAA's climate at a glance website (1895-present) indicates rainfall varies from 25 to over 50 inches (63.5 to 127 cm) annually (Figure 4). Christopher B. Burke Engineering Limited (CBBEL) calculated the 10-year moving average for the West Lakes Chain in Noble County as between 30 and 40 inches/year (76.2 to 101.6 cm). The Purdue Climate Change Research Center indicates an increase in average annual precipitation of over 4.2 inches/year (10.7 cm/year) from 1895 to 2029 (PCCRC, 2019). CBBEL (2020) further notes an increase in heavy rainfall events with one day per year exceeding the 99th percentile in 1900 to more than three days exceeding this level in 2016 (Figure 5). This suggests that more frequent extreme events and larger annual precipitation totals are likely occurring in the Oliver Lake Watershed. This likely results in more water moving through the system which impacts the watershed's lakes, streams and wetlands.

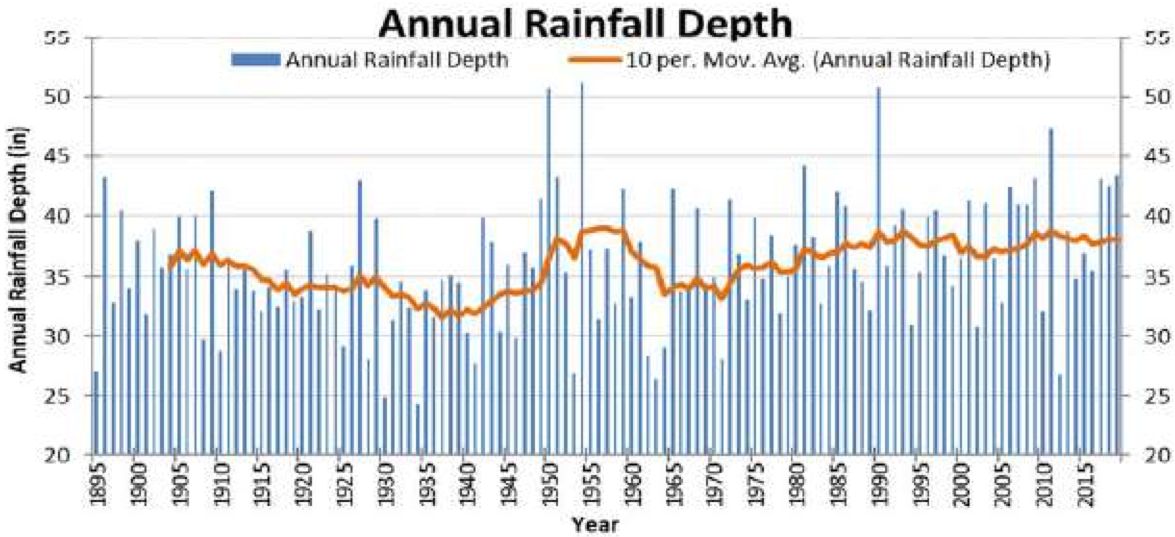


Figure 4. Annual rainfall depth for Noble County (CBBEL, 2020).

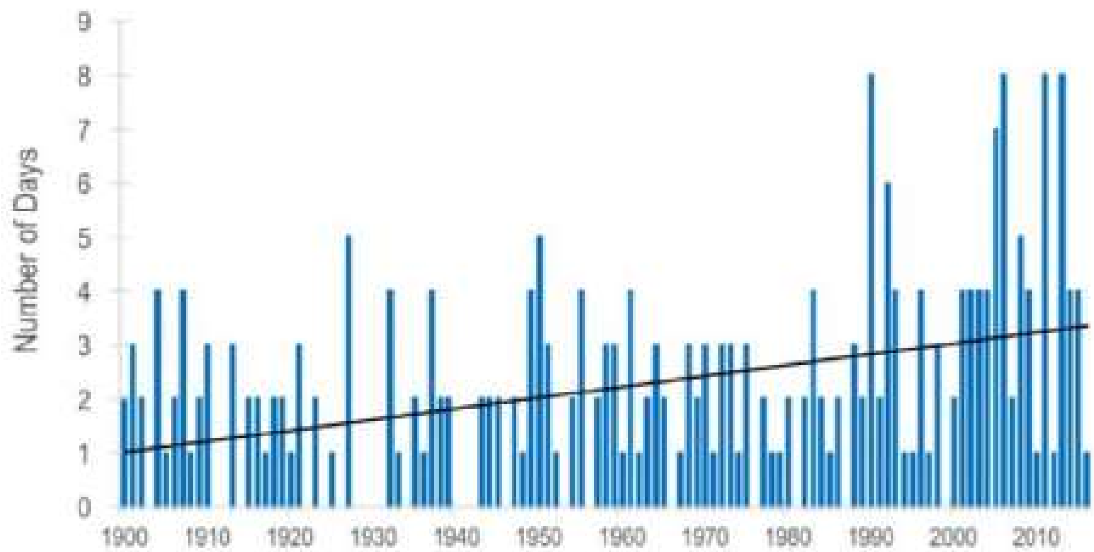


Figure 5. Number of days with extreme precipitation (ie events exceeding 99th percentile for Indiana (PCCRC from CBBEL, 2020).

2.4 Geology

Much of the landscape found in Indiana was formed by the movement of the last glacial age. As the Michigan, Erie, and Saginaw lobes of the Wisconsinan glaciers advanced and retreated, they laid thick material over two-thirds of the state. End moraines, ground moraines, and lake and outwash plains create a geologically diverse landscape across northern Indiana, including the Oliver Lake Watershed. The geology of the Oliver Lake Watershed is directly influenced by the advance and retreat of the Saginaw Lobe of the Wisconsinan glaciation. The major Packerton and Maxinkuckee moraines mark the extent of the Saginaw Lobe's cover in northern Indiana. The Oliver Lake Watershed lies within the Malott's Steuben Morainal Lake Area (Schneider, 1966). The Saginaw Lobe and its major moraines left many unnamed end moraines that contributed to the separation of the Oliver Lake Watershed from others in the area. The lakes of the Oliver Lake Watershed are characteristic of deep kettle lakes lying in an end moraine.

Surficial geology of the area indicates that the Oliver Lake Watershed lies within Wisconsinan glacial till material. Surficial geology of the watershed originates from silty clay loam and clay loam till materials. Coldwater Shale (black shale, gray shale, and limestone) underlie the watershed. Much of the watershed is covered by loam till (Figure 6). Undifferentiated outwash covers central portions of the watershed while mixed drift lies near the north- and southwestern boundaries of the watershed.

The Oliver Lake Watershed lies within the Northern Moraines and drainageways: Warsaw Moraines. Schneider (1966) notes that the landforms common in this diverse physiographic region includes till knobs and ice-contact sand and gravel kames, kettle holes and lakes, meltwater channels lined with outwash deposits or organic sediment, valley plains, and meltwater.

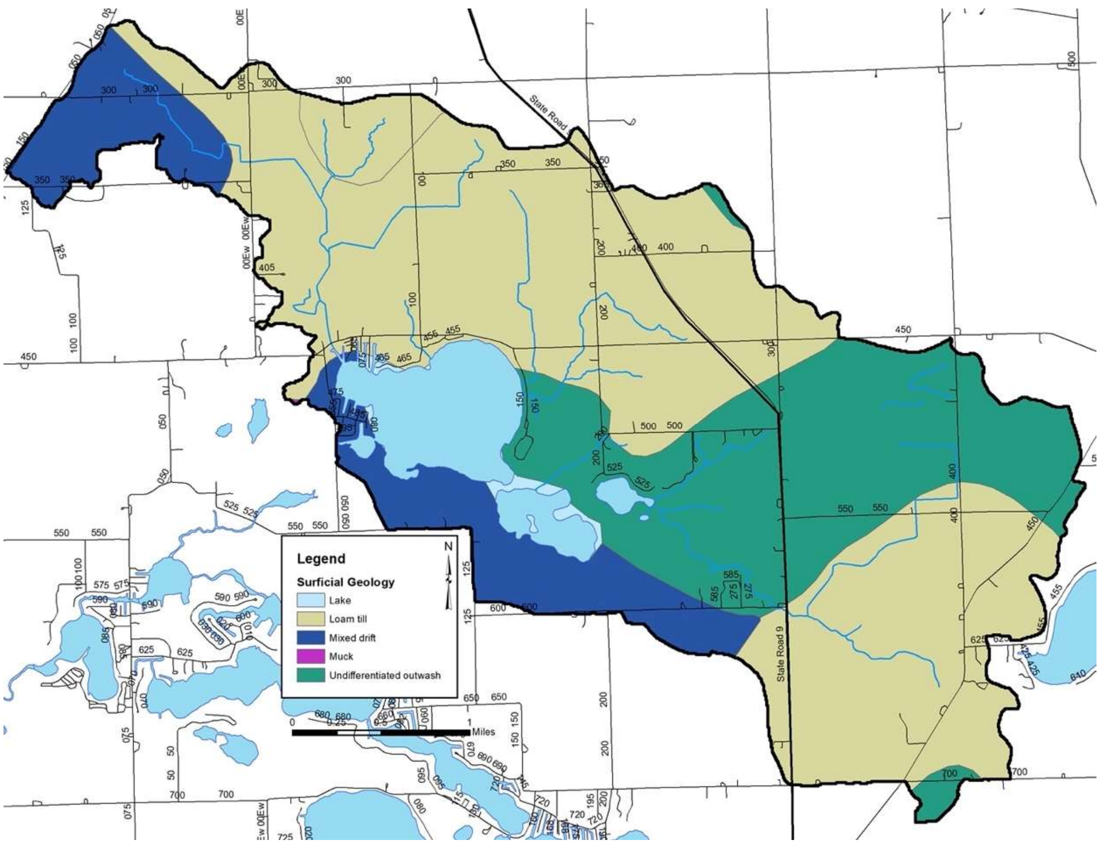


Figure 4. Surficial geology throughout the Oliver Lake Watershed.

2.5 <u>Soils</u>

There are numerous soil types located within the Oliver Lake Watershed. These soil types are delineated by their unique characteristics. Rather the individual soil types, which are mapped in subsequent sections, are used for field-by-field management decisions. Some specific soil characteristics of interest for watershed and water quality, including septic limitations and soil erodibility, are detailed below.

Hydrologic Soil Group

The hydrologic soil group classification is a means for categorizing soils by similar infiltration and runoff characteristics during periods of prolonged wetting. The vast majority of the Oliver Lake Watershed is covered by well to moderately well-drained soils. Soils are classified by the NRCS into four hydrologic soil groups based on the soil's runoff potential (Table 2). The majority of the watershed is covered by category A soils (24%) followed by category B soils (14%) and category C soils (3%). Dual hydrologic groups (A/D, B/D and C/D) cover roughly 51% of the watershed (Figure 6). Category A soils are well-drained with high infiltration, while Category B soils have moderate infiltration rates with moderately well-drained soils. C soils are characterized with finer textured soils and slower infiltration. In these areas, A/D and C/D soils appear most often in the watershed's floodplains along the lakes' shorelines and Dove Creek. These dual soil groups have high to slow infiltration rates when drained and very slow infiltration rates for undrained areas.

Table 2. Hydrologic soil group summary.

Hydrologic Soil Group	Description
A	Soils with high infiltration rates. Usually deep, well-drained sands or gravels. Little runoff.
B	Soils with moderate infiltration rates. Usually moderately deep, moderately well-drained soils.
C	Soils with slow infiltration rates. Soils with finer textures and slow water movement.
D	Soils with very slow infiltration rates. Soils with high clay content and poor drainage. High amounts of runoff.

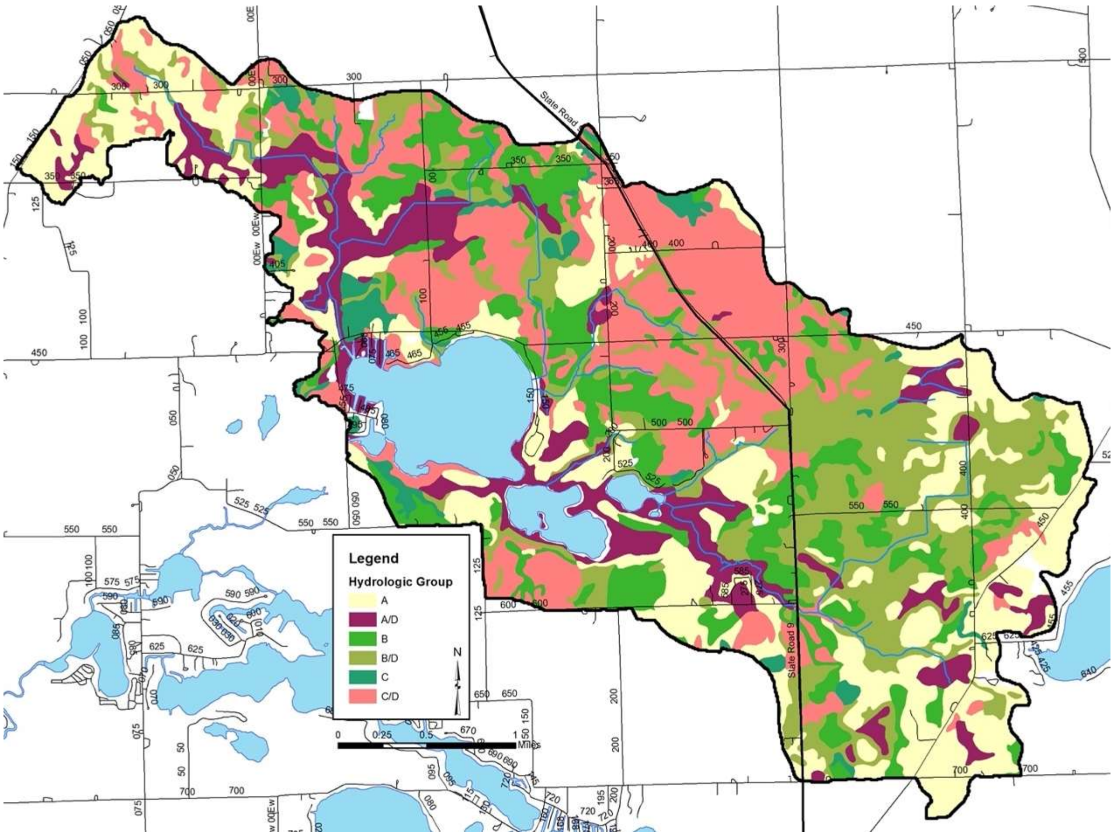


Figure 6. Hydrologic soil groups in the Oliver Lake Watershed.

2.5.1 Soil Erodibility

Soils that move from the landscape to adjacent waterbodies result in degraded water quality, limited recreational use, and impaired aquatic habitat and health. Soils carry attached nutrients, pesticides, and herbicides. These can result in impaired water quality. The ability or likelihood for soils to move from the landscape to waterbodies are rated by the NRCS. The NRCS uses soil texture and slope to classify soils into those that are considered highly erodible, potentially highly erodible, and non-erodible. The classification is based on an erodibility index which is determined by dividing the potential average annual rate of erosion by the soil unit's loss T or tolerance value. The T value is the maximum annual rate of erosion that can occur for a particular soil type without causing a decline in long-term productivity. Highly erodible soil determination is based on the slope steepness and length in addition to the erodibility index value. Highly erodible soils cover 3,945.5 acres (1,596.7 ha) or 54% of the Oliver Lake Watershed. Figure 7 details locations of highly erodible soils in the watershed. In these areas, special effort should be made to maintain constant cover on these soils.

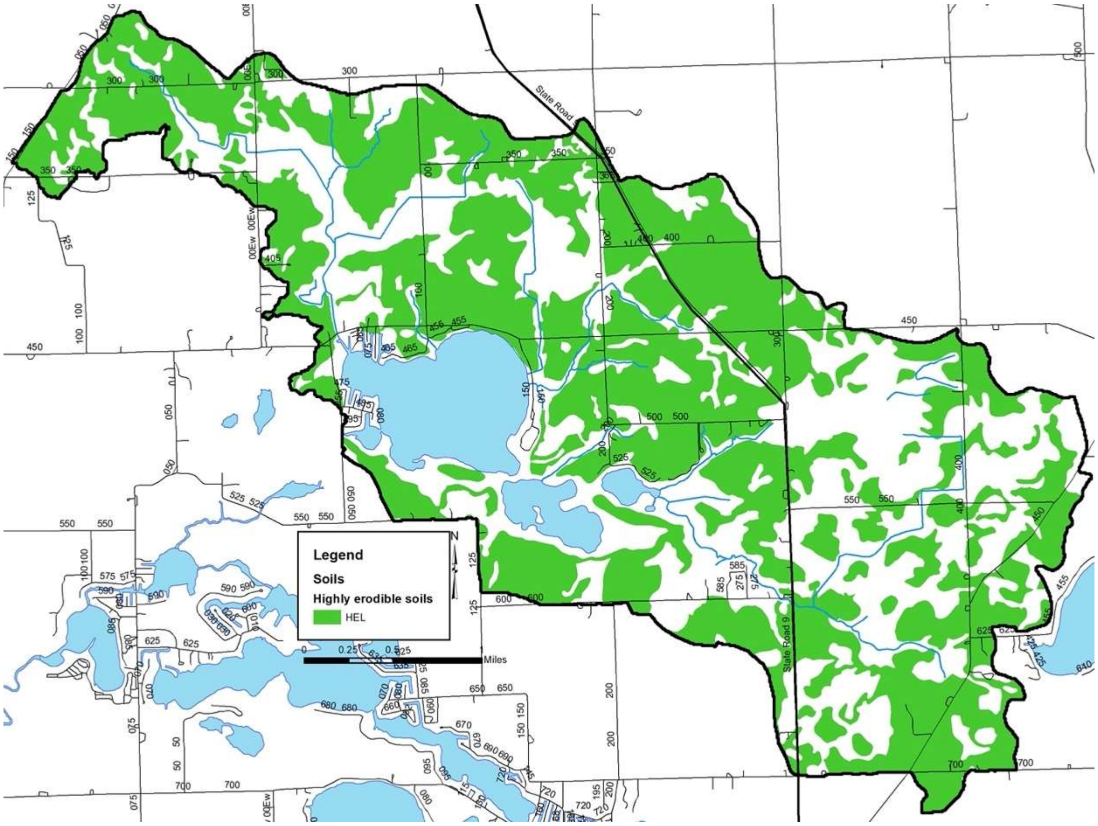


Figure 7. Highly erodible soils in the Oliver Lake Watershed.

It should be noted that the acreage of highly erodible soils mapped during the current project (3,945.5 acres (1,596.7 ha) differs from the acreage mapped as part of the 2009 Oliver Lake Diagnostic Study (534 acres/216 ha). This difference is likely due to changes in the definitions of highly erodible soils rather than an actual change in soil type. When compared, more soils south of Oliver Lake are considered highly erodible than those mapped as part of the 2009 Diagnostic Study.

2.5.2 Hydric Soils

Hydric soils are those which remain saturated for a sufficient period of time thereby generating a series of chemical, biological, and physical processes. After undergoing these processes, the soils maintain the resultant characteristics even after draining or use modification occurs. Approximately 1,900.6 acres (769.2 ha) or 26% of the watershed are covered by hydric soils (Figure 8). Hydric soils are located throughout the watershed. As these soils are considered to have developed under wetland conditions, they are a good indicator of historic wetland locations and therefore will be revisited in the land use section.

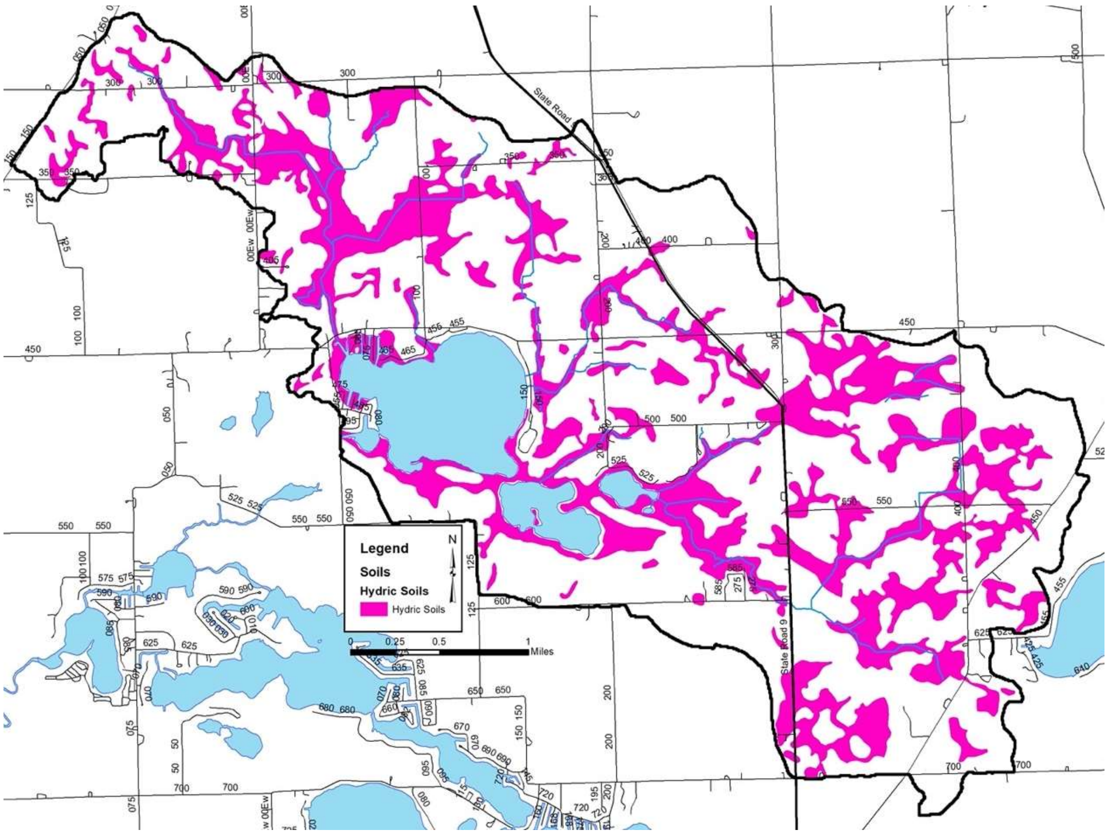


Figure 8. Hydric soils in the Oliver Lake Watershed.

2.5.3 Septic Tank Suitability

Throughout Indiana, including the Oliver Lake Watershed, households depend upon septic tank absorption fields in order to treat wastewater. Seven soil characteristics, including position in the landscape, soil texture, slope, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high-water table, are utilized to determine suitability for on-site septic treatment. Septic tanks require soil characteristics that allow for gradual movement of wastewater from the surface into the groundwater. A variety of characteristics limit the ability of soils to adequately treat wastewater. High water tables, shallow soils, compact till, and course soils all limit soils abilities in their use as septic tank absorption fields. Specific system modifications are necessary to adequately address soil limitation; however, in some cases, soils are too poor for treatment and therefore prove inadequate for use in septic tank absorption fields.

Until 1990, residential homes located on 10 acres or more and occurring at least 1,000 feet from a neighboring residence were not required to comply with any septic system regulations. In 1990, a new septic code corrected this loophole. Current regulations address these issues and require that individual septic systems be examined for functionality. Additionally, newly constructed systems cannot be placed within the 100-year flood elevation and systems installed at existing homes must be placed above the 100-year flood elevation. However, many residences grandfathered into this code throughout the state have not upgraded or installed fully functioning systems (Krenz and Lee, 2005). In these cases, septic effluent discharges into field tiles or open ditches and waterways and will likely continue to do so due to the high cost of repairing or modernizing systems (ISDH, 2001). Lee et al. (2005) estimates that 76,650 gallons (290,152 L) of untreated wastewater is expelled in the state of Indiana annually. The true impact of these systems on the water quality in the Oliver Lake Watershed cannot be determined without a complete survey of the systems.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: severely limited, moderately limited, or slightly limited Some soils are also unranked. Severe limitations delineate soils which present serious restrictions to the successful operation of a septic tank tile disposal field. Using soils with a severe limitation increases the probability of the system's failure and increases the cost of installation and maintenance. Soils designated as moderately limited present some drawbacks to the successful operation of a septic system; correcting these restrictions will increase the system's installation and maintenance costs. Slight limitations delineate soils with no known complications to the successful operation of a septic tank disposal field. Use of soils that are rated as moderately or severely limited generally require special design, planning, and maintenance to overcome limitations and ensure proper function.

In total, 5,932.3 acres (2,400.7 ha) or 82% of the Oliver Lake Watershed is covered by soils that are considered very limited for use in septic tank absorption fields. An additional 760.3 acres (10%, or 307.7 ha) are rated somewhat limited. The remaining 572.8 acres (231.8 ha) or 8% are not rated. Figure 7 details the septic tank suitability for soils throughout the Oliver Lake Watershed. As noted above, the volume of soils considered very limited is higher than those noted as severely limited in the 2009 Oliver Lake Diagnostic Study (64%) and those listed as moderately limited (15%) for a total of 5,439 acres (2,201 ha). These differences are again likely due to differences in classification methods over the last 20 years rather than changes in soil type in the Oliver Lake Watershed. Additionally, as noted in the Pigeon River Watershed Management Plan, the Lagrange County Health Department conducted a study to determine the number of faulty septic systems present within Lagrange County (2005). Through that study, it was determined that nearly 75% of all septic systems within Lagrange County were failing. The Pigeon River Watershed Management Plan noted that this high failure rate was likely due to the very few soils located within the county that are considered suitable for septic system usage by the USDA. Since this study was completed, the Lagrange County Regional Utility District expanded its sewer system coverage and connections throughout Lagrange County. Figure 10 details the sewer connection boundary for residences in the Oliver Lake Watershed.

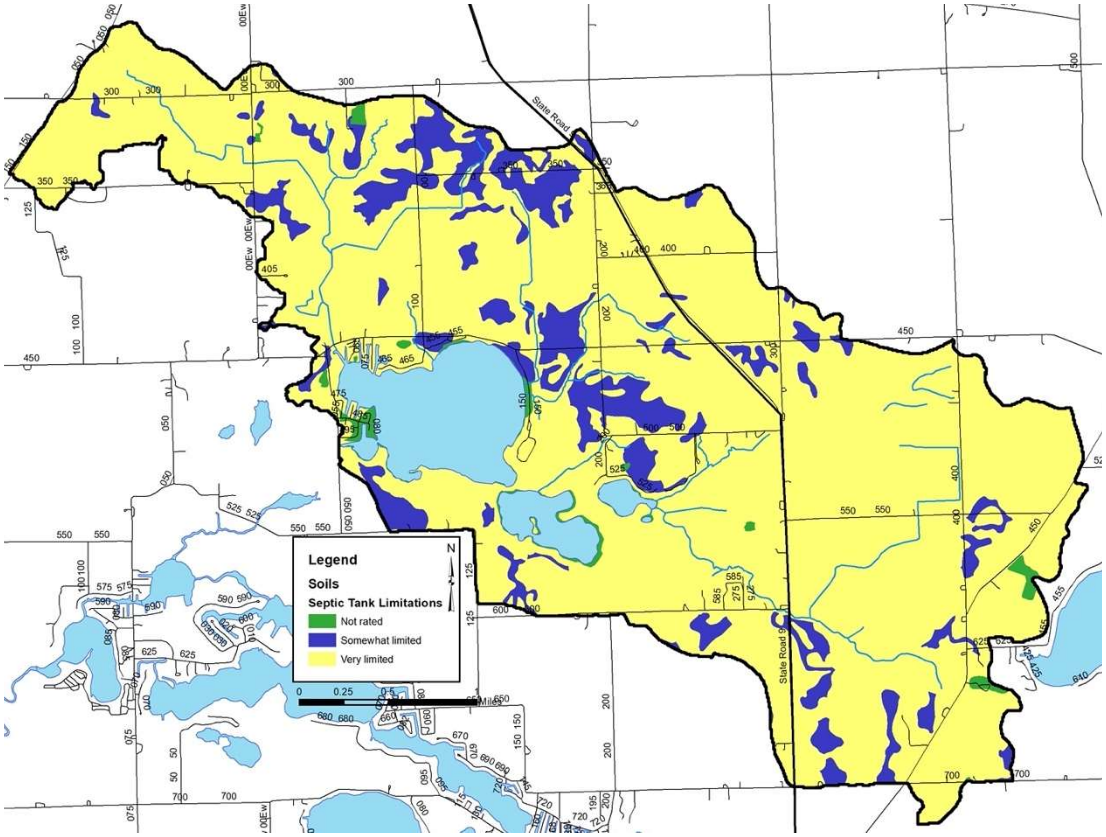


Figure 9. Suitability of soils for septic tank usage within the Oliver Lake Watershed.

Figure 10. Regional sewer district treatment boundary in the Oliver Lake Watershed.

2.6 Natural History

Geology, climate, geographic location, and soils all factor into shaping the native flora and fauna which occurs in a particular area. Deam (1921), Petty and Jackson (1966), Homoya et al. (1985), and Omernik and Gallant (1988) divided Indiana into several natural regions or ecoregions, each with similar geographic history, climate, topography, and soils. Because the groupings are based on factors that ultimately influence the type of vegetation present in an area, these natural areas or ecoregions tend to support distinctive native floral and faunal communities. The Oliver Lake Watershed lies in the Northern Lakes Natural Region, Northern Lakes Section. The watershed also lies in Southern Michigan/Northern Indiana Drift Plains Ecoregion as defined by Omernik and Gallant (1988). This ecoregion is defined as broad till plains with thick and complex deposits of drift, paleo beach ridges, relict dunes, morainal hills, kames, drumlins, meltwater channel, and kettles. More specifically, the Oliver Lake Watershed is split between two terrestrial ecoregions: Lake Country and Elkhart Till Plains (Figure 11). Lake Country ecoregion is characterized by pothole lakes, ponds, marshes, bogs, and clear streams while Elkhart Till Plains represent end moraines, kames, and lacustrine flats. Homoya et al. (1985) note that prior to European settlement, much of Lagrange County was covered by a mix of wetland land uses, including bog, fen, marsh, sedge meadow, swamp, seep, and spring as well as a mix of lakes and deciduous forest. Upland areas were likely covered by red, white, and black oak; maple, and shagbark and pignut hickory. Mesic habitats supported different vegetative communities than drier areas in the watershed. More wet areas were covered by beech, sugar maple, black maple, and tulip poplar. Historically, wet habitat mixed with upland habitat throughout the Oliver Lake Watershed. The hydric soils map indicates that wetland habitat covered much of the Oliver Lake Watershed including most of the lakes' shorelines.

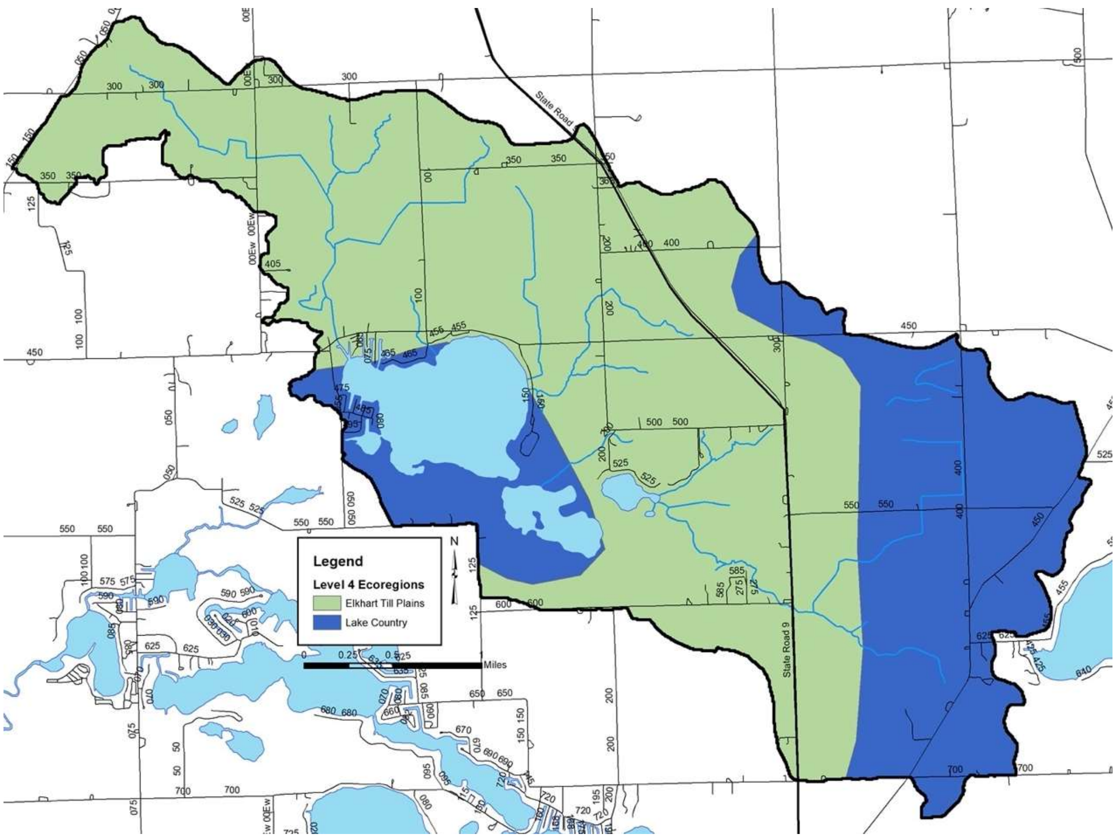


Figure 11. Ecoregions of the Oliver Lake Watershed.

2.7 Significant Natural Areas and Listed Species

The Indiana Natural Heritage Data Center, part of the Indiana Department of Natural Resources, Division of Nature Preserves, maintains a database documenting the presence of endangered, threatened, or rare species; high quality natural communities; and natural areas in Indiana. The database originated as a tool to document the presence of special species and significant natural areas and to assist with management of said species and areas where high quality ecosystems are present. The database is populated using individual observations which serve as historical documentation or as sightings occur; no systematic surveys occur to maintain the database.

The state of Indiana uses the following definitions to list species:

- Endangered: Any species whose prospects for survival or recruitment with the state are in immediate jeopardy and are in danger of disappearing from the state. This includes all species classified as endangered by the federal government which occur in Indiana. Plants currently known to occur on five or fewer sites in the state are considered endangered.
- Threatened: Any species likely to become endangered within the foreseeable future. This includes all species classified as threatened by the federal government which occur in Indiana. Plants currently known to occur on six to ten sites in the state are considered threatened.
- Rare: Plants and insects currently known to occur on eleven to twenty sites.

Based on correspondence with the Indiana Department of Natural Resources (IDNR), there are several observations of listed species and/or high-quality natural communities within the Oliver Lake Watershed. These observations include the state endangered fish, Cisco, last observed in Oliver, Olin and Martin lakes in 1988; state endangered and federal candidate reptile species, spotted turtle and Blanding's turtle, and the state endangered and federally threatened eastern massasauga; and state endangered bird species, black-crowned night-heron (1986). Several state endangered and state threatened vascular plants have also been observed in the watershed as have several state significant and high-quality natural communities, including northern lakes dry and mesic upland forests, circumneutral bog, wetland fen, and forested and shrub swamp. One bald eagle nest sighting was observed in 2015 at Oliver Lake. Locations of various species and habitats are shown in Figure 12. Appendix A includes the database results provided by the IDNR.

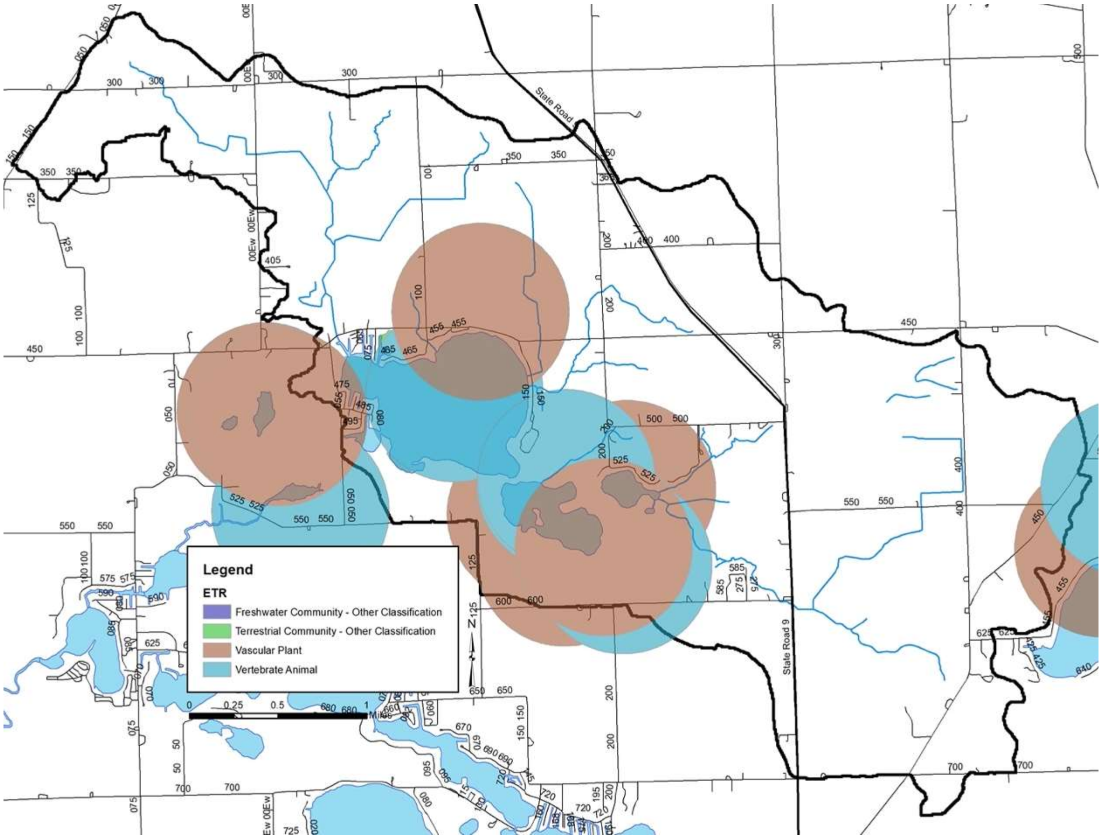


Figure 12. Endangered, Threatened, and Rare Species and high-quality communities in the Oliver Lake Watershed.

2.8 <u>Land Use</u>

Water quality is greatly influenced by land use both past and present. Different land uses contribute different contaminants to surface waters. As water flows across agricultural lands it can pick up pesticides, fertilizers, nutrients, sediment, pathogens, and manure, to name a few. However, when water flows across parking lots or from roof tops it not only picks up motor oil, grease, transmission fluid, sediment, and nutrients, but it reaches a waterbody faster than water flowing over natural or agricultural land. Hard or impervious surfaces present in parking lots or on rooftops create a barrier between surface and groundwater. This barrier limits the infiltration of surface water into the groundwater system resulting in increased rates of transport from the point of impact on the land to the nearest waterbody. A review of the historic land types present in the watershed will provide an idea of the types of restoration that could occur within the watershed and also a basis for the past uses of the land.

Agricultural land use is the major land use in the Oliver Lake Watershed, as shown in Figure 13 and described in Table 3. In total, 65% (4,724.6 ac) of the watershed is covered by agricultural row crop or pasture. Much of the agricultural land is utilized for corn and soybean production (ISDA, 2023). Forested lands, grasslands, and wetlands account for approximately 21% (1,548.0 ac) of the watershed land use, while urban land uses, including urban open space and low, medium, and high intensity developed areas, account for 6% (433.4 ac) of the watershed. Open water, including Oliver, Olin and Martin lakes, covers 7% (528.4 ac) of the watershed.

Table 3. Detailed land use in the Oliver Lake Watershed. Source: USGS, 2016.

Land Use	Area (acres)	Area (hectares)	Percent of Watershed (%)
Row Crop	3774.3	1,527.4	52%
Woody Wetland	1334.2	540.0	18%
Pasture/hay	950.3	384.6	13%
Open Water	528.4	213.9	7%
Developed Open Space	243.1	98.4	3%
Low Intensity Developed	173.0	70.0	2%
Deciduous Forest	127.7	51.7	2%
Emergent Wetland	63.9	25.9	1%
Shrub/scrub	33.4	13.5	0.5%
Medium Intensity Developed	11.4	4.6	0.2%
Grassland	9.6	3.9	0.1%
Mixed Forest	8.7	3.5	0.1%
High Intensity Developed	5.9	2.4	0.1%
Evergreen Forest	4.0	1.6	0.1%
Barren Land	0.2	0.1	>0.1%
Total	**7,268.0**	**2,941.4**	**100%**

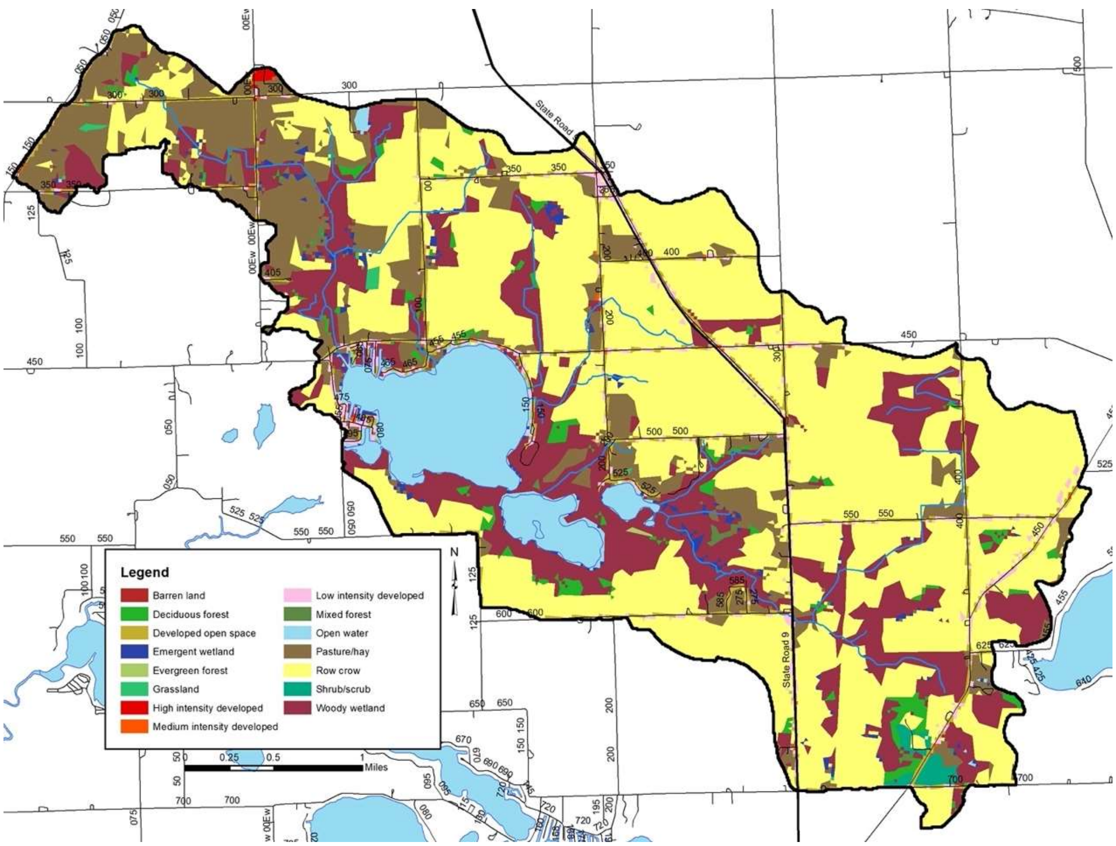


Figure 13. Land use in the Oliver Lake Watershed.

2.8.1 Agricultural Land Use

Individuals are concerned about the impact of agricultural practices on water quality. Specifically, the volume of exposed soil entering adjacent waterbodies, the prevalence of tiled fields (2,115.3 ac, Figure 14) and thus the transport of chemicals into waterbodies, the use of agricultural chemicals, and the volume of manure applied via small animal farms and confined animal feeding operations from outside the watershed are concerning to local residents. Each of these issues will be discussed in further detail below.

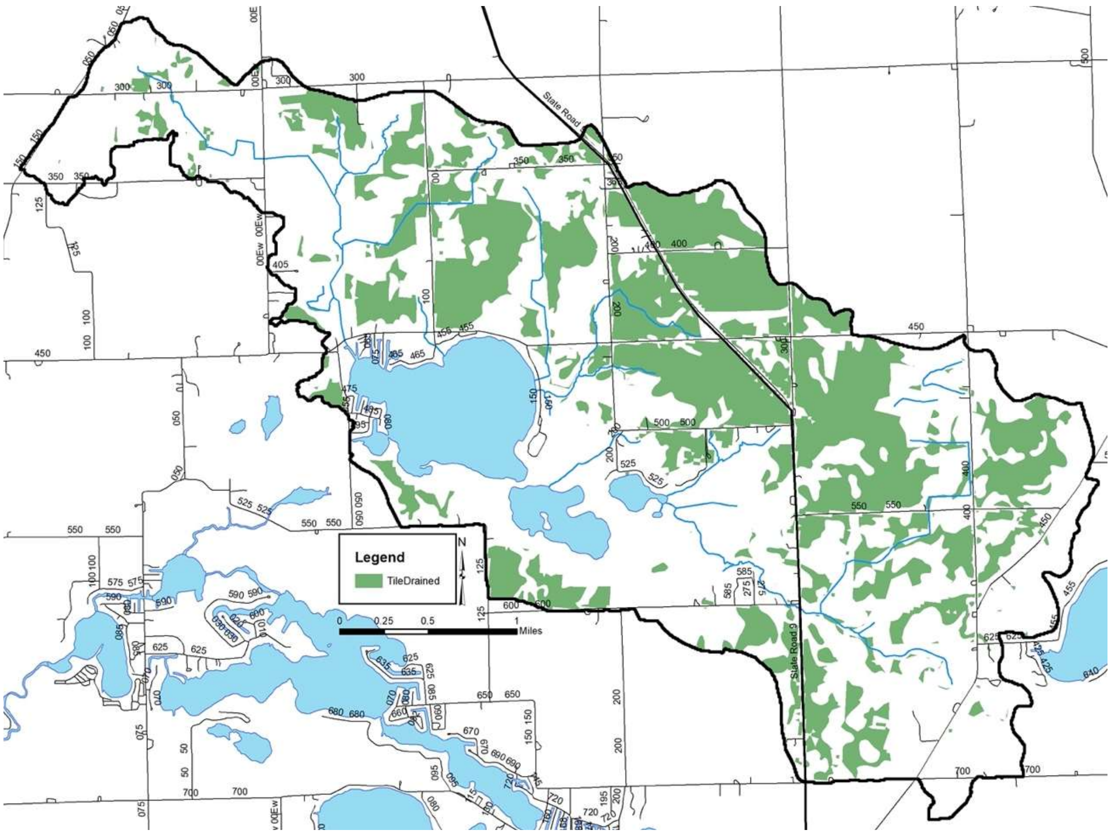


Figure 14. Tile drained in the Oliver Lake Watershed.

Tillage Transect

Tillage transect information data for Lagrange County was compiled (ISDA, 2022). As reported by ISDA, members of Indiana's Conservation Partnership (ICP) conduct a field survey of tillage methods. A tillage transect is an on-the-ground survey that identifies the types of tillage systems farmers are using and long-term trends of conservation tillage adoption using GPS technology, plus a statistically reliable model for estimating farm management and related annual trends. It is however, likely an underestimate of the actual use of tillage due to the early spring nature of the transect occurring. Table 3 provides the estimated total number of acres planted and percent of acres which are not tilled in Lagrange County by corn and soybeans. Note these are county-wide data which can be utilized to extrapolate use of these practices in the Oliver Lake Watershed.

Table 4. Percent not tilled estimates within the Oliver Lake Watershed county (Lagrange).

County	Corn (acres)	Corn (%)	Soybeans (acres)	Soybeans (%)
Lagrange	42,900	28.6%	30,600	27.4%

Confined Feeding Operations and Unregulated Livestock Operations

About 50 small, unregulated livestock operations are found within the Oliver Lake Watershed (Figure 15). Small farms are those which house less than 300 animals, while larger farms that house large numbers of animals for longer than 45 days per year, also known as Confined Feeding Operations (CFOs), are regulated by IDEM. There are no CFOs in the watershed (Figure 15). The Lagrange County Unified Development Ordinance (UDO) further defines animal feeding operations (AFOs; Lagrange County, 2023). AFOs are defined as 25-299 dairy cattle, 30-299 beef cattle, 100-599 swine, 15-499 draft horses, 30-499 buggy horses, 300-2,999 sheep and additional details for turkeys, chickens and ducks. In total, the unregulated animal facilities house 401 cows, 494 horses and 35 sheep as observed during the windshield survey. However, this is most likely an underestimate of the actual number as these animals are likely rotated through various pastureland. These small farms contain small numbers of cattle, horses, sheep or goats, which could be sources of nutrients and E. coli as these animals exist on small acreage lots with limited ground cover. In total, the observed animals generate approximately 12,560 tons of manure per year spread over the watershed. This volume of manure contains approximately 7,246 pounds of nitrogen, 3,596 pounds of phosphorus and 6.22E+14 col of E. coli. In total, 10 of the observed unregulated livestock operations would be defined as AFOs under Lagrange County's UDO. Based on the UDO, these AFOs must meet minimum setbacks of 1,320 feet (402.3 m) from shoreline/lake water line and 300 feet (91.4 m) setback from drainageways or wetlands.

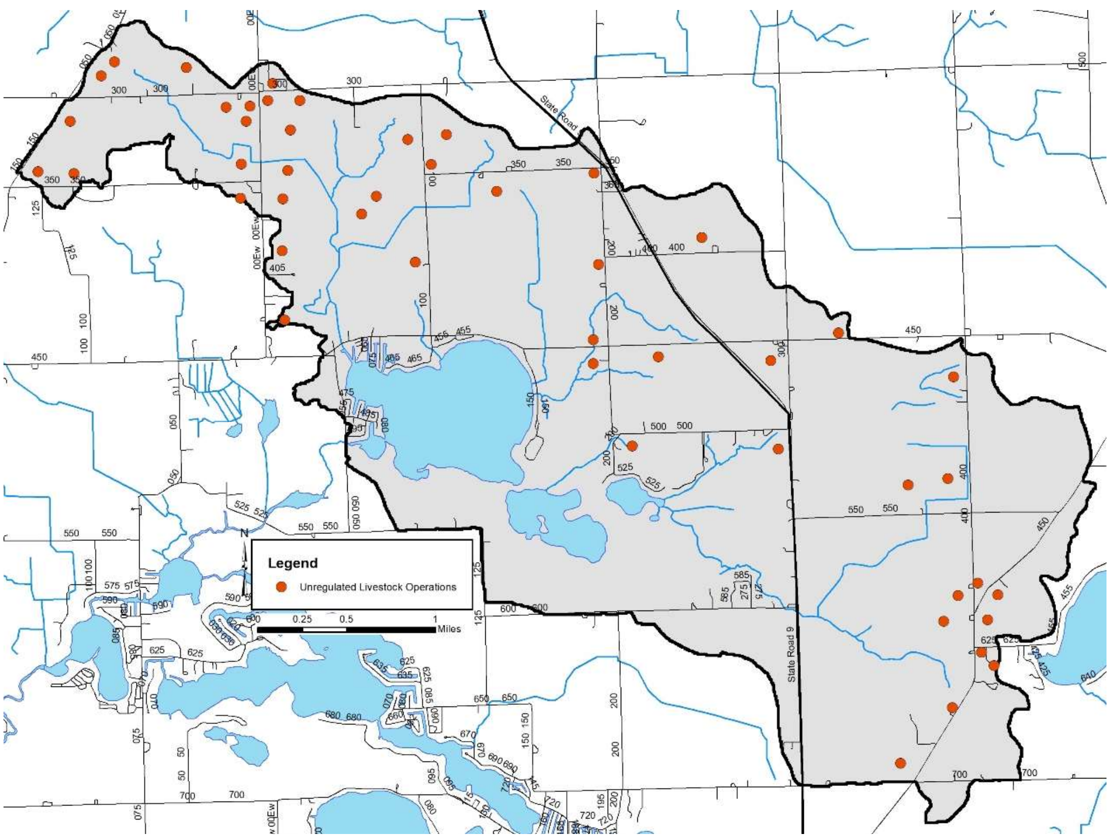


Figure 15. Confined feeding operations (CFO) and small, unregulated animal facilities in the Oliver Lake Watershed.

2.8.2 Managed Lands

Roughly 336 acres of land in the Oliver Lake Watershed is managed by the Nature Conservancy or the IDNR (Figure 16). Managed lands in the watershed include the Martin Lake and Olin Lake Nature Preserve

(Indiana DNR), Oliver Lake access site (Indiana DNR), Martin Lake Nature Preserve (Acres Land Trust) and an Olin Lake area (Acres Land Trust).

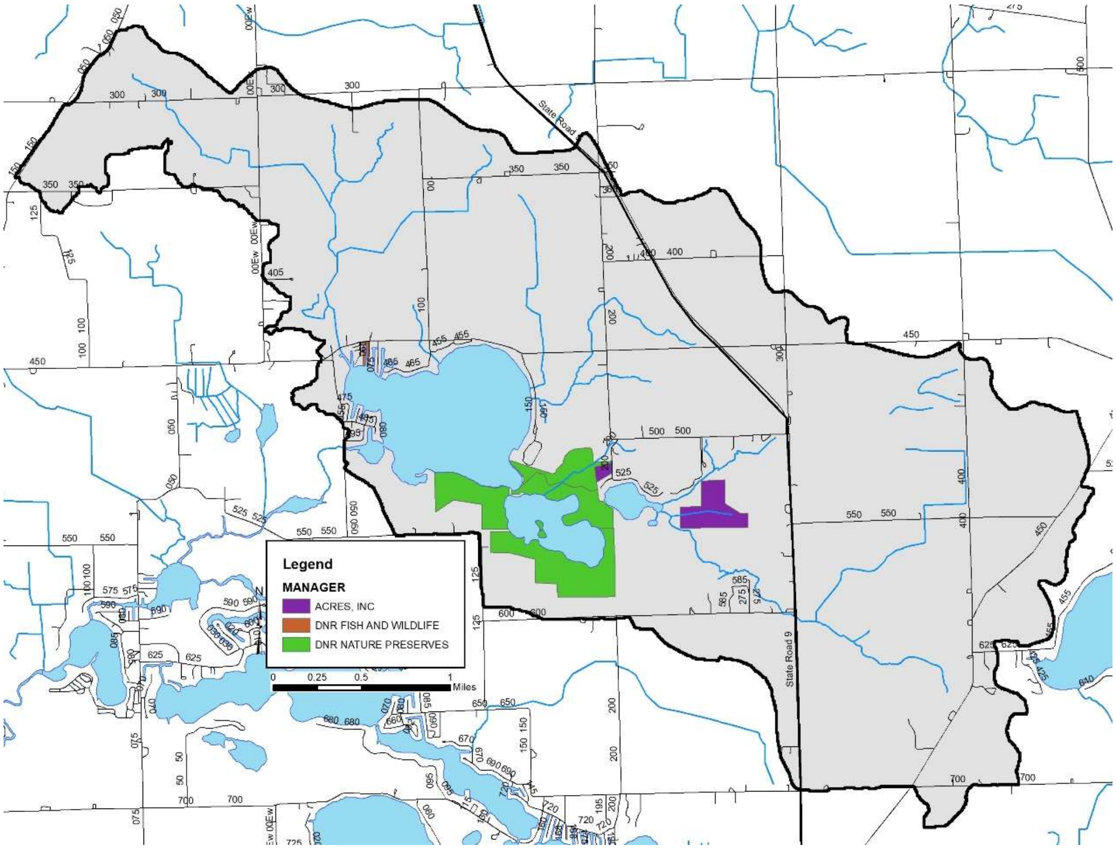


Figure 16. Managed areas in the Oliver Lake Watershed.

2.9 <u>Hydrology</u>

Watershed streams, lakes, legal drains, floodplains, wetlands, storm drains, groundwater, subsurface conveyances, and manmade drainage channels all contribute to the watershed's hydrology. Each component moves water into, out of, or through the system. Contributions from some of these will be covered in further detail in subsequent sections.

2.9.1 Watershed Streams

The Oliver Lake Watershed contains approximately 16.6 miles (26,716 m) of perennial and intermittent streams. Of these, approximately 11.7 miles (18,829.3 m) are regulated drains including the lakes' main inlets: Dove Creek or Colwell Ditch (OL01), Bert Hart Ditch (OL05), Stoner Ditch (OL08), Truman Flint Ditch (OL09), Logan Drain (OL11) and Eshelman Drain (OL10). These streams or legal drains are maintained by the County surveyor's office. Each drain may have both a regular maintenance fund and/or a regular maintenance schedule which could allow for additional targeted funding within the drains' portion of the watershed. Maintenance practices can include dredging with large construction equipment to maintain flow, debris removal, and vegetation management both within the regulated drain and the riparian zone. As these drains are subject to periodic cleaning, it is important to work with the county surveyor to establish priorities for these waterbodies in terms of water quality improvement and erosion control. Each time a ditch is cleaned out or maintained, this action increases the amount of sediment going downstream towards lakes in the Oliver Lake Watershed.

2.9.2 <u>Wetlands</u>

Because wetlands perform a variety of functions in a healthy ecosystem, they deserve special attention when examining watersheds. Functioning wetlands filter sediments and nutrients in runoff, store water for future release, provide an opportunity for groundwater recharge or discharge, and serve as nesting habitat for waterfowl and spawning sites for fish and semiaquatic species. By performing these roles, healthy, functioning wetlands often improve water quality and biological health of streams and lakes located downstream of wetlands.

The US Fish and Wildlife Service National Wetland Inventory map shows that wetlands cover 19% of the Oliver Lake Watershed, as shown in Figure 17 and described in Table 5. The U.S. Fish and Wildlife Service estimates an average of 2.6% of the nation's wetlands were lost annually from 1986 to 1997 (Zinn and Copeland, 2005). The IDNR estimates that approximately 85% of the state's wetlands have been filled (IDNR, 1996). Development of the land for agricultural purposes altered much of the natural hydrology, eliminating many of the wetlands.

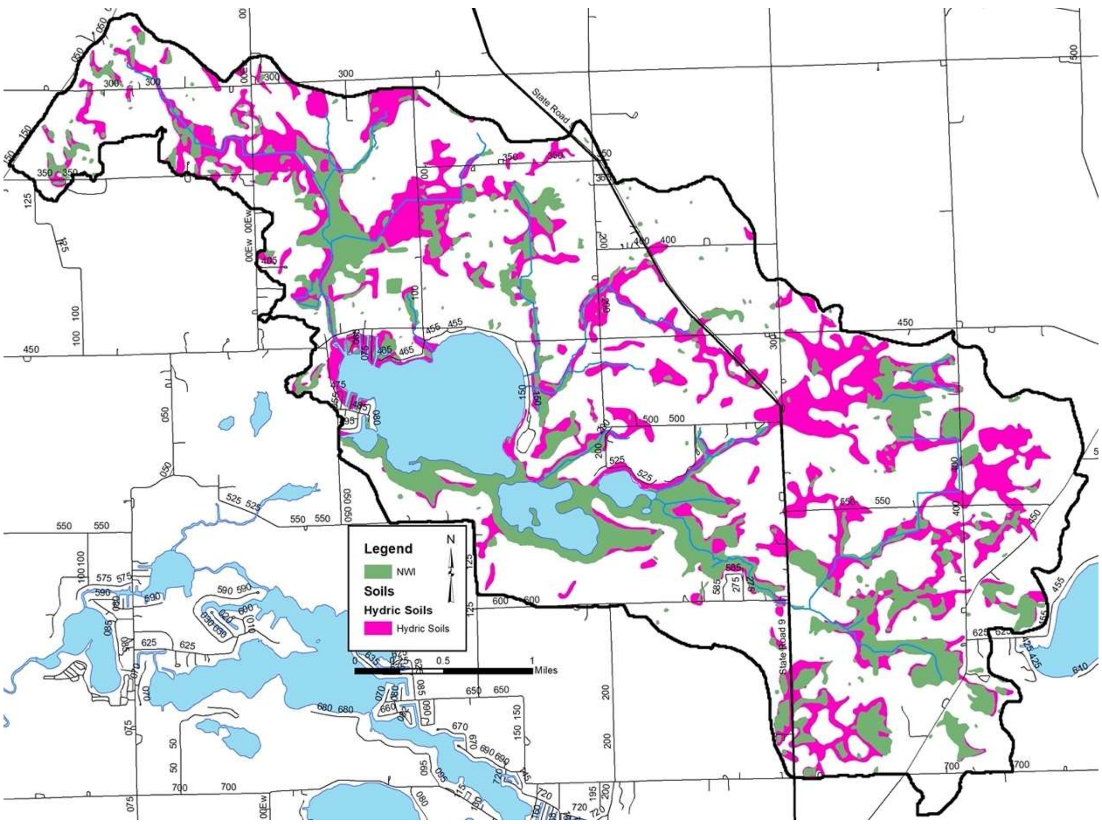


Figure 17. National Wetland Inventory wetlands in the Oliver Lake Watershed.

Table 5. Acreage and classification of wetland habitat in the Oliver Lake Watershed.

Wetland Type	Area (acres)	Area (hectares)	Percent of Wetlands	Percent of Watershed
Lake	502.5	203.4	34%	7%
Forest	493.9	199.9	33%	7%
Emergent	372.2	150.7	25%	5%
Shrub/scrub	111.3	45.0	7%	2%
Pond	17.4	7.1	1%	<0.1%
Total	**1497.2**	**606.2**	**100%**	**21%**

Conversion of wetlands to agricultural land uses has undoubtedly reduced wetland acreages in the Oliver Lake Watershed. Hydric soils, which formed under wetland conditions, cover 1,900.6 acres (769. ha) or 26% of the watershed. When compared to the acreage of wetlands mapped by the US Fish and Wildlife Service and the lake acreage is removed, a total of994.7 acres (402.7 ha) of wetland remain. This suggests that more than 79% of wetlands within the Oliver Lake Watershed have been lost.

3.0 HISTORIC STREAM WATER QUALITY ASSESSMENTS

A number of stream quality assessments have been completed within the Oliver Lake Watershed under a variety of conditions (Figure 18). Assessments include collection of water chemistry by IDEM (4), FX Browne (11 sites), Tri State University/Hippensteel (3 sites), as part of the Five Lakes Feasibility Study and Oliver Lake Diagnostic Study (JFNew, 4 sites) and via the Lagrange County Lakes Council (2 sites) and GOLC volunteers (5 sites).

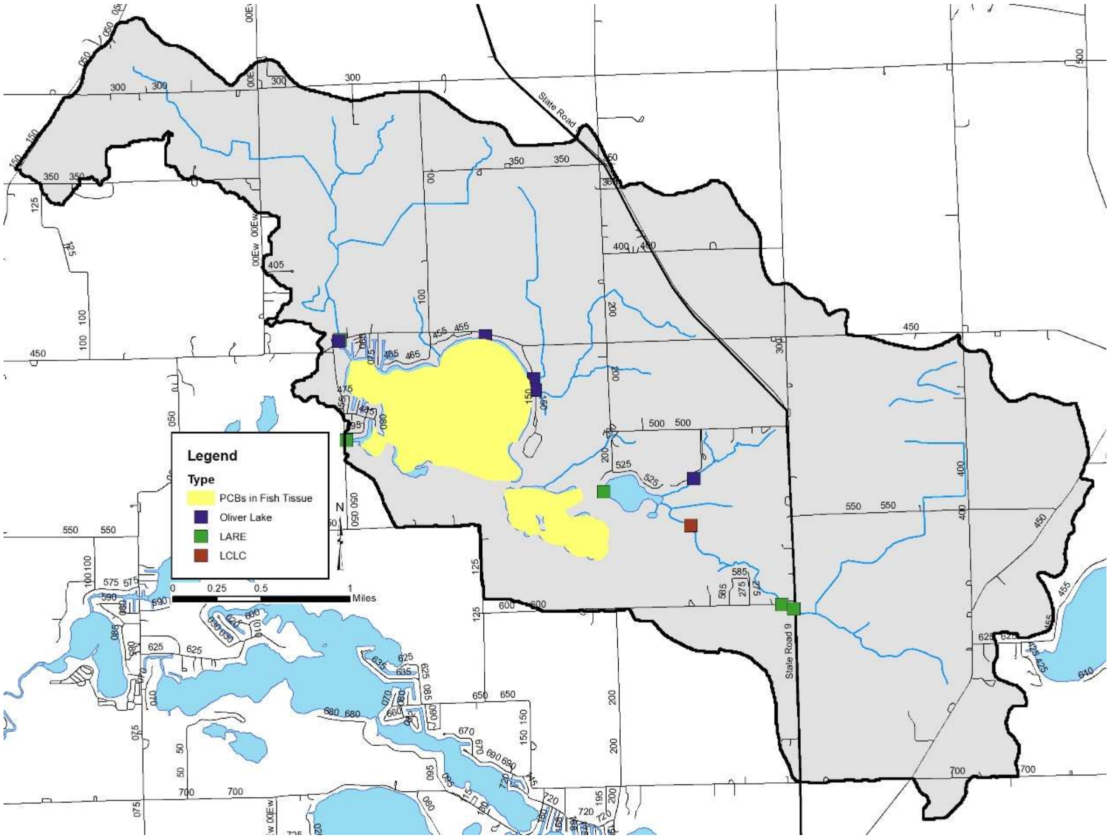


Figure 18. Historic water quality assessment locations and impaired waterbody locations in the Oliver Lake Watershed.

3.1 Water Quality Targets

Many of the historic water quality assessments occurred using different techniques or goals. Several sites were sampled only one time and for a limited number of parameters. While there is limitation in this data, which creates a reluctance to draw too many conclusions based on a single sampling event, there is a need to compare historical and current water quality assessments to standard values. Table 6 identifies a standard suite of parameters and the benchmark utilized to evaluate collected water quality data.

Table 6. Water quality benchmarks used to assess water quality from historic and current water quality assessments.

Parameter	Water Quality Benchmark	Source
Temperature	Monthly standard	Indiana Administrative Code
Dissolved oxygen	>4 mg/L	Indiana Administrative Code
Conductivity	1,000-1360 μmhos/cm	Indiana Administrative Code
pH	<6 or >9	Indiana Administrative Code
Turbidity	<5.7 NTU	USEPA (2000)
Nitrate-nitrogen	<1 mg/L	Ohio EPA (1999)
Ammonia-nitrogen	0.0-0.21 mg/L	Indiana Administrative Code
Total Kjeldahl nitrogen	<0.54 mg/L	USEPA (2000)
Orthophosphorus	<0.005 mg/L	Correll (1998)
Total phosphorus	<0.08 mg/L	Dodds et al. (1998)
Total suspended solids	<25 mg/L	Waters (1995)
E. coli	<235 colonies/100 mL	Indiana Administrative Code

3.2 Impaired Waterbodies List

The Indiana Department of Environmental Management 2024 303(d) lists the following Oliver Lake watershed streams as not assessed. Oliver Lake (394 acres or 160.6 ha) and Olin Lake (103 acres or 41.7) are listed as not supporting (impaired) for fish consumption due to polychlorinated biphenyls (PCBs) in fish tissue, while Martin Lake was listed as fully supporting (Table 7). The former county landfill located on County Road 300 South is the historic source of PCBs in the Oliver Lake Watershed. The landfill was closed in the mid 1970s; however, PCBs leached from the landfill to the lakes in advance of this closure.

Table 7. Waterbodies in the Oliver Lake Watershed impaired waterbodies list.

Waterbody Name	Assessment ID	Impairment(s)
Olin Lake Inlet	INJ01F3_T1002	Not Assessed
Oliver Lake Inlet	INJ01F3_T1003	Not Assessed
Oliver Lake Inlet	INJ01F3_T1004	Not Assessed
Oliver Lake Inlet	INJ01F3_T1005	Not Assessed
Dove Creek	INJ01F3_T1006	Not Assessed
Oliver Lake Outlet	INJ01F3_T1011	Not Assessed
Martin Lake Inlet	INJ01F3_T1013	Not Assessed
Martin Lake Inlet	INJ01F3_T1014	Not Assessed
Olin Lake	INJ01P1026_00	PCBs in Fish Tissue
Oliver Lake	INJ01P1025_00	PCBs in Fish Tissue

3.3 Fish Consumption Advisory

In Indiana, three state agencies collaborate annually to compile the Indiana Fish Consumption Advisory (FCA). The Indiana Department of Natural Resources, Indiana Department of Environmental Management, and Indiana State Department of Health have worked together since 1972 on this effort. Samples are collected through IDEM's rotating basin assessment for bottom feeding, mid-water column feeding, and top feeding fish. Fish tissue samples are then analyzed for heavy metals, PCBs, and pesticides. Advisories listings are as follows:

- Level 3 – limit consumption to one meal per month for adults. Pregnant or breastfeeding women, women who plan to have children, and children under 15 should consume zero volume of these fish.
- Level 4 – limit consumption to one meal every 2 months for adults; women and children detailed above having zero consumption.
- Level 5 – zero consumption or do not eat.

Oliver Lake contains the following site-specific or species-specific advisories. The Indiana FCA advises (ISDH, 2019) the sensitive population should not consume:
- Bowfin species all sizes, no more than one meal per week.
- Brown trout all sizes, no more than one meal per week.
- Common carp all sizes, no more than one meal per week.
- Largemouth bass all sizes, no more than one meal per week.

The following general population advisories are in place:
- Bowfin larger than 21 inches, no more than one meal per week.
- Brown trout all sizes, no more than one meal per week.
- Largemouth bass all sizes, no more than one meal per week.

3.4 Preliminary Investigation of 24 Lakes, Lagrange County, Indiana (1989)
In 1988, the Lagrange County Commissioners completed an assessment of Lagrange County lakes. Sampling of four streams in the Oliver Lake Watershed sites occurred as part of this assessment. Sites correspond with Dove Creek (OL01), Bert Hart Ditch (OL05) and its tributary (OL06) and Eshelman Drain (OL10). Based on assessment complete, the following conclusions can be drawn:
- In total, 33% of nitrate samples (1 of 3) exceeded water quality targets (1 mg/L).
- Similarly, 33% of orthophosphorus samples (3 of 6) exceeded water quality targets (0.03 mg/L).
- Total phosphorus concentration were elevated with 63% of samples (7 of 11) collected exceeding target concentrations (0.08 mg/L).
- Total suspended solids concentrations measured below water quality targets in all samples collected.

3.5 Feasibility Study of Ten Lagrange County Lakes (1992)
In 1991, FXBrowne completed an assessment of 10 Lagrange County lakes located in the Upper Elkhart River Watershed. Sampling of six stream sites within the Oliver Lake Watershed occurred as part of this assessment. Sample site correspond with Dove Creek (OL01), Bert Hart Ditch (OL05), Truman Flint Ditch (OL09) and the Oliver Lake outlet (OL12) as well as the Olin Lake outlet and the Eshelman Ditch (OL10) in the middle of the wetland. Based on assessment complete, the following conclusions can be drawn:
- Total phosphorus concentrations were elevated with 83% of samples (5 of 6) collected exceeding target concentrations (0.08 mg/L).
- Nitrate, orthophosphorus and total suspended solids concentrations measured below water quality targets in all samples collected.

3.6 Oliver Lake Diagnostic Study (2008)
In 2008, JFNew sampled water quality at four locations as part of the Oliver Lake Diagnostic Study (2009). Sample sites were located at the Dove Creek outlet (OL01), Martin Lake inlet (OL10), Bert Hart Drain (OL05) and Truman Flint Ditch (OL09). Based on the data, the following conclusions can be drawn:
- pH and conductivity measurements were all within standard ranges during the assessment.

- Dissolved oxygen did not meet the water quality target (4 mg/L) in 33% of samples (2 of 6).
- Nitrate exceeded water quality targets (1 mg/L) in 100% of samples (6 of 6) collected.
- Ortho-P concentrations exceeded water quality targets (0.03 mg/L) in 100% of samples (6 of 6) collected, while total phosphorus concentrations exceeded water quality targets (0.08 mg/L) in 33% of samples (2 of 6) collected.
- Total Kjeldahl nitrogen exceeded water quality targets (0.54 mg/L) in 50% of samples (3 of 6) collected.
- Total suspended solids exceeded target levels (15 mg/L) in 33% of samples (2 of 6) collected.
- Turbidity levels exceeded targets in 16% of samples (1 of 6) collected.
- E. coli exceeded state standards (235 colonies/100 mL) in 75% of samples (6 of 8 collected).
- Three of four stream site habitat rated poor scoring below the IDEM aquatic life use designation (51).
- Macroinvertebrate communities rated as moderately impaired at both sample sites.

3.7 Lagrange County Lakes Council (2011-2022 intermittent)
The Lagrange County Lakes Council sampled two lake inlets, one site each for Martin Lake and one for Oliver Lake, intermittently since 2011. Sampling occurred under various patterns most often occurring twice per summer. Based on assessments completed, the following conclusions can be drawn:
- pH and dissolved oxygen measured within target state standard ranges.
- Nitrate-nitrogen concentrations exceeded target concentrations in 39% of samples (11 of 28) collected.
- Total phosphorus concentrations exceeded the recommended criteria in 57% of samples collected (16 of 28).
- Total suspended solids concentrations exceeded the recommended criteria in 18% of samples collected (5 of 28).
- *E. coli* concentrations exceeded the state standard in 11% of samples collected (3 of 28).

3.8 Greater Olin Lake Conservancy (2022-2024)
The Greater Olin Lake Conservancy sampled water quality sites within the Oliver Lake Watershed from 2022 to 2024. In total, five sites were sampled in 2022, three sites were sampled in 2023 and three sites were sampled in 2024. In total, 15 sampling events occurred from 2022 to 2024. Based on the data, the following conclusions can be drawn:
- Dissolved oxygen concentrations measured below the lower state standard (4 mg/L) in 7% of samples collected (2 of 27).
- pH (38 of 38 samples) were within water quality standards in all of samples collected.
- E. coli exceeded state standards (235 col/100 ml) in 23 of 35 (66%) samples collected.
- Total suspended solids (TSS) samples exceeded targets in 12 of 37 (32%) of samples collected.
- Nitrate concentrations exceeded water quality targets in 22 of 35 (63%) of samples collected.
- TP concentrations exceeded water quality targets in 7 of 20 (35%) of samples collected.
- Samples were also collected following Hurricane Beryl passing through the watershed. All samples were elevated with E. coli measuring 2,420 col/100 mL at both sites, total suspended solids measuring more than 77 mg/L at both sites, nitrate concentrations measuring more than 75 mg/L and orthophosphorus measuring more than 0.45 mg/L at both sites.

3.9 Historic Stream Data Summary
In total, Oliver Lake streams have been sampled more than 80 times since 1988. Table 8 lists compiled Oliver Lake stream data by sample site. Dove Creek (OL01) has been sampled more often than other sites

with nearly 40 samples collected. pH at all sites measured within the state standard range. Dissolved oxygen concentrations measured outside the state standard (between 4 and 12 mg/L) in 9% of samples collected. All sites exhibited E. coli concentrations above the state standard (235 colonies/100 mL) with the Winling Creek north tributary (OL07) and Eshelman Drain (OL10) exceeding in all samples and Bert Hart Ditch (OL05) exceeding targets in 86% of collected samples. Bert Hart Ditch (OL05) also had the highest percentage exceedance for nitrate (88%) while its north tributary (OL07) exceeded targets in 83% of collected samples. Orthophosphorus was elevated at most sites with 80% of samples exceeding targets in Bert Hart Ditch (OL05) and 50% of samples exceeding water quality targets at Dove Creek (OL01) and Truman Flint Ditch (OL09). Total phosphorus concentrations were elevated at most sites with all but Eshelman Drain (OL10) exceeding targets in more than 50% of samples collected. The highest exceedances occurred at Bert Hart Ditch (OL05) and Turman Flint Ditch (OL09). Overall, total suspended solids concentrations and turbidity levels measured relatively low with only the Winling Creek north tributary (OL07) exceeding TSS targets in more than 50% of collected samples and only Bert Hart Ditch (OL05) exceeding turbidity targets in 50% of collected samples.

Table 8. Compiled historic stream water quality data from Oliver Lake streams by sample site.

Parameter	Dove Creek (OL01)	Bert Hart Ditch (OL05)	BH Ditch north trib (OL07)	Truman Flint Ditch (OL09)	Eshelman Drain (OL10)
pH	0%	0%	0%	0%	0%
Dissolved oxygen	9%	0%	0%	0%	0%
E. coli	14%	86%	100%	14%	100%
Nitrate	32%	88%	83%	57%	83%
Orthophosphorus	50%	80%	25%	50%	33%
Total phosphorus	53%	82%	57%	86%	13%
Total suspended solids	15%	39%	57%	14%	14%
Turbidity	17%	50%	--	0%	0%

4.0 STREAM WATER QUALITY ASSESSMENT

4.1 Introduction

The water quality assessment portion of the Oliver Lake Study consisted of water chemistry sampling during base flow and during a storm event, macroinvertebrate community assessment, and a habitat assessment. Water chemistry sampling was conducted at twelve sites within the Oliver Lake Watershed. Macroinvertebrate and habitat assessments were conducted at ten of the sites. The water quality assessment provides information on water quality, aquatic community health, and habitat availability. The data also assist in guiding the prioritization of management actions and direction of those actions towards the most critical areas.

4.1.1 Sample Locations

Twelve stream sample sites were strategically chosen throughout the Oliver Lake Watershed (Figure 19;Table 9). These sites were selected based on accessibility and correspond with historic sample sites. Sample sites correspond with major tributaries. The water quality assessment protocol also includes sampling at a reference site for comparative purposes. An ideal reference site for comparison of macroinvertebrate communities would occur in a relatively undisturbed watershed and would meet all criteria listed in Table 10. The inlet to Sand Lake possessed good habitat and a high-quality macroinvertebrate community and was chosen as the reference site.

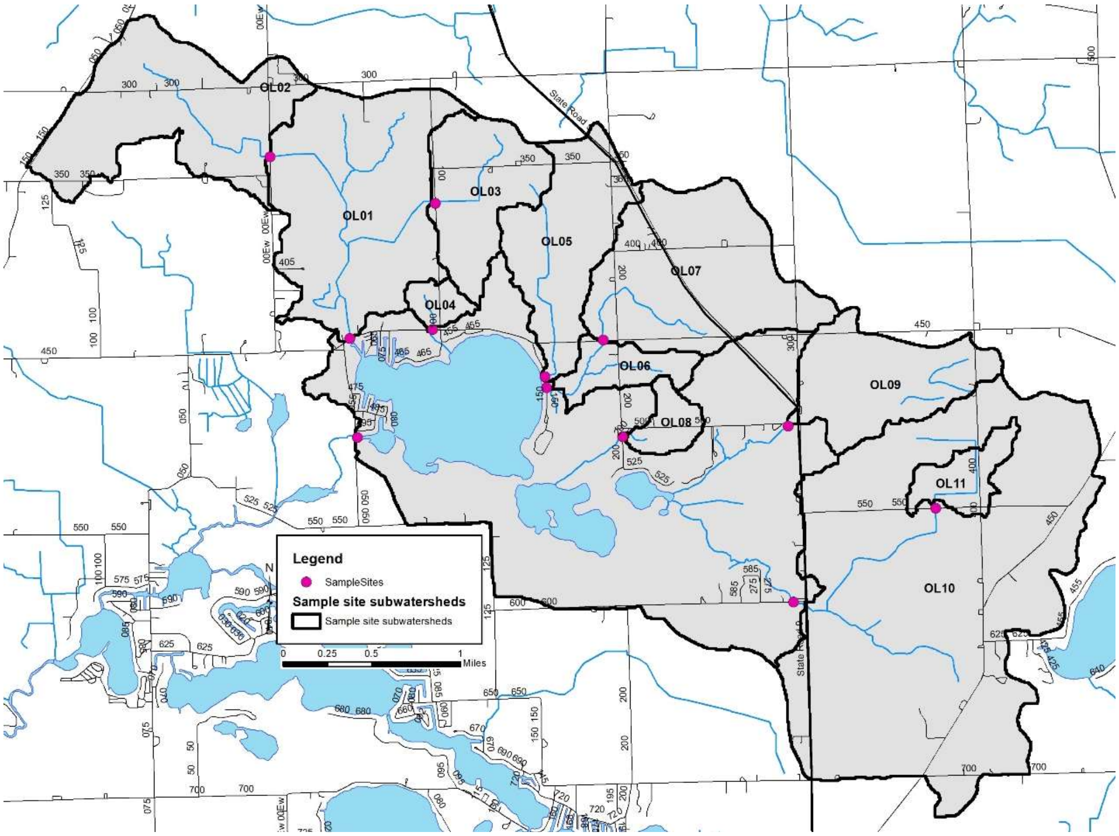


Figure 19. Oliver Lake Watershed stream sample sites and associated drainage basins.

Table 9. Detailed sampling location information for the Oliver Lake sampling sites.

Site	Stream Name	Road Crossing	Latitude	Longitude
1	Dove Creek	East CR 450 S	41.5773	-85.4157
2	Dove Creek tributary	South CR 00Ew	41.5921	-85.4241
3	Colwell Drain	South CR 100 E	41.5883	-85.4062
4	Unnamed tributary	East CR 450 S	41.5778	-85.4067
5	Bert Hart Ditch	South CR 150 E	41.5738	-85.3947
6	Winling Creek	South CR 150 E	41.5729	-85.3945
7	Winling Creek north tributary	East CR 450 South	41.5768	-85.3881
8	Stoner Ditch	South CR 200 E	41.5694	-85.3855
9	Truman Flint Ditch	East CR 500 S	41.5696	-85.3679
10	Eshelman Drain	East CR 600 S	41.5550	-85.3680
11	Logan Drain	East Cr 550 S	41.5625	-85.3524
12	Oliver Lake outlet	South CR 050 E	41.5691	-85.4153

Table 10. Minimum criteria for stream reference sites.

Reference Site Criteria
• pH>6 • Dissolved oxygen >4 mg/L • Nitrate<16.5 mg/L • Urban land use <20% of catchment area • Forest land use >25% of catchment area • Instream habitat rating optimal or suboptimal • Riparian buffer width >15 meters • No channelization • No point source discharges

Source: Plafkin et al., 1989.

4.2 <u>Water Chemistry Assessment</u>

4.2.1 Methods

The LARE sampling protocol requires assessing water quality of each stream site once during base flow and once during storm flow. Base flow sampling provides an understanding of the typical conditions in the streams. Following storm events, increased overland flow results in increased erosion of soil and nutrients from the land. Stream concentrations of nutrients and sediment are typically higher following storm events. Storm event sampling provides a "worst case" scenario picture of watershed pollutant loading.

Base flow samples were collected August 22, 2024 following a period of little precipitation. Storm event samples were collected June 26, 2024 following a 24-hour 0.9-inch rain event. Base flow and stormwater runoff samples included measurements of physical, chemical, and bacteriological parameters. Conductivity, temperature, and dissolved oxygen were measured in situ at each stream site. Water velocity was measured using an OTT MF pro current meter. Cross-sectional areas of the stream channel at each site were measured and discharge calculated by multiplying water velocity by the cross-sectional areas. In addition, water samples were collected from just below the water surface using a cup sampler and analyzed for the following parameters:

- Temperature
- Dissolved oxygen
- Conductivity
- pH
- Turbidity
- Nitrate-nitrogen
- Ammonia-nitrogen
- Total Kjeldahl nitrogen
- Orthophosphorus
- Total phosphorus
- Total suspended solids
- E. coli

Following collection, samples were stored on ice until analysis at the ESG laboratory in Fort Wayne, Indiana (E. coli) or the Indiana Clean Lakes Laboratory (all other parameters). All sampling techniques and laboratory analysis methods were performed in accordance with the procedures in *Standard Methods for the Examination of Water and Wastewater*, *20th Edition* (APHA, 1998).

The comprehensive evaluation of streams requires collecting data on the different water parameters listed above. A brief description of each parameter follows:

Temperature: Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. Likewise, water temperature regulates the species composition and activity of life associated with the aquatic environment. Since essentially all aquatic organisms are cold-blooded, the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (USEPA, 1976). The Indiana Administrative Code (327 IAC 2-16) sets maximum temperature limits to protect aquatic life for Indiana streams. For example, temperatures during the months of June and July should not exceed 90°F by more than 30°F. The code also states that the "maximum temperature rise at any time or place… shall not exceed 50°F in streams…"

Dissolved Oxygen (DO): DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need water to possess a DO concentration of at least 3-5 mg/L of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The IAC sets minimum DO concentrations at 6 mg/L for coldwater fish. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with DO. Waterbodies with large populations of algae and plants (macrophytes) often exhibit supersaturation due to the high levels of photosynthesis. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity: Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). During low flows, conductivity is higher than it is following a storm water runoff because the water moves more slowly across or through ion containing soils and substrates during base flow conditions. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity levels. Rather than setting a conductivity standard, the Indiana Administrative Code sets a standard for dissolved solids (750 mg/L). Multiplying a dissolved solids concentration by a conversion factor of 0.55 to 0.75 µmhos per mg/L of dissolved solids roughly converts a dissolved solids concentration to specific conductance (Allan, 1995). Thus, converting the IAC dissolved solids concentration standard to specific conductance by multiplying 750 mg/L by 0.55 to 0.75 µmhos per mg/L yields a specific conductance range of approximately 1000 to 1360 µmhos. This report presents conductivity measurements at each site in µmhos.

pH: The pH of stream water describes the concentration of acidic ions (specifically H+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Turbidity: Turbidity (measured in Nephelometric Turbidity Units or NTUs) is a measure of water coloration and particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU. Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978). The U.S. Environmental Protection Agency developed recommended water quality criteria as part work to establish numeric criteria for nutrients on an ecoregion basis. Recommended turbidity concentrations for this ecoregion are 5.7 NTUs (USEPA, 2000).

Nitrogen: Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the air we breathe is nitrogen gas. Nitrogen gas diffuses into water where it can be "fixed", or converted, by blue-green algae to ammonia for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

- **Nitrate-nitrogen (NO_3-N):** Nitrate is an oxidized form of dissolved nitrogen that is converted to ammonia by algae. It is found is streams and runoff when dissolved oxygen is present, usually in the surface waters. Ammonia applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams classified as warmwater habitat (WWH) was 1.0 mg/L. Warmwater habitat refers to those streams which possess minor modifications and little human influence. These streams typically support communities with healthy, diverse warmwater fauna. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams classified as modified warmwater habitat (MWH) was 1.6 mg/L. Modified warmwater habitat was defined as: the aquatic life use assigned to streams that have irretrievable, extensive, man-induced modification that precludes attainment of the warmwater habitat use designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). Nitrate-nitrogen concentrations exceeding 10 mg/L in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

- **Ammonia-nitrogen (NH_3-N):** Ammonia-nitrogen is a form of dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found in water where dissolved oxygen is lacking. Important sources of ammonia include fertilizers and animal manure. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum ionized ammonia concentrations for the study streams should not exceed approximately 1.94 to 7.12 mg/L, depending on the water's pH and temperature.

- **Organic Nitrogen:** Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. The most commonly measured form used to calculate organic nitrogen is total Kjeldahl nitrogen (TKN). Organic nitrogen is TKN minus ammonia. The U.S. Environmental Protection Agency developed TKN criterion as part work to establish numeric criteria for nutrients on an ecoregion basis. The recommended total Kjeldahl nitrogen concentration for this ecoregion is 0.54 mg/L (USEPA, 2000).

Phosphorus: Phosphorus is an essential plant nutrient and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and in yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles; there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a limiting nutrient in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

- **Soluble reactive phosphorus (SRP):** SRP or orthophosphorus is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/L are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

- **Total phosphorus (TP):** TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/L (or 30 µg/L) can cause algal blooms in lake systems. In stream systems, Dodd et al., 1998 suggests that streams with a total phosphorus concentration greater than 0.075 mg/L are typically characterized as productive or eutrophic. TP is often a problem in agricultural watersheds because TP concentrations required for eutrophication control are as much as an order of magnitude lower than those typically measured in soils used to grow crops (0.2-0.3 mg/L). The Ohio EPA (1999) found that the median TP concentration in wadeable streams that support WWM for fish was 0.10 mg/L, while wadeable streams that support MWH for fish was 0.28 mg/L. The U.S. Environmental Protection Agency recommended TP criterion for this ecoregion is 0.033 mg/L (USEPA, 2000).

Total Suspended Solids (TSS): A TSS measurement quantifies all particles suspended in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. The State of Indiana does not have a TSS standard. In general, TSS concentrations greater than 80 mg/L have been found to be deleterious to aquatic life; concentrations of 15 mg/L are often targeted as levels necessary for quality fishery production (Waters, 1995).

E. coli **and Fecal Coliform Bacteria:** *E. coli* is one member of a group of bacteria that comprise the fecal coliform bacteria and is used as an indicator organism to identify the potential presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments, and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 colonies/100 mL in any one sample within a 30-day period.

4.2.2 Water Chemistry Results and Discussion

Introduction

There are two useful ways to report water quality data in flowing water. Concentrations describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/L). Mass loading (in units of kilograms per day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is most important when considering the effects of these materials downstream. Because consideration of concentration and mass loading data is important, the following three sections will discuss 1) physical parameter concentrations, 2) chemical and bacterial parameter concentrations, and 3) chemical and sediment parameter mass loading.

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling are presented in Table 11. Each physical parameter is addressed in the following discussion.

Table 11. Physical parameter data collected during the stream chemistry sampling events in the Oliver Lake Watershed on June 26 (storm) and August 22, 2024 (base). Shaded squares indicate those samples that measure above Indiana State Standards (■) or recommended target values (■; Dodds et al., 1998; USEPA, 2000).

Site Number	Flow Condition	Flow (cfs)	Temperature (deg C)	DO (mg/L)	pH	Turbidity (NTU)	Conductivity (µS/cm)
1	Base	1.14	20.4	9.9	8.2	54.7	374
	Storm	2.00	21.9	4.9	7.7	25.0	531
2	Base	0.003	14.9	9.5	8.1	14.1	802
	Storm	0.03	18.9	8.3	8.2	24.3	479
3	Base	0.07	14.0	9.4	7.9	22.6	679
	Storm	0.05	15.6	8.1	6.1	20.6	440
4	Base	0.01	14.6	9.1	7.8	20.9	581
	Storm	0.02	19.7	8.4	8.1	21.8	624
5	Base	0.14	16.2	9.3	8.2	10.4	629
	Storm	0.10	16.7	8.9	8.5	21.1	625
6	Base	0.01	17.5	8.8	8.0	24.2	585
	Storm	0.20	19.4	8.2	8.2	24.6	590
7	Base	0.03	21.2	8.1	7.4	33.1	615
	Storm	0.03	18.3	8.4	7.5	45.1	615
8	Base	Dry					
	Storm	0.01	19.6	7.9	7.8	7.7	569
9	Base	0.25	19.1	9.2	8.2	19.1	560
	Storm	0.15	19.9	8.5	7.8	5.0	532
10	Base	0.22	16.7	9.4	8.1	18.9	619
	Storm	0.52	18.4	8.2	8.1	24.7	622
11	Base	0.0002	18.1	8.9	8.0	1.8	685
	Storm	0.02	20.5	8.8	7.9	3.1	606
12	Base	5.29	22.6	8.3	8.1	24.0	342
	Storm	9.70	25.5	8.7	8.2	24.3	360

Temperature: Water temperature varied with sample timing. Oliver Lake Watershed streams were warmer in June than in August. During storm flow sampling, the Oliver Lake Watershed streams exhibited a water temperature range from 60.1°F (15.6°C) at Colwell Drain (Site 3) to 77.9°F (25.5°C) at the Oliver Lake outlet (Site 12). During base flow, the temperature range was 57.2°F (14.0°C) at Colwell Drain (Site 3) to 72.7°F (22.6°C) in the Oliver Lake outlet (Site 12). Colwell Drain (Site 3) exhibited the lowest temperature during base and storm flow sampling. Oliver Lake outlet (Site 12) exhibited the highest temperatures during both base and storm flow. All temperatures were within ranges suitable for aquatic life. Those sites with cooler temperatures likely had a greater proportion of groundwater flowing in them. Streamside vegetation that provides shading to the water can also prevent heat gain.

Dissolved Oxygen: DO concentrations in Oliver Lake Watershed streams varied from 4.9 mg/L in Dove Creek (Site 1) to 8.7 mg/L in the Oliver Lake outlet (Site 12) during storm flow and from 8.1 mg/L in the Winling Creek north tributary (Site 7) to 9.9 mg/L in Dove Creek at (Site 1) during base flow. All sites during base and storm flow measured above the Indiana state minimum standard of 4 mg/L indicating the oxygen levels were sufficient to support aquatic life.

Conductivity: In general, conductivity values fell within acceptable ranges. Conductivity values in Oliver Lake Watershed streams ranged from 342 µS/cm in Oliver Lake outlet (Site 12) to 802 µS/cm at Dove Creek tributary (Site 2) during base flow and from 360 µS at Oliver Lake outlet (Site 12) to 625 µS/cm at Bert Hart Ditch (Site 5) during storm flow. None of the Oliver Lake streams exceeded the upper range obtained by converting the IAC dissolved solids standard into specific conductance.

pH: pH values in Oliver Lake Watershed streams ranged from 7.4 in Winling Creek (Site 6) to 8.2 in Dove Creek, Bert Hart Ditch and Truman Flint Ditch (Sites 1, 5 and 9) during base flow and from 7.5 in the Winling Creek north tributary (Site 7) to 8.5 in the Bert Hart Ditch (Site 5) during storm flow. These pH values are within the range of 6-9 units established as acceptable by the Indiana Administrative Code for the protection of aquatic life.

Turbidity: Turbidity levels ranged from 3.1 NTU in Logan Drain (Site 11) to 45.1 in the Winling Creek north tributary (Site 7) during storm flow. All sites, except Stoner Ditch (Site 8) and Logan Drain (Site 11) exceeded the turbidity levels commonly found in Indiana streams (15 NTUs; White, unpublished) during storm flow. Turbidity levels ranged from 1.8 in Logan Drain (Site 11) to 54.7 NTU in Dove Creek (Site 1) during base flow. All sites except Dove Creek tributary (Site 2), Bert Hart Ditch (Site 5) and Logan Drain (Site 11) exceeded the turbidity levels commonly found in Indiana streams (15 NTUs; White, unpublished) during base flow. Further, all sites during base and storm flow conditions Logan Drain (Site 11) during base and storm flow and Truman Flint Ditch (Site 9) during storm flow exceeded the USEPA recommended turbidity concentration (5.7 NTU; USEPA, 2000) The highest turbidity level was observed at Dove Creek (Site 1) during base flow conditions (54.7 NTU). Additionally, it is important to note that base flow turbidity conditions are greater than storm flow turbidity conditions in three of the eleven sites sampled.

Chemical and Bacterial Concentrations

Chemical and bacterial concentration data for the Oliver Lake Watershed streams are listed by site in Table 12. Figure 20 to Figure 27 present concentration information graphically.

Table 12. Chemical and bacterial characteristics of Oliver Lake Watershed on June 26 (storm) and August 22, 2024 (base). Shaded squares indicate those samples that measure above Indiana State Standards ( ) or recommended target values (; Correll, 1998; Dodds et al., 1998; Waters, 1998; USEPA, 2000).

Site Number	Flow Condition	Nitrate-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)	E. coli (col/100 ml)
1	Base	0.09	0.06	2.2	0.01	0.37	175	79
	Storm	0.5	0.22	1.7	0.06	0.25	81	1,300
2	Base	2.8	0.06	4.4	0.45	0.76	85	2,420
	Storm	3.0	0.1	4.1	0.15	0.31	93	1,010
3	Base	0.2	0.02	0.3	0.005	0.04	97	123
	Storm	1.1	0.04	1.9	0.006	0.02	129	649
4	Base	0.6	0.03	0.7	0.006	0.04	116	530
	Storm	0.4	0.04	0.6	0.007	0.02	121	1,990
5	Base	1.4	0.01	1.6	0.004	0.04	97	914
	Storm	4.3	0.0002	5.5	0.006	0.07	134	1,050
6	Base	1.9	0.01	2.2	0.008	0.04	129	921
	Storm	3.8	0.06	4.0	0.02	0.06	123	2,420
7	Base	2.2	0.06	2.4	0.006	0.04	136	259
	Storm	3.7	0.02	7.2	0.008	0.06	190	1,200
8	Base	Dry						
	Storm	1.1	0.02	2.6	0.009	0.04	122	387
9	Base	7.8	0.07	9.6	0.02	0.12	113	2,420
	Storm	7.5	0.01	9.6	0.01	0.05	77	148
10	Base	1.3	0.06	0.7	0.007	0.04	116	980
	Storm	3.4	0.03	6.8	0.01	0.09	139	2,420
11	Base	2.3	0.11	4.5	0.06	0.23	128	1,010
	Storm	3.6	0.03	7.7	0.02	0.08	88	2,420
12	Base	0.1	0.03	0.7	0.03	0.06	45	3
	Storm	0.4	0.06	1.5	0.008	0.01		75

Nitrate-nitrogen: Nitrate-nitrogen concentrations measured a majority of sites exceeded water quality targets during both base and storm flow (Figure 20). In total, 70% of samples exceed target concentrations. Base flow concentrations ranged from 0.09 mg/L in Dove Creek (Site 1) to 7.8 mg/L at Truman Flint Ditch (Site 9), while storm flow nitrate-nitrogen concentrations ranged from 0.39 mg/L in the unnamed tributary (Site 4) to 7.5 mg/L in Truman Flint Ditch (Site 9). Nitrate-nitrogen concentrations exceeded the median nitrate-nitrogen concentration observed in Ohio streams (1 mg/L) known to support healthy warmwater fauna (Ohio EPA, 1999) in 70% of the samples.

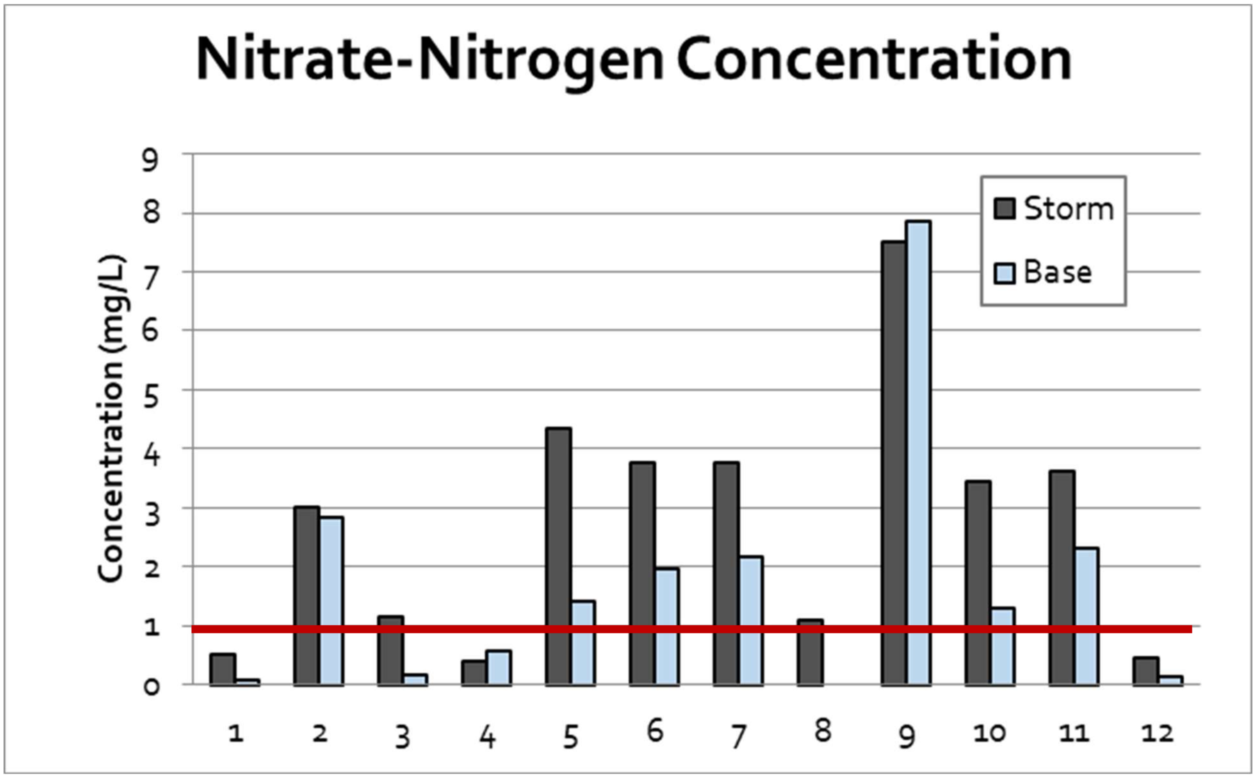


Figure 20. Nitrate-nitrogen concentration measurements during base and storm flow sampling of Oliver Lake Watershed streams. The red line indicates the target concentration (1.0 mg/L; Ohio EPA, 1999).

Ammonia-nitrogen: Ammonia-nitrogen concentrations measured relatively low at most sites during base and storm flow sampling with concentrations ranging from 0.01 to 0.22 mg/L (**Figure *21***). Dove Creek (Site 1) measured the highest ammonia (0.22 mg/L) during storm flow, while Eshelman Drain (Site 11) measured the highest ammonia (0.11 mg/L) during base flow.

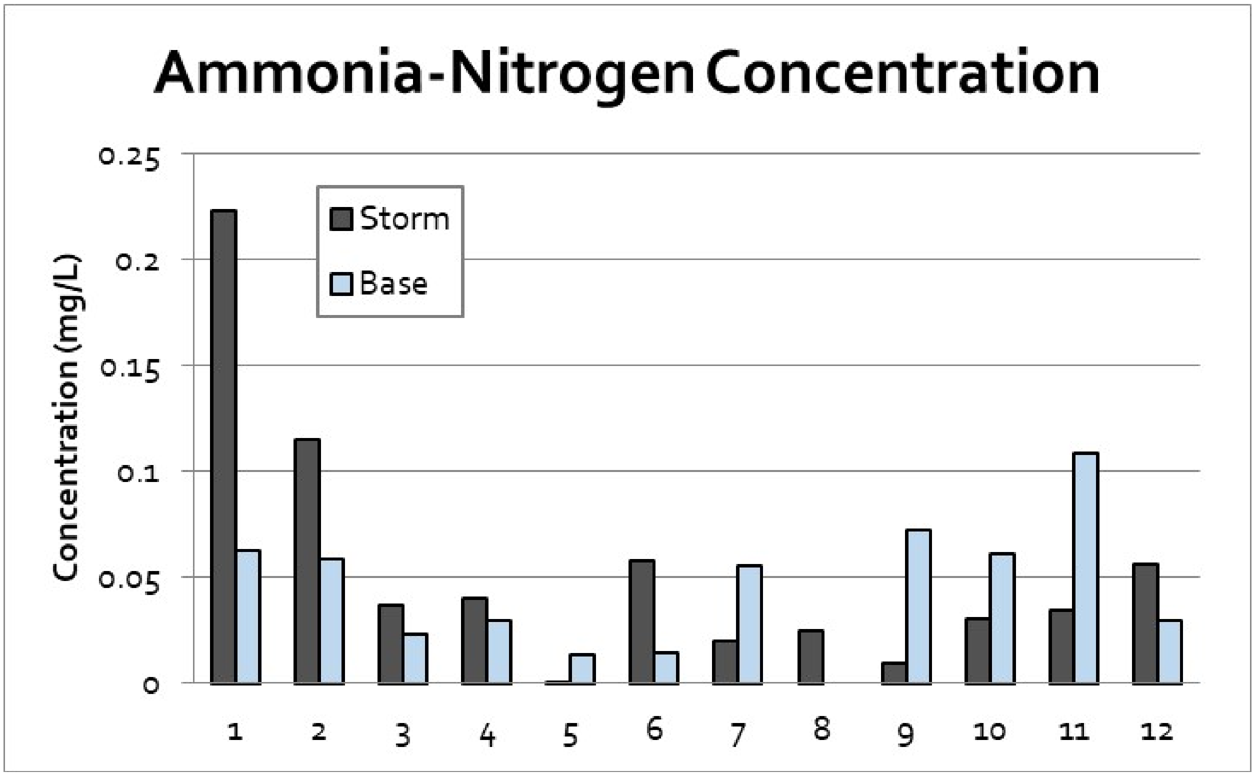


Figure 21. Ammonia-nitrogen concentration measurements during base and storm flow sampling of Oliver Lake Watershed streams.

Total Kjeldahl Nitrogen: Total Kjeldahl nitrogen (TKN) concentrations in the study streams measured relatively high for Indiana streams (Figure 22). All sites exceeded water quality targets except for Colwell Drain (Site 3) during base flow. Base flow concentrations ranged from 0.3 mg/L in Colwell Drain (Site 3) to 9.6 mg/L in Truman Flint Ditch (Site 9). Storm flow TKN concentrations ranged from 0.6 mg/L in the unnamed tributary (Site 4) to 9.6 mg/L in Truman Flint Ditch (Site 9). Truman Flint Ditch (Site 9) possessed the highest TKN concentrations during both base and storm flow conditions. In total, 96% of samples exceeded water quality targets (0.57 mg/L).

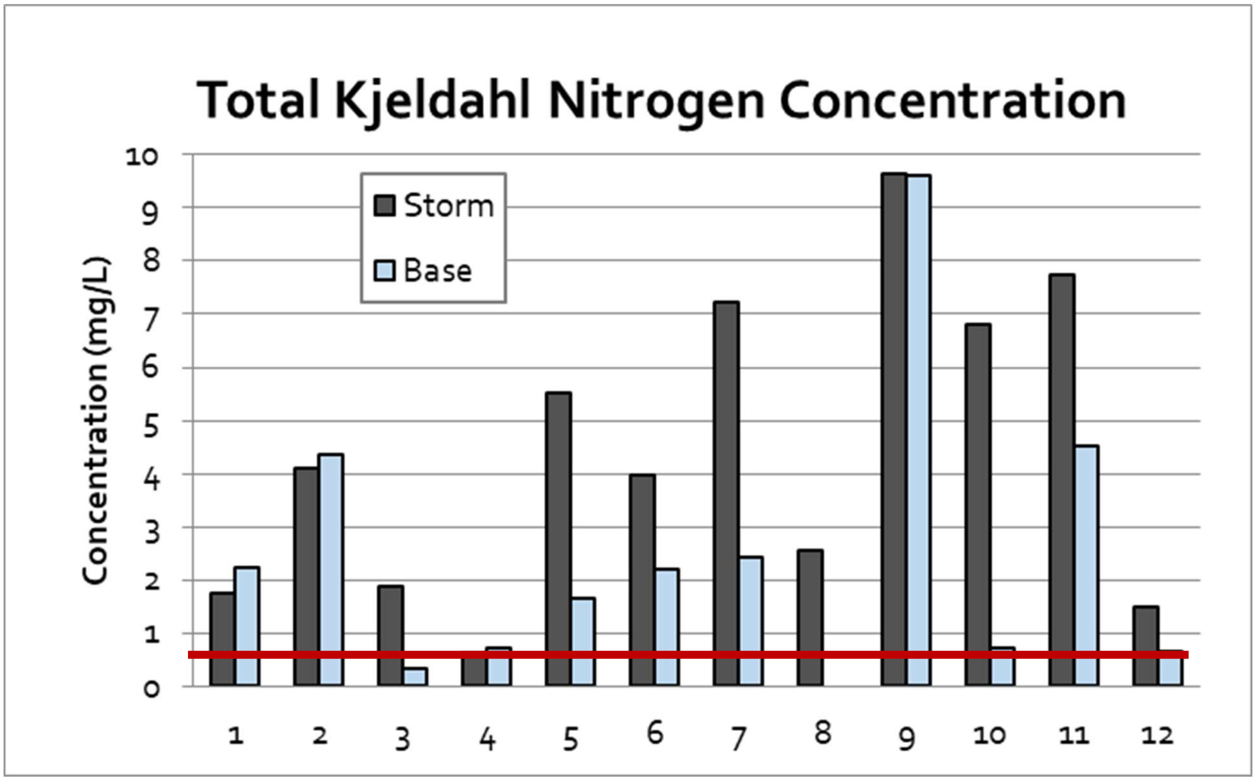


Figure 22. Total Kjeldahl nitrogen concentration measurements during base and storm flow sampling of Oliver Lake Watershed streams. The red line indicates the target concentration (0.54 mg/L; USEPA, 2000).

Orthophosphorus: Orthophosphorus concentrations measured relatively low in most Oliver Lake Watershed streams (Figure 23). Concentrations ranged from 0.004 at Bert Hart Ditch (Site 5) to 0.449 mg/L at the Dove Creek tributary (Site 2) during base flow and from 0.006 mg/L in Colwell Drain (Site 3) to 0.152 mg/L in the Dove Creek tributary (Site 2) under storm flow. The Dove Creek tributary (Site 2) exceeded target concentrations during base and storm flow, while Dove Creek (Site 1) exceeded target concentrations during storm flow and Logan Drain (Site 11) exceeded target concentrations during base flow. In total, 17% of samples exceeded orthophosphorus targets (0.03 mg/L) in 17% of samples collected.

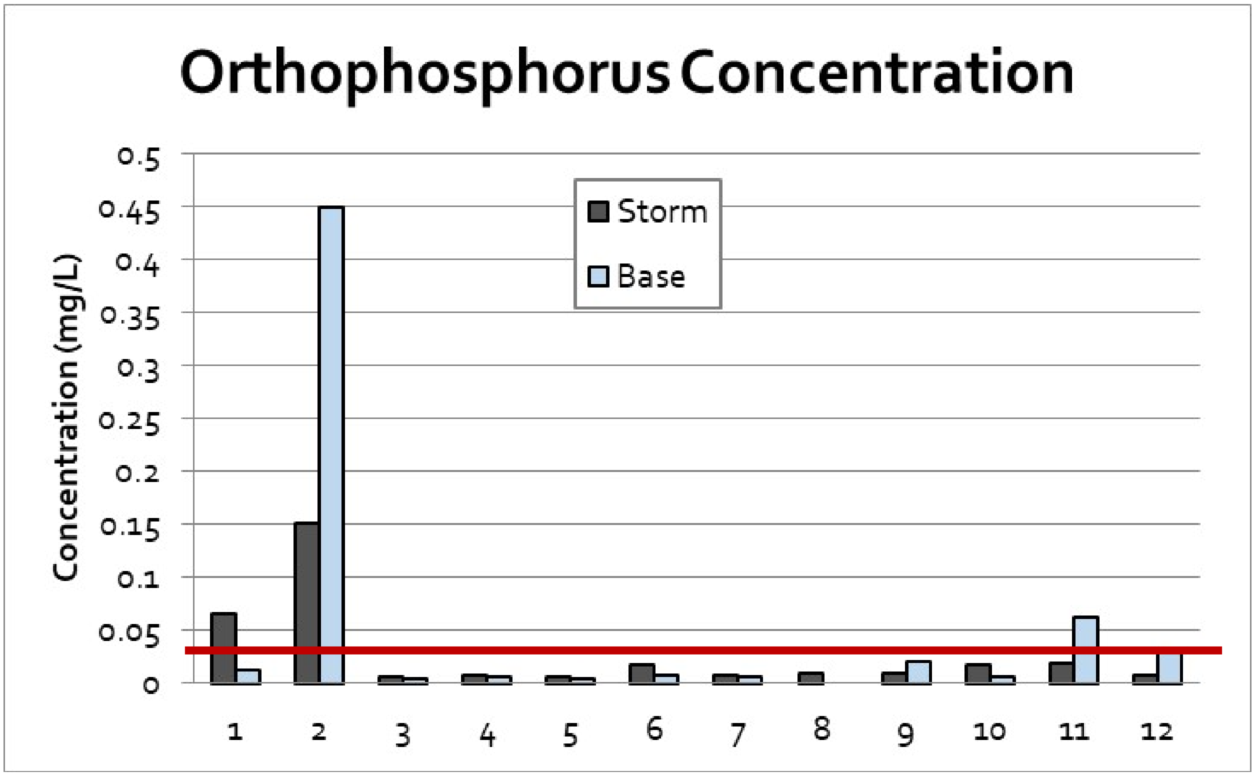


Figure 23. Orthophosphorus concentration measurements during base and storm flow sampling of Oliver Lake Watershed streams. The red line indicates the target concentration (0.03 mg/L) Correll, 1998).

Total Phosphorus: Total phosphorus (TP) concentrations measured relatively low across the Oliver Lake Watershed (Figure 24). Oliver Lake outlet (Site 12) measured the lowest during storm flow (0.01 mg/L), with Dove Creek tributary (Site 2) containing the highest concentrations (0.31 mg/L). During base flow, the lowest concentration measured 0.0351 mg/L at the unnamed tributary (Site 4), while the highest concentration measured 0.76 mg/L in the Dove Creek tributary (Site 2). During base and storm flow conditions, two sites, Sites 1 and 2 (Dove Creek) measured above target values. Truman Flint Ditch (Site 9) and Logan Drain (Site 11) measured above target values during base flow conditions. In total, 35% of samples exceed the USEPA recommended criterion (0.076 mg/L) for the ecoregion (USEPA, 2000) and possessed concentrations above the level found by Dodd et al. (0.08 mg/L; 1998) to mark the boundary between mesotrophic and eutrophic concentrations. This suggests that with relation to TP, the Oliver Lake Watershed streams have the ability to be extremely productive or eutrophic.

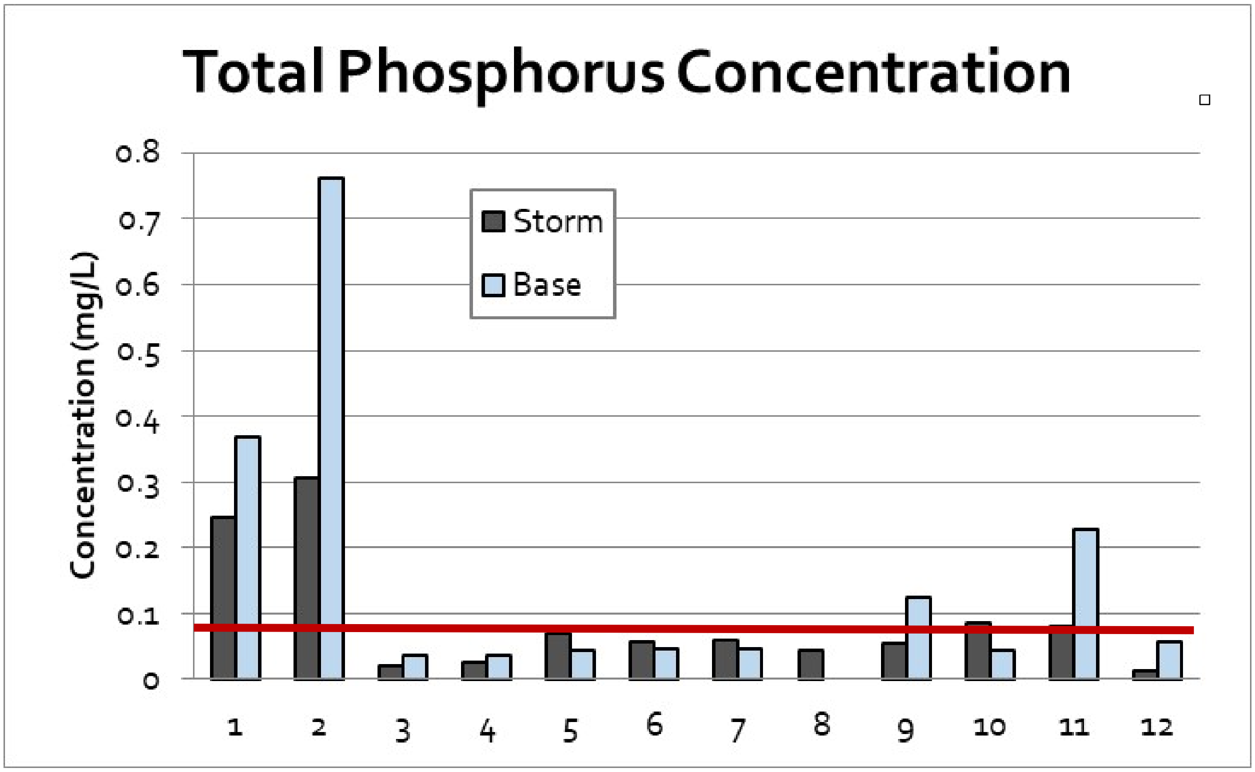


Figure 24. Total phosphorus concentration measurements during base and storm flow sampling of Oliver Lake Watershed streams. The red line indicates the target concentration (0.08 mg/L; Dodds et al., 1998).

Samples from Oliver Lake Watershed streams revealed that during both base and storm flow conditions, the soluble phosphorus fraction measured less than 30% of the total phosphorus concentration in a majority of samples collected. This suggests that most phosphorus loading to Oliver Lake Watershed stream was particulate phosphorus or soil-associated phosphorus rather than dissolved, available phosphorus (Figure 25). In some sites, including Dove Creek (Site 1) during base flow and Bert Hart Ditch (Site 5) during base and storm flow, particulate phosphorus comprised more than 90% of the sample indicating that dissolved, available phosphorus was nearly absent from the sample. Only the Dove Creek tributary (Site 2) and the Oliver Lake Outlet (Site 12) during storm flow contained a soluble phosphorus which measured higher than the particulate portion.

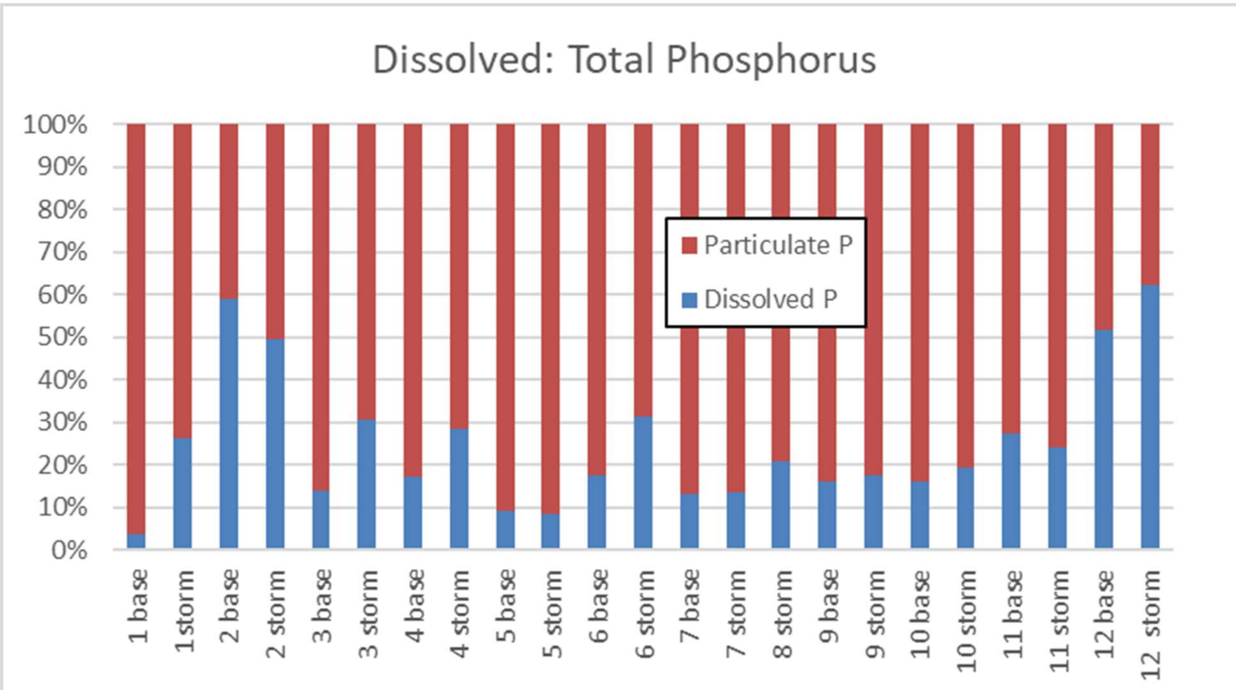


Figure 25. Fraction of dissolved to particulate phosphorus during base and storm flow sampling of Oliver Lake Watershed streams. Note: Site 8 was dry during base flow sampling.

Total Suspended Solids: Total suspended solids (TSS) concentration exceeded target concentrations at all sample sites under both base and storm flow conditions. During base flow conditions, samples collected from Oliver Lake outlet (Site 12) measured the lowest (4.5 mg/L), while Dove Creek (Site 1) exhibited the highest TSS concentration (17.5 mg/L). During storm flow, concentrations ranged from 54 mg/L in the Oliver Lake outlet (Site 12) to 190 mg/L in the Winling Creek north tributary (Site 7). All samples contained TSS concentrations that exceed the concentration found to be deleterious to aquatic life (15 mg/L; Waters, 1995). In total, 57% of samples exceed the target concentration (15 mg/L). Additionally, all sites possessed higher storm flow TSS concentrations than those observed under base flow. Higher overland flow velocities typically result in an increase in sediment particles in runoff. Greater streambank and streambed erosion typically occurs during high flow. Therefore, higher concentrations of suspended solids are typically measured in storm flow samples.

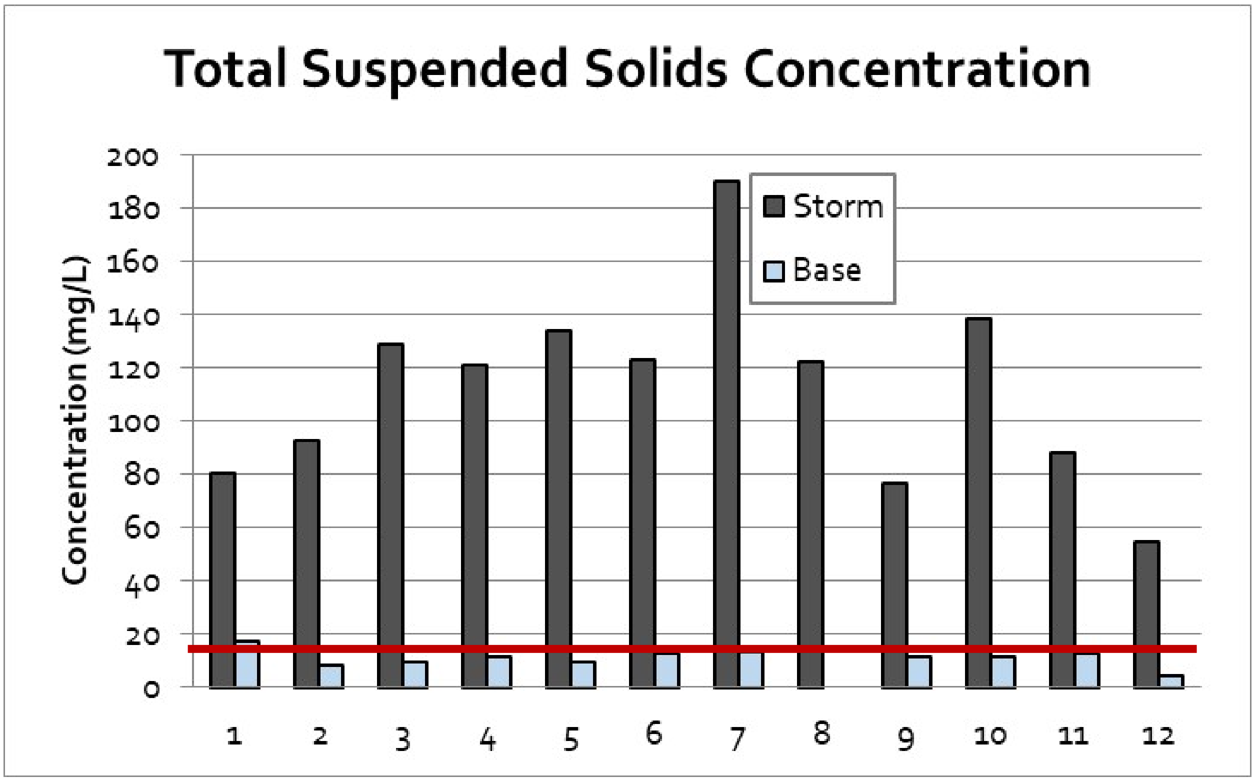


Figure 26. Total suspended solids concentration measurements during base and storm flow sampling of Oliver Lake Watershed streams. The red line indicates the target concentration (15 mg/L; Waters, 1995).

E. coli: Figure 27 displays the *E. coli* concentration data for Oliver Lake Watershed streams. *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 mL) at all sites except Dove Creek (Site 1), Colwell Drain (Site 3) and the Oliver Lake outlet (Site 12) under base flow conditions. Under base flow conditions, concentrations ranged from 3 col/100 mL at the Oliver Lake outlet (Site 12) to greater than 2,420 col/100 mL in the Dove Creek tributary (Site 2) and Truman Flint Ditch (Site 9). The Oliver Lake outlet (Site 12) contained the lowest *E. coli* concentration under storm flow conditions measuring 75 col/100 mL, while Winling Creek (Site 6), Eshelman Drain (Site 10) and Logan Drain (Site 11) measured above the laboratory detection limit (2,420 col/100 mL). In total, 78% of samples exceed state standards. These pathogens may impair biota in the Oliver Lake Watershed and limit human use of the streams. The precise sources of *E. coli* in the Oliver Lake Watershed have not been identified; however, wildlife, livestock, and/or domestic animal defecation; manure-based fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria in this region.

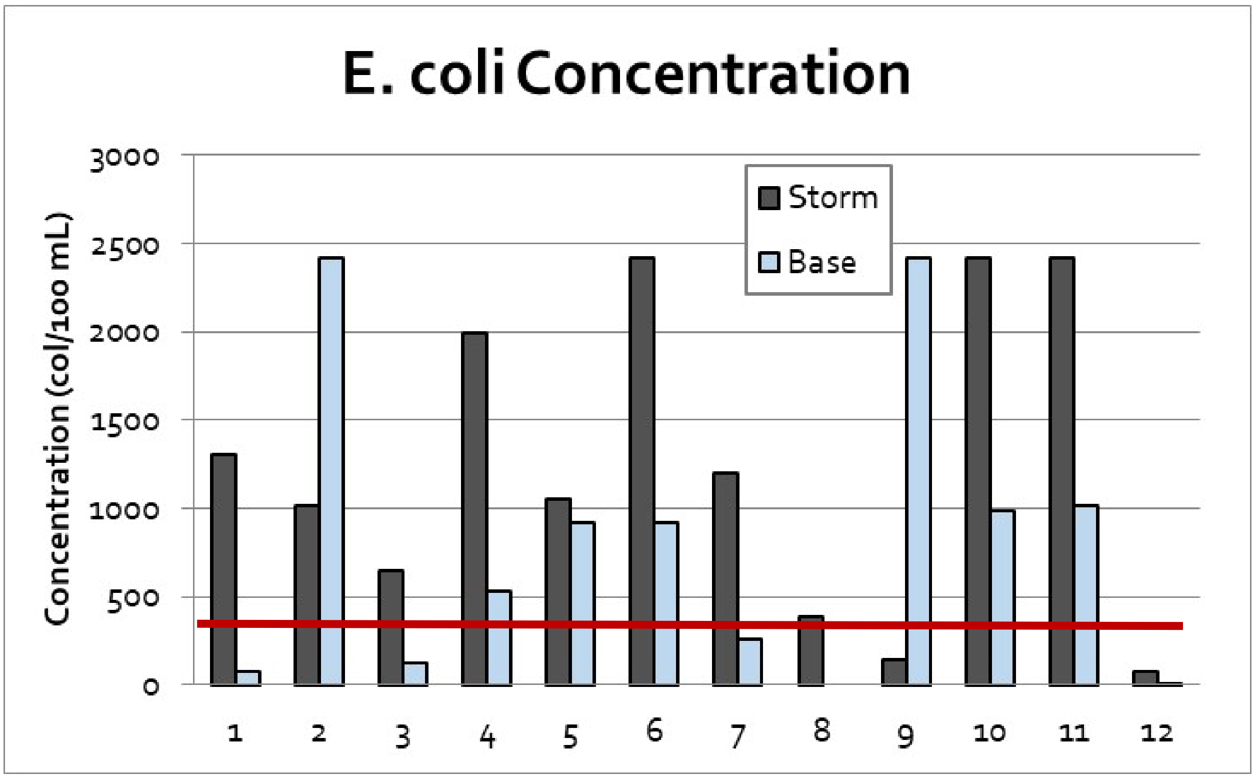


Figure 27. E. coli concentration measurements during base and storm flow sampling of Oliver Lake Watershed streams. The red line indicates the target concentration (235 col/mL; IAC).

Sediment and Chemical Loading

Table 13 lists the chemical and sediment mass loading data for Oliver Lake Watershed streams by site. Figure 28 to Figure 33 present mass loading information graphically. Under base and storm flow conditions, Dove Creek (Site 1) and Oliver Lake outlet (Site 12) generally possessed the greatest loads for all parameters. Dove Creek (Site 1) possesses the highest loading rates for total phosphorus under base and storm flows, the highest orthophosphorus loading rate under storm flow and the second highest loading rates for ammonia and total suspended solids under base and storm flow, the second highest TKN loading rate under storm flow and the second highest loading rate for orthophosphorus under base flow. The Oliver Lake outlet (Site 12) possesses the highest loading rates for TSS, ammonia and total Kjeldahl nitrogen under both base and storm flows, the highest loading rates for nitrate-nitrogen under storm flow and orthophosphorus under base flow as well as the second highest loading rate for total phosphorus under base and storm flow, nitrate under base flow and orthophosphorus under storm flow. Truman Flint Ditch (Site 9) possessed the highest nitrate-nitrogen loading rate under storm flow and the third highest ammonia, total Kjeldahl nitrogen, orthophosphorus and total phosphorus under base flow and the third highest nitrate loading under base flow. Eshelman Drain (Site 10) contained the second highest nitrate and total Kjeldahl nitrogen loading rates under storm flow and the third highest ammonia, orthophosphorus, total phosphorus and total suspended solids under storm flow and the third highest nitrate loading rate under base flow conditions.

Table 13. Sediment and chemical loading data for Oliver Lake Watershed streams. Red highlights the highest loading rates during base and storm flow conditions, while orange highlights the second highest and yellow highlights the third highest loading rates during base and storm flow conditions.

Site Number	Flow Condition	Nitrate Load (kg/yr)	Ammonia Load (kg/yr)	TKN Load (kg/yr)	OP Load (kg/yr)	TP Load (kg/yr)	TSS Load (kg/yr)
1	Base	90.2	63.9	2,271.7	13.5	373.3	17,804.8
	Storm	932.1	398.2	3,102.0	116.2	441.1	143,985.0
2	Base	7.6	0.2	11.7	1.2	2.0	22.7
	Storm	80.5	3.1	109.9	4.1	8.2	2,485.5
3	Base	10.8	1.5	21.2	0.3	2.2	604.7
	Storm	51.0	1.6	84.4	0.3	0.9	5,759.4
4	Base	5.1	0.3	6.4	0.1	0.3	103.5
	Storm	7.0	0.7	11.0	0.1	0.4	2,165.7
5	Base	176.3	1.7	207.0	0.5	5.5	1,214.5
	Storm	388.2	0.0	491.5	0.5	6.3	11,971.0
6	Base	12.2	0.1	13.7	0.1	0.3	80.6
	Storm	671.1	10.3	709.1	3.2	10.3	21,949.9
7	Base	57.7	1.5	64.8	0.2	1.2	364.1
	Storm	100.5	0.5	193.4	0.2	1.6	5,097.8
8	Base	dry					
	Storm	9.8	0.2	22.8	0.1	0.4	1,090.0
9	Base	1,752.2	16.1	2,141.5	4.5	27.6	2,521.2
	Storm	1,003.4	1.3	1,288.3	1.3	7.4	10,299.1
10	Base	253.5	12.0	140.8	1.3	8.6	2,277.6
	Storm	1,593.4	14.2	3,163.7	7.8	40.2	64,414.8
11	Base	4.1	0.2	8.1	0.1	0.4	22.8
	Storm	64.8	0.6	138.4	0.3	1.4	1,577.9
12	Base	615.6	138.8	3,132.0	140.2	273.4	21,386.9
	Storm	3,881.8	483.9	12,831.3	68.4	109.9	470,937.9

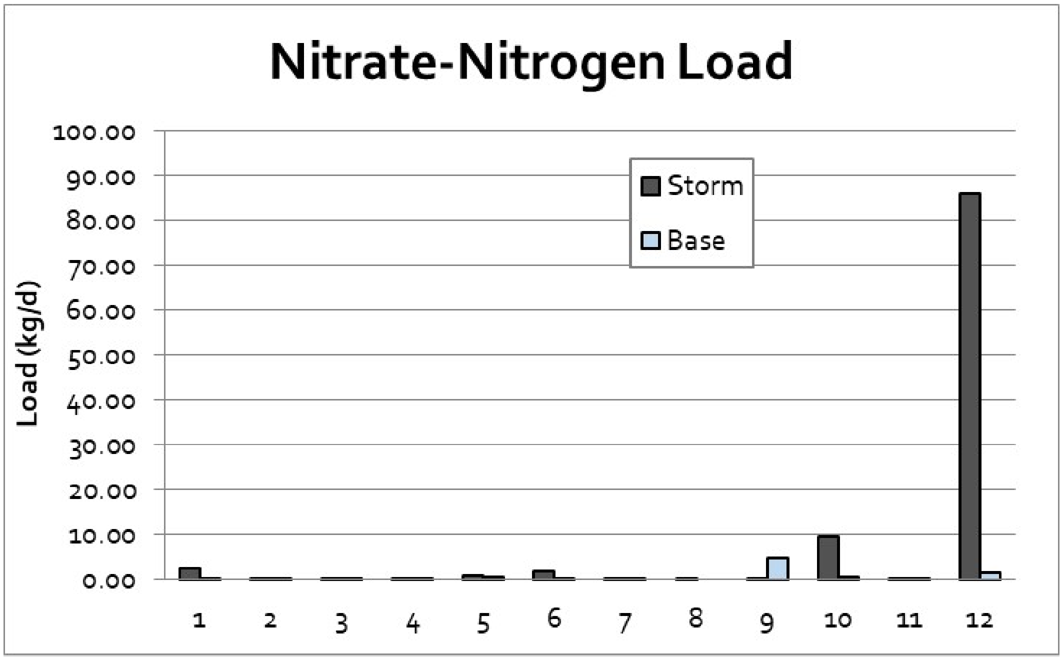


Figure 28. Nitrate-nitrogen loading rates measured during base and storm flow sampling of Oliver Lake Watershed streams.

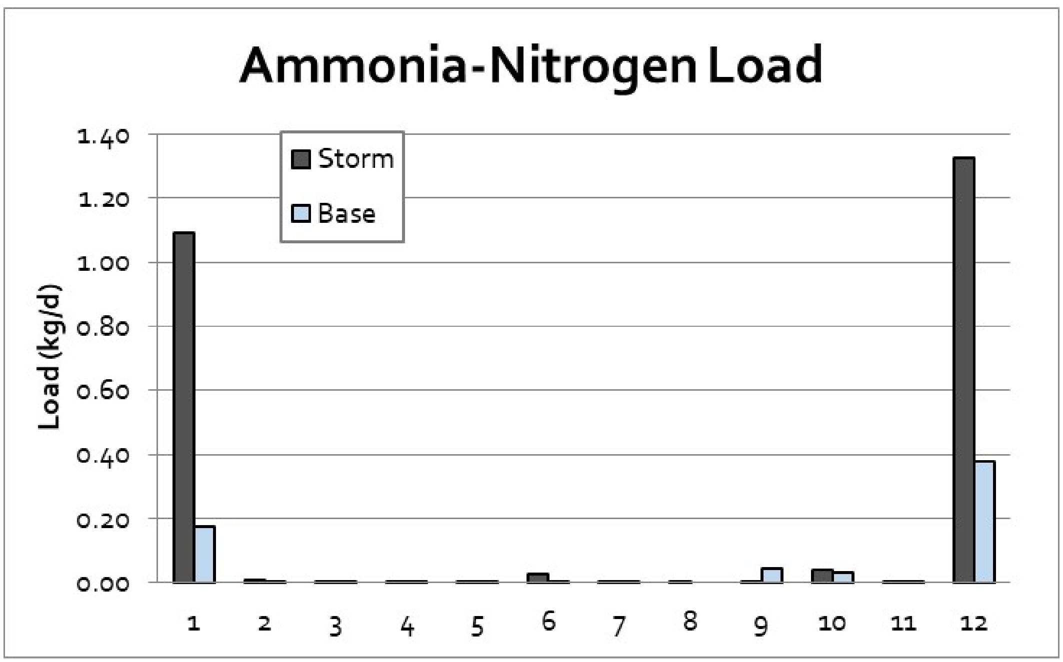


Figure 29. Ammonia-nitrogen loading rates measured during base and storm flow sampling of Oliver Lake Watershed streams.

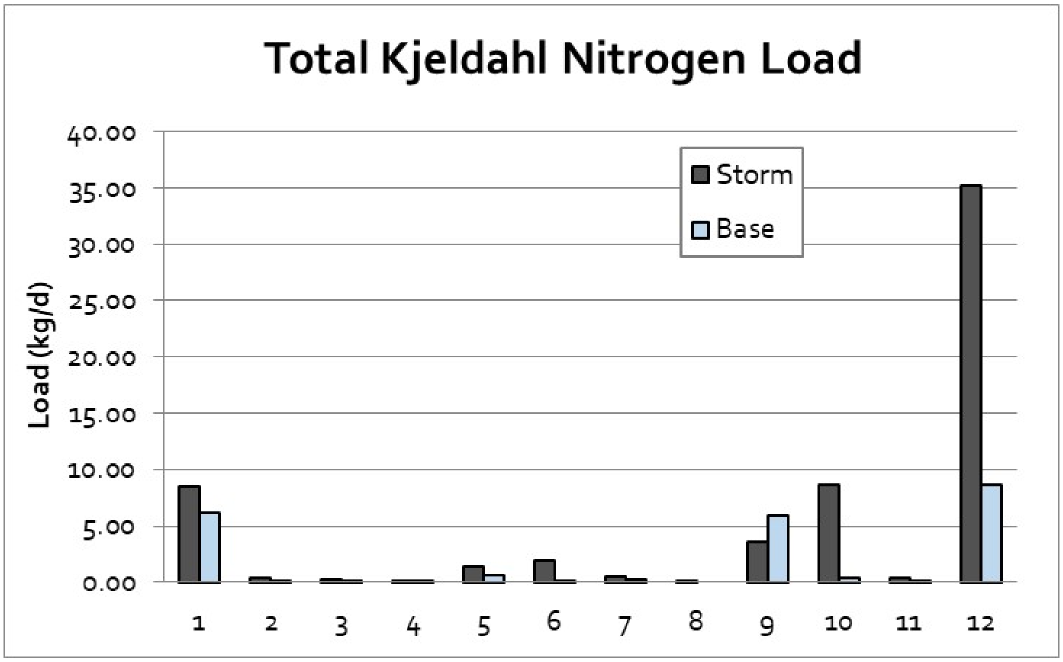


Figure 30. Total Kjeldahl nitrogen loading rates measured during base and storm flow sampling of Oliver Lake Watershed streams.

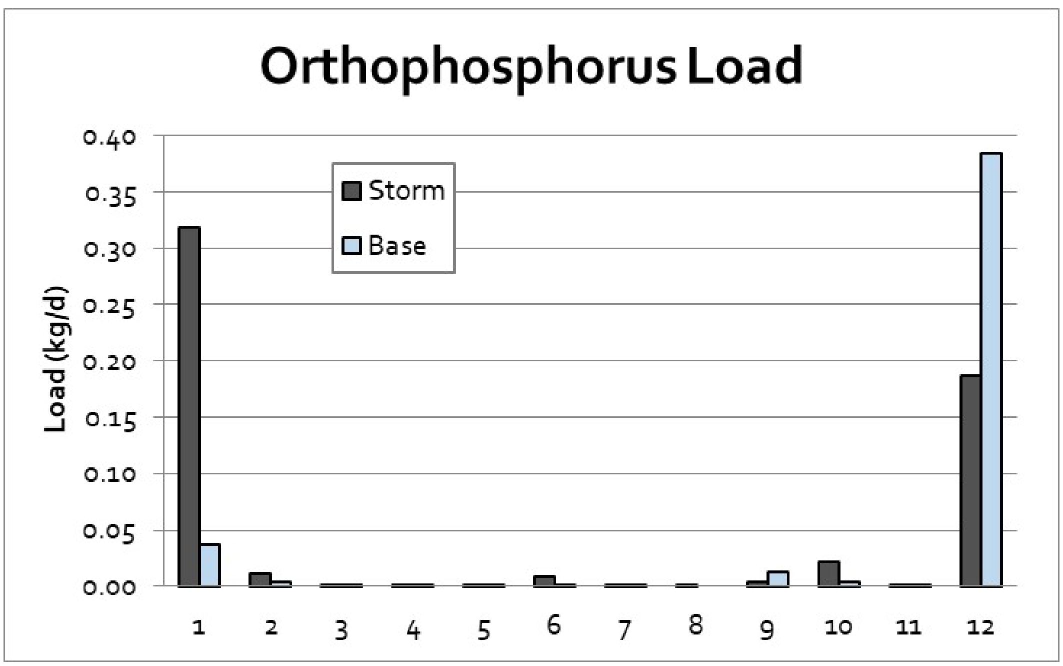


Figure 31. Orthophosphorus loading rates measured during base and storm flow sampling of Oliver Lake Watershed streams.

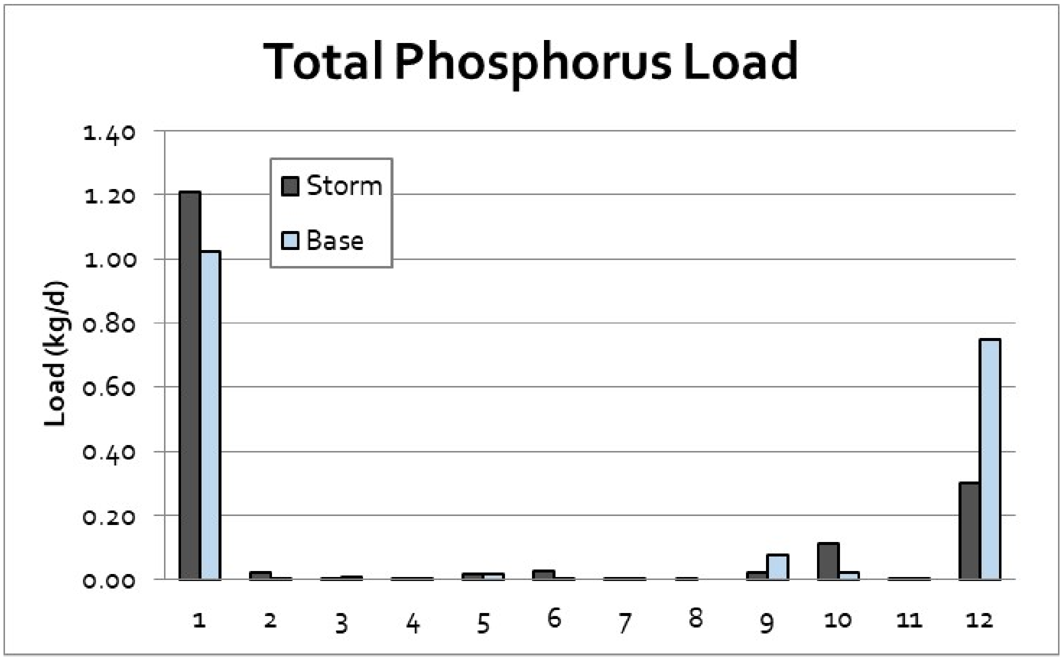


Figure 32. Total phosphorus loading rates measured during base and storm flow sampling of Oliver Lake Watershed streams.

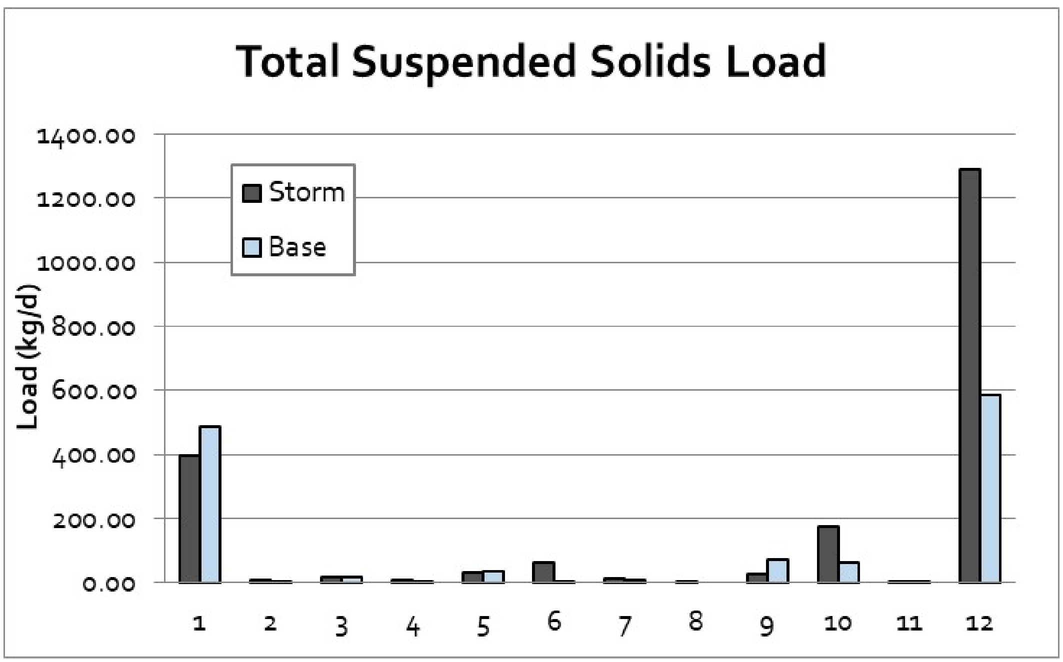


Figure 33. Total suspended solids loading rates measured during base and storm flow sampling of Oliver Lake Watershed streams.

Yield or Areal Loading

In an effort to normalize the nutrient and sediment loading rates, the rates were divided by subwatershed size draining to each sampling site (Table 14). Generally, sediment and nutrient areal loading was lower during base flow conditions than during storm flow conditions for all subwatersheds. The following conclusion can be drawn from these data:

- Dove Creek (Site 1) yields the highest rates per acre of total suspended solids and total phosphorus during base and storm flows; the highest orthophosphorus and ammonia-nitrogen during storm flow; the second highest total Kjeldahl nitrogen during base and storm flow abd second highest ammonia-nitrogen during base flow.
- Truman Flint Ditch (Site 9) yields the highest rates per acre for nitrate-nitrogen and total Kjeldahl nitrogen during storm and base flows; the highest ammonia-nitrogen during base flow; the second highest total phosphorus during base and storm flow, the second highest orthophosphorus and total suspended solids during base flow.
- The Oliver Lake outlet (Site 12) yields the highest loading rate per acres of orthophosphorus during base flow; the second highest orthophosphorus, ammonia-nitrogen and total suspended solids during storm flow; and the third highest total phosphorus and total Kjeldahl nitrogen during storm flow.
- Bert Hart Ditch (Site 5) possessed the second highest nitrate-nitrogen rate per acre under base and storm flow conditions and third highest total Kjeldahl nitrogen and total suspended solids rate per acre under base flow conditions.

Table 14. Areal loading of sediment and nutrients by subwatershed based on base and storm flow sampling events in the Oliver Lake Watershed. Red highlights the highest areal loading rates during base and storm flow conditions, while orange highlights the second highest areal loading rates during base and storm flow conditions.

Site Number	Flow Condition	Nitrate Load (kg/yr-ac)	Ammonia Load (kg/yr-ac)	TKN Load (kg/yr-ac)	Ortho P Load (kg/yr-ac)	Total P Load (kg/yr-ac)	TSS Load (kg/yr-ac)
1	Base	57.7	40.9	1,452.9	8.7	238.7	11,387.6
	Storm	596.2	254.7	1,984.0	74.3	282.1	92,090.3
2	Base	13.5	0.3	20.8	2.1	3.6	40.5
	Storm	143.5	5.5	195.9	7.2	14.6	4,428.3
3	Base	53.0	7.2	104.3	1.4	11.0	2,980.8
	Storm	251.3	8.1	416.0	1.3	4.3	28,388.2
4	Base	106.2	5.5	134.1	1.1	6.5	2,156.8
	Storm	145.5	15.1	228.7	2.6	9.2	45,119.3
5	Base	475.8	4.5	558.7	1.4	14.9	3,277.4
	Storm	1,047.6	0.0	1,326.3	1.4	16.9	32,305.1
6	Base	17.6	0.1	19.8	0.1	0.4	116.5
	Storm	970.0	14.9	1,025.0	4.7	14.9	31,726.9
7	Base	99.0	2.6	111.2	0.3	2.1	624.5
	Storm	172.4	0.9	331.7	0.4	2.7	8,743.5
8	Base	dry					
	Storm	91.9	2.1	214.8	0.8	3.6	10,259.8
9	Base	5,136.5	47.2	6,277.9	13.2	81.0	7,391.0
	Storm	2,941.6	3.8	3,776.8	3.8	21.6	30,192.0
10	Base	129.1	6.1	71.7	0.7	4.4	1,159.9
	Storm	811.5	7.2	1,611.2	3.9	20.5	32,805.8
11	Base	39.9	1.9	78.1	1.1	3.9	220.4
	Storm	624.7	6.0	1,334.7	3.3	13.7	15,218.8
12	Base	84.7	19.1	430.8	19.3	37.6	2,941.4
	Storm	533.9	66.6	1,764.7	9.4	15.1	64,769.0

4.2.3 Water Chemistry Summary

In general, physical and chemical parameter data collected from streams in the Oliver Lake Watershed indicate the potential for water quality degradation when compared with ideal conditions. E. coli, total Kjeldahl nitrogen and total suspended solids concentrations were elevated during base and storm flow conditions. Total Kjeldahl nitrogen concentrations measured above EPA target concentrations for all watershed samples except one. However, it should be noted that EPA targets are relatively low when compared with concentrations across the state.

Nitrate-nitrogen concentrations measured relatively normal for Indiana streams. Dove Creek tributary (Site 2), Bert Hart Ditch (Site 5), Winling Creek (Site 6), Winling Creek north tributary (Site 7), Truman Flint Ditch (Site 9), Eshelman Drain (Site 10) and Logan Drain (Site 11) exceeded target concentrations under base and storm flow conditions. This suggests that nitrate-nitrogen is loaded to the system under all flow conditions at these sites. Additionally, all sites contained total suspended solids concentrations that exceeded the target concentration (15 mg/L) during storm flow conditions and in Dove Creek (Site 1) under base flow conditions. This indicates sediment concentrations may be elevated in Oliver Lake Watershed streams, especially under storm flow conditions.

E. coli concentrations exceeded state standards at all sites during base and storm flow conditions except at Oliver Lake outlet (Site 12). Both the base and storm flow *E. coli* levels met state standards at Site 12. The Dove Creek tributary (Site 2) and Truman Flint Ditch (Site 9) exceeded the maximum laboratory concentration under base flow, while Winling Creek (Site 6), Eshelman Drain (Site 10) and Logan Drain (Site 11) exceeded the maximum laboratory concentration under storm flow conditions. This suggests the Dove Creek tributary (Site 2) and Truman Flint Ditch (Site 9) have continuous sources of E. coli as evidenced by their elevated concentrations under base flow conditions. Conversely, Winling Creek (Site 6), Eshelman Drain (Site 10) and Logan Drain (Site 11) have E. coli sources that occur under storm flow conditions. E. coli is an issue across the Oliver Lake Watershed with 78% of samples exceeding the state standard.

In particular, Dove Creek tributary (Site 2) generally possessed the poorest water quality when compared to other sites when concentrations are considered. During storm and base flow, Dove Creek tributary (Site 2) possessed elevated orthophosphorus and total phosphorus, nitrate-nitrogen and total Kjeldahl nitrogen, total suspended solids and E. coli. Truman Flint Ditch (Site 9) possessed extremely elevated nitrate-nitrogen and total Kjeldahl nitrogen concentrations under base and storm flow conditions with nitrate-nitrogen approaching the state standard for drinking water under both base and storm flow conditions (10 mg/L) suggesting that there is always as source of nitrogen within this watershed.

Under base and storm flow conditions, Dove Creek (Site 1) and Oliver Lake outlet (Site 12) generally possessed the greatest loads for all parameters. Dove Creek (Site 1) possesses the highest loading rates for total phosphorus under base and storm flows, the highest orthophosphorus loading rate under storm flow and the second highest loading rates for ammonia and total suspended solids under base and storm flow, the second highest TKN loading rate under storm flow and the second highest loading rate for orthophosphorus under base flow. The Oliver Lake outlet (Site 12) possesses the highest loading rates for TSS, ammonia and total Kjeldahl nitrogen under both base and storm flows, the highest loading rates for nitrate-nitrogen under storm flow and orthophosphorus under base flow as well as the second highest loading rate for total phosphorus under base and storm flow, nitrate under base flow and orthophosphorus under storm flow. Truman Flint Ditch (Site 9) possessed the highest nitrate-nitrogen loading rate under storm flow and the third highest ammonia, total Kjeldahl nitrogen, orthophosphorus and total phosphorus under base flow and the third highest nitrate loading under base flow. Eshelman

Drain (Site 10) contained the second highest nitrate and total Kjeldahl nitrogen loading rates under storm flow and the third highest ammonia, orthophosphorus, total phosphorus and total suspended solids under storm flow and the third highest nitrate loading rate under base flow conditions.

While some subwatersheds per unit area delivered low nutrient and sediment loads, others delivered significant loads of the parameters particularly during the storm event. Dove Creek (Site 1) yields the highest rates per acre of total suspended solids and total phosphorus during base and storm flows; the highest orthophosphorus and ammonia-nitrogen during storm flow; the second highest total Kjeldahl nitrogen during base and storm flow and second highest ammonia-nitrogen during base flow. Truman Flint Ditch (Site 9) yields the highest rates per acre for nitrate-nitrogen and total Kjeldahl nitrogen during storm and base flows; the highest ammonia-nitrogen during base flow; the second highest total phosphorus during base and storm flow, the second highest orthophosphorus and total suspended solids during base flow. The Oliver Lake outlet (Site 12) yields the highest loading rate per acres of orthophosphorus during base flow; the second highest orthophosphorus, ammonia-nitrogen and total suspended solids during storm flow; and the third highest total phosphorus and total Kjeldahl nitrogen during storm flow. Bert Hart Ditch (Site 5) possessed the second highest nitrate-nitrogen rate per acre under base and storm flow conditions and third highest total Kjeldahl nitrogen and total suspended solids rate per acre under base flow conditions.

4.3 <u>Macroinvertebrate Assessment</u>

4.3.1 Macroinvertebrate Methods

Data from macroinvertebrate sampling at Oliver Lake Watershed streams and the reference site (Sand Lake inlet at CR 200 East in Chain of Lakes State Park) were used to calculate a macroinvertebrate index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The macroinvertebrate community composition reflects water quality. Research shows that different macroinvertebrate orders and families react differently to pollution sources. Thus, indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995).

Macroinvertebrates were collected during base flow conditions on September 24, 2024 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the IDNR LARE macroinvertebrate sample collection and index calculation protocol. Organisms were identified to the genus level.

Macroinvertebrate data were used to calculate the modified Hilsenhoff Biotic Index (HBI). The HBI uses the macroinvertebrate community to assess the level of organic pollution in a stream. The HBI is based on the premise that different families of aquatic insects possess different tolerance levels to organic pollution. Hilsenhoff assigned each aquatic insect family a tolerance value from 1 to 10; those genera with lower tolerances to organic pollution were assigned lower values, while those families that were more tolerant of organic pollution were assigned higher values. Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). Benthic communities dominated by organisms that are tolerant of organic pollution will exhibit higher HBI scores compared to benthic communities dominated by intolerant organisms.

In addition to the HBI, macroinvertebrate results were analyzed using the IDNR LARE scoring criteria (IDNR, 2013). IDNR's mIBI is a multi-metric (8 metrics) index designed to provide a complete assessment of a stream's biological integrity. Karr and Dudley (1981) define biological integrity as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization compared to the best natural habitats within the region". Metrics include number of taxa; *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) Index, percent dominant taxa, ratio of EPT to *Chironomidae*, ratio of scrapers to filtering collectors, ratio of shredders to total, community loss index, and the modified HBI. Each metric is scored as detailed in Table *15*. Cumulative mIBI scores for each site are then compared with the mIBI score calculated for the reference site and the biological condition assigned as detailed in Table 16.

Table 15. mIBI metric scoring criteria for genus level identification.

Metric	**6**	**4**	**2**	**0**
Number of taxa	>80%	60-80%	40-60%	<40%
EPT Index	>90%	80-90%	70-80%	<70%
Percent dominant taxa	<20%	20-30%	30-40%	>40%
Ratio EPT: *Chironomid* Abundance	>75%	50-75%	25-50%	<25%
Modified Hilsenhoff Biotic Index	>85%	70-85%	50-70%	<50%
Ratio of Scrapers: Filter/Collectors	>50%	35-50%	20-35%	<20%
Ratio Shredders: Non-shredders	>50%	35-50%	20-35%	<20%
Community Loss Index (CLI)	<0.5	0.5-1.5	1.5-4.0	>4.0

Table 16. Biological condition category resulting from comparison of stream site data with reference site data.

Percent Comparison to Reference	**Biological Condition Category**
>83%	Non-impaired
54-79%	Slightly impaired
21-50%	Moderately impaired
<17%	Severely impaired

4.3.2 Macroinvertebrate Results

Dove Creek (Site 1) supported a more diverse community than other sites in the Oliver Lake Watershed with two Ephemeroptera, Plecoptera or Tricholoptera (EPT) taxa observed (Figure 34, Table 17) and scored as slightly impaired. The remaining sites contained minimal to no EPT individuals. The Dove Creek tributary (Site 2) contained only six total taxa and scored as severely impaired. All sites contained moderately pollution tolerant communities, which resulted in all sites scoring as to severely impaired. Dove Creek (Site 1), Dove Creek tributary (Site 3), unnamed tributary (Site 4) and Eshelman Drain (Site 10 rated as slightly impaired, Bert Hart Ditch (Site 5), Winling Creek (Site 6), the Winling Creek north tributary (Site 7), Stoner Ditch (Site 8) and Truman Flint Ditch (Site 9) rated as moderately impaired while the Dove Creek tributary (Site 2) rated as severely impaired. Appendix B details the macroinvertebrate species collected at each sample site. Most indices of biotic integrity are developed to ensure that there is a statistically significant difference between impairment categories (Karr and Chu, 1999). As such, the macroinvertebrate survey results suggest there is only a minimal difference between the biological integrity of the macroinvertebrate communities which rate as slightly impaired while there is significant difference between those rated as slightly impaired to those which rate as moderately impaired and to those which rate as severely impaired.

Table 17. Metric classification scores and mIBI score for the Oliver Lake Watershed sample sites as sampled September 24, 2024. Category classification: slight(SL); moderate (M); severe (SEVE).

Metric Scores	1	2	3	4	5	6	7	8	9	10	Ref
Taxa Richness	4	0	2	6	2	4	4	4	4	2	6
HBI	4	4	6	6	6	6	6	6	4	4	6
Scrapers/Filterer-Collectors	0	0	0	0	0	0	0	0	0	6	6
EPT/Chironomids	6	0	0	0	0	0	0	0	0	0	6
% Dominant Taxa	2	0	0	0	0	4	2	0	4	0	0
EPT Index	6	0	4	0	2	0	0	0	0	2	6
CLI	4	2	4	4	2	4	4	4	4	2	6
Shredders/Total	4	0	6	6	0	0	0	0	0	6	6
Total Score	**30**	**6**	**22**	**22**	**12**	**18**	**16**	14	16	22	42
Percent of Reference	71	14	52	52	29	43	38	33	38	52	
Category	SL	SEVE	SL	SL	M	M	M	M	M	SL	

SL=Slightly impaired, M=Moderately impaired; SEVE=Severely impaired

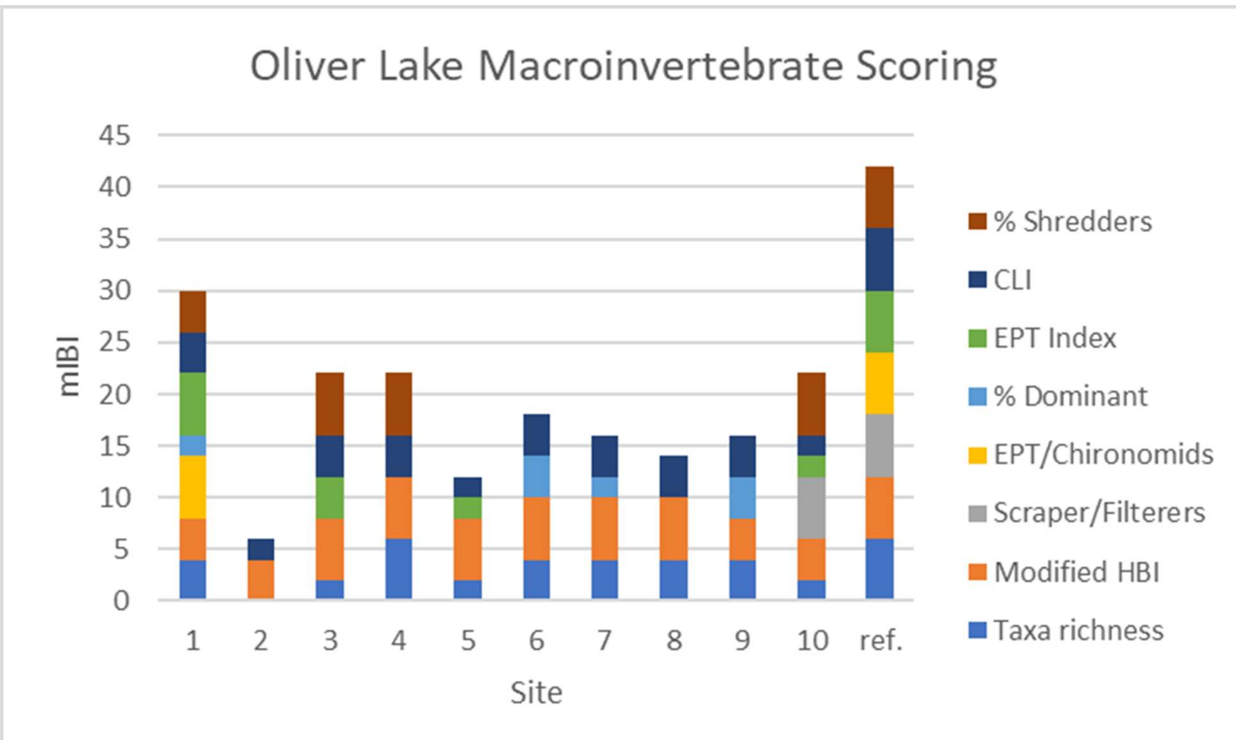


Figure 34. Cumulative metrics used to calculate mIBI scores for Oliver Lake Watershed streams.

When the macroinvertebrate communities at each sampling site are evaluated using the Hilenshoff Biotic Index (HBI), the HBI scores generally reflect the relative similarities in macroinvertebrate communities detailed above (Table 18). Sites were rated as fair (Bert Hart Ditch (Site 5), and Truman Flint Ditch (Site 9)), fairly poor (Dove Creek tributary (Site 3) and unnamed tributary (Site 4)), poor (Winling Creek (Site 6), the Winling Creek north tributary (Site 7), Stoner Ditch (Site 8) and Truman Flint Ditch (Site 9)) or very poor (Dove Creek (Site 1) and Dove Creek tributary (Site 2)). These results do not coincide with the mIBI score noted above where there is difference in mIBI scores between sites. Many sites were dominated by Amphipod species, which are ubiquitous to Indiana streams. Dove Creek (Site 1) possessed a better EPT/Chironomid score, while Eshelman Drain (Site 10) possessed better scraper to filterer/collector ratios than other sites. The unnamed tributary (Site 4) possessed better taxa richness than other sites. It is important to note that although possessing a low HBI value, Eshelman Drain (Site 10) does not reflect a higher abundance of sensitive groups. Similarly, a higher HBI value for Dove Creek (Site 1) is not conclusive as the site possesses a greater abundance of EPT individuals.

Table 18. HBI scores for Oliver Lake Watershed streams.

Site	Modified HBI	Rating
1	7.88	Very Poor: severe organic pollution
2	7.30	Very Poor: severe organic pollution
3	5.89	Fairly Poor: Significant organic pollution
4	5.98	Fairly Poor: Significant organic pollution
5	5.47	Fair: fairly substantial pollution
6	6.96	Poor: very substantial pollution
7	6.86	Poor: very substantial pollution
8	6.82	Poor: very substantial pollution
9	7.19	Poor: very substantial pollution
10	5.24	Fair: fairly substantial pollution
Ref	6.09	Fairly Poor: Significant organic pollution

4.4 <u>Habitat Assessment</u>

4.4.1 Habitat Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the stream and riparian zone habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates; amount and quality of instream cover; channel morphology; extent and quality of riparian vegetation; pool, run, and riffle development and quality; and gradient are some of the metrics used to determine the QHEI score. The QHEI score ranges from 20 to 100.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Small particles of soil and organic matter will settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

Instream cover, another metric of the QHEI, represents the type(s) and quantity of habitat provided within the stream itself. Examples of instream cover include woody logs and debris, aquatic and overhanging vegetation and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity and other factors that represent the stability and direct modification of the site are evaluated to comprise this metric score.

A wooded riparian buffer is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. According to the Ohio EPA (1999), riparian zones govern the quality of goods and services provided by riverine ecosystems. Riparian zone and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of bank erosion, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation does not offer as much infiltration potential as woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989).

The fifth QHEI metric evaluates the quality of pool/glide and riffle/run habitats in the stream. These zones in a stream, when present, provide diverse habitat and in turn can increase habitat quality and availability. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high gradients will have negative effects on habitat quality and the biota in the stream. Moderate gradients receive the highest score, 10, for this metric. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar.

QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1999). IDEM indicates that QHEI scores above 64 suggest the habitat is capable of supporting a balanced warmwater community; scores between 51 and 64 are only partially supportive of a stream's aquatic life use designation, while scores less than 51 are deemed non-supporting the stream's aquatic life use designation (IDEM, 2000).

4.4.2 Habitat Results

Table 19 lists and Figure 35 details the QHEI scores for the Oliver Lake Watershed sites. Habitat assessment occurred concurrent with macroinvertebrate sample collection occurring September 24, 2024. Based on the Oliver Lake Watershed QHEI assessments, Eshelman Drain (Site 10) scored the highest (39) but still rated as poor. The remaining sites rated as poor or very poor with Stoner Ditch (Site 8) scoring the lowest (21.5 points). Moderately stable substrate, fair channel development, no channelization, moderate silt and extensive embeddedness characterize Eshelman Drain (Site 10). Heavily embedded substrate, poor channel morphology, poor instream and canopy cover, lack of well-developed channel morphology and lack of pools and riffles and low stream gradients characterize the available habitat at most of the other sites. The majority of low QHEI scores suggest that most of the Oliver Lake Watershed stream reaches may not be capable of supporting healthy aquatic communities. This is not surprising as nearly all Oliver Lake Watershed streams are legal drains and are maintained to move water rather than provide habitat. Appendix C documents QHEI details.

Table 19. QHEI scores for Oliver Lake Watershed sample sites.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total	Rating
1	5	9	6	4.5	8	0	2	34.5	Poor
2	9	5	9	8	4	0	2	37	Poor
3	10	5	4	15	4	0	2	26.5	Very Poor
4	9	6	4.5	5.5	4	0	2	31.5	Poor
5	10.5	3	11	9	4	0	3	38.5	Poor
6	9	3	5	5.5	4	0	2	28.5	Very Poor
7	10	3	7	2	4	0	2	28	Very Poor
8	8	2	5	1.5	3	0	2	21.5	Very Poor
9	10	7	5	4	5	0	2	34	Poor
10	11	5	14	3	4	0	2	39	Poor

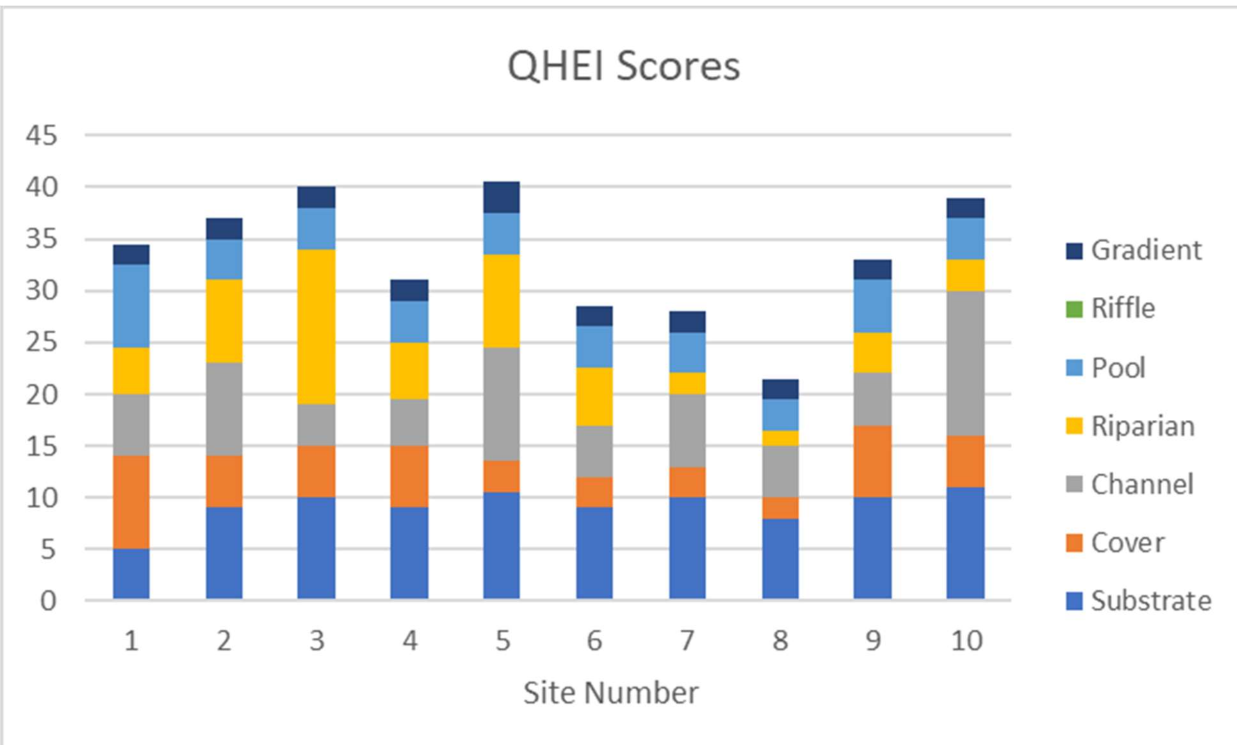


Figure 35. QHEI scores for Oliver Lake Watershed sample sites sampled during the macroinvertebrate community assessment.

4.5 Biological Community and Habitat Site Discussion

Dove Creek (Site 1): Dove Creek scored 34.5 out of a possible 100 points, rating as poor. Substrate composition at this site was predominately silt, with muck, detritus, and artificial substrate also present. Silt cover was heavy, while substrate embeddedness was extensive. Instream conditions were sparse with aquatic macrophytes and logs/woody debris present. Pools of greater than 1 meter depth, slow current, and lack of riffles characterizes this site (Figure 36). The site was surrounded by residential/park/new field. The riparian zone measured very narrow in width on one side of the streambank and moderate in width on the other streambank. Heavy to moderate erosion was observed on either side of the streambank. Channel stability was low. No sinuosity and poor development were observed in the stream reach with signs of channelization recovery. The mIBI score for this site was 30 scoring 71% of the reference site in the Chain of Lakes State Park indicating that the stream is "slightly impaired." Low taxa richness, low abundance of EPT taxa, and low numbers of scrapers and filterers characterize the macroinvertebrate community in this reach.

Figure 36. Site 1 sampling location at Dove Creek.

Dove Creek tributary (Site 2): This site received a QHEI score of 37 of a possible 100 rating as poor. The substrate composition at the site was primarily sand, with detritus, muck, and silt also present. Substrate embeddedness was extensive, and silt was heavy. This stream reach was dredged or cleaned by the County Surveyors Office as routine maintenance practices in 2017 (personal observation). Significant overhanging, herbaceous vegetation provided some canopy cover where instream cover of aquatic macrophytes and logs/woody debris was sparse. The site was surrounded by forest/swamp on one side and shrub/old field on the other side. The stream had poor sinuosity and there was limited evidence of a recovering channelization (Figure 37). The riparian zone ranged from wide on one side to moderate width on the other streambank. Both stream banks were moderately eroded. Pool depth was shallow and riffles were absent. Low taxa richness, absence of EPT taxa, and high percent dominant taxa characterize the macroinvertebrate community in this reach. The mIBI score was 6, scoring 14% of the reference site, indicating this site was "severely impaired".

Figure 37. Site 2 sampling location on Dove Creek tributary.

Dove Creek tributary (Site 3): This site scored 26.5 of a possible 100 points rating as very poor. Sand and gravel dominated the substrate, with detritus, artificial substrate, and silt also present. Silt levels were heavy to moderate with extensive to moderate levels of embeddedness. Overhanging vegetation and shallows provided sparse levels of instream cover. Riffles and pools were shallow. The stream possessed no sinuosity with observed evidence of recent channelization (Figure 38). The riparian buffer was absent with heavy to moderate erosion on both sides of the streambank. The site was mainly surrounded by row crop/open pasture. The stream is considered to be "slightly impaired" with an mIBI score of 22, which rated 52% of the reference site's score. Moderate taxa richness, poor EPT/Chironomid score, high percent of shredders and the absence of scrapers and filterers characterize the macroinvertebrate community in this reach.

Figure 38. Site 3 sampling location on Dove Creek tributary.

Unnamed tributary (Site 4): Site 4 received a QHEI score of 31.5, rating as poor. Sand dominated the substrate with gravel, artificial substrate, muck, detritus and silt also present. The substrate possessed moderate embeddedness with moderate levels of silt cover. Instream cover present in sparse levels include overhanging vegetation, shallows, and logs/woody debris (Figure 39). Little to no bank erosion was present throughout the reach, with low channel stability. Stream sinuosity was low to none with shallow pools and riffles present. The riparian buffer was very narrow with shrub/old field adjacent to one streambank, and residential/park/new field adjacent to the other streambank. The mIBI score (22) indicated that the macroinvertebrate community was slightly impaired, rating 52% of the reference site's score. High taxa richness, low number of EPT taxa, high percent of shredders, low numbers of scrapers and filterers, and high dominance by one species characterize the macroinvertebrate community in this reach.


Figure 39. Site 4 sampling location on unnamed tributary.

Bert Hart Ditch (Site 5): Site 5 received a QHEI score of 38.5, rating as poor. Sand and gravel dominated the substrate with silt also present. The substrate possessed extensive embeddedness with heavy to moderate levels of silt cover. Instream cover present in nearly absent levels include overhanging vegetation and logs/woody debris (Figure 22). Little to no bank erosion was present throughout the reach, with moderate channel stability. Stream sinuosity was low with shallow pools and no riffles present. The riparian buffer was wide with open pasture/row crop adjacent to both streambanks. The mIBI score (12) indicated that the macroinvertebrate community was moderately impaired, rating 29% of the reference site's score. Low taxa richness, low number of EPT taxa, low percent of shredders, low numbers of scrapers and filterers, and high dominance by two species characterize the macroinvertebrate community in this reach.

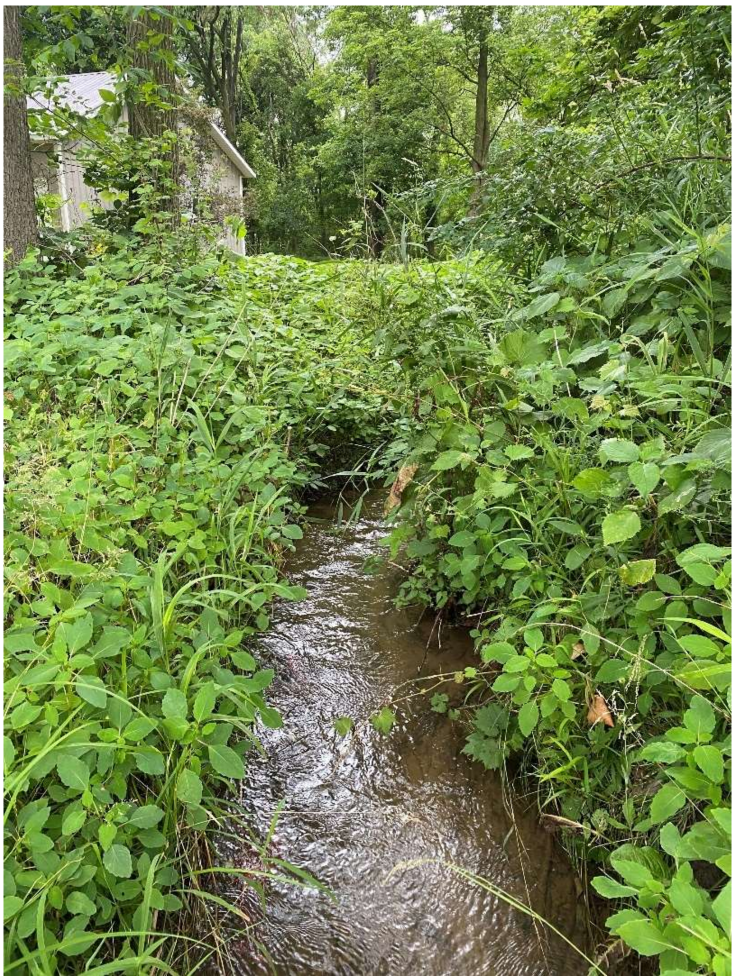


Figure 22. Site 5 sampling location on Bert Hart Ditch.

Winling Creek (Site 6): Site 6 received a QHEI score of 28.5, rating as very poor. Sand dominated the substrate with artificial substrate, muck, detritus and silt also present. The substrate possessed extensive embeddedness with heavy levels of silt cover. Instream cover present in nearly absent levels include overhanging vegetation and shallows (Figure 23). Moderate erosion was present throughout the reach, with low channel stability. Stream sinuosity was low with shallow pools and riffles present. The riparian buffer was narrow with shrub/old field adjacent to one streambank, and residential/park/new field adjacent to the other streambank. The mIBI score (18) indicated that the macroinvertebrate community was moderately impaired, rating 43% of the reference site's score. Moderate taxa richness, absence of EPT taxa, absence of shredders and low numbers of scrapers and filterers characterize the macroinvertebrate community in this reach.

Figure 23. Site 6 sampling location on Winling Creek.

Winling Creek north tributary (Site 7): Site 6 received a QHEI score of 28, rating as very poor. Sand dominated the substrate with artificial substrate and silt also present. The substrate possessed extensive embeddedness with moderate levels of silt cover. Instream cover present in nearly absent levels include overhanging vegetation and shallows (Figure 24). Moderate bank erosion was present throughout the reach, with low channel stability. Stream sinuosity was low with shallow pools and riffles present. No riparian buffer was present with open pasture/row crop adjacent to both streambanks. The mIBI score (16) indicated that the macroinvertebrate community was moderately impaired, rating 38% of the reference site's score. Moderate taxa richness, absence of EPT taxa, absence of shredders, low numbers of scrapers and filterers, and high dominance by one species characterize the macroinvertebrate community in this reach.

Figure 24. Site 7 sampling location on Winling Creek north tributary.

Stoner Ditch (Site 8): Site 8 received a QHEI score of 21.5, the lowest habitat score, rating as very poor. Muck dominated the substrate with detritus and sand also present. The substrate possessed extensive embeddedness with heavy levels of silt cover. Instream cover present in nearly absent levels includes overhanging vegetation (Figure 25). Heavy bank erosion was present throughout the reach, with low channel stability. Stream sinuosity was low with shallow pools and no riffles present. The riparian buffer was very narrow to none with open pasture/row crop adjacent to each streambank. The mIBI score (14) indicated that the macroinvertebrate community was moderately impaired, rating 33% of the reference site's score. Moderate taxa richness, absence of EPT taxa, absence of shredders, low numbers of scrapers and filterers, and high dominance by one species characterize the macroinvertebrate community in this reach.

Figure 25. Site 8 sampling location on Stoner Ditch.

Truman Flint Ditch (Site 9): Site 9 received a QHEI score of 34, rating as poor. Sand and gravel dominated the substrate with artificial substrate, detritus and silt also present. The substrate possessed extensive embeddedness with extensive levels of silt cover. Instream cover present in sparse levels include overhanging vegetation, shallows, aquatic macrophytes and logs/woody debris (Figure 26). Moderate bank erosion was present throughout the reach, with low channel stability. Stream sinuosity was low, with shallow pools and riffles present. The riparian buffer was narrow with open pasture/row crop adjacent to each streambank. The mIBI score (16) indicated that the macroinvertebrate community was moderately impaired, rating 38% of the reference site's score. Moderate taxa richness, low number of EPT taxa, absence of shredders, and low numbers of scrapers and filterers characterize the macroinvertebrate community in this reach.

Figure 26. Site 9 sampling location on Truman Flint Ditch.

Eshelman Drain (Site 10): Site 10 received a QHEI score of 39, the highest habitat score, rating as poor. Sand and gravel dominated the substrate with detritus and silt also present. The substrate possessed extensive embeddedness with moderate levels of silt cover. Instream cover present in sparse levels include overhanging vegetation and logs/woody debris (Figure 27). Moderate bank erosion was present throughout the reach, with low channel stability. Stream sinuosity was moderate with shallow pools and riffles present. The riparian buffer was very narrow with open pasture/row crop adjacent to each streambank. The mIBI score (22) indicated that the macroinvertebrate community was slightly impaired, rating 52% of the reference site's score. Low taxa richness, low number of EPT taxa, high percent of shredders, moderate numbers of scrapers and filterers, and high dominance by one species characterize the macroinvertebrate community in this reach.

Figure 27. Site 10 sampling location on Eshelman Drain.

4.6 <u>Biological and Habitat Discussion</u>

The overall evaluation of biotic health and habitat quality in the Oliver Lake Watershed indicates that stream sites are slightly to moderately degraded (Table 20). Many of the sites lacked at least one of the key elements of natural, healthy stream habitats. These missing key elements limit the functionality of these systems. The QHEI evaluations generally reflected absent or limited pool and riffle development in watershed streams. Moderate channel alterations and minimal riparian buffer zones at most sites reduce streams' resilience to agricultural runoff. These factors are critical for habitat diversity and biological integrity in the stream ecosystems. Further, instream cover is absent or limited at almost all sites.

Table 20. Biological and habitat assessment summary for Oliver Lake Watershed streams. Green shading indicates the highest rated stream reaches, while red indicates the poorest rated reaches.

Site	mIBI	QHEI
1	Slightly Impaired	Poor
2	Severely Impaired	Poor
3	Slightly Impaired	Very Poor
4	Slightly Impaired	Poor
5	Moderately Impaired	Poor
6	Moderately Impaired	Very Poor
7	Moderately Impaired	Very Poor
8	Moderately Impaired	Very Poor
9	Moderately Impaired	Poor
10	Slightly Impaired	Poor

Moderate to heavy sediment loading was an apparent factor in the degradation of substrate quality in the headwaters of the study streams. Nearly all sites have experienced moderate to heavy silt sedimentation levels. Moderate to extensive substrate embeddedness severely limits habitat diversity within these stream channels by filling in and closing off porous areas that offer refuge for a variety of aquatic organisms. This heavy sediment loading is reflected in the poor substrate scores of the QHEI evaluation. The range of substrate scores was five to 11 out of a possible 20 in these sites. The direct supply of sediment transport typically originates from the streambed and bank (Richards, 1982). Most sites show at moderate to heavy bank erosion; therefore, a source of silt and sediment could be autochthonous (originating from within the stream), stressing the importance of bank stability. Further, the surrounding land use most likely plays a role in the dominant contribution of allochthonous (originating from outside the stream) sources of sediment loading. Row crop agriculture and pastured land, the predominant land uses throughout the watershed, are typical sources of sediment and sediment-attached pollutants.

Typically, in watersheds in northern Indiana, stream channel morphology is greatly jeopardizing the integrity of the biological communities. Pool development and quality are determined by the sorting of particles in that stream reach. Pools provide deeper areas with slower velocity for various macroinvertebrates, diversifying habitat. The lack of deep pool development is likely associated with land use alterations and the activity of increased erosion and siltation of the streambed, which then interferes with typical sorting of particles that form both riffles and pools (Allan, 1995).

Another important aspect of good habitat quality that is lacking from most of the sites is an effective riparian zone to buffer stream systems from the surrounding land use. Stable, woody vegetation zones that naturally form adjacent to streams and other waterways provide distinct functions that enhance habitat quality (Ohio EPA, 1999). Primarily, this zone slows run off, collects sediment, and stores nutrients and sediment that would otherwise be loaded into the stream system. Poor QHEI and mIBI scores are likely related to riparian zone absence. Extensive woody vegetation around streams provides additional habitat in the form of logs and woody debris, overhanging vegetation, and submerged root wads. Riparian vegetation also provides canopy cover that shades the stream and minimizes thermal inputs. Shade can also limit extensive, nuisance levels of aquatic vegetation that are dependent upon sufficient levels of solar radiation. Unfiltered nutrient-rich runoff can also promote vegetation and algal growth. Mowed grassy vegetation adjacent to streams does little to slow runoff flows into the stream, and therefore, is less capable of trapping sediments and nutrients. Based on observations made during sampling events, the quality and quantity of riparian zones are moderately to severely limited throughout the watershed.

Each of these physical factors contributes to habitat quality, and their absence or degradation at most of the sites can be related to the macroinvertebrate community structure. Overall, the mIBI scores indicated slight to severe impairment at Oliver Lake Watershed sites. Impacts of degradation will tend to limit or eliminate organisms that are incapable of persisting in such systems.

4.7 Water Quality Assessment Summary

In general, physical and chemical parameter data collected from streams in the Oliver Lake Watershed indicates the potential for water quality degradation when compared with ideal conditions. Total Kjeldahl nitrogen (96% exceed), E. coli (78% exceed) and total phosphorus (70% exceed) concentrations were elevated during base and storm flow conditions. Total Kjeldahl nitrogen concentrations measured above EPA target concentrations for all watershed samples except one. However, it should be noted that EPA targets are relatively low when compared with concentrations across the state.

In particular, Dove Creek tributary (Site 2) and Truman Flint Ditch (Site 9) generally possessed the poorest water quality when compared to other sites when concentrations are considered. During storm and base flow, Dove Creek tributary (Site 2) possessed elevated orthophosphorus and total phosphorus, nitrate-nitrogen and total Kjeldahl nitrogen, total suspended solids and E. coli. Truman Flint Ditch (Site 9) possessed extremely elevated nitrate-nitrogen and total Kjeldahl nitrogen concentrations under base and storm flow conditions with nitrate-nitrogen approaching the state standard for drinking water under both base and storm flow conditions (10 mg/L) suggesting that there is always as source of nitrogen within this watershed.

Nutrient and Sediment Concentrations: Nitrate-nitrogen concentrations measured relatively normal for Indiana streams but were higher than water quality targets. Dove Creek (Site 2), Bert Hart Ditch (Site 5), Winling Creek (Site 6), the Winling Creek north tributary (Site 7), Truman Flint Ditch (Site 9), Eshelman Drain (Site 9) and Logan Drain (Site 10) exceeded water quality targets under base and storm flow conditions. This suggests that nitrate-nitrogen is loaded to the system under all flow conditions at these sites. Additionally, all sites contained total suspended solids concentrations that exceeded the target concentration (15 mg/L) during storm flow conditions. This indicates sediment concentrations may be elevated in Oliver Lake Watershed streams when high flows occur.

Pathogen Concentrations: E. coli concentrations exceeded state standards at all sites during base and storm flow conditions except at Oliver Lake outlet (Site 12). The specific sources of E. coli in the Oliver Lake Watershed have not been identified; however, wildlife, livestock and/or domestic animal defecations; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria. Efforts to reduce phosphorus and *E. coli* concentrations within the watershed streams should target nutrient management planning and septic system failure identification and subsequent improvements.

While some subwatersheds per unit area delivered low nutrient and sediment loads, others delivered significant loads during the storm event. Under base and storm flow conditions, Dove Creek (Site 1) and Oliver Lake outlet (Site 12) generally possessed the greatest loads for all parameters. Dove Creek (Site 1) possesses the highest loading rates for total phosphorus under base and storm flows, the highest orthophosphorus loading rate under storm flow and the second highest loading rates for ammonia and total suspended solids under base and storm flow, the second highest TKN loading rate under storm flow and the second highest loading rate for orthophosphorus under base flow. The Oliver Lake outlet (Site 12) possesses the highest loading rates for TSS, ammonia and total Kjeldahl nitrogen under both base and storm flows, the highest loading rates for nitrate-nitrogen under storm flow and orthophosphorus under base flow as well as the second highest loading rate for total phosphorus under base and storm flow, nitrate under base flow and orthophosphorus under storm flow. Truman Flint Ditch (Site 9) possessed the highest nitrate-nitrogen loading rate under storm flow and the third highest ammonia, total Kjeldahl nitrogen, orthophosphorus and total phosphorus under base flow and the third highest nitrate loading under base flow. Eshelman Drain (Site 10) contained the second highest nitrate and total Kjeldahl nitrogen loading rates under storm flow and the third highest ammonia, orthophosphorus, total phosphorus and total suspended solids under storm flow and the third highest nitrate loading rate under base flow conditions.

Tributaries to Oliver Lake are moderate sources of nutrients and sediment. Dove Creek (Site 1) yields the highest rates per acre of total suspended solids and total phosphorus during base and storm flows; the highest orthophosphorus and ammonia-nitrogen during storm flow; the second highest total Kjeldahl nitrogen during base and storm flow and second highest ammonia-nitrogen during base flow. Truman Flint Ditch (Site 9) yields the highest rates per acre for nitrate-nitrogen and total Kjeldahl nitrogen during storm and base flows; the highest ammonia-nitrogen during base flow; the second highest total phosphorus during base and storm flow, the second highest orthophosphorus and total suspended solids during base flow. The Oliver Lake outlet (Site 12) yields the highest loading rate per acre of orthophosphorus during base flow; the second highest orthophosphorus, ammonia-nitrogen and total suspended solids during storm flow; and the third highest total phosphorus and total Kjeldahl nitrogen during storm flow. Bert Hart Ditch (Site 5) possessed the second highest nitrate-nitrogen rate per acre under base and storm flow conditions and third highest total Kjeldahl nitrogen and total suspended solids rate per acre under base flow conditions.

The macroinvertebrate assessment results suggest there are differences between the biological integrity of the macroinvertebrate communities at the sites which rate from slightly to severely impaired. These differences can be further teased apart when mHBI scores are reviewed. Overall, taxa dominance by one or two species, limited or absent EPT taxa and the limited presence of scrapers and shredders characterize Oliver Lake Watershed streams.

Based on the Oliver Lake QHEI assessments, Eshelman Drain (Site 10) scored the highest rating (39) as poor with extensive substrate embeddedness, fair development of channel morphology, sparse available instream and canopy cover, very narrow riparian buffer and shallow pools and riffle. All other sites rated poor or very poor. Many had absent or limited pool and riffle development, moderate channel alterations and minimal riparian buffer.

Comparison with Historic Water Quality Data
Historic and current water quality data indicate elevated nutrients, sediment and E. coli levels in most Oliver Lake Watershed streams. Bert Hart Ditch (OL05) also had the highest percentage exceedance for nitrate (88%) while its north tributary (OL07) exceeded targets in 83% of collected samples (Table 8). Truman Flint Ditch (Site 9) under base and storm flow conditions and the unnamed tributary under base flow exceeded water quality targets. Orthophosphorus was elevated at most sites with 80% of samples exceeding targets in Bert Hart Ditch (OL05) and 50% of samples exceeding water quality targets at Dove Creek (OL01) and Truman Flint Ditch (OL09). All sites under storm flow conditions exceeded water quality targets while the Dove Creek tributary (Site 2) and Logan Drain (Site 11) also exceeded targets under base flow conditions. Total phosphorus concentrations were elevated at most sites with all but Eshelman Drain (OL10) exceeding targets in more than 50% of samples collected. The highest exceedances occurred at Bert Hart Ditch (OL05) and Turman Flint Ditch (OL09). Dove Creek (Site 1), Dove Creek tributary (Site 2) and Truman Flint Ditch (Site 9) under base flow and Dove Creek tributary (Site 2), Eshelman Drain (Site 10) and Logan Drain (Site 11) under storm flow conditions exceeded water quality targets.

Overall, total suspended solids concentrations and turbidity levels measured relatively low with only the Winling Creek north tributary (OL07) exceeding TSS targets in more than 50% of collected samples. Conversely, all samples exceeded water quality targets for total suspended solid under storm flow conditions during current sampling. Historic E. coli concentrations measured above the state standard (235 colonies/100 mL) in previously collected data with the Winling Creek north tributary (OL07) and Eshelman Drain (OL10) exceeding in all samples and Bert Hart Ditch (OL05) exceeding targets in 86% of collected samples. Similarly, E. coli concentrations were elevated in all sites except Dove Creek (Site 1), Colwell Drain (Site 3) and the Oliver Lake outlet (Site 12) under base flow condition and the Oliver Lake Outlet (Site 12) under storm flow conditions. The Dove Creek tributary (Site 2) and Truman Flint Ditch (Site 9) under base flow and Winling Creek (Site 6), Eshelman Drain (Site 10) and Logan Drain (Site 11) under storm flow measured above the laboratory detection limit (2,420 col/100 mL).

5.0 OLIVER LAKE ASSESSMENT

5.1 Historic Water Quality Data

The IDNR Division of Fish and Wildlife, Aquatic Weed Control (AWQ), JFNew, Davey Resource Group (DRG), Indiana Pollution Control Board (IPCB), US EPA, Indiana Clean Lakes Program (ICLP) staff and Clean Lakes Program volunteer monitors have conducted various water quality tests on Oliver Lake. Table 21 presents some selected water quality parameters for these assessments. Additionally, Figure 44 details transparency measurements observed in Oliver Lake by year.

Table 21. Summary of historic data for Oliver Lake, Lagrange County, Indiana. Note volunteer data represents averages for the year shown.

Date	Secchi (Ft)	% Oxic	pH epi	Ammonia hypo (mg/L)	Total Phosphorus avg (mg/L)	Chl a (µg/L)	Plankton (NU/L) or (cells/mL)*	Source
8/14/1972	7.5							IDNR
5/4/1973	11.2							US EPA
8/6/1973	5.9							US EPA
10/11/1973	9.8							US EPA
6/20/1975	10							IDNR
8/17/1977	9.8							IPCB

Date	Secchi (Ft)	% Oxic	pH epi	Ammonia hypo (mg/L)	Total Phosphorus avg (mg/L)	Chl a (µg/L)	Plankton (NU/L) or (cells/mL)*	Source
7/18/1983	10							IDNR
7/19/1993	5.6	100%	8.2	0.135	0.010	4.08	6,102	CLP
1993	9				0.030	1.50		CLP Volunteer
1994	11.9				0.023	1.41		CLP Volunteer
1995	8.8				0.021	1.46		CLP Volunteer
1996	10.5				0.006	0.76		CLP Volunteer
1997	10.2				0.011	1.62		CLP Volunteer
1998	9.2				0.027	1.23		CLP Volunteer
1999	9.6				0.030	1.50		CLP Volunteer
7/11/2000	6.9	77%	8.4	0.480	0.020	1.14	1,442	CLP
2000	8.1				0.041	2.26		CLP Volunteer
2001	10.5				0.017	0.66		CLP Volunteer
2002	9.2				0.013	0.46		CLP Volunteer
7/7/2003	6.6	80%	8.4	0.463	0.010	1.43	2,320	CLP
2003	10				0.031	1.59		CLP Volunteer
2004	9.4				0.025	1.73		CLP Volunteer
2005	10.4				0.022	1.28		CLP Volunteer
2006	6.7				0.021	0.25		CLP Volunteer
7/25/2006	8.5	78%	8.4	0.220	0.020		5,634	CLP
2007	7.2				0.013	1.02		CLP Volunteer
5/29/2008	14.5							IDNR
7/23/2008	5.3	75%	8.4	0.738	0.110	2.60	1,530	CLP/JFNew
8/6/2008	6.5							IDNR
2009	9.2				0.010	3.22		CLP Volunteer
2010	6.4				0.012	1.69		CLP Volunteer
2011	7.5				0.011	3.56		CLP Volunteer
4/10/2012	11.5							IDNR
6/25/2012	5.6	90%	8.0	0.018	0.020	3.34	5,709,652	CLP
7/31/2012	11.5							IDNR
2012	5.8				0.013	1.45		CLP Volunteer
8/6/2013	10							AWQ
2013					0.002	1.29		
7/22/2014	6							DRG
2014	10				0.009	6.53		CLP Volunteer
7/20/2015	8.5							DRG
6/29/2015	5.6	88%	8.5	0.147	0.030	5.94	3,152,221	CLP
2015	6.2				0.025	3.52		CLP Volunteer
7/20/2016	6.5							AWQ
2016	6.8				0.048	2.13		CLP Volunteer
7/25/2017	7.5							IDNR
8/16/2017	6.5							AWQ
8/30/2017	5.5							IDNR

Date	Secchi (Ft)	% Oxic	pH epi	Ammonia hypo (mg/L)	Total Phosphorus avg (mg/L)	Chl a (µg/L)	Plankton (NU/L) or (cells/mL)*	Source
9/11/2017	8.5							IDNR
9/18/2017	8							IDNR
10/16/2017	11.5							IDNR
2017	7.2				0.009	1.74		CLP Volunteer
8/17/2018	5.5							IDNR
8/23/2018	7.5							IDNR
8/30/2018	7							IDNR
2018	7.1				0.011	2.70		CLP Volunteer
6/24/2019	11.5	93%	8.4	0.312	0.020	4.08	318,128	CLP
6/25/2019	8		9.3					IDNR
8/28/2019	8							IDNR
9/11/2019	9							IDNR
2019	8.9				0.013	3.25		CLP Volunteer
8/26/2020	5							IDNR
2020	10.8				0.008	3.00		CLP Volunteer
8/30/2021	3							IDNR
2021	9.3				0.007	3.25		CLP Volunteer
8/30/2022	6							IDNR
2022	4.6				0.020	2.50		CLP Volunteer
8/30/2023	3.5							IDNR
2023	6.3				0.019	2.25		CLP Volunteer

*Plankton samples collected prior to 2012 are in natural units per liter, while samples collected in 2012 and after are in cells per milliliter.

Based on the data presented in Table 21 and Figure 40, Secchi disk transparency (a measure of water clarity) in Oliver Lake averages about 8.7 feet (2.5 m). Clarity ranged from a low of 3.0 feet (0.9 m) in August 2021 to a high of 23.25 feet (7.1 m) in April 1994. Overall, water clarity in Oliver Lake is better (8.1 feet or 2.7 m) than most lakes in Indiana (5.4 feet or 1.6 m) measured from 2019 to 2022. Overall, transparency declined by nearly 4 feet (1.2 m) over the last 40 years (Figure 40); however, some change is likely due to differences in when data were collected throughout the year. Water clarity typically measures the deepest in April (average 17.3 feet or 5.3 m), then declines in May (14.5 feet or 4.4 m), June (9.9 feet or 3.0 m) and again in July (6.9 feet or 2.1 m), before improving slightly in August (7.3 feet or 2.2 m) and again in September (9.0 feet or 2.8 m) and October (13.0 feet or 4.0 m).

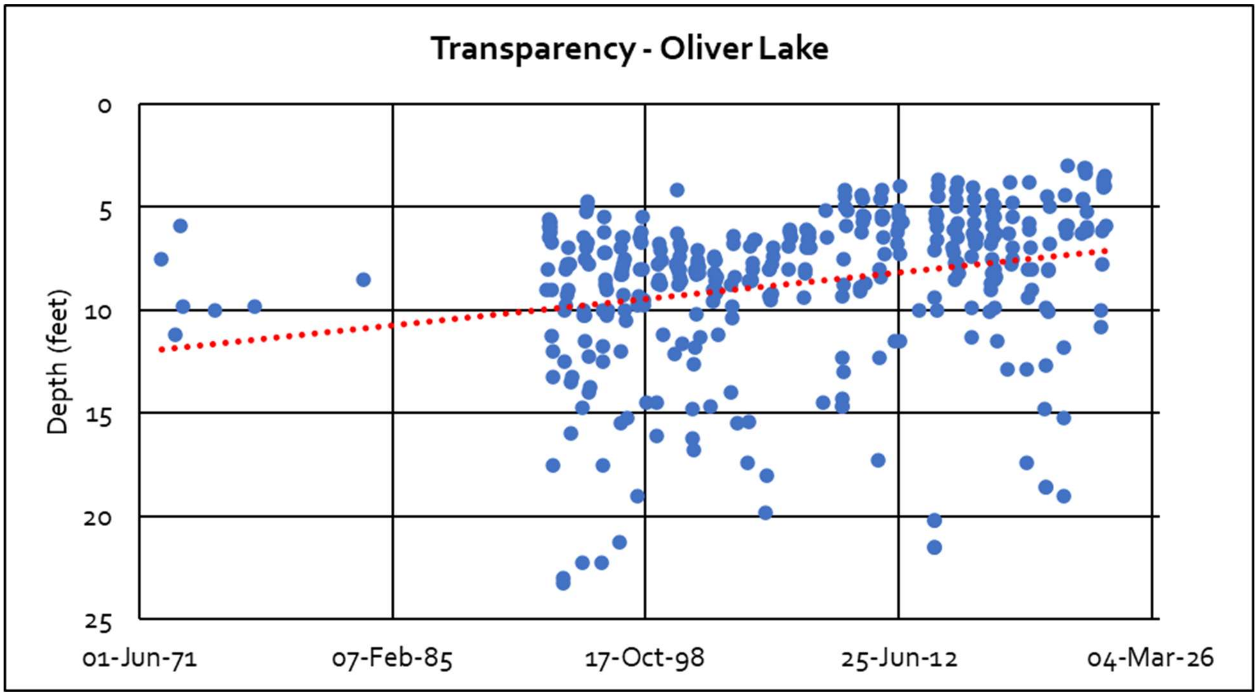


Figure 40. Historic Secchi disk transparency data, Oliver Lake, Lagrange County, Indiana.

Figure 41 displays the temperature profiles recorded during IDNR fisheries surveys and Indiana CLP assessments. All the temperature profiles show that Oliver Lake was stratified at the time of the assessments. The developed hypolimnion (bottom water) present during the surveys is very typical of Indiana lakes. The metalimnion, or area of rapidly changing water temperature, typically extends from 20 feet (6.1 m) to approximately 30 feet (9.1 m). The epilimnion (surface water) is located above the metalimnion, while the hypolimnion (bottom water) is located below the metalimnion. Water within the epilimnion and hypolimnion are typically separated during the summer in stratified lakes and do not mix. This is the case during all assessments.

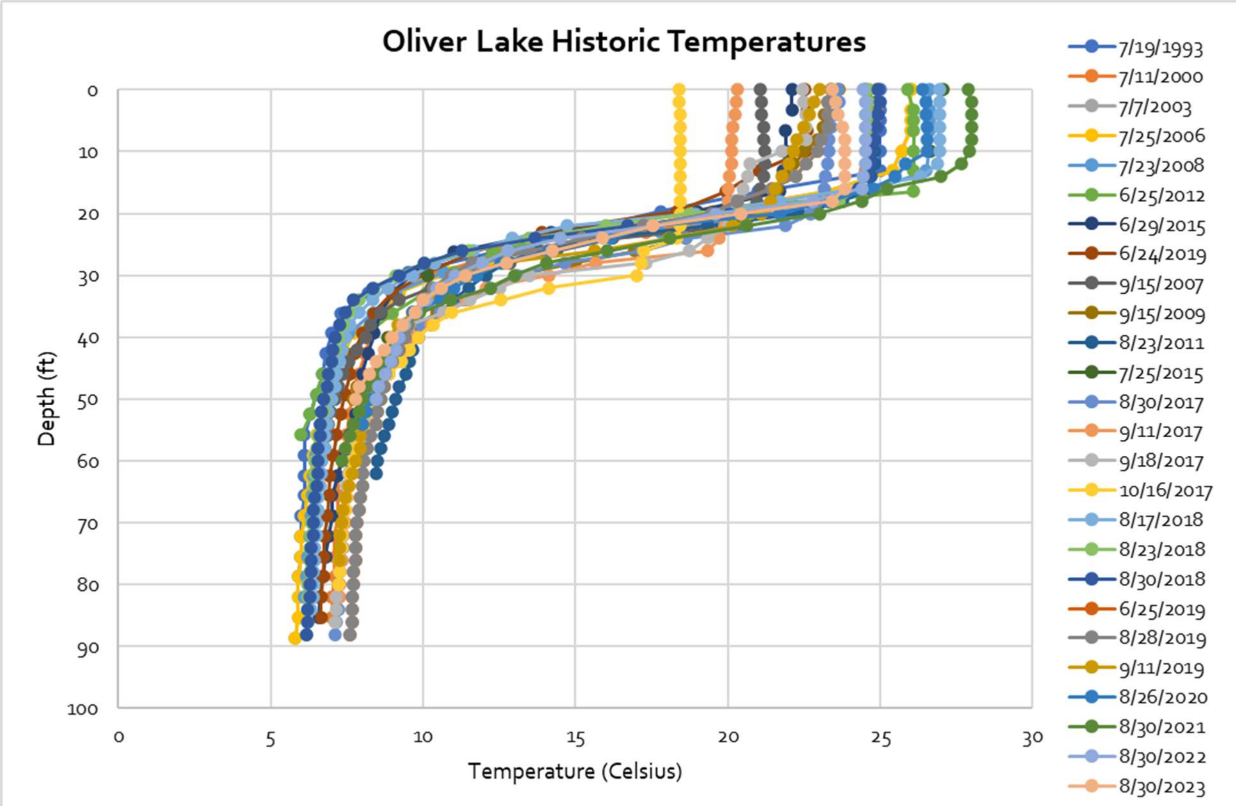


Figure 41. Historic temperature profiles for Oliver Lake, Lagrange County, Indiana.

The dissolved oxygen data also indicates that typically more than half of the water column is available for use by the lake's biota (Figure 42). However, low dissolved oxygen concentrations present at the lake bottom increase the potential for nutrient release from the lake's bottom sediments. Additionally, during many assessments, including 2006, 2012 and 2015, there is a sharp increase in dissolved oxygen in the lake's metalimnion. This results in a positive heterograde profile. Positive heterograde profiles are characterized by a peak in oxygen concentration at a depth below the water surface, such as the peaks in the 2012 and 2015 profiles beginning at 20 feet (6.0 m) and 16 (4.9 m) feet below the water's surface in 2006. The peak is likely associated with a higher concentration in phytoplankton at that particular depth layer. Called a metalimnetic oxygen maximum, the peak results when the rate of settling plankton slows in the denser waters of the metalimnion. At this depth, the plankton can take advantage of nutrients diffusing from the nutrient-enriched hypolimnion. As the plankton at this depth photosynthesize, they release oxygen into the water column, creating a peak in oxygen at that level. Cisco layers form when lake temperatures measure 20°C (68° F) or colder and oxygen measures 3 parts mg/L or more. Cisco layers are typically only found in lakes with high water clarity, which allows sunlight to penetrate into the deeper regions of the lake (Frey, 1955). Although conditions exist for the development of a cisco layer, IDNR (2019) lists cisco as extirpated from Oliver Lake.

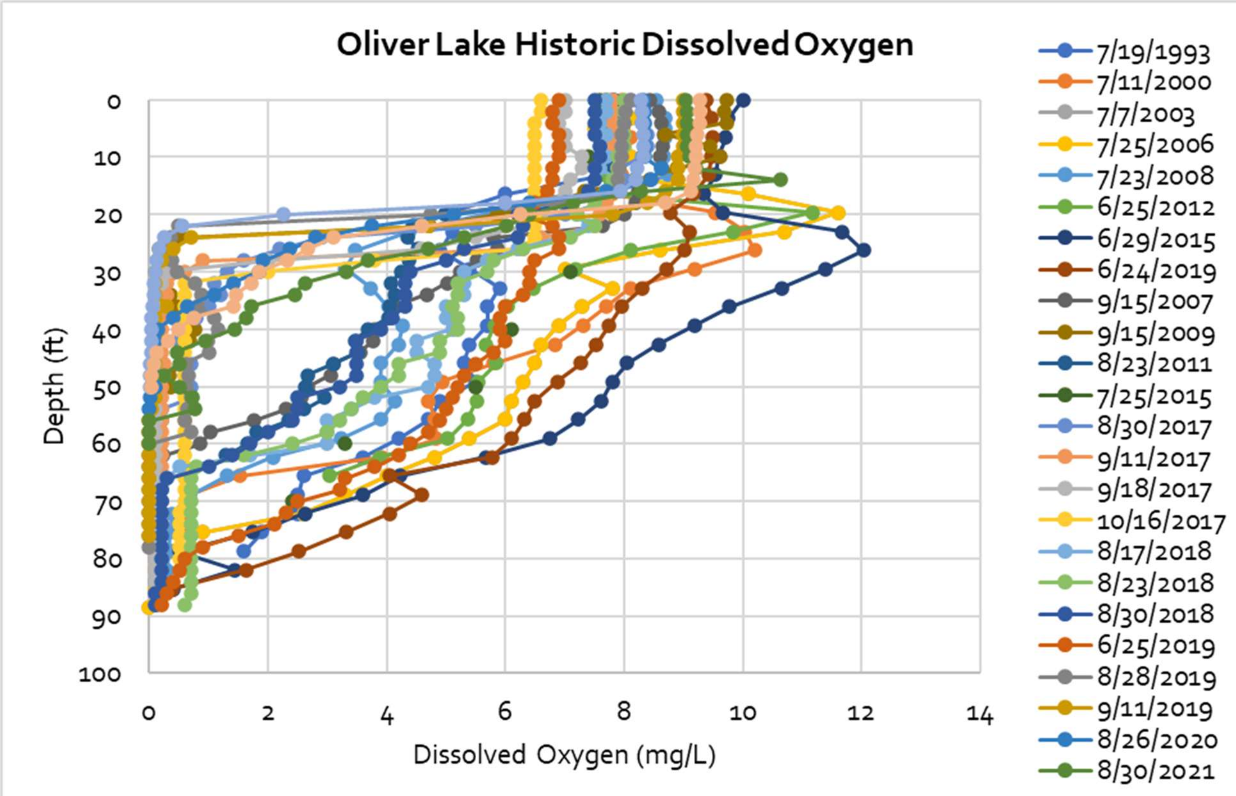


Figure 42. Historic dissolved oxygen profiles for Oliver Lake, Lagrange County, Indiana.

Much of the data presented above suggest that Oliver Lake is generally low to moderately productive. The historical percent oxic results (Table 21) and dissolved oxygen profiles (Figure 46) support this idea. Dissolved oxygen data indicate that the lake possessed dissolved oxygen greater than 1 mg/L in more than 50% of the water column depending on the sampling event. Late summer monitoring events in 2017, 2019 and 2022 indicate dissolved oxygen levels measuring less than 1 mg/L in the water column (42%, 31% and 42%, respectively). The dissolved oxygen data also indicates that generally more than half of the water column is typically available for use by the lake's biota. Low dissolved oxygen concentrations present at the lake bottom increase the potential for nutrient release from the lake's bottom sediments.

The lake's algae (plankton) density reflects the relatively moderate nutrient levels typically present in Oliver Lake (Table 21). It should be noted that the plankton counting method changed in 2012 with natural units per liter reported prior to 2012 and cells per liter reported for 2012 and after. Based on early data (pre-2012), plankton levels were very low when compared with other lakes in Indiana (14,803 cells/mL) monitored 2019 to 2022 (ICLP, unpublished). Plankton levels measured after 2012 measured higher than most lakes (1,302,418 cell/L) monitored 2019 to 2022 during both the 2012 and 2015 sampling events but measured less than one-third the median level for Indiana lakes during the 2019 assessment. Nutrients (nitrogen and phosphorus) promote the growth of algae and/or rooted plant populations. Total phosphorus concentrations measured via Clean Lakes Programs staff and volunteers indicate Oliver Lake contains phosphorus levels which measure relatively low with concentrations generally measuring lower than the surface concentration for most lakes in Indiana (0.028 mg/L) measured 2019 to 2022. Nearly all of the available phosphorus measured during Clean Lakes Program staff assessments is present in the bottom waters or hypolimnion. The relatively low nutrient concentrations present in the epilimnion or surface waters generally coincide with the relatively moderate plankton densities present in Oliver Lake during previous assessments. Chlorophyll *a* concentrations measure lower than most lakes in Indiana (7.25 μg/L).

The lack of oxygen in Oliver Lake's hypolimnion also affects the lake's chemistry. While mean total phosphorus and hypolimnetic ammonia-nitrogen concentrations are variable for the years, a more detailed evaluation shows that hypolimnetic total phosphorus concentrations are sometimes higher than epilimnetic total phosphorus concentrations. Under anoxic conditions, the iron in iron phosphate, a common precipitate in lake sediments, is reduced, and the phosphate ion is released into the water column. This phosphate ion is readily available to algae and can therefore spur algal growth. Further review of historical phosphorus data indicate that much of the total phosphorus in the hypolimnion was in the dissolved form of phosphorus (SRP). This indicates that Oliver Lake was releasing phosphorus from its bottom sediments.

5.2 Lake Water Quality Assessment Methods

The water quality sampling and analytical methods used for the Fish Lake assessment was consistent with those used in the Indiana Department of Environmental Management's (IDEM) Indiana Clean Lakes Program. Water samples were collected and analyzed for various parameters from the surface water (epilimnion) and bottom water (hypolimnion) over the lake's deepest point. Sample analysis included total phosphorus, orthophosphorus, nitrate-nitrogen, ammonia-nitrogen, organic nitrogen, and total Kjeldahl nitrogen from both the epilimnetic and hypolimnetic samples. Additionally, Secchi disk and oxygen saturation were recorded, chlorophyll *a* was determined for an epilimnetic sample, and a tow of plankton was made from the 1% light level depth to the water's surface and a plankton composite sample of the upper six feet of water was collected. Dissolved oxygen and temperature profiles were measured in 3-foot (1 m) intervals from the surface to the bottom. Conductivity, temperature, and dissolved oxygen were measured in situ.

All lake samples were placed in the appropriate bottle, with preservative if needed, and stored on ice until analysis at the Commonwealth Biomonitoring laboratory in Indianapolis, Indiana. All sampling techniques and laboratory analytical methods were performed in accordance with procedures in Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, 1998). Plankton counts were made using a standard Sedgewick-Rafter counting cell. Fifteen fields per cell were counted. Plankton identifications were made according to: Ward and Whipple (1959), Prescott (1982), Whitford and Schumacher (1984), and Wehr and Sheath (2003).

The following is a brief description of the parameters analyzed during the lake sampling efforts:

Temperature. Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. For example, water temperature affects the amount of dissolved oxygen in the water column. Likewise, life associated with the aquatic environment in any location has its species composition and activity regulated by water temperature. Since essentially all aquatic organisms are 'cold-blooded' the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (USEPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits to protect aquatic life for Indiana waters. For example, temperatures during the summer months should not exceed 90°F (32.2°C).

Dissolved Oxygen (DO). DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3 to 5 mg/L of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish, such as bass or bluegill. The IAC sets minimum

DO concentrations at 4 mg/L for warmwater fish, but all waters must have a daily average of 5 mg/L. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algal growth can over-saturate (greater than 100% saturation) the water with DO. Conversely, dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity. Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). Rather than setting a conductivity standard, the Indiana Administrative Code sets a standard for dissolved solids (750 mg/L). Multiplying a dissolved solids concentration by a conversion factor of 0.55 to 0.75 µmhos per mg/L of dissolved solids roughly converts a dissolved solids concentration to specific conductance (Allan, 1995). Thus, converting the IAC dissolved solids concentration standard to specific conductance by multiplying 750 mg/L by 0.55 to 0.75 µmhos per mg/L yields a specific conductance range of approximately 1000 to 1360 µmhos. This report presents conductivity measurements at each site in µmhos.

Nutrients. Limnologists measure nutrients to predict the amount of algal growth and/or rooted plant (macrophyte) growth that is possible in a lake. Algae and rooted plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy lake. Complete elimination of algae and/or rooted plants is neither desirable nor even possible and should, therefore, never be the goal in managing a lake. Algae and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a lake. Limnologists commonly measure nutrient concentrations in aquatic ecosystem evaluations to determine the potential for such nuisance growth.

Like terrestrial plants, algae and rooted aquatic plants rely primarily on phosphorus and nitrogen for growth. Aquatic plants receive these nutrients from fertilizers, human and animal waste, atmospheric deposition in rainwater, and yard waste or other organic material that reaches the lake or stream. Nitrogen can also diffuse from the air into the water. This nitrogen is then "fixed" by certain algae species into a usable, "edible" form of nitrogen. Because of this readily available source of nitrogen (the air), phosphorus is usually the "limiting nutrient" in aquatic ecosystems. This means that it is actually the amount of phosphorus that controls plant growth in a lake or stream.

Phosphorus and nitrogen have several forms in water. The two common phosphorus forms are **orthophosphorus (OP)** and **total phosphorus (TP)**. SRP is the dissolved form of phosphorus. It is the form that is "usable" by algae. Algae cannot directly digest and use particulate phosphorus. Total phosphorus is a measure of both dissolved and particulate forms of phosphorus. The most commonly measured nitrogen forms are **nitrate-nitrogen (NO3)**, **ammonium-nitrogen (NH4+)**, **total Kjeldahl nitrogen (TKN)** and **organic nitrogen (ON)**. Nitrate is a dissolved form of nitrogen that is commonly found in the upper layers of a lake or anywhere that oxygen is readily available. In contrast, ammonium-nitrogen is generally found where oxygen is lacking. **Anoxia**, or a lack of oxygen, is common in the lower layers of a lake. Ammonium is a byproduct of decomposition generated by bacteria as they decompose organic material. Like SRP, ammonium is a dissolved form of nitrogen and the one utilized by algae for growth. The TKN measurement parallels the TP measurement to some extent. TKN is a measure of the **total organic nitrogen** (particulate) and ammonium-nitrogen in the water sample.

While the United States Environmental Protection Agency (USEPA) has established some nutrient standards for drinking water safety, it has not established similar nutrient standards for protecting the biological integrity of a lake. (The USEPA, in conjunction with individual states, is currently working on developing these standards.) The USEPA has issued recommendations for numeric nutrient criteria for lakes (USEPA, 2000). While these are not part of the Indiana Administrative Code, they serve as potential target conditions for which watershed managers might aim. Other researchers have suggested thresholds for several nutrients in lake ecosystems as well (Carlson, 1977; Vollenweider, 1975). Lastly, the Indiana Administrative Code (IAC) requires that all waters of the state have a nitrate concentration of less than 10 mg/L, which is the drinking water standard for the state.

With respect to lakes, limnologists have determined the existence of certain thresholds for nutrients above which changes in the lake's biological integrity can be expected. For example, Correll (1998) found that soluble reactive phosphorus concentrations of 0.005 mg/L are enough to maintain eutrophic or highly productive conditions in lake systems. For total phosphorus concentrations, 0.03 mg/L (0.03 ppm – parts per million or 30 ppb – parts per billion) is the generally accepted threshold. Total phosphorus concentrations above this level can promote nuisance algae blooms in lakes. The USEPA's recommended nutrient criterion for total phosphorus is fairly low, 37.5 µg/L (USEPA, 2000). This is an unrealistic target for many Indiana lakes. It is unlikely that IDEM will recommend a total phosphorus criterion this low for incorporation in the IAC. Similarly, the USEPA's recommended nutrient criterion for nitrate-nitrogen in lakes is low at 8 µg/L (0.008 mg/L). This is below the detection limit of most laboratories. In general, levels of inorganic nitrogen (which includes nitrate-nitrogen) that exceed 0.3 mg/L may also promote algae blooms in lakes. High levels of nitrate-nitrogen can be lethal to fish. The nitrate LC50 is 5 mg/L for logperch, 40 mg/L for carp, and 100 mg/L for white sucker. (Determined by performing a bioassay in the laboratory, the LC50 is the concentration of the pollutant being tested, in this case nitrogen, at which 50% of the test population died in the bioassay.) The USEPA's recommended criterion for total Kjeldahl nitrogen in lakes is 0.66 mg/L.

It is important to remember that none of the threshold or recommended concentrations listed above are state standards for water quality. They are presented here to provide a frame of reference for the concentrations found. The IAC sets only nitrate-nitrogen and ammonia-nitrogen standards for waterbodies in Indiana. The Indiana Administrative Code requires that all waters of the state have a nitrate-nitrogen concentration of less than 10 mg/L, which is the drinking water standard for the state. The IAC standard for ammonia-nitrogen depends upon the water's pH and temperature, since both can affect ammonia-nitrogen's toxicity.

Secchi Disk Transparency. This refers to the depth to which the black and white Secchi disk can be seen in the lake water. Water clarity, as determined by a Secchi disk, is affected by two primary factors: algae and suspended particulate matter. Particulates (for example, soil or dead leaves) may be introduced into the water by either runoff from the land or from sediments already on the bottom of the lake. Many processes may introduce sediments from runoff; examples include erosion from construction sites, agricultural land, and riverbanks. Bottom sediments may be resuspended by bottom feeding fish such as carp, or in shallow lakes, by motorboats or strong winds. In general, lakes possessing Secchi disk transparency depths greater than 15 feet (4.5 m) have outstanding clarity. Lakes with Secchi disk transparency depths less than 5 feet (1.5 m) possess poor water clarity (ISPCB, 1976; Carlson, 1977). The USEPA recommended a numeric criterion of 10.9 feet (3.3 m) for Secchi disk depth in lakes in nutrient criteria region VII (USEPA, 2000).

Light Transmission. Similar to the Secchi disk transparency, this measurement uses a light meter (photocell) to determine the rate at which light transmission is diminished in the upper portion of the lake's water column. Another important light transmission measurement is determination of the 1% light level. The 1% light level is the water depth to which one percent of the surface light penetrates. This is considered the lower limit of algal growth in lakes. The volume of water above the 1% light level is referred to as the photic zone.

Plankton. Plankton are important members of the aquatic food web. Plankton include the algae (microscopic plants) and the zooplankton (tiny shrimp-like animals that eat algae). Plankton are collected by towing a net with a very fine mesh (63-micron openings = 63/1000 millimeter) up through the lake's water column from the one percent light level to the surface. Of the many different planktonic species present in the water, the blue-green algae are of particular interest. Blue-green algae are those that most often form nuisance blooms and their dominance in lakes may indicate poor water conditions. Plankton measurements occur in two forms: natural units per liter and cells per liter. Natural units are the historic unit used to quantify plankton in Indiana lakes. Essentially, a natural unit represents a single organism whether it is single celled or multi celled; natural units record one colonial filament of multiple cells as one natural unit and one cell of a singular algae as one natural unit. Cell density is the preferred method as each cell can live and reproduce independently alone or as part of larger colony. Converting between the two units of measurement requires calculation of plankton density (drying and weighing) for each species in each lake sampled. New methods for counting plankton make calculation of the Indiana Trophic State Index improbable as the plankton density score cannot be calculated.

Chlorophyll *a*. The plant pigments in algae consist of the chlorophylls (green color) and carotenoids (yellow color). Chlorophyll *a* is by far the most dominant chlorophyll pigment and occurs in great abundance. Thus, chlorophyll *a* is often used as a direct estimate of algal biomass. In general, chlorophyll *a* concentrations below 2 µg/L are considered low, while those exceeding 10 µg/L are considered high and indicative of poor water quality. The USEPA recommended a numeric criterion of 2.63µg/L as a target concentration for lakes in Aggregate Nutrient Ecoregion VII (USEPA, 2000).

5.3 Lake Water Quality Assessment Results

Results from the Oliver Lake water quality assessment are included in Figure 43 and Table 22 and Table 23.

Table 22. Water quality characteristics of Oliver Lake on July 23, 2024.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
Secchi Depth Transparency	4.8 feet		6
Light Transmission at 3 ft.	52%		2
% Saturation at 5 ft.	118%		0
Total Phosphorous	0.028 mg/L	0.078 mg/L	2
Orthophosphate	0.004 mg/L	0.017 mg/L	0
Nitrate-Nitrogen	0.432 mg/L	0.132 mg/L	0
Ammonia-Nitrogen	0.090 mg/L	1.132 mg/L	3
Organic Nitrogen	0.801 mg/L	1.182 mg/L	3
% Water Column Oxic	63%		2
Plankton Density	9,064 cells/mL		--
Blue-Green Dominance	82%		10
Chlorophyll *a*	3.2		--
			28

Mesotrophic*

*Note that plankton density is reported in cells/mL, while the Indiana trophic state index requires reporting in natural units per liter. The two are not easily converted thus the ITSI score calculated here does not include a plankton score and is not fully comparable to previously calculated ITSI scores.

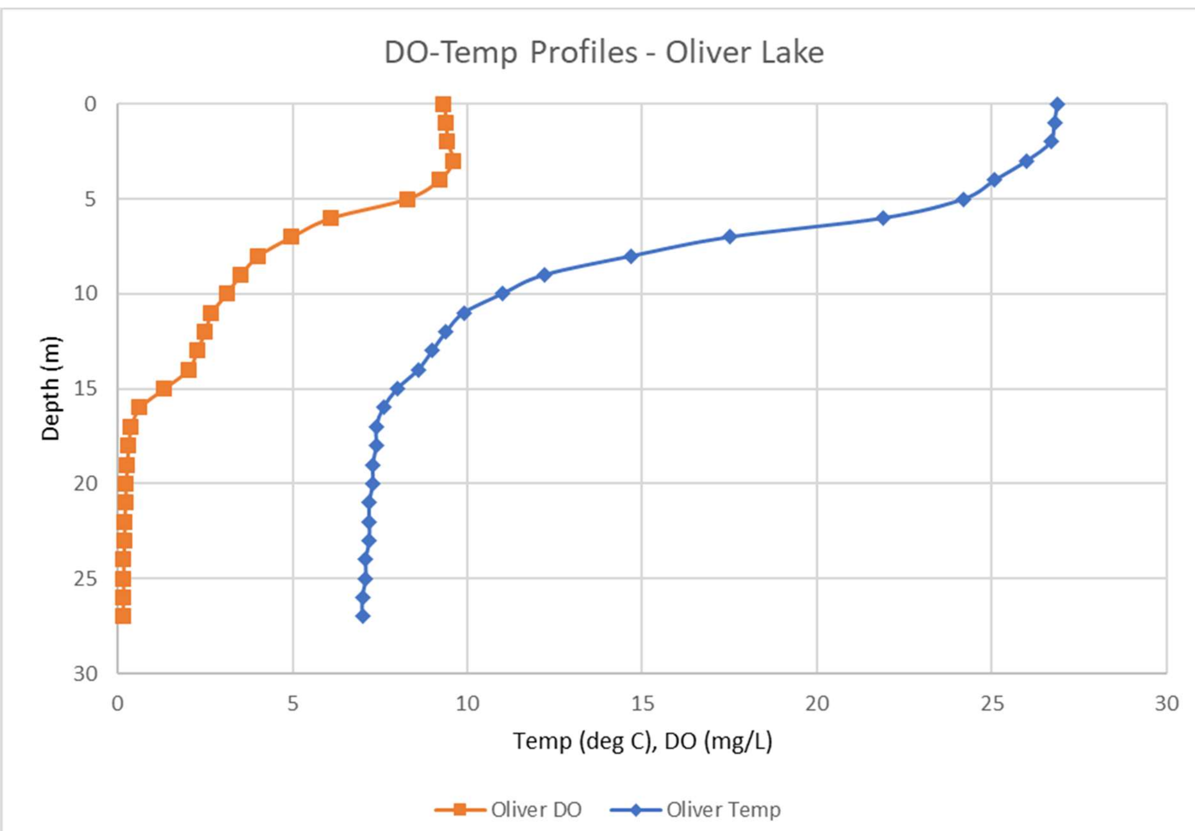


Figure 43. Temperature and dissolved oxygen profiles for Oliver Lake on July 23, 2024.

Table 23. Plankton sample assemblage identified in Oliver Lake on July 23, 2024.

Taxa	Functional Group	Cell Count (cells/mL)	Count (NU/L)
Aphanocapsa-Aphanothece	Blue Green algae	6,759.8	
Chroococcus	Blue Green algae	47.5	
Gomphosphaeria-Snowella	Blue Green algae	20.6	
Merismopedia	Blue Green algae	68.1	
Planktolyngbya	Blue Green algae	19.8	
Dolichospermum	Blue Green algae	199.2	
Microcystis	Blue Green algae	338.9	
Pseudanabaena	Blue Green algae	3.4	
Ceratium	Cryptophytes and Dinoflagellates	0.7	
Cryptomonas	Cryptophytes and Dinoflagellates	19.9	
Peridinales	Cryptophytes and Dinoflagellates	2.8	
Rhodomonas	Cryptophytes and Dinoflagellates	1.4	
Centrics	Diatoms	40.4	
Chrysophyta	Diatoms	21.3	
Mallomonas	Diatoms	9.9	
Pennate Diatoms	Diatoms	5.0	
Protozoan	Diatoms	0.0	
Chlorophytes	Green algae	1,122.8	
Crucigenia-Crucigniella	Green algae	29.8	
Desmodesmus-Scenedesmus	Green algae	29.8	
Oocystis	Green algae	8.5	
Unclassified (size)		167.3	
Unclassified (identity)		147.5	
Anuraeopsis	Zooplankton		2.7
Calanoid	Zooplankton		7.1
Cyclopoid	Zooplankton		10.3
Daphnia	Zooplankton		2.7
Diaphanosoma	Zooplankton		5.4
Kellicottia	Zooplankton		0.5
Keratella	Zooplankton		45.1
Nauplii	Zooplankton		20.6
Polyarthra	Zooplankton		21.2
	Total	**9,064.4**	**115.7**

Temperature and oxygen profiles for Oliver Lake show that the lake was stratified at the time of sampling (Figure 43). The oxygen concentration maintains a relatively high concentration for the first 9.9 feet (3 m) before sharply increasing in the metalimnion then rapidly declining to <1 mg/L at 52.4 feet (16 m). At the time of our sampling, the epilimnion (surface waters) was confined to the upper 16.4 feet (5 m) of water. The metalimnion transition was confined between 16.4 and 49.2 feet (6 and 15 meters), where the hypolimnion continued to the lake bottom. This corresponds with the top edge of the euphotic zone, or the locations were insufficient light limits photosynthesis by phytoplankton. In this portion of the lake, aquatic fauna is respiring, or using available oxygen, while bacteria are consuming oxygen during decomposition. All of this results in declining dissolved oxygen concentrations. Below this point, DO levels decline until there is no dissolved oxygen remaining in the lake. This is likely due to biological oxygen demand (BOD) from excess organic detritus in the lake's deeper waters. Respiration by aquatic fauna and decomposition of organic matter likely depleted the oxygen supply in the lake's deeper waters. Water below 16.4 feet (5 m) did not contain sufficient dissolved oxygen to support fish and other aquatic organisms. The lack of oxygen at the lake-sediment interface created conditions conducive to the release of phosphorus from the lake's sediments. In total, 54% of the lake's water column was oxic limiting the amount of habitat available for aquatic fauna.

Oliver Lake exhibited poor water clarity during the July 2024 sampling event. The lake's Secchi disk transparency at the time of sampling measured 4.8 feet (1.5 m). This result is poorer than average transparencies measured in Oliver Lake (8.7 feet or 2.7 m) and measures less than most lakes in Indiana (5.4 feet or 1.6 m). Oliver Lake was visibly chalky for much of the summer including during the July in-lake sampling.

Phosphorus and nitrogen are the primary plant nutrients in lakes. In the summer, Indiana lakes typically possess lower nutrient concentrations in their epilimnia compared to nutrient concentrations present in their hypolimnia. Algae in the lake's epilimnion often utilize a large portion of the readily available nutrients for growth. When the algae die and settle to the bottom sediments, nutrients are relocated to the hypolimnion. Higher concentrations of phosphorus in the hypolimnion may also result from chemical processes occurring at the sediment-water interface. Dissolved phosphorus concentrations are relatively low in the epilimnion (0.004 mg/L) and in the hypolimnion (0.018) of Oliver Lake. Both measured below the median values observed at lakes across Indiana from 2019 to 2022. Total phosphorus concentrations measured relatively low in the epilimnion (0.028 mg/L) but are much higher in the hypolimnion (0.078 mg/L) suggesting that sediment-attached phosphorus is likely readily available in the bottom waters of Oliver Lake. Total phosphorus concentration measured at the eutrophication threshold of 0.030 mg/L in the epilimnion (0.028 mg/L) suggesting that algae blooms are likely not an issue at the time of sample collection. Additionally, total phosphorus concentrations measured (2019-2022) below median levels observed in Indiana Lakes (0.028 mg/L) in the epilimnion and (0.142 mg/L) in the hypolimnion.

At the time of sampling, nitrate-nitrogen concentrations were elevated in the surface waters (0.432 mg/L) but measured lower in the bottom waters (0.132 mg/L). Typically, nitrogen rapidly oxidizes to nitrate-nitrogen in the presence of adequate oxygen, then moves from the water column into the atmosphere as nitrogen gas. The elevated nitrate-nitrogen concentrations suggest that nitrate-nitrogen is not rapidly converting to nitrogen gas but rather is being used by algae in the epilimnion. On average, nitrate-nitrogen concentrations exceed the USEPA target of 0.008 mg/L (USEPA, 2000a) and concentrations are higher than most Indiana lakes measured 2019 to 2022 (0.022 mg/L epilimnion, 0.029 mg/L hypolimnion). The ammonia-nitrogen concentration was elevated in the epilimnion (0.027 mg/L) and hypolimnion (1.132 mg/l) with both epilimnetic and hypolimnetic ammonia-nitrogen concentrations measured high for Indiana lakes (epilimnetic, 0.022 mg/L; hypolimnetic, 1.002 mg/L). Since ammonia is a byproduct of decomposition, a higher hypolimnetic concentration of ammonia-nitrogen suggests that decomposition is occurring in the lake's bottom waters.

Oliver Lake's plankton density (9,064.4 cells/mL) reflects the relatively elevated limited phosphorus concentrations in the lake but measures lower than most lakes in Indiana (14,803 cells/mL; ICLP, unpublished). Oliver Lake exhibited a chlorophyll *a* concentration 3.2 µg/L. This concentration is lower than most Indiana lakes (7.25 µg/L) but measures above the target USEPA concentration of 2.63 µg/L. At the time of the current assessment, blue-green algae were the dominant functional group. In total, 82% of the Oliver Lake plankton community consisted of blue-green algae. Blue-green algae are usually associated with degraded water quality. Blue-green algae are less desirable in lakes because they: 1) may form extremely dense nuisance blooms; 2) may cause taste and odor problems; and 3) are unpalatable as food for many zooplankton grazers.

6.0 OLIN LAKE ASSESSMENT

6.1 Historic Water Quality Data

The IDNR Division of Fish and Wildlife, Davey Resource Group (DRG), Aquatic Control (AC), Aquatic Weed Control (AWC), JFNew, Indiana Clean Lakes Program (CLP) staff and Clean Lakes Program volunteer monitors have conducted various water quality tests on Olin Lake.

Table **24** presents some selected water quality parameters for these assessments. Additionally, Figure 44 details transparency measurements observed in Olin Lake by year.

Table 24. Summary of historic data for Olin Lake, Lagrange County, Indiana. Note volunteer data represent averages for the year shown.

Date	Secchi (Ft)	% Oxic	pH epi	Ammonia hypo (mg/L)	Total Phosphorus avg (mg/L)	Chl a (µg/L)	Plankton (NU/L) or (cells/mL)*	Source
1975	9							IDNR
1988	10							IDNR
7/19/1993	8.2	82%	8.3	0.214	0.03	3.03	20,260	CLP
1993	11.7							CLP volunteer
1994	11.9				0.007	0.11		CLP volunteer
1995	9.1				0.069	2.26		CLP volunteer
1996	11.2				0.014	0.51		CLP volunteer
1997	9.9				0.021	1.81		CLP volunteer
1998	8.7				0.013	1.24		CLP volunteer
1999	8.9				0.017	1.07		CLP volunteer
2000	10.4				0.046	1.97		CLP volunteer
2001	11.5				0.024	0.63		CLP volunteer
2002	9.7				0.007	0.02		CLP volunteer
7/7/2003	5.6	100%	8.3	0.018	0.010	3.40	12,333	CLP
2003	8.9				0.025	1.79		CLP volunteer
2004	10.1				0.036	2.48		CLP volunteer
2005	10.5				0.012	0.80		CLP volunteer
2006	7.4				0.021	0.34		CLP volunteer
2007	7.9				0.025	1.79		CLP volunteer
8/6/2008	5							JFNew
5/29/2008	10							JFNew
7/23/2008	6.9	66%	8.4	0.690	0.170	2.00	10,953	CLP
2009	11.1				0.016	1.58		CLP volunteer
7/20/2010	5.9	44%	8.3	0.251	0.010	1.15	2,570,096	CLP

Date	Secchi (Ft)	% Oxic	pH epi	Ammonia hypo (mg/L)	Total Phosphorus avg (mg/L)	Chl a (μg/L)	Plankton (NU/L) or (cells/mL)*	Source
2010	7.2				0.009	1.58		CLP volunteer
2011	8.3				0.019	1.87		CLP volunteer
7/31/2012	9							AC
4/10/2012	16.5							AC
2012	6.7				0.006	0.33		CLP volunteer
2013					0.044	2.43		
8/6/2013	8.5							AWC
7/23/2014	6							DRG
2014	9.1				0.044	7.33		CLP volunteer
2015	5.4				0.036	3.62		CLP volunteer
2016	5.9				0.006	1.43		CLP volunteer
8/30/2017	8.5							IDNR
2017	6.6				0.005	1.39		CLP volunteer
8/30/2018	6							IDNR
2018	7.2				0.008	2.19		CLP volunteer
8/5/2019	10.2	81%	8.11	0.201	0.020	1.59	286,893	CLP
8/28/2019	7.5							IDNR
2019	9				0.016	2.00		CLP volunteer
7/11/2000	3.9	75%	8.4	0.536	0.050	1.22	2,641	CLP
8/26/2020	4.5							IDNR
2020	11.2				0.008	1.75		CLP volunteer
6/22/2021	6.7	92%	6.75	0.252	0.010	2.30	299,000	CLP
8/30/2021	4							IDNR
2021	7.4				0.008	1.25		CLP volunteer
8/30/2022	7							IDNR
2022	5.9				0.024	2.00		CLP volunteer
8/30/2023	4							IDNR
2023	5.5				0.016	2.25		CLP volunteer

*Plankton samples collected prior to 2010 are in natural units per liter, while samples collected in 2010 and after are in cells per milliliter.

Based on the data presented in

Table ***24*** and Figure 44, Secchi disk transparency (a measure of water clarity) in Olin Lake averages about 8.9 feet (2.7 m). Clarity ranged from a low of 3.9 feet (1.2 m) in 2000 to a high of 16.5 feet (5.0 m) in 2012. Overall, water clarity in Olin Lake is better (8.9 feet) than most lakes in Indiana (5.4 feet or 1.6 m) measured 2019 to 2022. Overall, transparency declined by nearly 4 feet (1.2 m) over the last 48 years (Figure 44); however, some change is likely due to differences in when data were collected throughout the year. Water clarity typically measures the deepest in April (19.3 feet or 5.9 m) before declining through May (11.9 feet or 3.6 m), June (13.4 feet or 4.1 m), June (13.4 feet or 4.1 m) and again in July (11.9 feet or 3.6 m) and August (11.4 feet or 3.5 m) before improving in September (11.8 feet or 3.6m) and October (14.7 feet or 4.5 m).

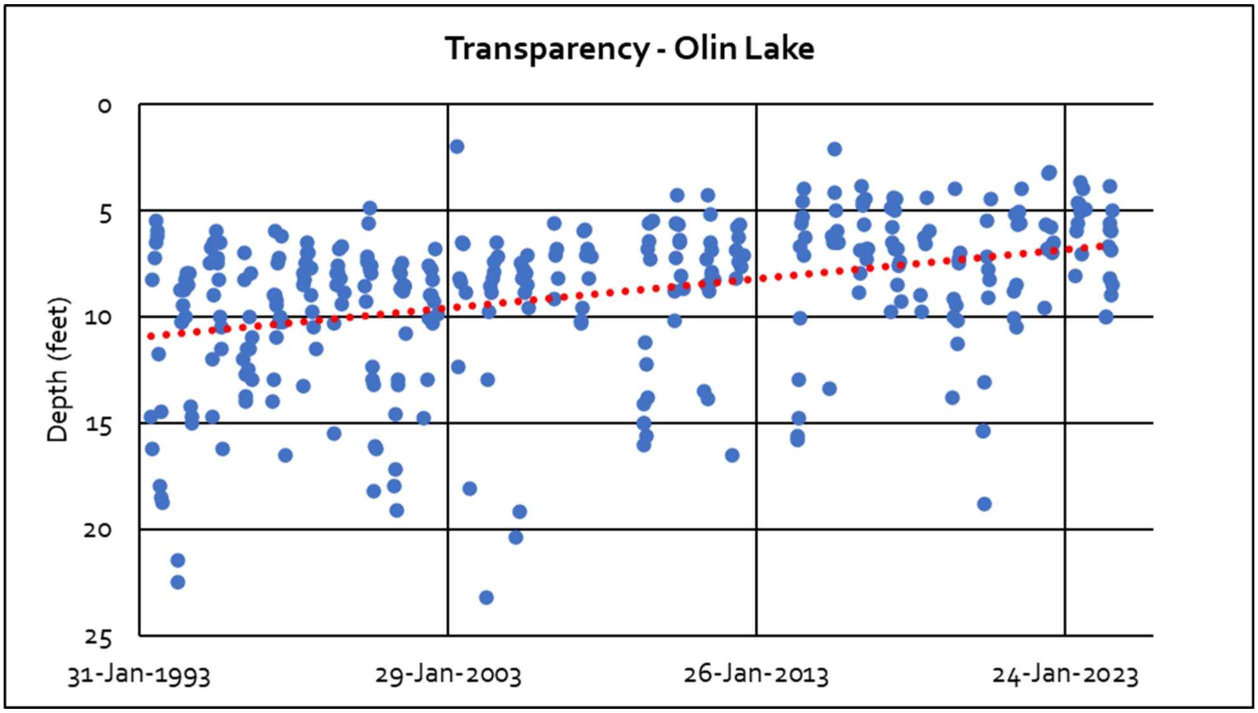


Figure 44. Historic Secchi disk transparency data, Olin Lake, Lagrange County, Indiana.

The lake's algae (plankton) density reflects the relatively moderate nutrient levels typically present in Olin Lake (

Table ***24***). Nutrients (nitrogen and phosphorus) promote the growth of algae and/or rooted plant populations. Total phosphorus concentrations measured via Clean Lakes Programs staff and volunteers indicate Olin Lake contains phosphorus levels which are relatively low compared to most Indiana lakes. Nearly all of the available phosphorus measured during Clean Lakes Program staff assessments is present in the bottom waters or hypolimnion. The relatively low nutrient concentrations present in the epilimnion or surface waters generally coincide with the relatively moderate plankton densities present in Olin Lake during previous assessments. Chlorophyll *a* concentrations measured relatively low during the all sampling events with all samples measuring below the median concentration measured in Indiana lakes (7.25 µg/L) from 2019 to 2023.

Figure 45 displays the temperature profiles recorded during IDNR fisheries surveys and Indiana CLP assessments. All the temperature profiles show that Olin Lake was stratified at the time of the assessments. The developed hypolimnion (bottom water) present during the surveys is very typical of Indiana lakes. The metalimnion, or area of rapidly changing water temperature, typically extends from 10 feet (3.0) to approximately 34 feet (10.4 m). The epilimnion (surface water) is located above the metalimnion, while the hypolimnion (bottom water) is located below the metalimnion. Water within the epilimnion and hypolimnion are typically separated during the summer in stratified lakes and do not mix. This is the case during all assessments.

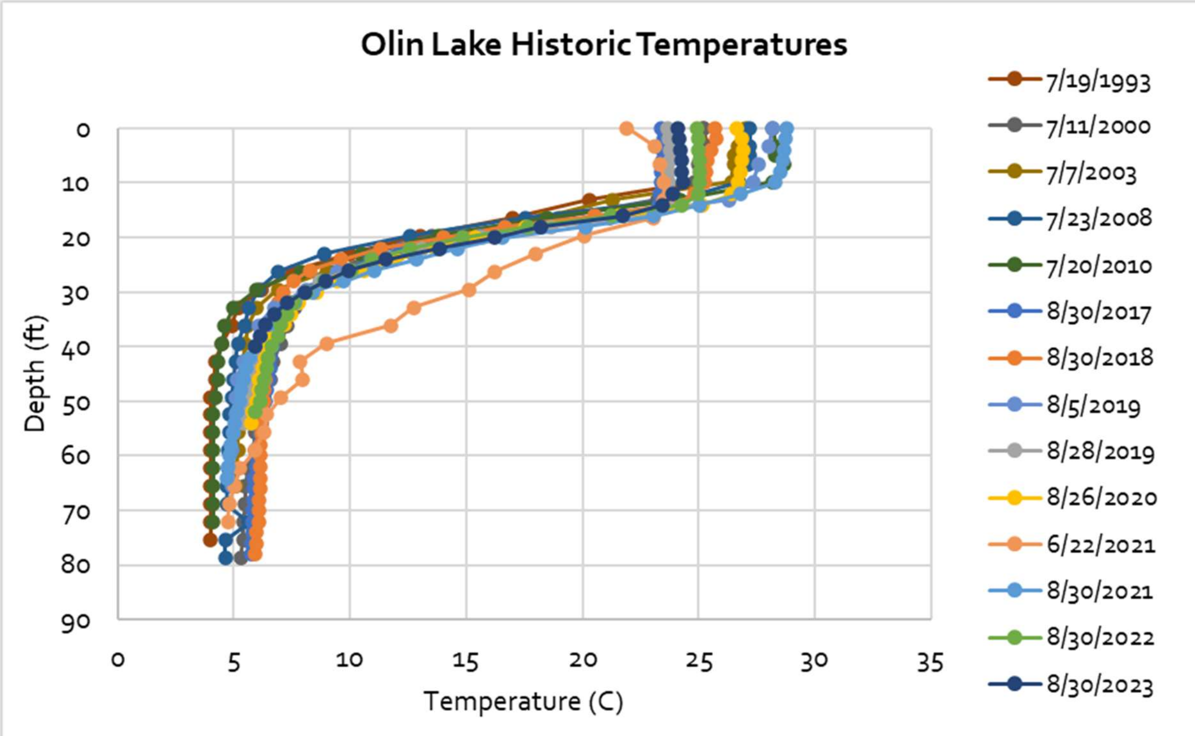


Figure 45. Historic temperature profiles for Olin Lake, Lagrange County, Indiana.

The dissolved oxygen data also indicate that typically more than half of the water column is available for use by the lake's biota (Figure 46). However, low dissolved oxygen concentrations present at the lake bottom increases the potential for nutrient release from the lake's bottom sediments. Additionally, during many assessments, including 2000 and 2003, there is a sharp increase in dissolved oxygen in the lake's metalimnion. This results in a positive heterograde profile. Positive-heterograde profiles are characterized by a peak in oxygen concentration at a depth below the water surface, such as the peaks in the 2000 and 2003 profiles beginning at 13 feet (4.0 m) below the water's surface. The peak is likely associated with a higher concentration in phytoplankton at that particular depth layer. Called a metalimnetic oxygen maximum, the peak results when the rate of settling plankton slows in the denser waters of the metalimnion. At this depth, the plankton can take advantage of nutrients diffusing from the nutrient-enriched hypolimnion. As the plankton at this depth photosynthesize, they release oxygen into the water column, creating a peak in oxygen at that level. Cisco layers form when lake temperatures measure 20°C (68° F) or colder and oxygen measures 3 parts mg/L or more. Cisco layers are typically only found in lakes with high water clarity, which allows sunlight to penetrate into the deeper regions of the lake (Frey, 1955). Although conditions exist in Olin Lake for a cisco layer, cisco is considered to be extirpated from Olin Lake (INDR, 2019).

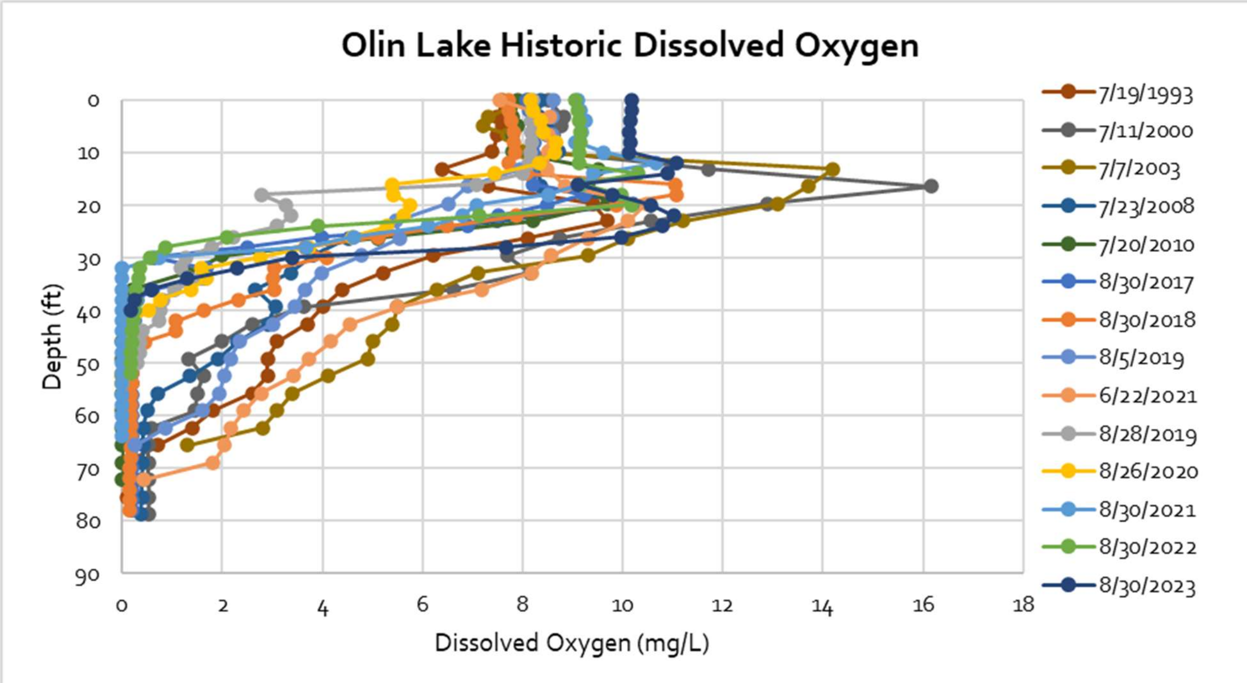


Figure 46. Historic dissolved oxygen profiles for Olin Lake, Lagrange County, Indiana.

Much of the data presented above suggest that Olin Lake is generally low to moderately productive. The historical percent oxic results (

Table **24**) and dissolved oxygen profiles (Figure 46) support this idea. Dissolved oxygen data indicate that the lake possessed dissolved oxygen greater than 1 mg/L in more than 50% of the water column depending on the sampling event. A late summer monitoring event in 2021 indicated insufficient dissolved oxygen in 55% of the water column. This low oxygen observation coincided with a lower than average Secchi depth. The dissolved oxygen data also indicate that generally more than half of the water column is typically available for use by the lake's biota. Low dissolved oxygen concentrations present at the lake bottom increases the potential for nutrient release from the lake's bottom sediments.

The lack of oxygen in Olin Lake's hypolimnion also affects the lake's chemistry. While mean total phosphorus and hypolimnetic ammonia-nitrogen concentrations are variable for the years, a more detailed evaluation shows that hypolimnetic total phosphorus concentrations are typically higher than epilimnetic total phosphorus concentrations. Under anoxic conditions, the iron in iron phosphate, a common precipitate in lake sediments, is reduced, and the phosphate ion is released into the water column. This phosphate ion is readily available to algae and can therefore spur algal growth. Further review of historical phosphorus data indicate that much of the total phosphorus in the hypolimnion was in the dissolved form of phosphorus (SRP). This indicates that Olin Lake was releasing phosphorus from its bottom sediments.

6.2 Lake Water Quality Assessment Methods

See Section 4.2 for Lake Water Quality Assessment Methods.

6.3 Lake Water Quality Assessment Results

Results from the Olin Lake water quality assessment are included in Figure 47, Table 26 and Table 26.

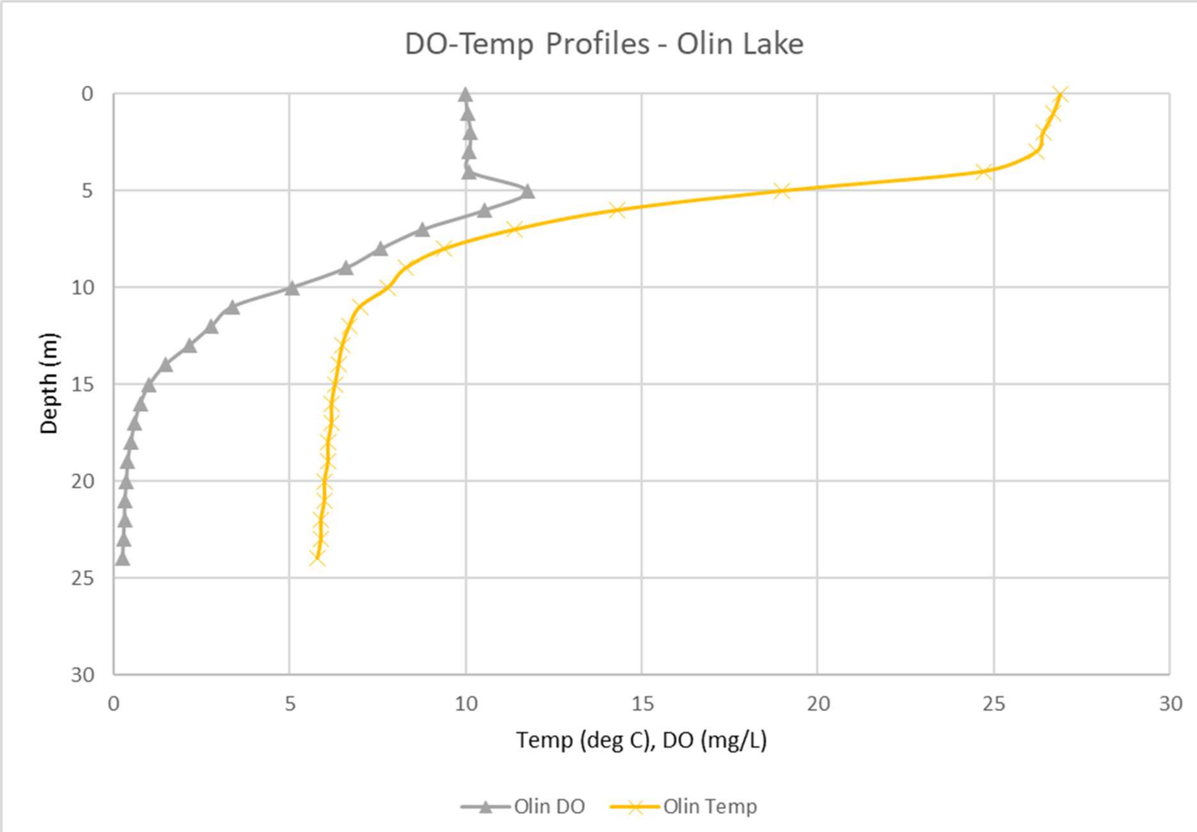


Figure 47. Temperature and dissolved oxygen profiles for Olin Lake on July 23,2024.

Table 25. Water quality characteristics of Olin Lake on July 23, 2024.

Parameter	**Epilimnetic Sample**	**Hypolimnetic Sample**	**Indiana TSI Points (based on mean values)**
Secchi Depth Transparency	4.1 feet		6
Light Transmission at 3 ft.	48%		3
% Saturation at 5 ft.	125%		0
Total Phosphorous	0.032mg/L	0.078 mg/L	2
Orthophosphate	0.004 mg/L	0.018 mg/L	0
Nitrate-Nitrogen	1.209 mg/L	0.145 mg/L	2
Ammonia-Nitrogen	0.027 mg/L	1.101 mg/L	2
Organic Nitrogen	1.304 mg/L	1.424 mg/L	3
% Water Column Oxic	63%		2
Plankton Density	10,559 cells/mL		--
Blue-Green Dominance	82%		10
Chlorophyll *a*	3.6		
			30

mesotrophic*

*Note that plankton density is reported in cells/mL, while the Indiana trophic state index requires reporting in natural units per liter. The two are not easily converted thus the ITSI score calculated here does not include a plankton score and is not fully comparable to previously calculated ITSI scores.

Table 26. Plankton sample assemblage identified in Olin Lake on July 23, 2024.

Taxa	Functional Group	Cell Count (cells/mL)	Count (NU/L)
Aphanizomenon (Aph.)	Blue Green algae	193.5	
Aphanocapsa-Aphanothece	Blue Green algae	7,805.9	
Dolichospermum	Blue Green algae	45.1	
Merismopedia	Blue Green algae	412.5	
Microcystis	Blue Green algae	51.6	
Planktolyngbya	Blue Green algae	86.8	
Pseudanabaena	Blue Green algae	9.6	
Raphidiopsis	Blue Green algae	16.4	
Centrics	Cryptophytes and Dinoflagellates	54.8	
Dinobryon	Cryptophytes and Dinoflagellates	8.1	
Mallomonas	Cryptophytes and Dinoflagellates	12.9	
Pennate Diatoms	Cryptophytes and Dinoflagellates	22.6	
Cryptomonas	Diatoms	11.3	
Peridinales	Diatoms	4.8	
Rhodomonas	Diatoms	4.8	
Chlorophytes	Green algae	1,368.1	
Crucigenia-Crucigniella	Green algae	9.7	
Quadrigula-Elakatothrix	Green algae	8.1	
Unclassified (identity)		182.1	
Unclassified (size)		251.4	
Asplanchna			0.6
Brachionus			1.8
Calanoid			1.8
Cyclopoid			10.9
Daphnia			3.0
Filinia			1.8
Kellicottia			1.8
Keratella			39.9
Nauplii			24.2
Polyarthra			10.3
Trichocerca			1.8
	Total	**10,559.9**	**97.9**

Temperature and oxygen profiles for Olin Lake show that the lake was stratified at the time of sampling (Figure 47). The oxygen concentration maintains a relatively high concentration for the first 13.2 feet (4 m) before increasing in the metalimnion then rapidly declining to <1 mg/L at 49.2 feet (15 m). As noted in Olin Lake's historic dissolved oxygen profiles, this profile is known as a positive heterograde profile. Positive-heterograde profiles are characterized by a peak in oxygen concentration at a depth below the water surface. The small peak is likely associated with a higher concentration in phytoplankton at that particular depth layer. Called a metalimnetic oxygen maximum, the peak results when the rate of settling plankton slows in the denser waters of the metalimnion. At this depth, the plankton can take advantage of nutrients diffusing from the nutrient-enriched hypolimnion. As the plankton at this depth photosynthesize, they release oxygen into the water column, creating a peak in oxygen at that level. This suggests that a weak cisco layer – areas where high levels of dissolved oxygen may have been present in the metalimnion while temperatures are dropping – was present during this assessment. Cisco layers form when lake temperatures measure 20°C (68° F) or colder and oxygen measures 3 parts mg/L or more. Cisco layers are typically only found in lakes with high water clarity, which allows sunlight to penetrate into the deeper regions of the lake (Frey, 1955).

At the time of our sampling, the *epilimnion* (surface waters) was confined to the upper 9.8 feet (3 m) of water. The metalimnion transition was confined between 9.8 and 26.2 feet (3 and 8meters), where the hypolimnion continued to the lake bottom. This corresponds with the top edge of the *euphotic zone*, or the locations were insufficient light limits photosynthesis by phytoplankton. In this portion of the lake, aquatic fauna is respiring, or using available oxygen, while bacteria are consuming oxygen during decomposition. All of this results in declining dissolved oxygen concentrations. Below this point, DO levels decline until there is no dissolved oxygen remaining in the lake. This is likely due to biological oxygen demand (BOD) from excess organic detritus in the lake's deeper waters. Respiration by aquatic fauna and decomposition of organic matter likely depleted the oxygen supply in the lake's deeper waters. Water below 49.2 feet (15 m) did not contain sufficient dissolved oxygen to support fish and other aquatic organisms. The lack of oxygen at the lake-sediment interface created conditions conducive to the release of phosphorus from the lake's sediments. Only 63% of the lake's water column was oxic limiting the amount of habitat available for aquatic fauna.

Olin Lake exhibited poor water clarity during the July 2024 sampling event. The lake's Secchi disk transparency at the time of sampling measured 4.1 feet (1.2 m). This result is poorer thana average transparencies measured in Olin Lake (8.9 feet (2.7 m) and measures less than most lakes in Indiana (5.4 feet or 1.6 m).

Phosphorus and nitrogen are the primary plant nutrients in lakes. In the summer, Indiana lakes typically possess lower nutrient concentrations in their epilimnia compared to nutrient concentrations present in their hypolimnia. Algae in the lake's epilimnion often utilize a large portion of the readily available nutrients for growth. When the algae die and settle to the bottom sediments, nutrients are relocated to the hypolimnion. Higher concentrations of phosphorus in the hypolimnion may also result from chemical processes occurring at the sediment-water interface. Dissolved phosphorus concentrations are relatively low in the epilimnion (0.004 mg/L) and in the hypolimnion (0.018) of Olin Lake. Both measured below the median values observed at lakes across Indiana from 2019 to 2022. Total phosphorus concentrations measured relatively low in the epilimnion (0.032 mg/L) but are much higher in the hypolimnion (0.078 mg/L) suggesting that sediment-attached phosphorus is likely readily available in the bottom waters of Olin Lake. Total phosphorus concentration measured at the eutrophication threshold of 0.030 mg/L in the epilimnion (0.028 mg/L) suggesting that algae blooms are likely not an issue at the time of sample collection. Additionally, total phosphorus concentrations measured (2019-2022) below median levels observed in Indiana Lakes (0.028 mg/L) in the epilimnion and (0.142 mg/L) in the hypolimnion.

At the time of sampling, nitrate-nitrogen concentrations were elevated in the surface waters (1.209 mg/L) but measured lower in the bottom waters (0.145 mg/L). Typically, nitrogen rapidly oxidizes to nitrate-nitrogen in the presence of adequate oxygen, then moves from the water column into the atmosphere as nitrogen gas. The elevated nitrate-nitrogen concentrations suggest that nitrate-nitrogen is not rapidly converting to nitrogen gas but rather is being used by algae in the epilimnion. On average, nitrate-nitrogen concentrations exceed the USEPA target of 0.008 mg/L (USEPA, 2000a) and concentrations are higher than most Indiana lakes measured 2019 to 2022 (0.022 mg/L epilimnion, 0.029 mg/L hypolimnion). The ammonia-nitrogen concentration was elevated in the epilimnion (0.027 mg/L) and hypolimnion (1.101 mg/l) with both epilimnetic and hypolimnetic ammonia-nitrogen concentrations measured high for Indiana lakes (epilimnetic, 0.022 mg/L; hypolimnetic, 1.002 mg/L). Since ammonia is a byproduct of decomposition, a higher hypolimnetic concentration of ammonia-nitrogen suggests that decomposition is occurring in the lake's bottom waters.

Olin Lake's plankton density (10,559.9 cells/mL) reflects the relatively elevated limited phosphorus concentrations in the lake but measures lower than most lakes in Indiana (14,803 cells/mL; ICLP, unpublished). Olin Lake exhibited a chlorophyll *a* concentration 3.6 µg/L. This concentration is lower than most Indiana lakes (7.25 µg/L) but measures above the target USEPA concentration of 2.63 µg/L. At the time of the current assessment, blue-green algae were the dominant functional group. In total, 82% of the Olin Lake plankton community consisted of blue-green algae. Blue-green algae are usually associated with degraded water quality. Blue-green algae are less desirable in lakes because they: 1) may form extremely dense nuisance blooms; 2) may cause taste and odor problems; and 3) are unpalatable as food for many zooplankton grazers.

7.0 MARTIN LAKE ASSESSMENT

7.1 Historic Water Quality Data

The IDNR Division of Fish and Wildlife, Davey Resource Group (DRG), Aquatic Weed Control (AWC), Aquatic Control (AC), JFNew, Indiana Clean Lakes Program (ICLP) staff and Clean Lakes Program volunteer monitors have conducted various water quality tests on Martin Lake. Table 27 presents some selected water quality parameters for these assessments. Additionally, Figure 48 details transparency measurements observed in Martin Lake by year.

Table 27. Summary of historic data for Martin Lake, Lagrange County, Indiana. Note volunteer data represent averages for the year shown.

Date	Secchi (Ft)	% Oxic	pH epi	Ammonia hypo (mg/L)	Total Phosphorus avg (mg/L)	Chl a (µg/L)	Plankton (NU/L) or (cells/mL)*	Source
1975	10.5							IDNR
1988	15.0							IDNR
1990	11.8	81%		0.959	0.018		287,312	CLP
1993	12.5	66%		0.493	0.175		21,384	CLP
1993	10.4							CLP volunteer
1994	12.1				0.035	3.45		CLP volunteer
1995	10.3				0.032	1.17		CLP volunteer
1996	8.7				0.041	11.99		CLP volunteer
1997	9.4				0.032	2.10		CLP volunteer
1998	10.2				0.013	2.12		CLP volunteer
1999	9.7				0.047	2.02		CLP volunteer
7/11/2000	12.1	56%	8.25	1.200	0.042	1.02	10,666	CLP
2000	8.9				0.035	2.29		CLP volunteer
2001	11.1				0.018	0.76		CLP volunteer

Date	Secchi (Ft)	% Oxic	pH epi	Ammonia hypo (mg/L)	Total Phosphorus avg (mg/L)	Chl a (μg/L)	Plankton (NU/L) or (cells/mL)*	Source
2002	11.0				0.021	0.71		CLP volunteer
7/7/2003	12.1	66%	8.3	0.747	0.014	0.10	32,389	CLP
2003	13.0				0.033	0.84		CLP volunteer
2004	9.2				0.050	5.81		CLP volunteer
2005	11				0.028	1.13		CLP volunteer
2006	7.6				0.027	4.37		CLP volunteer
2007	10.2				0.056	3.86		CLP volunteer
5/29/2008	11.5							JFNew
7/23/2008	11.1	43%	8.3	0.984	0.034	0.89	28,295	CLP
8/6/2008	7.5							JFNew
2009	9.9				0.015	3.25		CLP volunteer
2010	7.9				0.075	3.11		CLP volunteer
2011	9.1				0.018	2.58		CLP volunteer
7/11/2011	12.1	37%	8.4	0.130	0.021	2.00	329,625	CLP
4/10/2012	17							AC
7/31/2012	7.5							AC
2012	7.8				0.015	1.65		CLP volunteer
8/6/2013	16							AWC
7/23/2014	9							DRG
2014	9.1				0.002	0.67		CLP volunteer
2015	8.3				0.022	2.60		CLP volunteer
6/29/2015	4.6	69%	8.2	1.834	0.059	20.33	2,906,670	CLP
2016	7.6				0.056	2.89		CLP volunteer
8/30/2017	9							IDNR
2017	10.1				0.046	2.20		CLP volunteer
8/30/2018	9.5							IDNR
2018	7.7				0.008	1.72		CLP volunteer
8/28/2019	4							IDNR
2019	5.1				0.013	5.16		CLP volunteer
8/26/2020	4							IDNR
2020	8.1				0.028	9.50		CLP volunteer
8/30/2021	6							IDNR
2021	7.5				0.021	5.00		CLP volunteer
8/30/2022	6	51%						IDNR
2022	6.2				0.021	10.00		CLP volunteer
8/30/2023	5.5	55%						IDNR
2023	10.2				0.025	5.00		CLP volunteer

*Plankton samples collected prior to 2010 are in natural units per liter, while samples collected in 2010 and after are in cells per milliliter.

Based on the data presented in Table 27 and Figure 48, Secchi disk transparency (a measure of water clarity) in Martin Lake averages about 9.4 feet (2.9 m). Clarity ranged from a low of 2 feet (0.6 m) in June

1997 and 2020 to a high of 17.3 feet (5.3 m) in June 2016. Overall, water clarity in Martin Lake is better (9.4 feet or 2.9 m) than most lakes in Indiana (5.4 feet or 1.6 m) measured 2019 to 2022. Overall, transparency declined by nearly 3 feet (0.9 m) over the last 48 years (Figure 44)); however, some change is likely due to differences in when data were collected throughout the year. Water clarity typically measures on average the deepest in April (14 feet or 4.3 m), May (11.4 feet or 3.5 m) and June (11.4 feet or 3.5 m) before improving in July (13.8 feet or 4.2 m) and August (12.7 feet or 3.9 m) before declining in September (8.8 feet or 2.7 m) and October (9.9 feet or 3.0 m).

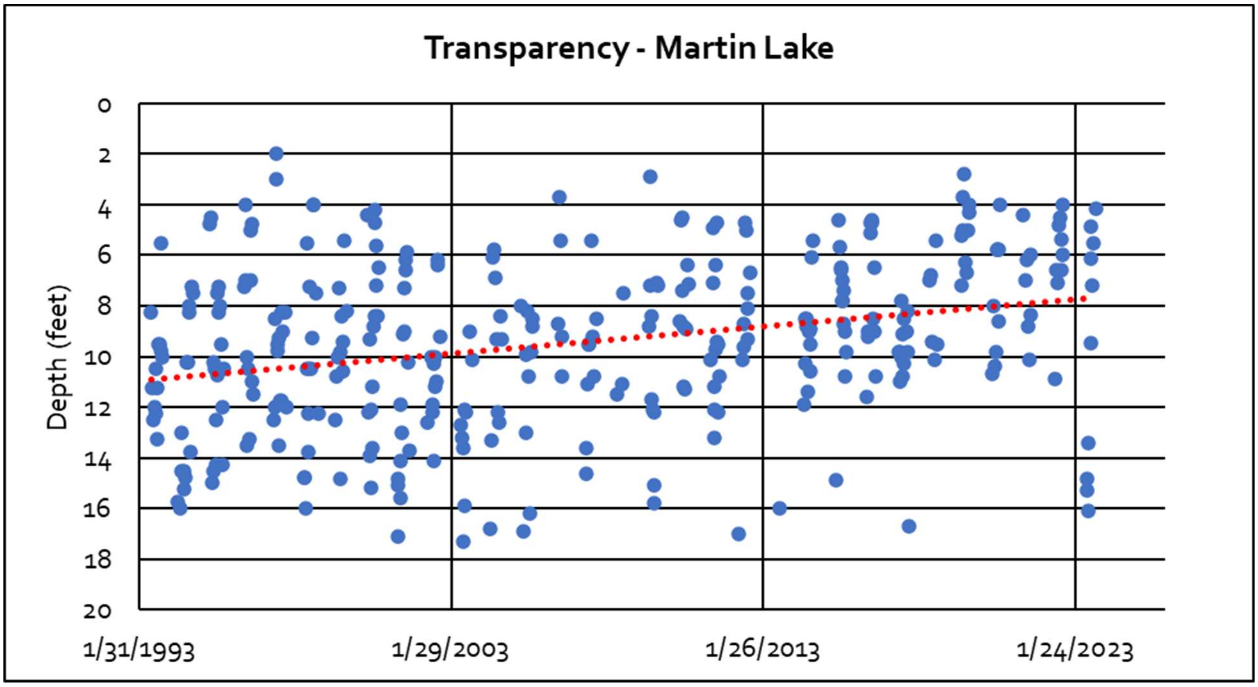


Figure 48. Historic Secchi disk transparency data, Martin Lake, Lagrange County, Indiana.

The lake's algae (plankton) density reflects the relatively moderate nutrient levels typically present in Martin Lake (Table 27). Despite the relatively moderate nutrient levels similar to Olin and Oliver Lake, Martin Lake typically exhibits higher plankton densities than those observed in Olin and Oliver Lake. Plankton concentrations were elevated during the 1990 sampling event measuring an order of magnitude more dense in natural units/liter than any other event through 2010. Densities measured after 2010 are in cells per millilieter and measured below the average concentration for Indiana lakes during the 2011 event but above for the 2015 event. Nutrients (nitrogen and phosphorus) promote the growth of algae and/or rooted plant populations. Total phosphorus concentrations measured via Clean Lakes Programs staff and volunteers indicate Martin Lake contains phosphorus levels which measure in the low to medium categories of the Indiana Trophic State Index. Nearly all of the available phosphorus measured during Clean Lakes Program staff assessments is present in the bottom waters or hypolimnion. Chlorophyll *a* concentrations were low during most sampling events; however, volunteer-collected chlorophyll *a* average exceeded the median for Indiana lakes during 1996, 2020 and 2022 as well as during the 2015 ICLP sampling event.

Figure 49 displays the temperature profiles recorded during IDNR fisheries surveys and Indiana CLP assessments. All of the temperature profiles show that Martin Lake was stratified at the time of the assessments. The developed hypolimnion (bottom water) present during the surveys is very typical of Indiana lakes. The metalimnion, or area of rapidly changing water temperature, typically extends from 6 feet (1.8 m) to approximately 30 feet (9.1 m). The epilimnion (surface water) is located above the metalimnion, while the hypolimnion (bottom water) is located below the metalimnion. Water within the epilimnion and hypolimnion are typically separated during the summer in stratified lakes and do not mix. This is the case during all assessments.

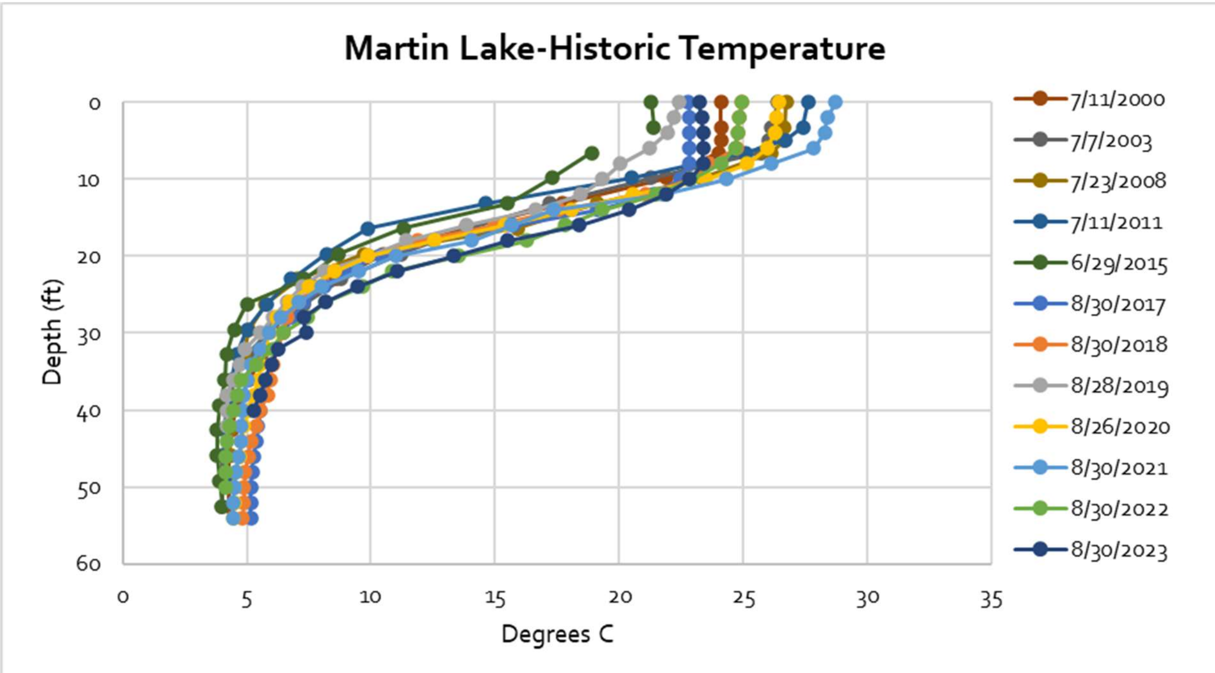


Figure 49. Historic temperature profiles for Martin Lake, Lagrange County, Indiana.

The dissolved oxygen data also indicate that typically more than half of the water column is available for use by the lake's biota (Figure 50). However, low dissolved oxygen concentrations present at the lake bottom increases the potential for nutrient release from the lake's bottom sediments. Additionally, during many assessments, including 2000,2003 and 2023, there is a sharp increase in dissolved oxygen in the lake's metalimnion. This results in a positive heterograde profile. Positive-heterograde profiles are characterized by a peak in oxygen concentration at a depth below the water surface, such as the peaks in the 2000 and 2003 profiles beginning at 10 feet (3.0 m) and the 2023 profile at 18 (5.5 m) feet below the water's surface, respectively. The peak is likely associated with a higher concentration in phytoplankton at that particular depth layer. Called a metalimnetic oxygen maximum, the peak results when the rate of settling plankton slows in the denser waters of the metalimnion. At this depth, the plankton can take advantage of nutrients diffusing from the nutrient-enriched hypolimnion. As the plankton at this depth photosynthesize, they release oxygen into the water column, creating a peak in oxygen at that level. Cisco layers form when lake temperatures measure 20°C (68° F) or colder and oxygen measures 3 parts mg/L or more. Cisco layers are typically only found in lakes with high water clarity, which allows sunlight to penetrate into the deeper regions of the lake (Frey, 1955). Although conditions exist for a cisco layer, the Indiana DNR Division of Fish & Wildlife (2019) lists cisco as extirpated from Martin Lake.

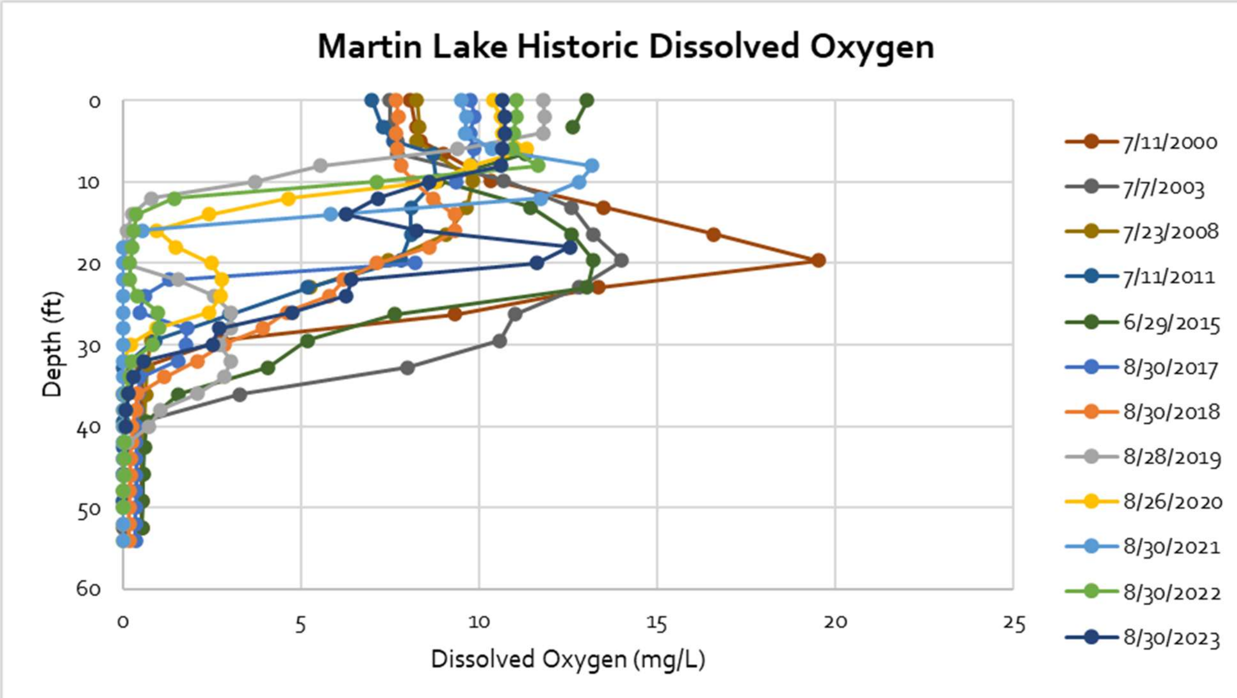


Figure 50. Historic dissolved oxygen profiles for Martin Lake, Lagrange County, Indiana.

Much of the data presented above suggest that Martin Lake possesses relatively low nutrient concentrations but that it is generally moderately to highly productive. The historical percent oxic results (Table 27) and dissolved oxygen profiles (Figure 50) support this idea. Dissolved oxygen data indicate that the lake possessed dissolved oxygen greater than 1 mg/L in more than 50% of the water column depending on the sampling event. During the 2008 and 2011 sampling events, dissolved oxygen data indicated insufficient dissolved oxygen (<1 mg/L) in a majority of the water column. These low oxygen observations coincided with a higher than average Secchi depths. The dissolved oxygen data also indicate that generally more than half of the water column is typically available for use by the lake's biota. Low dissolved oxygen concentrations present at the lake bottom increases the potential for nutrient release from the lake's bottom sediments.

The lack of oxygen in Martin Lake's hypolimnion also affects the lake's chemistry. While mean total phosphorus and hypolimnetic ammonia-nitrogen concentrations are variable for the years. The relationship of hypolimnetic total phosphorus concentrations to epilimnetic total phosphorus concentrations is variable from year to year. Under anoxic conditions, the iron in iron phosphate, a common precipitate in lake sediments, is reduced, and the phosphate ion is released into the water column. This phosphate ion is readily available to algae and can therefore spur algal growth. Further review of historical phosphorus data indicate that amount of the total phosphorus in the hypolimnion that was in the dissolved form of phosphorus (SRP) was variable from year to year. This indicates that Martin Lake was releasing phosphorus from its bottom sediments.

7.2 Lake Water Quality Assessment Methods

See section 4.2 for Lake Water Quality Assessment Methods.

7.3 Lake Water Quality Assessment Results

Results from the Martin Lake water quality assessment are included in Table 28, Table 29 and Figure 51.

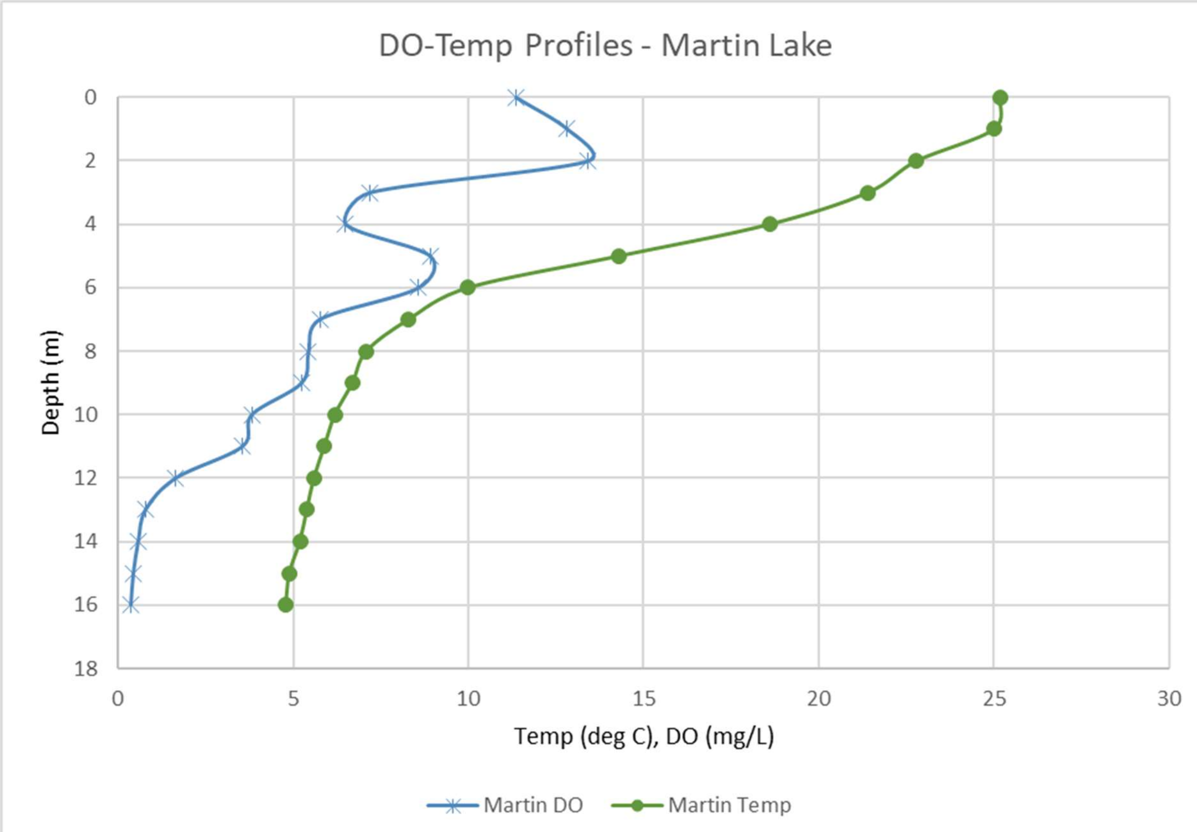


Figure 51. Temperature and dissolved oxygen profiles for Martin Lake on July 23, 2024.

Table 28. Water quality characteristics of Martin Lake, July 23,2024.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
Secchi Depth Transparency	3.1 feet		6
Light Transmission at 3 ft.	44%		3
% Saturation at 5 ft.	81%		0
Total Phosphorous	0.041 mg/L	0.183 mg/L	3
Orthophosphate	0.004 mg/L	0.024 mg/L	0
Nitrate-Nitrogen	3.667 mg/L	0.281 mg/L	3
Ammonia-Nitrogen	0.042 mg/L	1.984 mg/L	4
Organic Nitrogen	3.924 mg/L	2.858 mg/L	4
% Water Column Oxic	75%		1
Plankton Density	11,689 cells/mL		--
Blue-Green Dominance	87%		10
Chlorophyll *a*	6.8		--
			34

eutrophic*

*Note that plankton density is reported in cells/mL, while the Indiana trophic state index requires reporting in natural units per liter. The two are not easily converted thus the ITSI score calculated here does not include a plankton score and is not fully comparable to previously calculated ITSI scores.

Table 29. Plankton sample assemblage identified in Martin Lake, July 23, 2024.

Taxa	Functional Group	Cell Count (cells/mL)	Count (NU/L)
Aphanocapsa-Aphanothece	Blue Green algae	8,383.8	
Merismopedia	Blue Green algae	618.2	
Aphanizomenon (Aph.)	Blue Green algae	1,051.4	
Dolichospermum	Blue Green algae	32.2	
Microcystis	Blue Green algae	23.6	
Pseudanabaena	Blue Green algae	118.0	
Chrysophyta	Cryptophytes and Dinoflagellates	62.2	
Mallomonas	Cryptophytes and Dinoflagellates	2.1	
Cryptomonas	Diatoms	8.6	
Rhodomonas	Diatoms	12.9	
Chlorophytes	Green algae	927.9	
Crucigenia-Crucigniella	Green algae	58.0	
Desmodesmus-Scenedesmus	Green algae	25.8	
Oocystis	Green algae	146.0	
Quadrigula-Elakatothrix	Green algae	8.6	
Unclassified (size)		124.5	
Unclassified (identity)		85.9	
Anuraeopsis			13.8
Calanoid			2.6
Cyclopoid			13.0
Daphnia			5.2
Dicranophorus			0.9
Kellicottia			11.2
Keratella			6.0
Nauplii			32.8
Polyarthra			5.2
	Total	**11,689.5**	**90.7**

Temperature and oxygen profiles for Martin Lake show that the lake was stratified at the time of sampling (Figure 51). The oxygen concentration maintains a relatively high concentration for the first 6.6 feet (2 m) before sharply declining to 13.2 feet (4 m) before increasing in the metalimnion then rapidly declining to <1 mg/L at 45.8 feet (14 m). As noted in Olin Lake's historic dissolved oxygen profiles, this profile is known as a positive heterograde profile. Positive-heterograde profiles are characterized by a peak in oxygen concentration at a depth below the water surface. The peak is likely associated with a higher concentration in phytoplankton at that particular depth layer. Called a metalimnetic oxygen maximum, the peak results when the rate of settling plankton slows in the denser waters of the metalimnion. At this depth, the plankton can take advantage of nutrients diffusing from the nutrient-enriched hypolimnion. As the plankton at this depth photosynthesize, they release oxygen into the water column, creating a peak in oxygen at that level. This suggests that a weak cisco layer – areas where high levels of dissolved oxygen may have been present in the metalimnion while temperatures are dropping – was present during this assessment. Cisco layers form when lake temperatures measure 20°C (68° F) or colder and oxygen measures 3 parts mg/L or more. Cisco layers are typically only found in lakes with high water clarity, which allows sunlight to penetrate into the deeper regions of the lake (Frey, 1955).

At the time of our sampling, the *epilimnion* (surface waters) was confined to the upper 9.9 feet (3 m) of water. The metalimnion transition was confined 9.9 and 22.9 feet (2 and 7 meters), where the hypolimnion continued to the lake bottom. This corresponds with the top edge of the *euphotic zone*, or the locations were insufficient light limits photosynthesis by phytoplankton. In this portion of the lake, aquatic fauna is respiring, or using available oxygen, while bacteria are consuming oxygen during decomposition. All of this results in declining dissolved oxygen concentrations. Below this point, DO levels decline until there is no dissolved oxygen remaining in the lake. This is likely due to biological oxygen demand (BOD) from excess organic detritus in the lake's deeper waters. Respiration by aquatic fauna and decomposition of organic matter likely depleted the oxygen supply in the lake's deeper waters. Water below 39.4 feet (12 m) did not contain sufficient dissolved oxygen to support fish and other aquatic organisms. The lack of oxygen at the lake-sediment interface created conditions conducive to the release of phosphorus from the lake's sediments. In total, 75% of the lake's water column was oxic limiting the amount of habitat available for aquatic fauna.

Martin Lake exhibited poor water clarity during the July 2024 sampling event. The lake's Secchi disk transparency at the time of sampling measured 3.1 feet (0.9 m). This result is poorer thana average transparencies measured in Martin Lake (9.4 feet or 2.9 m) and measures less than most lakes in Indiana (5.4 feet or 1.6 m).

Phosphorus and nitrogen are the primary plant nutrients in lakes. In the summer, Indiana lakes typically possess lower nutrient concentrations in their epilimnia compared to nutrient concentrations present in their hypolimnia. Algae in the lake's epilimnion often utilize a large portion of the readily available nutrients for growth. When the algae die and settle to the bottom sediments, nutrients are relocated to the hypolimnion. Higher concentrations of phosphorus in the hypolimnion may also result from chemical processes occurring at the sediment-water interface. Dissolved phosphorus concentrations are relatively low in the epilimnion (0.004 mg/L) and in the hypolimnion (0.024) of Martin Lake. Both measured below the median values observed at lakes across Indiana from 2019 to 2022. Total phosphorus concentrations measured relatively low in the epilimnion (0.024 mg/L) but are much higher in the hypolimnion (0.183 mg/L) suggesting that sediment-attached phosphorus is likely readily available in the bottom waters of Martin Lake. Total phosphorus concentration measured above the eutrophication threshold of 0.030 mg/L in the epilimnion (0.041 mg/L) suggesting that algae blooms could be an issue at the time of sample collection. Additionally, total phosphorus concentrations measured (2019-2022) above median levels observed in Indiana Lakes (0.028 mg/L) in the epilimnion and (0.142 mg/L) in the hypolimnion.

At the time of sampling, nitrate-nitrogen concentrations were elevated in the surface waters (3.667 mg/L) but measured lower in the bottom waters (0.281 mg/L). Typically, nitrogen rapidly oxidizes to nitrate-nitrogen in the presence of adequate oxygen, then moves from the water column into the atmosphere as nitrogen gas. The elevated nitrate-nitrogen concentrations suggest that nitrate-nitrogen is not rapidly converting to nitrogen gas but rather is being used by algae in the epilimnion. On average, nitrate-nitrogen concentrations exceed the USEPA target of 0.008 mg/L (USEPA, 2000a) and concentrations are higher than most Indiana lakes measured 2019 to 2022 (0.022 mg/L epilimnion, 0.029 mg/L hypolimnion). The ammonia-nitrogen concentration was elevated in the epilimnion (0.042 mg/L) and hypolimnion (1.984 mg/l) with both epilimnetic and hypolimnetic ammonia-nitrogen concentrations measured high for Indiana lakes (epilimnetic, 0.022 mg/L; hypolimnetic, 1.002 mg/L). Since ammonia is a byproduct of decomposition, a higher hypolimnetic concentration of ammonia-nitrogen suggests that decomposition is occurring in the lake's bottom waters.

Martin Lake's plankton density (11,689.5 cells/mL) reflects the relatively elevated limited phosphorus concentrations in the lake but measures lower than most lakes in Indiana (14,803 cells/mL; ICLP, unpublished). Martin Lake exhibited a chlorophyll *a* concentration 6.8 µg/L. This concentration is lower than most Indiana lakes (7.25 µg/L) but measures above the target USEPA concentration of 2.63 µg/L. At the time of the current assessment, blue-green algae were the dominant functional group. In total, 87% of the Martin Lake plankton community consisted of blue-green algae. Blue-green algae are usually associated with degraded water quality. Blue-green algae are less desirable in lakes because they: 1) may form extremely dense nuisance blooms; 2) may cause taste and odor problems; and 3) are unpalatable as food for many zooplankton grazers.

8.0 <u>LAKE ASSESSMENT SUMMARY</u>

The interpretation of a comprehensive set of water quality data can be quite complicated. Often, attention is directed at the important plant nutrients (phosphorus and nitrogen) and to water transparency (Secchi disk) since dense algal blooms and poor transparency greatly affect the health and use of lakes. To more fully understand the water quality data, it is useful to compare data from Oliver Lake Watershed lakes to standards, if they exist, to other lakes, or to criteria that most limnologists agree upon. Because there are no nutrient standards for Indiana Lakes, results from Oliver Lake Watershed Lakes are compared below with data from other lakes and with generally accepted criteria.

8.1 <u>Comparison with Vollenweider's Data</u>

Results of studies conducted by Richard Vollenweider in the 1970's are often used as guidelines for evaluating concentrations of water quality parameters. Vollenweider's results are given in Table 30. Vollenweider relates the concentrations of selected water quality parameters to a lake's trophic state. The trophic state of a lake refers to its overall level of nutrition or biological productivity. Trophic categories include: oligotrophic, mesotrophic, eutrophic and hypereutrophic. Lake conditions characteristic of these trophic states are:

Oligotrophic - lack of plant nutrients keep productivity low (i.e. few rooted plants, no algal blooms); lake contains oxygen at all depths; clear water; deeper lakes can support trout.

Mesotrophic - moderate plant productivity; hypolimnion may lack oxygen in summer; moderately clear water; warm water fisheries only - bass and perch may dominate.

Eutrophic - contains excess nutrients; blue-green algae dominate during summer; algal scums are probable at times; hypolimnion lacks oxygen in summer; poor transparency; rooted macrophyte problems may be evident.

Hypereutrophic - algal scums dominate in summer; few macrophytes; no oxygen in hypolimnion; fish kills possible in summer and under winter ice. These are only guidelines; similar concentrations in a particular lake may not cause problems if something else is limiting the growth of algae or rooted plants.

Olin and Oliver lakes fall between the mesotrophic to eutrophic range for total nitrogen and total phosphorus, while Martin Lake falls between eutrophic and hypereutrophic for total nitrogen and total phosphorus (Table 30). Olin and Oliver lakes measure oligotrophic to mesotrophic, while Martin Lake measures mesotrophic to eutrophic for chlorophyll *a*. These data suggest that all three lakes are moderately to highly productive and have the nutrient levels to be more productive than was observed during the 2024 assessment. In other words, the lakes are not realizing their full potential as the chlorophyll *a* concentration measured lower than expected for Olin and Oliver Lakes compared with the more productive nutrient concentrations. Specifically, the elevated total phosphorus concentrations measured in the lakes coupled with the relatively moderate chlorophyll *a* concentrations suggests that phosphorus may be limiting productivity in these lakes.

Table 30. Mean values for some water quality parameters and their relationships to lake production (after Vollenweider, 1975).

	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
Oligotrophic	0.008	0.661	1.7
Mesotrophic	0.027	0.753	4.7
Eutrophic	0.084	1.875	14.3
Hypereutrophic	>0.750	-	-
Olin Lake	**0.055**	**1.364**	**3.6**
Oliver Lake	**0.053**	**0.991**	**3.2**
Martin Lake	**0.112**	**3.391**	**6.8**

8.2 Comparison with Other Indiana Lakes

The Olin, Oliver and Martin lake results can also be compared with other Indiana lakes. Table 31 presents data from Indiana lakes collected during July and August from 2019 to 2022 under the Indiana Clean Lakes Program. The set of data summarized in the table are mean values obtained for the epilimnetic and hypolimnetic pollutant concentrations in samples from each of the lakes sampled. The table is then populated with the minimum mean sample, maximum mean sample, and median sample for all lakes. It should be noted that a wide variety of conditions, including geography, morphometry, time of year, and watershed characteristics, can influence the water quality of lakes. Thus, it is difficult to predict and even explain the reasons for the water quality of a given lake.

Table 31. Water quality characteristics Indiana lakes sampled from 2019 through 2022 by the Indiana Clean Lakes Program (CLP, unpublished). Means of epilimnion and hypolimnion samples were used for all nitrogen and phosphorus parameters. Squares shaded oragne denote those values in excess of the median lake concentration.

	Secchi Disk (ft)	NO3 epi (mg/L)	NO3 hypo (mg/L)	NH4 epi (mg/L)	NH4 hypo (mg/L)	ON epi (mg/L)	ON hypo (mg/L)	OP epi (mg/L)	OP hypo (mg/L)	TP epi (mg/L)	TP hypo (mg/L)	Chl *a* (µg/L)
Max	**19.9**	8.978	2.573	1.798	215.700	8.411	8.248	0.244	8.284	1.076	6.250	285.77
Min	**0.5**	0.005	0.005	0.005	0.005	0.030	0.030	0.002	0.002	0.005	0.004	0.35
Median	**5.4**	0.022	0.029	0.022	1.002	0.712	0.655	0.010	0.090	0.028	0.142	7.25
Olin	**4.1**	**1.209**	**0.145**	**0.027**	**1.101**	**1.304**	**1.424**	**0.004**	**0.018**	**0.032**	**0.078**	**3.6**
Oliver	**4.8**	**0.432**	**0.132**	**0.090**	**1.132**	**0.801**	**1.182**	**0.004**	**0.017**	**0.028**	**0.078**	**3.2**
Martin	**3.1**	**3.667**	**0.281**	**0.042**	**1.984**	**3.924**	**2.858**	**0.004**	**0.024**	**0.041**	**0.183**	**6.8**

All three lakes possessed higher surface water (epi) nutrient concentrations for all parameters except dissolved or orthophosphorus. Additionally, all three lakes possessed higher bottom water (hypo) organic nitrogen concentrations than most Indiana lakes. Samples collected in all three lakes contained ammonia-nitrogen higher than the median concentrations for Indiana lakes with most of the ammonia-nitrogen originating from the lake bottom under stratified conditions. In all three lakes, total phosphorus concentrations measure higher than most Indiana lakes in surface and bottom waters. These data suggest that phosphorus concentrations are sufficiently elevated; however, as noted with Vollenweider's data above, the available nutrients are not translating into productivity as chlorophyll *a* concentrations remain low.

8.3 Indiana Trophic State Index (ITSI)

In addition to simple comparisons with other lakes, lake water quality data can be evaluated through the use of a trophic state index or TSI. Indiana and many other states use a trophic state index (TSI) to help evaluate water quality data. A TSI condenses water quality data into a single, numeric index. Different index (or eutrophy) points are assigned for various water quality concentrations. The index total, or TSI, is the sum of individual eutrophy points for a lake.

The Indiana Trophic State Index was developed by the Indiana Stream Pollution Control Board and published in 1986 (IDEM, 1986). The original ITSI differed slightly from the one in use today. The most recent ITSI uses ten different water quality parameters to calculate a score. As noted above, the Indiana TSI score for all three lakes was calculated without the plankton density score as the density is measured differently than the measurement used to calculate the Indiana TSI and moving between the two measurements is not a simple conversion. Appendix D shows the point values assigned to each parameter.

Values for each water quality parameter are totaled to obtain an ITSI score. Based on this score, lakes are then placed into one of four categories:

TSI Total	*Water Quality Classification*
0-15	Oligotrophic
16-31	Mesotrophic
32-46	Eutrophic
47-75	Hypereutrophic

These categories correspond to the qualitative lake productivity categories described earlier (IDEM, 2000). At the time of the 2024 sampling, Martin Lake possessed the highest ITSI score (34), while Olin Lake scored 30 and Oliver Lake scored 28 (without the plankton density scores). Based on these scores, Martin Lake rates as eutrophic or highly productive, while Olin and Oliver Lakes rate as mesotrophic or moderately productive. These conclusions are relatively consistent with results obtained from the comparison of the lake data to Vollenweider's data (Figure 32), where parameters suggested all Martin Lake rated as eutrophic but chlorophyll *a* rated as mesotrophic to eutrophic while Olin and Oliver lakes rated as mesotrophic for all but chlorophyll *a* for which is rated as oligotrophic to mesotrophic. It should be noted that the ITSI relies heavily on plankton density and blue-green algae dominance and that the Indiana Clean Lakes Program no longer calculates the Indiana TSI due to this reliance as well as the difference in the enumeration method for plankton. Further assessment and comparison of these two scoring methodologies will be discussed in subsequent sections. Because the ITSI captures one snapshot of a lake in time, using the ITSI to track trends in lake productivity may be the best use of the ITSI. It is suggested that any future data collections include all parameters necessary to calculate the ITSI so that this comparison can be completed.

Because the ITSI captures one snapshot of a lake in time, using the ITSI to track trends in lake productivity may be the best use of the ITSI. Figure 52 illustrates the change in Olin, Oliver and Martin lakes' ITSI scores over time (Figure 52). It should be noted that while the Indiana Clean Lakes program assessed the lakes' water quality between 2008 and 2024, they stopped calculating the ITSI in 2010. Figure 52 indicates that Oliver Lake generally measures oligotrophic (2000) to mesotrophic (1989, 1993, 2003, 2008, 2024), Olin Lake generally measures mesotrophic (all years scored), while Martin Lake measures oligotrophic (1993) to eutrophic (1989, 2024). This year's assessment rated poorer (higher) than previous scores for all three lakes; however, it should be noted that this score does not include a plankton density score.

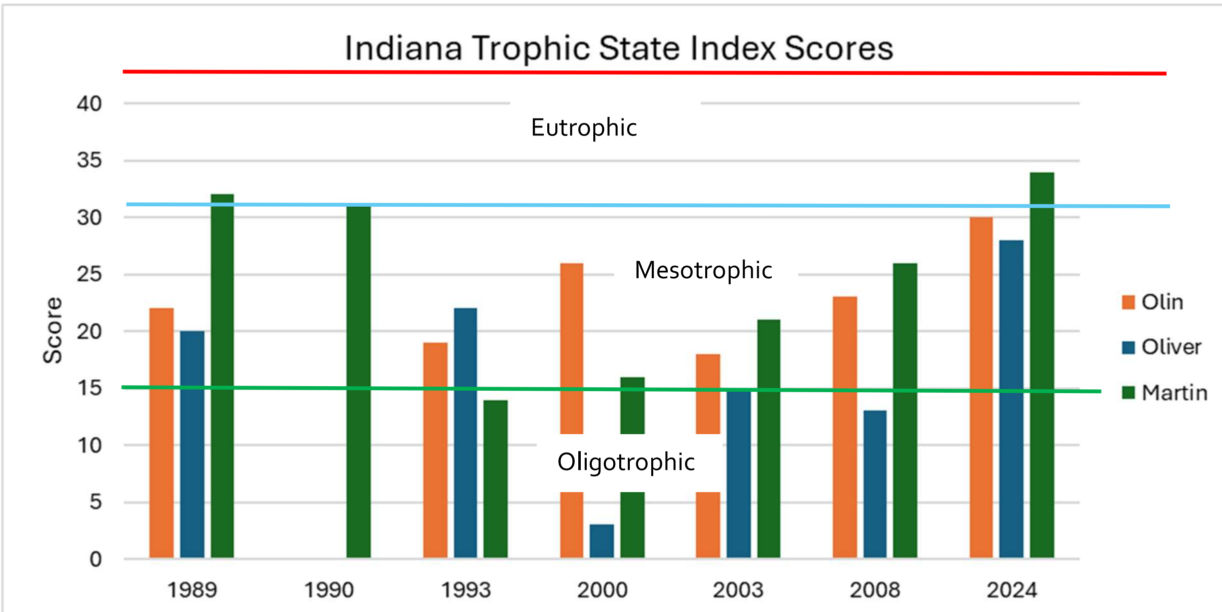


Figure 52. Indiana Trophic State Index scores for Olin, Oliver and Martin Lakes, 1989-2024.

8.4 <u>Carlson's Trophic State Index</u>

Because the Indiana TSI has not been statistically validated and because of its heavy reliance on algal parameters, the Carlson TSI may be more appropriate for evaluating Indiana lake data. Developed by Bob Carlson (1977), the Carlson TSI is the most widely used and accepted TSI. Carlson analyzed summertime total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among the three parameters. He developed mathematical equations for these relationships, and these relationships form the basis for the Carlson TSI. Using this index, a TSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll *a*, or total phosphorus. Data for one parameter can also be used to predict the value for another. The TSI values range from 0 to 100. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass (Figure 53).

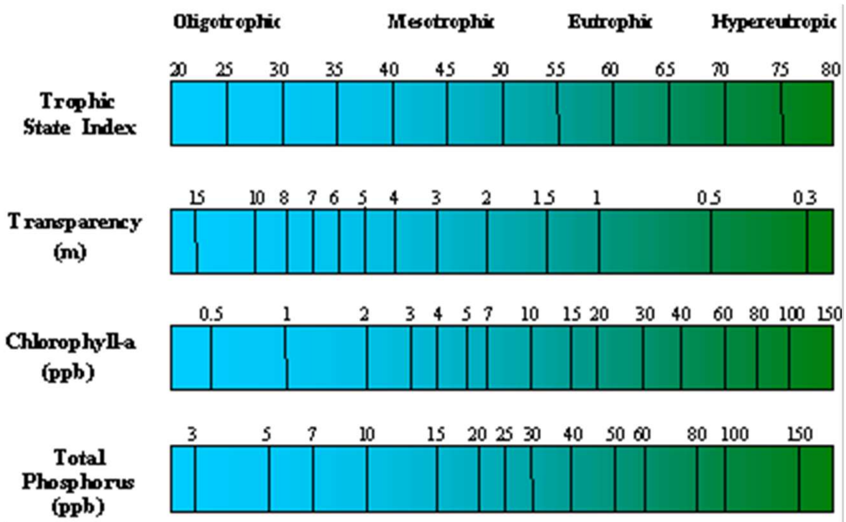


Figure 53. Carlson's Trophic State Index.

As a further aid in interpreting TSI results, Carlson's scale is divided into four lake categories: oligotrophic (least productive), mesotrophic (moderately productive), eutrophic (very productive), and hypereutrophic (extremely productive). Using Carlson's index, a lake with a summertime Secchi disk depth of 3.3 feet would have a TSI of 60 points (located in line with the 1 meter or 3.3 feet). This lake would be in the eutrophic category. Because the index was constructed using relationships among transparency, chlorophyll *a*, and total phosphorus, a lake having a Secchi disk depth of 1 meter (3.3 feet) would also be expected to have 20 µg/L chlorophyll *a* and 48 µg/L total phosphorus.

Not all lakes have the same relationship between transparency, chlorophyll *a*, and total phosphorus as Carlson's lakes do. Other factors such as high suspended sediments or heavy predation of algae by zooplankton may keep chlorophyll *a* concentrations lower than might be otherwise expected from the total phosphorus concentrations or transparency measurements. High suspended sediments would also make transparency worse than otherwise predicted by Carlson's index. It is also useful to compare the actual trophic state points for a particular lake from one year to the next to detect any trends in changing water quality. While climate and other natural events will cause some variation in water quality over time (possibly 5-10 trophic points), larger point changes may indicate important changes in lake quality.

Analysis of the lakes' total phosphorus Carlson's TSI scores suggests that all three lakes rates as eutrophic with Martin Lake scoring the highest (58), followed by Olin Lake (54) and Oliver Lake (52). The transparency scores suggest that all three lakes rate as eutrophic with Martin Lake again scoring the highest (60), followed by Olin Lake (56) and Oliver Lake (54). As noted previously, despite the available nutrients, all three lakes rate as mesotrophic for chlrophyll (Martin 59, Olin 43, Oliver 42). This analysis is relatively consistent with the results obtained when comparing the lake data to Vollenweider's data, which suggested that the lakes were moderately to highly productive for nutrients but had lower actual productivity based on chlorophyll concentrations. Using Carlson's TSI, analysis suggests the lake possesses sufficient phosphorus to support a greater level of productivity than the level suggested by the lake's chlorophyll *a* concentration and transparency. These data further suggest that Carlson's TSI may not be the most appropriate mechanism by which they should be rated.

8.5 Lake Assessment Discussion

Olin, Oliver and Martin Lakes contain more phosphorus than is ideal despite the surface phosphorus concentrations found in the lakes measuring relatively low when compared with other lakes in the state. The potential exists for excessive algal production to occur in the lakes. Olin and Oliver Lakes are considered oligotrophic to mesotrophic while Martin Lake is considered mesotrophic to eutrophic depending on the trophic state comparison utilized. All three lakes exhibit moderate plankton density but relatively poor water clarity when compared to other Indiana lakes. Years of plant and algae production and transport of organic material into the lakes from their watershed have led to a build-up of decaying organic matter in the sediments (Table 32). As bacteria decompose this material, they consume oxygen and leave the bottom waters *anoxic* (dissolved oxygen concentrations < 1.0 mg/L). Currently, the lakes become anoxic resulting in more than 54% of Oliver Lake's, 63% of Olin Lake's and 75% of Martin Lake's water column containing insufficient dissolved oxygen for aquatic biota.

Table 32. Summary of mean total phosphorus, total nitrogen, Secchi disk transparency, and chlorophyll *a* results for Oliver Lake.

Parameter	Olin Lake	Oliver Lake	Martin Lake
Percent anoxic	63%	54%	75%
Mean total phosphorus (mg/L)	0.055	0.053	0.112
Mean orthophosphorus (mg/L)	0.011	0.011	0.014
Hypolimnetic ammonia-nitrogen (mg/L)	1.101	1.132	1.194
Total N:Total P[1]	24.8	18.7	30.3
Secchi disk transparency (ft)	4.1	4.3	3.1
Chlorophyll *a* (mg/L)	3.6	3.2	6.8
Sediment phosphorus release factor[2]	4.6	4.2	5.5

[1]Total nitrogen: Total phosphorus ratio is calculated based on epilimnetic concentrations.
[2]Hypo SRP concentration/Epi SRP concentration. For example, Oliver Lake's hypolimnetic OP concentration is 0.017 mg/L or more than four times the OP concentration present in the epilimnion (0.004 mg/L). This is evidence of limited internal loading of phosphorus.

In addition to the presence of anoxic conditions, there is evidence of internal phosphorus release from all three lakes. All three lakes exhibit a high sediment release rate (Table 32). Hypolimnetic orthophosphorus concentrations measure higher than epilimnetic concentrations generating sediment phosphorus release factors of more than four. There is evidence that phosphorus is being liberated from the sediments when oxygen is depleted, or the lake is *anoxic*. The row labeled "Sediment Phosphorus Release" details the amount of soluble phosphorus (the form of phosphorus that can be released from the sediments) in the deep water (hypolimnetic) sample to the surface (epilimnetic). The sample ratio measures 4.2 for Oliver Lake, 4.6 for Olin Lake and 5.5 for Martin Lake, which indicates that sediment phosphorus release is likely occurring in all three lakes. In most lakes in Indiana, phosphorus release from the sediments is an additional and important source of phosphorus to the lake that must be addressed along with watershed practices when designing a management plan to reduce nutrient loading to the lake. This *internal loading* of phosphorus is another source of phosphorus to these lakes that can promote excessive algae production.

All three lakes also contain relatively high ammonia nitrogen concentrations in the hypolimnion (Table 32). Ammonia is a by-product of bacterial decomposition. When ammonia occurs in high concentrations, it is evidence of high biological oxygen demand. This biological oxygen demand comes from organic waste, such as dead algae and rooted plants, within the sediments, which provides further evidence of excess algae and rooted plant growth in these lakes.

All three lakes also exhibit high total nitrogen to total phosphorus (TN:TP) ratios. Oliver Lake's TN:TP ratio measures the lowest (18.7) which is near the ratio where it is suggested that phosphorus is the limiting nutrient (ie. if more phosphorus were available, more algal blooms could occur). Olin Lake's TN:TP ratio measures 24.8, while Martin Lake measures 30.3. These ratios suggest that nitrogen is the limiting nutrient, and it is the restrictor of algal production.

9.0 MODELING

9.1 Non-Point Source Modeling

Nonpoint source pollution is generated from diffuse sources found on public and private lands. The USEPA details sources of nonpoint pollution to include urban runoff, construction activities, manmade modifications to stream hydrology, agriculture, irrigation pumping and water returns, solid waste disposal, atmospheric deposition, streambank erosion, and more. The critical sources identified within the Oliver Lake Watershed are detailed in the Watershed Inventory Section. These data were generated using available watershed maps and watershed inventory information and are generally useful for detailing water quality problems as a supplement to available water quality monitoring data.

Another mechanism for determining sources of nonpoint pollution is hydrologic simulation models. Hydrologic models detail the transport of pollutants across the land surface as surface runoff. Rainwater flows over the land and through the groundwater collecting pollutants, including sediment and nutrients as it moves. The soil characteristics and land uses influence the way that water moves through the system and each hydrologic model simulates the movement in a different way. These computer models provide useful information that can serve as a baseline for future land use changes. They also serve as a check on the water chemistry samples and GIS-based watershed data.

Watershed loading rates can be estimated using a variety of loading models for a variety of parameters. A tabular-based nonpoint source pollution loading model (STEPL) was used to assess the nonpoint source pollution of four of the pollutants of concern: total nitrogen, total phosphorus, total suspended solids, and E. coli. STEPL provides a basis for comparison of runoff for these pollutants within each subwatershed. In total, 6,988 pounds of phosphorus, 27,264 pounds of nitrogen, 3,202 tons of sediment and 2,424 billion colonies of E. coli loading occurs in the Oliver Lake Watershed annually (Table 33). Based on STEPL results, Eshelman Drain (OL10) contains the highest loading rate for nitrogen, Dove Creek (OL01) contains the highest loading rate for phosphorus and sediment, while the Dove Creek tributary (OL02) contains the highest E. coli loading rate.

Table 33. Estimated annual loads for each Oliver Lake Subwatersheds using STEPL. The two highest loading rates are designated by red and orange, respectively.

Site Number	Subwatershed Name	Nitrogen Load (lb/yr)	Phosphorus Load (lb/yr)	Sediment Load (t/yr)	E. coli Load (Bil col/yr)
1	Dove Creek	3,754.2	1,153.4	1,028.2	717.1
2	Dove Creek tributary	1,729.9	380.1	101.9	1,007.1
3	Colwell Drain	2,951.3	747.0	142.7	294.5
4	Unnamed	435.0	116.3	32.6	23.5
5	Bert Hart Ditch	3,609.0	927.0	171.5	134.5
6	Winling Creek	1,644.5	435.3	94.4	24.2
7	Winling Creek north tributary	3,414.5	722.8	280.5	76.4
8	Stoner Ditch	383.6	105.5	63.7	6.0
9	Truman Flint Ditch	1,442.0	345.3	165.1	25.5
10	Eshelman Drain	4,107.5	1,095.4	604.3	49.9
11	Logan Drain	416.6	122.6	79.9	5.4
	Direct to lake	3,376.0	836.9	437.0	59.8
	Total	**27,264.1**	**6,987.8**	**3,201.7**	**2,423.8**

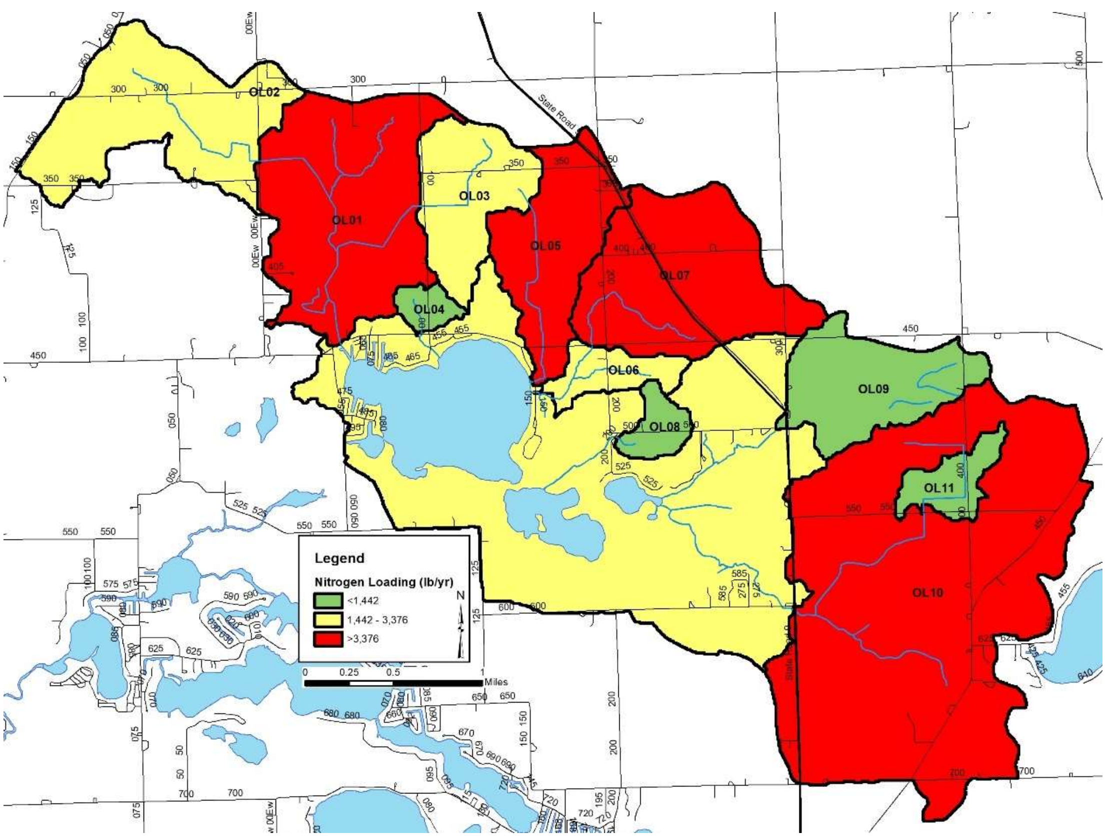


Figure 54. Total nitrogen loading estimate using STEPL.

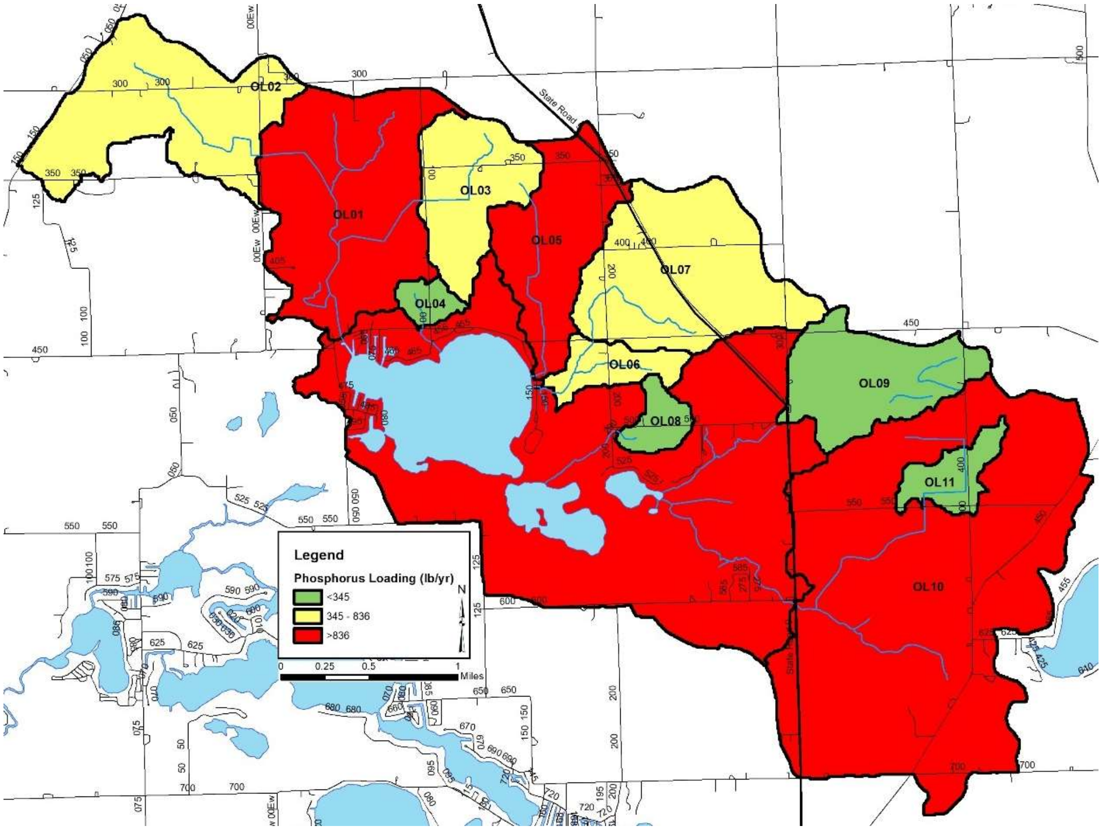


Figure 55. Total phosphorus loading estimate STEPL.

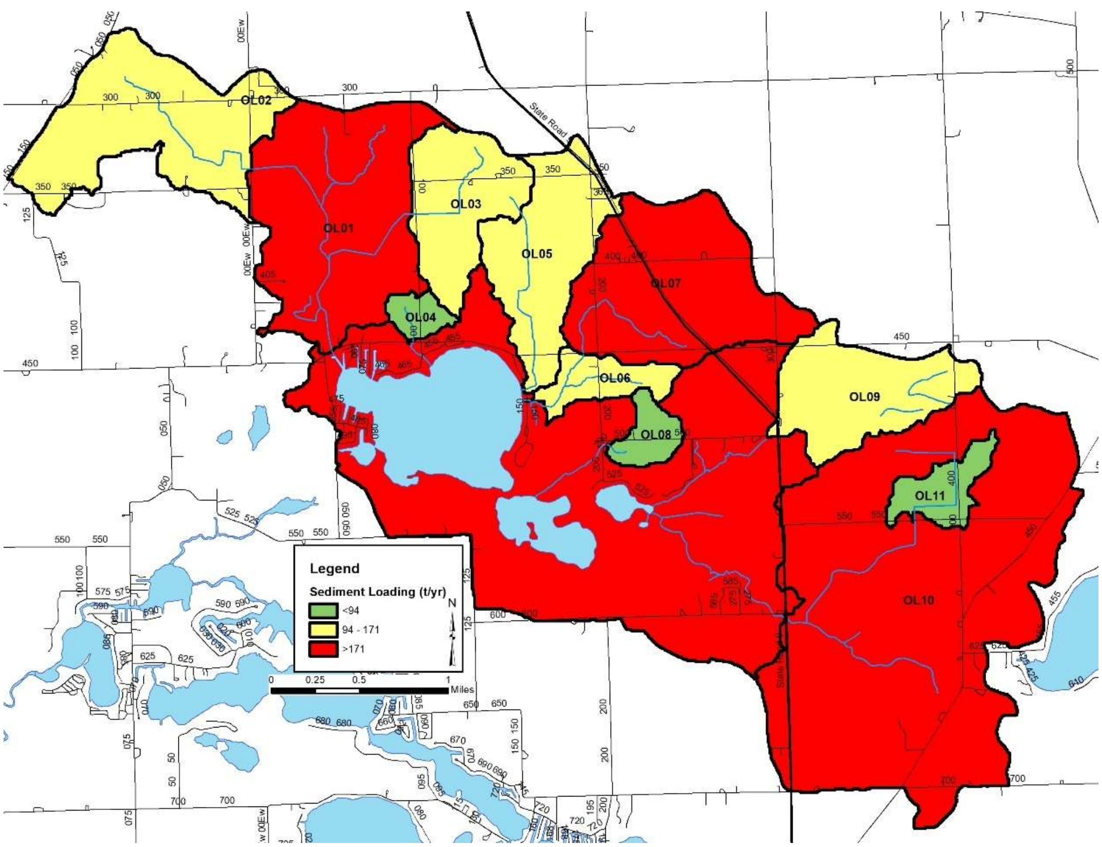


Figure 56. Total suspended sediments loading estimate using STEPL.

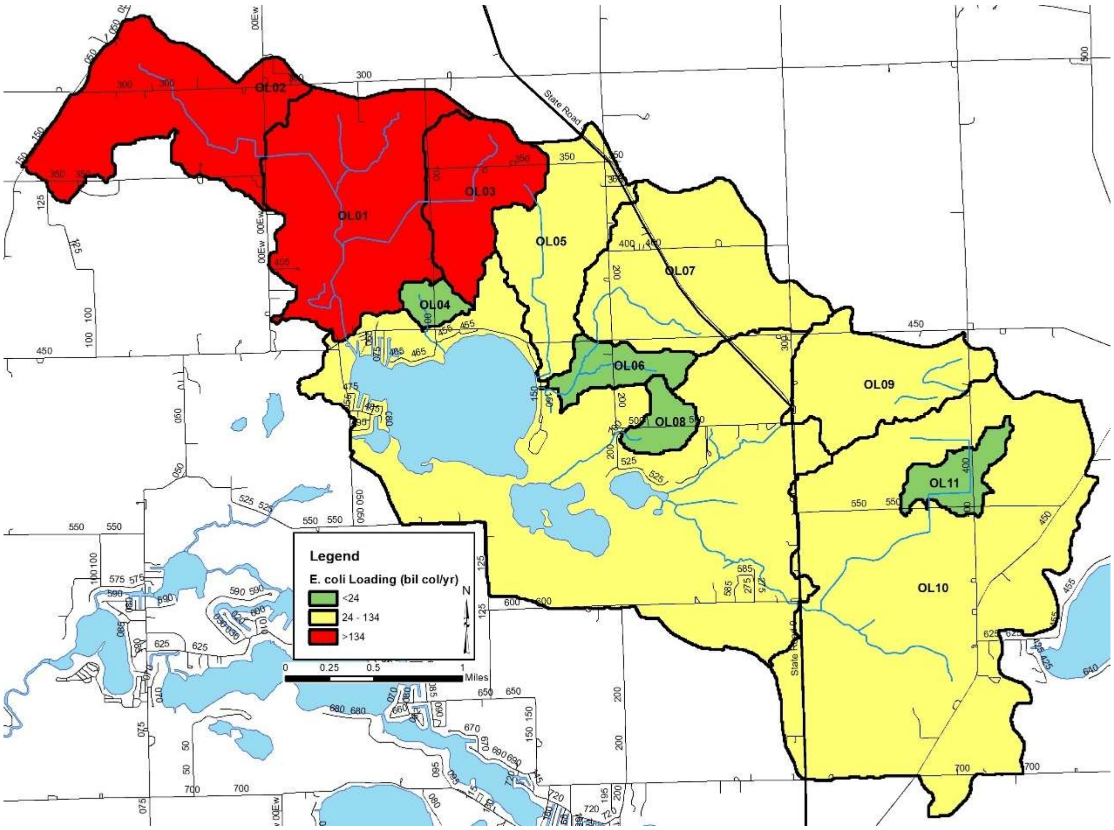


Figure 57. E. coli loading estimate using STEPL.

Figure 58 details sources of total nitrogen, total phosphorus, total suspended solids and E. coli within the watershed. It should be noted that these sources include only field observed streambank erosion sources. Cropland provides the highest source of nitrogen, phosphorus, and sediment loading, while pastureland provides the highest *E. coli* loading. Urban land, which includes residential, commercial and roadway development, is the second highest source of nitrogen, phosphorus, and sediment loading, while cropland is the second highest source of E. coli loading.

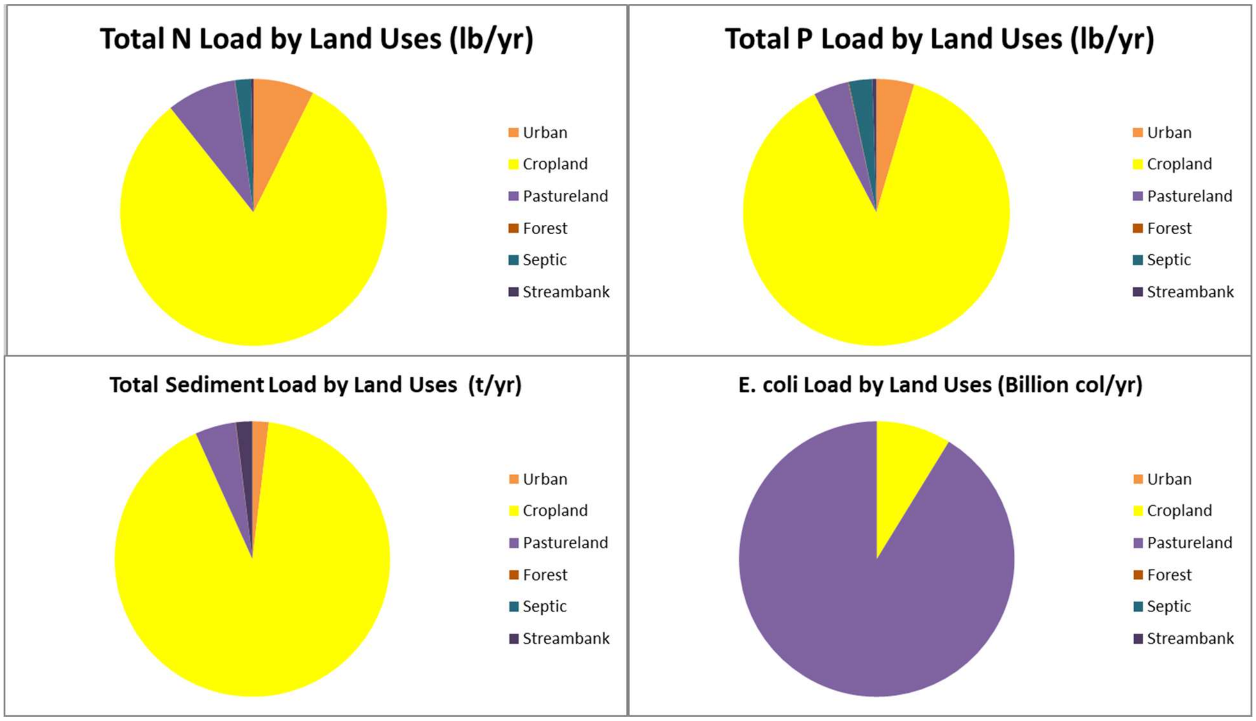


Figure 58. Sources of total nitrogen, total phosphorus and total suspended solids in the Oliver Lake Watershed.

Loading data generally compare well with water chemistry results. However, modeled results may not fully mimic water quality monitoring results for the following reasons:

- The STEPL model uses soil and land use information to evaluate surface runoff and is unaware of increased nitrogen transport rates due to tile drainage located in the agricultural portions of the Oliver Lake Watershed.
- Sediment and phosphorus generated from overland is accounted for in the STEPL model; however, non-field sediment and phosphorus, such as that originating from streambank erosion or channel erosion, are only accounted for using the STEPL model when streambank erosion was directly observed and the length of erosion calculated.

10.0 WATERSHED INVENTORY

10.1 Agricultural Conservation Planning Framework (ACPF) Summary

The Agricultural Conservation Planning Framework (ACPF) was developed by the USDA's Agricultural Research Service in partnership with the USDA Natural Resources Conservation Service. ACPF supports agricultural watershed management by using high-resolution elevation data and an ArcGIS toolbox to identify site-specific opportunities for installing conservation practices across watersheds. This non-prescriptive approach provides a menu of conservation options to facilitate conservation discussions. The framework is used in conjunction with local knowledge of water and soil resource concerns, landscape features, and producer conservation preferences. Together, these provide a better understanding of the options available to develop and implement a watershed management plan.

Sediment delivered from watershed erosion can cause substantial damage and degradation to waterways and water quality. Controlling sediment loading requires knowledge about soil erosion and sedimentation. Drainage area, basin slope, climate, land use and land cover affect the sediment delivery process. Problems caused by soil erosion and sediments include losses of soil productivity, water quality degradation, and less capacity to prevent natural disasters such as floods. Sediments may carry pollutants into water systems and cause significant water quality problems. Sediment yields are also associated with waterway damage. Sediment deposition in streams reduces channel capacity and results in flooding damage. The water storage capacity of a reservoir can be depleted by accumulated sediment deposition. Sediment yield is a critical factor in identifying non-point source pollution as well as in the design of the construction of dams and reservoirs. However, sediment yield is usually not available as a direct measurement but estimated by using a sediment delivery ratio (SDR).

Figure 59 details the sediment delivery ratio for each agricultural field in the Oliver Lake Watershed. Sediment delivery ratio utilizes both the distance from the stream and the field's steepness to calculate the rating. Coarser texture sediment and sediment from sheet and rill erosion have more chances to be deposited or to be trapped, compared to fine sediment and sediment from channel erosion. Therefore, the delivery ratio of sediment with coarser texture or from sheet and rill erosion are relatively lower than the fine sediment or sediment from channel erosion. A small watershed with a higher channel density has a higher sediment delivery ratio compared to a large watershed with a low channel density. Conversely, a watershed with steep slopes has a higher sediment delivery ratio than a watershed with flat and wide valleys. Those fields which rate 'high' for sediment delivery ratio are recommended targets to curtail sediment delivery to downstream waterbodies, while those that rate 'medium' or 'low' are likely of lower priority as they are rated lower risk as a sources of sediment for Oliver Lake.

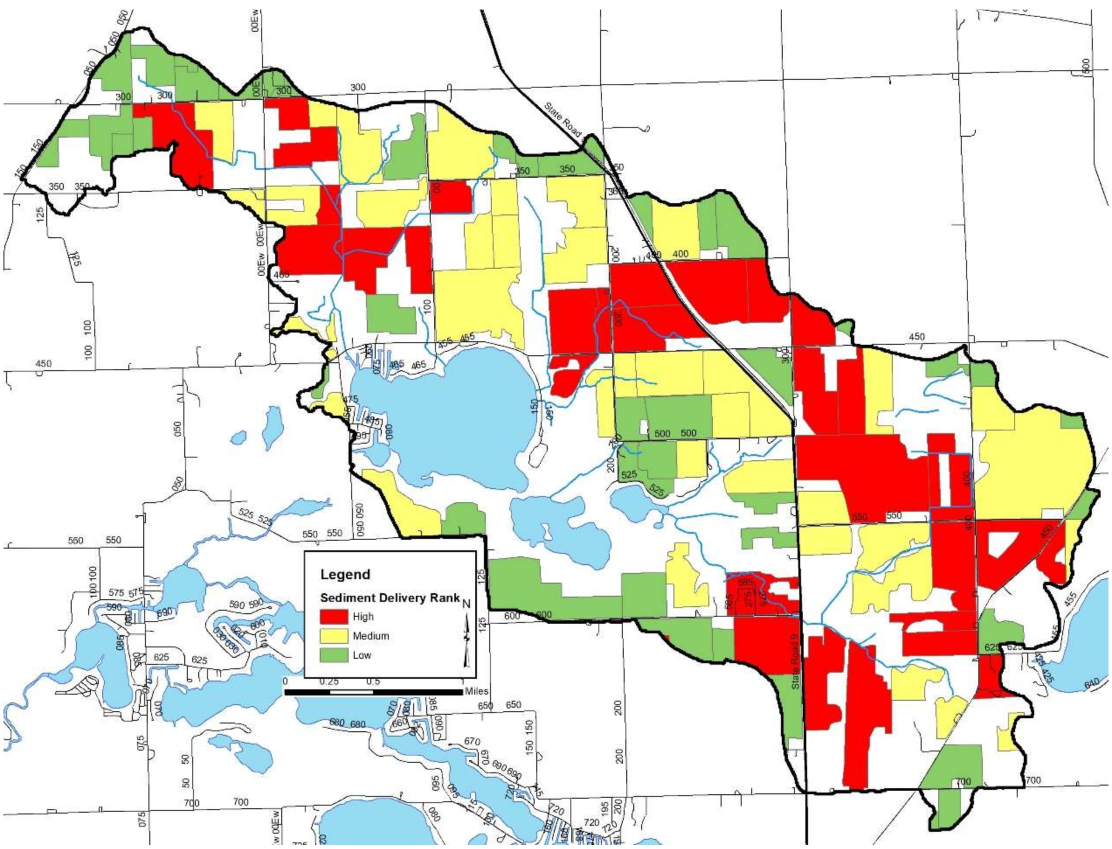


Figure 59. Sediment delivery risk developed using ACPF for the Oliver Lake Watershed.

Similarly, runoff risk calculates the direct runoff contribution to stream channels in the watershed. Runoff risk prioritizes fields where multiple erosion control practices are most needed. Fields that are closer in proximity to a stream and are steeper in slope have a higher runoff risk. Those that are further away, or flatter, have a lower runoff risk. Because sediment and phosphorus are not lost evenly from all parts of a fields but rather are lost from a few critical source areas these are the most limiting areas of significant extent or are generally those areas of the field that have the steepest slope. Figure *60* details the runoff risk for farm fields in the Oliver Lake Watershed. Runoff risk is categorized into low, moderate, high and very high. It should be noted that even fields rated as low will benefit from runoff control-based conservation practices; however, fields which rank moderate, high or very high will likely benefit more.

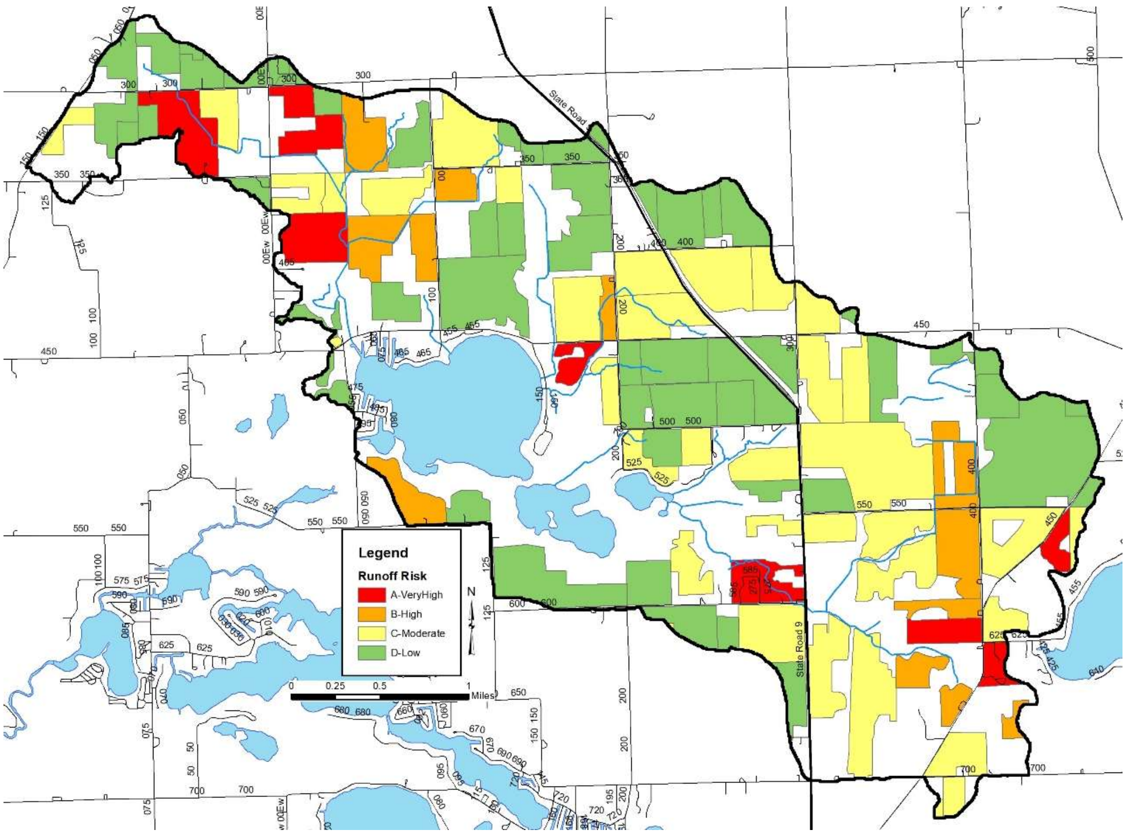


Figure 60. Runoff risk developed using ACPF for the Oliver Lake Watershed.

Figure 63 identifies potential agricultural BMP installation locations generated by ACPF modeling. These areas could benefit from infiltration-based practices (wetlands, depressions) or agricultural field-based practices (water and sediment control basins, bioreactors).

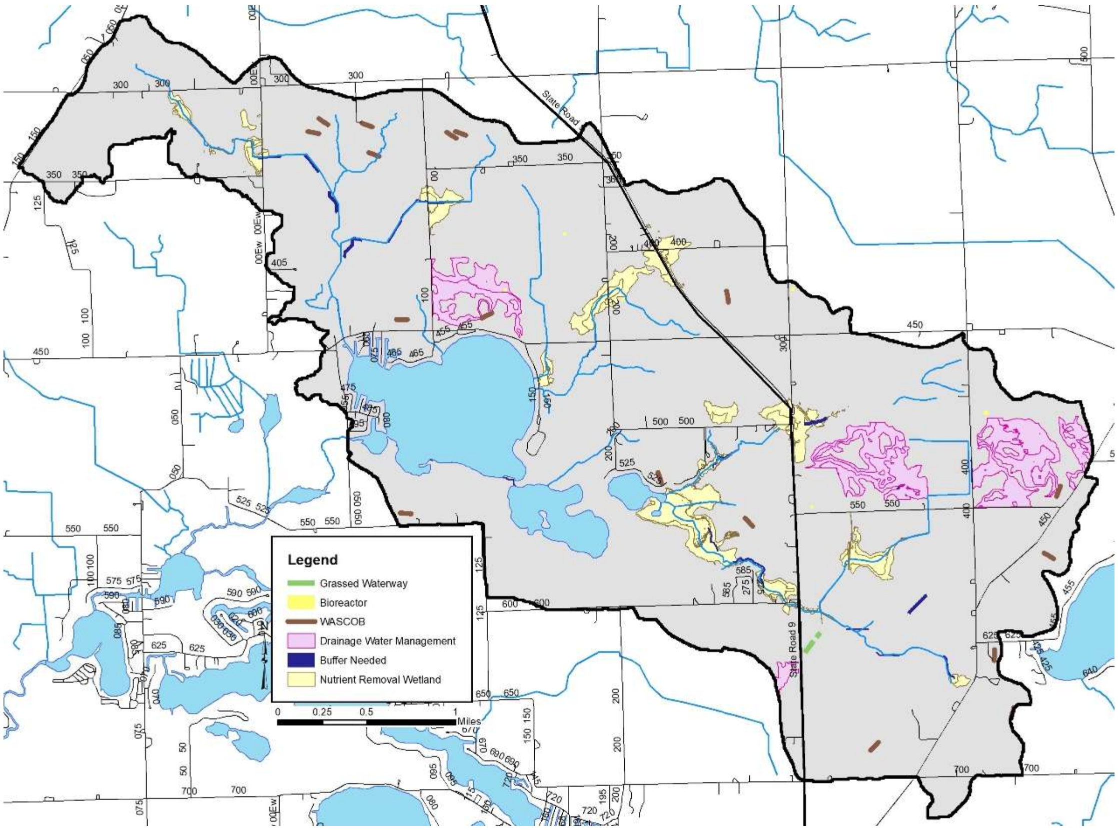


Figure 61. Potential problem areas identified in the Oliver Lake Watershed via ACPF modeling.

10.2 Walking and Driving Tour Observations

Identifying areas of concern and selecting sites for future management are the goals of the visual watershed inspections. Inspections included driving, windshield survey, walking tours and a survey of the Olin, Oliver and Martin lakes shoreline. Identified problems include streambank erosion, locations where narrow buffers were observed and locations where livestock impacts to watershed streams were identified. (Figure 62). Figure 63 offers a summary of observations made during the walking and windshield survey efforts. Each point represents a potential problem area. Additionally, It should be noted that not all watershed streams could be accessed during the walking and driving tours, thus these lengths likely underrepresent the full extent of issues present in the Oliver Lake Watershed.

Figure 62. Livestock impacts including barnyard runoff to pastured field and livestock in watershed stream observed in the Oliver Lake Watershed.

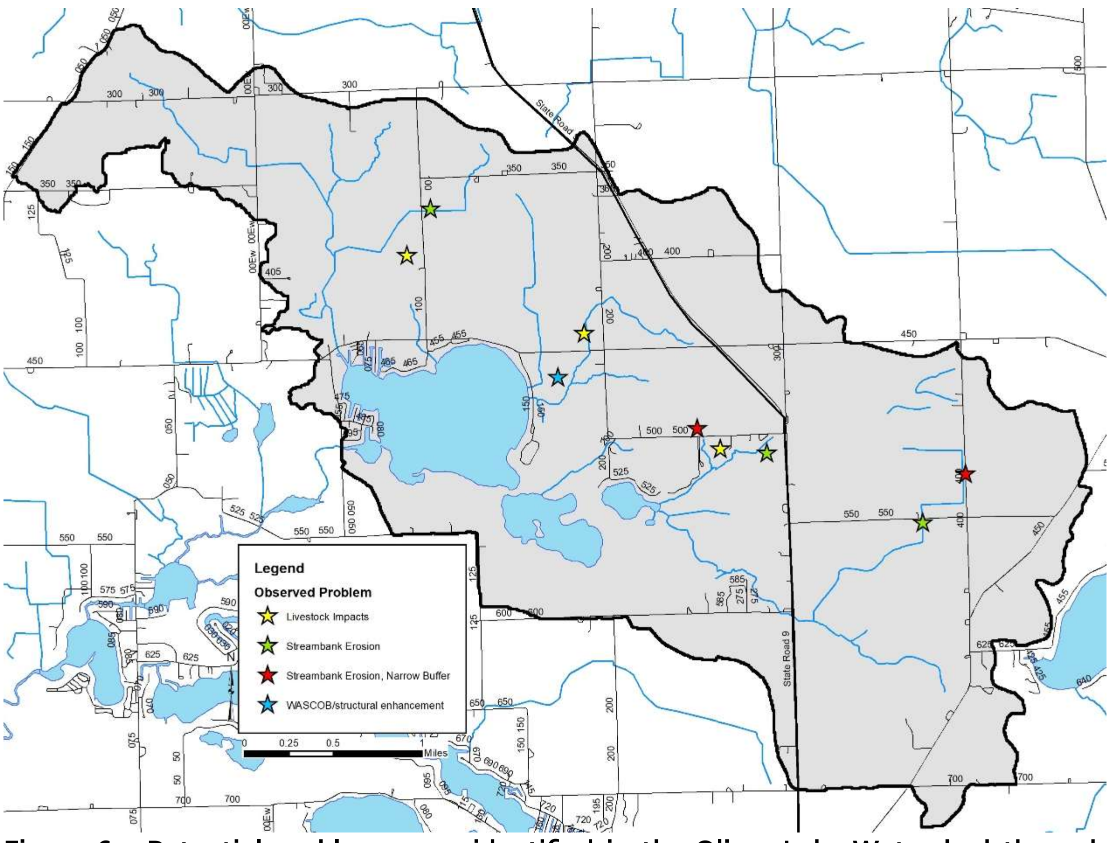


Figure 63. Potential problem areas identified in the Oliver Lake Watershed through watershed inventory and the public input processes.

10.3 <u>Shoreline Erosion Assessment</u>

Oliver, Olin and Martin lakes possess a largely natural shoreline with modification to rock, wood or concrete seawall by residents. Figure 64 details areas around the lakes where in-lake management opportunities are present. Specifically, one small erosion area where the shoreline is erodible behind the rock seawall was observed during the shoreline survey, multiple areas where emergent, native species are present but in lower density than historically and restoration of the native community is recommended as well as areas of interest.

Figure 64. Shoreline erosion and other observations around Olin, Oliver and Martin lakes.

10.4 <u>Agricultural Impacts</u>

Non-point source pollution originates from land runoff, atmospheric deposition, hydrologic modification, drainage, and other diffuse sources. Agricultural impacts within the Oliver Lake Watershed generally originate from two sources: row crop agriculture and pasture lands. Specifically, irrigation impacts on both the quality of water entering the lakes and the quantify of water pulled from their aquifer, the volume of exposed soil entering adjacent waterbodies, the use of agricultural chemicals, the potential for the transport of chemicals into waterbodies, and the volume of nutrients applied to agricultural fields throughout the Oliver Lake Watershed. Over 52% (3,997 acres or 1,247 ha) of the watershed is covered by row crow agriculture. The acres in row crop agriculture would benefit from a soil health-focused program. Such a program would promote the use of conservation tillage, including reduced till, no till, and strip till methods, and cover crops.

Using county tillage transect data, which record tillage pattern and the presence or absence of cover crops, the use of these soil health practices in the Oliver Lake Watershed were estimated. Specifically, the total acreage of Lagrange County, 247,680 acres (100,232 ha); the percent of the county within the watershed (2.9% of Lagrange County); and the total acres of conservation tillage (no till) estimated by tillage transect for Lagrange County (75,130 acres or 30,404 ha) and cover crops for Lagrange County (26,537 acres or 10,739 ha) were used to estimate the current use of conservation tillage (no till) and cover crops in the Oliver Lake Watershed. Estimates suggest that 1,144 acres (463 ha) within the Oliver Lake Watershed utilize conservation tillage (no till), while cover crops are planted on an estimated 404 acres (163 ha) within the Oliver Lake Watershed.

10.5 Sources of Pollutants

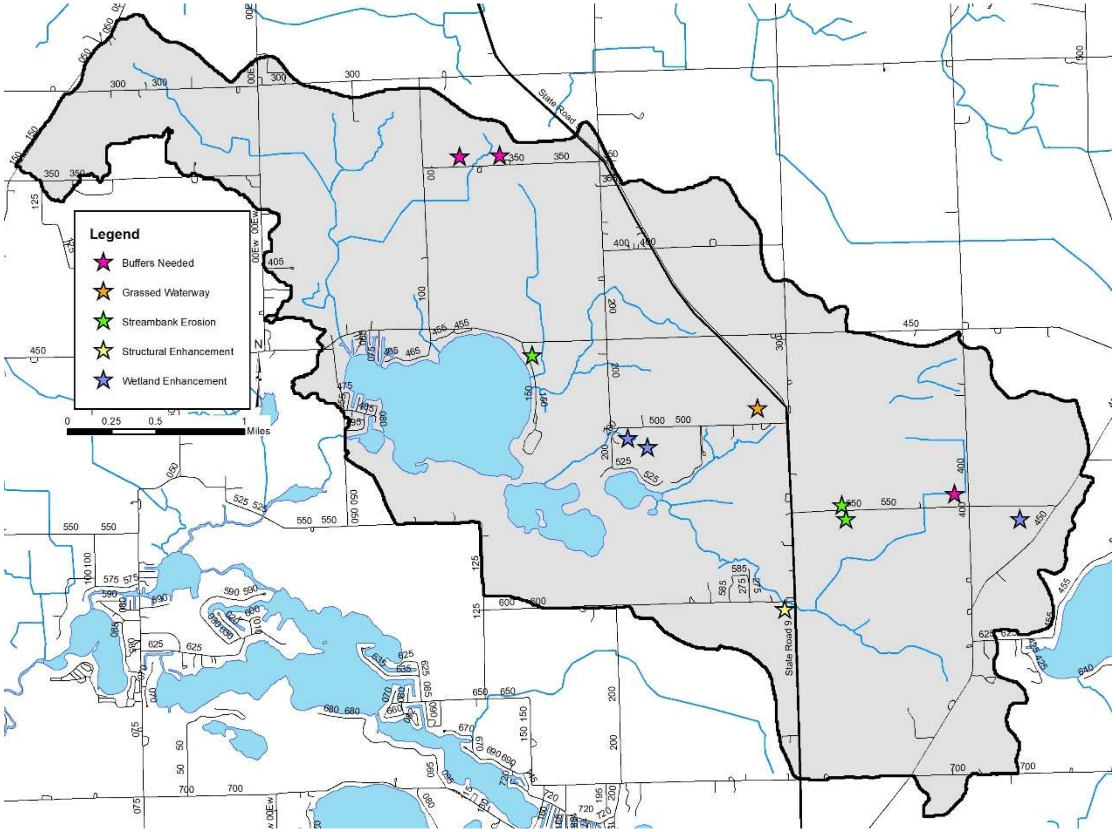
There are many sources of nitrogen, sediment, phosphorus, and E. coli within the Oliver Lake Watershed. Table 34 details the sources of these pollutants and can be used to determine relative contributions from these sources.

Table 34. Sources of nutrients, sediment, and pathogens in the Oliver Lake Watershed.

Source	Area Affected
Agricultural row crop	3,774 acres (52% of watershed)
Pasture	950 acres (13% of the watershed)
Highly erodible soils	2,945 acres (54% of watershed)
Wetland loss	19% of historic wetlands
Soils severely limited for septic use	5,821 acres (82% of watershed)
Residences utilizing septic tanks	The shoreline of Oliver Lake and north shoreline of Martin Lake are connected to sewer system operated by the Lagrange County Regional Sewer District. In total, 51 residences throughout the watershed filed septic permits per data displayed on Beacon.
Livestock observed	401 cows, 194 horses and 35 sheep were observed; estimate 12,560 tons of manure produced which contains 7,246 pounds of nitrogen, 3,596 pounds of phosphorus and 6.22E+14 col of E. coli
Livestock impacts	Two areas of livestock impacts to streams observed
Eroded streambanks	Five areas eroding streams observed
Narrow buffer	Two areas of narrow buffer observed
Shoreline erosion	One location where shoreline erosion was observed
Native emergent vegetation loss	High density use and boat impacts are likely impacting the presence, diversity and coverage of emergent plant beds within Oliver Lake. These areas should be mapped and compared with historic extent mapping. High quality areas should be considered for future IDNR Eco Zone designation.

10.6 Status of Previously Installed Practices

Nearly 30 potential in-lake and watershed-based water quality improvement projects were identified during previously completed projects (Table 35). The status of these projects was reviewed as part of the completion of the Upper Elkhart River Watershed Management Plan (Arion



Consultants, 2023).

Figure *65* details sites which were deemed as not complete when reviewed. These sites should be revisited to determine if the problem is still occurring and if a practice could be implemented to address that problem area. Two projects identified as part of the Oliver Lake Feasibility Study (Davey Resource Group, 2014) were completed via LARE funded construction in 2017. In total, 65 feet of streambank were stabilized and new culverts installed. Additionally, utilizing funding from the Great Lakes Commission, the Lagrange County SWCD completed twelve projects including subsurface drains, watering facilities, fencing, water access provision, waste facility construction, heavy use area protection construction and roof runoff trenching and the Lagrange County Parks and Recreation Department installed a shoreline protection project. Nearly $160,000 in best management practices cover 120 acres and treat 279.6 acres of the Oliver Lake Watershed. Projects were installed 2017 to 2020 and have a ten-year lifetime. The status of these projects should be reviewed in the next few years to determine if they are still functioning as designed or if repairs are needed to extend their lifetime.

Table 35. Status of previously identified water quality improvement projects in the Oliver Lake Watershed.

Project/Improvement	Vendor(s)	Month/Year	Location Description	Date/Current status
Widen buffer on pasture adjacent to ditch	Cardno/JF New	2009-10	West side of S400E North of E550S Martin-Truman ditch	Not Complete. The site should be reviewed to determine if this is still an issue.
Potential wetland restoration	Cardno/JF New	2009-10	South side of E550S West of S450E Martin-Truman ditch	Not Complete.
Install grassed waterway, encourage no-till	Cardno/JF New	2009-10	North and South side of E550S East of SR9 Martin-Truman Ditch	Not Complete. The site should be reviewed to determine if this is still an issue
Remove berms adjacent to ditch	Cardno/JF New	2009-10	North side of E500S West of SR9 Martin-Truman ditch	Not Complete. The site should be reviewed to determine if this is still an issue
Reconstruct existing grass waterways	Cardno/JF New	2009-10	South side of E500S West of SR9 Martin Lk unnamed tributary	Not Complete. The site should be reviewed to determine if this is still an issue
Create two small wetlands adjacent to pasture	Cardno/JF New	2009-10	North side of E525S at end of the road	Not Complete. The site should be reviewed to determine if there is still an issue
Remediate bank erosion County Reg Ditch 45 & 49B	Davey Resource Group	2014-02	E550S West of S400E on the South side of road	Completed all construction and landscaping and final report published 10/23/2015.
Wetland restoration	Davey Resource Group	2014-02	32 acre tract east of Martin Lake owned by ACRES land trust.	Not completed. Wetland restoration should be done in a way that includes adjacent private properties between this and Martin Lake. Also currently no road access to this parcel.
Reevaluate hypolimnetic aeration several years if efforts to reduce nutrient inputs to lakes do not improve water quality.	F. X. Browne Associates, Inc	1992-02	At W600S and S085W in LaGrange Co	Unknown if any subsequent reevaluation of aeration has been completed.
Establish a Watershed Management District for the 10-lakes of Lagrange County, plus a number of general	F. X. Browne Associates, Inc	1992-02	Adams, Atwood, Dallas Hackenburg, Messick, Martin, Oliver, Olin, Westler, Witmer	No such watershed management district (aka Conservancy District) was created. Recommendations specific to individual lakes are outlined separately by lake.

Project/Improvement	Vendor(s)	Month/Year	Location Description	Date/Current status
watershed recommendations.				
General recommendations	V3 Companies	2008-03	Oliver, Martin Dallas, Westler, Witmer & Eve Lakes	Advised that Elkhart River critical area 24 occurs in the Oliver Lake Watershed. Problems: sediment loading, E. Coli and nutrient loading be addressed by channel management, filter strips, sediment basin management and other BMP's
Stabilize eroding ravine in Olin Nature Preserve	IN DNR DNP	2014-03	Olin Nature Preserve	Completed installation of 8-10 glacial stone water control structures in 2018 by DNR. No streambank repair or stabilization completed.
Dredge mouth of Dove Creek and adjacent channels	F. X. Browne Associates, Inc	1992-02	On E450S between E050S and E150S in LaGrange Co.	Limited dredging project completed in 1993 or 94 and more extensive Dove Creek dredging project completed in 2017 but not adjacent channels.
Extend existing tile to E450S and develop alt watering station	Cardno/JF New	2009-10	West of S200E North of E450S unnamed tributary	Not Complete. The site should be reviewed to determine if there is still an issue
Install erosion control on embankments at old sand mining operation	Cardno/JF New	2009-10	E450S just East of S100E on Sout side.	Not Complete. The site should be reviewed to determine if there is still an issue
Extend buffers along E-W ditch adjacent to a no-till field	Cardno/JF New	2009-10	East and West sides of S100E 1/5 mile South of E350S	Not Complete. The site should be reviewed to determine if there is still an issue
Repair existing tile riser and outlet damaged by livestock	Cardno/JF New	2009-10	North side of E350S 1/4 mi. East of S100E	Not Complete. The site should be reviewed to determine if there is still an issue
Sediment Removal				There is not an implementation project report on the LARE website corresponding with this grant, however, former President of Lake Association confirmed this project was to dredge the DNR Public Access Channel and was completed in 2010.
Streambank stabilization	Property Owner	2014-03	Small unidentified inlet to Oliver Lk at 1290 E450S	Completed. The property owner installed glacial stone on banks and inlet bottom at own expense in 2018.

Project/Improvement	Vendor(s)	Month/Year	Location Description	Date/Current status
Dove Creek Sediment Removal Project	Superior Docking & Dredging, Inc.	2014-03	100 yards East of S050E at E450S on North side.	Completed dredging Dove Creek July 2018. Unknown contractor for County Surveyor also completed dredging 200 yards of Dove Creek on the North side of E450S.
Ag field erosion control	Davey Resource Group	2014-03	North side of 450S and East of 100E	Not complete. 10-12 acres of field used to grow seed corn form a steep parabolic swale that empties into a tributary on the north side of Oliver Lake. Video documentation of a significant rain event shared with LCS&WCD and property owner. The attempt at cover crop planting the previous year was not successful. Using 2016 GLC Grant in 2017, NRCS designed a more robust grass filter and rock splash barrier to slow water flow, but property owner declined to install the project.

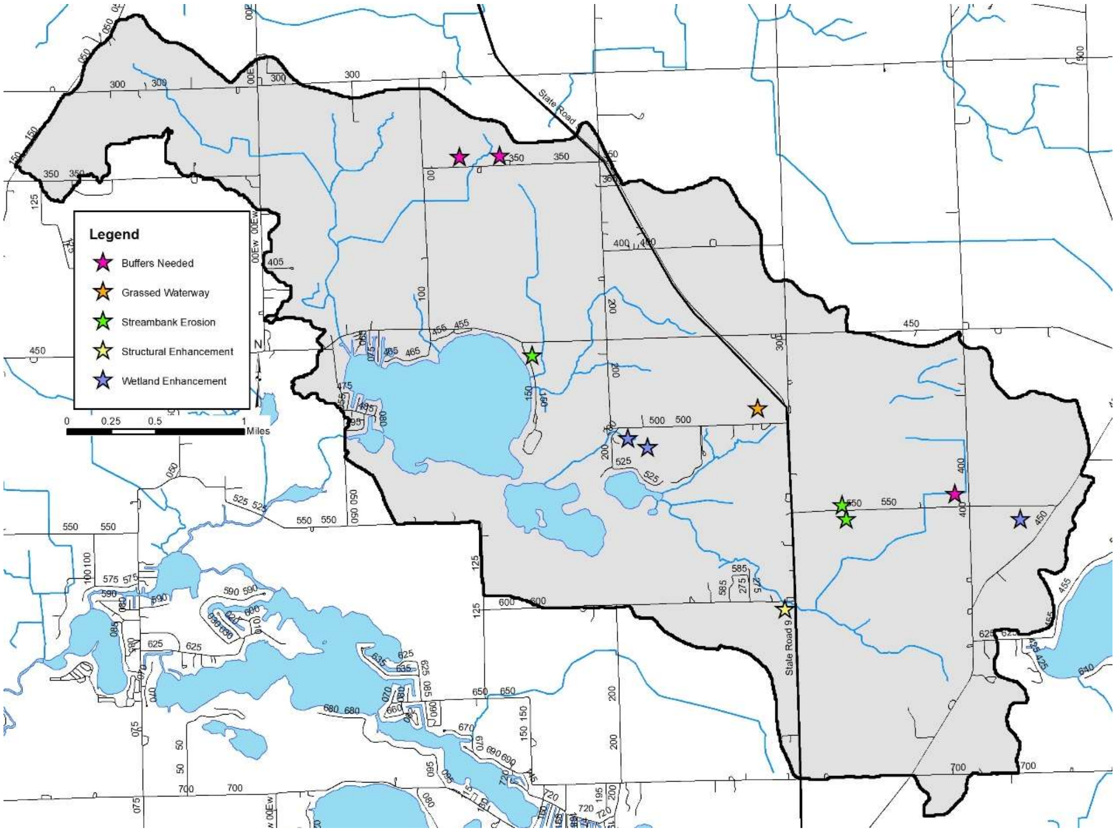


Figure 65. Project sites identified during previous planning efforts.

11.0 MANAGEMENT

A wide variety of practices are available for on-the-ground implementation. Many of these practices will result in the reduction of sediment, nutrient, and pathogen loading to Oliver Lake and their watershed. A list of the most appropriate and most likely to successfully produce improved nutrient, sediment and pathogen levels within the Oliver Lake Watershed were selected. The selected best management practices are categorized as agricultural or urban. It should be noted that the following practice list is not exhaustive and that additional techniques may be both possible and necessary to reach water quality goals. Potential load reductions associated with the implementation of each practice type are also detailed below.

11.1 Watershed Management

The prevalence land covered by highly erodible soils in row crop agricultural production, this land use is the first watershed management technique reviewed. Ravine management, streambank stabilization and other management techniques are covered in this section as well.

11.1.1 Agricultural Best Management Practices

Agricultural best management practices are implemented on agricultural lands, typically row crop agricultural lands, in order to protect water resources and aquatic habitat while improving land resources and quality. Based on modeling within the ACPF framework, several potential practices were identified (Figure 66). ACPF suggests installation of six bioreactors, two grassed waterways, 16 water and sediment control basins, sixteen critical buffer locations totaling more than 7,200 feet (2,400 m), more than 273 acres (110.5 ha) where drainage water management and 269 acres (108.8 ha) of wetland restoration could be installed. It should be noted that all potential practices should be field checked and are recommended based on modeled results which may not reflect conditions on the ground. These practices control nonpoint source pollutants reducing their loading to Oliver Lake watershed streams by minimizing the volume of available pollutants. Potential agricultural best management practices designed to control and trap agricultural nonpoint sources of pollution include:

- Conservation Tillage
- Cover Crop
- Manure Management Planning and Livestock Access
- Nutrient/Pest Management Planning
- Grassed Waterway
- Wetland Construction or Restoration or depression restoration
- Water and Sediment Control Basins

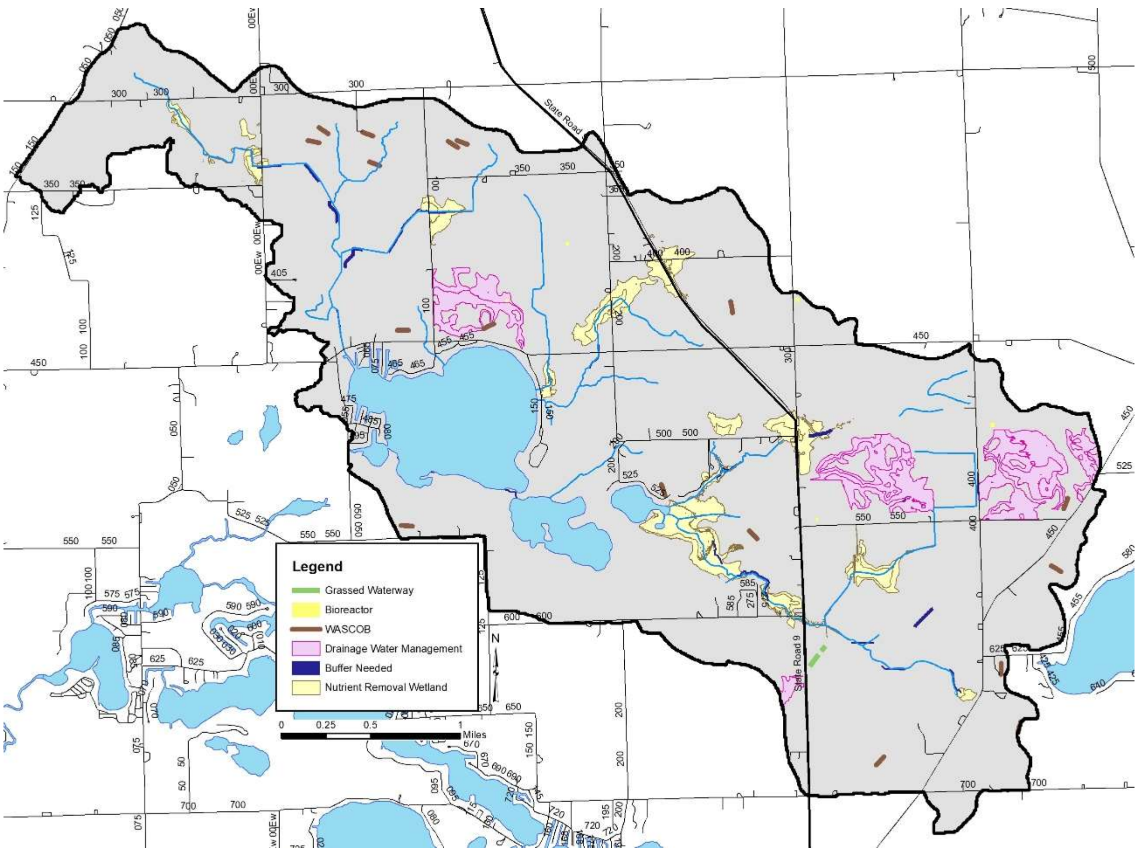


Figure 66. ACPF-modeled, potential locations for agricultural best management practice installation or restoration.

Conservation Tillage

Conservation tillage refers to several different tillage methods or systems that leave at least 30% of the soil covered with crop residue after planting (Holdren et al., 2001). Tillage methods encompassed by conservation tillage include no-till, mulch-till, ridge-till, zero till, slot plant, row till, direct seeding, or strip till. The purpose of conservation tillage is to reduce sheet and rill erosion, maintain or improve soil organic matter content, conserve soil moisture, increase available moisture, reduce plant damage, and provide habitat and cover for wildlife. The remaining crop residue helps reduce soil erosion and runoff volume.

Several researchers have demonstrated the benefits of conservation tillage in reducing pollutant loading to streams and lakes. A comprehensive comparison of tillage systems showed that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (Conservation Technology Information Center, 2000). Reductions in pesticide loading have also been reported (Olem and Flock, 1990). Conservation tillage can be implemented as part of a soil health-focused program, which works to avoid, control and trap nutrients in their current location. Approximately 3,774 acres (1,527 ha) of the Oliver Lake Watershed is in row crop agriculture. Based on Indiana State Department of Agricultural 2023 data, 1,144 acres (463 ha) of the watershed participate in no-till or conservation tillage practices. This means a potential 2,629 acres (1,064 ha) would benefit from the usage of soil health practices, including conservation tillage.

Cover Crop

Cover crops include legumes, such as clover, hairy vetch, field peas, alfalfa, and soybean, and non-legumes, such as rye, oats, wheat, radishes, turnips, and buckwheat which are planted prior to or following crop harvest. Cover crops typically grow for one season to one year and are typically grown in non-cropping seasons. Cover crops are used to improve soil quality and future crop harvest by improving soil tilth, reducing wind and water erosion, increasing available nitrogen, suppressing weed cover, and encouraging beneficial insect growth. Cover crops reduce phosphorus transport by reducing soil erosion and runoff from both wind and water erosion. Sediment that reaches water bodies may release phosphorus into the water. The cover crop vegetation recovers plant-available phosphorus in the soil and recycles it through the plant biomass for succeeding crops meaning that nutrients are readily available for the next season's crop. Approximately 3,774 acres (1,528 ha) of the Oliver Lake Watershed is in row crop agriculture. Based on Indiana State Department of Agricultural 2023 data, approximately 404 acres (163 ha) of the Oliver Lake Watershed is planted in cover crop. This means a potential 3,370 acres (1,364 ha) would benefit from the usage of soil health practices, including cover crops.

Nutrient/Pest Management Planning

Nutrient management is the management of the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize the transport of applied nutrients into surface water or groundwater. Nutrient management seeks to supply adequate nutrients for optimum crop yield and quantity, while also helping to sustain the physical, biological, and chemical properties of the soil. A nutrient budget for nitrogen, phosphorus, and potassium is developed considering all potential sources of nutrients including, but not limited to, animal manure, commercial fertilizer, crop residue, and legume credits. Realistic yields are based on soil productivity information, potential yield, or historical yield data based on a 5-year average. Nutrient management plans specify the form, source, amount, timing, and method of application of nutrients on each field in order to achieve realistic production levels while minimizing transport of nutrients to surface and/or groundwater.

Manure Management Planning and Livestock Access

Animal waste is a minor source of pollution to Oliver Lake Watershed waterbodies as only a small volume is produced within the watershed. However, adjacent watersheds contain a high number of confined feeding operations which readily produce large volumes of manure which could be moved into the watershed. To protect the health of aquatic ecosystems and meet water quality standards, manure must be safely managed. Good management of manure keeps livestock healthy, returns nutrients to the soil, improves pastures, and gardens, and protects the environment, specifically water quality. Poor manure management may lead to sick livestock, unsanitary and unhealthy conditions for humans and other organisms, and increased insect and parasite populations. Proper management of animal waste can be done by implementing BMPs, through safe storage, by application as a fertilizer, and through composting. Proper manure management can effectively reduce E. coli concentrations, nutrient levels, and sedimentation. Manure management can also be addressed in education and outreach to encourage farmers to participate in this BMP.

An estimated estimate 12,560 tons of manure and an associated 7,246 pounds of nitrogen, 3,596 pounds of phosphorus and 6.22E +14 col of E. coli are generated by the two confined feeding operations and the small, unregulated animal operations throughout the Oliver Lake Watershed. While the CFOs are required to have manure management plans as part of their permitting process. It is unknown at this time how many of the small, unregulated entities have manure management plans in place and/or are currently using these plans to manage the volume of manure produced on their facility. Manure management planning includes consideration of the volume and type of manure produced annually, crop rotations by field, the volume of manure and nutrients needed for each crop, field slope, soil type, and manure collection, transportation, storage, and distribution methods. Manure management planning uses similar techniques to nutrient management planning with regards to nutrient budgets. Additionally, this can include reducing the access of livestock to the waterway. The use of fencing can limit access, thereby lowering the amount of waste directly being discharged to the waterway. Livestock access occurs at two observed locations within the Oliver Lake Watershed. Additional areas where access occurs may be present but not observed during inventory efforts.

Grassed Waterway
Grassed waterways are natural or constructed channels established for transport of concentrated flow at safe velocities using adequate channel dimensions and proper vegetation. They are generally broad and shallow by design to move surface water across farmland without causing soil erosion. Grassed waterways are used as outlets to prevent rill and gully formation. The vegetative cover slows the water flow, minimizing channel surface erosion. When properly constructed, grassed waterways can safely transport large water flows downslope. These waterways can also be used as outlets for water released from contoured and terraced systems and from diverted channels. The amount of precipitation that runs off the soil surface rather than infiltrating down into the soil profile is increased by tillage and other farming activities that increase soil compaction and decrease soil organic matter and macro-pore content. For these reasons, the establishment or refurbishing of a grassed waterway should, when possible, be coupled with other practices that aim to increase the rate of water infiltration into the soil. This BMP can reduce sediment concentrations of nearby waterbodies and pollutants in runoff. The vegetation improves soil aeration and water quality due to its nutrient removal through plant uptake and absorption by soil. The waterways can also provide wildlife corridors and allow more land to be natural areas.

Water and Sediment Control Basin
A water and sediment control basin is an earthen embankment constructed across the slope of a minor watercourse to form a sediment trap and water detention basin with a stable outlet. This practice can reduce watercourse and gully erosion, trap sediment, and reduce downstream runoff. It is particularly applicable where watercourse or gully erosion is a problem and where sheet and rill erosion is controlled by other conservation practices. It can help in areas where sediment in runoff is severe, though it needs to be placed where adequate outlets can be provided.

11.1.2 Streambank Stabilization and Restoration
Streambank stabilization or stream restoration techniques are used to improve stream conditions so they more closely mimic natural conditions. Streambank erosion areas were identified at five stream

locations. Additional erosion areas are likely present in areas not accessible along other watershed streams. The most feasible restoration options return the stream to natural stream conditions without restoring the stream to its original condition. In these cases, the current conditions are addressed to reduce streambank erosion using natural stone and native vegetation; however, stabilization methods will likely never fully match the original, pre-settlement instream conditions. Restoration and stabilization options are limited by available floodplain, modifications to natural flows, and development structure locations. Reestablishment of riparian buffers, restoration of stream channels, stabilization of eroding stream banks, installation of riffle-pool complexes, and general maintenance can all improve stream function while reducing sediment and nutrient transport into and within the system. Five areas of erosion and two areas of narrow buffers were observed during inventory efforts.

11.2 Shoreline Management

Individual property owners can take several actions to improve Oliver Lake. Shoreline landowners should consider re-landscaping lakeside properties to protect their lake. Additionally, three areas of active erosion were identified with one, county-owned property identified which may serve as a good example for installation of a bioengineered seawall. Many of the homes on Oliver Lake have maintained turf grass lawns that extend to a concrete seawall at the lake's edge (Figure 67). Runoff from residential lawns can be very high in phosphorus. In a study on residential areas in Madison, Wisconsin, Bannerman et al. (1993) found extremely high total phosphorus concentrations in stormwater samples from residential lawns. The average phosphorus concentration of runoff water from residential lawns was nearly 100 times the concentration at which algae blooms are expected in lake water. While some dilution occurs as runoff water enters the lake, this source of phosphorus is not insignificant. Other researchers have found similarly high total phosphorus concentrations in lawn runoff water (Steuer et al., 1997).

Figure 67. Example of turf grass directly adjacent to concrete seawalls on Oliver Lake, July 2024.

The ideal way to re-landscape a shoreline is to replant as much of the shoreline as possible with native shoreline species. Rushes, sedges, pickerel weed, arrowhead, and blue flag iris are all common species native to northeastern lake margins. These species provide an aesthetically attractive, low-profile community that will not interfere with views of the lake. Plantings can even occur in front of existing seawalls. Bulrushes and taller emergent species are recommended for planting in these areas. On drier areas, a variety of upland forbs and grasses that do not have the same fertilizer/pesticide maintenance requirements as turf grass may be planted to provide additional filtering of any runoff. Plantings can be arranged so that access to a pier or a portion of the lakefront still exists. Henderson et al. (1998) and IDNR (2009) illustrate a variety of landscaping options to achieve water quality and access goals.

Restoring Oliver Lake's shoreline by planting the area with native vegetation will return the functions the shoreline once provided the lake. In addition to filtering runoff, well-vegetated shorelines are less likely to erode, reducing sediment loading to the lake. Well-vegetated shorelines also discourage Canada geese. Canada geese prefer maintained lawns because any predators are clearly visible in lawn areas. Native vegetation is higher in profile than maintained lawns and has the potential to hide predators, increasing the risk for the geese. Unlike concrete or other hard seawalls, vegetated shorelines dampen wave energy, reducing or even eliminating the "rebound" effect seen with hard seawalls. Waves that rebound off hard seawalls continue to stir the lake's bottom sediments, reducing water clarity and impairing the lake's aesthetic appeal. (Residents might also consider replacing or refacing concrete seawalls with glacial stone to reduce the "rebound" effect.) Finally, well-vegetated shorelines provide excellent habitat for native waterfowl and other aquatic species.

In addition to re-landscaping lakefront property, all lake and watershed property owners should reduce or eliminate the use of fertilizers and pesticides. These lawn and landscape-care products are a source of nutrients and toxins to the lake. Landowners typically apply more fertilizer to lawns and landscaped areas than necessary to achieve the desired results. Plants can only utilize a given amount of nutrients. Nutrients not absorbed by the plants or soil can run into the lake either directly from those residents' lawns along the lake's shoreline or indirectly via storm drains. This simply fertilizes the rooted plants and algae in the lake. At the very minimum, landowners should follow dosing recommendations on product labels and avoid fertilizer/pesticide use within 10 feet of hard surfaces such as roads, driveways, and sidewalks and within 10 to 15 feet of the water's edge. Where possible, natural landscapes should be maintained to eliminate the need for pesticides and fertilizers.

11.2.1 Residential Best Management Practices

Development and the spread of impervious surfaces along the shoreline of Oliver Lake is ongoing occurring mostly as redevelopment of existing properties and structures. As shoreline redevelopment occurs, the volume and velocity of stormwater entering Oliver Lake and its tributaries, especially steeply sloped north shoreline ravines, will also increase. The best way to mitigate stormwater impacts is to infiltrate, store, and treat stormwater onsite before it can run off into adjacent waterbodies. Lagrange County's new zoning ordinance will require any building permit submitted for lake (L-1) parcels to include a stormwater plan. The practices detailed here could be utilized as part of those stormwater planning efforts. Urban best management practices designed to complete these actions are as follows:

- Rain Barrel
- Rain Garden
- Pervious Pavement
- Pet Waste Control

Rain Barrel

A rain barrel is a container that collects and stores rainwater from your rooftop (via your home's disconnected downspouts) for later use on your lawn, garden, or other outdoor uses. Rainwater stored in rain barrels can be useful for watering landscapes, gardens, lawns, and trees. Rain is a naturally soft water and devoid of minerals, chlorine, fluoride, and other chemicals. In addition, rain barrels help to reduce peak volume and velocity of stormwater runoff to streams and storm sewer systems. Although rain barrels don't specifically reduce nutrient or sediment loading to waterbodies, their presence can reduce the first flush of water reaching storm drains. More than 175 residences are located along the shoreline of Oliver Lake. This suggests that if one rain barrel were installed per household, more than 175 rain barrels could be installed at residences around the Oliver Lake. These barrels would retain more than 169,000 gallons of stormwater annually.

Rain Garden

Rain gardens are small-scale bioretention systems that be can be used as landscape features and small-scale stormwater management systems for single-family homes and to treat parking lot or building runoff. Rain gardens provide a landscape feature for the site and reduce the need for irrigation and can be used to provide stormwater depression storage and treatment near the point of generation. These systems can be integrated into the stormwater management system since the components can be optimized to maximize depression storage, pretreatment of the stormwater runoff, promote evapotranspiration, and facilitate groundwater recharge. The combination of these benefits can result in decreased flooding due to a decrease in the peak flow and total volume of runoff generated by a storm event. Additionally, rain gardens can be designed to provide a significant improvement in the quality of the stormwater runoff.

Pet Waste Control

Pet waste cannot be considered the predominant waste product within a watershed nor the one that produces the greatest impact. Nonetheless, the cumulative impact of pet waste within a watershed can produce a major impact on water quality. Pet waste contains bacteria and parasites, organic matter, phosphorus, nitrogen, and E. coli and can carry diseases including *Campylobacteriosis*, *Salmonellosis*, and *Toxocarisis*. Studies indicate that the average dog produces 13 pounds of nitrogen, 2 pounds of phosphorus, and 1,200 pounds of sediment annually (Miles, 2007).

Many options for managing pet waste are available with most efforts focusing on educational options to turn pet waste from an 'out of sight, out of mind' issue to one that every pet owner considers for their pet. Pet waste can be flushed, resulting in waste traveling to the wastewater treatment plant or through the septic system for treatment, buried, where it gradually breaks down over time with nutrients entering the soil and microorganisms converting diseases and bacteria into less benign forms, or trashed, resulting in potential landfill issues. Ordinances, signage, and public education are needed to inform the community about options for treating pet waste issues.

11.3 <u>In-Lake Management</u>

11.3.1 Boating Impacts to Sediment Resuspension

Boat wakes have been shown to have erosive impacts on shorelines (Castillo et al., 2000; Bauer et al., 2002), scour the bottom of the shore and temporarily decrease water clarity. The energy of boat wakes and their associated impact is event dependent, influenced by vessel length, channel shape and boat speed. Wakes are most destructive in shallow waters or narrow waterways as wake energy does not have the opportunity to dissipate over distance (FitzGerald et al, 2011). Although boat wakes are periodic disturbances when compared with wind waves, wakes can be a significant source of erosive wave force due to their longer wave period, greater wave height and total wave energy (Houser, 2010). A review of literature suggests that small recreational vehicles within 500 feet (150 m) of the shoreline are capable of producing wakes that can cause shoreline erosion and increase turbidity (Zabawa and Ostrum, 1980).

Many factors control the impact of boat wakes on shoreline erosion and sediment resuspension in shallow areas. These include the following:

- Local vessel usage: The amount of boat wake energy impacts on a given shoreline originate from the size and speed of vessels as well as vessel frequency or how often a boat moves through a particular area. Shallow draft vessels like personal watercraft that can run at high speed in shallow areas may disproportionally impact shoreline erosion as they can operate closer to shoreline than larger, deeper draft vessels; however, they generally generate lower energy waves when compared with larger boats.
- Wave energy at a site: Zabawa and Ostrum (1980) reviewed the impact of boat wakes compared with wind waves determining that 6% of total annual shoreline wave energy was attributed to boats. Other studies found higher boating impacts but determined that between 30 and 50% of cumulative energy along the shoreline originates from boat-generated waves.
- Shoreline characteristics: Erosion rates along gently sloping and vertical shore profile marsh shorelines experience greater wave thrust and higher erosion impacts than terraced shorelines (Tonelli et al., 2010).
- Vegetation: The presence or absence of shoreline vegetation determines how exposed soils are and how easily they erode. Soils with high sand content are more easily eroded than soils with finer-grained soils (Feagin et al., 2009). Shorelines that are vegetated tend to have finer grained sediment than non-vegetated soils.

One of the most common impacts associated with motor boating is a decrease in water clarity. As motorboats travel through shallow water, the energy from movement of the boat propeller may be sufficient to resuspend sediment from the lake bottom, decreasing the lake's water clarity. Several researchers have documented either an increase in turbidity or a decrease in Secchi disk transparency during and following motorboat activity (Wagner, 1990; Asplund, 1996; Yousef et al., 1980). Crisman (1986) reports a decrease in Secchi disk transparency following holiday weekend use of Lake Maxinkuckee in Culver, Indiana. Asplund (1996) also observed poorer water clarity in his study of lakes following weekend boating and that this decrease in water clarity is more pronounced in lakes with generally better water clarity. This finding is particularly significant for many lakes throughout the watershed as they generally exhibit better water clarity than the typical Indiana lake.

The ability of a motorboat to resuspend sediment from the lake bottom depends on several factors. Some of these factors, such as boat length, motor size, and boat speed, are related to the boat itself and the boat's operator. Yousef et al. (1978) found that 10 horsepower (hp) motors were capable of mixing the water column to a depth of 6 feet (1.8 m), while 50 hp motors were capable of mixing the water column to a depth of 15 feet (4.6 m). While larger motor sizes have greater potential to resuspend sediments than smaller motors, longer boats and higher speeds do not automatically translate to a greater ability to resuspend sediments. Boats that are 'planing' on the water actually have little impact on the lake's bottom. This is because the velocity of water at the lake bottom created by a motorboat depends on the boat's displacement, which is a function of boat length and speed. Beachler and Hill (2003) suggest that boat speeds in the range of 7 to 12 mph may have the greatest potential to resuspend sediment from the lake bottom. (This range is based on typical recreational boat length.)

Certain characteristics of lakes also influence the ability of motorboats to resuspend sediments. Shallow lakes are obviously more prone to water clarity degradation associated with motor boating than deeper lakes. Wagner (1990) suggests little impacts from motor boating are likely in water deeper than 10-15 feet (3.0-4.6 m). With this in mind, the portion of Oliver Lake mapped as ten feet or shallower is shown in Figure 68. In total, 33% (102.2 acres or 41.3 ha) of Oliver Lake is ten feet deep or less. This same map could be created for Olin and Martin lakes; however, the wide, flat, shallow areas present around Oliver Lake are much narrower than those present in Olin and Martin lakes and thus the impact in these lakes is likely much more limited.

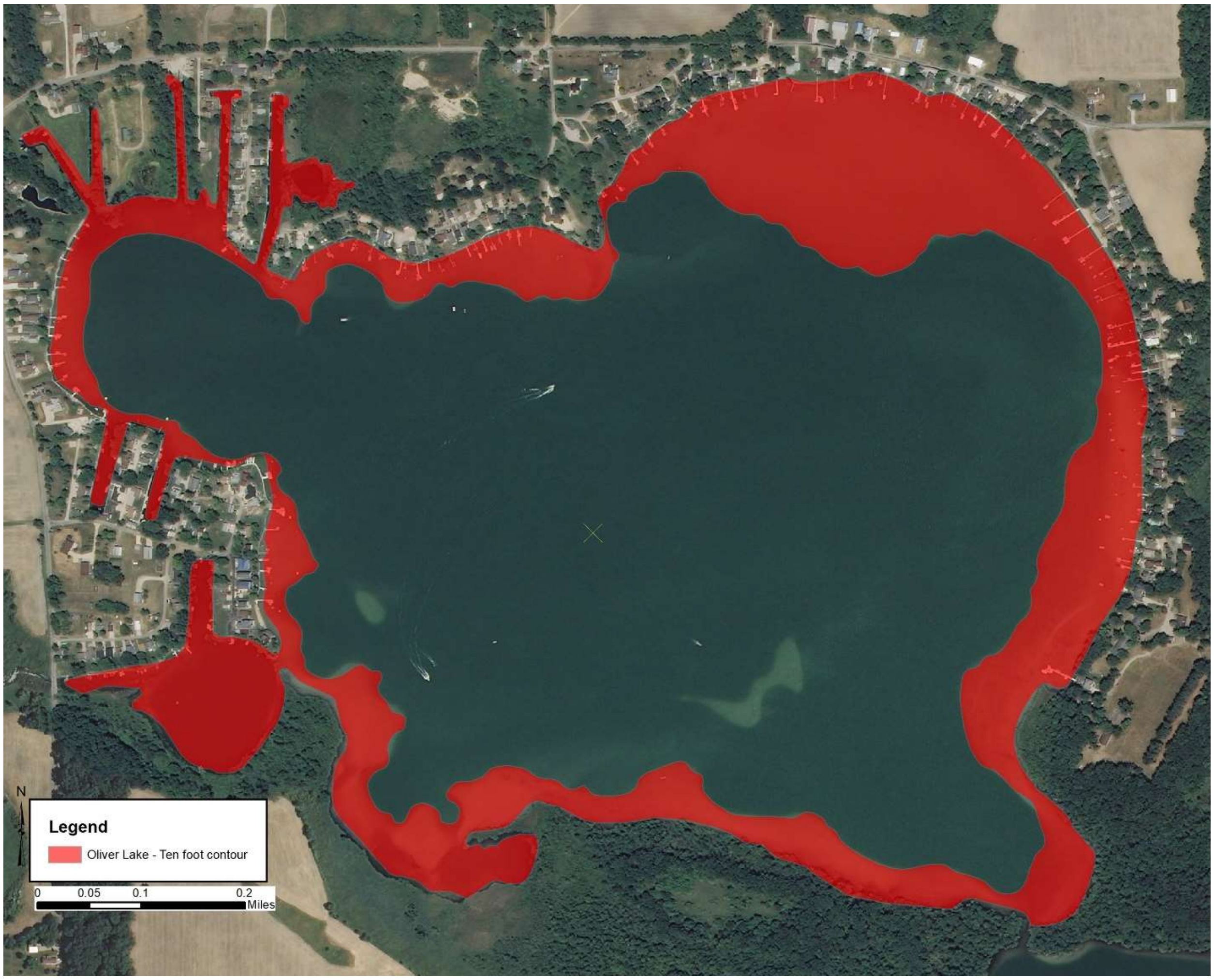


Figure 68. Portion of Oliver Lake measuring ten feet or shallower.

Additinoaly, lakes with soft fine sediments are more likely to suffer from sediment resuspension than lakes with coarser substrates. Lakes with extensive rooted plant coverage throughout the littoral zone are less prone to motorboat related resuspension problems than lakes with sparse vegetation since plants help hold the lake's bottom substrate in place.

It is important to note that the decrease in water clarity is not usually permanent. Once motor boating activity ceases, resuspended materials will sink to the lake bottom again. However, this process can take several days. Wagner (1990) found that while turbidity levels steadily decreased following boating activity in his shallow study lakes, the turbidity had not returned to baseline levels even two days after the activity. Crisman (1986) found similar lags on Lake Maxinkuckee. Thus, Oliver Lake users may need to wait several days before their lake returns to its baseline clarity following heavy weekend motor boating use.

In addition to a decrease in water clarity, several other potential ecological impacts from motor boating exist. Various researchers have documented increased phosphorus concentrations, damage to rooted plants, changes in rooted plant distribution, and increased shoreline erosion associated with motor boating activity (Asplund, 1996; Asplund and Cook, 1997; Schloss, 1990; Yousef et al., 1980). Less commonly studied concerns include potential increases in heavy metal and hydrocarbon pollution, changes in algal populations, and impacts to lake fauna.

Just as the potential impact of motor boating on a lake's water clarity depends in large part on the specific characteristics of the lake, the potential for other ecological impacts associated with motor boating often depend on characteristics of the specific lake (Wagner, 1990). For example, Yousef et al. (1980) found increases in total phosphorus concentrations associated with motor boating activity in all his study lakes. However, only one of Wagner's study lakes showed an increase in phosphorus concentrations associated with motor boating activity. This lake possessed a nutrient rich, fine particle substrate. Similarly, Schloss (1990) reported greater increases in phosphorus concentrations due to motorboat activities in those New Hampshire lakes with high levels of internal phosphorus loading. New Hampshire lakes with lower levels of internal phosphorus loading were less likely to see large increases in phosphorus concentration associated with motorboat activity.

Finally, boating activities can cause negative impacts to the aquatic plant community. Vermaat and Bruyne (1993) noted that boat-generated waves were the key factor in determining the distribution of aquatic plans. This is likely due to the potential impacts of boat motors through uprooting, dragging, and tearing of plant material. Figure 69 details the mechanisms and impacts that watercraft can have on aquatic plant communities. All of these factors lead to the ecological carrying capacity of a lake or the maximum level of use before an unacceptable or irreversible decline in the ecosystem occurs (Pigram, 1983).

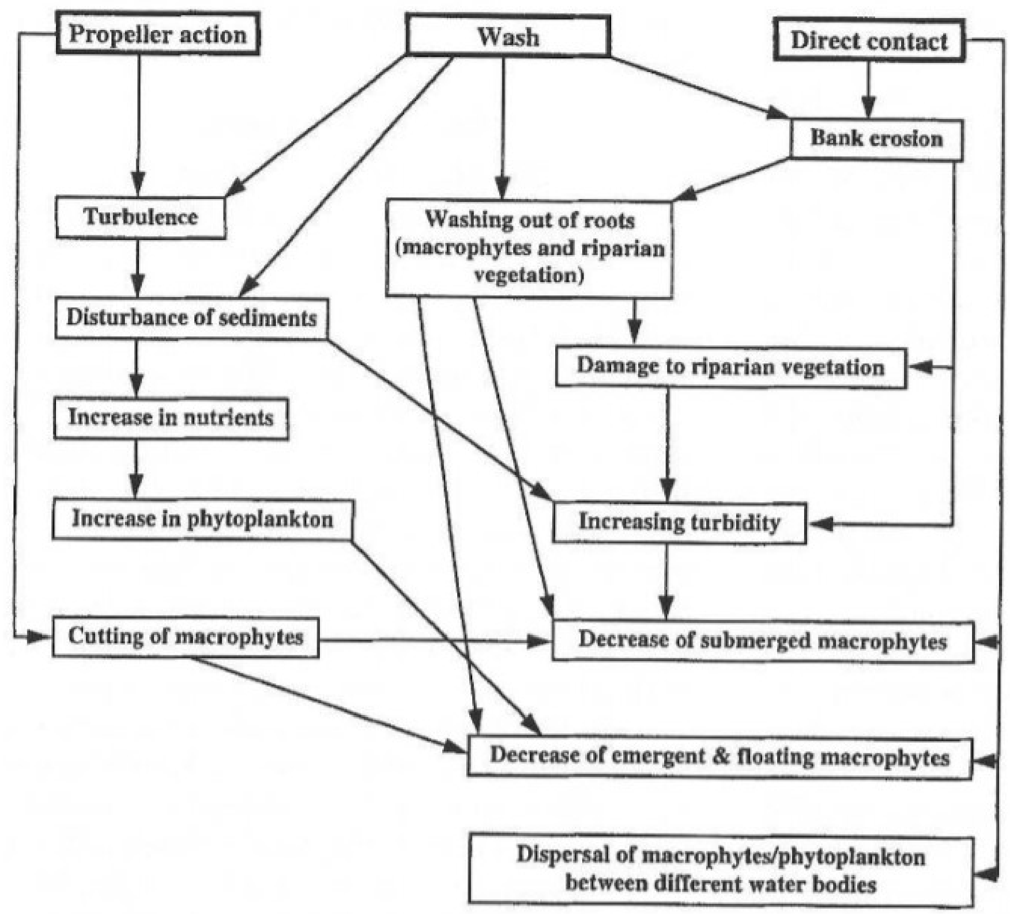


Figure 69. Impacts of watercraft to aquatic plant communities. Source: Morisch and Arthington, 1998.

Recent research has focused on lake impacts related to turbidity and erosion of specifically wake boats in shallow water and the associated build up of wind driven waves. Based on Fay et al. (2022) funded on behalf of the wake boat industry, wake boat impacts are minimized when they are operated at least 200 feet (60.9 m) from shore in 10 feet (3.1 m) of water or deeper. Michigan DNR (Francis et al., 2023) recommends the following best practices:

- When operating in wake surfing or boarding modes, users should operate wake boats at least 500 feet (152.4) from docks and shorelines regardless of water depth.
- When operating in wake surfing or boarding modes, users should operate in water no less than 15 feet (4.6) in depth.
- Completely drain ballast tanks prior to transporting the boat over land.

Figure 68 documents the 267.5 acres (108.3 ha) of Oliver Lake which would be open for wake boating excluding water that measures 10 feet (2.3 m) deep or shallower. Figure 70 documents the 281.8 acres (114.1 ha) of Oliver Lake which would be open for wake boating excluding areas that are 200 feet (60.9 m) from shore.

Figure 70. Portion of Oliver Lake measuring 200 feet from shoreline.

11.3.2 Emergent Aquatic Plant Community Restoration

The wide, shallow shelves located around Oliver Lake look to be losing vital emergent aquatic vegetation. These shallow areas are impacted by boat propellers moving across these areas removing plants, which may be growing and disturbing the sediment surface as well as wave action from boating activities in other areas of the lake. Historic aerial photographs suggest that emergent plants, such as bulrushes, water lilies, and spatterdock, vegetated large expanses of these shallow areas. Two potential options for improving fish habitat and holding these lake sediments in place include: restoration or revegetation of these areas and placement of fish attractors. Fish attractors will likely not be permitted for installation by DNR and are thus not encouraged as a solution fat this time. Nonetheless, both options will require addressing boating within the shallow areas, potentially through the creation of a formal eco-zone (IC 14-15-7-3), as well as DNR review and approval prior to initiating in-lake habitat restoration.

If restoration is selected, small treatment areas should be identified and submerged vegetation planted within defined enclosures to improve the long-term potential for restoration. Ideal planting sites contain ample light and organic matter of less than 5 percent (Koch, 2001). Texture (Barko and Smart, 1996; Koch, 2001; Weisner, 1987;Weisner, 1991), organic matter content (Barko and Smart, 1996; Koch, 2001), and slope (Hawes et al., 2003) have all been used to explain limitation of growth. How each of these factors affect different species or types of plants can also vary, complicating the matter even more.

Of the substrate characteristics, texture may play the largest role in determining the probability of plant growth. A majority of the reviewed studies cited substrate texture as a determining factor of plant growth. Lower growth rates have been documented on sandy substrates and mucks (Barko and Smart, 1986). In both substrates, nutrient limitation was used to explain the diminished growth. Sands naturally contain low nutrient concentrations. Additionally, nutrients bind to the organic matter in mucks, making those nutrients unavailable to plants. After excluding those substrates, not much consensus could be found on an optimal texture and variation is likely between different species. In general, a substrate must provide both stability and nutrients.

Wave action can also inhibit plant growth. The primary mechanism of this inhibition is attributed to the shifting of substrate. Wave action can scour the planting area, removing sediment from the base of the plants, or deposit sediment, burying the plants. Either scenario can inhibit plant growth or cause recession among already established plant beds. In addition, wave action can increase turbidity, thereby negatively affecting the light availability in an area. As such, most aquatic plant restoration projects have accounted for lake fetch. To reduce lake fetch projects have been located in sheltered locations, such as bays or by placing structure like silt fences to encircle the planted area.

While most well-established aquatic plants can endure large water level fluctuations, those fluctuations have been cited as potential reasons for failure among newly planted restoration beds. In addition, most established aquatic plant beds can endure some level of herbivory, but carp, waterfowl, turtles, and muskrats can cause restoration failure if they impact plants before they are properly established.

Once suitability has been ensured, the primary obstacles to establishment tend to be herbivory and water level fluctuation. Herbivory is typically limited through the use of exclosures. The effect of fluctuating water levels is typically limited by taking fluctuations into account during site selection and choosing plants that can tolerate the typical range of water levels at a particular depth. In some cases, wave action can be a consideration. When considered, planting areas were protected by coir logs (biologs) or breakers placed in front of the planting zones. Despite the presence of general guidelines, much of the design process depends on the specific site requirements and goals of the project. For example, actual recommended planting depths depend on the species used and substrate on-site, which in turn depend on the location of the lake and goals of the project.

Restoration of littoral zone vegetation has been attempted by numerous lake associations, towns, and other citizen groups. The majority of these projects focused more on education and volunteer participation than on actual results. As a result, most projects have not included any post-planting monitoring or documentation of techniques and results. Of those groups that did monitor the plantings, few included a control plot for comparison and many have not publicly released their results. Consequently, the success rate for littoral zone restoration techniques is not well-documented, especially over the long-term (five years after planting or more). Analysis of the few studies that included monitoring (Hellsten et al., 1996; Smart et al., 1998; Burdick et al., 2004; Dick et al., 2004 a, b, c; Peel, 2007; Richardson, 2009) found that short-term (five years or less after planting) success rates were highly variable. The few sites monitored after five years (Dick et al., 2004a) found low survival rates. However, no maintenance activities were implemented at these sites, which allowed herbivores to breach the exclosures.

11.4 Non-point Source Load Reductions

Load reduction calculations were estimated for nitrogen, phosphorus and sediment based on the potential best management practices to be implemented within the Oliver Lake Watershed. Table 36 details the volume of each practice to be installed in the Oliver Lake Watershed using a few representative practices as an example and the expected load reductions for each best management practice. Practices to be installed and volumes of each are based on the potential problem areas and potential projects sites identified as part of the watershed inventory. If the Oliver Lake Watershed is blanketed with the proposed projects, pollutant loading will be reduced beyond the current projected watershed load for all parameters. However, the limitations of the STEPL model should be noted with consideration to sediment loading from streambank erosion.

Table 36. Potential load reduction achieved by installation of each best management practice or strategy within the Oliver Lake Watershed.

BMP/Strategy	Volume	Nitrogen (lb)	Phosphorus (lb)	Sediment (t)
Cover Crop	1,000 acres	15,000	7,000	36,010
Conservation Tillage	1,000 acres	21,000	10,000	67,540
Streambank Stabilization	500 feet	0	525	1,120
Livestock Restriction	TBD	--	--	--
Water and Sediment Control Basin	3 units	389	195	169
Current Load estimated by STEPL		27,264	2,988	2,424
Total Load Reduction		36,389	17,720	104,839
% Reduction		>100%	>100%	>100%

Implementation of best management practices within the Oliver Lake Watershed should be multipronged with focus on the implementation of a soil health program targeting cover crop and conservation tillage in agricultural areas and a rain barrel and rain garden program targeting residential and commercial locations. Filter strip planting, streambank stabilization and urban retrofits should also be targeted; however, due to limited landowner willingness and cost to benefit ratios, these practices should be given lower priority.

11.5 Implementation Costs

The total estimated cost for implementing the above recommendations is $142,500. Total costs are detailed in

Table ***37***. The majority of these costs are associated with streambank stabilization costs, which will need to be refined for each potential project site once a feasibility assessment is complete. Soil health and filter strip costs represent true costs for implementation and do not reflect potential cost share or incentive payment amounts, which are available from the Natural Resources Conservation Serve and Lake and River Enhancement Program.

Table 37. Estimated costs associated with each strategy.

BMP/Strategy	Volume	Cost/Unit	Total Cost
Cover Crop	1,000 acres	$45/acre	$45,000
Conservation Tillage	1,000 acres	$15/acres	$15,000
Livestock Restriction	TBD	Varies	--
Streambank Stabilization	500 feet	$150/lineal foot	$75,000
Water and Sediment Control Basin	3 units	$2,500/unit	$7,500
Total Cost			$142,500

11.6 Potential Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Community groups, lake associations, and/or Soil and Water Conservation Districts can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though the use of specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. Potential funding sources are detailed in Appendix E.

12.0 PUBLIC ENGAGEMENT

The public was engaged within the Oliver Lake Diagnostic Study in a variety of manners. These included one public meeting, a newsletter article highlighting study findings and creation of an informational fact sheet.

12.1 Public Meetings

One public meeting was held as part of the Oliver Lake Diagnostic Study. The first occurred on June 8, 2024. The goal of the first meeting was to introduce the project, review data collected to that point, and gather input from attendees on their knowledge and concerns about the watershed. The goal of the second meeting was to review the data collected throughout the project, highlight potential future work and project areas, and allow attendees to prioritize recommendations for the future of Oliver Lake and its watershed.

12.1.1 Meeting 1: June 15, 2024

Approximately 85 individuals attended the first public meeting. The Greater Olin Lake Conservancy met in concert with the Oliver Lake Association. The groups started the meeting highlighting the history of the project. Sara Peel with Arion Consultants provided the following points:

- Defining what a watershed is and why water quality is important.
- Information on the Oliver Lake Watershed and it's unique resources.
- The purpose of the study is to assess the conditions and trends of water quality within Oliver Lake Watershed and to further prioritize future projects that would benefit the watershed and its citizens within it.
- The scope of work for the study entails:
    - mapping current watershed conditions
    - collecting habitat, chemical, and biological data on surface waters
    - modeling pollution in surface waters

    - prioritizing potential projects
    - producing a final document
- The study will be available for public comment towards the end of 2024.
- The final approved document will be available to the public in early 2025.
- The study is funded by the Indiana Department of Natural Resources Lake and River Enhancement Program as well as through various forms of support from over a dozen local partners.

Below is a summary of the information gathered from the activity:
- Shoreline erosion due to boating impacts is a concern.
- Water clarity – seems worse than a few years ago.
- Please highlight what individuals can do – cultivate aquatic plants, don't fertilize your shoreline, protect your shoreline, etc.
- Aquatic plant management – is treatment needed? None organized for 2024.
- Too much farm-based runoff entering the lake.
- Livestock have access to local streams.
- Were previously identified projects implemented?

12.2 Executive Summary
In lieu of hosting a second meeting, a more detailed executive summary was provided to the GOLC for membership distribution. Arion Consultants were available to answer questions as needed.

12.3 Informational Fact Sheet
The informational fact sheet is included in Appendix F.

13.0 INSTITUTIONAL RESOURCES
Successful implementation of the Oliver Lake Diagnostic Study requires participation of several key groups within the watershed. A variety of institutional resources exist in the watershed to aid in water quality improvement and implementation efforts. These range from local government offices to state and federal agency personnel and programs as well as non-profit conservation organizations. The following sections detail various resources and provide contact information.

13.1 Local Government Offices
13.1.1 Soil and Water Conservation District
Indiana's Soil and Water Conservation Districts (SWCDs) were established by the Indiana Conservation Action (IC 14-32). SWCDs are chartered, legal subdivisions of the State Government whose territories are aligned with county boundaries. SWCDs develop and implement conservation programs based on a set of priorities and channel resources from all levels of government into action at the local and county level. Indiana's SWCDs are each governed by a board of supervisors, consisting of three local elected supervisors and two appointed supervisors who maintain their permanent residence in the district.

The LaGrange County Soil and Water Conservation District works to provide leadership for soil, water, and related natural resource concerns in LaGrange County. The SWCD offers a number of conservation and environmental education programs on soil, water, forestry, and wildlife, which are available to all citizens in LaGrange County. The SWCD exists to serve all the citizens of LaGrange County, including landowners, schools, youth organizations, wildlife organizations, and agricultural related businesses.

Partnering with other agencies is also important to the success of the SWCD's activities. Partners include US Department of Agriculture, Natural Resource Conservation Service; Farm Service Agency; LaGrange County Purdue Extension; and Pheasants Forever.

The LaGrange County Soil & Water Conservation District Board of Supervisors holds a board meeting at 6:00pm on the fourth Tuesday of each month with an executive session which proceeds the board meeting at 5:30. The exception to this is during the months of April, May, September, and October when the executive session starts at 7:00pm and the regular meeting starts at 7:30pm to accommodate the farmer board members who are either planting or harvesting in those months. The meetings are held at ParGil Natural Resources Learning Center at 2335 North State Road 9, LaGrange, IN. Meetings are open to the public.

For questions regarding any of LaGrange County SWCD's programs contact:
Martin Franke, District Manager
910 S. Detroit Street
LaGrange, IN 46761
Phone: (260) 462-3471 ext. 3
Martin.franke@in.nacdnet.net

13.1.2 Surveyors and Drainage Board

County surveyors and drainage boards play a critical role in the implementation of streamside BMPs, as well as potential restoration efforts that may involve the manipulation of current above or below ground drainage infrastructure. The Indiana Drainage Code of 1965 sets forth the authority to create a Drainage Board in each County. The Drainage Board consists of either the County Commissioners or a citizen board with one Commissioner as a member. The County Surveyor sits on the Board as an Ex-Officio Member. This position is a non-voting position, and the County Surveyor serves as a technical advisor to the Board.

The Drainage Board has the authority to construct, maintain, reconstruct or vacate a regulated drain. They may also create new regulated drains if so petitioned by landowners. The Board is in charge of maintaining drains by putting the drain back to its original specifications by dredging, repair tile, clearing, removing obstructions or other work necessary to keep the drain in proper working order. The County surveyors are often the best contact for drainage projects or concerns, or to coordinate with the Drainage Boards.

The Surveyor's Office is also typically task with establishing, reestablishing and recording all section corners throughout the county; supervising all civil engineering work of the county; recording the location of legal surveys; supervising construction, reconstruction and maintenance of drains and ditches; developing drainage studies and specifications, issues drainage related permits; and calculating drainage assessments.

None of the streams and ditches in the watershed are official 'regulated drains' and are therefore not under the authority of the drainage boards and surveyors. The LaGrange County Drainage Board meets on the first Monday of each month at 6:00pm in the Commissioner's Room on the first floor of the county office building. For questions about the drainage board and the future of legal drains in the Oliver Lake Watershed contact:

Zach Holsinger, County Surveyor
1st Floor Commissioner's Room
114 West Michigan Street
LaGrange, IN 46761
Phone: (260) 499-6306
zholsinger@lagrangecounty.org

13.1.3 Planning and Zoning Authorities

County-wide Comprehensive Plans can provide a significant amount of information on both natural resources in an area, as well as population statistics, traffic plans, and current and future land use zoning. Such zoning designations, if enforced, often drive where future residential and commercial/industrial growth will occur. The authority to rezone land into different land use categories and the power to grant variances from local ordinances related to development, often lie with local Zoning Boards or Plan Commissions.

LaGrange County's comprehensive plan is dated September 2022 and is comprised of three major elements for guiding the county's development – the Planning Foundation, the Land Use Plan and the Natural Environment. The purpose of the Planning Foundation is to guide the vision of the county's future through goals and strategies, while the Land Use Plan describes how the vision links to the future development of the land while the Natural Environment details how these areas can be protected and enhanced in the future. In addition to drafting plans and ordinances, the Plan Commission also has the authority to approve and deny land subdivisions based on the subdivision control ordinance. The Board of Zoning Appeals hears petitions and appeals regarding the zoning of land and is task with granting variances or special exceptions for specific land use types.

The Plan Commission meets monthly on the fourth Monday of the month at 7:00 p.m. in the Commissioners Room in the LaGrange County Office Building, which is located on the northwest corner of the Courthouse Square at 114 West Michigan Street, LaGrange, IN. The Commissioners Room is on the main floor on the northeast corner of the building. The meetings are open to the public. The best contact for watershed land use concerns related to development or zoning in LaGrange County is:

Robbie Miller
114 West Michigan Street
LaGrange, IN 46761
Phone: (260) 499-6347
rmiller@lagrangecounty.org

13.1.4 Health Department

In order, to protect, promote, maintain and improve the health and quality of life for LaGrange County citizens, the health department offers a number of health protection programs. Assessment and reduction of human health risks is accomplished through investigations, inspections and regulatory enforcement of these programs. Programs include, but are not limited to: drinking water monitoring, food sanitation, sewage treatment, animal and vector control, and housing sanitation and safety.

The construction of a septic system requires several procedures and permits from the county. These procedures are in place to prevent diseases that could be spread by improperly managed sewage. The LaGrange County Health Department has records for septic systems installed after 1967. For environmental health and septic system questions and information contact:

Alf García, Environmental Health Specialist
304 N. Townline Road, Suite 1
LaGrange, IN 46761
Phone: (260) 499-4182 ext. 222
agarcia@lagrangecounty.org

13.2 State and Federal Offices

13.2.1 Indiana DNR and DEM

The Indiana Department of Natural Resources (IDNR) and the Indiana Department of Environmental Management (IDEM) have a variety of programs and staff dedicated to water quality assessments and watershed planning initiatives. The most relevant contacts at these agencies to assist local leaders in water quality planning efforts are listed below. While there are countless specialists at these agencies, the below staff should be able to guide local questions to appropriate personnel.

Indiana Department of Natural Resources Division of Fish & Wildlife – Lake and River Enhancement Program (LARE)
Nate Thomas, LARE Program Manager
1353 S. Governors Drive
Columbia City, IN 46725
Phone 260-213-4601
nthomas@dnr.in.gov

Indiana Department of Environmental Management Office of Water Quality
Caleb Rennaker, Section Chief
100 N. Senate Avenue
Indianapolis, IN 46204
crennake@idem.in.gov

Indiana Department of Environmental Management Office of Water Quality
Miranda Wentz, Watershed Specialist
100 N. Senate Ave.
Indianapolis, IN 46204
mwentz@idem.in.gov

13.2.2 State Department of Agriculture

The Division of Soil Conservation belongs to the Indiana Conservation Partnership; however, it is situated in the State Department of Agriculture (ISDA). As part of the Partnership, ISDA provides technical, educational, and financial assistance to citizens to solve erosion and sediment-related problems occurring on the land or impacting public waters. The Division of Soil Conservation is divided into Conservation Implementation Teams (CIT) that cover specific counties. These teams can deliver advice to landowners regarding best management practices, assist with engineering design, and secure/coordinate associated project permits and cost share amounts.

Heath Hurst, Resource Specialist
100 E. Park Drive
Albion, IN 46701
Phone: 317-800-1700
hhurst@isda.in.gov

13.2.3 Natural Resources Conservation Service

The NRCS is a Federal agency that works with landowners and managers to conserve their soil, water, and other natural resources. NRCS employees provide technical assistance based on a customer's specific needs in such areas as animal husbandry and clean water, ecological sciences, engineering, resource economics, and social sciences. They also provide financial assistance for many conservation activities. The NRCS programs are all voluntary participation programs.

Erica Wyss, District Conservationist
910 S. Detroit Street
LaGrange, IN 46761
Phone: (260) 462-3471 ext. 3
Erica.wyss@usda.gov

13.2.4 US Geological Survey

The USGS is a multi-disciplinary science organization focused on biology, geography, geology, geospatial information, and water. They work to study the study of the landscape, our natural resources, and the natural hazards that threaten us.

Indiana Office
5957 Lakeside Boulevard
Indianapolis, IN 46278
Phone: (317) 290-3333

14.0 <u>RECOMMENDATIONS</u>

A look back at the 2009 Olin, Oliver and Martin Lakes Diagnostic Study (JFNew, 2009) provides a good foundation for future recommendations. The 2009 diagnostic study noted that Oliver Lake had good water clarity in the spring but it declined during the summer survey and that Olin and Martin lakes followed that trend. The study noted that *each lake's total phosphorus concentration place the lake in the mesotrophic category based on Carlson's TSI. The lakes' chlorophyll a concentration, Indiana TSI score, and Secchi disk depth suggested all three lakes were either mesotrophic or slightly oligotrophic, in nature. Oliver, Olin, and Martin lakes historically exhibited good water quality and recent samplings indicate that water quality remains good.* The study noted that although by most of the trophic classifications, the lakes were oligotrophic to mesotrophic, the trend might not continue in the future without continued watershed management. There was some evidence that the internal loading of phosphorus in Oliver and Olin lakes represented a significant potential for algal growth under the right conditions. Specifically, JFNew (2009) stated that *compounded with external phosphorus loading from the watershed, the lakes could turn eutrophic and have issues such as nuisance algal blooms and large areas of the water column that become anoxic.* Specifically, the study noted that *external phosphorus loading from the watershed needs be reduced in conjunction with a reduction in internal phosphorus loading. Given the bathymetry of each of the lakes, it may be easier to reduce external loading through proper watershed management than to reduce internal loading through dredging or alum treatments.*

14.1 <u>Comparison with Oliver Lake Diagnostic (JFNew, 2009) Data</u>

The 2009 Oliver, Olin and Martin Lakes Diagnostic Study (JFNew, 2009) noted that all three lakes exhibited good water quality and that phosphorus levels in all three lakes were below or at the median average for Indiana lakes. Olin and Martin lakes were classified as mesotrophic using the Indiana TSI, while Oliver Lake was classified as oligotrophic. The diagnostic study noted that *years of plant and algae* *production and transport of organic material into OOM Lakes from its watershed have led to a build-up of decaying organic matter in the sediments of OOM Lakes. As bacteria decompose this material, they consume oxygen and leave the bottom waters anoxic (dissolved oxygen concentrations < 1.0 mg/L). Currently (2008), Oliver Lake contains the highest percentage of the water column containing sufficient dissolved oxygen for aquatic life at 74.6% and Martin Lake the lowest at 48.6%. The presence of anoxic conditions has led to internal phosphorus release from Oliver and Olin lakes sediment, which is evident by the high sediment phosphorus release factor. The sediment phosphorus release factor is the amount of soluble phosphorus (the form of phosphorus that can be released from the sediments) in the deepwater (hypolimnetic) sample to the surface (epilimnetic) sample. In Oliver and Olin Lakes, the ratio is 20.6/1 and 34.2/1, respectively. Martin Lake does not show evidence of internal loading of phosphorous because there are equal concentrations of soluble phosphorus in the hypolimnia and epilimnion. In most lakes in Indiana, phosphorus release from the sediments is an additional and important source of phosphorus to the lake that must be addressed along with watershed practices when designing a management plan to reduce nutrient loading to the lake. This internal loading of phosphorus is another source of phosphorus to these lakes that can promote excessive algae production. Current data suggest that internal loading of phosphorus is a large component of Oliver and Olin lakes phosphorus load.*

During the 2024 assessment, Martin Lake possessed the highest percentage of the water column containing insufficient dissolved oxygen for aquatic life at 75%, while Olin Lake was 63% anoxic and Oliver Lake was 54% anoxic. Sediment release occurred in all three lakes during the 2024 assessment; however, all measured an order of magnitude lower than Oliver and Olin lakes observations in 2008. During 2024, the Martin Lake sediment release factor was the highest at 5.5/1, with Olin Lake measuring 4.6/1 and Oliver Lake measuring 4.2/1. This suggests that phosphorus is being released from the sediment in all three lakes; however, the release occurs at a lower rate in Olin and Oliver lakes and higher rate in Martin Lake than observed in 2008.

Modeling completed as part of the 2009 diagnostic study estimate that phosphorus loading to Oliver Lake from its watershed totals 1,835 kg/year, while Martin Lake loading is 877.1 kg/year and Olin Lake is 260.6 kg/year. Additional efforts to determine internal versus external sources of phosphorus to the lakes generated a negative internal loading rate for Martin Lake. JFNew (2019) suggests that *the sediments of most lakes serve as sinks for nutrients, particulates, and other materials that settle down out of the water column due to gravity. In lakes where this happens, we often see significant rates of internal phosphorus release. We don't see this in Martin Lake, at least not on 7/23/08 when we collected the water samples. On the day we sampled, the hypolimnetic soluble phosphorus concentration was the same as the epilimnetic soluble phosphorus concentration. This suggests no internal phosphorus loading. In past years' data for Martin Lake, we see little evidence of internal phosphorus loading either. Another possibility is that given the rapid hydraulic flushing rate (nearly 4 lake volumes per year) for Martin Lake, much of this excess phosphorus likely gets washed into Olin Lake, especially during storm events. However, our 7/23/08 sampling date did not closely follow a storm event so we measured only "normal" concentrations of phosphorus in Martin Lake. We suspect that storm event sampling on Martin Lake would yield different results.*

Modeling (which will be discussed in subsequent sections) indicate that phosphorus loading to Oliver Lake measured 4,482 lb/year, while Martin Lake receives 1,563 lb/year and Olin Lake received 106 lb/year. When historic data units are converted, Oliver Lake estimates are higher currently (4,482 lb/year) than historic estimates (4,045 lb/year), while Martin Lake estimates are lower now (1,663 lb.year) than historically (1,933.7 lb/year), as are Olin Lake estimates (106 lb/year, current; 260.6 lb/year, historic). These differences are likely due to differences in methods used to calculate loading rates as well as the fact that direct to the lakes' drainage was not included in any one lake and adds an additional 837 lb/year in loading to the current (2024) estimates.

Finally, the diagnostic study noted that *eliminating internal phosphorus loading alone will not meet the reduction needed to achieve acceptable phosphorus loading rates to these lakes. A significant reduction in watershed phosphorus loading will be required to reduce the trophic state of Olin, Oliver and Martin lakes.*

14.2 <u>Historic Recommendations</u>

JFNew (2009) recommended the following activities to reduce phosphorus, nitrate, organic matter and bacteria concentrations and loads which were identified as being of concern for the lakes' long term health:

- Implement agricultural best management practices such as restoring existing failed structures, installing and increasing stream buffer width, and repairing and installing grassed waterways.
- Stabilize the eroding ravines on the IDNR's Olin Lake Nature Preserve to reduce sediment and nutrient loading to Olin and Oliver lakes.
- Implement individual property owner management techniques.
- Manage the Eurasian watermilfoil present in the lakes and private channels to prevent its spread and protect the diverse, native submergent rooted plant community.
- Restore wetland habitat within the OOM lakes watershed where feasible.
- Monitor and improve erosion control techniques on residential and commercial development sites throughout the watershed.
- Pursue opportunities to connect residential properties adjacent to drainage ditches to the existing sewer system.
- Increase usage of the Conservation Reserve Program in the OOM lakes watershed particularly on land mapped in highly erodible soils.
- Stabilize or restore stream channels or drainages within the OOM lakes watershed (outside of the Olin Lake Nature Preserve) to reduce sediment and nutrient loading to all three lakes.
- Continue active volunteer monitoring through the Indiana Clean Lakes Program volunteer monitoring program.

Many of these recommendations were implemented including addressing failed structures, stabilizing streambanks throughout the watershed and eroding ravines on the Olin Lake Nature Preserve. Additional efforts are needed including revisiting some of these recommendations.

14.3 <u>Current Recommendations</u>

All of the subwatersheds within the Oliver Lake Watershed could benefit from soil health and targeted stormwater retention strategies as already described in detail above. A number of protection project sites were identified based on previously completed watershed projects, physical observation and GIS modeling (Figure 71). Based on watershed monitoring and modeling loading rates, the prevalence of highly erodible soils and relevance of agriculture across the watershed, implementation efforts should generally focus on the implementation of agricultural BMPs. Based on loading calculations and field observations, efforts should target the Dove Creek and Truman Flint Ditch subwatershed drainages first followed by other subwatersheds, then in lake and shoreline projects. Finances, time, volunteer time, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

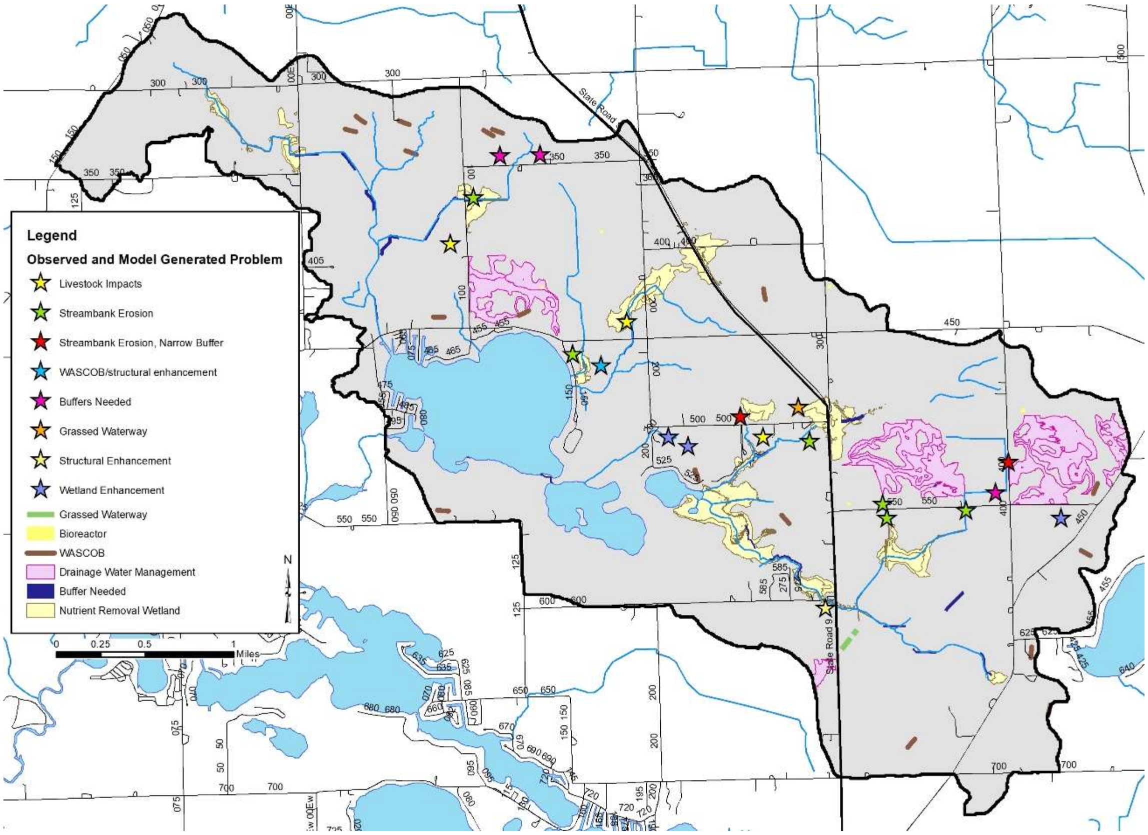


Figure 71. Potential projects identified in the Oliver Lake Watershed.

The recommendations listed below are prioritized based on potential impact. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed in the future.

It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval, along with stakeholder input, may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to provide data to the individuals attending the second public meeting. They used these data as well as personal preference to prioritize recommendations for future work. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the primary recommendations section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

1. Review function and status of previously installed Best Management Practices
Practices installed as part of LARE and GLC funded efforts should be reviewed to confirm that they are still functioning as installed. Most of these practices are nearly their 10 year lifespan.

2. Apply for Lake and River Enhancement (LARE) funds to implement best management practices.
LARE feasibility, design and construction funding can be utilized to address shoreline and streambank erosion, structural repairs, livestock restriction, buffer installation, in lake restoration, invasive plant eradication, dredging and other potential projects. LARE watershed land treatment funds could be utilized to address agricultural BMPs, including filter strips, livestock distribution, and soil health-focused conservation tillage and cover crop planting. Traditional funds can be used to address maintenance issues for previously installed practices as well as addressing streambank and lakeshore erosion. Funding can be obtained from a variety of sources such as the Conservation Reserve Program, Clean Water Indiana, Great Lakes Restoration Initiative and the Environmental Quality Incentives Program. These funds can be used separately or in conjunction with LARE Watershed Land Treatment funds.

3. Target best management practice implementation on non-protected parcels mapped as highly erodible land and/or those fields noted as of highest concern for runoff risk and/or sediment delivery.
Approximately 54% of the watershed (2,945 acres) is mapped as highly erodible soils. Efforts for these parcels should focus on enrolling tracts of land mapped as highly erodible in the conservation reserve program (Figure 7). Additionally, fields mapped as high for sediment deliver risk (Figure 59) and/or very high for runoff risk (Figure 60) should also be targeted.

4. Reduce total phosphorus concentrations in streams throughout the watershed.
Total phosphorus concentrations were elevated at all watershed streams during both base and storm flow. Concentrations in the tributaries exceeded recommended target concentrations for total phosphorus (0.08 mg/L). Best management practice implementation to reduce phosphorus loading to the streams, including livestock fencing, septic system inspection and maintenance, and sewer maintenance, streambank and shoreline stabilization should be targeted.

5. Reduce total suspended solids concentrations in streams throughout the watershed.
TSS concentrations were elevated and exceeded the target concentration (15 mg/L) during base and storm flow across the watershed. Best management practice implementation to reduce TSS loading to the streams and the lakes, including streambank stabilization, cover crop planting, conservation tillage, streambank erosion, lakeshore erosion and in lake habitat restoration practices should be the focus. Areas which rank high for sediment runoff risk ratio should be explored first to address sediment runoff.

6. Reduce *E. coli* concentrations in streams throughout the watershed.
E. coli concentrations exceeded the state standard at many sites during base and storm flow events. Historic data indicate that elevated E. coli concentrations are common in the Oliver Lake Watershed. Two livestock exclusion sites were identified as part of the inventory process. Additionally, the volume of manure produced on small, unregulated animal facilities is concerning for the watershed. The specific sources of *E. coli* in the Oliver Lake Watershed have not been identified; however, wildlife, livestock and/or domestic animal defecations; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are

common sources of the bacteria. Livestock restriction, manure management planning and septic maintenance can all address pathogen issues in the Oliver Lake Watershed.

7. Consider options to protect and restore emergent vegetation in shallow areas of Oliver Lake.
More than one-third of Oliver Lake measures ten feet deep or shallower. The wide, shallow shelves which surround the entire lake are subject to wind and wave action which can be exacerbated by boating activities. These areas should be investigated for options to protect what emergent plant beds remain and options for restoring these plant beds should be explored. Additionally, these areas should be considered for future designation as an IDNR Eco Zone.

8. Extend management to the watershed level.
Although streamside localized BMPs are important, research conducted in Wisconsin shows that the biotic community mostly responds to large-scale watershed influences rather than local riparian land use changes (Weigel et al., 2000). More than 4 miles of Oliver Lake Watershed streams possess streambank erosion. Addressing these eroded areas through LARE feasibility and design/construction projects. An example of working at the watershed-level is coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans. It is important to note that the LARE Program through the local SWCD and NRCS programs will provide cost-share incentives for large-scale land practices like conservation tillage. Large-scale reductions in agricultural non-point source pollutions are necessary for stream health improvement (Osmond and Gale, 1995).

9. Invite producers and other landowners to visit successful project sites.
There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.

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