Ridinger Lake Watershed Diagnostic Study

KOSCIUSKO AND WHITLEY COUNTIES, INDIANA

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RIDINGER LAKE WATERSHED DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

The Ridinger Lake watershed covers over 22,100 acres (8,950 ha or 34.5 square miles) southeast of North Webster, Indiana. The watershed forms the headwaters of the Grassy Creek sub-basin of the Upper Tippecanoe River watershed. Three major lakes, Ridinger Lake, Robinson Lake, and Troy Cedar Lake, as well as several smaller lakes, lie within the Ridinger Lake watershed. The movement of two different glacial ice lobes influenced the formation of the Ridinger Lake watershed resulting in a prevalence of clay-rich Morley soils in the central and eastern portion and sandier soils (Riddles, Wawasee, and Miami) in the western portion of the watershed. Currently, agricultural land uses occupy most (>80%) of the watershed. Residential and commercial land uses cover less than 2% of the watershed.

Nutrient concentrations in the Ridinger Lake watershed streams were average or slightly elevated compared to other northern Indiana streams. However, nutrient concentrations in the streams were generally high enough to label the streams eutrophic, or highly productive. The high levels of nutrients likely play a role in impairing the biotic communities of the watershed streams. Biotic integrity scores from all of the assessed streams suggest that the biotic communities in these streams are moderately impaired. The watershed streams offer poor habitat conditions which also play a role in degrading the biological communities. None of the streams possessed Qualitative Habitat Evaluation Index scores in the range considered by the Indiana Department of Environmental Management to be fully supportive of aquatic life uses. Shanton Ditch and Elder Ditch exhibited the highest pollutant loading rates. Even when drainage size is used to normalize the pollutant loading rates, the pollutant loading rates in Shanton Ditch and Elder Ditch, as well as Mathias Ditch, warrant concern.

All of the Ridinger Lake watershed's major lakes are highly productive lakes. Ridinger Lake is best classified as a hypereutrophic lake, while Troy Cedar Lake falls between the eutrophic and hypereutrophic categories. Robinson Lake has elevated nutrient concentrations that are comparable to the other two lakes, but there is limited evidence that the lake assimilates its nutrient loads better than Ridinger Lake and Troy Cedar Lake. Robinson Lake is best described as a eutrophic lake with a high potential for becoming hypereutrophic. In general, the lakes possess poorer water clarity and higher nutrient concentrations than most Indiana lakes. The lakes have large watershed area to lake volume ratios resulting in short hydraulic residence times. Ridinger Lake's hydraulic residence time is only 36 days; hydraulic residence times in Robinson and Troy Cedar Lakes are 2.5 and 7 months, respectively. Phosphorus modeling indicates most of the phosphorus load to the lakes is from external (watershed) sources.

Lake and watershed data point to the need to prioritize watershed management over in-lake management to improve the water quality in Ridinger, Robinson, and Troy Cedar Lakes. Nearly 100 watershed management steps were identified to improve water quality in the Ridinger Lake watershed. These potential projects include livestock fencing, filter strip installation and widening, riparian restoration, bank stabilization, wetland restoration, grassed waterway installation, no-till conservation tillage usage, Conserve Reserve Program implementation, and residential/commercial development erosion control. In general, projects in the Shanton Ditch and Elder Ditch subwatersheds should receive the highest priority when implementing projects.

ACKNOWLEDGMENTS

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RIDINGER LAKE WATERSHED DIAGNOSTIC STUDY
KOSCIUSKO AND WHITLEY COUNTIES, INDIANA

1.0 INTRODUCTION

Ridinger Lake watershed lies in the Grassy Creek sub-basin of the Upper Tippecanoe River watershed, southeast of North Webster, Indiana (Figure 1). Specifically, the watershed is located in Sections 3-4, 6-12, 14-21, 23, and 28-32 in Township 32 North, Range 8 East; Sections 1-2, 10-15, and 21-25 in Township 32 North, Range 7 East; Sections 31 and 36 in Township 33 North, Range 7 East; and Sections 33 and 34 in Township 33 North, Range 8 East. The Ridinger Lake watershed stretches out to the east and south of the Ridinger Lake encompassing 22,180 acres (8,980 ha or 34.7 square miles) and covering portions of two counties (Figure 2). The Ridinger Lake watershed includes three major lakes: Ridinger Lake, Robinson Lake, and Troy Cedar Lake. This diagnostic study focuses on each of the three major lakes and the entire Ridinger Lake watershed.

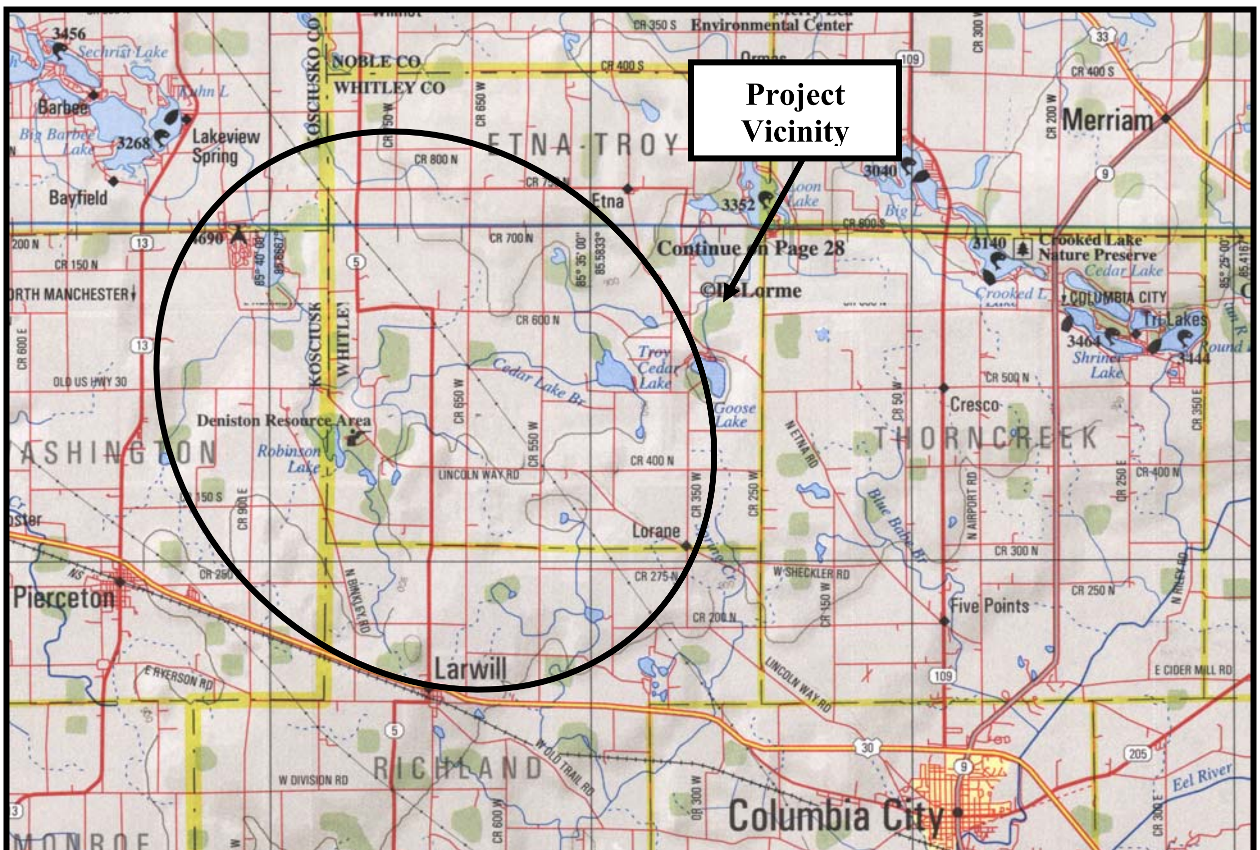


Figure 1. Location map for the Ridinger Lake Watershed Diagnostic Study. Source: DeLorme, 1998.

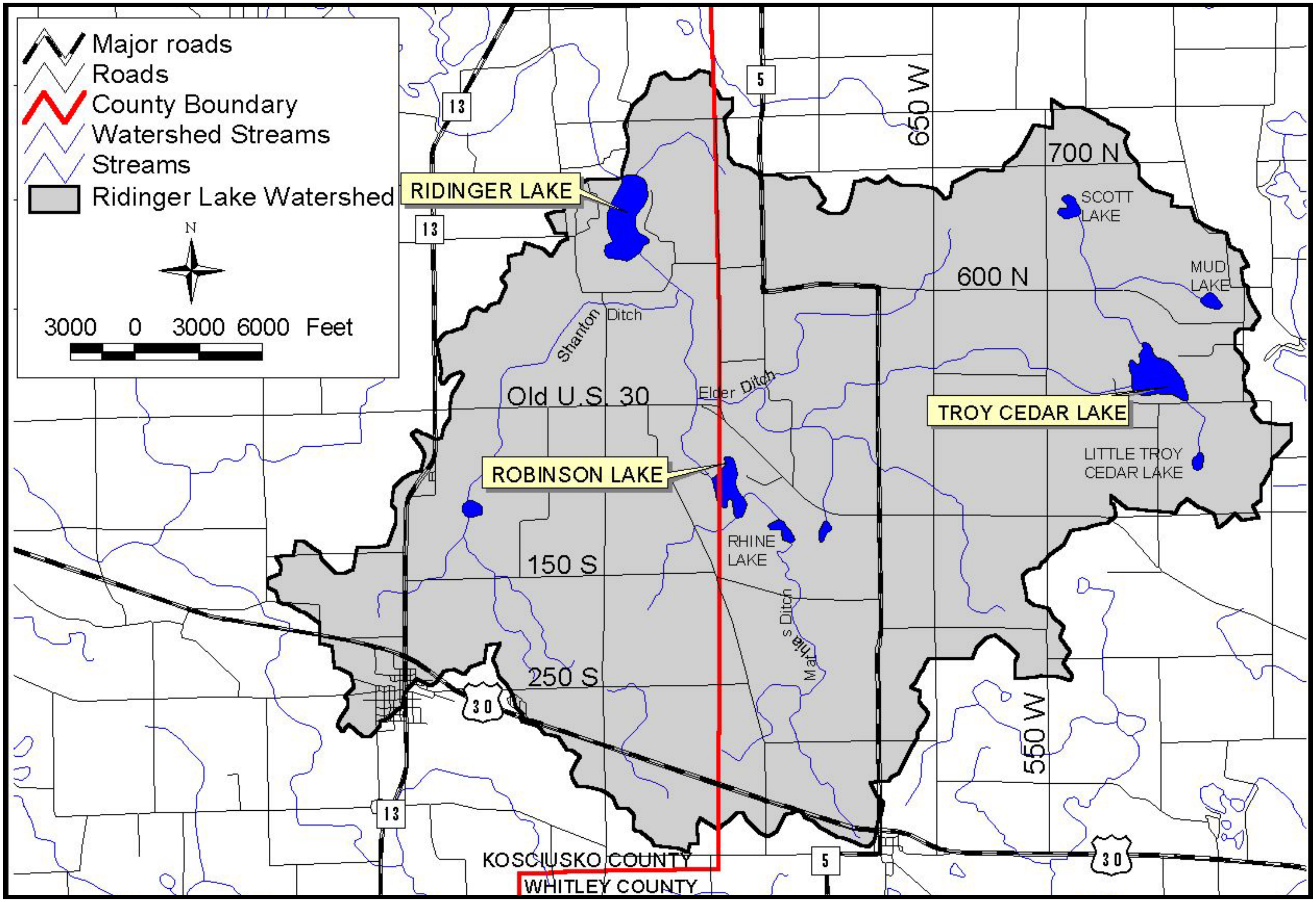


Figure 2. The Ridinger Lake watershed.
Source: See GIS sources appendix (Appendix A). Scale: 1”=7,000’.

Historical studies have highlighted water quality concerns in the Grassy Creek sub-basin of the Upper Tippecanoe River watershed and, specifically, in Ridinger Lake and its watershed. In a 1970s survey of lakes, Ridinger Lake possessed one of the highest trophic state index scores of all the lakes in Kosciusko County (IDEM, 1986). A 1989 study of area lakes found that Ridinger Lake exhibited the one of the poorest Secchi disk transparency measurements (a measure of water clarity) and the highest total phosphorus concentration of all the study lakes (Hippensteel, 1989). Hippensteel (1989) also found elevated concentrations of total phosphorus, the nutrient primarily responsible for lake eutrophication, in several streams in the Ridinger Lake watershed. Despite the water quality concerns, Hippensteel (1989) identified the Ridinger Lake watershed as one of the four "priority watersheds that have critical and solvable problems." Another study conducted a year later found similarly poor water quality in Ridinger Lake and singled out the Elder Ditch subwatershed as the primary source of sediment and nutrient loading to Ridinger Lake (IST, 1990). Fish kills, due to poor water quality, have been reported in Ridinger Lake (Pearson, 1981) and Troy Cedar Lake (Braun, 1981). Finally, the Indiana Clean Lakes Program (CLP) consistently found high phosphorus concentrations in Ridinger, Robinson, and Troy Cedar Lakes (CLP, 2000).

The studies listed above document the water quality problems in Ridinger Lake and other lakes and streams within the Ridinger Lake watershed. Unfortunately, Grassy Creek transports many of these water quality problems to lakes situated downstream of Ridinger Lake, including the Barbee Chain of Lakes and Lake Tippecanoe. A 2000 Indiana Department of Natural Resources (IDNR) Lake and River Enhancement Program (LARE) diagnostic study of the Barbee Chain of Lakes found that Grassy Creek delivered the more nutrients and sediment to the lakes than the lakes' other inlets (JFNew, 2000). The delivery of large amount of pollutants had serious consequences for the lakes. JFNew (2000) also reported that the lakes on the Barbee Chain that lie directly on the Grassy Creek pathway (Big Barbee, Little Barbee, and Sawmill Lakes) exhibited poorer water quality than the other Barbee Chain Lakes which discharge into one of the lakes listed above. Big Barbee, Little Barbee, and Sawmill Lakes generally exhibited poorer water quality than most Indiana lakes. A 1995 IDNR LARE diagnostic report of Lake Tippecanoe documented similar concerns with the Grassy Creek sub-basin (JFNew, 1995).

The results of the 1995 and 2000 LARE diagnostic studies of Lake Tippecanoe and the Barbee Chain of Lakes, respectively, indicate that improving the water quality in the Ridinger Lake watershed is critical to improving the water quality in Lake Tippecanoe and the Barbee Chain of Lakes. While previous studies of the Ridinger Lake watershed provide broad ranging recommendations, they do not list site specific projects that may be completed to improve water quality in the watershed. In an effort to identify site specific management actions that may be taken to improve water quality in the Ridinger Lake watershed, the Barbee Lakes Property Owners Association (BLPOA) applied for and received funding from the IDNR Lake and River Enhancement Program to complete the diagnostic study of Ridinger Lake and its watershed. The purpose of the study was to describe the conditions and trends in Ridinger, Robinson, and Troy Cedar Lakes and the Ridinger Lake watershed, identify potential problems, and make prioritized recommendations addressing these problems. The study consisted of a review of historical studies, interviews with area residents and state/local regulatory agencies, the collection of current water quality data, pollutant modeling, and field investigations. In order to obtain a broad understanding of the water quality in each of the study lakes (Ridinger, Robinson, and

Troy Cedar) and the quality of the water entering each lake, this diagnostic study included an examination of the water chemistry and the biotic communities (macroinvertebrates, plankton, macrophytes) of each lake and the lakes' inlet streams. The lakes' and their inlet streams' habitat was also assessed to help distinguish between water quality and habitat effects on the existing biotic communities. This report documents the results of the diagnostic study.

2.0 WATERSHED CHARACTERISTICS

2.1 Physical Characteristics

Figure 3 illustrates the topographical relief of the 22,181-acre (8,976-ha) Ridinger Lake watershed. The varied topography of the Ridinger Lake watershed reflects the geological history of the area. Some of the highest areas of the watershed lie on the southern edge of the watershed where glacial activities deposited the Packerton Moraine. Elevations in this area of the watershed reach over 950 feet above mean sea level. The Packerton Moraine extends northeasterly along the watershed's southeastern and eastern edges where the Packerton Moraine blends together with the Mississinewa and Salamonie Moraines. Elevations along the eastern edge of the watershed top out at 970 feet above mean sea level. The Ridinger Lake watershed streams carve valleys in the watershed's landscape as they flow from the watershed headwaters to Ridinger Lake in the northwest corner of the watershed. The valley through which Shanton Ditch flows is the broadest stream valley. Wetland habitat likely covered this flat area in pre-settlement times. The elevation in this valley ranges from 840 to 860 feet above mean sea level. Ridinger Lake, which lies at 843 feet above mean sea level, is the lowest point in the watershed.

2.1.1 Ridinger Lake

Three main drainage systems transport water from the watershed to Ridinger Lake. Elder Ditch and its tributaries flow westerly from the eastern portion of the watershed until Elder Ditch combines with Mathias Ditch, which drains the south central portion of the watershed. Shanton Ditch and its tributaries drain the western portion of the Ridinger Lake watershed. Figure 4 shows the approximate drainage areas for each of these tributaries to Ridinger Lake. (Figures 5 and 6 provide similar information for Robinson and Troy Cedar Lakes, respectively.) Each distinctly shaded region represents that portion of land draining directly to the tributary for which the subwatershed is named.

Table 1 presents the approximate sizes of each of the three major subwatersheds as well as the size of the subwatershed that drains directly to Ridinger Lake or is below the confluence of the major drainages. Elder Ditch is the largest subwatershed, draining 10,202 acres (4,129 ha) and covering nearly 50% of the Ridinger Lake watershed. Shanton Ditch and Mathias Ditch drain similar sized areas, 5,261 acres (2,129 ha) and 4,584 acres (1,855 ha), respectively. Approximately 2,134 acres (863 ha) of land drain to Elder Ditch below its confluence with Mathias and Shanton Ditches or directly into Ridinger Lake. Combined, Ridinger Lake possesses a watershed area of 22,181 acres (8,976 ha).

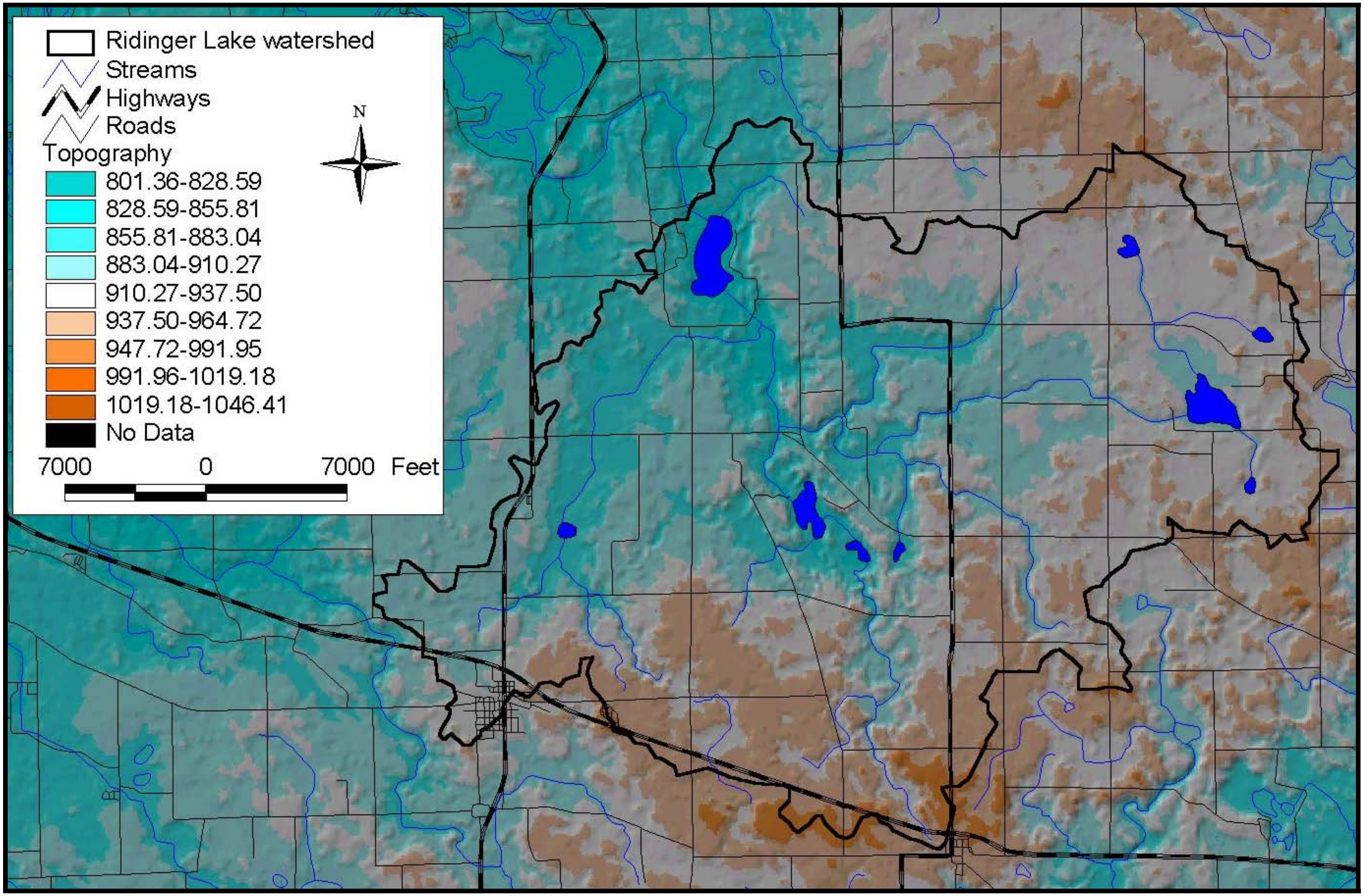


Figure 3. Topographical map of the Ridinger Lake watershed.
Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Table 1. Watershed and subwatershed sizes for the Ridinger Lake watershed.

Subwatershed	Area (acres)	Area (hectares)	Percent of Watershed
Elder Ditch	10,202	4,129	46%
Shanton Ditch	5,261	2,129	24%
Mathias Ditch	4,584	1,855	21%
Area adjacent to Ridinger Lake	2,134	864	10%
Total Watershed	22,181	8,976	100%
Watershed to Lake Area Ratio	165:1		

Table 1 also provides the watershed area to lake area ratio for Ridinger Lake. Watershed size and watershed to lake area ratios can affect the chemical and biological characteristics of a lake. For example, lakes with large watersheds have the potential to receive greater quantities of pollutants (sediments, nutrients, pesticides, etc.) from runoff than lakes with smaller watersheds. For lakes with large watershed to lake ratios, watershed activities can potentially exert a greater influence on the health of the lake than lakes possessing small watershed to lake ratios. Conversely, for lakes with small watershed to lake ratios, shoreline activities and internal lake processes may have a greater influence on a lake's health than lakes with large watershed to lake ratios.

Ridinger Lake possesses a watershed to lake ratio of approximately 165:1. This is an extremely large watershed area to lake area ratio. In other words, Ridinger Lake has a large watershed relative to the size of the lake. Ridinger Lake's watershed area to lake area ratio is well above the typical ratio for glacial lakes. Many glacial lakes have watershed area to lake area ratios of less than 50:1 and watershed area to lake area ratios on the order of 10:1 are fairly common. Ridinger Lake's watershed area to lake area ratio is more typical of reservoirs, where the watershed area to reservoir area ratio typically ranges between 100:1 and 300:1 (Vant, 1987). As a result of Ridinger Lake's high watershed area to lake area ratio, watershed activities can potentially exert a greater influence on the health of the lake than shoreline activities and in-lake processes. This fact is important in evaluating potential management efforts.

2.1.2 Robinson Lake

Robinson Lake possesses two main drainages. Mathias Ditch is the larger of the two streams and enters Robinson Lake in its southeast corner. Mathias Ditch drains 4,396 acres (1,779 ha) of land south and east of Robinson Lake (Figures 5; Table 2). Doke Ditch enters Robinson Lake in its southwest corner and drains 1,519 acres (615 ha) immediately south and west of Robinson Lake. Approximately 151 acres (61 ha) of land drains directly from the watershed into Robinson Lake. In total, the Robinson Lake watershed covers approximately 4,396 acres (1,779 ha). Robinson Lake's watershed area to lake area ratio is approximately 75:1, which is relatively high for a glacial lake.

Table 2. Watershed and subwatershed sizes for the Robinson Lake watershed.

Subwatershed	Area (acres)	Area (hectares)	Percent of Watershed
Mathias Ditch	2,725	1,103	62%
Doke Ditch	1,519	615	35%
Area adjacent to Robinson Lake	152	61	3%
Total Watershed	4,396	1,779	100%
Watershed to Lake Area Ratio	75:1		

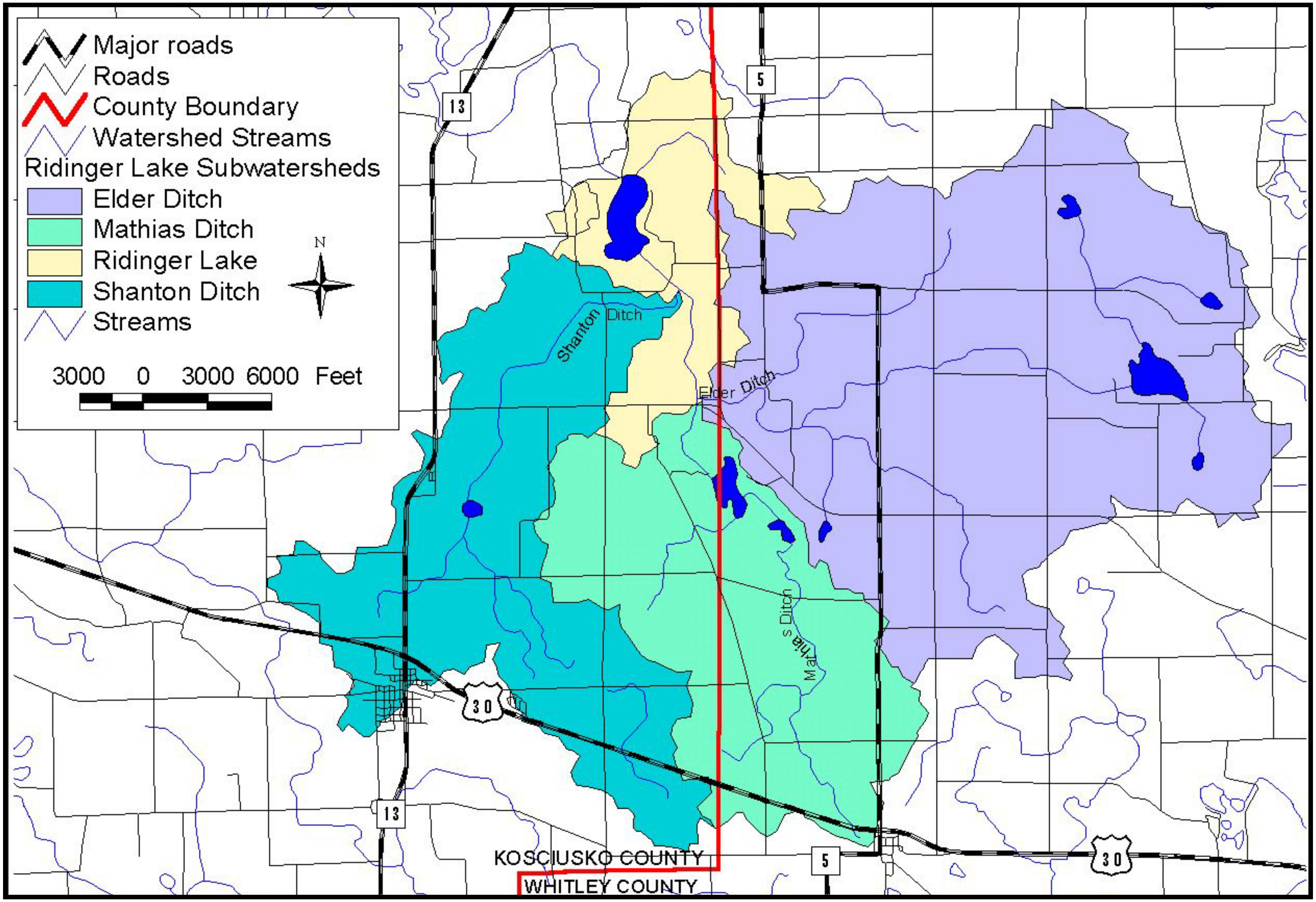


Figure 4. Ridinger Lake subwatersheds.
Source: See GIS sources appendix (Appendix A). Scale: 1”=7,000’.

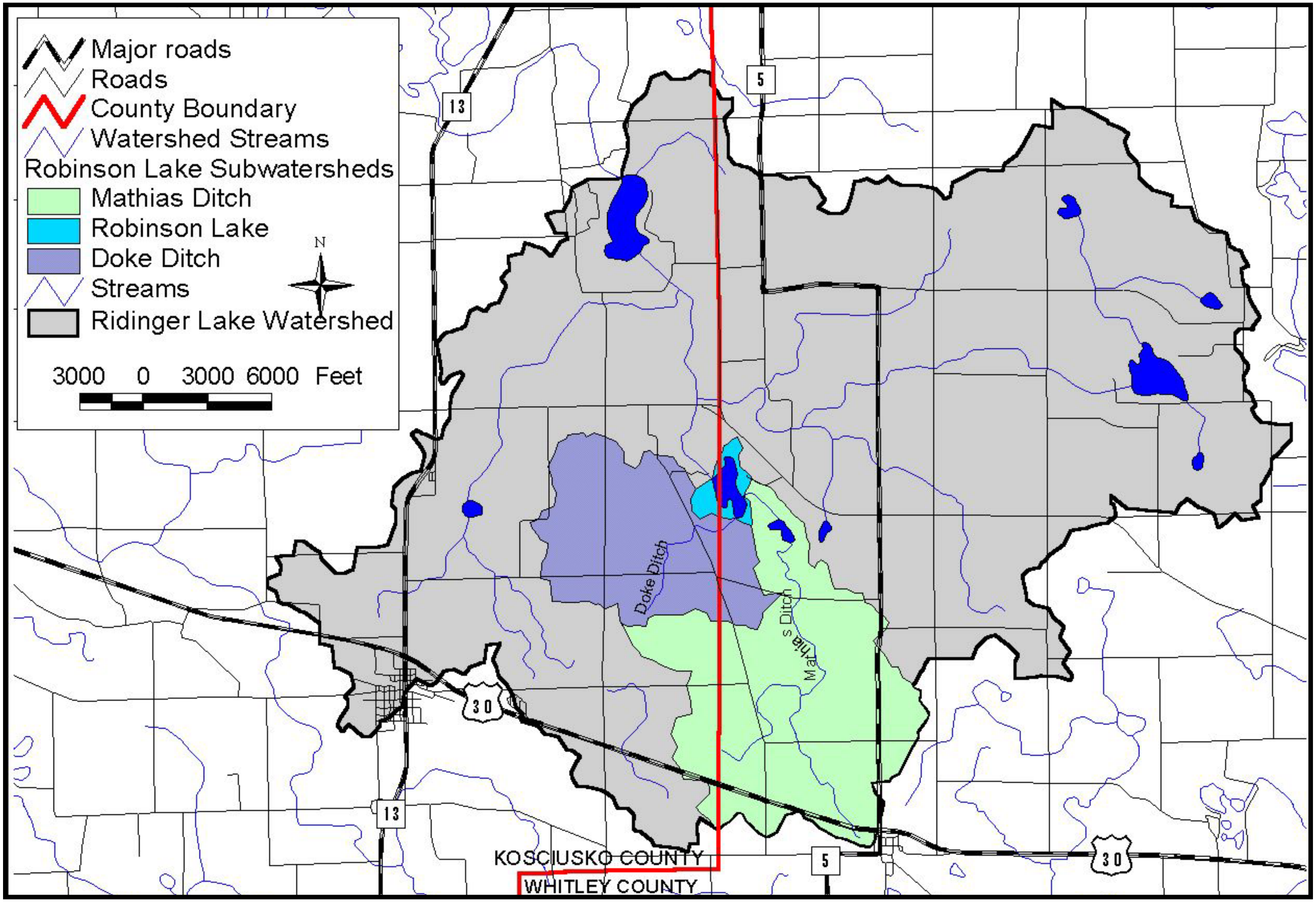


Figure 5. Robinson Lake subwatersheds.
Source: See GIS sources appendix (Appendix A). Scale: 1”=7,000’.

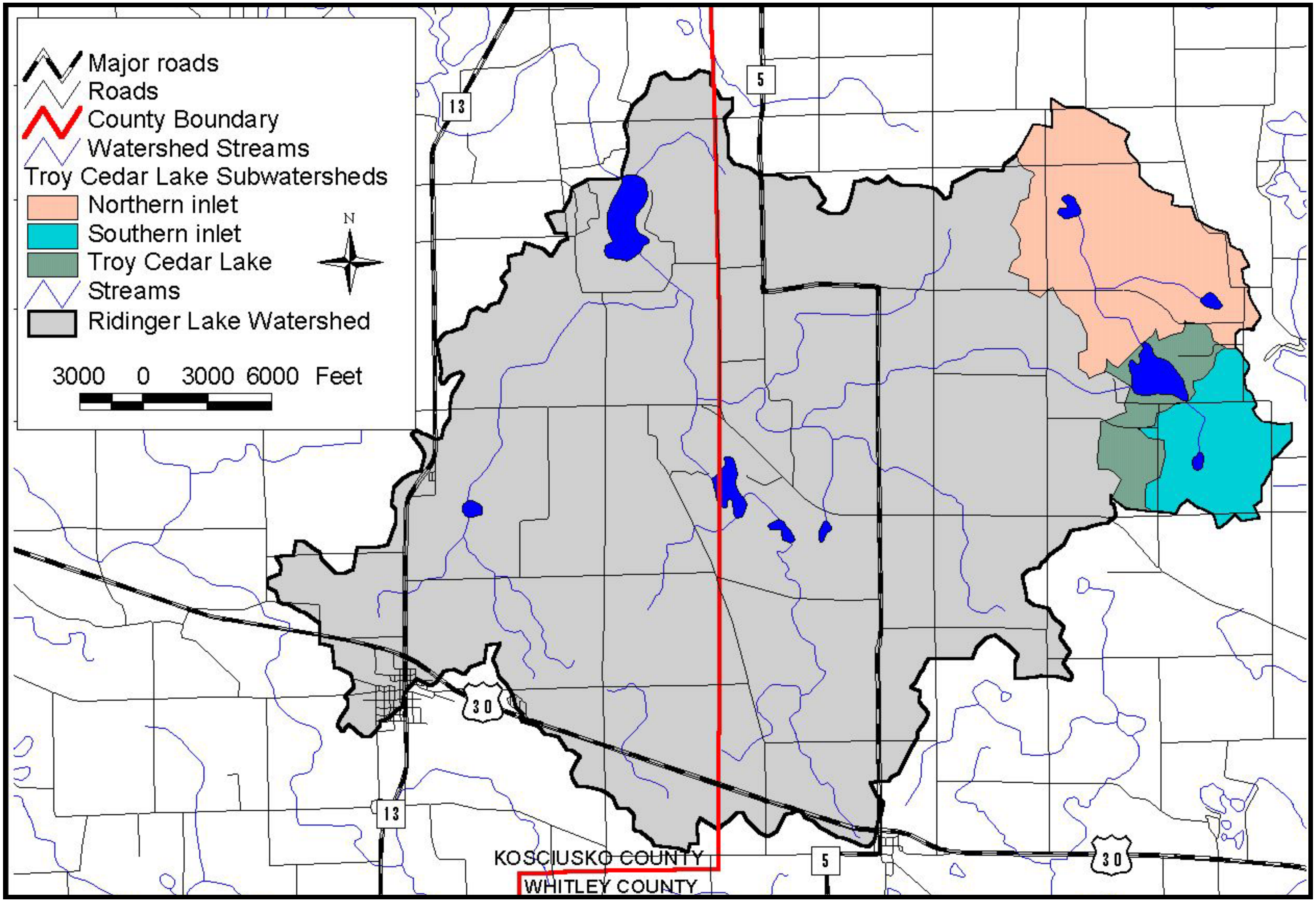


Figure 6. Troy Cedar Lake subwatersheds.
Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

2.1.3 Troy Cedar Lake

Two unnamed drainages transport water from Troy Cedar Lake's watershed to the lake. Troy Cedar Lake's northern inlet is the larger of the two streams. The northern inlet drains 1,880 acres (761 ha) from the north of Troy Cedar Lake (Figures 6; Table 3). The southern inlet drains most of the land from the south and east of the lake. Approximately 530 acres (215 ha) of land drains directly from the watershed into Troy Cedar Lake. In total, Troy Cedar Lake receives drainage from approximately 3,147 acres (1,274 ha). Troy Cedar Lake's watershed area to lake area ratio is the lowest of the three lakes at 35:1. This ratio is relatively high for a glacial lake.

Table 3. Watershed and subwatershed sizes for the Troy Cedar Lake watershed.

Subwatershed	Area (acres)	Area (hectares)	Percent of Watershed
Northern inlet	1,880	761	60%
Southern inlet	736	298	23%
Area adjacent to Troy Cedar Lake	531	215	17%
Total Watershed	3,147	1,274	100%
Watershed to Lake Area Ratio	35:1		

2.2 Climate

Indiana Climate

Indiana's climate can be described as temperate with cold winters and warm summers. The National Climatic Data Center summarizes Indiana weather well in its 1976 Climatology of the United States document no. 60: "Imposed on the well known daily and seasonal temperature fluctuations are changes occurring every few days as surges of polar air move southward or tropical air moves northward. These changes are more frequent and pronounced in the winter than in the summer. A winter may be unusually cold or a summer cool if the influence of polar air is persistent. Similarly, a summer may be unusually warm or a winter mild if air of tropical origin predominates. The action between these two air masses of contrasting temperature, humidity, and density fosters the development of low-pressure centers that move generally eastward and frequently pass over or close to the state, resulting in abundant rainfall. These systems are least active in midsummer and during this season frequently pass north of Indiana" (National Climatic Data Center, 1976). Prevailing winds in Indiana are generally from the southwest but are more persistent and blow from a northerly direction during the winter months.

Ridinger Lake Watershed Climate

The climate of the Ridinger, Robinson, Troy Cedar Lakes watershed is characterized as having four well-defined seasons of the year. Winter temperatures average 26º F (-3.3º C), while summers are warm, with temperatures averaging 70º F (21.1º C). The growing season typically begins in early April and ends in September. Yearly annual rainfall averages 38.52 inches (97.8 cm). Winter snowfall averages about 30 inches (76.2 cm). During summers, relative humidity varies from about 60 percent in mid-afternoon to near 80 percent at dawn. Prevailing winds typically blow from the southwest except during the winter when westerly and northwesterly winds predominate. In 2003, almost 45 inches (114 cm) of precipitation (Table 4) was recorded at Columbia City in Whitley County. When compared with 30-year average for the area, the 2003 annual rainfall exceeded the average by more than six inches (1.5 cm).

Table 4. Monthly rainfall data (in inches) for year 2003 as compared to average monthly rainfall. All data was recorded at Columbia City in Whitley County. Averages are 30-year normals based on available weather observations taken during the years of 1971-2000 at Columbia City (Purdue Applied Meteorology Group, 2004).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2003	0.57	1.04	2.33	2.49	6.78	2.72	8.79	8.06	4.28	2.21	2.82	2.65	**44.74**
Average	2.12	1.80	2.90	3.67	3.70	4.44	3.82	3.58	3.52	2.80	3.31	2.86	**38.52**

2.3 Geology

The advance and retreat of the glaciers in the last ice age (the Wisconsin Age) shaped much of the landscape found in Indiana today. As the glaciers moved, they laid thick till material over the northern two thirds of the state. Ground moraine left by the glaciers covers much of the central portion of the state. In the northern portion of the state, ground moraines, end moraines, lake plains, and outwash plains create a more geologically diverse landscape compared to the central portion of the state. End moraines, formed by the layering of till material when the rate of glacial retreat equaled the rate of glacial advance, add topographical relief to the landscape. Distinct glacial lobes, such as the Michigan Lobe, Saginaw Lobe, and the Erie Lobe, left several large, distinct end moraines, including the Valparaiso Moraine, the Maxinkuckee Moraine, and the Packerton Moraine, scattered throughout the northern portion of the state. Glacial drift and ground moraines cover flatter, lower elevation terrain in northern Indiana. Major rivers in northern Indiana cut through sand and gravel outwash plains. These outwash plains formed as the glacial meltwaters flowed from retreating glaciers, depositing sand and gravel along the meltwater edges. Lake plains, characterized by silt and clay deposition, are present where lakes existed during the glacial age.

The movement and stagnation of the Saginaw Lobe of the Wisconsin glacial age shaped much of the Ridinger Lake watershed, although the influence of the Erie Lobe can be seen on the watershed's landscape as well. The Saginaw glacial lobe moved out of Canada to the south carrying a mixture of Canadian bedrock with it. The Packerton Moraine, an end moraine which forms the southern boundary of the Ridinger Lake watershed, marks the edge of the Saginaw Lobe's advance into Indiana. The Packerton Moraine extends northeasterly along the eastern edge of the Ridinger Lake watershed. Along the watershed's eastern boundary, however, the Packerton Moraine blends together with the Mississinewa and Salamonie Moraines, which mark stagnation points of the Erie Lobe that originated from the east. Fragments of the Packerton Moraine are scattered along the Ridinger Lake watershed's northeastern edge. These fragments form a ridge separating the Grassy Creek basin from the upper part of the Tippecanoe River basin. (Figure 3 shows the areas of greater relief (in orange and tan) associated with the Packerton Moraine along the watershed's southern boundary, the relief associated with the interlobate region, where the Packerton Moraine meets the Mississinewa and Salamonie Moraines, along the watershed's eastern edge, and the relief associated with the fragments of the Packerton Moraine along the watershed's northeastern edge.)

The geology and resulting physiography of the Ridinger Lake watershed typify the physiographic region in which the watershed lies. The Ridinger Lake watershed lies within Malott's Steuben Morainal Lake Area. Schneider (1966) notes that the landforms common in this diverse physiographic region include till knobs and ice-contact sand and gravel kames, kettle holes and lakes, meltwater channels lined with outwash deposits or organic sediment, valley trains, outwash plains, and small lacustrine plains. Many of these landforms are visible on the Ridinger Lake watershed landscape. Troy Cedar Lake is a good example of a deep (relative to many lakes in the region) kettle lake lying in an end moraine. Its part of the "knob and kettle" topography that is characteristic of end moraines. The flat area north of Troy Cedar Lake likely demarcates the extent of the original waterbody that covered Troy Cedar Lake and the area to the north of the lake many years ago. This waterbody has been reduced to only Troy Cedar Lake. As will be discussed in the next section, Houghton muck, a common soil type of aged lakes, is the dominant soil type in this area, lending evidence to the idea that this area was once part of a larger lake. Till knobs and kames occur along the watershed's northeastern edge. Many other reminders of the watershed's geologic history exist.

The bedrock underlying the watershed's surficial geology includes rock from three different periods. Antrim shale underlies the northwestern portion of the Ridinger Lake watershed. This bedrock shale is from the Devonian-Mississippian Period. Older Muscatatuck rocks, likely limestone, from the Devonian Period lie under a central band stretching from east to west across the watershed. Bedrock found in the southern portion of the watershed consists of rock from the still older Silurian Period (Gutschick, 1966).

2.4 Soils

The Ridinger Lake watershed's geological history described in the previous section determined the soil types found in the watershed and is reflected in the eight major soil associations that cover the Ridinger Lake watershed (Figure 7). The watershed's soils show the influence of both the Erie Lobe and the Saginaw Lobe of the last Wisconsin period. Because the Erie Lobe originated from the east and scoured historical Lake Maumee, the Erie Lobe left glacial till with a high clay content. In contrast, the Saginaw Lobe moved from the north toward the south, leaving sandier till material that is more characteristic of Canadian bedrock. The Erie Lobe left the Mississinewa and Salamonie Moraines, the remains of which border the western edge of the Ridinger Lake watershed. Consequently, soils with relatively high clay content, such as Morley soils, are common in western portion of the Ridinger Lake watershed. The Packerton Moraine, left by the Saginaw Lobe, forms the southern edge of the watershed. Sandier soils, such as Riddles, Wawasee, and Miami, cover the southeastern and eastern portion of the watershed.

Before detailing the major soil associations covering the Ridinger Lake watershed, it may be useful to examine the concept of soil associations. Major soil associations are determined at the county level. Soil scientists review the soils, relief, and drainage patterns on the county landscape to identify distinct proportional groupings of soil units. The review process typically results in the identification of eight to fifteen distinct patterns of soil units. These patterns are the major soil associations in the county. Each soil association typically consists of two or three soil units that dominate the area covered by the soil association and several soil units that occupy only a small portion of the soil association's landscape. Soil associations are named for their dominant components. For example, the Riddles-Wawasee association consists primarily of Riddles fine sandy loam and Wawasee fine sandy loam.

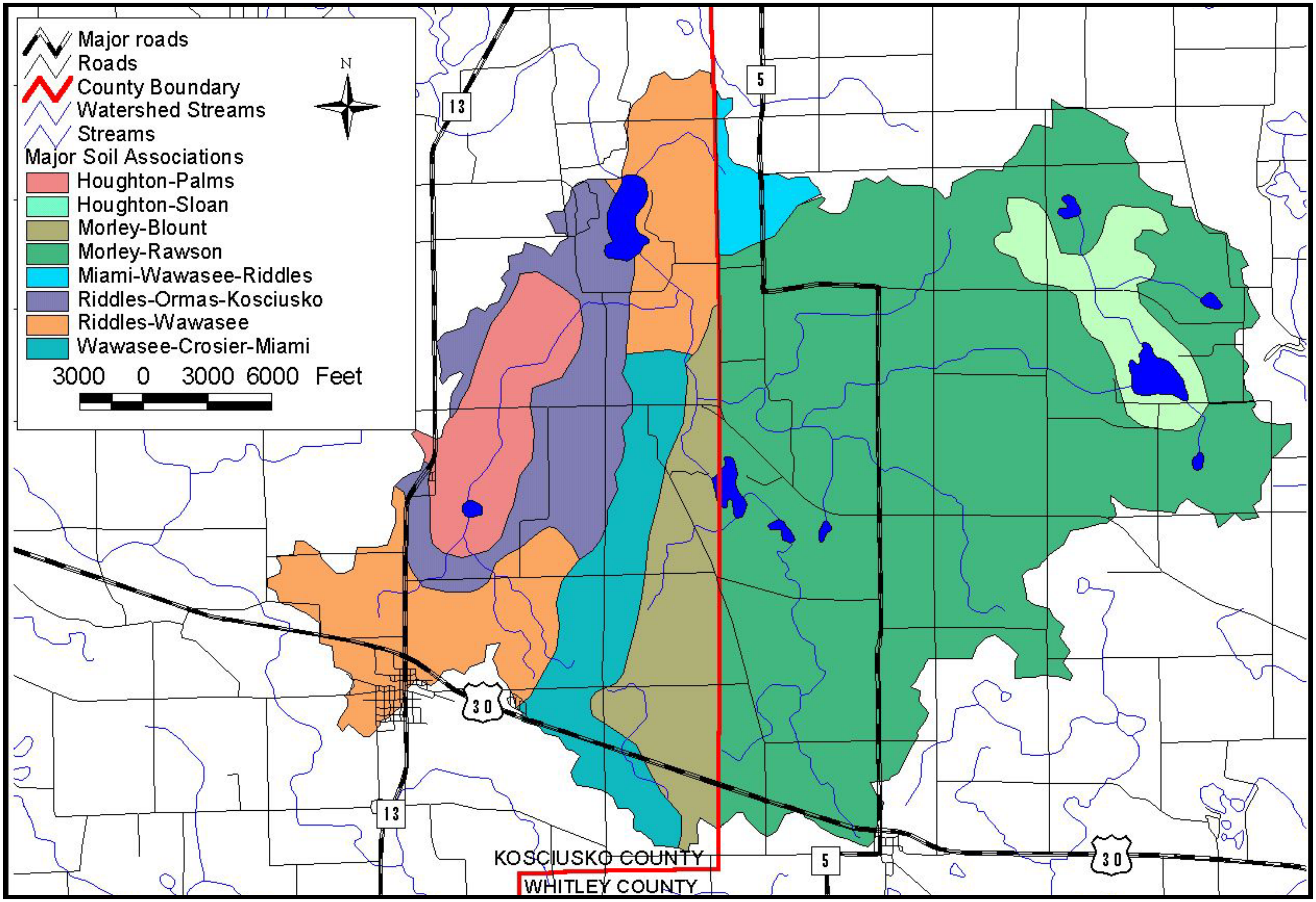


Figure 7. The major soil associations covering the Ridinger Lake watershed.
Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Because soil scientists developed soil association maps at different times, soil associations in one county are not always consistent with soil associations in an adjacent county. Ruesch (1990) points to three reasons for the differences observed in soil association maps published at different times: 1. changes in the concepts of soil series occur; 2. variations in the extent of the soils occur; and 3. variations in the slope range allowed in the association occur. Differences between county soil association maps can be the result of one or more of these reasons.

The Kosciusko County and Whitley County soil association maps were published at different times. The Kosciusko County Soil Survey (Staley, 1989) was issued in 1989, while the Whitley County Soil Survey (Ruesch, 1990) was published one year later. Consequently, soil associations in these counties do not agree with one another. Because the Ridinger Lake watershed encompasses part of both counties, the soil associations covering the watershed end abruptly at the county line (Figure 7).

Despite the fact that several of the major soil associations of the Ridinger Lake watershed end abruptly at the Kosciusko County/Whitley County line, adjacent soil associations are somewhat similar in composition. In Kosciusko County, the Morley-Blount soil association lies along most of the western edge of the Kosciusko County/Whitley County line. The Morley-Rawson soil association lies directly east of the Morley-Blount soil association on the Whitley County side of the Ridinger Lake watershed. Morley soils dominate both of these soil associations, accounting for 45-57% of each association. The other major component of each of these soil associations accounts for no more than 15% of the association. In essence, the dominance of Morley soils spreads across the two counties, covering much of the Elder Ditch subwatershed. Similarly, the Riddles-Wawasee soil association covers the landscape immediately west of the Kosciusko County/Whitley County line, while the Miami-Wawasee-Riddles association lies directly east of the Riddles-Wawasee soil association on the Whitely County side of the line. Wawasee and Riddles soils account for 57-63% of each association. Essentially, the dominance of Wawasee and Riddles soils spreads across the two counties in the north central portion of the watershed.

Eight major soil associations cover the Ridinger Lake watershed (Figure 7). Five of these associations, Morley-Blount, Riddles-Ormas-Kosciusko, Riddles-Wawasee, Wawasee-Crosier-Miami, and Houghton-Palms, lie within the Kosciusko County portion of the Ridinger Lake watershed. The Riddles-Wawasee soil association covers the largest portion of the Ridinger Lake watershed within Kosciusko County. This association is the second most common soil association found in Kosciusko County covering approximately 10% of the county landscape. Generally, all of the remaining soil associations are equally proportioned throughout Kosciusko County portion of the watershed. The Wawasee-Miami-Crosier association is the most common soil association found in Kosciusko County covering approximately 28% of the county landscape. The other three associations are less common in Kosciusko County. Morley-Blount, Riddles-Ormas-Kosciusko, and Houghton-Palms soil associations cover approximately 4%, 6%, and 9%, respectively (Staley, 1989). The following discussion on soil associations in the Kosciusko County portion of the Ridinger Lake watershed relies heavily on the *Soil Survey of Kosciusko County* (Staley, 1989). Readers should refer to this source for a more detailed discussion of soil associations covering Kosciusko County.

The Riddles-Wawasee soil association covers the northeastern portion of the watershed within Kosciusko County (from adjacent to Ridinger Lake to the Kosciusko County line) and the southwestern tip of the watershed including the town of Pierceton and the headwaters of Shanton Ditch. This soil association exists along broad ridges, on knobs, and in depressional areas that are dominated by small lakes and ponds. This soil association consists largely of Riddles (44%) and Wawasee (19%) soils. Both soils possess fine sandy loam surface layers that overlay fine sandy loam, sandy clay loam, and loam subsoil. Minor components of this association include Barry loam, Griswold loam, Martinsville sandy loam, Rensselaer loam, and Whitaker loam soils. Erosion is a concern with this soil association in sloping areas. Like many of the soil associations in the Ridinger Lake watershed, the Riddles-Wawasee association is moderately limited for septic system usage.

The Riddles-Ormas-Kosciusko association is relatively uncommon in Kosciusko County, covering only 6% of the county. This association is found in the western portion of the Ridinger Lake watershed adjacent to and southwest of Ridinger Lake. Well drained soils with moderately well defined surface drainage patterns characterize this soil association. Soils in this association are typically found on knobs, ridges, and in deep depressional areas. Riddles soils comprise 31% of the association, while Ormas soils and Kosciusko soils comprise 25% and 24%, respectively. Riddles soils are found on the tops of ridges and on the highest points across the landscape. Surface layers of Riddles soils are fine sandy loams with even finer textured (loams and clay loams) soils below the surface layer. Ormas soils are typically found at lower elevations on south and east facing slopes. Ormas soils consist of loamy sand over loamy sand and sand substratum. Kosciusko soils are found on lower elevation ridge tops than Riddles soils and on north and west facing slopes. Kosciusko soils consist of a sandy loam surface layer over gravelly sandy clay loam and gravelly loamy sand. Minor components in the Riddles-Ormas-Kosciusko association include Boyer loamy sand, Brady sandy loam, Gilford sandy loam, and Houghton muck soils. Producers should consider the erosion potential of this soil association when cultivating crops on sloped land in this soil association. Riddles soils are moderately limited for septic system development due to permeability, while poor filtering capacity limits Ormas and Kosciusko soils.

The Houghton-Palms soil association covers the area south of Rhine Lake and surrounds most of the Shanton Ditch mainstem. This soil association exists in a depressional area near the western edge of the watershed. Very poorly drained, nearly level muck soils dominate the Houghton-Palms association. These soils developed from partially decaying organic matter that accumulated in depressional areas of the county. In general, Houghton soils account for 46% of the soils in the association, while Palms soils comprise 16% of the association. Minor components of the association include Gilford mucky sandy loam, Sebewa mucky loam, Edwards muck, and Histosols and Aquolls. Houghton soils are deep with the black muck extending to a depth of 51 inches (129.5 cm) or more. Palms soils contain layers of muck, sandy clay loam, and loam with gravelly coarse sand substrate. When drained, soils in this association may be utilized for agriculture; however, undrained soils in the Houghton-Palms association often hold water and serve best as wetland habitat. Soils in this association typically have severe limitations for use as septic system absorption fields.

Wawasee-Crosier-Miami soil association lies generally along the ridge separating the Shanton Ditch subwatershed from the Elder Ditch and Mathias Ditch subwatersheds. Wawasee soils comprise 30% of the soil association, while Crosier and Miami soils account for 26% and 24% of the association, respectively. Wawasee soils occur in well-drained, gently to strongly sloped areas along ridge tops and side slopes. Fine sandy loam, loam, and sandy clay loam soils overlay fine sandy loam substrate. Crosier soils are poorly drained soils found at lower elevations on the landscape below Wawasee soils. Well drained Miami soils occur on knobs and low ridges and in swells. Both soils possess loam and/or clay loam textured surface and subsurface layers which overlay loam layers. Aubbennaubbee sandy loam, Barry loam, Metea loamy sand, Rensselaer loam, Riddles fine sandy loam, and Washtenaw silt loam soils are minor components of the Wawasee-Crosier-Miami soil association. Like many of the other soils in the Ridinger Lake watershed, erosion is a concern on sloped areas. Wetness and slow percolation severely limit the use of Crosier soils as septic system leach fields. Slope and slow percolation moderately to severely limit Wawasee and Miami soils for use as septic system leach fields.

The Morley-Blount soil association covers the central portion of the watershed immediately west of the Kosciusko County/Whitley County line, including a large portion of the Doke Ditch subwatershed. Soils in the Morley-Blount association range for well drained to somewhat poorly drained and are found on nearly level to steeply sloping landscapes. Soils in this soil association typically cover clay loam glacial till, reflecting the influence of the Erie Lobe on this portion of the Ridinger Lake watershed. Morley and Blount soils comprise approximately 72% of the soil association. Morley soils lie on ridges, swells, and the side slopes of deeply incised drainageways, while Blount soils occupy lower elevation slopes and drainages. Minor soil units in the association include Metea loamy sand, Martinsville sandy loam, and Pewamo silty clay loam. Erosion is a problem on Morley soils, and, in general, the soils in this association are severely limited for use as a septic tank absorption field due to wetness, slow permeability, and slope.

Three major soil associations, Morley-Rawson, Houghton-Sloan, and Miami-Wawasee-Riddles, cover the Whitley County portion of the Ridinger Lake watershed. Soils in the northwestern corner of the Whitley County portion of the watershed belong to the Miami-Wawasee-Riddles soil association, while the Houghton-Sloan soil association surrounds Troy Cedar Lake and extends northward from Troy Cedar Lake toward Scott Lake. The Morley-Rawson soil association covers the remaining portion of the Ridinger Lake watershed which lies within Whitley County. The following discussion on soil associations in the Whitley County portion of the Ridinger Lake watershed relies heavily on the *Soil Survey of Whitley County* (Ruesch, 1990). Readers should refer to this source for a more detailed discussion of soil associations covering Whitley County.

The Morley-Rawson soil association covers nearly all of the Whitley County portion of the Ridinger Lake watershed. Like the soils in the Morley-Blount soil association in the Kosciusko County portion of the Ridinger Lake watershed, soils in the Morley-Rawson soil association reflect of geological heterogeneity of the landscape. Ruesch (1990) notes that “the association is on hills and ridges and in ravines and depressions.” These soils developed in glacial till and loamy outwash over glacial till. Fine textured silty clay loam and clay loam glacial till underlies much of this association. Morley soils comprise the dominant portion (45%) of the soil association. Morley soils are well drained and located on gentle to steep slopes. Surface layers of Morley soils are loamy to clay loam in texture, while the subsoil has a clayey and clay loam texture. Rawson soils account for 13% of the Morley-Rawson soil association. They are similar in texture to Morley soils but have more sand in them than Morley soils. Minor soil units in the Morley-Rawson soil association include Blount silt loam, Coesse silty clay loam, Glynwood loam and clay loam, Haskins loam, Houghton muck, Muskego muck, Pewamo silty clay loam, and Seward loamy fine sand soils. Generally, the minor components of the soil association are less well drained than the major components. Erosion is a concern in the Morley-Rawson soil association, and slope, permeability, and wetness severely limit the use of soils in this association to serve as a septic tank absorption field.

The Miami-Wawasee-Riddles association covers a small part of the northern tip of the Ridinger Lake watershed. Soils in the Miami-Wawasee-Riddles association are well drained and are found on gently to moderately steep slopes. Miami, Wawasee, and Riddles soils comprise nearly 70% of the soil association. The major soils in the soil association typically have sandy loam or clay loam surface layers that overlay loam and clay loam subsoil. Minor soil units in the association include Boyer sandy loam, Brookston loam, Coesse silty clay, Houghton muck, Martinsville loam, Rensselaer loam, Seward loamy fine sand, and Spinks sand. Erosion is a problem in steeply sloped areas. Miami soils are severely limited for use as a septic tank absorption field, while the other two major soils are only moderately limited.

Soils in the Houghton-Sloan association surround Troy Cedar Lake and extend north from the lake toward Scott Lake. This soil association exists in low areas and along old glacial lakebeds and sloughs. Very poorly drained, nearly level muck soils dominate the Houghton-Sloan association. In general, Houghton and Sloan soils account for 60% of the total soils in the association. Minor soils, including Boyer sandy loam and loamy sand, Mermill loam, Sebewa loam, and Shoals silt loam, account for the remaining 40% of the association. When drained, soils in this association may be used for agriculture; however, undrained soils in the Houghton-Sloan association often hold water and serve best as wetland habitat. Houghton soils have severe limitation for use as a septic absorption field due to ponding, low soil strength, and high organic matter content, while Sloan soils are severely limited for septic absorption field use due to wetness and flooding.

Soils in the watershed, and in particular their ability to erode or sustain certain land use practices, can impact the water quality of lakes and streams in the watershed. The dominance of Riddles, Morley, Miami, and Wawasee soils across the Ridinger Lake watershed suggests much of the watershed is prone to erosion; common erosion control methods should be implemented when the land is used for agriculture or during residential development to protect waterbodies in the Ridinger Lake watershed. Similarly, very poorly drained soils in the Houghton-Palms and Houghton-Sloan associations cover the areas adjacent to some of the watershed's lakes and streams. Areas immediately adjacent to Ridinger and Troy Cedar Lakes are most likely to be developed for residential use, or could be in the future. Given the distance of these areas from towns or cities with sewer systems, these areas are most likely one in which septic systems will be used to treat residential waste. The coupling of high density residential land use with soils that are poorly suited for treating septic tank effluent is of concern for water quality in the Ridinger Lake watershed. More detailed discussion of highly erodible soils and soils used to treat septic tank effluent in the Ridinger Lake watershed follows below.

2.4.1 Highly Erodible Soils

Soils that erode from the landscape are transported to waterways where they degrade water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals, like some herbicides and pesticides, can kill aquatic life and damage water quality.

Highly erodible and potentially highly erodible are classifications used by the Natural Resources Conservation Service (NRCS) to describe the potential of certain soil units to erode from the landscape. The NRCS examines common soil characteristics such as slope and soil texture when classifying soils. The NRCS maintains a list of highly erodible soil units for each county. Table 5 lists the soil units in the Ridinger Lake watershed that the NRCS considers to be highly erodible. Table 5 can be cross referenced with the county soil surveys to locate highly erodible soils on the Ridinger Lake watershed landscape.

Table 5. Highly erodible and potential highly erodible soils units in Kosciusko and Whitley Counties.

County	Soil Unit	Status	Soil Name	Soil Description
Kosciusko	KoB-KoC	PHES	Kosciusko sandy loam	0-6% slopes
Kosciusko	KoE	HES	Kosciusko sandy loam	18-30% slopes
Kosciusko	KtA	HES	Kosciusko silt loam	0-2% slopes
Kosciusko	MaB-MaC	PHES	Martinsville sandy loam	2-12% slopes
Kosciusko	MbC	PHES	Metea loamy sand	0-2% slopes
Kosciusko	MeC	PHES	Metea loamy fine sand	6-12% slopes
Kosciusko	MlB-MlC	PHES	Miami loam	2-12% slopes
Kosciusko	MrC3-MrD3	HES	Miami clay loam	6-18% slopes, severely eroded
Kosciusko	MsB	PHES	Miami-Owosso-Metea complex	2-8% slopes
Kosciusko	MsD	HES	Miami-Owosso-Metea complex	10-25% slopes
Kosciusko	MvC	HES	Morley loam	6-12% slopes
Kosciusko	MxC3-MxD3	HES	Morley silty clay loam	5-25% slopes, severely eroded
Kosciusko	MzB	PHES	Morley-Glynwood complex	1-4% slopes
Kosciusko	OrC	PHES	Ormas loamy sand	6-12% slopes
Kosciusko	OtC	PHES	Ormas loamy sand, sandy substratum	6-12% slopes
Kosciusko	Pg	PHES	Gravel pits	
Kosciusko	RlB-RlC	PHES	Riddles fine sandy loam	2-12% slopes
Kosciusko	RlD	HES	Riddles fine sandy loam	12-18% slopes
Kosciusko	RxB-RxC	PHES	Riddles-Ormas-Kosciusko complex	2-12% slopes
Kosciusko	ShB	PHES	Shipshe sandy loam	2-6% slopes
Kosciusko	Ud	PHES	Udorthents	
Kosciusko	WlB	PHES	Wawasee fine sandy loam	2-6% slopes
Kosciusko	W1C2	PHES	Wawasee fine sandy loam	6-12% slopes, eroded
Kosciusko	WlD2	HES	Wawasee fine sandy loam	12-18% slopes, eroded
Whitley	BmB2	PHES	Blount silt loam	1-4% slopes, eroded
Whitley	BvC	PHES	Boyer loamy sand	2-6% slopes
Whitley	BvD	HES	Boyer loamy sand	6-12% slopes
Whitley	BwA-BwC	PHES	Boyer sandy loam	0-12% slopes
Whitley	Fu	PHES	Fulton silty clay loam	
Whitley	GsB2	PHES	Glynwood loam	3-6% slopes, eroded

County	Soil Unit	Status	Soil Name	Soil Description
Whitley	GsB3	HES	Glynwood clay loam	3-8% slopes, severely eroded
Whitley	HbA	HES	Haskins loam	0-3% slopes
Whitley	KaA	PHES	Kalamazoo sandy loam	0-2% slopes
Whitley	MbB-MbC	PHES	Martinsville loam	1-15% slopes
Whitley	MmB2-MmC2	PHES	Miami sandy loam	2-12% slopes
Whitley	MvB2	PHES	Morley loam	3-6% slopes, eroded
Whitley	MxC3	PHES	Morley clay loam	5-12% slopes, severely eroded
Whitley	RcB-RcC	PHES	Rawson sandy loam	2-12% slopes
Whitley	RhB-RhC	PHES	Riddles sandy loam	1-12% slopes
Whitley	SfC	PHES	Seward loamy fine sand	6-15% slopes
Whitley	SpC	PHES	Spinks sand	6-15% slopes
Whitley	WmC	PHES	Wawasee sandy loam	6-15% slopes
Whitley	Wt	PHES	Whitaker loam	

* PHES=Potentially highly erodible soil; HES=Highly erodible soil
Source: 1988 USDA/SCS Indiana Technical Guide Section II-C for Kosciusko County; 1988 USDA/SCS Indiana Technical Guide Section II-C for Whitley County.

Highly erodible and potentially highly erodible soil units cover much of the Ridinger Lake watershed. Morley, Miami, Riddles, and Wawasee soils cover much of the watershed. Areas of the watershed that are mapped in these soil units and have gentle slopes are still considered moderately limited for agricultural production. As slope increases, the severity of the limitation increases. Some steeply sloped Morley and Miami soils are considered unsuitable for agricultural production due to the erosion hazard. The erosion hazard likely also applies to residential development on these soils.

Several studies have quantified the amount of highly and potentially highly erodible soils covering at least a portion of the Ridinger Lake watershed landscape. Mapping work completed as part of Purdue University's Upper Tippecanoe River Hydrologic Unit Area Project shows that the majority of the highly erodible and potentially highly erodible soils lie in eastern portion of the Tippecanoe River's headwaters, which includes the Ridinger Lake watershed. Specifically, work done under this project show highly and potentially highly erodible soils dominate the southern and central portions of the watershed, west of Troy Cedar Lake and east of Shanton Ditch. In his work on lakes in Kosciusko County, Hippensteel (1989) estimated that highly erodible soils cover 29.1% of the Shanton Ditch subwatershed. He also found that approximately 35% of the Grassy Creek watershed, of which the Ridinger Lake composes a large portion, is mapped in highly erodible soils. Based on the *Soil Survey of Kosciusko County, Soil Survey of Whitley County*, and the previous studies of the watershed, it is likely that highly erodible soils cover 30-35% of the Ridinger Lake watershed.

2.4.2 Soils used for septic tank absorption fields

Nearly half of Indiana's population lives in residences having private waste disposal systems. As is common in many areas of Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatment around Ridinger, Robinson, and Troy Cedar Lakes and other lakes in the Ridinger Lake watershed. (The Jellystone Park on the northwest side of Ridinger Lake has its own waste treatment operation rather than utilizing individual septic systems at each residential/camp lot.) This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent to levels that protect surface and groundwater from contamination. The soil's ability to sequester and degrade pollutants in septic tank effluent will ultimately determine how well surface and groundwater is protected.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent (waste discharge) depends on four factors: the amount of accessible soil particle surface area; the chemical properties of the surfaces; soil conditions like temperature, moisture, and oxygen content; and the types of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand, and therefore, a greater potential for chemical activity. However, soil surfaces only play a role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water closing the larger pores in the profile. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel rapidly through the soil profile. Soils located on sloped land also may have difficulty in treating wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations of positive charge to their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses, and some organic compounds.

Environmental soil conditions influence the microorganism community which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition process (and therefore, effluent treatment) becomes less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as oxygen is present. Pathogens can be both retained and inactivated within the soil as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater, and therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may adsorb bacteria and viruses, but retention is not necessarily permanent. During storm flows, bacteria and viruses may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with the natural soil microorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

Taking into account the various factors described above, the NRCS has ranked 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: slightly limited, moderately limited, or severely limited. Use of septic absorption fields in moderately or severely limited soils generally requires special design, planning, and/or maintenance to overcome the limitations and ensure proper function.

While all septic system use in the Ridinger Lake watershed has the potential to impact the water quality of the lakes, the ability of the soil immediately adjacent to Ridinger Lake to treat septic effluent has a more direct effect on Ridinger Lake's water quality than the ability of the soil in other areas of the watershed. Likewise, the soils directly adjacent to Robinson Lake have a more direct effect on Robinson Lake than the soils in other areas of the watershed, while the soils adjacent to Troy Cedar Lake more directly affect Troy Cedar Lake's water quality. Therefore, the following discussion focuses on the soils adjacent to Ridinger, Robinson, and Troy Cedar Lakes, respectively.

Ridinger Lake
Figure 8 shows the soil units surrounding Ridinger Lake, while Table 6 summarizes the soils' suitability for use as septic tank absorption fields. Following Table 6 is a short description of the soils listed in the table.

Figure 8. Soil series bordering Ridinger Lake.
Source: Staley, 1989. Scale: 1"=1,667'

Table 6. Soil types adjacent to Ridinger Lake and their suitability to serve as a septic tank absorption field.

Symbol	Name	Depth to High Water Table	Suitability for Septic Tank Absorption Field
Ao	Aquents-Urban land complex	--	--
Ed	Edwards muck	+1.0-0.5 ft	Severe: ponding, percs slowly
Gf	Gilford sandy loam	+0.5-1.0 ft	Severe: ponding, poor filter
He	Histosols and Aquolls	--	--
KoB	Kosciusko sandy loam	>6.0 ft	Severe: poor filter
KoE	Kosciusko sandy loam	>6.0 ft	Severe: poor filter, slope
MaB-MaC	Martinsville sandy loam	>6.0 ft	Slight
OrB	Ormas loamy sand	>6.0 ft	Severe: poor filter
Pb	Palms muck	+1.0-1.0 ft	Severe: subsidence, ponding
Re	Rensselaer loam	+0.5-1.0 ft	Severe: ponding

Source: Staley, 1989.

Aquents-Urban land complex, rarely flooded (Ao) typically occurs on the edges of lakes, where marshes have been filled with soil material. This unit is rarely flooded, except for brief periods by stream or lake overflow. In many areas, it is ponded by runoff from the higher adjacent soils. The physical characteristics of the Aquents are highly variable, and suitability for use depends on the thickness and texture of the fill, depth to the seasonal high water table, and the nature of the underlying material. Because of the flooding, the soils are generally unsuitable as sites for buildings and septic tank absorption fields. Under current Indiana regulations, it is illegal to place septic systems in these soils. Much of the eastern shoreline of Ridinger Lake is mapped in this soil unit.

The Histosols and Aquolls (He) are very poorly drained soils frequently ponded by runoff from the higher adjacent soils or by lake or stream overflow. The water table is typically near or above the surface most of the year, which makes these soils generally unsuitable for septic tank absorption fields.

Edwards muck (Ed) and Palms muck (Pb) soils are poorly drained, organic soils found in depressional areas and on outwash plains. Typically, these soils are located adjacent to lakes and streams. Shallow water generally covers them for some portion of the year. Staley (1989) characterizes these soils as optimal for wildlife habitat but poor for all other uses. These soils are absolutely unsuitable for sanitary facilities due to ponding and permeability issues. Because these soils generally occupy some of the lowest points on the landscape, pumping systems are necessary for adequate drainage.

Rensselaer loam (Re) and Gilford sandy loam (Gf) are very poorly drained soils. They are found in slight depressions on broad outwash plains and terraces, along small drainageways, and in depressions on till plains, terraces, and outwash plains. Because of the ponding, these soils are unsuitable for septic tank absorption fields.

Martinsville sandy loam (MaB-MaC) soils are slightly limited for usage in treating septic adsorption fields. These moderately permeable soils are often found on the edges of outwash plains and terraces. These soils lie along a portion of Ridinger Lake's western shoreline and some houses exist on these soils.

The remaining soil types are all severely limited for septic system usage. Rapid permeability impairs ability of the remaining three soil types found adjacent to Ridinger Lake to serve as septic absorption fields. Kosciusko sandy loam (KoB, KoE) is a well-drained soil. Permeability is moderate in the subsoil and very rapid in the underlying material. Ormas loamy sand (OrB) is a well-drained soil. Permeability rates are rapid to moderately rapid in the subsoil and very rapid in the underlying material. Due to the rapid permeability of these three soil types, they do not provide adequate filtering capability for septic tank absorption fields and may cause pollution of the ground water.

The Jellystone Park campground, which is located on the eastern shoreline, is sited on soils that are severely limited for septic tank absorption fields. However, the park operates and maintains an individual wastewater treatment facility during their peak business season, May to October. In order to treat the park's wastewater, the facility utilizes a contact stabilization treatment technique followed by chlorination. The effluent is then passed through a sand filter (IST, 1989). The facility is permitted to discharge 76,000 gallons of treated wastewater downstream of Ridinger Lake. The facility's permits include concentration and load requirements for dissolved oxygen, total suspended solids, and ammonia-nitrogen. No permit violations were recorded for the facility from September 2001 though October 2003 (USEPA, 2004).

Robinson Lake

Figure 9 shows the soil units surrounding Robinson Lake, while Table 7 summarizes the soils' suitability for use as septic tank absorption fields. Following Table 7 is a short description of the soils listed in the table.

Table 7. Soil types adjacent to Robinson Lake and their suitability to serve as a septic tank absorption field.

Symbol	Name	Depth to High Water Table	Suitability for Septic Tank Absorption Field
HeG	Hennepin loam	>6.0 ft	Severe: wetness, percs slowly
Md	Martisco muck	+1.0-1.0 ft	Severe: flooding, ponding, percs slowly
MvC; MvC2	Morley loam	>6.0 ft	Severe: percs slowly
MvD2	Morley loam	>6.0 ft	Severe: percs slowly, slope
Pe	Pewamo muck	+1.0-1.0 ft	Severe: percs slowly, ponding
So	Sloan loam	0-1.0 ft	Severe: flooding, wetness, percs slowly
Wc	Wallkill silty clay loam	+1.0-1.0 ft	Severe: ponding, percs slowly

Source: Staley, 1989; Ruesch, 1990.

Figure 9. Soil series bordering Robinson Lake.
Source: Staley, 1989; Ruesch, 1990. Scale: 1”=1,320’

Hennepin loam (HeG) soils are very poorly drained soils. They are found in slight depressions on broad outwash plains and terraces, along small drainageways, and in depressions on till plains, terraces, and outwash plains. Because of the ponding, these soils are unsuitable for septic tank absorption fields.

Martisco muck (Md) soils are nearly level, very poorly drained soils found in broad depressions on outwash plains and around lakes. These soils are frequently ponded by runoff and/or by lake overflow. The available water capacity is very high and runoff is very slow or ponded. The water table is near or above the surface most of the year. Because of the ponding, these soils are unsuitable for septic tank absorption fields.

Like Martisco muck, Pewamo silty clay loam (Pe) and Sloan loam (So) soils are nearly level, very poorly drained soils. These soils are found in depressions and other low-lying areas. Ponding, flooding, and wetness make these soils unsuitable for use a septic tank absorption fields.

Morley loam (MvC, MvC2-MvD2) soils are found on gently to strongly sloping hillsides of uplands. Fluid movement through the soil type is moderately slow. The slow permeability and wetness generally inhibit complete waste treatment. The slow permeability of Morley soils is a result of soil formation and aging processes. When Morley silt loams are located along steep slopes, slope can also pose problems for proper septic field function.

Wallkill silty clay loam (Wc) soils formed in wetlands, and because they typically occupy depressional areas, shallow water generally covers them at some time during the year. The water table is typically near the soil surface in winter and spring months. Proper septic system function in Wallkill silt loam soils is severely limited because the soil tends to remain wet and does not readily absorb liquid waste.

As shown in Table 7, all of the soils surrounding Robinson Lake are severely limited in their use as a septic tank absorption field. Currently, no residences exist along the shoreline. If the shoreline becomes developed, then residents should take extra care in septic leach field placement and sizing. However, because the Robinson Lake shoreline remains undeveloped, septic system leaching does not impact water quality in Robinson Lake at this time.

Troy Cedar Lake

Figure 10 shows the soil units surrounding Troy Cedar Lake, while Table 8 summarizes the soils' suitability for use as septic tank absorption fields. Following Table 8 is a short description of the soils listed in the table.

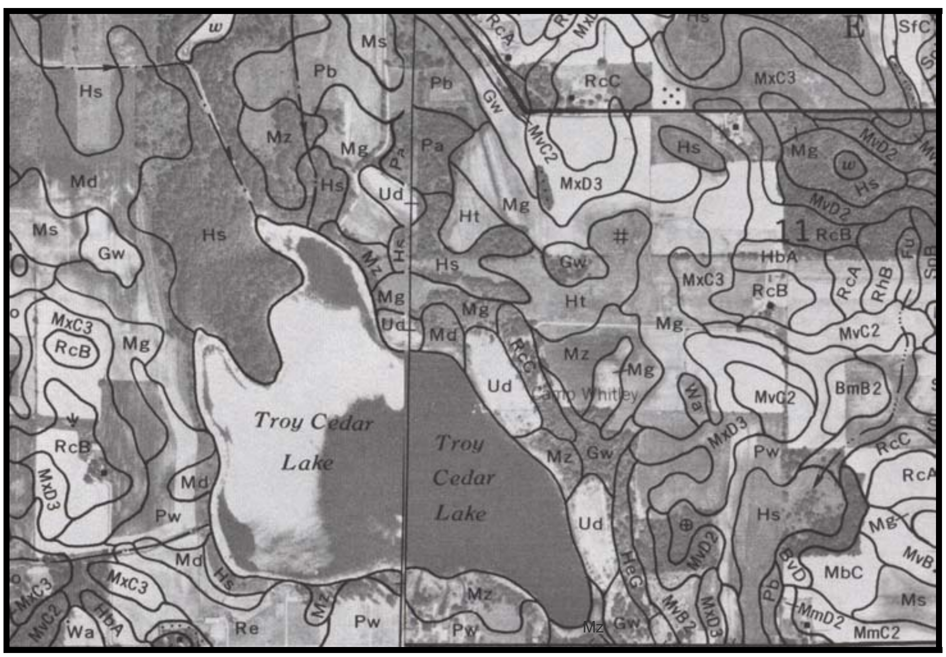


Figure 10. Soil series bordering Troy Cedar Lake.
Source: Ruesch, 1990. Scale: 1"=1,320'

Table 8. Soil types adjacent to Troy Cedar Lake and their suitability to serve as a septic tank absorption field.

Symbol	Name	Depth to High Water Table	Suitability for Septic Tank Absorption Field
Hs	Houghton muck	+1.0-1.0 ft	Severe: subsidence, ponding, percs slowly
Md	Martisco muck	+1.0-1.0 ft	Severe: flooding, ponding, percs slowly
Mg	Mermill loam	+1.0-1.0 ft	Severe: ponding, percs slowly
Mz	Muskego muck	+1.0-1.0 ft	Severe: ponding, percs slowly
Pw	Pewamo silty clay loam	+1.0-1.0 ft	Severe: ponding, percs slowly
Re	Rensselaer loam	+0.5-1.0 ft	Severe: ponding
Ud	Udorthents	--	--

Source: Ruesch, 1990

Houghton muck (Hs), Martisco muck (Md), and Muskego muck (Mz) soils are nearly level, very poorly drained soils found in broad depressions on outwash plains and around lakes. These soils are frequently ponded by runoff and/or by lake overflow. The availability water capacity is very high and runoff is very slow or ponded. The water table is near or above the surface most of the year. For these reasons, these soils are unsuitable for septic tank absorption fields.

Mermill loam (Mg), Rensselaer loam (Re), and Pewamo silty clay loam (Pw) soils are also very poorly drained soils. They are found in slight depressions on broad outwash plains and terraces, along small drainageways, and in depressions on till plains, terraces, and outwash plains. Because of the ponding, these soils are unsuitable for septic tank absorption fields.

The suitability of Udorthents (Ud) for septic tanks varies among locales. Udorthents are moderate to strongly sloping, well-drained soil typically found in disturbed areas. Septic suitability limitations can include restricted permeability, wetness, and steep slopes.

As shown in Table 8, all of the soils surrounding Troy Cedar Lake are severely limited in their use as a septic tank absorption field. Currently, most of the residences exist along the southeastern and southern shorelines where soils are mapped as Udorthents (Ud), Martisco loam (Md), Mermill loam (Mg), Muskego muck (Mz), Rensselaer loam (Re), and Pewamo silty clay loam (Pw). Septic fields placed in these soils typically require larger leach fields to overcome the ponding and slow permeability of these soils. Unfortunately enlarging the existing septic leach fields or creating new leach fields if sufficient room exists may be too costly. At a minimum, residents in existing homes should take steps to properly care for their septic systems such as pumping their septic tanks annually, avoiding the disposal of household chemicals that may kill soil bacteria, and implementing water conservation measures to alleviate strain on the system.

2.5 Land Use

The Ridinger Lake watershed is located in the central portion of the Northern Lakes Natural Region (Homoya et al., 1985). Prior to European settlement, the Northern Lakes Natural Region was a mixture of numerous natural community types including bog, fen, marsh, prairie, sedge meadow, swamp, seep spring, lake and deciduous forest (Homoya et al., 1985). Many of these natural community types undoubtedly covered the Ridinger Lake watershed. Most of the watershed was likely forested. Oak-hickory forest composed of red oak, white oak, shagbark hickory, and pignut hickory likely occupied the dry to dry-mesic uplands in the watershed. More mesic areas in the Ridinger Lake watershed probably harbored beech, sugar maple, black maple, and tulip poplar. Soil types and topography suggest swamps covered much of the area along Shanton Ditch and along Elder Ditch near its confluence with Shanton Ditch. Common dominants in these swamps may have been American elm, black ash, green ash, silver maple, and red maple.

2.5.1 Ridinger Lake

Land use across the Ridinger Lake watershed has changed over the past two centuries. Figure 11 and Table 9 present current land use information for the Ridinger Lake watershed. (Appendix B provides the land use data for each of Ridinger Lake's subwatersheds.) Land use data from the U.S. Geological Survey (USGS) forms the basis of Figure 11. In the Indiana Land Cover Data Set, the USGS defines high intensity residential areas as areas with high densities of multi-family residences (apartment complexes, condominiums, etc.). Hardscape covers approximately 80-100% of the landscape in the high intensity residential land use category. Low intensity residential areas consist largely of single family homes; hardscape covers only 30-80% of the landscape.

Table 9. Detailed land use in the Ridinger Lake watershed.

Land Use	Area (acres)	Area (hectares)	Percent of Watershed
Row crop agriculture	14,683.8	5,944.9	66.2%
Pasture/hay	3,394.1	1,374.1	15.3%
Deciduous forest	2,632.5	1,065.8	11.9%
Woody wetlands	691.9	280.1	3.1%
Open water	398.1	161.2	1.8%
High intensity commercial	221.5	89.7	1.0%
Emergent herbaceous wetlands	119.9	48.5	0.5%
Low Intensity residential	19.9	8.1	0.1%
High intensity residential	10.7	4.3	<0.1%
Evergreen forest	6.9	2.8	<0.1%
Mixed forest	1.1	0.4	<0.1%
Total	**22,180.4**	**8,979.9**	**100%**

Agricultural land use dominates the Ridinger Lake watershed. Row crop agriculture covers 66% of the watershed, while pasture or hay vegetate an additional 15% of the watershed. Most of the agricultural land in the Ridinger Lake watershed is used for growing corn and soybeans. County wide tillage transect data for Kosciusko and Whitley Counties provides an estimate for the portion of cropland in conservation tillage for the Ridinger Lake watershed. (The following data is for 2003 and was obtained from the Purdue University/IDNR Soil and Water Quality Program web site (Purdue University and IDNR, no date).) In Kosciusko County, corn producers utilized no-till methods on 28% and some form of reduced tillage methods on 42% of corn fields. The percentage of corn fields on which no-till methods were used in Kosciusko County was above the statewide median percentage. Producers in Whitley County utilized no-till methods on 22% and some form of reduced tillage methods on 43% of corn fields. Usage of no-till methods on corn fields in Whitley County was below the statewide median percentage of acreage in no-till. Kosciusko County soybean producers used no-till methods on 62% of soybean fields and some form of reduced tillage method on 31% of soybean fields in production. Soybean producers in Whitley County utilized no-till methods on nearly 80% and some form of reduced tillage methods on 15% of the soybean fields in production. Whitley and Kosciusko Counties ranked 8th and 28th, respectively, in the state for use of conservation tillage on soybean fields.

Land uses, other than agricultural, occupy less than 20% of the watershed. Natural landscapes including forested areas and wetlands account for approximately 16% of the watershed. Large tracts of natural areas surround Robinson and Rhine Lakes. A large wetland/forest complex borders the southern edge of Scott Lake as well. Other large forested tracts are located along the Mathias Ditch, Shanton Ditch, and Elder Ditch tributary stream corridors (Figure 11). Open water, including Ridinger, Robinson, Rhine, Troy Cedar, Mud, and Scott Lakes, accounts for another 2% of the watershed. The remainder of the watershed is classified as low or high intensity residential or high intensity commercial land use. High intensity commercial areas occupy approximately 1% of the watershed. Most of the commercial areas within the watershed are located along the U.S. Highway 30 corridor in the southern and southwestern portions of the watershed. Low and high intensity residential areas cover less than 1% of the Ridinger Lake watershed. Most of the residential areas are located along the U.S. 30 corridor within the towns of Pierceton and Larwill. The Yogi Bear Campground on the northwest shore of Ridinger Lake is an additional tract of concentrated residential land.

Land use in the Ridinger Lake watershed is similar to land use across the region. The Ridinger Lake watershed supports a slightly higher percentage of land in agricultural use (81%) compared to the Upper Tippecanoe River watershed (76%) (TELWF, 2002). (The Upper Tippecanoe River watershed is the area of land draining to the Lake Oswego outlet.) The percentage of land in agricultural use in the Ridinger Lake watershed is also higher than the percentage for Kosciusko County (70%), and Whitley County (77%) (U.S. Census of Agriculture, 1999). Despite the fact that a greater percentage of Ridinger Lake watershed is used for agricultural purposes, the watershed has a higher percentage of forested land (16%) compared to entire Upper Tippecanoe River watershed (11.6%). Wetlands cover a smaller percent of the Ridinger Lake watershed (3.6%) than the Upper Tippecanoe River watershed (5%).

2.5.2 Robinson Lake

Agricultural land use dominates the Robinson Lake watershed landscape (Table 10). Row crop agriculture covers approximately 70% of the watershed, while pasture or hay accounts for nearly 12% (Figure 11). Land use other than agriculture accounts for the remaining 18% of the watershed. Natural landscapes, including forested areas and wetlands, account for approximately 12% and 4% of the watershed, respectively. Most of these natural areas surround Robinson Lake and the Mathias Ditch corridor. Open water, primarily Robinson Lake, covers 2% of the watershed. A negligible area (<1%) of the Robinson Lake watershed is utilized for residential and commercial uses. (Appendix B divides land use for the Robinson Lake watershed by subwatershed.)

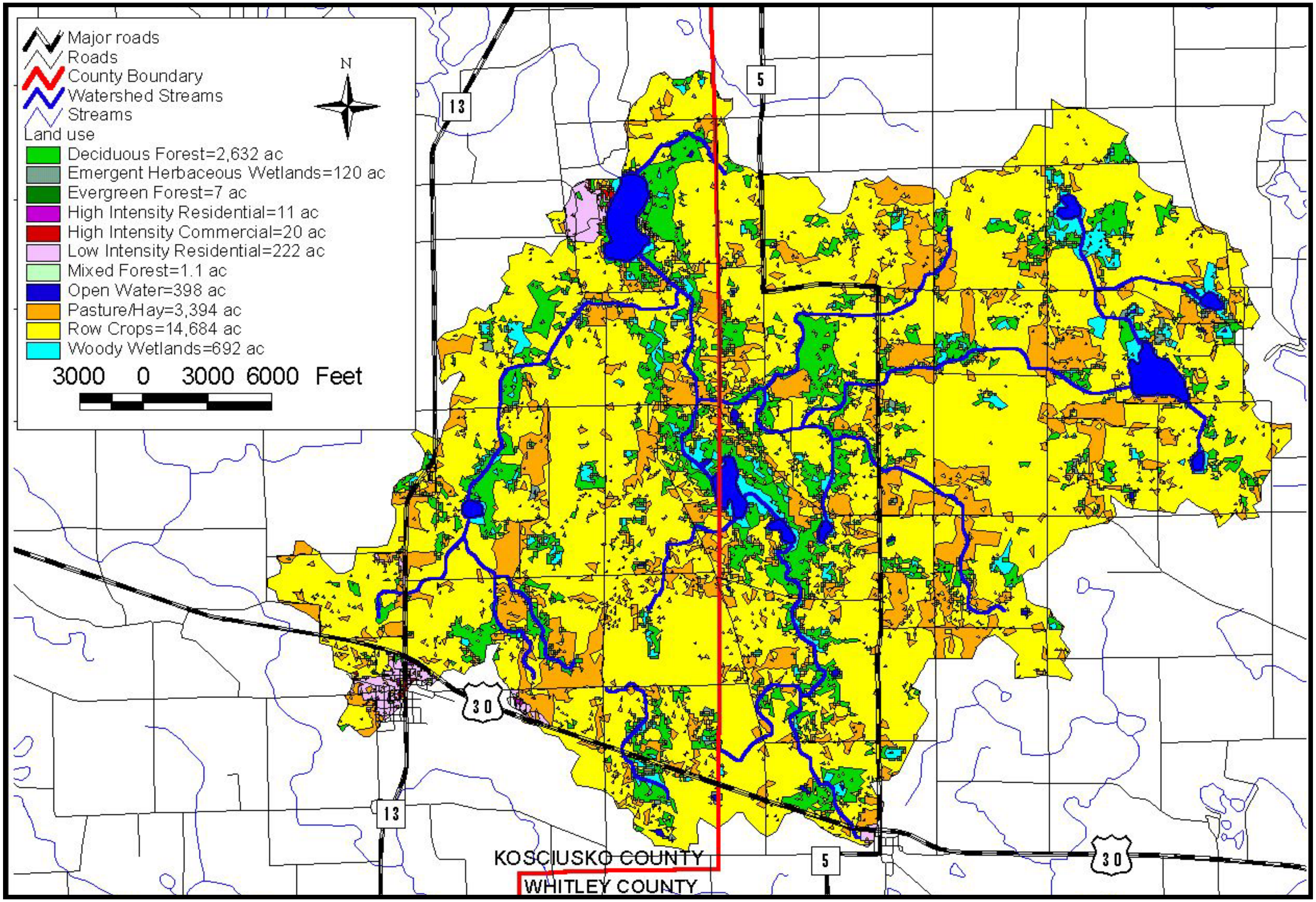


Figure 11. Land use in the Ridinger Lake watershed.
Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Table 10. Detailed land use in the Robinson Lake watershed.

Land Use	Area (acres)	Area (hectares)	Percent of Watershed
Row Crops	3,084.7	1248.9	70.2%
Deciduous Forest	537.0	217.4	12.2%
Pasture/Hay	506.8	205.2	11.5%
Woody Wetlands	159.0	64.4	3.6%
Open Water	80.6	32.6	1.8%
Emergent Herbaceous Wetlands	15.2	6.2	0.3%
Low Intensity Residential	9.9	4.0	0.2%
Evergreen Forest	0.7	0.3	<0.1%
Mixed Forest	0.2	0.1	<0.1%
High Intensity Commercial	0.2	0.1	<0.1%
Total	**4,394.3**	**1779.1**	**100.0%**

2.5.3 Troy Cedar Lake

Agricultural land use also dominates the Troy Cedar Lake watershed (Table 11). Row crop agriculture covers nearly 70% of the watershed, while pasture or hay accounts for an additional 10%. Land use other than agriculture accounts for the remaining 20% of the watershed. Natural landscapes including forested areas and wetlands account for approximately 9% and 7% of the watershed, respectively. Open water, mainly Troy Cedar, Little Troy Cedar, Scott and Mud Lakes, covers another 4% of the watershed. Commercial and high intensity land uses do not exist with the Troy Cedar Lake watershed. Low intensity residential land use is limited to the area immediately adjacent to Troy Cedar Lake. (Appendix B divides land use for the Troy Cedar Lake watershed by subwatershed.)

Table 11. Detailed land use in the Troy Cedar Lake watershed.

Land Use	Area (acres)	Area (hectares)	Percent of Watershed
Row Crops	2174.2	880.3	69.1%
Pasture/Hay	311.6	126.1	9.9%
Deciduous Forest	272.8	110.4	8.7%
Woody Wetlands	215.5	87.2	6.8%
Open Water	138.9	56.2	4.4%
Emergent Herbaceous Wetlands	32.2	13.0	1.0%
Low Intensity Residential	1.7	0.7	0.1%
Evergreen Forest	0.7	0.3	<0.1%
Total	**3147.4**	**1274.2**	**100.0%**

2.6 Wetlands

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. By performing these roles, healthy, functioning wetlands often improve the water quality and biological health of streams and lakes located downstream of the wetlands.

The United States Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) Map (Figure 11) shows that wetlands cover approximately 10% of the Ridinger Lake watershed. (Table 12 presents the acreage of wetlands by type according to the National Wetland Inventory.) Largest contiguous tract of wetland habitat surround Robinson, Mud, Scott, and Troy Cedar Lakes. The remaining wetland habitat is scattered throughout the watershed.

Table 12. Acreage and classification of wetland habitat in the Ridinger Lake watershed.

Wetland Type	Area (acres)	Area (hectares)	Percent of Watershed
Forested	806.3	326.4	3.6%
Herbaceous	721.7	292.2	3.3%
Lake	285.5	115.6	1.3%
Shrubland	140.1	56.7	0.6%
Pond	125.6	50.8	0.6%
River	5.0	2.0	0.0%
Total	**2,084.3**	**843.8**	**9.4%**

Source: National Wetlands Inventory.

The USFWS NWI data differs in its estimate of wetland habitat acreage in the watershed from the USGS data presented in Table 12 and Figure 11. The USGS Land Cover Data Set suggests that wetlands cover approximately 3.7% of the Ridinger Lake watershed and open water covers an additional 1.8% of the watershed (Table 9). The primary difference between the two data sets is the acreage of emergent wetland. The USFWS reports over 700 acres of emergent wetland habitat exists in the Ridinger Lake watershed compared to just over 100 acres of emergent wetland habitat reported by the USGS. The differences in reported wetland acreage in the Ridinger Lake watershed reflect the differences in project goals and methodology used by the different agencies to collect land use data.

The IDNR estimates that approximately 85% of the state's wetlands have been filled (IDNR, 1996). The greatest loss has occurred in the northern counties of the state such as Noble and Whitley Counties. The last glacial retreat in these northern counties left level landscapes dotted with wetland and lake complexes. Development of the land in these counties for agricultural purposes altered much of the natural hydrology, eliminating many of the wetlands. The 1978 Census of Agriculture found that drainage is artificially enhanced on 38% and 45% of the land in Kosciusko and Whitley Counties, respectively (cited in Hudak, 1995). Shoreline development around lakes has also significantly reduced wetland acreage.

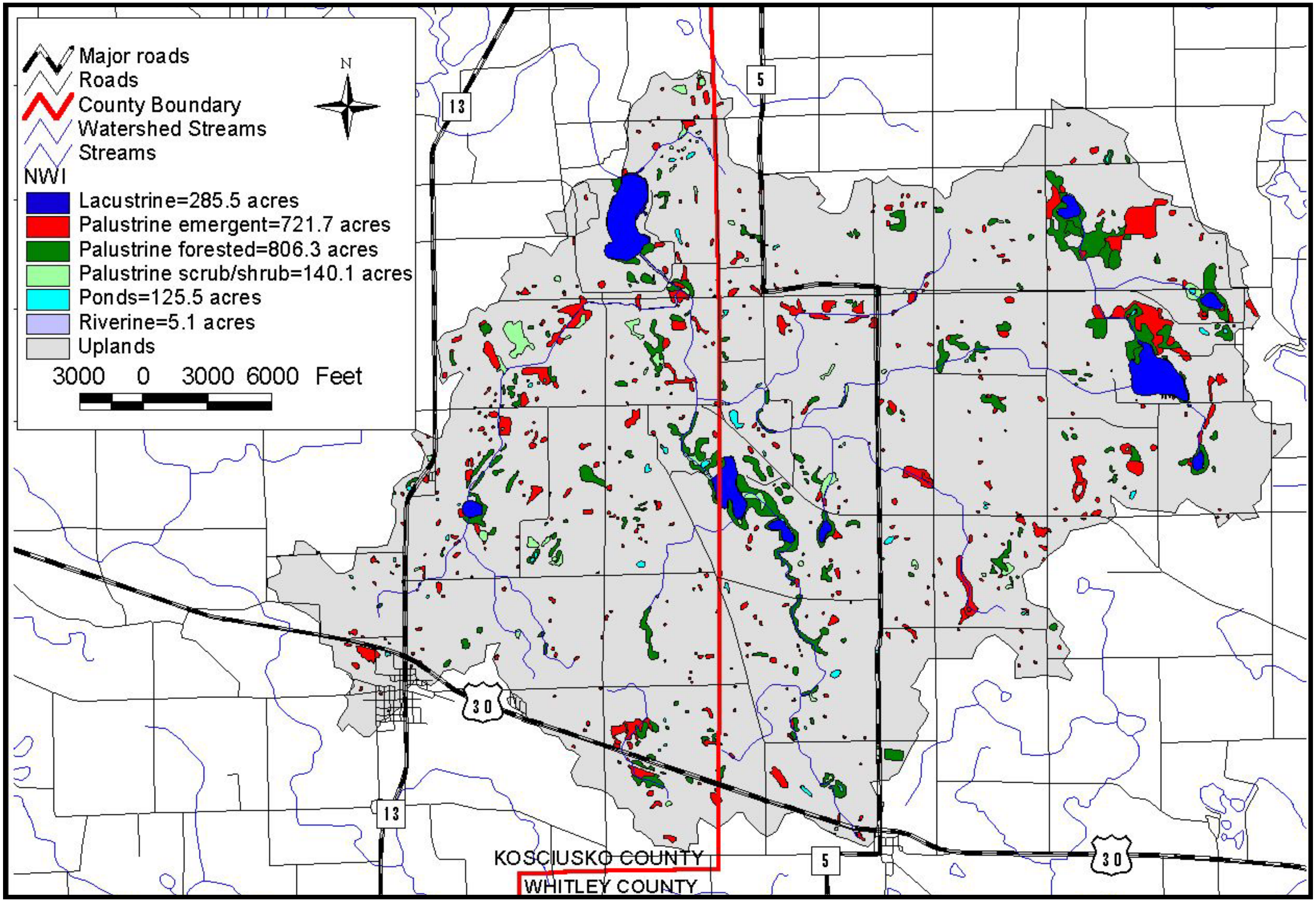


Figure 11. Wetlands in the Ridinger Lake watershed.
Source: See GIS sources appendix (Appendix A). Scale: 1”=7,000’.

2.7 Endangered, Threatened, and Rare Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species; high quality natural communities; and natural areas in Indiana. The Indiana Department of Natural Resources developed the database to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the IDNR. Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee that the listed species is present or that the listed area is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed in a specific location.

Appendix C presents the results from the database search for the Ridinger Lake watershed. (For additional reference, Appendix D provides a listing of endangered, threatened, and rare species (ETR) documented in Kosciusko and Whitley Counties.) The habitat within the watershed supports one state endangered animal species, the bobcat (*Lynx rufus*), and one species of interest, the great blue heron (*Ardea herodias*). The database locates both animal species along the northeast side of Robinson Lake near the Kosciusko County/Whitley County line. The database indicates that both the bobcat and the great blue heron observations were recent, occurring in 1990. The database also records the presence of two state endangered plants: nuttall pondweed (*Potamogeton epihydrus*) and foxtail sedge (*Carex alopecoidea*). Nuttall pondweed was last observed in Ridinger Lake in 1962 according to the database. Recent surveys by the IDNR Division of Fish and Wildlife and JFNew have not found this species there. The database notes that foxtail sedge was found near Robinson Lake in 1985. (The ETR list in Appendix D includes additional species; however these species sightings actually occurred outside of the Ridinger Lake watershed boundaries.)

3.0 STREAM ASSESSMENT

3.1 Stream Assessment Methods

3.1.1 Water Chemistry

Water samples were collected and analyzed for various parameters from seven streams in the Ridinger Lake watershed (Table 13 and Figure 13). The LARE sampling protocol requires assessing the water quality of each designated stream site once during base flow and once during storm flow. This is because water quality characteristics change markedly between these two flow regimes. A storm flow sample will be influenced by runoff from the landscape and usually contains higher concentrations of soil and soil-associated nutrients. A base flow sample represents the ‘usual’ water characteristics of the stream. Storm flow samples were collected on May 1, 2003, following 1-2 inches (2.5-5 cm) of rain. (The National Weather Service office in North Webster, Indiana reported 2.16 inches of rain on April 30, 2003.) Base flow samples were collected on August 6, 2003 following a period of little precipitation.

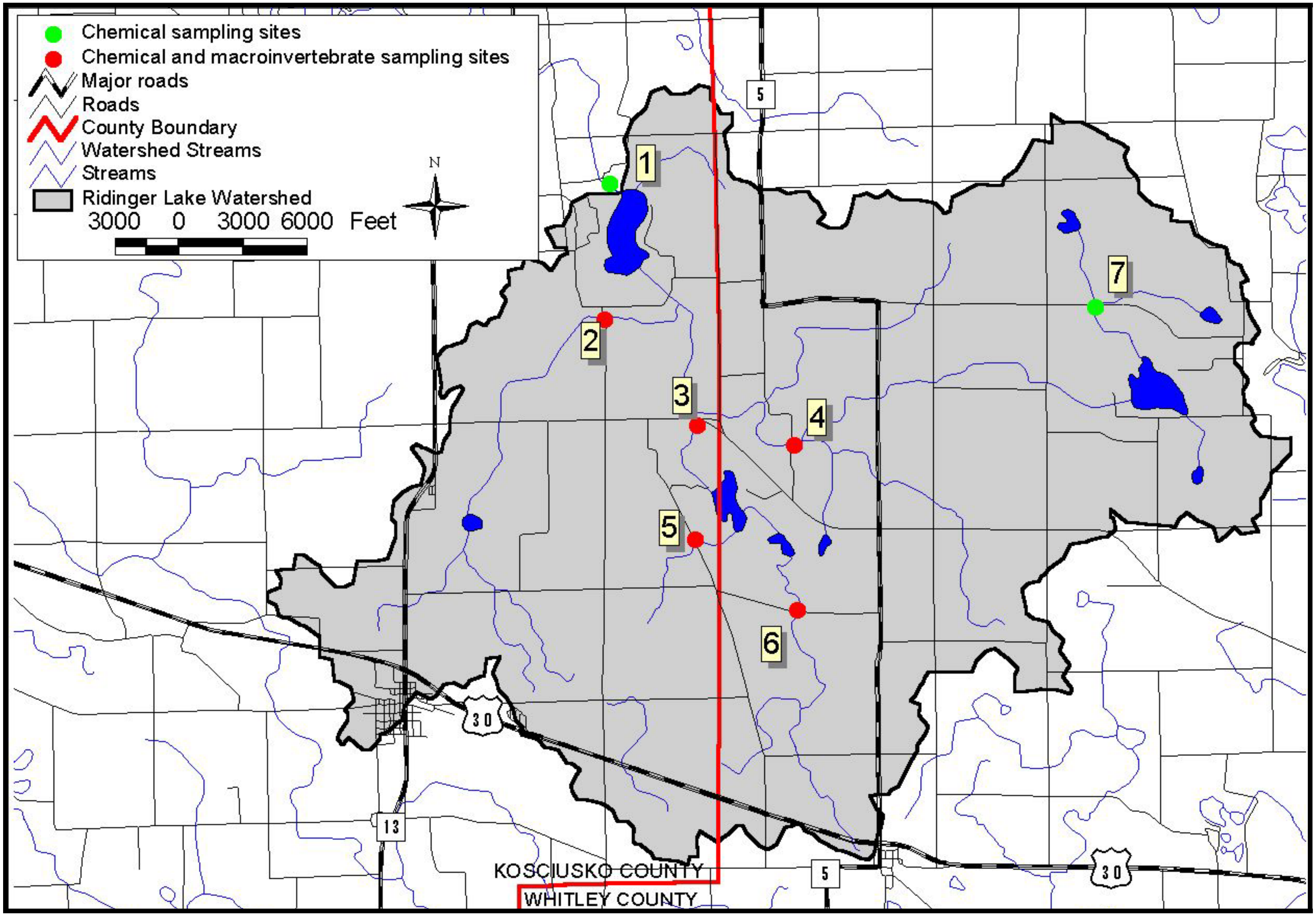


Figure 13. Stream sampling sites.
Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Table 13. Location of stream sampling sites.

Site No.	Stream Name	Sampling Location	Latitude	Longitude
1	Ridinger Lake outlet	Ridinger Lake outlet	41^o 16.230’	85^o 40.146’
2	Shanton Ditch	County Road 900 East	41^o 14.575’	85^o 40.148’
3	Robinson Lake outlet	Old Highway 30	41^o 14.003’	85^o 28.213’
4	Elder Ditch	Elder Road	41^o 14.099’	85^o 39.194’
5	Doke Ditch	Robinson Lake Road	41^o 13.150’	85^o 39.215’
6	Mathias Ditch	County Road 325 North	41^o 59.270’	87^o 17.189’
7	Delano Ditch	County Road 600 North	41^o 15.004’	85^o 35.148’

Stream water chemistry samples were analyzed for pH, alkalinity, conductivity, total phosphorus, soluble reactive phosphorus, nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, organic nitrogen, total suspended solids, turbidity, and *E. coli* bacteria. Conductivity, temperature, and dissolved oxygen were measured *in situ* at each stream site with an YSI Model 85 meter. Stream water velocity was measured using a Marsh-McBirney Flo-Mate current meter. The cross-sectional area of the stream channel at each site was measured and discharge calculated by multiplying water velocity by the cross-sectional areas.

All water samples were placed in the appropriate bottle (with preservative if needed) and stored in an ice chest until analysis at Indiana University School of Public and Environmental Affair’s (SPEA) laboratory in Bloomington. Soluble reactive phosphorus samples were filtered in the field through a Whatman GF-C filter. The *E. coli* bacteria samples were taken to EIS Analytical Laboratory in South Bend, Indiana for analysis. 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).

The following is a brief description of the parameters analyzed during the stream 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 oxygen dissolved 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 streams. For example, temperatures during the month of May should not exceed 80 ^oF (23.7 ^oC) by more than 3 ^oF (1.7 ^oC). Temperatures during the summer months should not exceed 90 ^oF (32.2 ^oC).

Dissolved Oxygen (D.O). D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 mg/L of D.O. Coldwater fish such as trout generally require higher concentrations of D.O. than warmwater fish such as bass or bluegill. The IAC sets minimum D.O. concentrations at 4 mg/L for warmwater fish, but all waters must have a daily average of 5 mg/L. D.O. 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 D.O. 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). During low discharge, conductivity is higher than during high discharge because the water moves more slowly across or through ion containing soils and substrates during base flow. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity measurements.

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 water describes the concentration of acidic ions (specifically H+) present in 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 to 9 pH units for the protection of aquatic life. pH concentrations in excess of 9 are considered acceptable when the concentration occurs as daily fluctuations associated with photosynthetic activity.

Alkalinity. Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater and the runoff water moves across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional buffering capacity.

Nutrients. Limnologists measure nutrients to predict the amount of algae growth and/or rooted plant (macrophyte) growth that is possible in a lake or stream. Algae and rooted plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy lake or stream. 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 or stream. Algae and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a lake or stream. 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 **soluble reactive phosphorus (SRP)** 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 (NO_3)**, **ammonium-nitrogen (NH_4^+)**, and **total Kjeldahl nitrogen (TKN)**. 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. Because oxygen should be readily available in stream systems, nitrate-nitrogen is often the dominant dissolved form of nitrogen in stream systems. In contrast, ammonium-nitrogen is generally found where oxygen is lacking. 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 stream. (The USEPA, in conjunction with the States, is currently working on developing these standards.) The USEPA has issued recommendations for numeric nutrient criteria for streams (USEPA, 2000a). While these are not part of the Indiana Administrative Code, they serve as potential target conditions for which watershed managers might aim. The Ohio EPA has also made recommendations for numeric nutrient criteria in streams based on research on Ohio streams (Ohio EPA, 1999). These, too, serve as potential target conditions for those who manage Indiana streams. Other researchers have suggested thresholds for several nutrients in aquatic ecosystems as well (Dodd et al., 1998). 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.

Researchers have recommended various thresholds and criteria for nutrients in streams. The USEPA's recommended targets for nutrient levels in streams are fairly low. The agency recommends a target total phosphorus concentration of 0.033 mg/L in streams (USEPA, 2000a). Dodd et al. (1998) suggest the dividing line between moderately (mesotrophic) and highly (eutrophic) productive streams is a total phosphorus concentration of 0.07 mg/L. The Ohio EPA recommended a total phosphorus concentration of 0.1 mg/L in wadeable streams to protect the streams' aquatic biotic integrity (Ohio EPA, 1999). (This criterion is for streams classified as Warmwater Habitat, or WWH, meaning the stream is capable of supporting a healthy, diverse warmwater fauna. Streams that cannot support a healthy, diverse community of warmwater fauna due to "irretrievable, extensive, man-induced modification" are classified as Modified Warmwater Habitat (MWH) streams. Table 14 indicates how the Ridinger Lake watershed streams were classified for the purposes of this report.) The Ohio EPA's recommended total phosphorus concentration for WWH headwater streams is 0.08 mg/L and for MWH headwater streams is 0.34 mg/L (Ohio EPA, 1999).

Table 14. Potential classification of the Ridinger Lake watershed streams using Ohio EPA's (1999) criteria.

Stream	Site Number	Drainage Size*	Classification
Ridinger Lake outlet	Site 1	Wadeable	Warmwater Habitat
Shanton Ditch	Site 2	Headwaters	Warmwater Habitat
Robinson Lake outlet	Site 3	Headwaters	Warmwater Habitat
Elder Ditch	Site 4	Headwaters	Modified Warmwater Habitat
Doke Ditch	Site 5	Headwaters	Modified Warmwater Habitat
Mathias Ditch	Site 6	Headwaters	Warmwater Habitat
Delano Ditch	Site 7	Headwaters	Modified Warmwater Habitat

* The Ohio EPA defines "wadeable streams" as those with drainage areas between 20 and 200 square miles and "headwaters streams" as those with drainage areas less than 20 square miles.

The USEPA sets aggressive nitrogen criteria recommendations for streams compared to the Ohio EPA. The USEPA's recommended criteria for nitrate-nitrogen and total Kjeldahl nitrogen concentrations for streams in Aggregate Nutrient Ecoregion VII are 0.30 mg/L and 0.24 mg/L, respectively (USEPA, 2000a). In contrast, the Ohio EPA suggests using nitrate-nitrogen criteria of 1.0 mg/L in WWH wadeable and headwater streams and MWH headwater streams to protect aquatic life. Dodd et al. (1998) suggests the dividing line between moderately and highly productive streams using nitrate-nitrogen concentrations is approximately 1.5 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 in the Ridinger Lake watershed streams. 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. None of the Ridinger Lake watershed streams violated the state standard for either nitrate-nitrogen or ammonia-nitrogen.

Turbidity. Turbidity (measured in Nephelometric Turbidity Units) is a measure of 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 (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978). As part of their effort to make numeric nutrient criteria recommendations, the USEPA set 9.9 NTUs as a target for turbidity in stream ecosystems (USEPA, 2000a).

Total Suspended Solids (TSS). A TSS measurement quantifies all particles suspended and dissolved in water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in water. In general, the concentration of suspended solids is greater in streams 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 sediment in water originates from many sources, but a large portion of sediment entering streams comes from active construction sites or other disturbed areas such as unvegetated stream banks and poorly managed farm fields.

Suspended solids impact streams and lakes in a variety of ways. When suspended in the water column, solids can clog the gills of fish and invertebrates. As the sediment settles to the creek or lake bottom, it covers spawning and resting habitat for aquatic fauna, reducing the animals' reproductive success. Suspended sediments also impair the aesthetic and recreational value of a waterbody. Few people are enthusiastic about having a picnic near a muddy creek or lake. Pollutants attached to sediment also degrade water quality. In general, TSS concentrations greater than 80 mg/L have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* 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 for the 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 or a geometric mean of 125 colonies per 100 ml for five samples collected in any 30-day period. In general, fecal coliform bacteria have a life expectancy of less than 24 hours.

3.1.2 Macroinvertebrates

Macroinvertebrate samples from each of the designated stream sites in the Ridinger Lake watershed were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The insect community composition can reflect water quality; research shows that different macroinvertebrate orders and families react differently to pollution sources. 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 August 6, 2003 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes; a third researcher aided in the collection for 10 minutes, for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used: 1) to collect data comparable to that collected by IDEM in the state; 2) because it allows for increased organism identification accuracy; 3) because several studies support the adequacy of family-level analysis (Furse et al., 1984, Ferraro and Cole, 1995, Marchant, 1995, Bowman and Bailey, 1997, Waite et al., 2000).

The benthic community at each sample site was evaluated using two biological indices: the Hilsenhoff Family Level Biotic Index (FBI) (Hilsenhoff, 1988) and IDEM's macroinvertebrate Index of Biotic Integrity (mIBI) (IDEM, unpublished). The FBI uses the macroinvertebrate community to assess the level of organic pollution in a stream. (IDEM uses the abbreviation HBI to refer to the FBI.) The FBI 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 9; those families with lower tolerances to organic pollution were assigned lower values, while families that were more tolerant to organic pollution were assigned higher values. The FBI is calculated by multiplying the number of organisms from each family collected at a given site by the family tolerance value, summing these products, and dividing by the total number of organisms in the sample:

$$FBI = \frac{\Sigma x_i t_i}{n}$$

where x_i is the number of species in a given family, t_i is the tolerance values of that family, and n is the total number of organisms in the sample. Benthic communities dominated by organisms that are tolerant of organic pollution will exhibit higher FBI scores compared to benthic communities dominated by intolerant organisms. Table 15 relates the FBI score obtained using the equation above to a stream's water quality and degree of organic pollution.

Table 15. Water quality correlation to family level Hilsenhoff Biotic Index score.

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

IDEM's mIBI is a multi-metric index designed to provide a complete assessment of a creek'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 comparable to the best natural habitats within a region". It is likely that this definition of biological integrity is what IDEM means by biological integrity as well. The mIBI consists of ten metrics (Table 16) which measure the species richness, evenness, composition, and density of the benthic community at a given site. The metrics include family-level HBI (Hilsenhoff's FBI), number of taxa, number of individuals, percent dominant taxa, EPT Index, EPT count, EPT count to total number of individuals, EPT count to chironomid count, chironomid count, and total number of individuals to number of squares sorted. (EPT stands for the Ephemeroptera, Plecoptera, and Trichoptera orders.) A classification score of 0, 2, 4, 6, or 8 is assigned to specific ranges for metric values. For example, if the benthic community being assessed supports nine different families, that community would receive a classification score of 2 for the "Number of Taxa" metric. The mIBI is calculated by averaging the classification scores for the ten metrics. mIBI scores of 0-2 indicate the sampling site is severely impaired; scores of 2-4 indicate the site is moderately impaired; scores of 4-6 indicate the site is slightly impaired; and scores of 6-8 indicate that the site is non-impaired.

Table 16. Benthic macroinvertebrate scoring criteria used by IDEM in the evaluation of pool-riffle streams in Indiana.

	SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI) USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
	CLASSIFICATION SCORE				
	0	2	4	6	8
Family Level HBI	≥5.63	5.62- 5.06	5.05-4.55	4.54-4.09	≤4.08
Number of taxa	≤7	8-10	11-14	15-17	≥18
Number of individuals	≤79	129-80	212-130	349-213	≥350
Percent dominant taxa	≥61.6	61.5-43.9	43.8-31.2	31.1-22.2	<22.1
EPT index	≤2	3	4-5	6-7	≥8
EPT count	≤19	20-42	43-91	92-194	≥195
EPT count to total number of individuals	≤0.13	0.14-0.29	0.30-0.46	0.47-0.68	≥0.69
EPT count to chironomid count	≤0.88	0.89-2.55	2.56-5.70	5.71-11.65	≥11.66
Chironomid count	≥147	146-55	54-20	19-7	≤6
Total number of individuals to number of squares sorted	≤29	30-71	72-171	172-409	≥410

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Non-impaired

IDEM developed the classification criteria based on five years of wadeable riffle-pool data collected in Indiana. Because the values for some of the metrics can vary depending upon the collection and subsampling methodologies used to survey a stream, it is important to adhere to the collection and subsampling protocol IDEM used when it developed the mIBI. Since the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999) was utilized in this survey to ensure adequate representation of all macroinvertebrate taxa, the protocol dependent metrics of the mIBI (number of individuals and number of individuals to number of squares sorted) were not included in the metric classification score averaging. Eliminating the protocol dependent metrics allows the mIBI scores at sites surveyed using different survey protocols to be compared to mIBI scores at sites sampled using the IDEM recommended protocol.

Although the Indiana Administrative Code does not include mIBI scores as numeric criteria for establishing whether streams meet their aquatic life use designation, IDEM hints that it may be using mIBI scores to make this determination. (Under state law, all waters of the state, except for those noted as Limited Use in the Indiana Administrative Code, must be capable of supporting recreational and aquatic life uses.) In the 2000, 305 (b) report, IDEM suggests that those waterbodies with mIBI scores less than 2 are considered non-supporting for aquatic life use. Similarly, waterbodies with mIBI scores between 2 and 4 are considered to be partially supporting for aquatic life use. Under federal law, waters that do not meet their designated uses must be placed on the 303 (d) list and remediation/restoration plans (Total Maximum Daily Load plans) must be developed for these waters.

3.1.3 Habitat

The physical habitat at the three study stream sites was evaluated using the Qualitative Habitat Evaluation Index (QHEI) The Ohio EPA developed the QHEI for streams and rivers in Ohio (Rankin 1989, 1995). The QHEI is a physical habitat index designed to provide an empirical, quantified evaluation of the general lotic macrohabitat (Ohio EPA, 1989). While the Ohio EPA originally developed the QHEI to evaluate fish habitat in streams, IDEM and other agencies routinely utilize the QHEI as a measure of general "habitat" health. The QHEI is composed of six metrics including substrate composition, in-stream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle-run quality, and map gradient. Each metric is scored individually then summed to provide the total QHEI score. The QHEI score generally 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. Because the rock (gravel, cobble, boulder) that comprise a stream's substrate do not fit together perfectly like pieces in a jigsaw puzzle, small pores and crevices exist between the rock in the stream's substrate. Many stream organisms can colonize these pores and crevices, or microhabitats. In streams that carry high silt loads, the pores and crevices between substrate rock become clogged over time. This clogging, or "embedding", of the stream's substrate eliminates habitat for the stream's biota. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

In-stream cover, another metric of the QHEI, refers to the type(s) and quantity of habitat provided within the stream itself. Examples of in-stream 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 comprise this metric score.

A stream's buffer, which includes the riparian zone and floodplain zone, is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. Riparian zones govern the quality of goods and services provided by riverine ecosystems (Ohio EPA, 1999). Riparian zone (the area immediately adjacent to the stream), floodplain zone (the area beyond the riparian zone that may influence the stream though runoff), 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 erosion in the stream, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian zone consists only of forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation has higher runoff potential than woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989). Streams with grass or other herbaceous vegetation growing in the riparian zone receive low QHEI scores for this metric.

Metric 5 of the QHEI 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. 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 gradient streams will have negative effects on habitat quality. Moderate gradient streams receive the highest score, 10, for this metric. The gradient ranges for scoring take into account the varying influence of gradient with stream size.

The QHEI evaluates 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 (IDEM, 2000).

3.2 Stream Assessment Results and Discussion

3.2.1 Water Chemistry

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling of the Ridinger Lake watershed streams are presented in Table 17. Stream discharges measured during base and storm flow conditions are shown in Figure 14. Stream cross-sections, determined while measuring discharge, are shown in Figure 15.

Table 17. Physical characteristics of the Ridinger Lake watershed streams on 5/1/03 (storm flow) and 8/6/03 (base flow).

Site Name	Site #	Date	Event	Flow (cfs)	Temp (°C)	D.O.* (mg/L)	D.O. % Sat	TSS (mg/L)	Turbidity (NTU)
Ridinger Lake outlet	1	5/1/03	storm	12.0	18.8	11.4	121.0	4.2	2.5
		8/6/03	base	8.5	27.4	9.4	118.7	10.0	3.4
Shanton Ditch	2	5/1/03	storm	2.7	19.6	16.8	183.1	10.8	5.0
		8/6/03	base	1.5	26.1	6.6	81.1	7.8	4.0
Robinson Lake outlet	3	5/1/03	storm	1.7	20.2	10.6	117.7	6.5	5.5
		8/6/03	base	0.7	25.2	12.6	152.0	2.3	1.9
Elder Ditch	4	5/1/03	storm	2.2	18.9	12.8	136.9	5.9	5.8
		8/6/03	base	1.9	23.3	6.8	79.6	8.4	6.0
Doke Ditch	5	5/1/03	storm	0.5	18.0	11.1	116.6	4.2	8.0
		8/6/03	base	0.2	19.1	6.9	74.5	6.0	5.0
Mathias Ditch	6	5/1/03	storm	1.0	18.0	12.9	136.5	0.4	2.8
		8/6/03	base	0.6	19.3	8.9	96.5	4.6	4.6
Delano Ditch	7	5/1/03	storm	0.5	20.0	10.5	115.0	12.1	5.5
		8/6/03	base	0.4	23.2	7.5	92.7	0.4	4.3

* Storm sampling D.O. values appear inexplicably high; the stream sampling equipment may have been malfunctioning at the time of sampling. This data should be interpreted with caution.

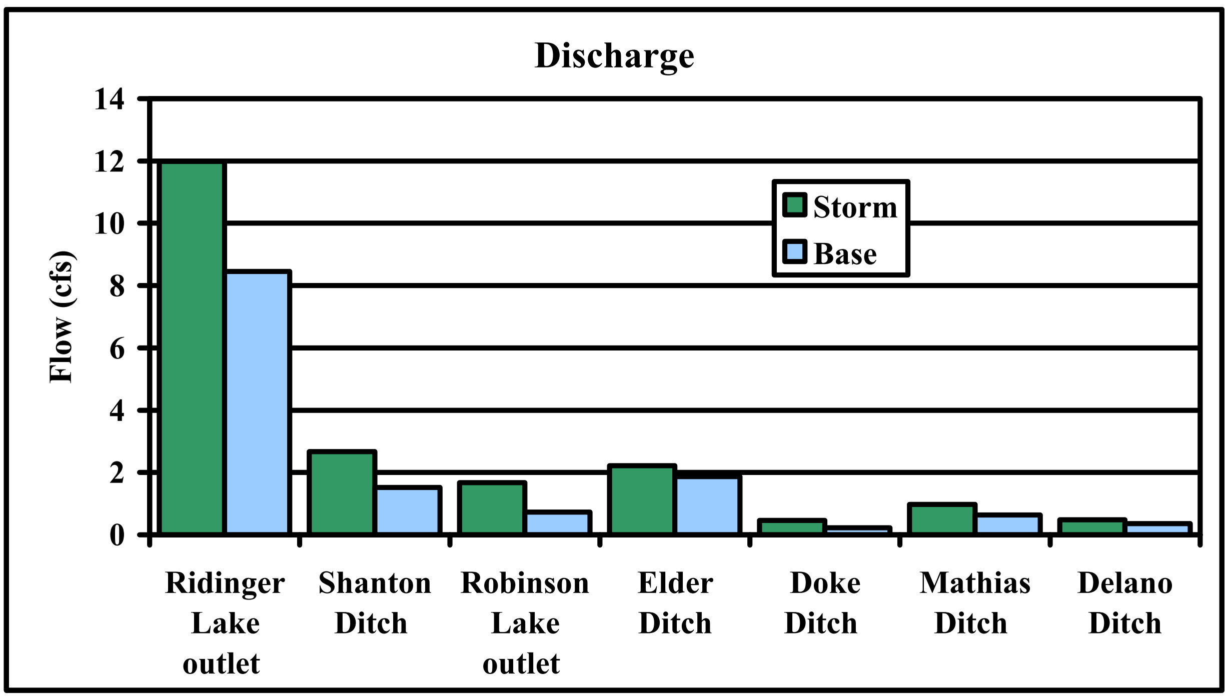


Figure 14. Discharge measurements during base flow and storm flow sampling of Ridinger Lake watershed streams.

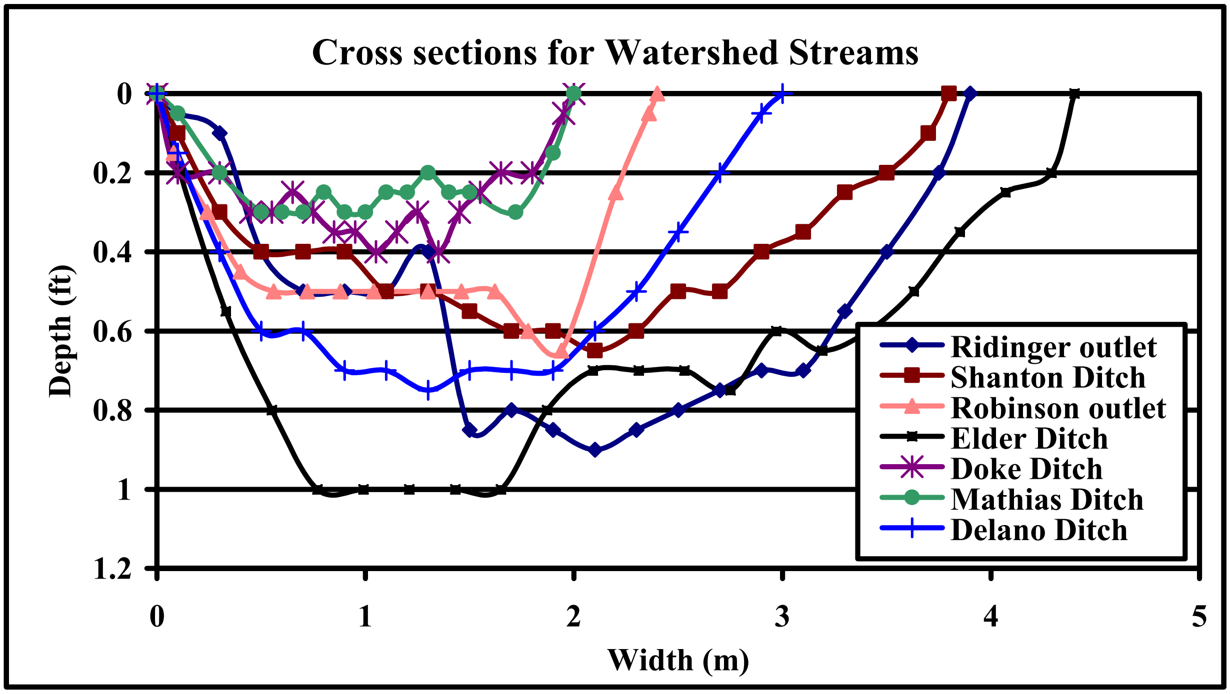


Figure 15. Physical dimensions at the sampling locations of Ridinger Lake watershed streams.

Water temperatures in the Ridinger Lake watershed streams varied with season. As expected, stream temperatures in early Mary during storm flow conditions were lower than stream temperatures in August during storm flow conditions. Water temperatures during the storm flow ranged from 18.0 ^{O}C in Mathias and Doke Ditches to 20.2 ^{O}C in the Robinson Lake outlet stream. Greater variation was observed during base flow when stream temperatures ranged from 19.1 ^{O}C in Doke Ditch to 27.4 ^{O}C in the Ridinger Lake outlet stream. None of the observed water temperatures exceeded the Indiana Administrative Code standard for the protection of aquatic life.

Base flow dissolved oxygen concentrations in the Ridinger Lake watershed streams ranged from 6.6 mg/L in Shanton Ditch to 12.6 mg/L in the Robinson Lake outlet stream. None of the streams possessed dissolved oxygen levels below the minimum IAC level of 5.0 mg/L set to protect aquatic life. Dissolved oxygen saturation levels at base flow were generally within the normal range for Indiana streams. The exception to this is the dissolved oxygen saturation in the Robinson Lake outlet stream. This stream was supersaturated (152%) with oxygen at the time of base flow sampling. The supersaturation observed at this location is likely due to intense photosynthesis. A large bed of coontail covered the stream channel at the sampling point on the Robinson Lake outlet stream. Photosynthesizing plants such as the coontail could have elevated the dissolved oxygen concentration and therefore the percent dissolved oxygen saturation of the stream.

Total suspended solids concentrations in the Ridinger Lake watershed streams ranged from 0.4 mg/L in Delano Ditch during base flow and Mathias Ditch during storm flow to 10.8 mg/L in Shanton Ditch during storm flow. Total suspended solids concentrations usually increase with increased stream flow because of in-stream scouring and inputs from overland flow from surrounding lands. This relationship occurred in three of the seven watershed streams: Shanton Ditch, the Robinson Lake outlet stream, and Delano Ditch. Local land use activities could result in isolated increases in erosion during base flow measurement, leading to increased total suspended solids concentration. None of the concentrations in the Ridinger Lake watershed streams exceeded 80 mg/L, the threshold at which Waters (1995) found to be deleterious to aquatic life.

Turbidity concentrations in the Ridinger Lake watershed streams were generally low. Turbidity concentrations ranged from 1.9 NTU in the Robinson Lake outlet stream during base flow to 8.0 NTU in Doke Ditch at storm flow. As with the total suspended solids concentrations, turbidity concentrations in streams are expected to be higher during storm flow conditions. Storms tend to wash soil and other particulates from the landscape into streams, resulting in higher turbidity concentrations. This relationship occurred in four of the seven streams: Shanton Ditch, the Robinson Lake outlet stream, Doke Ditch, and Delano Ditch. None of the streams possessed turbidity concentrations above the USEPA recommended target of 9.9 NTU (USEPA, 2000a).

Chemical and Bacterial Characteristics

The chemical and bacterial characteristics of the Ridinger Lake watershed streams during base and storm flow conditions are shown in Table 18. In a recent study of 85 relatively undeveloped basins across the United States, the USGS reported the following median concentrations: ammonia (0.020 mg/L), nitrate (0.087 mg/L), total nitrogen (0.26 mg/L), soluble reactive phosphorus (0.010 mg/L), and total phosphorus (0.022 mg/L) (Clark et al., 2000). Nutrient concentrations in the Ridinger Lake streams all exceeded these median concentrations, some parameters by an order of magnitude.

Table 18. Chemical and bacterial characteristics of the Ridinger Lake watershed streams on 5/1/03 (storm flow) and 8/6/03 (base flow).

Site	Site #	Date	Event	pH	Alk. (mg/L)	Cond (μmhos)	NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	*E. coli* (col/100 mL)
Ridinger Lake outlet	1	5/1/03	storm	8.7	188	n/a	2.430	0.044	1.292	0.010*	0.044	20
		8/6/03	base	8.4	147	440	1.647	0.101	1.557	0.021	0.118	34
Shanton Ditch	2	5/1/03	storm	8.4	217	n/a	2.088	0.056	1.673	0.022	0.096	200
		8/6/03	base	7.7	229	590	0.846	0.354	1.276	0.055	0.144	630
Robinson Lake outlet	3	5/1/03	storm	7.8	166	n/a	0.950	0.090	1.038	0.017	0.089	470
		8/6/03	base	7.7	173	550	0.600	0.108	0.745	0.045	0.091	23
Elder Ditch	4	5/1/03	storm	8.4	201	n/a	1.234	0.073	1.170	0.093	0.177	980
		8/6/03	base	8.2	203	415	1.528	0.064	0.896	0.069	0.064	950
Doke Ditch	5	5/1/03	storm	8.1	242	n/a	1.219	0.053	0.853	0.025	0.045	1,410
		8/6/03	base	7.6	317	600	0.893	0.068	0.545	0.021	0.064	380
Mathias Ditch	6	5/1/03	storm	8.3	213	n/a	1.666	0.421	1.130	0.051	0.178	210
		8/6/03	base	8.1	257	600	1.789	0.018*	0.958	0.066	0.097	13,100
Delano Ditch	7	5/1/03	storm	8.0	174	n/a	2.396	0.129	1.872	0.051	0.010#	1,390
		8/6/03	base	7.7	186	400	1.162	0.119	1.425	0.058	0.094	180

n/a=Not sampled
*Method detection level.
The high inorganic matter content of the sample necessitated manipulating the sample according to the methodology outlined in *Standard Methods*. The result should be interpreted with caution.

Alkalinity, pH, and conductivity values were within normal ranges for Indiana streams. Alkalinity concentrations were typical of well buffered streams, suggesting the presence of carbonates and other alkalinity-producing materials in the watershed's bedrock. Alkalinity ranged from 147 mg/L in the Ridinger Lake outlet at base flow to 317 mg/L in Doke Ditch at base flow. The watershed streams' pH values were slightly alkaline, ranging from 7.6 in Doke Ditch at base flow to 8.7 in the Ridinger Lake outlet during storm flow. All of the pH values were within the range that is appropriate for supporting aquatic life. Conductivity values ranged from 400 μmhos in Delano Ditch to 600 μmhos in Doke Ditch and Mathias Ditch. None of the conductivity values exceeded the Indiana state water quality standard.

Nitrate-nitrogen concentrations in the Ridinger Lake watershed streams were slightly elevated for Indiana streams. Nitrate-nitrogen concentrations ranged from a low of 0.6 mg/L in the Robinson Lake outlet stream during base flow to a high of 2.4 mg/L in the Ridinger Lake outlet stream during storm flow. Many sites exceeded the Ohio EPA recommended nitrate-nitrogen concentration to protect aquatic life. Nitrate-nitrogen concentrations in the Ridinger Lake outlet stream, Elder Ditch, Mathias Ditch, and Delano Ditch exceeded the Ohio EPA criterion during both base flow and storm flow conditions. Nitrate-nitrogen concentrations in Doke Ditch and Shanton Ditch exceeded the Ohio EPA recommended criterion during storm flow. Nitrate-nitrogen concentrations in the Robinson Lake outlet were generally good. Despite the fact that many of the streams exceeded the Ohio EPA's recommendation for nitrate-nitrogen concentration, none of the streams possessed nitrate-nitrogen concentrations of 3-4 mg/L, the threshold at which Ohio EPA found to definitively impair biotic communities (Ohio EPA, 1999). Similarly, none of the watershed streams possessed nitrate-nitrogen concentrations that violated the Indiana state water quality standards.

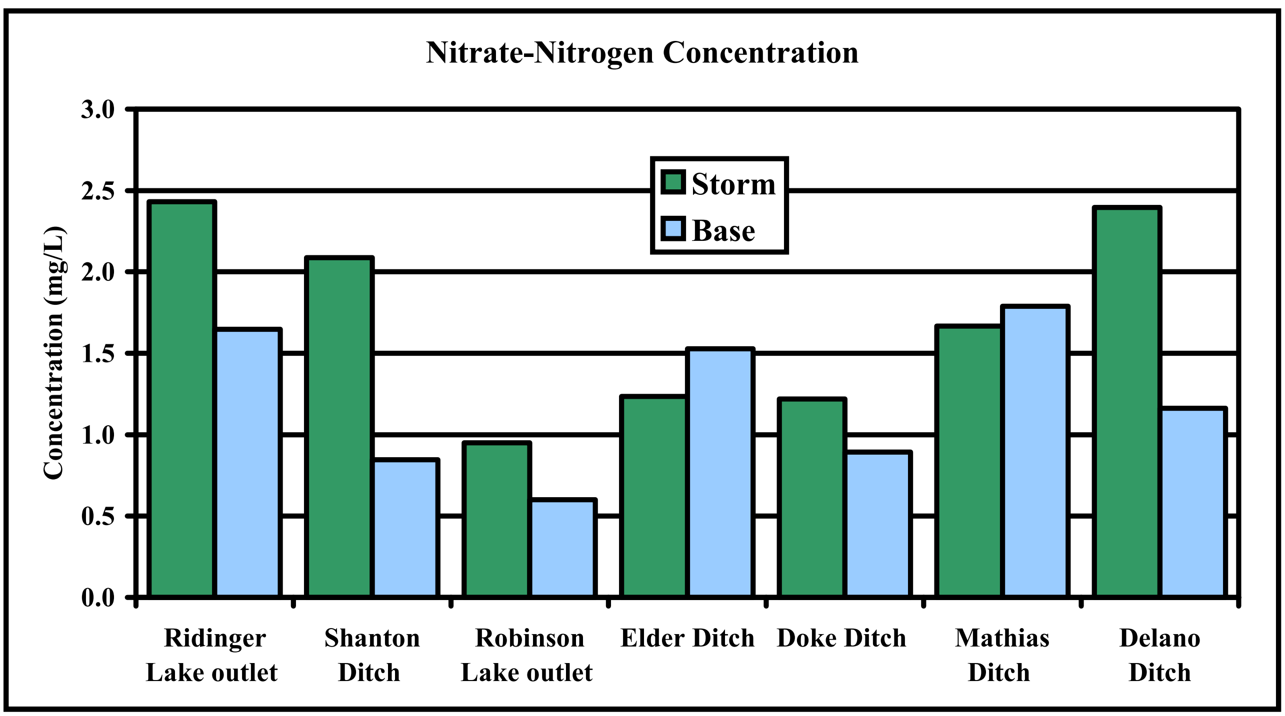


Figure 16. Nitrate-nitrogen concentrations in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03. Detection limit is 0.022 mg/L.

Ammonia concentrations ranged from below the laboratory detection limit in Mathias Ditch at base flow to 0.421 mg/L in Mathias Ditch during storm flow. Relatively high ammonia concentrations were also observed in Shanton Ditch during base flow and Delano Ditch during both base and storm flow conditions. Ammonia is a by-product of decomposition and therefore streams with high levels of organic material are expected to have higher ammonia concentrations. Both Mathias Ditch and Shanton Ditch possessed high total phosphorus concentrations during the same sampling event that they registered the high ammonia concentrations. High total phosphorus concentrations are indicative of high levels of organic matter. Similarly, Delano Ditch possessed high total organic nitrogen (total Kjeldahl nitrogen minus ammonia) levels during both base flow and storm flow conditions, suggesting the presence of organic matter. Delano Ditch's substrate is composed largely of muck and silty organic matter, so the high ammonia concentration in that stream is not surprising. Additionally, the sluggish nature of Delano Ditch compounds the ammonia problem. Small, natural streams are typically well oxygenated because of the turbulent flow. In well oxygenated streams, ammonia is usually oxidized to nitrate. However, oxygen does not readily diffuse into the slow flowing Delano Ditch, and this chemical reaction likely does not occur there.

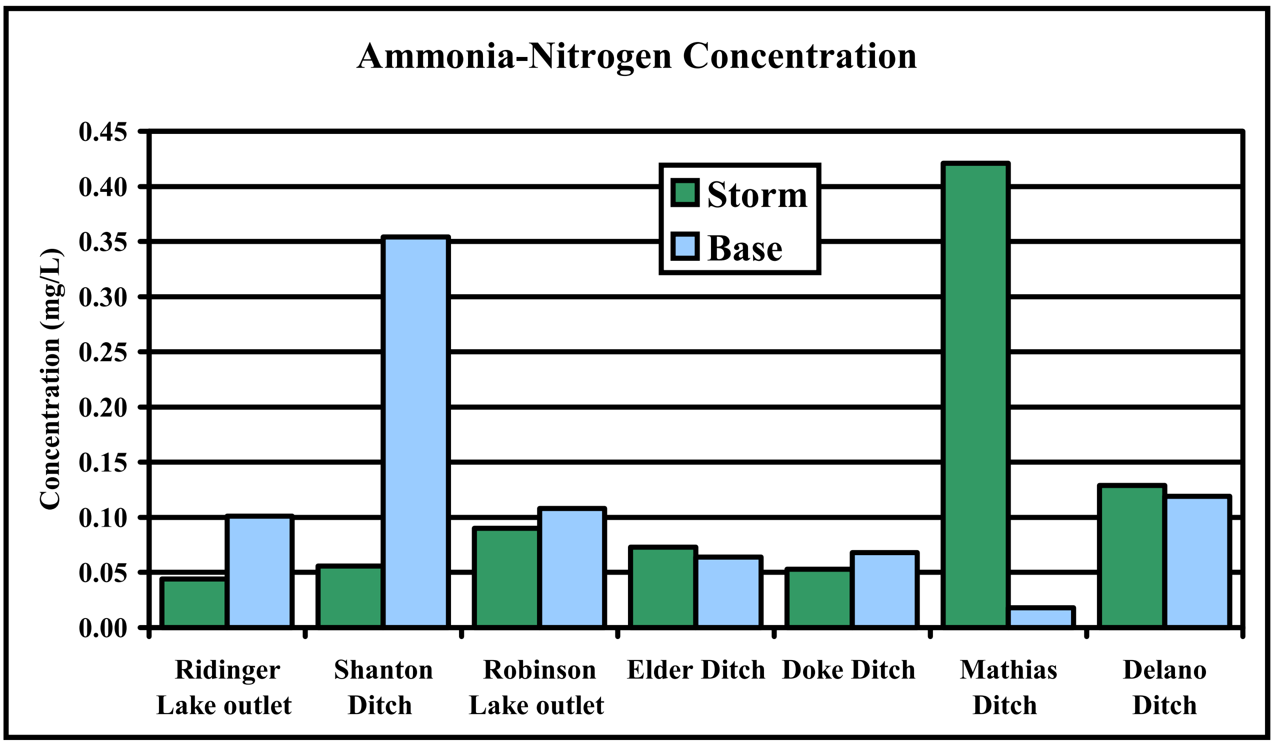


Figure 17. Ammonia-nitrogen concentrations in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03. Detection limit is 0.018 mg/L.

Total Kjeldahl nitrogen levels in the Ridinger Lake watershed streams were roughly average for northern Indiana streams. TKN concentrations ranged from 0.545 mg/L in Doke Ditch at base flow to 1.872 mg/L in Delano Ditch during storm flow. Relatively high TKN concentrations were also observed in Delano Ditch at base flow and Shanton Ditch and the Ridinger Lake outlet at both base and storm flow. Typically storm flow concentrations of TKN exceed base flow concentrations since runoff liberates significant organic material stored within the stream and in riparian areas adjacent to the stream. This relationship occurred at all sampling sites except the Ridinger Lake outlet stream. The Ridinger Lake outlet stream exhibited relatively similar base flow and storm flow TKN concentrations. All of the streams exhibited TKN concentrations greater than the target concentration of 0.24 mg/L recommended by the USEPA (2000a).

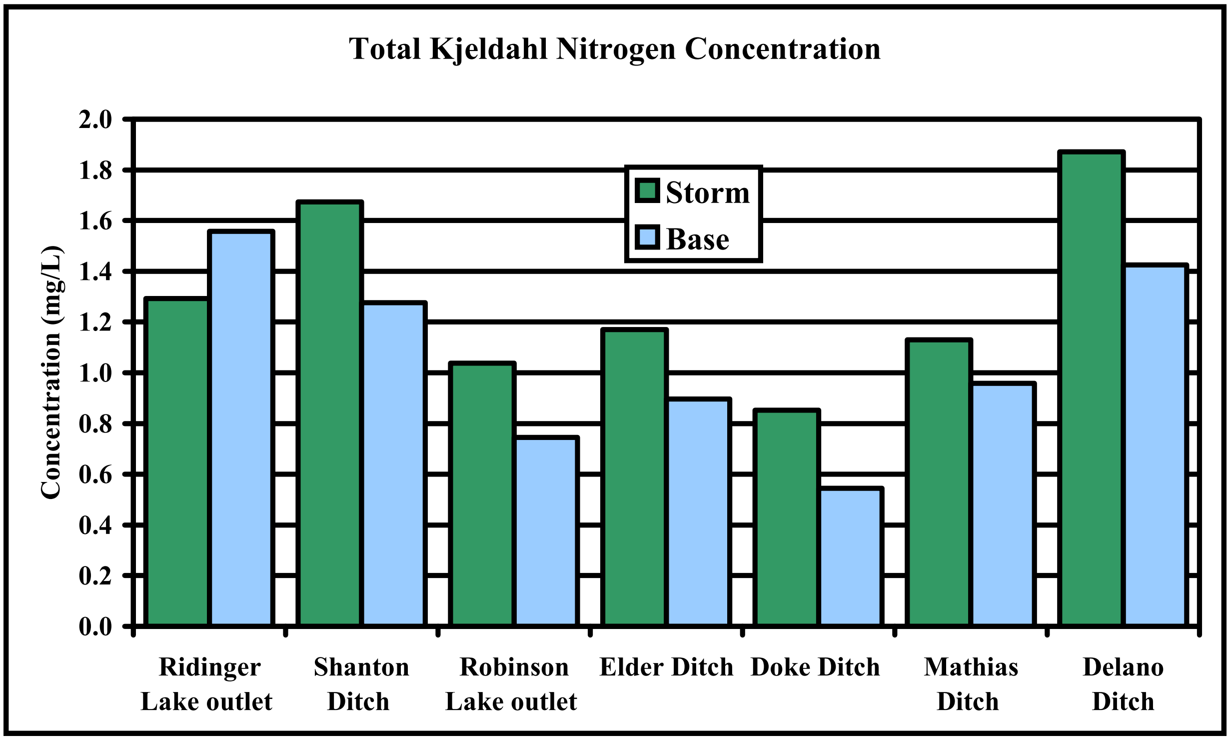


Figure 18. Total Kjeldahl nitrogen concentrations in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03. Detection limit is 0.230 mg/L.

Soluble reactive phosphorus (SRP) is the dissolved component of total phosphorus. Understanding what portion of the total phosphorus concentration is dissolved aids in directing management efforts. Dissolved phosphorus usually comes from fertilizer and waste (wildlife and human). Chemical reactions within the stream can also contribute to the dissolved phosphorus levels in the stream. SRP concentrations in the Ridinger Lake watershed streams were higher than desired for headwater streams. (All of the Ridinger Lake watershed streams, except the Ridinger Lake outlet, have drainages less than 20 square miles thus defining them as headwater streams.) SRP concentrations in the Ridinger Lake watershed streams ranged from at or below the detection limit of 0.010 mg/L in the Ridinger Lake outlet during storm flow to 0.093 mg/L in Elder Ditch at storm flow. Elder Ditch also exhibited the highest base flow SRP concentration, which was higher than the SRP concentrations at all the other sites during base or storm flow. High SRP concentrations were also observed in Mathias Ditch and Delano Ditch during both base and storm flow. Elder Ditch, Mathias Ditch, and the Troy Cedar Lake also possessed relatively high *E. coli* concentrations during base and/or storm flow. Waste (wildlife and/or human) may be increasing the SRP concentrations in these streams. Management efforts should focus on reducing the waste reaching these streams. Nutrient (fertilizer) management should also be a priority on agricultural and residential land in these subwatersheds.

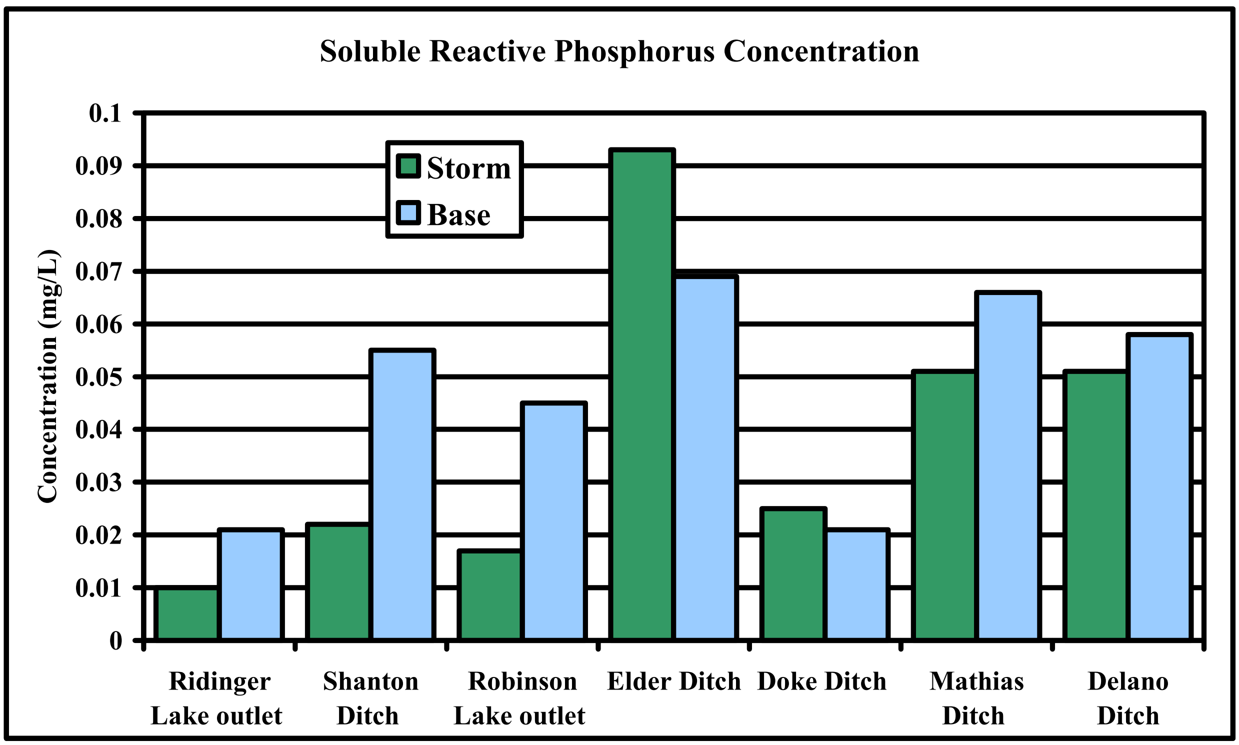


Figure 19. Soluble reactive phosphorus concentrations in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03. Detection limit is 0.010 mg/L.

Like the TKN levels, total phosphorus concentrations in the Ridinger Lake watershed streams were average for northern Indiana streams (Figure 20). Total phosphorus concentrations ranged from 0.044 mg/L in the Ridinger Lake outlet during storm flow to 0.178 mg/L in Mathias Ditch during storm flow. Mathias Ditch also exhibited a relatively high base flow total phosphorus concentration of nearly 0.1 mg/L. Like Mathias Ditch, Shanton Ditch and the Robinson Lake outlet possessed high total phosphorus concentrations during both base and storm flow conditions. Elder Ditch exhibited a storm flow total phosphorus concentration of nearly equal magnitude to the storm flow total phosphorus concentration observed in Mathias Ditch. The Ridinger Lake outlet possessed a relatively high base flow total phosphorus concentration. Doke Ditch total phosphorus concentrations were the lowest. Neither the storm or base flow total phosphorus concentrations in Doke Ditch were of concern.

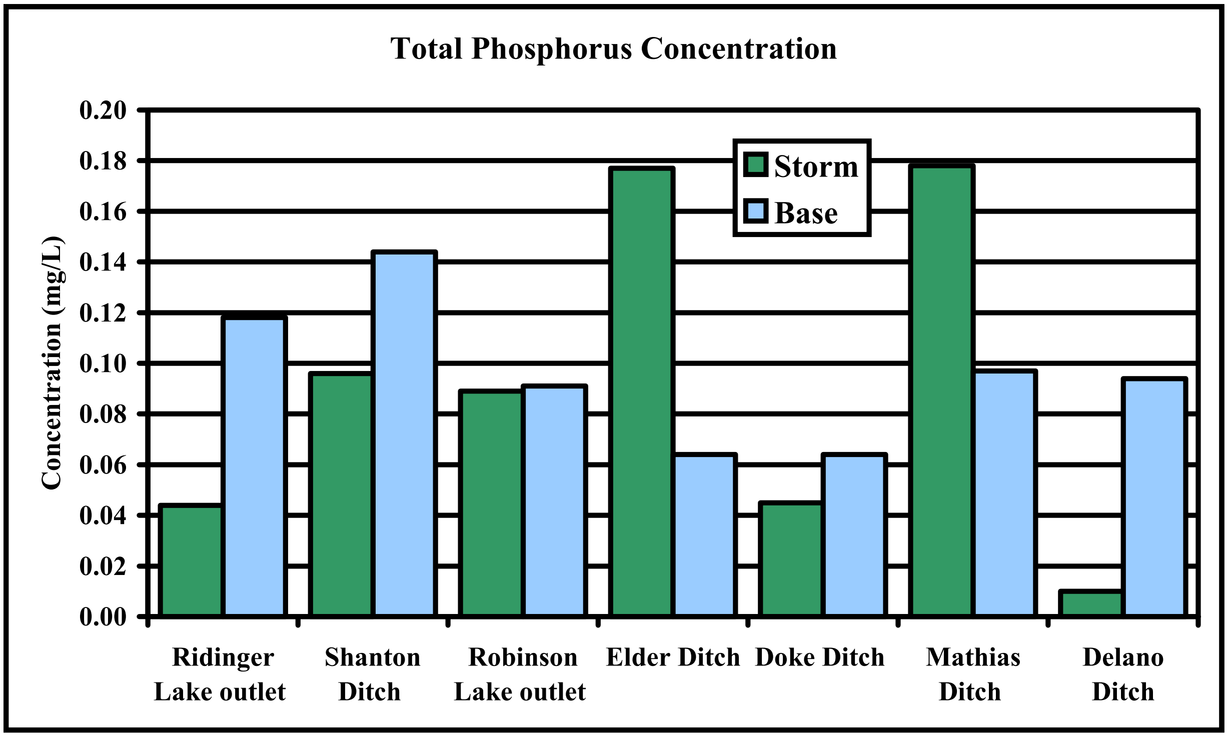


Figure 20. Total phosphorus concentrations in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03. Detection limit is 0.010 mg/L.

Despite the fact that the concentrations were relatively average for northern Indiana, the total phosphorus concentrations in some of the streams suggested that they were fairly productive streams and this high productivity has the potential to impair the streams' biotic communities. All of the streams, except Doke Ditch, possessed base and/or storm flow total phosphorus concentrations that would place the streams in the eutrophic, or highly productive, category using Dodd et al.'s (1998) criteria. Total phosphorus concentrations in all of the watershed streams at base and storm flow conditions exceeded the USEPA recommended target criterion of 0.033 mg/L (USEPA, 2000a). Similarly, storm and base flow total phosphorus concentrations in Shanton Ditch, the Robinson Lake outlet, and Mathias Ditch exceeded the Ohio EPA's recommended total phosphorus criterion to protect aquatic life of 0.1 mg/L in wadeable WWH streams (Ohio EPA, 1999). (Elder Ditch and Delano Ditch possessed total phosphorus concentrations on par with these three streams; however, because Elder Ditch and Delano Ditch fit the definition of MWH they should be evaluated using the Ohio EPA's total phosphorus criterion for MWH, which is 0.34 mg/L.) The high total phosphorus concentrations observed in the watershed streams, particularly in Shanton Ditch, the Robinson Lake outlet, and Mathias Ditch, may be impairing the streams' biotic communities.

E. coli concentrations in the Ridinger Lake watershed streams were relatively high. More than half of the water quality samples collected from the Ridinger Lake watershed streams contained *E. coli* concentrations that violated state water quality standards (Figure 21). In addition to violating the state standard, *E. coli* concentrations at four of the sampling sites were above the average *E. coli* concentration of 650 col/100mL found in Indiana waters (White, unpublished data). *E. coli* concentrations in the Ridinger Lake watershed streams ranged from 20 col/100mL in the Ridinger Lake outlet stream during storm flow to 13,100 col/100mL in Mathias Ditch at base flow. Elder Ditch and Doke Ditch exhibited high *E. coli* concentrations during both base and storm flow sampling efforts. Only *E. coli* concentrations in the Ridinger Lake outlet stream during both storm and base flow and the Robinson Lake outlet during base flow could be considered low. Because *E. coli* is killed by UV light, it is not unusual to observe low *E. coli* concentration downstream of lakes, particularly under normal or base flow conditions. Water in lakes is exposed to light for a prolonged period.

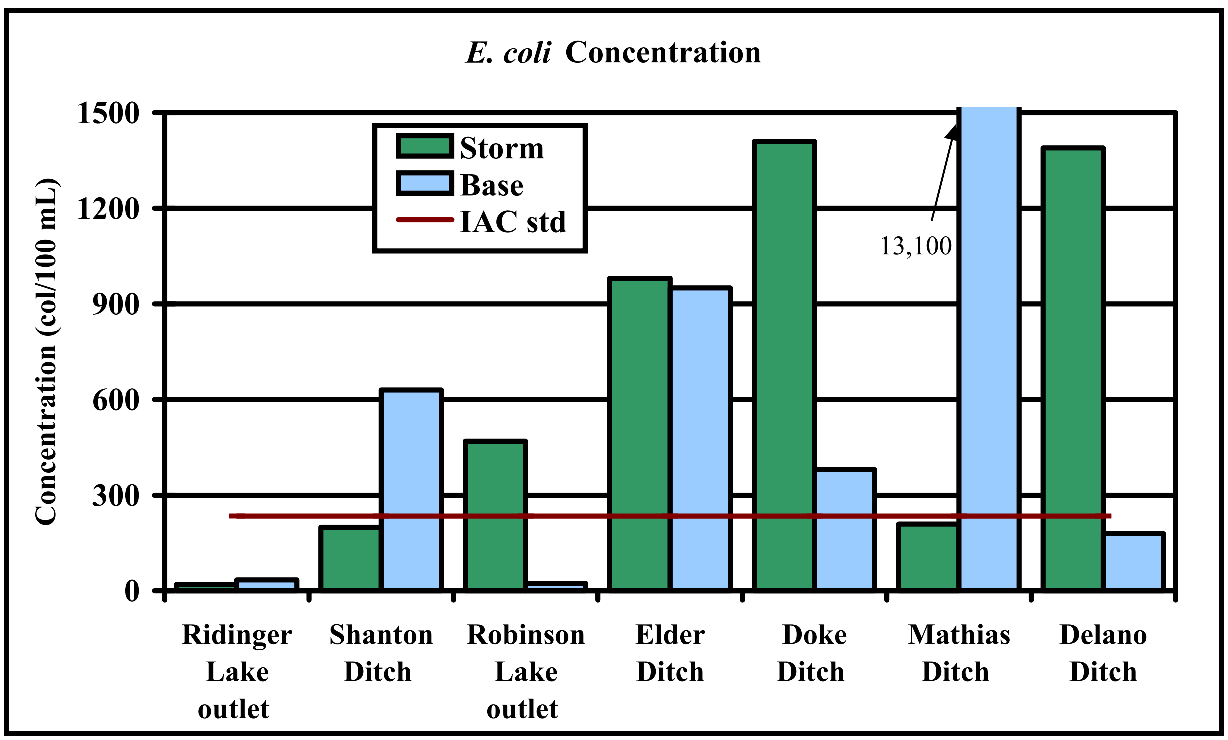


Figure 21. *E. coli* concentrations in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03. The red line indicates the Indiana state standard (235 colonies/100 mL).

Chemical and Sediment Loading

Table 19 lists the chemical and sediment loading data for the Ridinger Lake watershed sites. Figures 22-27 present mass loading information graphically.

Table 19. Chemical and sediment load characteristics of the Ridinger Lake watershed streams on 5/1/03 (storm flow) and 8/6/03 (base flow). Red shading indicates base and storm flow sites which possessed the highest load, while pink indicates those sites with the second highest load.

Site Name	Site #	Date	Event	NO_3-N Load (kg/d)	NH_3-N Load (kg/d)	TKN Load (kg/d)	SRP Load (kg/d)	TP Load (kg/d)	TSS Load (kg/d)
Ridinger Lake outlet	1	5/1/03	storm	2.516	0.046	1.338	bdl	0.046	4.348
		8/6/03	base	1.202	0.074	1.137	0.015	0.086	7.301
Shanton Ditch	2	5/1/03	storm	0.482	0.013	0.386	0.005	0.022	2.493
		8/6/03	base	0.111	0.046	0.168	0.007	0.019	1.021
Robinson Lake outlet	3	5/1/03	storm	0.137	0.013	0.150	0.002	0.013	0.939
		8/6/03	base	0.038	0.007	0.047	0.003	0.006	0.144
Elder Ditch	4	5/1/03	storm	0.237	0.014	0.225	0.018	0.034	1.137
		8/6/03	base	0.247	0.010	0.145	0.011	0.010	1.357
Doke Ditch	5	5/1/03	storm	0.049	0.002	0.034	0.001	0.002	0.170
		8/6/03	base	0.018	0.001	0.011	0.000	0.001	0.119
Mathias Ditch	6	5/1/03	storm	0.140	0.035	0.095	0.004	0.051	0.034
		8/6/03	base	0.099	bdl	0.053	0.004	0.005	0.253
Delano Ditch	7	5/1/03	storm	0.099	0.005	0.077	0.002	bdl	0.501
		8/6/03	base	0.036	0.004	0.044	0.002	0.003	0.012

bdl=Below laboratory detection level

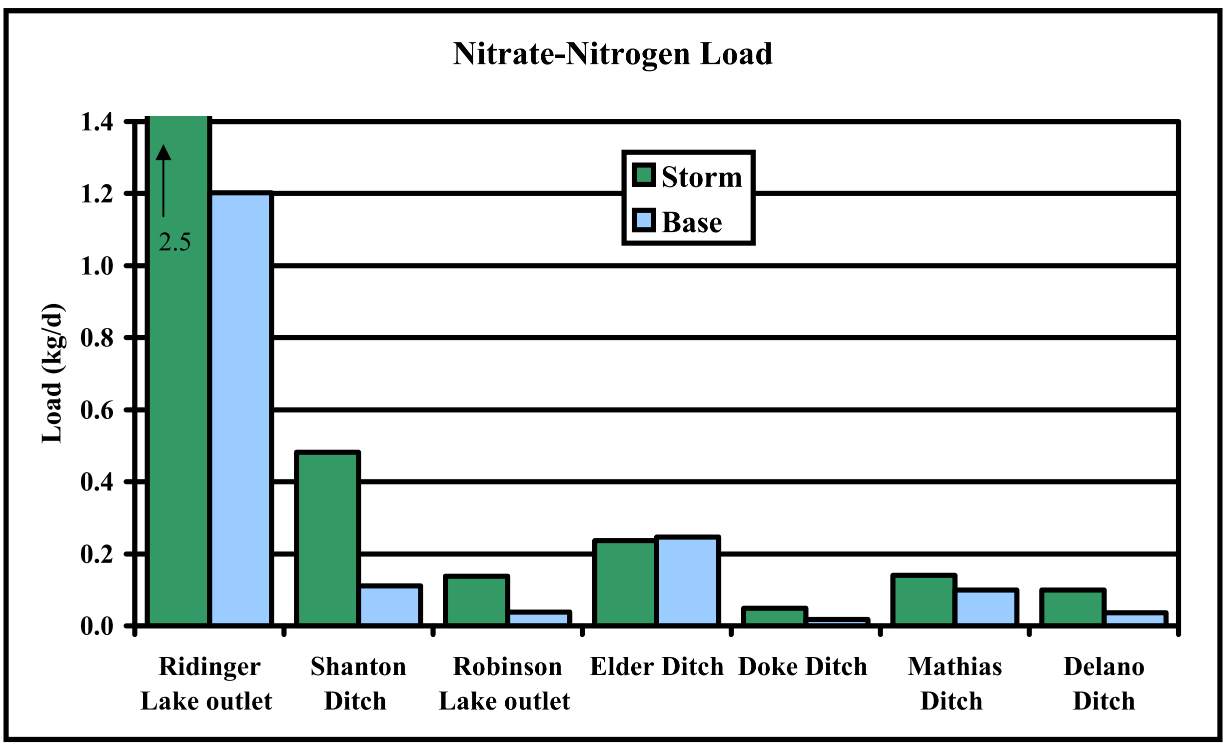


Figure 22. Nitrate-nitrogen loads in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03.

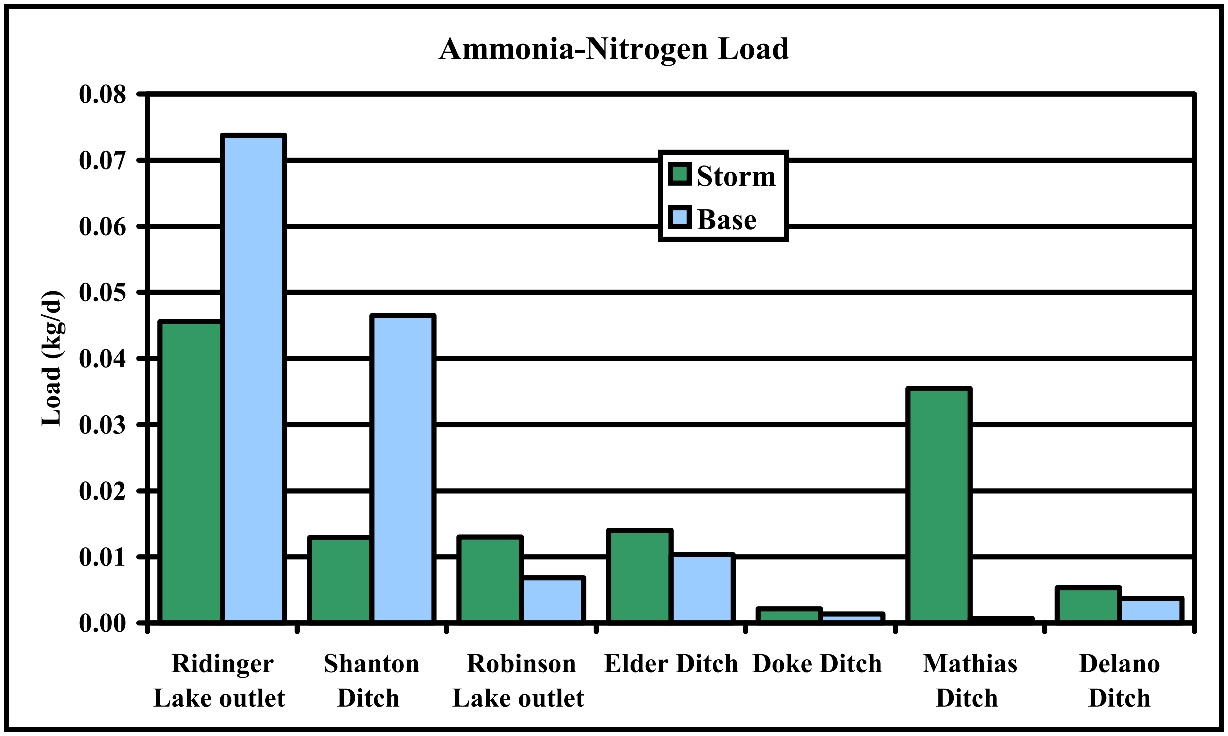


Figure 23. Ammonia-nitrogen loads in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03.

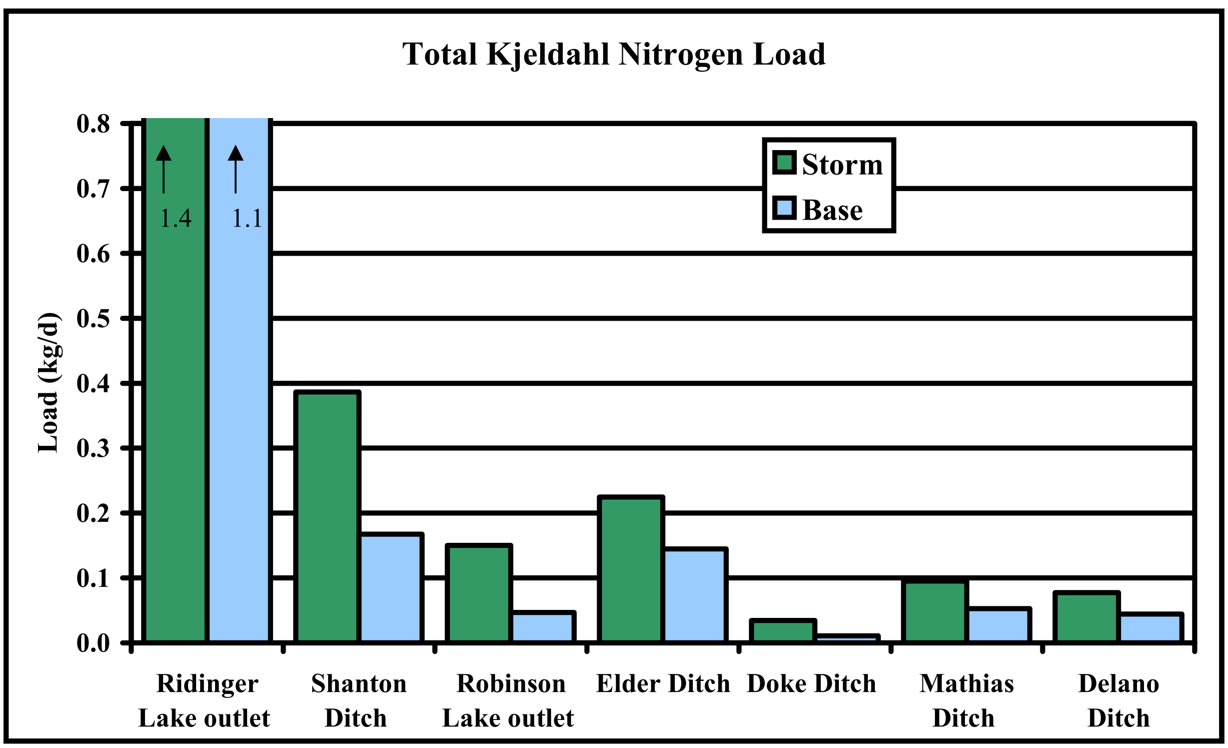


Figure 24. Total Kjeldahl nitrogen loads in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03.

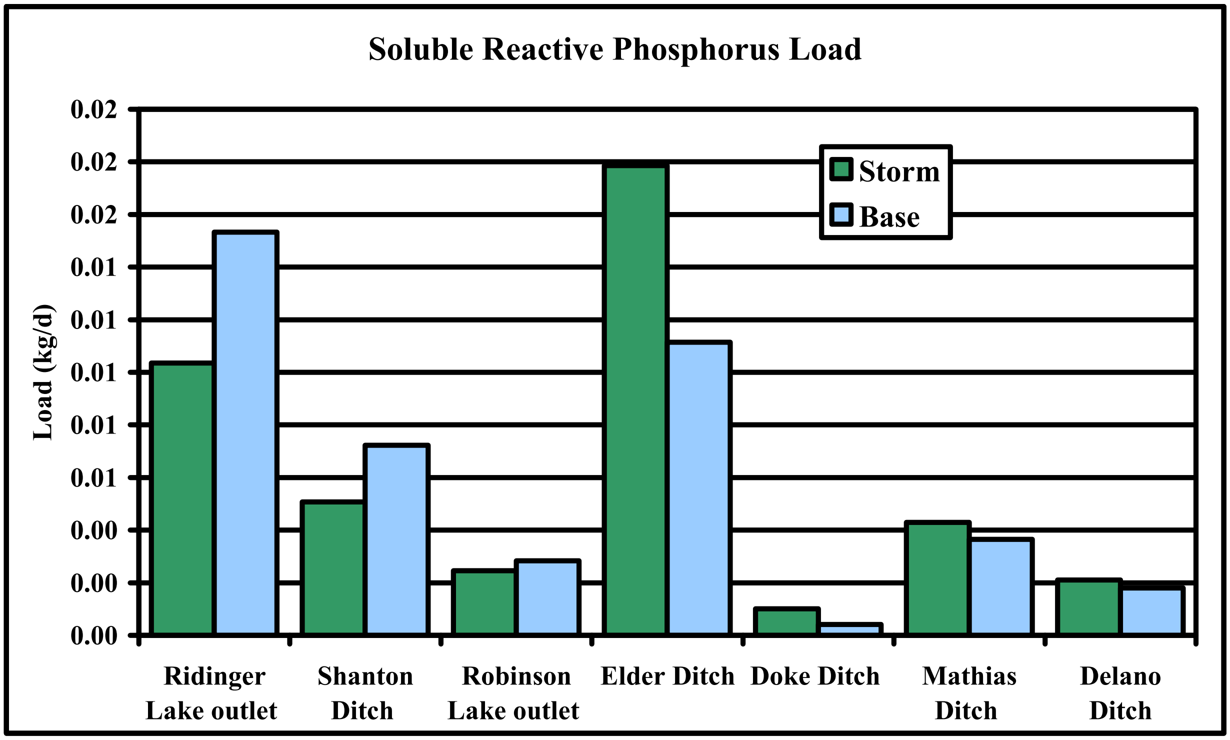


Figure 25. Soluble reactive phosphorus loads in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03.

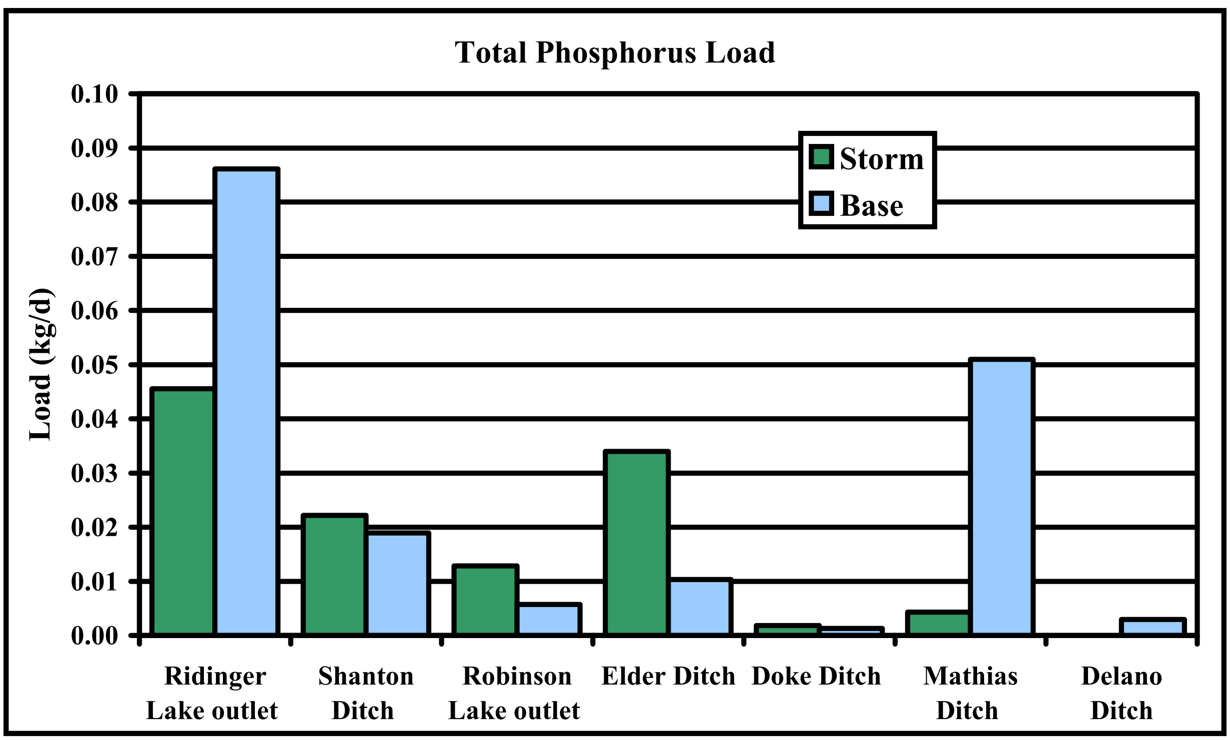


Figure 26. Total phosphorus loads in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03.

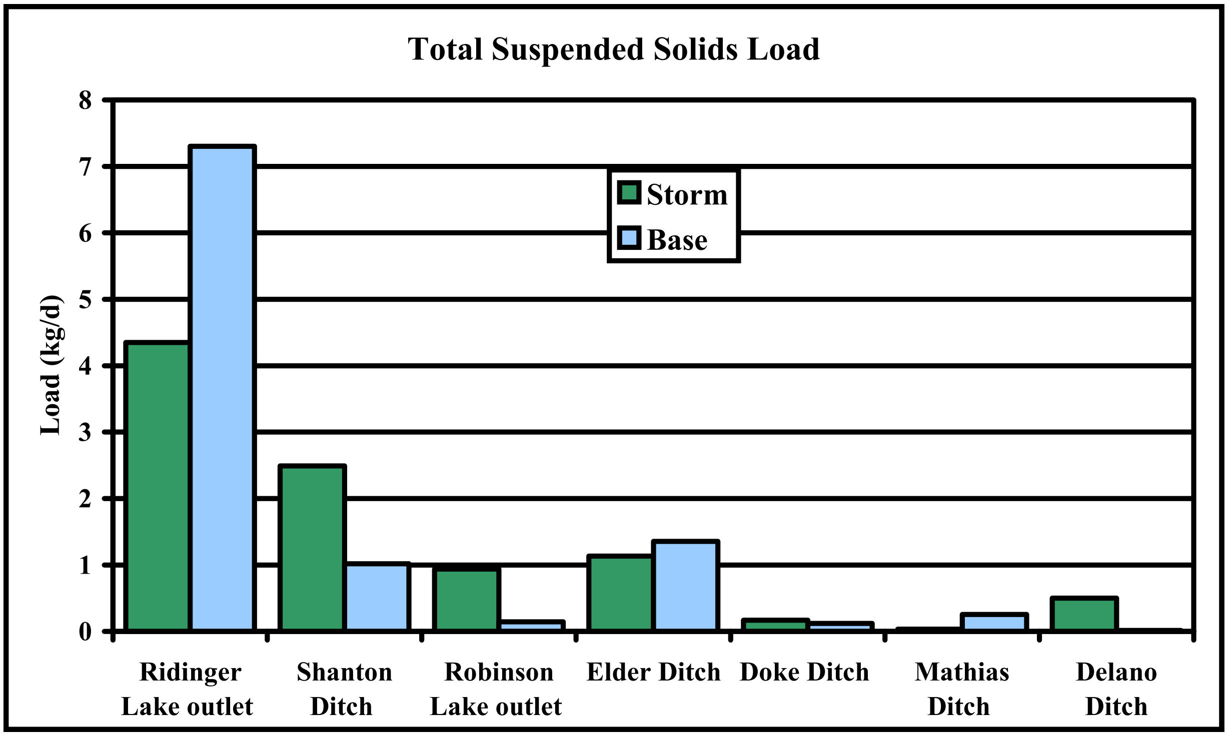


Figure 27. Total suspended solids loads in Ridinger Lake watershed streams as sampled 5/1/03 and 8/6/03.

While pollutant concentration data provides an understanding of the water quality at a given time and the conditions to which stream biota are subjected, pollutant loading data provides an understanding of how much actual pollutant (mass) is delivered to a downstream waterbody per unit of time. For example, an inlet stream that has high pollutant concentrations does not necessarily contribute the greatest amount of pollutants to its downstream lake. If the inlet stream possesses a very low discharge (i.e. water flow), it likely does not transport as much pollution to the lake as other inlets to the lake that have higher discharge levels. Thus, is it important to evaluate inlet streams' pollutant loading rates to fully understand which inlet is contributing the greatest amount of pollutants to a lake. This information is essential to prioritizing watershed management.

When each of the watershed streams is compared to one another (Figures 22-27), one notices that the Ridinger Lake outlet possessed the highest loading rate for most of the pollutants measured. The only exception to this is Elder Ditch, which exhibited the highest SRP loading rate at storm flow. That the Ridinger Lake outlet had the greatest loading rates, particularly for sediment and particulate nutrient pollutants, is not surprising. This portion of the stream possesses the greatest watershed area and therefore has the greatest potential for pollutant delivery. In-stream and in-lake chemical processes effect the transport of dissolved nutrients, so it is not unusual for variations in the magnitude of dissolved nutrient loading rates to occur between sampling stations as occurred in the Ridinger Lake watershed streams.

Knowing that the Ridinger Lake outlet possessed the greatest pollutant loading rates does little to help direct watershed management efforts, so it is useful to consider which streams aside from the Ridinger Lake outlet possessed high pollutant loading rates. Of the remaining streams, Shanton Ditch and Elder Ditch generally exhibited the highest pollutant loading rates under both base and storm flow conditions. The only exception was Mathias Ditch, which possessed the highest ammonia-nitrogen loading rate during storm flow. The high pollutant loading rates measured in Shanton and Elder Ditches suggest that management efforts should be directed at these subwatersheds.

It is also important to evaluate ***areal pollutant loading rates*** of the streams in determining prioritization of watershed management efforts. The areal pollutant loading rate normalizes the pollutant loading rates by drainage size. By dividing the pollutant loading rate of a stream by the drainage (or watershed) size of the stream, one obtains a *per acre pollutant loading rate*. Thus, pollutant loading rates in streams with large drainages, which are expected to have high pollutant loading rates, are directly comparable to pollutant loading rates in streams with small drainages, which are expected to have lower pollutant loading rates.

Examination of the areal pollutant loading rates for each of the inlet streams (Table 20) shows that, in general, Shanton Ditch and Mathias Ditch delivered more pollutants per acre of watershed than the other Ridinger Lake watershed streams. Pollutant delivery rates per acre of watershed in Elder Ditch and Delano Ditch are also of concern, but they generally were not as high as the areal loading rates observed in Shanton and Mathias Ditches. These results suggest that management efforts to reduce pollutant loading to the watershed lakes should focus on the Shanton Ditch and Mathias Ditch subwatersheds. Theoretically, treatment efforts in these subwatersheds will provide the greatest benefit per acre of treatment.

Table 20. Areal pollutant loading rates for the Ridinger Lake watershed streams on 5/1/03 (storm flow) and 8/6/03 (base flow). Red shading indicates base and storm flow sites which possessed the highest load, while pink indicates those sites with the second highest load.

Site Name	Site #	Area	Date	Event	NO_3-N Load (g/ha-yr)	NH_3-N Load (g/ha-yr)	TKN Load (g/ha-yr)	SRP Load (g/ha-yr)	TP Load (g/ha-yr)	TSS Load (g/ha-yr)
Ridinger Lake outlet	1	22,181 ac (8,980 ha)	5/1/03	storm	102.26	1.85	54.37	bdl	1.85	176.74
			8/6/03	base	48.87	3.00	46.20	0.62	3.50	296.74
Shanton Ditch	2	5,261 ac (2,130 ha)	5/1/03	storm	82.60	2.22	66.19	0.87	3.80	427.26
			8/6/03	base	19.04	7.97	28.72	1.24	3.24	175.04
Robinson Lake outlet	3	4,396 ac (1,780 ha)	5/1/03	storm	28.20	2.67	30.81	0.50	2.64	192.50
			8/6/03	base	7.76	1.40	9.64	0.58	1.18	29.57
Elder Ditch	4	7,653 ac (3,098 ha)	5/1/03	storm	27.92	1.65	26.47	2.10	4.00	133.97
			8/6/03	base	29.08	1.22	17.05	1.31	1.22	159.88
Doke Ditch	5	1,519 ac (615 ha)	5/1/03	storm	29.13	1.27	20.38	0.60	1.08	100.96
			8/6/03	base	10.53	0.80	6.43	0.25	0.75	70.77
Mathias Ditch	6	2,487 ac (1007 ha)	5/1/03	storm	50.88	12.86	34.51	1.32	18.49	12.21
			8/6/03	base	35.86	bdl	19.20	1.32	1.94	91.63
Delano Ditch	7	1,880 ac (761 ha)	5/1/03	storm	47.45	2.55	37.07	1.01	bdl	240.35
			8/6/03	base	17.33	1.77	21.26	0.87	1.40	5.97

bdl=Below laboratory detection level

There is limited evidence that both Ridinger and Robinson Lakes serve as sediment traps for sediment and particulate nutrients. The sum of the total phosphorus and total suspended solid loading rates from Shanton Ditch, Elder Ditch, and the Robinson Lake outlet during storm flow was greater than the total phosphorus and total suspended solid loading rates in the Ridinger Lake outlet at storm flow. The sum of the inlets' total phosphorus loading rates at base flow also exceeded the total phosphorus loading rate in the Ridinger Lake outlet at base flow. Similarly, the sum of the total organic nitrogen, total phosphorus, and total suspended solid loading rates from Doke Ditch and Mathias Ditch at base flow was greater than the total organic nitrogen, total phosphorus, and total suspended solid loading rates in the Robinson Lake outlet at base flow. The sum of the total phosphorus loading rates from Doke Ditch and Mathias Ditch at storm flow also exceeded the total phosphorus loading rate the Robinson Lake outlet at storm flow.

The sampling regime did not definitively determine that Ridinger and Robinson Lakes trapped sediment or particulate nutrients. It is possible that sediment and particulate nutrients were sequestered by the riparian zones of the inlet streams or by wetlands at the mouths of the lakes. Mathias Ditch in particular possesses a relatively healthy riparian zone, so some sediment and particulate nutrients may be deposited in the stream's riparian zone before reaching Robinson Lake. A different sampling regime would be needed to better understand the extent of these lakes' ability to serve as sediment and particulate nutrient traps.

Ridinger Lake
Three of the watershed streams sampled as part of this study represent the three major subwatersheds of Ridinger Lake: the Shanton Ditch subwatershed, the Elder Ditch subwatershed, and the Robinson Lake/Mathias Ditch subwatershed. Understanding which stream (and therefore which subwatershed) delivers more pollutants will help direct management efforts for restoring Ridinger Lake. As noted above, Shanton Ditch and Elder Ditch possessed the highest pollutant loading rates for most of the pollutants measured in this study. Shanton Ditch also exhibited some of the highest areal pollutant loading rates in the study, and Elder Ditch's areal pollutant loading rates were of concern. Combined, this data suggest that *management efforts to improve water quality in Ridinger Lake* should focus on treating the Shanton Ditch subwatershed for all pollutants and the Elder Ditch subwatershed specifically for reducing phosphorus and sediment loading.

Robinson Lake
Of the two inlets to Robinson Lake, Mathias Ditch contributes more pollutants to Robinson Ditch compared to Doke Ditch. The only exception was during storm flow, Doke Ditch exhibited a higher total suspended solids loading rate. These results are not surprising given that Mathias Ditch drains nearly twice as much land as Doke Ditch. However, even when areal loading rates are compared to account for drainage size, Mathias Ditch still generally delivers more pollutants to Robinson Lake per acre of watershed. Doke Ditch delivered more total suspended solids during storm flow and more nitrate and ammonia during base flow per acre of watershed than Mathias Ditch. These results suggest *watershed management efforts to improve water quality in Robinson Lake* should target Mathias Ditch for the most part. Efforts to curb sediment transport to the lake should prioritize treatment in the Doke Ditch subwatershed.

3.2.2 Macroinvertebrates

The results of the macroinvertebrate survey do little to help direct watershed management decisions. Each of the watershed streams possessed a moderately impaired macroinvertebrate community dominated by moderately tolerant to very tolerant species. (Appendix E presents a list of macroinvertebrate families collected at each site.) The streams' overall mIBI scores ranged from a low of 2.8 in Elder and Mathias Ditches to a high of 3.5 in Shanton and Doke Ditches (Table 21). Although the streams' scores differ slightly, each site fell in the same biotic integrity class. Karr and Chu (1999) indicate that differences between scores *within* an integrity class are not statistically significant; these differences within integrity classes often reflect the large variability associated with sampling natural biological communities rather than true differences in community quality.

Table 21. Summary of classification scores and mIBI scores for each stream sampling site within the Ridinger Lake watershed, August 14, 2003.

	Shanton Ditch Site 2	Robinson Lake Outlet Site 3	Elder Ditch Site 4	Doke Ditch Site 5	Mathias Ditch Site 6
HBI	2	0	0	0	2
No. Taxa (family)	4	6	4	8	4
% Dominant Taxa	2	4	4	8	4
EPT Index	0	4	6	2	2
EPT Count	4	0	2	0	2
EPT Count/Total Count	6	2	2	2	2
EPT Abun./Chironomid Abun.	4	2	0	2	2
Chironomid Count	6	6	4	6	4
mIBI Score	**3.5**	**3.0**	**2.8**	**3.5**	**2.8**

The individual metrics that make up the mIBI show that some difference between the macroinvertebrate communities in the watershed sites exist. The number of taxa found in each stream differed. Shanton and Mathias Ditches supported only 14 families, while Doke Ditch supported 21 families of macroinvertebrates. The evenness of the taxa differed among streams as well. In Shanton Ditch, members of the *Hydropsychidae* family comprised 50% of the total macroinvertebrates collected. By comparison, the dominant taxon in Doke Ditch accounted for only 13% of the total macroinvertebrate community. The streams supported varying number of EPT (*Ephemeroptera, Plecoptera*, and *Trichoptera*) taxa. Elder Ditch and the Robinson Lake outlet stream are home to five and six different EPT taxa, respectively, while the other watershed streams supported only two or three EPT taxon. Given these differences in individual metrics among the watershed streams, it may be useful to consider each of the streams' macroinvertebrate communities individually.

Shanton Ditch (Site 2)

Low species diversity and, in particular, low EPT diversity relative to the other watershed streams characterize Shanton Ditch's macroinvertebrate community (Table 22). Despite the stream's low EPT diversity, members of the *Hydropsychidae* family, in the order *Trichoptera*, dominate the stream's macroinvertebrate community accounting for 50% of the community. The gravelly substrate present at the Shanton Ditch sampling site is ideal habitat for *Hydropsychidae,* so the dominance of this family at this sampling site is not surprising. Members of the moderately tolerant *Chironomidae* and very tolerant *Asellidae* families were subdominant components of Shanton Ditch's macroinvertebrate community. The stream's Hilsenhoff family biotic index (HBI) was 5.50 indicating fairly substantial organic pollution is likely in the stream. The water chemistry sampling supports this. Shanton Ditch exhibited relatively high total phosphorus and total organic nitrogen concentrations at base flow, or under normal conditions. Overall, the stream's mIBI score was 3.5, suggesting its macroinvertebrate community is moderately impaired.

Table 22. Raw metric scores, classification scores, and mIBI score for Shanton Ditch (Site 2), August 14, 2003.

mIBI Metric	Raw Score	Metric Score
HBI	5.50	2
Number of Taxa (family)	14	4
% Dominant Taxa	50.0	2
EPT Index	2	0
EPT Count	63	4
EPT Count/Total Count	0.54	6
EPT Count./Chironomid Count	3.50	4
Chironomid Count	18.00	6
mIBI Score		3.5

Robinson Lake outlet (Site 3)

Moderately tolerant (*Hydropsychidae* and *Chironomidae*) and very tolerant (*Asellidae* and *Talitridae*) families dominate the Robinson Lake outlet stream's macroinvertebrate community. Individuals from the two most tolerant families account for nearly half of the stream's total macroinvertebrate population. The stream's HBI score reflects the dominance of extremely tolerant families (Table 23). The stream's low HBI score of 8.10 is indicative of severe organic pollution. The water chemistry results do not necessarily agree with this assessment. Habitat impairment may be influencing the biotic community at this site more than water quality. The stream supported a high number of EPT families relative to the other watershed sites; however few individuals from these families were collected. Overall, the stream's mIBI score was 3.0, suggesting its macroinvertebrate community is moderately impaired.

Table 23. Raw metric scores, classification scores, and mIBI score for the Robinson Lake outlet (Site 3), August 14, 2003.

mIBI Metric	Raw Score	Metric Score
HBI	8.10	0
Number of Taxa (family)	16	6
% Dominant Taxa	33.0	4
EPT Index	5	4
EPT Count	18	0
EPT Count/Total Count	0.18	2
EPT Count./Chironomid Count	1.29	2
Chironomid Count	14.00	6
mIBI Score		3.0

Elder Ditch (Site 4)

Like the Robinson Lake outlet stream, moderately tolerant (*Gerridae* and *Chironomidae*) and very tolerant (*Asellidae*) families dominate Elder Ditch. The ditch also possessed the poorest diversity with only 13 families represented in the macroinvertebrate community (Table 24). Despite its low diversity, almost half of the families found in Elder Ditch were EPT families. As observed in the Robinson Lake outlet, the number of individuals from each these EPT families was low. The ditch's HBI score was 6.40, indicating that substantial organic pollution was likely in the stream. The results of the water chemistry assessment showed the ditch has moderate total organic nitrogen levels relative to the other watershed streams. Habitat may also play a role in the observed poor mIBI score of 2.8.

Table 24. Raw metric scores, classification scores, and mIBI score for Elder Ditch (Site 4), August 14, 2003.

mIBI Metric	Raw Score	Metric Score
HBI	6.40	0
Number of Taxa (family)	13	4
% Dominant Taxa	35.0	4
EPT Index	6	6
EPT Count	22	2
EPT Count/Total Count	0.17	2
EPT Count./Chironomid Count	0.76	0
Chironomid Count	29.00	4
mIBI Score		2.8

Doke Ditch (Site 5)

It high taxa richness and evenness distinguish Doke Ditch from the other watershed streams (Table 25). Doke Ditch supported 21 taxa at the time of sampling and, compared to the other watershed streams, individuals were relatively evenly distributed among these 21 taxa. Members of the Gastropod family *Ancylidae* accounted for 13% of the ditch's macroinvertebrate community. Members of the moderately tolerant (*Hydropsychidae*) and the extremely tolerant (*Corixidae*) families represented 20% of the community. Only 14 individuals from three EPT families were observed in Doke Ditch; however the ditch supported one member of the extremely sensitive Lepidostomatidae family. Overall, the ditch possessed a mIBI score of 3.5, suggesting its macroinvertebrate community is moderately impaired.

Table 25. Raw metric scores, classification scores, and mIBI score for Doke Ditch (Site 5), August 14, 2003.

mIBI Metric	Raw Score	Metric Score
HBI	6.10	0
Number of Taxa (family)	21	8
% Dominant Taxa	13.0	8
EPT Index	3	2
EPT Count	14	0
EPT Count/Total Count	0.14	2
EPT Count/Chironomid Count	2.00	2
Chironomid Count	7.00	6
mIBI Score		3.5

Mathias Ditch (Site 6)

The relative lack of individuals from very tolerant families differentiates the macroinvertebrate community in Mathias Ditch from the macroinvertebrate communities in the other watershed streams. Most (82%) individuals in Mathias Ditch represent the moderately tolerant families *Chironomidae*, *Simuliidae*, *Baetidae*, and *Hydropsychidae* (Table 26). The ditch supported fewer families (14) than most of the other watershed streams. Twenty-nine individuals from three EPT families were observed in Mathias Ditch. While the ditch supports few individuals from EPT families, it support similar numbers to all the other Ridinger Lake watershed streams except Shanton Ditch. Overall, the ditch possessed a mIBI score of 2.8, suggesting its macroinvertebrate community is moderately impaired.

Table 26. Raw metric scores, classification scores, and mIBI score Mathias Ditch (Site 6), August 14, 2003.

mIBI Metric	Raw Score	Metric Score
HBI	5.30	2
Number of Taxa (family)	14	4
% Dominant Taxa	32.3	4
EPT Index	3	2
EPT Count	29	2
EPT Count/Total Count	0.28	2
EPT Count/Chironomid Count.	0.89	2
Chironomid Count	33.00	4
mIBI Score		2.8

3.2.3 Habitat

In addition to a stream's water chemistry, habitat quality also influences the quality of the biotic community inhabiting the stream. Thus, it is useful to examine the habitat quality of the stream in the Ridinger Lake watershed. Table 27 presents the results of the QHEI calculated at each of the seven study sites. (Appendix F presents the QHEI data sheets for each of the seven study sites.) The following paragraphs provide a short description of the in-stream and riparian characteristics observed at each of the study sites.

Table 27. QHEI Scores for the Ridinger Lake watershed streams, August 14, 2003.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Site 1	12	8	7.5	7.5	8	0	10	**53**
Site 2	6	11	9	5.5	6	2	4	**44**
Site 3	11	11	8.5	4.5	7	3	2	**47**
Site 4	5	4	5	2.5	7	0	6	**30**
Site 5	12	10	13	9	3	1	6	**54**
Site 6	12	13	16	7	6	3	4	**61**
Site 7	1	5	4	5.3	0	0	4	**19**

Ridinger Lake outlet stream (Site 1)

Open pasture and forest surround the Ridinger Lake outlet stream at the sampling site (Figure 28). A residential campground, home to several thousand permanent and seasonal residents, is located immediately upstream from the sampling site. The riparian buffer zone is wide on along both banks reaching widths greater than 150 feet (45 m). Within the riparian buffer, the vegetation consists mostly of trees and shrubs with some grasses adjacent to the stream banks. In-stream cover at the site is sparse with the presence of one deep pool, some overhanging vegetation, aquatic macrophytes, and woody debris. Bank erosion is moderate. The stream lacks sinuosity and has poorly developed pools. This is a result of recent dredging operations. There is no riffle habitat in the study reach. These are characteristic of a channelized stream. A mixture of sand and gravel covers the stream channel. The gravel is moderately to extensively embedded. The stream's QHEI score was 53 out of 100. It received the third highest habitat score of the Ridinger Lake watershed streams.

Figure 28. Ridinger Lake outlet (Site 1) sampling location.

Shanton Ditch (Site 2)

Old fields and residential yards surround Shanton Ditch at the sampling site (Figure 29). The stream's riparian buffer is narrow extending at most 30 feet (9 m) from the banks. The buffer's vegetation consists of trees and shrubs. The stream has a moderate amount of in-stream cover including overhanging vegetation, deep pools, and woody debris. Bank erosion is moderate along both banks. The low sinuosity and poor pool and riffle development highlight the historical channelization of the stream. Muck and gravel are the dominant substrate types. The substrate is extensively embedded and a thick layer of silt covers the channel. Shanton Ditch received a low QHEI score of 44 out of 100 points.

Figure 29. Shanton Ditch (Site 2) sampling location.

Robinson Lake outlet stream (Site 3)

Open pastures and residential land surround the Robinson Lake outlet stream at the sampling site (Figure 30). The width of the riparian buffer is narrow, ranging from 15 to 30 feet (5 to 9 m). Vegetation within the buffer is comprised mostly of grasses with some small trees and shrubs. Overhanging vegetation, shallow water, and deep pools provide a moderate amount of in-stream cover. Bank erosion on both banks is moderate. A portion of the sampling reach shows some recovery from channelization while the rest of the study reach shows no recovery from channelization. Like many streams in the Ridinger Lake watershed, the Robinson Lake outlet stream possesses low sinuosity and poor pool and riffle development. The dominant substrate in the stream is sand; however muck and gravel are also present in lower quantities. The substrate is moderately embedded and has some silt cover. Bank stability is low. The Robinson Lake outlet stream's QHEI score of 47 was the median for the Ridinger Lake watershed streams.

Figure 30. Robinson Lake (Site 3) outlet sampling location.

Elder Ditch (Site 4)

Row crop agriculture surrounds Elder Ditch at the sampling site (Figure 31). At the time of sampling, all wooded vegetation along the banks was being cleared with a backhoe leaving exposed soils. In-stream cover is nearly absent from the ditch, although a limited amount of woody debris and deep pools exist. Bank erosion is severe due to vegetation removal. Recent dredging operations have contributed to the stream's low sinuosity and poor pool development. No riffle habitat exists in the sampling reach. The dominant substrate components are sand and muck. Overall habitat quality is extremely poor in Elder Ditch as evidenced by its QHEI score of 30 out of 100. Elder Ditch received the second lowest QHEI score of all the Ridinger Lake watershed streams.

Figure 31. Elder Ditch (Site 4) sampling location.

Doke Ditch (Site 5)

The land surrounding Doke Ditch at the sampling site is forested with a riparian buffer extending over 150 feet (45 m). Trees and shrubs with some grasses are the main components of the riparian vegetation (Figure 32). Moderate in-stream cover is comprised of overhanging vegetation, shallow water, and aquatic macrophytes. Stream banks are experiencing moderate erosion. Stream sinuosity is low with a fair pool and riffle development. Substrate is comprised mostly of gravel and sand with the presence of some cobble and silt. Silt cover and level of embeddedness of the substrate are moderate. Overall, Doke Ditch scored the second highest among the watershed sampling sites, a 54 out of 100.

Figure 32. Doke Ditch (Site 5) sampling location.

Mathias Ditch (Site 6)
Forested and residential land surrounds Mathias Ditch at the sampling site (Figure 33). The riparian zone extends more than 150 feet (45 m) along the right bank (facing downstream) and between 30 and 150 feet (9 and 45 m) along the left bank. Riparian vegetation is a mixture of small to mature trees and grasses. In-stream cover is moderate and includes undercut banks, overhanging vegetation, rootwads, aquatic macrophytes, and woody debris. Bank erosion varies from moderate (right bank) to severe (left bank). Mathias Ditch possesses moderate sinuosity and good pool and riffle development. Gravel and sand are the dominant substrate features. Cobble is present in smaller quantities. The extent of substrate embeddedness is low, and silt covers only a portion of the channel bottom. Mathias Ditch had the best QHEI score among the Ridinger Lake watershed streams, receiving a QHEI score of 61 out of 100.

Figure 33. Mathias Ditch (Site 6) sampling location.

Delano Ditch (Site 7)
Delano Ditch is a narrow, slow flowing ditch that bisects a corn field (Figure 34). The ditch's riparian zone is fairly narrow. On one corner, the landowner maintains a 66-foot (20.1-m) wide filter strip planted with warm season grasses. This filter strip is enrolled in the Conservation Reserve Program. In-stream cover is sparse with limited overhanging vegetation and some aquatic macrophytes. Little bank erosion was observed. The stream is highly channelized with no apparent sinuosity or pool development. No riffle habitat exists in the study reach. A thick layer of muck/silt (over 2 feet in depth) covers the channel bottom. Overall Delano Ditch's habitat is extremely poor; the site received a QHEI score of 19 out of 100, the lowest of all the Ridinger Lake watershed streams.

Figure 34. Troy Cedar inlet (Site 7) sampling location.

The QHEI scores help explain the low biotic integrity scores observed in the Ridinger Lake watershed streams. The QHEI scores indicate that in-stream and riparian habitat is impaired at all sites except Mathias Ditch. Mathias Ditch possessed a QHEI score of 61, suggesting that it is capable of supporting a healthy warmwater fauna. Thus, the biotic impairment at that site is likely due to poor water quality. The Ridinger Lake outlet stream and Doke Ditch QHEI scores suggested that habitat impairment at these sites was minor compared to the other sites. Recent dredging operations have impaired the habitat in the Ridinger Lake outlet stream. Both the Ridinger Lake outlet stream and Doke Ditch possessed QHEI scores in IDEM's "partially supportive" rather than "fully supportive" range. Thus, it is likely that water quality played a greater role in impairing the biotic community at these sites than habitat quality. QHEI scores of the remaining watershed streams indicate severe habitat impairment. In these streams (Shanton Ditch, the Robinson Lake outlet stream, Elder Ditch, and Troy Cedar Ditch), both poor water quality and poor habitat quality play a role in impairing the streams' biotic communities.

Many of the sites share some common characteristics. Riffles are absent or poorly developed in each of the watershed streams. Many of the streams offer only run habitat to aquatic biota. This lack of habitat diversity leads to a lack of biotic diversity since different organisms occupy different habitat types, or ***niches***, within a stream. The watershed streams also lack in-stream cover. This is especially true in Elder Ditch and the Troy Cedar inlet where dredging operations removed most of the natural cover. Substrate quality is relatively poor in each of the watershed streams. The dominance of muck/silt substrate, heavy silt covering, and embeddedness of the substrate resulted in exceptionally poor substrate quality scores in Elder Ditch and the Troy Cedar inlet. Riparian cover was noticeably better in Mathias Ditch, the Ridinger Lake outlet stream, and Doke Ditch, which all have at least "partially supportive" habitat, compared to the other watershed streams. Overall, habitat quality is generally poor in the Ridinger Lake watershed streams and restoration measures are necessary to ensure healthy, functioning stream systems.

4.0 LAKE ASSESSMENT

4.1 Morphology and Shoreline Development

4.1.1 Ridinger Lake

Ridinger Lake is approximately 135 acres (54.6 ha) in size and has a volume of approximately 2,572 acre-feet (3,173,833 m^3) (Table 28). Ridinger Lake is fairly shallow with approximately 67% of the lake's surface area covering water that is less than 30 feet (9.1 m) deep (Figure 35). Figure 36 (based on the IDNR bathymetric map created in 1954) shows that Ridinger Lake steadily deepens until 42 feet in depth (12.2 m). The relative straightness of the curve indicates that shallow and deep water are proportionate in this lake. For example, excessive shallows which are capable of supporting rooted aquatic plants do not exist in this lake. Volume increases fairly uniformly with depth in Ridinger Lake until approximately 30 feet (9.1 m) in depth where there is a sharp increase in depth per unit volume (Figure 37). The sharp increase in depth per unit volume in the lake's deeper water suggests that very little of Ridinger Lake's volume is contained in the lake's deepest waters.

Table 28. Morphological characteristics of Ridinger Lake.

Ridinger Lake	
Surface Area	135 acres (54.6 ha)
Volume	2,572 acre-feet (3,173,833 m^3)
Maximum Depth	42 feet (12.8 m)
Mean Depth	19 feet (5.8 m)
Shoreline Length	12,645 feet (3,854 m)
Shoreline Development Ratio	1.5:1

The shoreline development ratio is a measure of the development potential of a lake. It is calculated by dividing the shoreline length by the circumference of a circle that has the same area as the lake. A perfectly circular lake with the same area as Ridinger Lake (135 acres or 54.6 ha) would have a circumference of 8,596 feet (2,260 m). Dividing Ridinger Lake's shoreline length (12,645 feet or 3,854 m) by 8,594 feet yields a ratio of 1.5:1. This ratio is fairly low compared to shoreline development ratios observed on many other developed, northern Indiana lakes. Ridinger Lake contains a limited number of shoreline channels that are typically observed on other popular Indiana lakes such as lakes in the Barbee Chain and Lake Tippecanoe. Shoreline channels increase the lake's shoreline development ratio and increase the potential for the development around the lake. Given the immense popularity of lakes in northern Indiana, this potential is often realized. Greater development around a lake has obvious impacts on the health of the lake system.

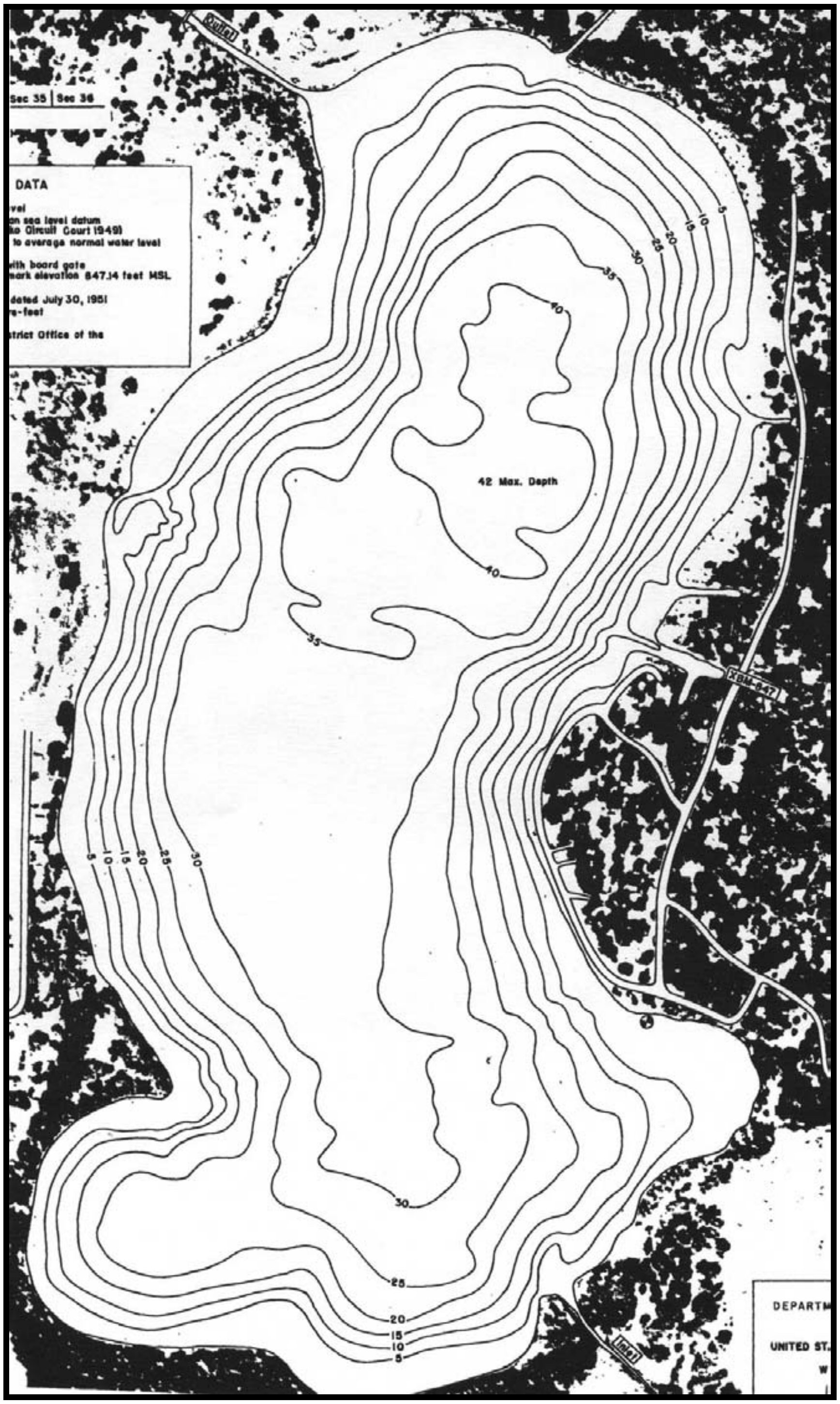


Figure 35. Bathymetric map of Ridinger Lake. Source: IDNR, 1954. Scale: 1”=800’.

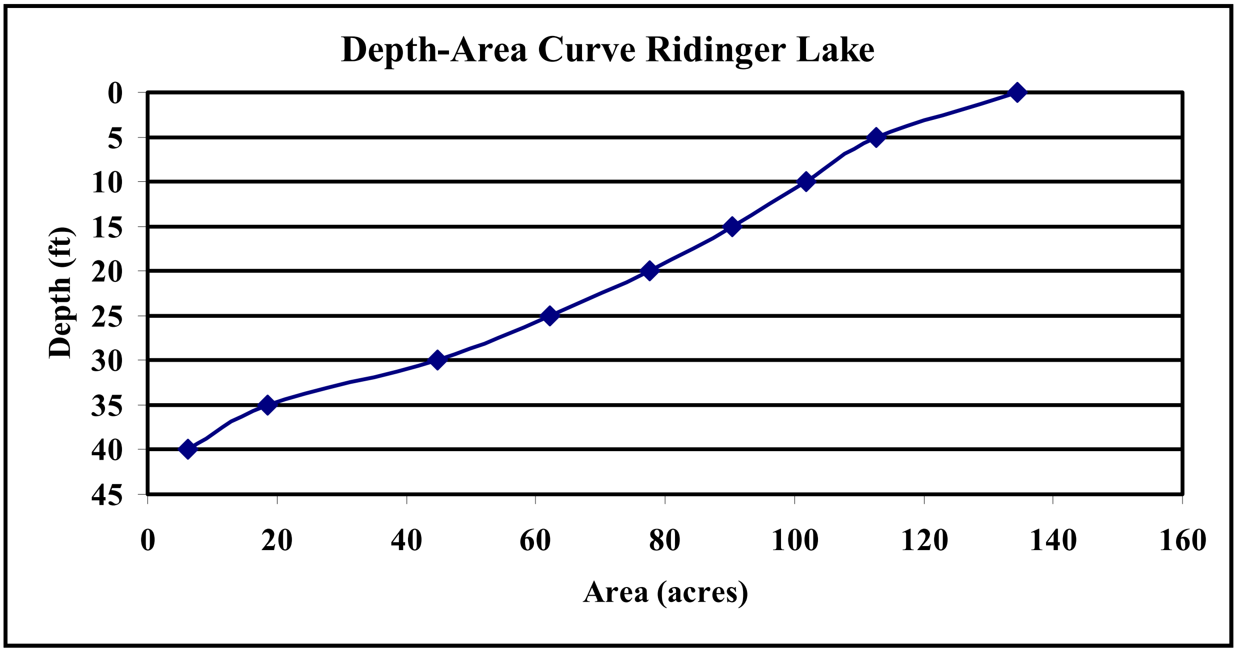


Figure 36. Depth-area curve for Ridinger Lake.

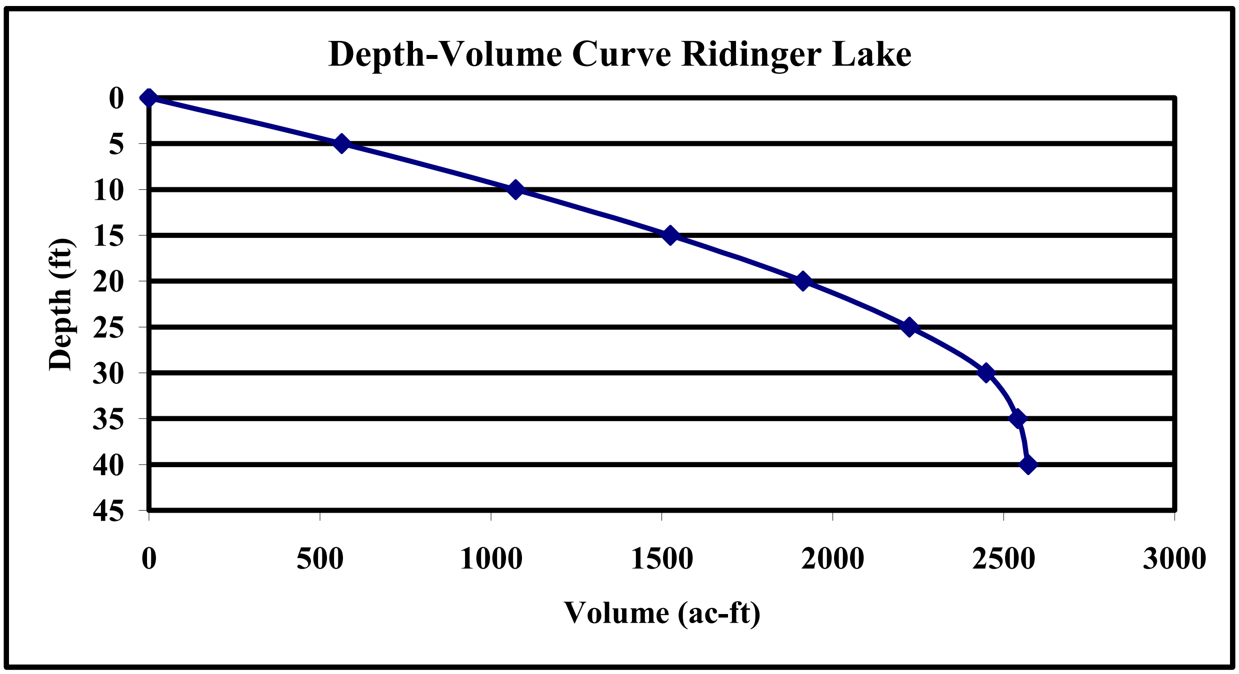


Figure 37. Depth-volume curve for Ridinger Lake.

Ridinger Lake's shoreline is moderately developed compared to other northern Indiana lakes (Figure 38). Grant (1999) notes that lakeside residential development in the area began in the 1950s and 1960s. This is likely true on Ridinger Lake. In 1978, IDNR fisheries biologists noted that the east and west shorelines of Ridinger Lake had been residentially developed with a large campground, the Jellystone Park, located on the western shore (Pearson, 1979). Hippensteel estimated in 1980 that 116 homes lined the shores of Ridinger Lake (Hippensteel, 1989). (This estimate excludes Jellystone Park.) International Science and Technology (IST) concurred with this estimate, noting that most of the development was concentrated on the east and southwest shorelines. In 1990, Jellystone Park supported a maximum capacity of 1200 campsites and was typically 25-30% full. Generally, the campground only reached maximum capacity over holiday weekends (IST, 1990). In 1995, IDNR fisheries biologists noted that residential development appeared much the same as that observed in 1979 (Pearson, 1995).

Currently, residential development around Ridinger Lake appears to be very similar to levels observed in 1980. In total, approximately 120 homes and Jellystone Park surround Ridinger Lake. Much of the eastern and western shorelines are developed for residential use. The soils map (Figure 8) suggests much of the eastern shoreline and at least a portion of the western shoreline have been altered to allow this residential development. Some emergent vegetation, mostly low profile species such as pickerel weed, is present along these shorelines. Throughout the remainder of the developed area, residents have created beaches and installed a limited number of wooden and rock seawalls and even fewer concrete seawalls. Jellystone Park maintains sandy beach for visitor access to the Ridinger Lake and provides pontoon and boat rentals for facility visitors (Jellystone Park, 2004). The concrete boat ramp maintained by Jellystone Park can be seen in Figure 38 along the western shoreline of the lake. The ramp is private, but can be accessed for a small fee.

The southeastern, southern, northwestern, and northern shorelines remain largely undeveloped. IDNR fisheries biologists label three of these areas, the southeastern, southern, and northwestern areas, as significant wetland habitat along the lakeshore (Pearson, 1995). One residence is present along the southern shoreline; however, a shrub and tree buffer is present along a majority of their lake frontage.

A few minor erosion areas were noted during the shoreline erosion survey of the lake. Some erosion due to wave action is occurring along the southwestern shoreline where a homeowner maintains a mowed grass yard to the lake's edge. Other areas of minor erosion were noted along the eastern shoreline near the intersection of channels with the main body of the lake. All of these areas could benefit from the installation and planting of shoreline buffers. (See the **Management Section** for more information about shoreline stabilization techniques.)

Figure 38. Aerial photograph of Ridinger Lake. Source: USGS, 1998. Scale: 1"=800'.

4.1.2 Robinson Lake

Robinson Lake is approximately 59 acres (23.9 ha) in size and has a volume of approximately 1,025 acre-feet (1,264,844 m^3) (Table 29). The lake contains three deep holes, the deepest of which extends to a depth of 51 feet (15.2 m) and is located in the southwest corner of the lake (Figure 39). Figures 40 and 41 present depth-area and depth-volume curves for Robinson Lake based on the IDNR bathymetric map (IDNR, 1959). Robinson Lake deepens steadily until a depth of 40 feet (12.2 m) at which point the change in lake depth with area increases rapidly. Approximately one third of the lake is less than 10 feet (3.1 m) in depth, which is generally considered the lower limit of rooted plant growth. This means that a third of Robinson Lake's surface area could potentially support rooted aquatic plants. Approximately 71% of the lake's surface area is less than 30 feet (9.1 m) in depth, indicating the lake is very shallow in nature. Volume increases fairly uniformly with depth in Robinson Lake until approximately 35 feet (10.7 m) in depth where there is a sharp increase in depth per unit volume. The sharp increase in depth per unit volume in the lake's deeper water suggests that very little of Robinson Lake's volume is contained in the lake's deepest waters. Robinson Lake's irregular shape results in a shoreline development ratio that is similar to Ridinger Lake's shoreline development ratio. Given that Robinson Lake's shoreline is largely IDNR property, it's realistic development potential is low at this time.

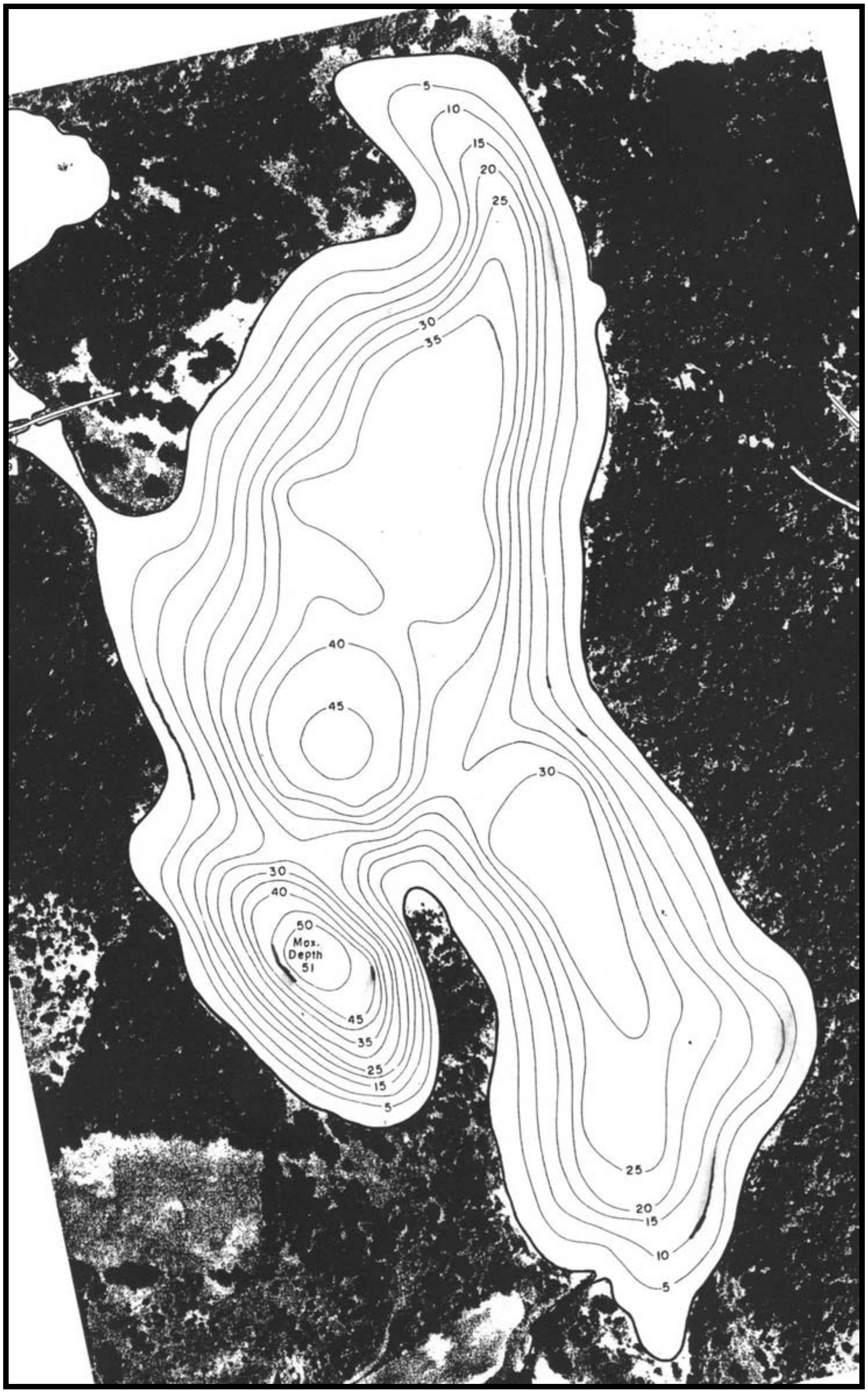


Figure 39. Bathymetric map of Robinson Lake. Source: IDNR, 1959. Scale: 1"=440'

Table 29. Morphological characteristics of Robinson Lake.

Robinson Lake	
Surface Area	59 acres (23.9 ha)
Volume	1,025 acre-feet (1,264,844 m^3)
Maximum Depth	51 feet (15.2 m)
Mean Depth	17.4 feet (5.3 m)
Shoreline Length	8,280 feet (2,524 m)
Shoreline Development Ratio	1.5:1

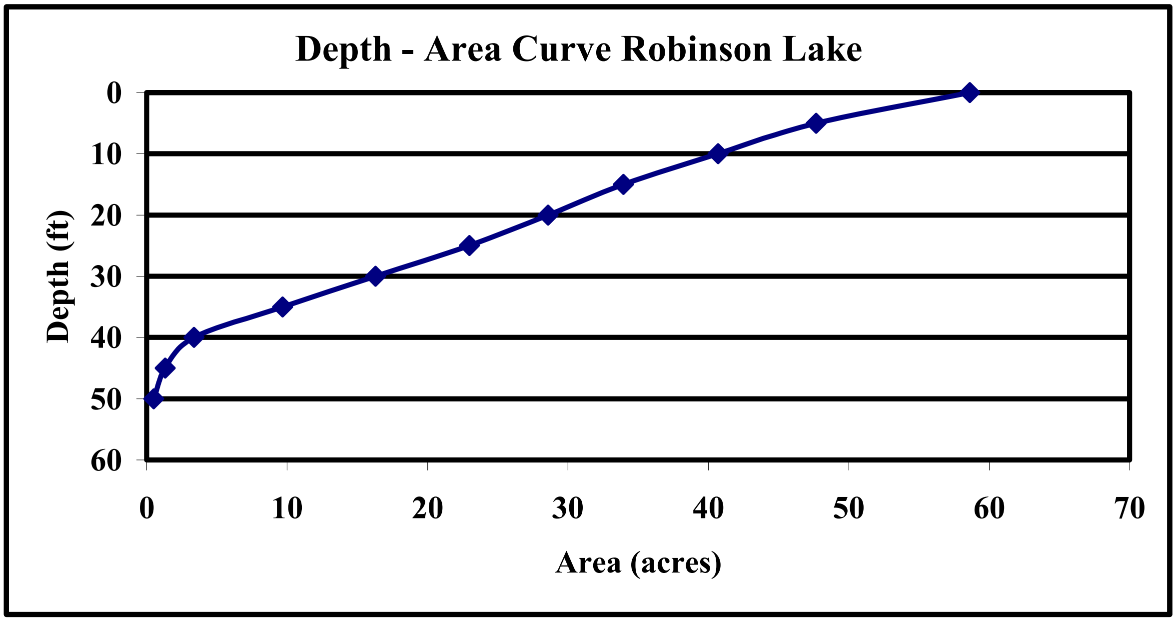


Figure 40. Depth-Area curve for Robinson Lake.

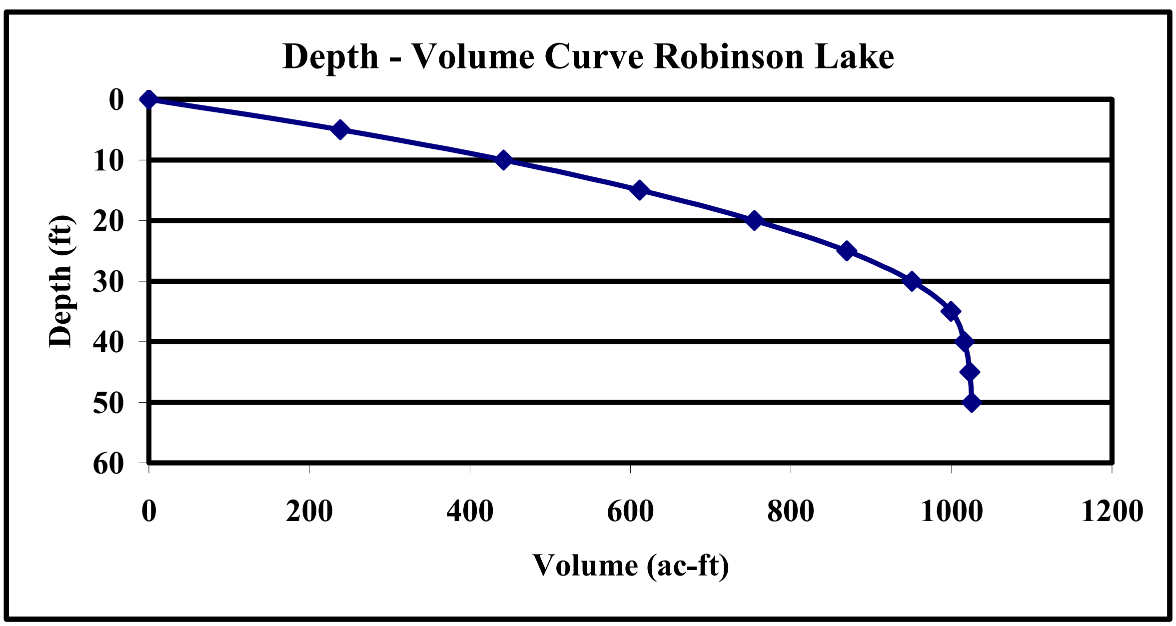


Figure 41. Depth-volume curve for Robinson Lake.

The Robinson Lake shoreline remains almost completely undeveloped (Figure 42). Until 1993, the Boy Scouts of America (BSA) owned property that bordered three-quarters of the Robinson Lake shoreline. With the exception of a small area near the southwest corner of the lake that was used for a beach, the BSA did not disturb the lake's natural shoreline (Braun, 1994). In December 1993, the Indiana Department of Natural Resources purchased the BSA property and converted it to the Deniston Resource Area. The shoreline remains unchanged with the exception of the beach, which was converted to a gravel, public access ramp (Braun, 1997). Three other property owners control the remaining portion of the lakeshore, which has also remained undeveloped. IDNR fisheries biologists noted the presence of a small, gravel boat ramp near the northeast corner of the lake and two piers along the eastern shoreline (Braun, 1997). During the current study, a pier and very small beach area were observed in the southwest corner of the lake. In general, however, Robinson Lake remains undeveloped.

Figure 42. Aerial photograph of Robinson Lake. Source: USGS, 1998. Scale: 1"=600'.

4.1.3 Troy Cedar Lake

Troy Cedar Lake is approximately 89 acres (36 ha) in size and has a volume of approximately 2,211 acre-feet (2,728,362 m^3). The lake reaches a maximum depth of 86 feet (30 m) near the center of the lake (Figure 43). The depth-area curve for Troy Cedar Lake shows that most of the lake's surface area (78%) covers water that is less than 40 feet (12.2 m) deep (Figure 44). Approximately 25% of the lake's surface area covers water that is less than 10 feet (3.1 m) deep, which is generally considered the lower limit of rooted plant growth. This means that 25% of Troy Cedar Lake's surface area could potentially support rooted aquatic plants. Figure 45 shows that the lake's volume gradually increases until about the 30-foot (9.1-m) depth where the curve gradually becomes steeper with each 5-foot interval in depth. The deeper waters of Troy Cedar Lake occupy proportionally less volume of water. Troy Cedar Lake's shoreline development ratio is 1.5:1 (Table 30). This shoreline development ratio is relatively small and reflects the lack of channels on the lake.

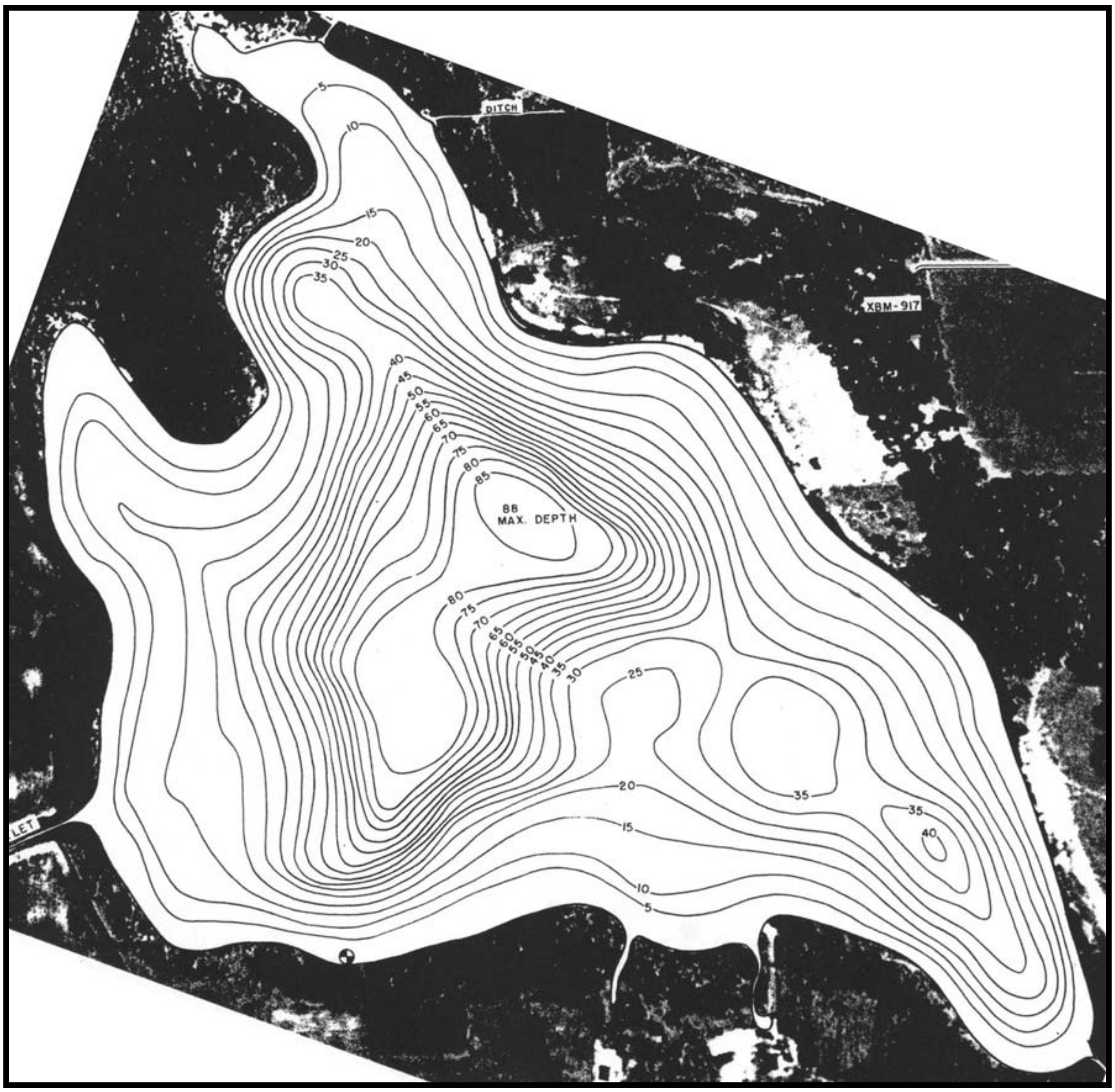


Figure 42. Bathymetric map of Troy Cedar Lake. Source: IDNR, 1956. Scale: 1"=400'.

Table 30. Morphological characteristics of Troy Cedar Lake.

Troy Cedar Lake	
Surface Area	89 acres (36 ha)
Volume	2,211 acre-feet (2,728,362 m^3)
Maximum Depth	86 feet (30 m)
Mean Depth	24.8 feet (7.6 m)
Shoreline Length	10,414 feet (3,174 m)
Shoreline Development Ratio	1.5:1

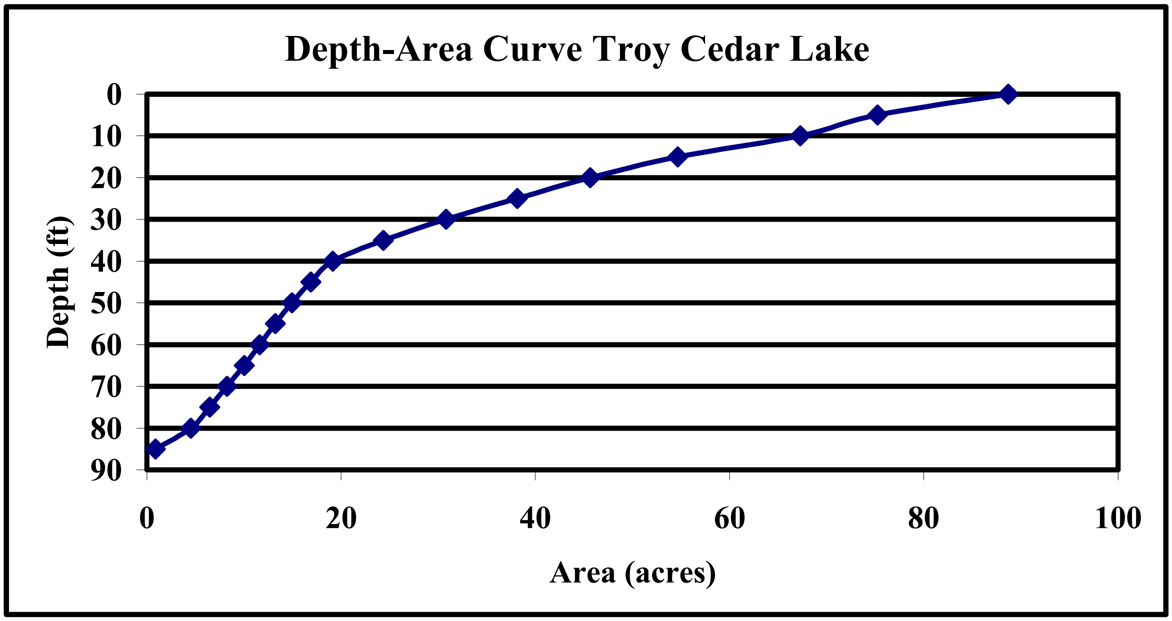


Figure 43. Depth-area curve for Troy Cedar Lake

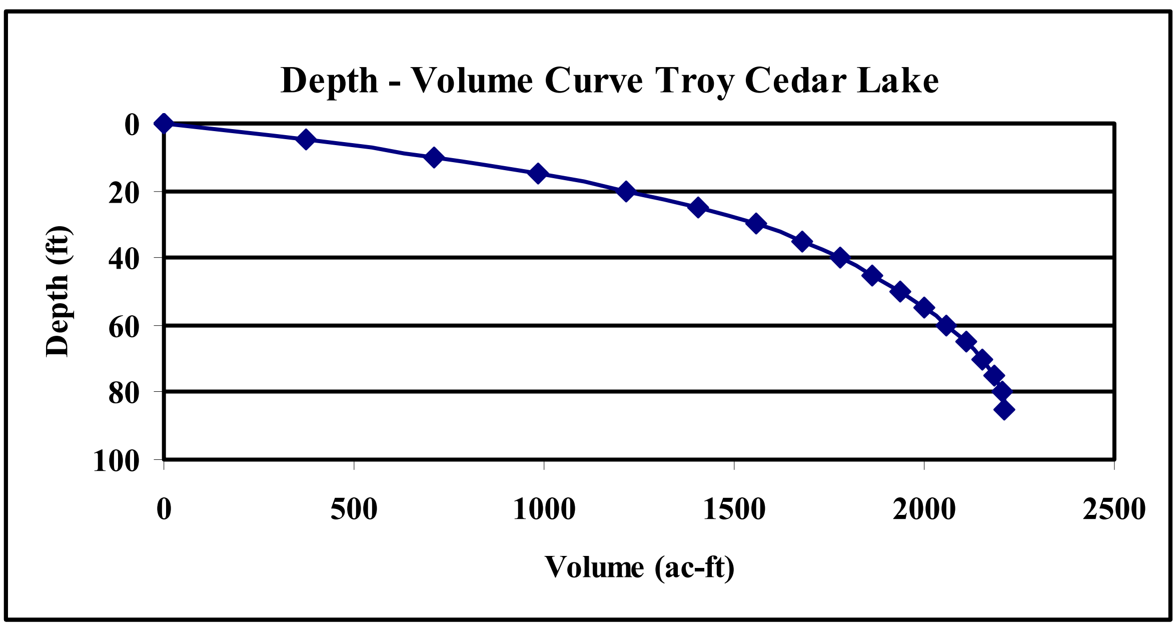


Figure 44. Depth-volume curve for Troy Cedar Lake

Troy Cedar Lake's shoreline is relatively undeveloped when compared to other lakes in northern Indiana. In 1965, IDNR fisheries biologists indicated that approximately 98% of Troy Cedar Lake's shoreline remained forested. Biologists noted the presence of four cottages, nine trailers, and a youth camp around Troy Cedar Lake. Despite the limited residential development, IDNR biologists counted approximately fifty boats and two pontoons moored on the lake at the time of their survey (McGinty, 1966). Over the next fifteen years residential development continued. Braun (1982) observed that much of the southern shoreline was developed for residential use by 1981, although the homes occupied larger lots than typical waterfront property. A youth camp and expanded trailer park bordered the lake's eastern shoreline (Braun, 1982).

Currently, Troy Cedar Lake's shoreline appears much the same as it did in 1981. In total, approximately 70 houses, including those in the trailer park, surround Troy Cedar Lake (Figure 46). The trailer park and youth camp still exist along the lake's eastern shoreline. Residents along the eastern shoreline have created beaches or maintain mowed grass lawns to the lake's edge. A limited number of glacial rock seawalls have also been constructed along the eastern shoreline. Troy Cedar Lake's private, gravel boat ramp is located along the eastern shoreline and is accessible through the trailer park for a small fee (Figure 46). The southern shoreline is almost entirely residentially developed. The houses located along the southern shoreline are set back from Troy Cedar Lake's shoreline resulting in less alteration of the lake's natural shoreline compared to the eastern shoreline. In general, the southern shoreline has a more natural vegetation pattern than that observed along the eastern shoreline with trees and shrubs growing along much of the lakeshore transitioning into emergent vegetation along and within Troy Cedar Lake. The southwestern, western, and northwestern shorelines remain largely undeveloped; however land immediately west of the lake's western shoreline has been developed for agricultural purposes, leaving a narrow buffer between the farmland and the lake. A similar situation occurs in the northeast corner of the lake. Because of its semi-natural shoreline, significant erosional areas were not evident during a survey of the lake's shoreline.

Figure 46. Aerial photograph of Troy Cedar Lake. Source: USGS, 1998.

4.2 Historical Water Quality Data

4.2.1 Ridinger Lake

The Indiana Department of Natural Resources, Division of Fish and Wildlife, the Indiana Stream Pollution Control Board, International Science & Technology, Inc., Dr. Peter Hippensteel, and the Indiana Clean Lakes Program have conducted various water quality tests on Ridinger Lake. Table 31 presents a summary of some selected water quality parameters from these assessments of Ridinger Lake.

Based on the parameters in Table 31, Ridinger Lake's water quality appears to have worsened over the past 30 years. There has been gradual decrease in water clarity in Ridinger Lake over the past 20 years. Secchi disk transparency depths ranged from 2.5 to 3.5 feet (0.8 to 1.1 m) in the 1970's. The IDNR Division of Fish and Wildlife recorded a Secchi disk transparency depth of 6 feet (1.8 m), the highest summer time Secchi disk transparency depth for Ridinger Lake, in 1981. Water clarity decreased in the years following 1981, reaching a low of 2.1 feet (0.65 m) in 1998. Both IU-SPEA and JFNew measured Secchi disk transparency depths of 2.0 feet (0.6 m) at different times in 2003. Total phosphorus concentrations in Ridinger Lake have increased from 1970 to 1998. This "trend" should be viewed with caution it is based on only three data points (excluding the Hippensteel data since collection and analysis methodology is unknown). The percentage of the water column that contains oxygen has decreased from a high of 63% in 1978 to the low observed in the current study of 16%. This decrease in oxygen limits the availability of habitat for the lake's inhabitants and increases the potential for nutrient release from the lake's bottom sediments.

Table 31. Summary of historic data for Ridinger Lake.

Date	Secchi (ft)	Mean TP (mg/L)	Percent Oxic (%)	Plankton Density (#/L)	TSI score (based on means)	Data Source
1970's	3.5	0.05*	-	-	58**	IDEM, 1986
1978	2.5	-	61%	-	-	Pearson, 1979
1981	6.0	-	38%	-	-	Pearson, 1981
1982	5.0	-	25%	-	-	Pearson, 1982
1983	4.5	-	25%	-	-	Pearson, 1983
1988	4.0	0.55***	-	-	-	Hippensteel, 1989
1989	3.3	0.179*	25%	-	42**	IST, 1990
1995	3.5	-	25%	-	-	Pearson, 1995
1998	2.1	0.216	25%	34,050	45	CLP, 1998
2003	2.0	0.398	16%	28,761	48	Present Study

* Water column average; all other values are mean of epilimnion and hypolimnion values.
** Eutrophication Index (EI) score. The EI differs slightly but is still comparable to the TSI used today.
*** Collection and analysis methodology not provided in the report, so comparison to other data is questionable.

In contrast to this data, the Indiana TSI scores for Ridinger Lake decreased slightly from the initial lake assessment in the 1970's to the more recent assessments in 1989, 1998, and 2003. In the 1970's the TSI score of 58 indicated that the lake was hypereutrophic. The drop in TSI score to 42 in 1989 suggests the lake's productivity decreased slightly. The 1989 and 1998 TSI scores places the lake in the productive end of eutrophic. Results from the 2003 (current) survey indicate the lake is hypereutrophic. Combined, the TSI data suggest that Ridinger Lake falls in between the eutrophic and hypereutrophic productivity categories.

Table 32 and Figure 47 present the results from the most recent (excluding the current study) comprehensive examination of Ridinger Lake. The data indicate that, in general, water quality conditions were poor and Ridinger Lake was best described as eutrophic-hypereutrophic lake. Only 25% of the water column is oxic. Figure 47 shows that there was virtually no oxygen in the water below 4 meters. Water clarity was also poor. Secchi disk transparency depth was only 2.1 feet (0.65 m). Only 9% of the incident light reached a water depth of 3 feet. In clearer lakes, light transmission at 3 feet can be expected to exceed 50%. By a depth of six feet, light had been extinguished to the point where photosynthesis could not be supported. This limits the habitat availability for rooted plants. The data show that Ridinger Lake supported a healthy algal population. The concentration of chlorophyll *a* was very high, 34 μg/L. Chlorophyll *a* concentrations of this magnitude are usually characteristic of hypereutrophic lakes. Blue-green algae, a nuisance algae associated with productive lakes, dominated the Ridinger Lake algal community. Combined, this data suggest Ridinger Lake was a eutrophic-hypereutrophic lake at the time of the 1998 CLP sampling.

Table 32. Historical water quality characteristics of Ridinger Lake, 7/07/1998.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.65	7.32	-
Alkalinity	162.8 mg/L	190.3 mg/L	-
Conductivity	420 μmhos	320 μmhos	-
Secchi Depth Transparency	0.65 m	-	6
Light Transmission @ 3 ft.	9%	-	4
1% Light Level	6 ft	-	-
Total Phosphorous	0.072 mg/L	0.359 mg/L	4
Soluble Reactive Phosphorous	0.0108 mg/L	0.187 mg/L	3
Nitrate-Nitrogen	1.477 mg/L	0.222 mg/L	2
Ammonia-Nitrogen	0.030 mg/L	1.333 mg/L	3
Organic Nitrogen	1.288 mg/L	0.433 mg/L	2
Oxygen Saturation @ 5ft.	146%	-	3
% Water Column Oxic	25%	-	4
Plankton Density	34,050 #/L	-	4
Blue-Green Dominance	92.6%	-	10
Chlorophyll-a	33.95 μg/L	-	-
		TSI score	**45**

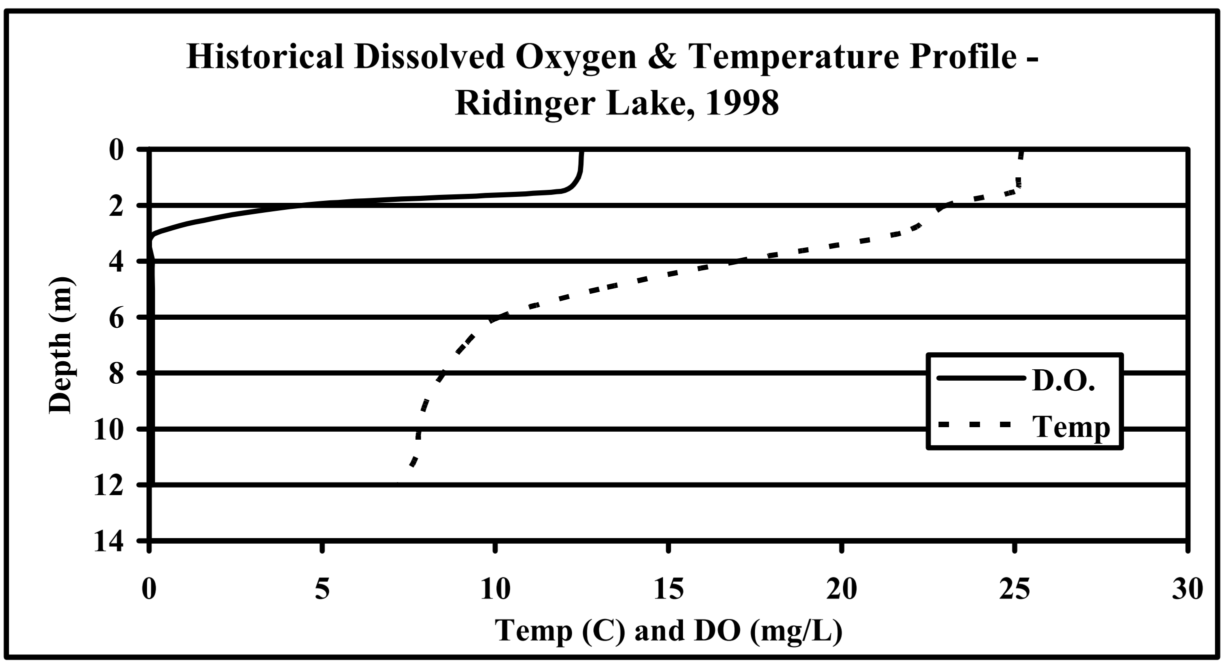


Figure 47. Historical dissolved oxygen profiles for Robinson Lake, which were sampled by the Clean Lakes Program.

4.2.2 Robinson Lake

There have been very few water quality evaluations completed on Robinson Lake. This is likely due to the limited public access on the lake until the Indiana Department of Natural Resources purchased the Crossland Scout Reservation from the Boy Scouts of America. The IDNR, Division of Fish and Wildlife and the Indiana Clean Lakes Program have both conducted various water quality tests on Robinson Lake. Table 33 presents a summary of some selected water quality parameters from these assessments of Robinson Lake.

Taken together, the data in Table 33 suggest the water quality in Robinson Lake is typical or slightly poorer than most Indiana lakes and is declining slightly. Secchi disk transparency depth fluctuated from year to year, but in all years, except 1999, Secchi disk transparency depths were less than the median Secchi disk transparency depth for Indiana lakes. Total phosphorus concentrations were moderate for Indiana lakes in 1990 and 1998 but increased in 2003. Historical total phosphorus concentrations indicate that Robinson Lake likely supported algal blooms in the summer. Historical oxygen concentrations are low limiting habitat availability for fish and other aquatic organisms. The 1993 and 1996 sampling efforts occurred in June when oxygen levels are expected to be higher. The 1999 sampling effort also occurred in June. The decline in June oxygen levels in the lake means the lake is processing more organic sediment and depleting its supply of oxygen earlier than it did in previous years. The Indiana TSI scores suggest overall productivity increased from 1990 to 1998 and 2003. The 1990 TSI score places the lake in the mesotrophic or moderately productive category, while the 1998 and 2003 scores indicate the lake is eutrophic.

Table 33. Summary of historic data for Robinson Lake.

Date	Secchi (ft)	Mean TP (mg/L)	Percent Oxic (%)	Plankton Density (#/L)	TSI score (based on means)	Data Source
1990	2.3	0.100	20%	1,214	28	CLP1990
1993	4.0	-	60%	-	-	Braun, 1994
1996	4.5	-	40%	-	-	Braun, 1997
1998	3.0	0.139	21.4%	7,463	38	CLP, 1998
1999	6.1	-	20%	-	-	Braun, 2001
2003	3.3	0.491	19.7%	6,755	33	Present Study

Because of the comprehensive nature of the Clean Lakes Program (CLP) assessments, it may be useful to provide the complete results of previous CLP examinations of Robinson Lake for comparison to the current study's results. Tables 34 and 35 and Figure 48 display those results. The lake assessments suggest that while the lake possessed relatively poor water clarity, its historical nutrients levels were moderate compared to other regional lakes. Total phosphorus levels were moderate for Indiana lakes. In both years, hypolimnetic total phosphorus concentrations were higher than epilimnetic total phosphorus concentrations. Much of this total phosphorus was comprised of SRP, suggesting that the lake was releasing the phosphorus from its bottom sediments. Similarly, ammonia levels were moderate, and, in both years, hypolimnetic ammonia concentrations were higher than epilimnetic ammonia concentrations. This suggests decomposition was occurring in the lake's bottom waters.

Table 34. Historical water quality characteristics of Robinson Lake, July 3, 1990.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8	6.3	-
Alkalinity	170.5 mg/L	192.6 mg/L	-
Conductivity	420 mmhos	378 mmhos	-
Secchi Depth Transparency	0.7 m	-	6
Light Transmission @ 3 ft.	24%	-	4
1% Light Level	9 ft	-	-
Total Phosphorous	0.058 mg/L	0.136 mg/L	3
Soluble Reactive Phosphorous	0.010* mg/L	0.105 mg/L	3
Nitrate-Nitrogen	0.711 mg/L	0.892 mg/L	2
Ammonia-Nitrogen	0.020 mg/L	1.048 mg/L	3
Organic Nitrogen	1.326 mg/L	1.348 mg/L	3
Oxygen Saturation @ 5ft.	53.6%	-	0
% Water Column Oxic	20%	-	4
Plankton Density	1,214 #/L	-	0
Blue-Green Dominance	12.4%	-	0
		TSI score	**28**

* Method Detection Limit

Table 35. Historical water quality characteristics of Robinson Lake, July 7, 1998.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.39	7.57	-
Alkalinity	153.1 mg/L	206.8 mg/L	-
Conductivity	600 μmhos	420 μmhos	-
Secchi Depth Transparency	0.9 m	-	6
Light Transmission @ 3 ft.	11%	-	4
1% Light Level	7 ft	-	-
Total Phosphorous	0.081 mg/L	0.197 mg/L	3
Soluble Reactive Phosphorous	0.010* mg/L	0.11 mg/L	2
Nitrate-Nitrogen	0.681 mg/L	0.573 mg/L	2
Ammonia-Nitrogen	0.029 mg/L	0.989 mg/L	2
Organic Nitrogen	0.986 mg/L	0.470 mg/L	2
Oxygen Saturation @ 5ft.	85%	-	0
% Water Column Oxic	21.4%	-	4
Plankton Density	7,463 #/L	-	2
Blue-Green Dominance	58%	-	10
Chlorophyll-a	27.21 μg/L		
		TSI score	**38**

* Method Detection Limit

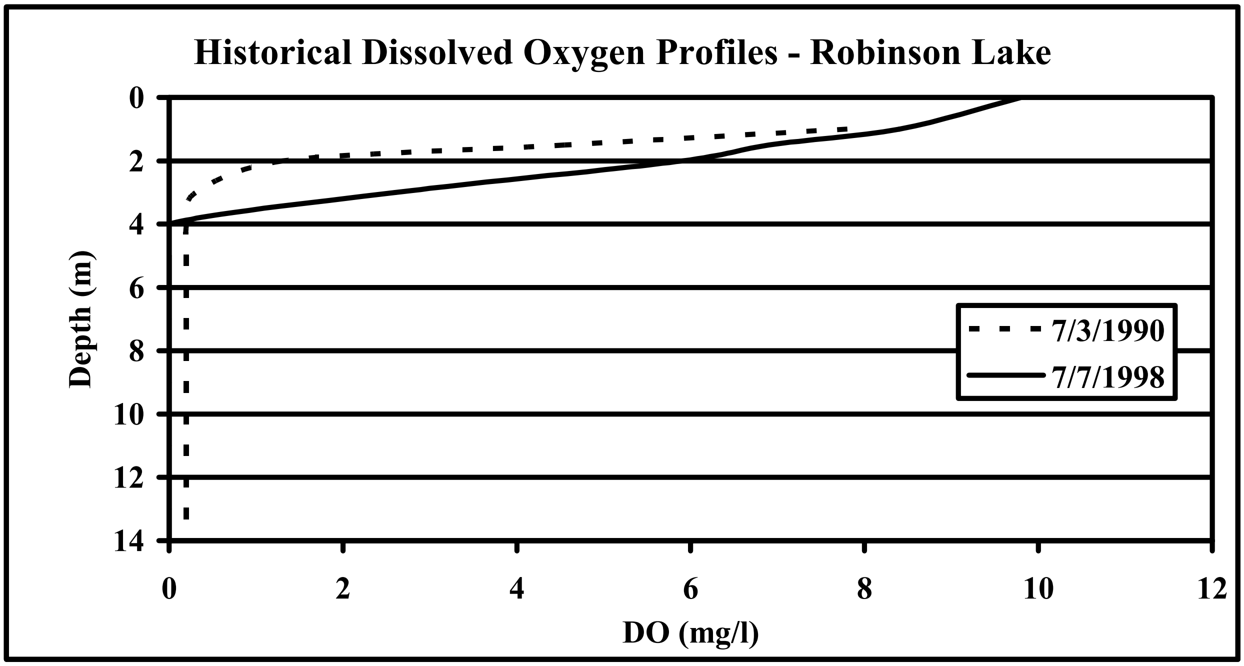


Figure 48. Historical dissolved oxygen profiles for Robinson Lake, which were sampled by the Clean Lakes Program during 1990 and 1998.

The Indiana TSI scores place Robinson Lake in two different productivity classes. The 1990 TSI score suggests the lake is mesotrophic, while the 1998 score indicates the lake is eutrophic. The difference between the two scores is largely due to the change in the algal community composition. In 1998, blue-green algae dominated the Robinson Lake community. As a consequence, 10 additional points were added to the lake's TSI score. These points were enough to move the lake from the mesotrophic to eutrophic category. The weighting of the Indiana TSI based on algal data has been one of the problems with the Indiana TSI. However, Robinson Lake's poor Secchi disk transparency depth, high total phosphorus concentration, and high chlorophyll a concentration in 1998 would place the lake in the eutrophic-hypereutrophic category if it were evaluated using Carlson's (1997) TSI. Thus, the Indiana TSI score of 38 suggesting that Robinson Lake was eutrophic in 1998 is likely accurate.

4.2.3 Troy Cedar Lake

The Indiana Department of Natural Resources, Division of Fish and Wildlife, the Indiana Stream Pollution Control Board, and the Indiana Clean Lakes Program have conducted various water quality tests on Troy Cedar Lake. Table 36 presents a summary of some selected water quality parameters from these assessments of Troy Cedar Lake.

Some of the historic data shown in Table 36 reveals Troy Cedar Lake's water quality has degraded slightly over the past 40 years. Overall, there has been a general decrease in water clarity as evidenced by the Secchi disk transparency depths. This suggests a decrease in water quality. Water clarity decreased from 1965 to 1982 but rebounded in 1990. Since 1990, water clarity has been decreasing again. Total phosphorus concentrations have been variable, but there is a general difference in magnitude between the 1990 concentration and the concentrations observed in 1994, 1998, and the current study. Like the worsening water clarity, the increase in total phosphorus concentrations suggests a decline in overall water quality.

The other parameters displayed in Table 36 do not show a trend or suggest that Troy Cedar Lake's water quality is actually improving. Historical data suggest only a small portion of the lake contains enough oxygen to support fish and other aquatic organisms. This lack of oxygen in the water column generally occurs each year. With the exception of 1990, only approximately 5-22% of the lake's water column contained oxygen each year. Plankton densities were variable for the years in which it was collected, making it difficult to discern any trends in water quality from this data. The Indiana TSI scores, which combine many of the individual parameters into a single index score, suggest the lake's water quality has improved. The TSI score of 60 from the 1970s places the lake in hypereutrophic category. Scores from the 1990s place the lake in the mesotrophic and eutrophic ranges.

Table 36. Summary of historic data for Troy Cedar Lake.

Date	Secchi (ft)	Percent Oxic	Mean TP (mg/L)	Plankton Density (#/L)	TSI score (based on means)	Data Source
1965	8.0	17%	-	-	-	McGinty 1966
1970s	4.5	-	0.08*	-	60**	IDEM 1986
1981	4.0	5%	-	-	-	Braun 1981
1982	2.3	22%	-	-	-	Braun 1982
1990	5.2	71%	0.062	39582	34	CLP1990
1994	3.0	19%	0.249	17668	37	CLP 1994
1998	3.1	12%	0.198	10280	29	CLP 1998
2003	1.6	13%	0.205	30720	43	Present Study

* Water column average; all other values are mean of epilimnion and hypolimnion values.
** Eutrophication Index (EI) score. The EI differs slightly but is still comparable to the TSI used today.

Tables 37 through 39 and Figures 49 and 50 present the results from the most recent (excluding the current study) comprehensive examinations of Troy Cedar Lake. All three temperature profiles show Troy Cedar Lake was stratified and indicate a strongly developed hypolimnion. This is typical in such a deep lake. During 1994 and 1998, the stratification resulted in anoxic conditions below 5 meters. The 1990 sampling event illustrates a different scenario with a sharp increase in oxygen at 6 meters, which is called a negative-heterograde profile. Increased respiration by bacteria in the metalimnion as they decompose settling phytoplankton is usually the cause of such profiles.

Water clarity data from the 1990, 1994, and 1998 sampling efforts are similar to the overall trend in water clarity shown in Tables 37 to 39. In addition to the Secchi disk transparency depths, other parameters indicate that Troy Cedar Lake's water clarity is decreasing. The amount of light that has penetrated the lake's water column to a depth of three feet decreased in each of the study years. Similarly, the lake's 1% light level decreased from 12.5 feet (3.8 m) in 1990 to 8.2 feet (2.5 m) in 1998.

The nutrient data provide additional information about Troy Cedar Lake. While mean total phosphorus is variable for the three years as shown in Tables 37 to 39, the more detailed evaluations show that hypolimnetic total phosphorus concentrations are much higher than epilimnetic total phosphorus concentrations. The detailed evaluations also show that much of the total phosphorus is the dissolved form of phosphorus (SRP). This indicates that the lake is releasing phosphorus from its bottom sediments. Troy Cedar Lake exhibited high hypolimnetic ammonia concentrations, suggesting decomposition of organic matter is occurring in the lake's bottom waters. Nitrate levels were very high in 1990, but this does not occur in other years. Additionally, nitrate concentrations were consistently higher in the hypolimnion compared to the epilimnion. Diffusion of nitrate from the groundwater may play a role in higher hypolimnetic concentrations observed. The Indiana TSI scores for each of the three years are similar. The main difference lies in the fact that in 1998, blue-green algae do not account for more than 50% of the plankton community. Consequently, no points were added to the total score for this parameter, whereas 10 points were added to the 1990 and 1994 scores. Generally, the Indiana TSI scores suggest in the 1990s Troy Cedar Lake was a mesotrophic-eutrophic lake.

Table 37. Historical water quality characteristics of Troy Cedar Lake, July 3, 1990.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.6	7.1	-
Alkalinity	165.9 mg/L	51.04 mg/L	-
Conductivity	470 μmhos	370 μmhos	-
Secchi Depth Transparency	1.6 m	-	0
Light Transmission @ 3 ft.	35%	-	3
1% Light Level	12.5 ft.	-	-
Total Phosphorous	0.036 mg/L	0.088 mg/L	3
Soluble Reactive Phosphorous	0.027 mg/L	0.137 mg/L	3
Nitrate-Nitrogen	3.296 mg/L	3.878 mg/L	4
Ammonia-Nitrogen	0.033 mg/L	0.191 mg/L	0
Organic Nitrogen	2.373 mg/L	2.357 mg/L	4
Oxygen Saturation @ 5ft.	118%	-	1
% Water Column Oxic	70.8%	-	1
Plankton Density	39,582 #/L	-	5
Blue-Green Dominance	91.8%	-	10
		TSI score	**34**

Table 38. Historical water quality characteristics of Troy Cedar Lake, July 26, 1994.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.6	7.4	-
Alkalinity	135 mg/L	202 mg/L	-
Conductivity	365 mmhos	350 mmhos	-
Secchi Depth Transparency	0.9 m	-	6
Light Transmission @ 3 ft.	15%	-	4
1% Light Level	10 ft.	-	-
Total Phosphorous	0.059 mg/L	0.439 mg/L	4
Soluble Reactive Phosphorous	0.010* mg/L	0.392 mg/L	3
Nitrate-Nitrogen	0.022 mg/L	0.040 mg/L	0
Ammonia-Nitrogen	0.018* mg/L	1.091 mg/L	2
Organic Nitrogen	0.571 mg/L	0.591 mg/L	1
Oxygen Saturation @ 5ft.	100%	-	0
% Water Column Oxic	19%	-	4
Plankton Density	17,668 #/L	-	3
Blue-Green Dominance	80.5%	-	10
Chlorophyll-a	3.27 μg/L	-	-
		TSI score	**37**

* Method Detection Limit

Table 39. Historical water quality characteristics of Troy Cedar Lake, July 20, 1998.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.75	7.31	-
Alkalinity	140.8 mg/L	183.7 mg/L	-
Conductivity	375.2 μmhos	288.1 μmhos	-
Secchi Depth Transparency	0.95 m	-	6
Light Transmission @ 3 ft.	5.5 %	-	4
1% Light Level	8.25 ft	-	-
Total Phosphorous	0.044 mg/L	0.351 mg/L	3
Soluble Reactive Phosphorous	0.010* mg/L	0.288 mg/L	3
Nitrate-Nitrogen	0.022 mg/L	1.137 mg/L	2
Ammonia-Nitrogen	0.018* mg/L	0.601 mg/L	1
Organic Nitrogen	1.047mg/L	0.703 mg/L	2
Oxygen Saturation @ 5ft.	120%	-	2
% Water Column Oxic	12%	-	4
Plankton Density	10,280 #/L	-	2
Blue-Green Dominance	29.34%	-	0
Chlorophyll-a	19.58 μg/L	-	-
		TSI score	**29**

* Method Detection Limit

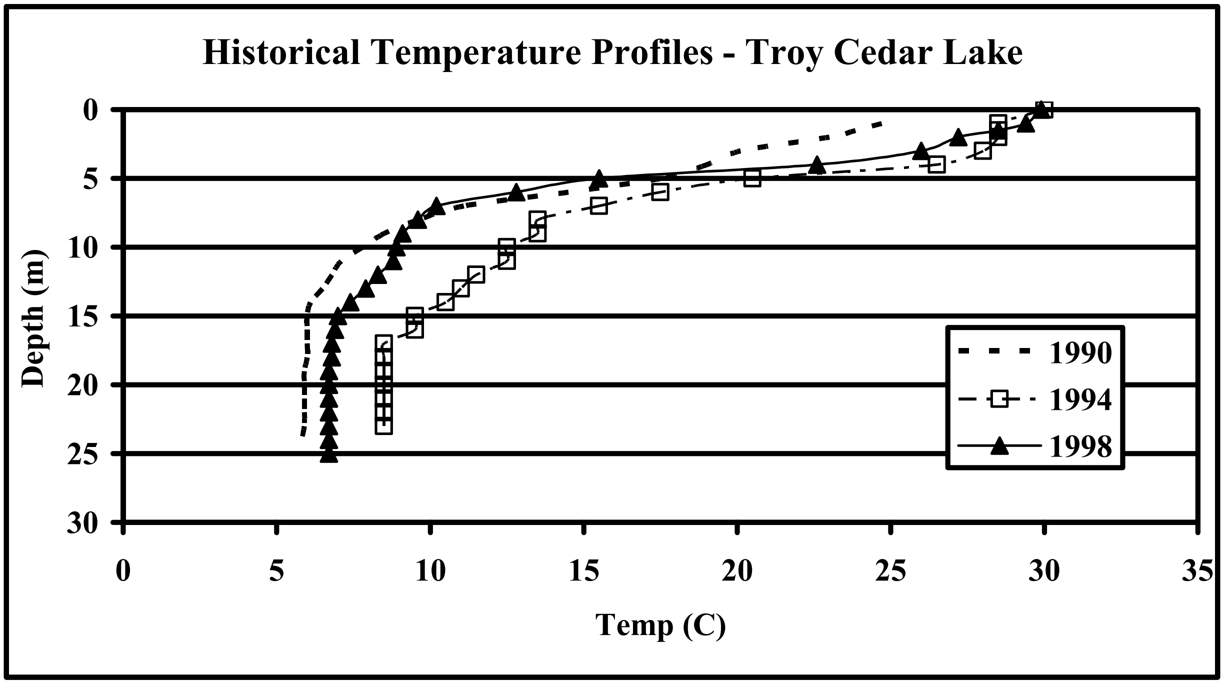


Figure 49. Historical temperature profiles for Troy Cedar Lake, 1990, 1994, and 1998.

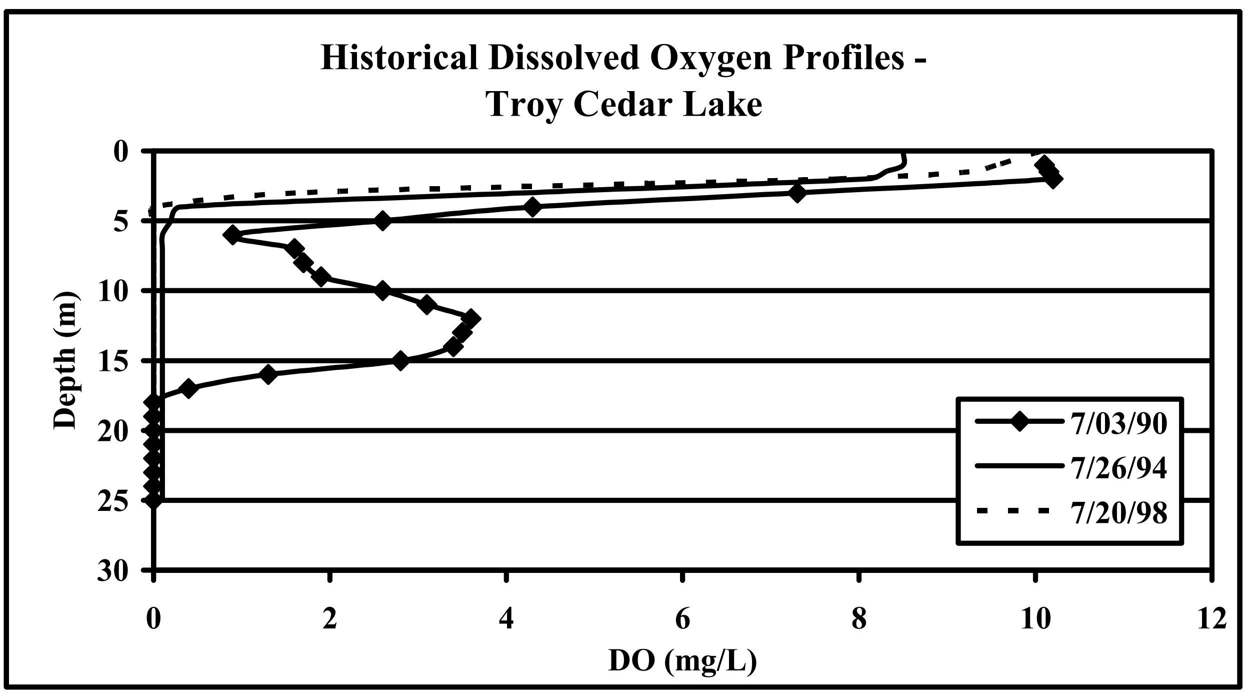


Figure 50. Historical dissolved oxygen profiles for Troy Cedar Lake, 1990, 1994, and 1998.

4.3 Lake Assessment Methods

The water sampling and analytical methods used for Ridinger, Robinson, and Troy Cedar Lakes were consistent with those used in IDEM's Indiana Clean Lakes Program and IDNR's Lake and River Enhancement Program. Water samples were collected and analyzed for various parameters from Ridinger, Robinson, and Troy Cedar Lakes on August 19, 2003 from the surface waters (***epilimnion***) and from the bottom waters (***hypolimnion***) of the lake at a location over the deepest water. These parameters include pH, alkalinity, conductivity, total phosphorus, soluble reactive phosphorus, nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, and organic nitrogen. In addition to these parameters, several other measurements of lake health were recorded. Secchi disk, light transmission, and oxygen saturation are single measurements made in the epilimnion. Chlorophyll was determined only for an epilimnetic sample. Dissolved oxygen and temperature were measured at one-meter intervals from the surface to the bottom. A tow to collect plankton was made from the 1% light level depth up to the water surface. Conductivity, temperature, and dissolved oxygen were measured *in situ* with an YSI Model 85 meter.

All lake samples were placed in the appropriate bottle (with preservative if needed) and stored in an ice chest until analysis at SPEA's laboratory in Bloomington. SRP samples were filtered in the field through a Whatman GF-C filter.

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: Prescott (1982), Ward and Whipple (1959), and Whitford and Schumacher (1984).

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 oxygen dissolved 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 ^{o}F (32.2 ^{o}C).

Dissolved Oxygen (D.O). D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 mg/L of D.O. Coldwater fish such as trout generally require higher concentrations of D.O. than warmwater fish such as bass or bluegill. The IAC sets minimum D.O. concentrations at 4 mg/L for warmwater fish, but all waters must have a daily average of 5 mg/L. D.O. 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 D.O. 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.

pH. The pH of water describes the concentration of acidic ions (specifically H+) present in 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 to 9 pH units for the protection of aquatic life. pH concentrations in excess of 9 are considered acceptable when the concentration occurs as daily fluctuations associated with photosynthetic activity.

Alkalinity. Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH.

Nutrients. Limnologists measure nutrients to predict the amount of algae growth and/or rooted plant (macrophyte) growth that is possible in a lake or stream. Algae and rooted plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy lake or stream. 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 or stream. Algae and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a lake or stream. 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 **soluble reactive phosphorus (SRP)** 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 (NO_3)**, **ammonium-nitrogen (NH_4^+)**, and **total Kjeldahl nitrogen (TKN)**. 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 the States, is currently working on developing these standards.) The USEPA has issued recommendations for numeric nutrient criteria for lakes (USEPA, 2000b). 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, 14.75 μg/L (USEPA, 2000b). 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. 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 LC_{50} 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 LC_{50} 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 0.56 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 in Ridinger, Robinson, and Troy Cedar Lakes. 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. The Ridinger, Robinson, and Troy Cedar Lakes samples did not exceed the state standard for either nitrate-nitrogen or ammonia-nitrogen.

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 (3.33m) for Secchi disk depth in lakes (USEPA, 2000b).

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.

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 poorer water quality. The USEPA recommended a numeric criterion of 2.6 μg/L as a target concentration for lakes in Aggregate Nutrient Ecoregion VII (USEPA, 2000b).

4.4 Lake Assessment Results

4.4.1 Ridinger Lake

The results from the Ridinger Lake water quality assessment are included in Tables 40 and 41 and Figure 51.

Table 40. Water quality characteristics of Ridinger Lake, August 19, 2003.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.9	7.5	-
Alkalinity	130 mg/L	251 mg/L	-
Conductivity	433.2 µmhos	419.3 µmhos	-
Secchi Depth Transparency	0.6 meters	-	6
Light Transmission @ 3 ft.	18 %	-	4
1% Light Level	6.5 feet	-	-
Total Phosphorous	0.059 mg/L	0.736 mg/L	4
Soluble Reactive Phosphorous	0.013 mg/L	0.664 mg/L	4
Nitrate-Nitrogen	1.036 mg/L	0.013* mg/L	2
Ammonia-Nitrogen	0.038 mg/L	3.280mg/L	4
Organic Nitrogen	1.492 mg/L	1.050 mg/L	3
Oxygen Saturation @ 5ft.	168 %	-	4
% Water Column Oxic	16 %	-	4
Plankton Density	28,761 #/L	-	3
Blue-Green Dominance	62.8 %	-	10
Chlorophyll *a*	46.73 µg/L	-	-
		TSI score	**49**

*Method Detection Limit

Table 41. The plankton sample representing the species assemblage on August 19, 2003.

Species	Abundance (#/L)
Blue-Green Algae (Cyanophyta)	
Aphanizomenon	13,797
Anabaena	3,501
Microcystis	208
Coelosphaerium	119
Aphanocapsa	445
Green Algae (Chlorophyta)	
Pediastrum	30
Ulothrix	208
Staurastrum	59
Diatoms (Bacillariophyta)	
Synedra	8,011
Other Algae	
Chrysosphaerella	30
Ceratium	771
Dinobryon	178
Zooplankton	
Filinia	89
Keratella	475
Polyarthra	564
Asplanchna	30
Ptygura	89
Nauplius	118
Cyclopoid Copepod	22
Calanoid Copepod	17
Total Number of Plankton	**28,761**

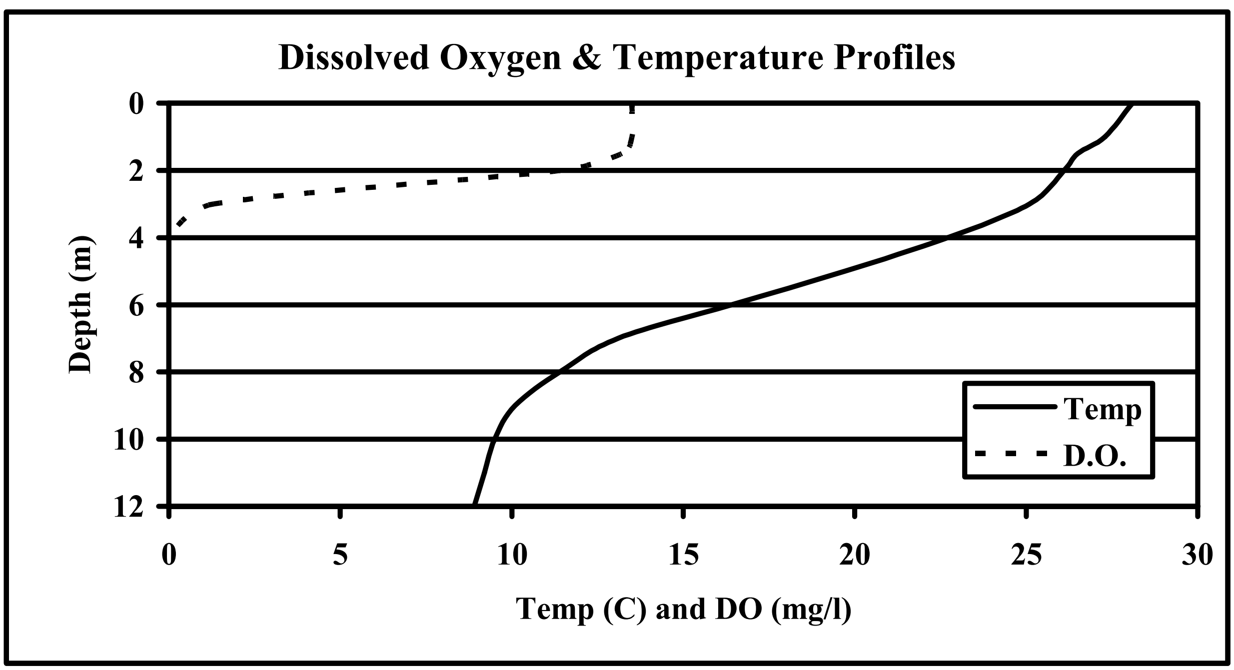


Figure 51. Temperature and dissolved oxygen profiles for Ridinger Lake on August 19, 2003.

The temperature profile for Ridinger Lake shows that the lake was stratified at the time of sampling (Figure 51). During thermal stratification, the bottom waters (*hypolimnion*) of the lake are isolated from the well-mixed *epilimnion* (surface waters) by temperature-induced density differences. The boundary between these two zones, where temperature changes most rapidly with depth is called the *metalimnion*. At the time of sampling, the epilimnion was confined to the upper 3 meters of water. The decline in temperature between 3 and about 9 meters defined the metalimnion or transition zone. The hypolimnion occupied water deeper than 9 meters.

Ridinger Lake's dissolved oxygen profile is characteristic of shallow, productive lakes. The lake's epilimnion was supersaturated with oxygen; percent dissolved oxygen at 5 feet (1.5 m) was 168%. Supersaturation is usually symptomatic of intense phytoplankton photosynthesis. The high epilimnetic pH and chlorophyll *a* concentration lend evidence to the hypothesis that the observed supersaturation was due to photosynthesizing algae. Dissolved oxygen concentrations declined rapidly between depths of 2 and 4 meters. The lake reached anoxic (D.O.<1.0 mg/L) conditions around the depth of 3 meters. This is likely due to biochemical oxygen demand from excess organic detritus in the lake's deeper waters. Water below 4 meters had no oxygen content 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 16% of the lake's water column was oxic, limiting the amount of habitat available for aquatic fauna.

Values for pH were within the normal range for Indiana lakes and typical of most fresh waters (Kalff, 2002). The epilimnetic pH was relatively high. A high epilimnetic pH may indicate the presence of photosynthesizing algae. During the process of photosynthesis, algae remove carbon dioxide, a weak acid, from the water column, thereby increasing the water's pH. The lack of photosynthesis in the hypolimnion and the liberation of carbon dioxide by respiring bacteria keep pH levels lower in the hypolimnion. Conductivity values, a measure of dissolved ions, were within the normal range for Indiana lakes.

Alkalinity is a measure of the water's ability to resist change in pH, or acid content. It is also referred to as acid neutralizing capacity or buffering capacity. This buffering action is important because it ensures a relatively constant chemical and biological environment in lakes. Alkalinity is determined largely by the availability and chemistry of carbonate in water. Sources of carbonate to natural waters include limestone (calcium carbonate) and carbon dioxide. The alkalinity concentrations within Ridinger Lake suggest that the lake is moderately to well buffered.

Consistent with the historical trend of declining water clarity, Ridinger Lake exhibited a Secchi disk depth of only 2 feet (0.6 m) at the time of sampling. This Secchi disk depth is much poorer than the target Secchi disk transparency depth of nearly 11 feet (3.3 m) recommended by the USEPA (2000b). Light transmission was also poor, with only 9% of the incident light reaching a depth of 3 feet (0.9 m) below the water's surface. It is likely that both algal and non-algal turbidity play a role in reducing water clarity in Ridinger Lake.

The 1% light level, which limnologists use to determine the lower limit where photosynthesis can occur, extended to 6.5 feet (2 m). Based on the depth-area curve in Figure 36 approximately 18.5% of lake bottom (approximately 25 acres) is shallower than 6.5 feet. This represents the area of the lake bottom with sufficient light to support rooted plants. This area is called the ***littoral zone***. Based on the depth-volume curve (Figure 37), approximately 670 acre-feet of Ridinger Lake (26% of total lake volume) lies above the 6.5-foot 1% light level. This volume, referred to as the ***photic zone***, represents the amount of water with sufficient light to support algae growth. These two zones, the littoral zone and the photic zone, provide insight into the potential for primary production (plant growth) in Ridinger Lake.

Total and soluble reactive phosphorus concentrations were generally high in Ridinger Lake. The total phosphorus concentration in Ridinger Lake's epilimnion was moderate for Indiana lakes. Despite this, the epilimnion total phosphorus concentration of 0.059 mg/L still exceeds the 0.03 mg/L concentration threshold that is considered high enough to support eutrophic conditions (Wetzel, 2001). The total phosphorus concentration was considerably higher in the hypolimnion, 0.736 mg/L. Soluble reactive phosphorus concentration in the epilimnion was just over the laboratory detection limit. This is typical in lakes since SRP is readily consumed by algae in the lake's epilimnion. The SRP concentration in Ridinger Lake's hypolimnion was high. The data indicate that most of the total phosphorus concentration in the hypolimnion consists of SRP. This dominance of the dissolved form of phosphorus coupled with the lack of oxygen in the deep waters over the bottom sediments suggests that dissolved phosphorus is being released from the lake's bottom sediments. This is called ***internal phosphorus loading*** and can be a significant additional source of phosphorus in some lakes. (The extent of internal phosphorus loading will be examined using a model later in this report.) Comparing the 2003 results to the 1998 lake assessment, phosphorus concentrations appear to be increasing in Ridinger Lake.

Levels of dissolved nitrogen also warrant concern in Ridinger Lake. Epilimnetic nitrate-nitrogen was high (1.036 mg/L). Ammonia oxidizes rapidly to nitrate in the presence of adequate oxygen and nitrifying bacteria. The high nitrate concentration in the epilimnion coupled with the high ammonia concentration in the lake's hypolimnion suggest ammonia is diffusing into the epilimnion from the hypolimnion and being converted to nitrate in the well-oxygenated epilimnion. The lake also receives relatively high nitrate loads from its tributary.

Nitrate, on the other hand, is reduced to ammonia when oxygen is low. Ridinger Lake's hypolimnion lacks oxygen, therefore any nitrate reaching the lake's lower waters is quickly converted to ammonia. Ammonia is also a byproduct of bacterial decomposition. The decomposition of organic materials in the lake's hypolimnion contributes to the relatively high ammonia concentration observed in Ridinger Lake (3.3 mg/L). Like the total phosphorus concentrations, ammonia concentrations, particularly the hypolimnetic concentration, increase from 1998 to 2003 suggesting a worsening of water quality conditions in Ridinger Lake.

Plankton enumerated from the sample collected from Ridinger Lake are shown in Table 41. *Aphanizomenon*, a blue-green algae, was the most dominant genera found, and accounted for almost half the plankton density. In addition to this particular blue-green algae, other blue-green species contributed to the overall plankton dominance by blue-greens of 62.8%. Blue-greens 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. This blue-green dominance contributes to the relatively high TSI score in 2003.

4.4.2 Robinson Lake

The results from the Robinson Lake water quality assessment are included in Tables 42 and 43 and Figure 52.

Table 42. Water quality characteristics of Robinson Lake, August 19, 2003.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.4	7.4	-
Alkalinity	155 mg/L	238 mg/L	-
Conductivity	455.8 µmhos	372.6 µmhos	-
Secchi Depth Transparency	1.0 meters	-	6
Light Transmission @ 3 ft.	27 %	-	4
1% Light Level	8.0 feet	-	-
Total Phosphorous	0.037 mg/L	0.944 mg/L	4
Soluble Reactive Phosphorous	0.010* mg/L	0.825 mg/L	4
Nitrate-Nitrogen	1.549 mg/L	0.013* mg/L	2
Ammonia-Nitrogen	0.066 mg/L	3.612 mg/L	4
Organic Nitrogen	1.184 mg/L	1.032 mg/L	3
Oxygen Saturation @ 5ft.	102 %	-	0
% Water Column Oxic	19.7 %	-	4
Plankton Density	6,755 #/L	-	1
Blue-Green Dominance	45.6 %	-	0
Chlorophyll *a*	13.4 µg/L	-	-
		TSI score	**33**

*Method Detection Limit

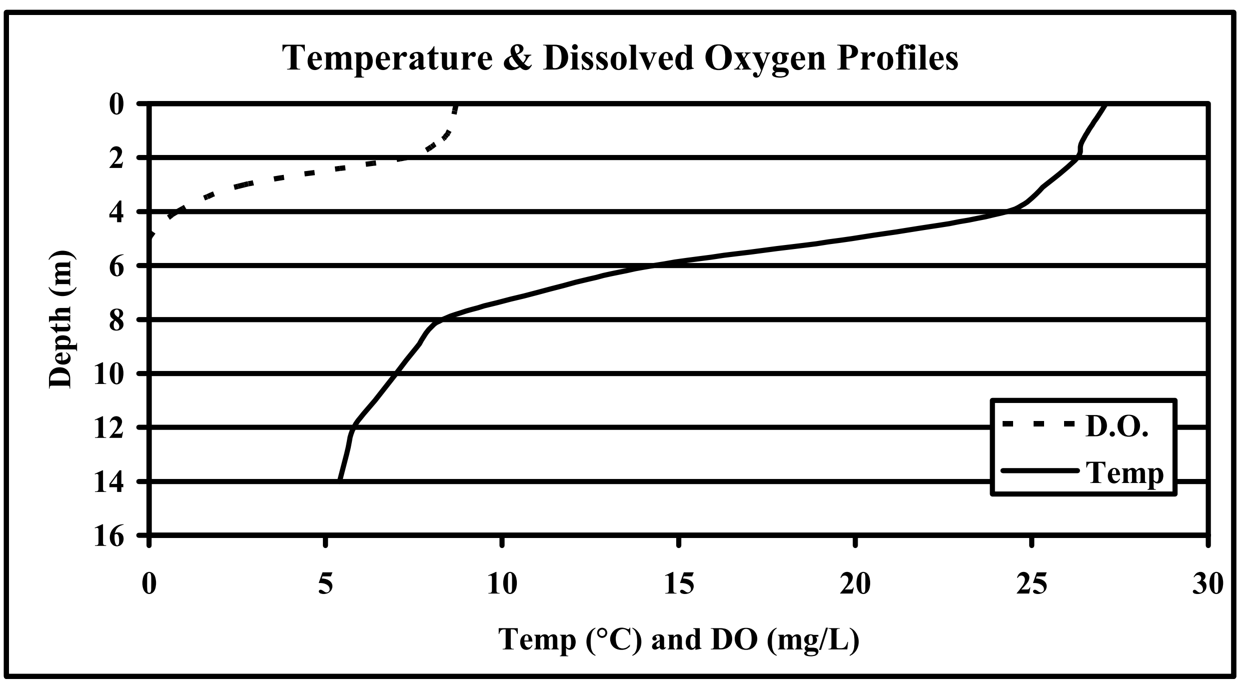


Figure 52. Temperature and dissolved oxygen profile for Robinson Lake, August 19, 2003.

Table 43. The plankton sample representing the species assemblage on August 19, 2003.

Species	**Abundance (#/L)**
Blue-Green Algae (Cyanophyta)	
Aphanizomenon	2371
Anabaena	456
Oscillatoria	68
Coelosphaerium	46
Aphanocapsa	137
Green Algae (Chlorophyta)	
Ulothrix	182
Diatoms (Bacillariophyta)	
Synedra	1801
Other Algae	
Synura	23
Ceratium	980
Zooplankton	
Filinia	68
Keratella	251
Polyarthra	160
Asplanchna	23
Ptygura	91
Nauplius	127
Daphnia	2
Cyclopoid Copepod	2
Calanoid Copepod	25
Bosmina	1
Ostracoda	1
Total Number of Plankton	**6,755**

The temperature and oxygen profiles for Robinson Lake are typical of a productive, stratified lake (Figure 52). Robinson Lake's epilimnion extended from the surface to about 4 meters below the surface at the time of sampling. The lake's metalimnion occurred between 4 and about 6 meters, while the hypolimnion occupied water deeper than 6 meters. The dissolved oxygen profile mirrored the shape of the temperature profile and is consistent with historical dissolved oxygen profiles for the lake (Figure 47). The oxygen concentration decreases within the epilimnion rapidly down to a depth of 5 meters, at which point there is no dissolved oxygen remaining in the lake. Respiration by aquatic fauna and decomposition of organic matter likely depleted the oxygen supply in the lake's deeper waters. Water below 5 meters had no oxygen content to support fish and other aquatic organisms.

Conductivity, alkalinity, and pH values were all within normal ranges for Indiana. The high alkalinity values of 155 mg/L and 238 mg/L, for the epilimnion and hypolimnion, indicate that Robinson Lake is a well buffered system. As is typical, Robinson Lake's epilimnetic pH was slightly higher than its hypolimnetic pH. Photosynthesis, which occurs only in the epilimnion in

Robinson Lake, removes carbon dioxide from the water column, increasing the pH. In the hypolimnion, respiration causes the release of carbon dioxide into the water column, decreasing the water's pH.

Water clarity was relatively poor in Robinson Lake. The lake's Secchi disk depth was 3.3 feet (1.0 m) which is well below the USEPA (2000b) target Secchi disk transparency depth of nearly 11 feet (3.3 m). Poor water clarity in Robinson Lake limited the ability of light to penetrate through the water column. The lake's 1% light level extended to only 8 feet (2.44 m). Based on the depth-area and depth volume curves in Figures 40 and 41, this means the lake's littoral zone covered approximately 35% of lake bottom (approximately 21 acres) and the lake's photic zone occupies only 360 acre-feet or 35% of total lake volume. In other words, due to poor water clarity only about one-third of the lake has enough light to support aquatic plant and algae growth.

Several nutrients showed increases over historical concentrations, particularly in the hypolimnion. While the lake's epilimnetic total phosphorus concentration was lower than those measured during the 1990 and 1998 CLP surveys, Robinson Lake's hypolimnetic total phosphorus concentration during the current sampling effort was more than four times the hypolimnetic total phosphorus concentrations measured in the CLP surveys. Much of the hypolimnetic total phosphorus concentration found in the current sampling effort is composed of soluble reactive phosphorus indicating that the lake is releasing phosphorus from its bottom sediments. The lake's current hypolimnetic ammonia concentration was more than three times its historical hypolimnetic ammonia concentrations. Because ammonia is a by-product of decomposition, the high hypolimnetic ammonia concentration suggests the lake is processing more organic material than in previous years. The increase in ammonia concentration in the hypolimnion may be driving the lake's high epilimnetic nitrate concentration. As ammonia diffuses through the water column toward the lake's surface, the ammonia oxidizes to nitrate once it reaches the well-oxygenated epilimnion.

Table 43 presents the plankton enumerated from the sample collected from Robinson Lake. *Aphanizomenon*, a blue-green algae, was the most dominant genera found, and accounted for one-third of the plankton density. As noted in the Ridinger Lake results section, blue-greens are considered nuisance algae and are usually associated with degraded water quality. Unlike Ridinger Lake, blue-green algae did not represent more than half of the plankton community. In Robinson Lake, the diatom species, *Synedra*, was co-dominant with *Aphanizomenon*, representing 27% of the sample.

4.4.3 Troy Cedar Lake

The results from the Troy Cedar Lake water quality assessment are included in Tables 44 and 45 and Figure 53.

Table 44. Water quality characteristics of Troy Cedar Lake, August 19, 2003.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	9	7.5	-
Alkalinity	121 mg/L	189 mg/L	-
Conductivity	377.3 μmhos	298.3 μmhos	-
Secchi Depth Transparency	0.5 meters	-	6
Light Transmission @ 3 ft.	7 %	-	4
1% Light Level	5 feet	-	-
Total Phosphorous	0.047 mg/L	0.363 mg/L	4
Soluble Reactive Phosphorous	0.010* mg/L	0.300 mg/L	3
Nitrate-Nitrogen	0.126 mg/L	0.403 mg/L	0
Ammonia-Nitrogen	0.018* mg/L	1.044 mg/L	2
Organic Nitrogen	2.062 mg/L	1.156 mg/L	3
Oxygen Saturation @ 5ft.	135 %	-	3
% Water Column Oxic	12.5 %	-	4
Plankton Density	30,720 #/L	-	4
Blue-Green Dominance	80.49 %	-	10
Chlorophyll *a*	31.86 μg/L	-	-
		TSI Score	**43**

* Method Detection Limit

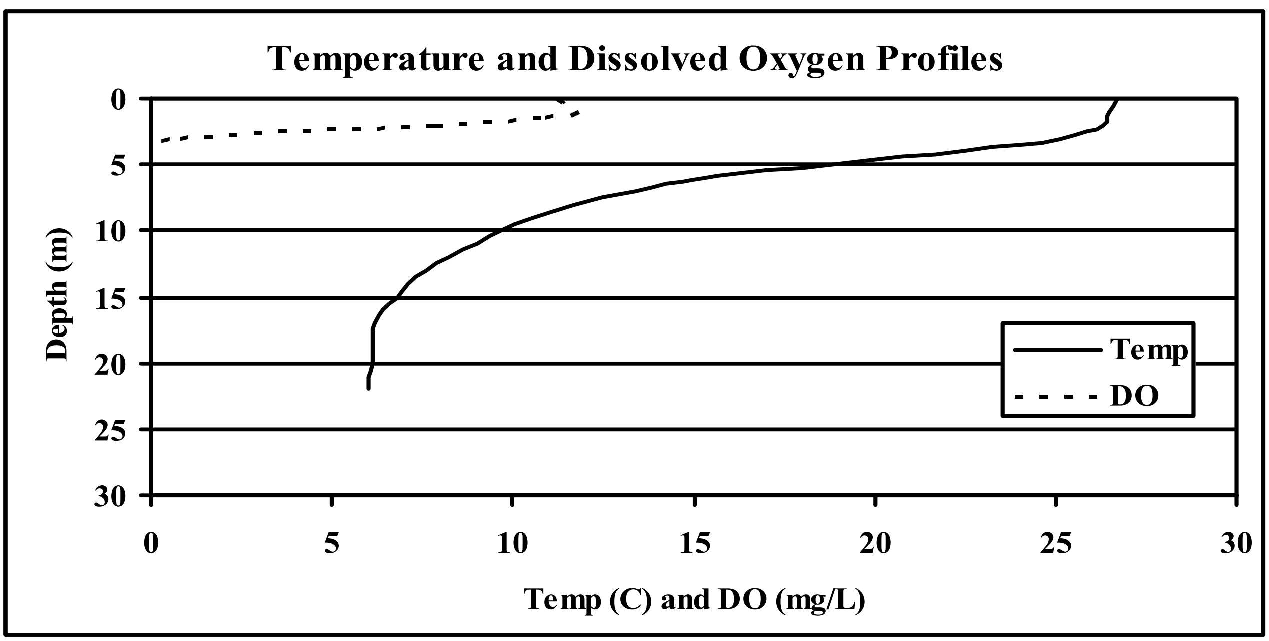


Figure 53. Temperature and dissolved oxygen profiles for Troy Cedar Lake, August 19, 2003.

Table 45. The plankton sample representing the species assemblage on August 19, 2003.

Species	Abundance (#/L)
Blue-Green Algae (Cyanophyta)	
Aphanizomenon	15873
Anabaena	6461
Microcystis	1345
Coelosphaerium	197
Aphanocapsa	853
Green Algae (Chlorophyta)	
Ulothrix	361
Pediastrum	33
Staurastrum	33
Diatoms (Bacillariophyta)	
Synedra	3903
Other Algae	
Ceratium	656
Zooplankton	
Filinia	164
Keratella	361
Polyarthra	197
Asplanchna	131
Ptygura	
Nauplius	105
Daphnia	11
Cyclopoid Copepod	32
Calanoid Copepod	14
Total Number of Plankton	**30,720**

Temperature and oxygen profiles for Troy Cedar Lake show that the lake was thermally stratified at the time of sampling (Figure 53). At the time of sampling, the epilimnion occupied the upper 3 meters of water. Between 3 and about 7 meters, the lake's water temperature decreased rapidly with depth. By definition then, Troy Cedar Lake's metalimnion or transition zone occurred between 3 and 7 meters. Water temperature decreased more slowly with depth below 7 meters, marking the lake's hypolimnion. The lake's oxygen profile is consistent with the findings of previous studies on the lake. Troy Cedar Lake lacked oxygen below 4 meters, therefore only 12.5% of the lake's water column was oxic. This limits the availability of habitat for fish and other aquatic organisms.

Troy Cedar Lake's conductivity, alkalinity, and pH values were all within normal ranges for Indiana. The alkalinity values of 121 mg/L and 189 mg/L, for the epilimnion and hypolimnion, indicate that Troy Cedar Lake is a well-buffered system. The lake's eplimnetic pH value of 9 is on the high end of the normal range. High epilimnetic pH values are typically indicative of the presence of photosynthesizing algae. During photosynthesis, algae consume carbon dioxide, increasing the water's pH. The lake was supersaturated with oxygen at 5 feet (1.5 m) and possessed a high chlorophyll *a* concentration. These data lend evidence to the hypothesis that a dense population of algae were photosynthesizing in the lake's surface layer at the time of sampling.

Troy Cedar Lake exhibited poor water clarity at the time of inspection. The lake's Secchi disk transparency depth of 1.6 feet (0.5 m) was worse than Secchi disk transparency depths recorded in previous years. The shallow 1% light level and poor light transmission at 3 feet (0.9 m) suggest that dense algal concentrations and suspended matter at the lake surface were intercepting much of the available light and shading out deeper depths of the lake. Troy Cedar Lake's 1% light level extended to only 5 feet (1.5 m) which is worse than in the three previous comprehensive assessments of the lake. Based on the depth-area curve in Figure 44, a 1% light level extending to 5 feet (1.5 m) means the littoral zone occupied only approximately 16% of lake bottom (approximately 14 acres). Additionally, based on the depth-volume curve (Figure 45), Troy Cedar Lake's photic zone encompasses only 376 acre-feet of Troy Cedar Lake (17% of total lake volume). In other words, the areas of Troy Cedar Lake where photosynthesis is possible represent a rather small fraction of the total lake area and volume.

Phosphorus concentrations were similar to concentrations observed in 1994 and 1998. At the time of sampling, the epilimnetic total phosphorus concentration was relatively low for Indiana lakes but still high enough to support nuisance algal blooms. As seen in the 1994 and 1998 lake evaluations, Troy Cedar Lake exhibited higher hypolimnetic total phosphorus and SRP concentrations than epilimnetic phosphorus concentrations. A large portion of the lake's hypolimnetic total phosphorus consisted of SRP, indicating that internal release of phosphorus from the lake's sediments is occurring.

Nitrate nitrogen concentrations were relatively low for a lake surrounded by extensive agricultural use. The nitrate concentration in the epilimnion was 0.126 mg/L, while the hypolimnion was 0.403 mg/L. Nitrate is reduced to ammonia when oxygen is low, which makes the higher hypolimnetic nitrate concentration unusual since the environment is anoxic. Ammonia, on the other hand, oxidizes rapidly to nitrate in the presence of adequate oxygen and nitrifying bacteria, which partially explains the increased concentration of nitrate in the epilimnion in comparison to the hypolimnion. The higher hypolimnetic ammonia concentration (1.044 mg/L) indicates the presence of a high amount of biochemical oxygen demand (BOD) in the organic matter present on or near the sediments. Bacteria that decompose the organic matter produce NH_4 as a byproduct.

Table 45 displays the plankton enumerated from the sample collected from Troy Cedar Lake. Like Ridinger and Robinson Lakes, *Aphanizomenon*, a blue-green algae, dominated the Troy Cedar Lake plankton community. This genera accounted for over half the plankton density in Troy Cedar Lake. Combined with other blue-green plankton species, *Cyanobacteria* represented over 80% of the total sample. As noted previously, blue-green algae are usually associated with degraded water quality and are less desirable in lakes for a variety of reasons.

4.5 Lake Assessment Discussion

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 the lake in question 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 Ridinger, Robinson, and Troy Cedar Lakes are compared below with data from other lakes and with generally accepted criteria.

Comparison with Vollenweider's Data

Results of studies conducted by Richard Vollenweider in the 1970's are often used as guidelines for evaluating concentrations of water quality parameters. His results are given in the Table 46. 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 algae 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; algae 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.

The units in the table are either milligrams per liter (mg/L) or micrograms per liter (μg/L). One mg/L is equivalent to one part per million (ppm) while one microgram per liter is equivalent to one part per billion (ppb). 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.

Table 46. Mean values of some water quality parameters and their relationship to lake production (after Vollenweider, 1975).

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total Phosphorus (mg/L or ppm)	0.008	0.027	0.084	>0.750
Total Nitrogen (mg/L or ppm)	0.661	0.753	1.875	-
Chlorophyll *a* (μg/L or ppb)	1.7	4.7	14.3	-

Table 47 shows the mean concentrations of total phosphorus, total nitrogen, and chlorophyll *a* for the study lakes. All of the lakes' mean total phosphorus and total nitrogen concentrations exceed Vollenweider's mean total phosphorus and total nitrogen concentrations in eutrophic lakes. Likewise, Ridinger and Troy Cedar Lakes' chlorophyll *a* concentrations were above the mean chlorophyll *a* concentration in Vollenweider's eutrophic lakes. Robinson Lake's chlorophyll *a* concentration is just below the mean chlorophyll *a* concentration in Vollenweider's eutrophic lakes; however it is still in the range of chlorophyll *a* values exhibited by eutrophic lakes in Vollenweider's study.

Table 47. Summary of mean total phosphorus, total nitrogen, and chlorophyll a results for the Ridinger Lake watershed lakes.

Parameter	Ridinger Lake	Robinson Lake	Troy Cedar Lake
Total Phosphorus (mg/L or ppm)	0.232	0.276	0.189
Total Nitrogen (mg/L or ppm)	2.248	2.146	2.134
Chlorophyll *a* (μg/L or ppb)	46.73	13.4	31.86

Comparison with Other Indiana Lakes

The Ridinger, Robinson, and Troy Cedar Lakes results can also be compared with other Indiana lakes. Table 48 presents data from 355 Indiana lakes collected during July and August from 1994 to 1998 under the Indiana Clean Lakes Program. The set of data summarized in the table are mean values obtained by averaging the epilimnetic and hypolimnetic pollutant concentrations in samples from each of the 355 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 48. Water quality characteristics of 355 Indiana lakes sampled from 1994 through 1998 by the Indiana Clean Lakes Program. Means of epilimnion and hypolimnion samples were used.

	Secchi Disk (m)	NO_3 (mg/L)	NH_4 (mg/L)	TP (mg/L)	SRP (mg/L)	Chl. *a* (μg/L)
Median	1.8	0.025	0.472	0.097	0.033	5.33
Maximum	9.2	9.303	11.248	4.894	0.782	230.9
Minimum	0.1	0.022	0.018	0.001	0.001	0

All of the parameters measured in Ridinger Lake watershed lakes, except the ammonia-nitrogen in Troy Cedar Lake, were above the median values measured for the set of Indiana lakes. This suggests that Ridinger, Robinson, and Troy Cedar Lakes had worse overall water quality than most Indiana lakes at the time of the August, 19 2003 sampling. Stated another way, the watershed lakes exhibited poorer water clarity (Secchi disk) and generally higher nutrient levels than most Indiana lakes. The study lakes also were more productive (chlorophyll *a*) than most Indiana lakes.

Table 49. Comparison of Ridinger Lake watershed lakes to the median for all Indiana lakes for selected water parameters.

Lake	Secchi Disk	NO_3	NH_4	TP	SRP	Chl. *a*
Troy Cedar	worse	worse	better	worse	worse	worse
Robinson	worse	worse	worse	worse	worse	worse
Ridinger	worse	worse	worse	worse	worse	worse

Using a Trophic State Index

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 TSI

The Indiana TSI (ITSI) 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. Today's ITSI uses ten different water quality parameters to calculate a score. Table 50 shows the point values assigned to each parameter.

Table 50. The Indiana Trophic State Index.

Parameter and Range			Eutrophy Points
I.	Total Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
II.	Soluble Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5

III.	Organic Nitrogen (ppm)		
	A.	At least 0.5	1
	B.	0.6 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
IV.	Nitrate (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
V.	Ammonia (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.5	2
	C.	0.6 to 0.9	3
	D.	1.0 or more	4
VI.	Dissolved Oxygen: Percent Saturation at 5 feet from surface		
	A.	114% or less	0
	B.	115% to 119%	1
	C.	120% to 129%	2
	D.	130% to 149%	3
	E.	150% or more	4
VII.	Dissolved Oxygen: Percent of measured water column with at least 0.1 ppm dissolved oxygen		
	A.	28% or less	4
	B.	29% to 49%	3
	C.	50% to 65%	2
	D.	66% to 75%	1
	E.	76% to 100%	0
VIII.	Light Penetration (Secchi Disk)		
	A.	Five feet or under	6
IX.	Light Transmission (Photocell) : Percent of light transmission at a depth of 3 feet		
	A.	0 to 30%	4
	B.	31% to 50%	3
	C.	51% to 70%	2
	D.	71% and up	0

X. Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface:

A.	less than 3,000 organisms/L	0
B.	3,000 - 6,000 organisms/L	1
C.	6,001 - 16,000 organisms/L	2
D.	16,001 - 26,000 organisms/L	3
E.	26,001 - 36,000 organisms/L	4
F.	36,001 - 60,000 organisms/L	5
G.	60,001 - 95,000 organisms/L	10
H.	95,001 - 150,000 organisms/L	15
I.	150,001 - 5000,000 organisms/L	20
J.	greater than 500,000 organisms/L	25
K.	Blue-Green Dominance: additional points	10

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

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

Four of these categories correspond to the qualitative lake productivity categories described earlier. The fifth category, dystrophic, is for lakes that possess high nutrient concentrations, but have limited rooted plant and algal productivity (IDEM, 2000). A rising TSI score for a particular lake from one year to the next indicates that water quality is worsening, while a lower TSI score indicates improved conditions. However, natural factors such as climate variation can cause changes in TSI scores that do not necessarily indicate a long-term change in lake condition. (Jones (1996) suggests that changes in TSI scores of 10 or more points are indicative of changes in trophic status, while smaller changes in TSI scores may be more attributable to natural fluctuations in water quality parameters.)

The Indiana Trophic State Index values calculated for Ridinger, Robinson, and Troy Cedar Lakes are shown in Table 51. These values place the Ridinger Lake in the hypereutrophic range, while Robinson and Troy Cedar Lakes fall in the eutrophic range of the Indiana TSI. This conclusion is generally consistent with results obtained from the comparison of the lake data to Vollenweider's data (Table 46) and other Indiana lakes (Table 48). The Vollenweider data indicate that Ridinger and Troy Cedar Lakes lie on the hypereutrophic side of the eutrophic-hypereutrophic dividing line, while Robinson Lake falls on the eutrophic side of eutrophic-hypereutrophic dividing line. As will be described later in this section, the Indiana TSI scores for all three lakes are also generally consistent with the analysis of the lake data using Carlson's TSI.

Table 51. The Ridinger Lake watershed lakes Indiana Trophic State Index scores for sampling conducted between the 1970's and 2003.

	1970's	1989	1990	1994	1998	2003
Ridinger Lake	58	42	-	-	45	49
Robinson Lake	-	-	28	-	37	33
Troy Cedar Lake	60	-	34	37	29	43

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. Table 51 presents historical ITSI scores for Ridinger, Robinson, and Troy Cedar Lakes. The ITSI scores show an increase in water quality in Ridinger and Troy Cedar Lakes from the 1970s to 1989/1990 but relatively stable water quality since then. The ITSI scores for Robinson Lake suggest that water quality has remained fairly stable over the past 13 years.

Using the ITSI to compare Ridinger, Robinson, and Troy Cedar Lakes to other lakes in the region, water quality is on par with or worse than most lakes in the region. Based on data collected by the Indiana Clean Lakes Program's 1998 assessment, approximately 12% of the lakes in the Upper Wabash Basin (which includes the Ridinger Lake watershed) were classified as oligotrophic (IDEM, 2000). Another 35% rated as mesotrophic. Forty-five percent fell in the eutrophic category, while 8% fell in the hypereutrophic category. Ridinger Lake's placement in the hypereutrophic category and Robinson and Troy Cedar Lakes placement in the eutrophic category based on the ITSI suggests that their water quality is among the bottom half of lakes in the region when ranked by water quality.

The Carlson TSI

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 a 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 54).

As a further aid in interpreting TSI results, Carlson's scale is divided into four lake productivity 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 1 meter (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.

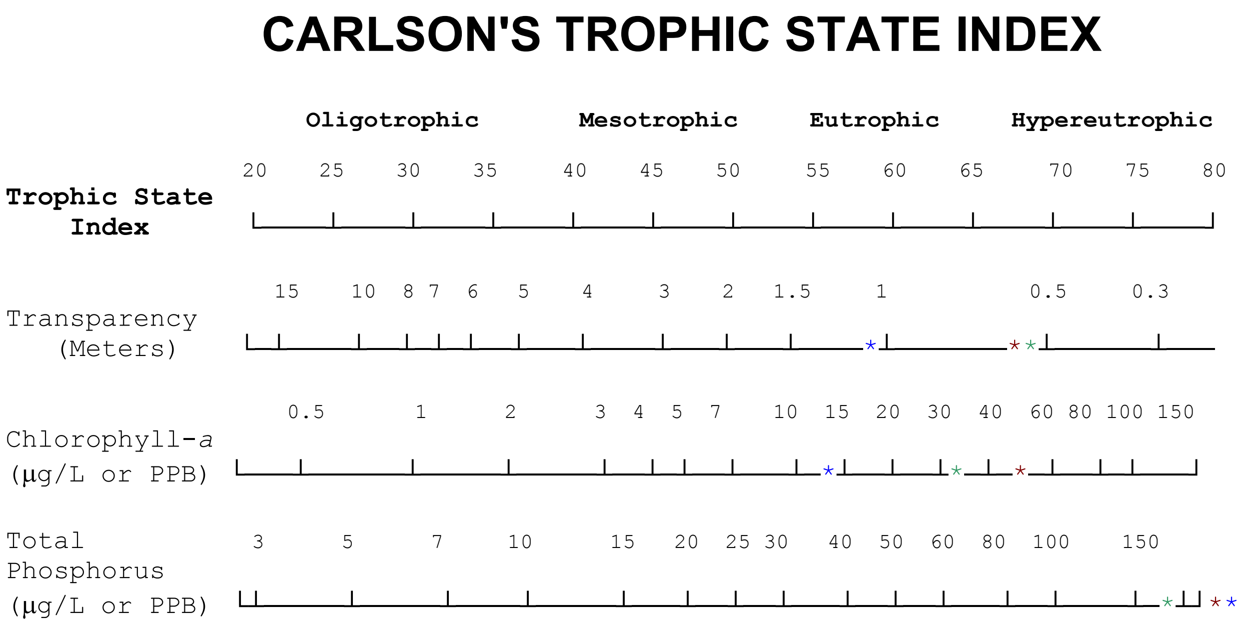


Figure 54. Carlson's Trophic State Index with Ridinger (*), Robinson (*), and Troy Cedar (*) Lakes indicated by asterisks.

Analysis of Ridinger, Robinson, and Troy Cedar Lakes total phosphorus, transparency, and chlorophyll *a* data according to Carlson's TSI suggests that the lakes are eutrophic to hypereutrophic (Figure 54). Ridinger Lake's transparency places the lake in the eutrophic category, while its total phosphorus and chlorophyll *a* concentrations place it in the hypereutrophic category. Robinson Lake's chlorophyll *a* concentration places the lake in the eutrophic category and its total phosphorus concentration places it in the hypereutrophic category. Robinson Lake's transparency TSI score falls between the eutrophic and hypereutrophic categories. Troy Cedar Lake's chlorophyll *a* concentration places the lake along the border between the eutrophic and hypereutrophic categories. Troy Cedar Lake's transparency and total phosphorus concentration suggest the lake is hypereutrophic in nature. The three study lakes' high total phosphorus concentrations create conditions suitable for high levels of productivity. It is likely that the lakes' poor clarity, particularly non-algal turbidity, may be preventing the levels of productivity from reaching their potential.

Summary
Ridinger, Robinson, and Troy Cedar Lakes all have more phosphorus than is ideal. The potential exists for excessive algae production and this occurs periodically in the lakes. All of the lakes are considered hypereutrophic when evaluated with Carlson's total phosphorus TSI. There is evidence of historic excessive biological production in the sediments of the lakes (Table 52). For example, there is considerably more soluble phosphorus in the hypolimnia (bottom waters) of the lakes, especially Robinson Lake, compared to the lakes' epilimnetic concentrations. This is strong evidence that phosphorus is being liberated from the sediments when oxygen is depleted. This *internal loading* of phosphorus is another source of phosphorus to these lakes that can promote excessive algae production.

These same lakes also have relatively high ammonia-nitrogen concentrations in their hypolimnetic waters (Table 52). Ammonia is a by-product of bacterial decomposition. When ammonia occurs in high concentrations, it is evidence of high biochemical oxygen demand (BOD). This BOD comes from organic wastes (dead algae, rooted plants) on the sediments – further evidence of excess algae and plant growth in these lakes.

Table 52. Summary data for the Ridinger Lake watershed lakes collected August 19, 2003.

Lake	Secchi Disk Transparency Trend	Sediment Phos. Release Factor[1]	Hypolimnetic Ammonia Conc. (mg/L)	Carlson's Total Phosphorous TSI
Troy Cedar	decreasing	30	1.044	77
Robinson	increasing	82	3.612	>80
Ridinger	no trend	51	3.280	79

[1]Hypo SRP concentration/Epi SRP concentration. For example, Troy Cedar's hypolimnetic SRP concentration is 30 times that in the epilimnion. This difference is strong evidence of substantial internal loading of phosphorus.

5.0 MACROPHYTE INVENTORY

5.1 Macrophyte Inventory Introduction

There are many reasons to conduct an aquatic rooted plant survey as part of a complete assessment of a lake and its watershed. Like other biota in a lake ecosystem (e.g. fish, microscopic plants and animals, etc.), the composition and structure of the lake's rooted plant community often provide insight into the long term water quality of a lake. While sampling the lake water's chemistry (dissolved oxygen, nutrient concentrations, etc.) is important, water chemistry sampling offers a single snapshot of the lake's condition. Because rooted plants live for many years in a lake, the composition and structure of this community reflects the water quality of the lake over a longer term. For example, if one samples the water chemistry of a typically clear lake immediately following a major storm event, the results may suggest that the lake suffers from poor clarity. However, if one examines the same lake and finds that rooted plant species such as northern water milfoil, white stem pondweed, and large leaf pondweed, all of which prefer clear water, dominate the plant community, one is more likely to conclude that the lake is typically clear and its current state of turbidity is due to the storm rather than being its inherent nature.

The composition and structure of a lake's rooted plant community also help limnologists understand why the lake's fish community has a certain composition and structure. For example, lakes with dense stands of rooted submerged plants often have large, stunted bluegill populations. Dense rooted plant stands provide ample cover or protection for small prey fish such as bluegills from larger predators such as largemouth bass. With greater coverage, the prey fish may begin to overpopulate the lake since fewer are being eaten by the predators. As the prey fish overpopulate, their food resources are spread thinner. This, in turn, leads to stunting of the prey fish. Similarly, lakes with depauperate emergent plant communities may have difficulty supporting some top predators that require the emergent vegetation for spawning. In these and other ways, the lake's rooted plant community illuminates possible reasons for a lake's fish community composition and structure.

A lake's rooted plant community impacts the recreational uses of the lake. Swimmers and power boaters desire lakes that are relatively plant-free, at least in certain portions of the lake. In contrast, anglers prefer lakes with adequate rooted plant coverage, since those lakes offer the best fishing opportunity. Before lake users can develop a realistic management plan for a lake, they must understand the existing rooted plant community and how to manage that community. This understanding is necessary to achieve the recreational goals lake users may have for a given lake.

For the reasons outlined above, as well as several others, JFNew conducted a general macrophyte (rooted plant) survey on Ridinger, Robinson, and Troy Cedar Lakes as part of the overall lake and watershed diagnostic study. Before detailing the results of the macrophyte survey, it may be useful to outline the conditions under which lakes may support macrophyte growth. Additionally, an understanding of the roles that macrophytes play in a healthy, functioning lake ecosystem is necessary for lake users to manage the lake's macrophyte community. The following paragraphs provide some of this information.

Conditions for Growth

Like terrestrial vegetation, aquatic vegetation has several habitat requirements that need to be satisfied in order for the plants to grow or thrive. Aquatic plants depend on sunlight as an energy source. The amount of sunlight available to plants decreases with depth of water as algae, sediment, and other suspended particles block light penetration. Consequently, most aquatic plants are limited to maximum water depths of approximately 10-15 feet (3-4.5 m), but some species, such as Eurasian water milfoil, have a greater tolerance for lower light levels and can grow in water deeper than 32 feet (10 m) (Aiken et al., 1979). Hydrostatic pressure rather than light often limits plant growth at deeper water depth (15-20 feet or 4.5-6 m).

Water clarity affects the ability of sunlight to reach plants, even those rooted in shallow water. Lakes with clearer water have an increased potential for plant growth. Ridinger, Robinson and Troy Cedar Lakes all possess poorer water clarity than the average Indiana lake. The Secchi disk depths measured during the plant surveys were all less than 3 feet (0.9 m). (These measurements were consistent with the Secchi disk depths measured for each lake during the in-lake sampling portion of the study.) The poor water clarity likely impairs aquatic plant growth. As a general rule of thumb, rooted plant growth is restricted to the portion of the lake where water depth is less than or equal to 2-3 times the lake's Secchi disk depth. This is true in Ridinger, Robinson, and Troy Cedar Lakes, where rooted plants were not observed in water deeper than 8 feet, which is approximately 3 times the lakes' average Secchi disk depth.

Aquatic plants also require a steady source of nutrients for survival. Aquatic macrophytes differ from microscopic algae (which are also plants) in their uptake of nutrients. Aquatic macrophytes receive most of their nutrients from the sediments via their root systems rather than directly utilizing nutrients in the surrounding water column. Some competition with algae for nutrients in the water column does occur. The amount of nutrients taken from the water column varies for each macrophyte species. Because macrophytes obtain most of their nutrients from the sediments, lakes which receive high watershed inputs of nutrients to the water column will not necessarily have aquatic macrophyte problems.

A lake's substrate and the forces acting on the substrate also affect a lake's ability to support aquatic vegetation. Lakes that have mucky, organic, nutrient-rich substrates have an increased potential for plant growth compared to lakes with gravelly, rocky substrates. Sandy substrates that contain sufficient organic material typically support healthy aquatic plant communities. Lakes that have significant wave action that disturb the bottom sediments have decreased ability to support plants. Disturbance of bottom sediment may decrease water clarity, limiting light penetration, or may affect the availability of nutrients for the macrophytes. Wave action may also create significant shearing forces prohibiting plant growth altogether.

Boating activity may affect macrophyte growth in conflicting ways. Rooted plant growth may be limited if boating activity regularly disturbs bottom sediments. Alternatively, boating activity in rooted plant stands of species that can reproduce vegetatively, such as Eurasian water milfoil, may increase macrophyte density rather than decrease it. Boating activity may be increasing the size and density of the Eurasian water milfoil stands in Ridinger, Robinson, and Troy Cedar Lakes.

Ecosystem Roles

Aquatic plants are a beneficial and necessary part of healthy lakes. Plants stabilize shorelines holding bank soil with their roots. The vegetation also serves to dissipate wave energy further protecting shorelines from erosion. Plants play a role in a lake's nutrient cycle by up-taking nutrients from the sediments. Like their terrestrial counterparts, aquatic macrophytes produce oxygen which is utilized by the lake's fauna. Plants also produce flowers and unique leaf patterns that are aesthetically attractive.

Emergent and submerged plants provide important habitat for fish, insects, reptiles, amphibians, waterfowl, shorebirds, and small mammals. Fish utilize aquatic vegetation for cover from predators and for spawning and rearing grounds. Different species depend upon different percent coverages of these plants for successful spawning, rearing, and protection for predators. For example, bluegill require an area to be approximately 15-30% covered with aquatic plants for successful survival, while northern pike achieve success in areas where rooted plants cover 80% or more of the area (Borman et al., 1997).

Aquatic vegetation also serves as substrate for aquatic insects, the primary diet of insectivorous fish. Waterfowl and shorebirds depend on aquatic vegetation for nesting and brooding areas.

Numerous aquatic waterfowl were observed utilizing Ridinger, Robinson, and Troy Cedar Lakes as habitat during the macrophyte survey. Aquatic plants such as pondweed, coontail, duckweed, water milfoil, and arrowhead, also provide a food source to waterfowl. Duckweed in particular has been noted for its high protein content and consequently has served as feed for livestock. Turtles and snakes utilize emergent vegetation as basking sites. Amphibians rely on the emergent vegetation zones as primary habitat.

5.2 Macrophyte Inventory Methods

JFNew surveyed Ridinger, Robinson, and Troy Cedar Lakes on August 26, 2003 according to the Indiana State Tier One sampling protocol (Schuler and Hoffmann, 2002). JFNew examined the entire littoral zone of each lake. As defined in the protocol, the lakes' littoral zones were estimated to be approximately three times each lake's Secchi disk depth. This estimate approximates the 1% light level, or the level at which light penetration into the water column is sufficient to support plant growth. (See the **Lake Assessment** section for a full discussion of the 1% light level and the reading recorded during the in-lake sampling effort.) At the time of sampling, Ridinger Lake's Secchi disk depth was 2.0 feet (0.6 m); thus, its 1% light level was estimated to be approximately 6 feet (1.8 m). Consequently, JFNew sampled that area of Ridinger Lake that is less than 6 feet deep. Similarly, Robinson and Troy Cedar Lakes' Secchi disk depths were 2.7 feet (0.8 m) and 2.0 feet (0.6 m), respectively. Their 1% light levels were estimated to be 8.1 feet (2.5 m) and 6 feet (1.8 m), respectively, and JFNew sampled the areas of Robinson and Troy Cedar Lakes that are less than 8 and 6 feet deep, respectively.

A survey crew, consisting of two aquatic ecologists and one botanist, surveyed Ridinger, Robinson, and Troy Cedar Lakes in a clockwise manner, starting at the public boat launches. The survey crew drove their boat in a zig-zag pattern across the littoral zone of each lake while visually identifying plant species. The crew maintained a tight pattern to ensure the entire zone was observed. While the estimated littoral zones of each lake were quite shallow allowing for good visual identification of plant species, in areas of dense plant coverage, rake grabs were performed to ensure all species were identified. Once the crew had visually surveyed an entire plant bed, the crew broadly estimated species abundance, canopy coverage by strata (emergent, rooted floating, non-rooted floating, and submergent), and bed size. The crew also noted the bed's bottom substrate type. The crew recorded all data on data sheets (Appendix F). After completing one bed, the crew continued surveying the littoral zone until all plant beds were identified and the appropriate data were recorded.

5.3 Macrophyte Inventory Results

5.3.1 Ridinger Lake

Ridinger Lake supports roughly 14 plant beds ringing its shoreline (Figure 55). The plant beds range in size from approximately 900 square feet (84 m^2) to 1.7 acres (0.7 ha). The largest beds tend to be adjacent to undeveloped shoreline. The lake's largest bed, for example, stretches along the lake's northwestern corner near its outlet. The largest plant bed extends approximately 100 feet (30 m) from the shoreline, but most beds extend to a maximum of only 40 to 55 feet (12 to 17 m) from the shoreline. In general, Ridinger Lake's rooted plant community is confined to depths less than 10 feet (3 m). This is consistent with the estimated extent of the littoral zone of 6 feet.

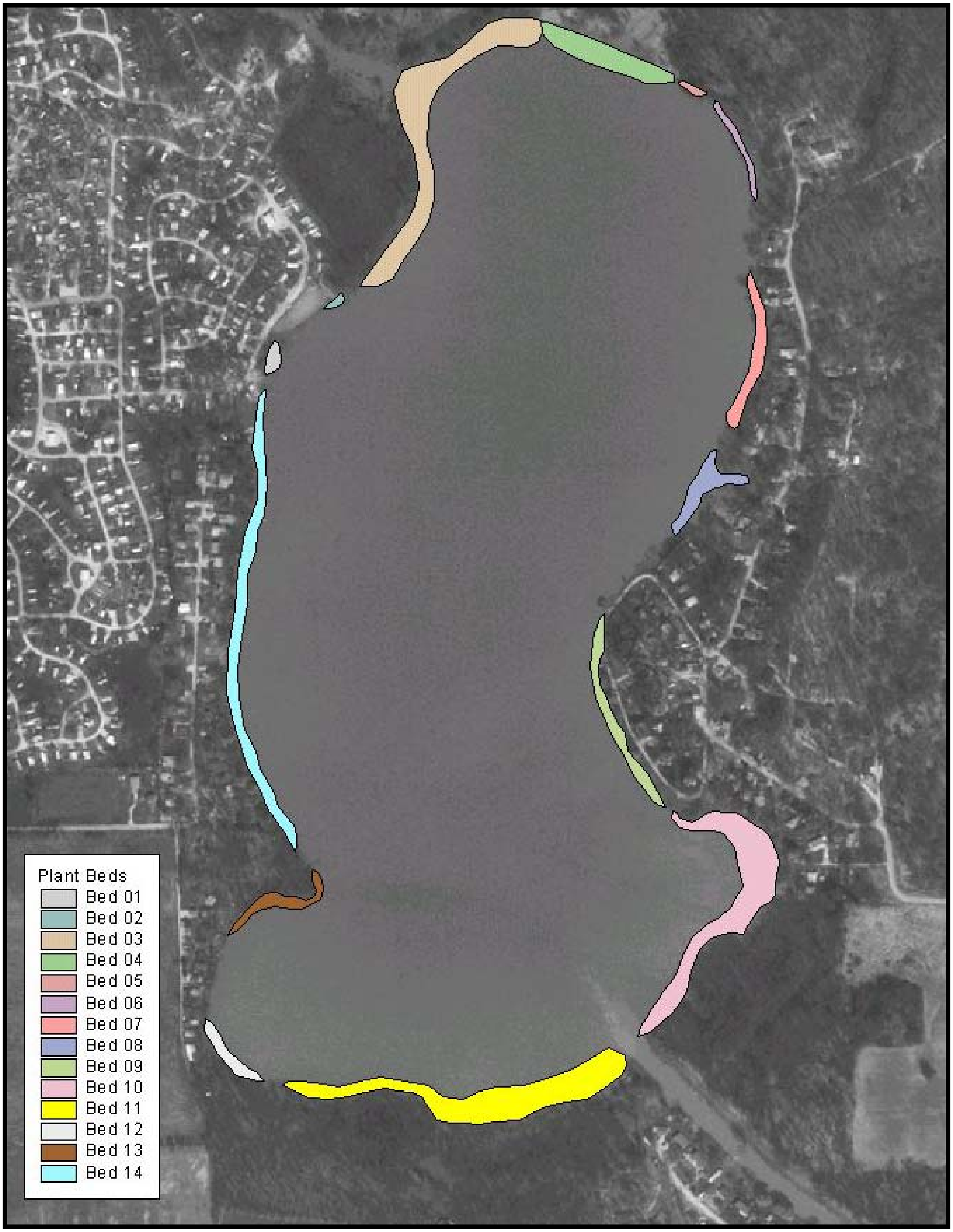


Figure 55. Ridinger Lake plant beds as mapped August 26, 2003. Scale: 1"=750'.

Ridinger Lake supports 36 different species of rooted plants. Most of these are emergent (16 species) or submerged (11 species). The dominant emergent species in Ridinger Lake is pickerel weed. Common submerged species include Eurasian water milfoil, coontail, and Sago pondweed, while spatterdock dominates the floating stratum. Diversity among the individual plant beds on the lake varies from 6 to 21, although most of the plant beds supported 13 to 17 species. There was no obvious correlation between the size of the plant bed and number of species it supports. Similarly, there was no observable correlation between whether the bed existed along a developed portion of the lake and plant bed species richness.

The general sparseness of Ridinger Lake's plant beds distinguishes this lake from many others in the area. None of the plant beds exhibit a submerged species canopy coverage greater than 2%. Similarly, canopy coverage of the emergent and floating strata is generally less than 20%. Aquatic applicators have conducted chemical treatment on Ridinger Lake in the past (IDNR, personal communication). It is possible that individual property owners are also implementing management measures along their property. Many of the plant beds along developed areas are extremely sparsely vegetated. The following paragraphs detail the composition and structure of each plant bed in Ridinger Lake. (Appendix G provides the data sheets for each of the plant beds).

Beds 01 and 02

Beds 01 and 02 are located north of the public boats launch, along the western shoreline of Ridinger Lake. Both beds are relatively small in size (less than a tenth of an acre in size) and are typical of the plant beds found along developed portions of the lake. Floating species, including spatterdock and white water lilies, dominate Bed 01 and account for the large portion of the bed's canopy coverage. In contrast, the emergent species, pickerel weed, dominates Bed 02. The two beds also differ in the number of species they support. Bed 01 supports 15 species, while Bed 02 supports only six. Although the plant stands are relatively small, Bed 01 does support a relatively high diversity of submerged species (7). Purple loosestrife grows along the shoreline near these beds.

Bed 03

Compared to Beds 01 and 02, Bed 03 is much larger, covering approximately 1.7 acres of lake. Bed 03 lies along the undeveloped portion of the lake near the lake's outlet. Rooted floating species such as spatterdock and emergent species, primarily pickerel weed, dominate Bed 03. Bed 03 supports 11 species on its sandy silt substrate. Eurasian water milfoil and coontail, both of which can be nuisance species, dominate the bed's submerged stratum. Filamentous algae is also a problem in this location.

Bed 04

Like Bed 03, Bed 04 borders an undeveloped portion of the lack. However, Bed 04 lacks the emergent and rooted floating plant growth that characterizes Bed 03. Bed 04 is sparsely vegetated. Filamentous algae dominates the plant community and accounts for the greatest canopy coverage. Eurasian water milfoil, coontail, and Sago pondweed, species that are commonly found in eutrophic lakes, are subdominants in Bed 04. Bed 04 is approximately 0.6 acres in size and supports 13 species.

Beds 05 and 06

Beds 05 and 06 lie along a developed portion in the northeast corner of Ridinger Lake. While the two beds are different in size, they support similar communities. Bed 05 supports a total of 14 species, while Bed 06 supports a total of 13 species. Emergent plants provide most of the canopy coverage in these beds. Pickerel weed dominates Bed 05's emergent community, while pickerel weed and narrow leaved cattail dominate Bed 06's emergent community. Floating and submerged species are minor components of each bed's community. Sago pondweed, coontail, and southern naiad dominate Bed 05's submerged community. Bed 06's dominant submerged species include Sago pondweed, coontail, and long-leaf pondweed.

Beds 07 and 08

Beds 07 and 08 lie adjacent to the eastern shoreline of the lake. The increase in floating species marks the transition from Beds 05 and 06 to Beds 07 and 08. Floating (rooted and non-rooted) species cover 21-60% of Bed 07. The dominant floating plant species in Bed 07 include spatterdock, watermeal, duckweed, and filamentous algae. Floating species cover between 2 and 20% of Bed 08. The same species that dominate Bed 07 dominate Bed 08 only in lesser quantities. In general, Bed 08 is sparsely vegetated, with several piers and docks interrupting the bed. Sago pondweed, Eurasian water milfoil, and coontail dominate the Bed 07's submerged stratum; Sago pondweed, southern naiad, and coontail dominate the Bed 08's submerged stratum. The nuisance, exotic reed canary grass was observed adjacent to Bed 07. Although they are minor components of the plant beds, both Bed 07 and 08 support some taller emergent species such as softstem bulrush, chairmaker's rush, and giant burreed. The woody emergent species, button bush, was observed in Bed 08.

Bed 09

Like Bed 08, Bed 09 is very sparsely vegetated. The bed stretches across approximately one third of an acre. The shoreline adjacent to Bed 09 is developed and several piers and docks interrupt Bed 09. Bed 09 supports a total of 15 species. Emergent species dominate Bed 09. The most common emergent species are pickerel weed and lizard's tail. Floating and submerged species are minor components of Bed 09. Like many of the other plant beds Sago pondweed, Eurasian water milfoil, and coontail dominate the Bed 09's submerged stratum. These species are very tolerant of poor water clarity and high nutrient concentrations.

Bed 10

An increase in the abundance and canopy coverage of floating and emergent species marks the transition from Bed 09 to Bed 10. Bed 10 includes a cove in the lake's southeastern corner as well as the inlet to Ridinger Lake. These areas provide ideal habitat for spatterdock, a floating species. Consequently, spatterdock covers a large portion of the Bed 10. The dominance of pickerel weed and giant burreed, both emergent species, also characterizes Bed 10. Bed 10 shares some similarities with the other beds on Ridinger Lake. Specifically, the submerged stratum in Bed 10 is only a minor component of the bed's plant community. In addition, the dominant submerged species include many of the same dominants found in the submerged stratum of other beds: Sago pondweed, Eurasian water milfoil, and coontail. Long-leaf pondweed is another dominant in Bed 10's submerged community. Like Sago pondweed, Eurasian water milfoil, and coontail, long-leaf pondweed is tolerant of poor water clarity and eutrophic conditions.

Bed 11
Bed 11 is a very sparsely vegetated bed located along an undeveloped portion of the lake's southern shoreline, west of the lake's outlet. The bed supports 14 species and possesses the greatest richness of submerged species (8). Despite the high species richness relative to this lake, the nuisance species, Eurasian water milfoil and coontail, dominate the plant bed. Both species typically reflect poor water quality conditions. Several individuals of small pondweed were noted in Bed 11. Small pondweed is listed as a state rare species. This species was only found in Beds 11 and 13, although several other beds supported unidentifiable narrow-leaved pondweeds which could possibly include small pondweed. While this species is relatively rare in Indiana, it can live in turbid conditions (Borman et al., 1997), so its presence does not necessarily mean Ridinger Lake possesses good water quality.

Beds 12 and 13
Beds 12 and 13 are similarly sized beds located in the southwest corner of Ridinger Lake. The beds have somewhat similar structure in that floating species dominate both beds. Like the southeast corner of the lake, the southwest corner of the lake consists largely of a protected cove. This cove habitat is ideal for floating species. Spatterdock dominates both beds. Watermeal is another dominant in Bed 12. With respect to the submerged community, both beds share some common dominants as well; however in addition to the dominants shared by both beds, Eurasian water milfoil and coontail, southern naiad and Sago pondweed also dominate Bed 13's submerged stratum. The largest difference between the two beds is their species richness. Bed 13 supports 10 more species than Bed 12. Eight submerged species and seven emergent species grow in Bed 13 compared to three submerged and three emergent species in Bed 12. Bed 13 also supports the state rare small pondweed.

Bed 14
Bed 14 is a sparsely vegetated bed stretching along the lake's western shoreline. The bed supports nine species. Most of these species are found in every bed in the lake. Floating species, primarily spatterdock, dominates the bed's community. Sago pondweed and southern naiad dominate the bed's submerged community.

5.3.2 Robinson Lake
Rooted aquatic plants entirely ring Robinson Lake forming one contiguous plant bed. (Appendix G contains plant bed data sheets.) On average, the plant community extends approximately 30-40 feet (9-12 m) from the lake's shoreline, although in places along the southern and northern ends of the lake, the plant community extends nearly 100 feet (30 m) from the shoreline. Using the bathymetric map for Robinson Lake, this suggests the aquatic plant community was restricted to water depths near 5 feet (1.5 m). Occasionally, rooted plants were observed in deeper water (depths closer to 10 feet or 3 m). This is generally consistent with the estimated extent of the littoral zone based on the lake's Secchi disk depth of 2.7 feet (0.8 m), measured at the time of the aquatic plant survey.

The Robinson Lake survey revealed the presence of 26 species. The lake has representative species from all three major strata (emergent, floating, and submerged) of plant communities. Emergent plant species are the most diverse group in the lake accounting more than half of the total plant species by number. Pickerel weed and arrow arum dominate the emergent portion of the plant community. These species possess canopy abundance ratings of 2-20%. Coontail is pervasive in the lake. Dense, nuisance stands of the species ring the entire lake. Eurasian water milfoil is also a dominant component of the lake's submerged plant stratum. Other submerged species such as large-leaved pondweed and long-leaf pondweed exist only as small stands with few individual plants. Rooted and non-rooted floating species cover a large portion of the plant bed. Watermeal, spatterdock, and white water lilies are co-dominants with coontail. Finally, filamentous algae coats many of the rooted plants in Robinson Lake.

5.3.3 Troy Cedar Lake

Like Robinson Lake, a narrow band of rooted plants rings much of Troy Cedar Lake (Figure 56). (Appendix G contains plant bed data sheets.) Based on community composition and structure, this ring can be divided into two distinct beds. In general, Bed 01 parallels the southern, western, and northern shoreline, while Bed 02 lies along the eastern shoreline of the lake. On average, Bed 01 extends approximately 40-45 feet (12-13.7 m) from the shoreline. This width varies widely along the edge of the bed. In some spots, particularly in the cove areas, Bed 01 extends approximately 125 feet (38 m) from the shoreline. Bed 02 is slightly narrower with an average width closer to 40 feet (12 m) and a maximum width of about 55 feet (17 m). In total, Troy Cedar Lake supports 23 species.

There are several similarities in the plant community's composition and structure between Bed 01 and Bed 02. Rooted floating species dominate the plant community in both beds. In Bed 01, floating species account for 21-60% of the bed's canopy coverage. Bed 02 is much more sparsely vegetated, but floating species still provide most of the canopy coverage. Spatterdock and white water lilies dominate Bed 01's floating stratum, while only spatterdock exists in Bed 02. Dominant submerged species in Bed 01 include coontail and Eurasian water milfoil. Water heartsease, Sago pondweed, long-leaf pondweed, and eel grass are minor components of Bed 01's submerged stratum. Only Eurasian water milfoil, coontail, and eel grass grow in in the submerged stratum of Bed 02.

The biggest difference between Beds 01 and 02 in Troy Cedar Lake is the difference in the composition of the emergent stratum. Bed 01 supports 11 species compared to the 6 species observed in Bed 02. Large stands of chairmaker's rush grow along the undeveloped edge of Bed 01. In contrast, few individuals of any emergent species vegetate the eastern edge of Troy Cedar Lake, which as been developed for residential use.

Figure 56. Troy Cedar Lake plant beds as mapped August 26, 2003. Scale: 1"=500'.

5.4 Macrophyte Inventory Discussion

In general, the results of the Ridinger Lake aquatic plant survey were consistent with findings from other surveys of the lake. Historical studies record that many of the species that currently dominate Ridinger Lake also dominated the lake in recent history. The 1978 and 1995 IDNR Division of Fish & Wildlife fisheries surveys of the lake reported that pickerel weed, spatterdock, coontail, Eurasian water milfoil, and filamentous algae were either common or abundant. Similarly, the 1990 International Science & Technology study noted that Eurasian water milfoil and spatterdock were the most common species in Ridinger Lake. The maximum depth in which plants were found was also similar among historical studies and the current study. During the current study, plants were not observed in water depths greater than 10 feet (3 m). The IDNR studies place the extent of the littoral zone closer to 8 feet (2.4 m).

The biggest difference between the current study of the Ridinger Lake plant community and the historical studies is the difference in species richness. IST observed only 14 species, while the

IDNR noted the presence of 15 species in 1978 and 16 species in 1995. In contrast, 36 species were observed during the current study. All of the species recorded in historical studies were noted in the current study. A difference in survey methodology is likely the reason for the observed difference in species richness rather than an actual increase in the number of plant species in Ridinger Lake.

Less historical data is available for Robinson and Troy Cedar Lakes. The results of the current survey of Robinson Lake are similar to the results of the vegetation component of the 1999 IDNR fisheries survey on the lake. The 1999 IDNR study noted the abundance of coontail in Robinson Lake; coontail covered 100% of the each of the four transects in that study. Eurasian water milfoil was also a dominant component of the submerged community in each transect in the 1999 study. Like the current study, the 1999 study also recorded the dominance of filamentous algae in all four transects and various duckweed genera in two of the four transects. Vegetation in the 1999 study was limited to a maximum water depth of 12 feet. These similarities between the 1999 IDNR study and the current study suggest there has been little change in the Robinson Lake aquatic plant community in the past several years.

In contrast, a comparison of the current survey results to results of vegetation component of the 1965 IDNR fisheries study shows that the composition of the aquatic community in Troy Cedar Lake has changed over the past 40 years. The most significant change occurred in the community's submerged strata. In 1965, 10 submerged species were observed including one state endangered species, straight leafed pondweed (*Potamogeton strictifolius*), and two pondweeds that are sensitive to turbidity, big leaf pondweed and Illinois pondweed. Only seven submerged species were observed in Troy Cedar Lake during the current survey. Additionally, the three species noted above were absent from the lake during the current survey. Troy Cedar Lake's water clarity has declined over the past 40 years (See the **Historical Water Quality** section). This decline likely led to the demise of species such as Illinois pondweed and big leaf pondweed, which were noted as important components of the lake's aquatic plant community in 1965. These species may still exist as very minor components of the Troy Cedar Lake plant community, but they do not play the same role as they did in 1965. This loss can have important implications for the lake's fishery.

The plant communities of Ridinger, Robinson, and Troy Cedar Lakes reflect the water quality conditions in each of these lakes. Each of these lakes rates as eutrophic or hypereutrophic using Carlson's or the Indiana Trophic State Index. Similarly, each lake possesses a relatively high epilimnetic and mean total phosphorus concentration. Not surprisingly then, many of the dominant rooted plant species found in each lake are well adapted to eutrophic water quality conditions. For example, coontail, which is very tolerant of eutrophic conditions, is a dominant species in each of the lakes. Eurasian water milfoil, which is similarly tolerant of poor water quality, is a major component in each lakes' submerged community. Robinson Lake, which possessed the highest mean total phosphorus concentration of the three lakes, also supports dense populations of filamentous algae, watermeal, and duckweed. These species obtain their nutrients directly from the water column, so they are typically abundant in high nutrient lakes.

The structure and composition of the aquatic plant community can influence the structure and composition of a lake's fish community. IDNR fisheries reports show that, of the three lakes, Ridinger Lake has the highest percentage (by numbers) of predator fish. Ridinger Lake lacks the dense growth of submerged plants that rings Robinson Lake and a least of portion of Troy Cedar Lake. This limits cover for prey fish such as bluegill and improves the opportunity for predators to capture prey. The relative ease in capturing prey may, at least in part, be responsible for the abundance of predators in Ridinger Lake. Similarly, the most recent fisheries survey (1999) of Robinson Lake showed that despite the lake's significant largemouth bass population, bluegill composed over 60% of the fish community by number. The dense stands of coontail may be protecting the bluegill from the lake's largemouth bass, allowing bluegill population to thrive. Management of the coontail may be necessary if the bluegill population begins to show signs of stunting. (It is important to note that Braun (1999) also points to a difference in weather conditions between the 1999 survey of Robinson Lake and surveys conducted in previous years. Weather conditions may have played a role in the observed increase in the bluegill percentage in Robinson Lake. Please see Braun, 2001 for full details.)

Nuisance and Exotic Plants

All three study lakes support one or several nuisance and/or exotic aquatic plant species. The plant surveys revealed the presence of Eurasian water milfoil, a submerged aggressive exotic, and reed canary grass in or along all three study lakes. Ridinger Lake supports one additional emergent exotic plant species: purple loosestrife. Wetland areas bordering both Robinson and Troy Cedar Lakes likely harbor purple loosestrife as well. As nuisance species, these species have the potential to proliferate if left unmanaged, so lake residents and visitors must treat these species as a threat to their lakes' health.

The presence of Eurasian water milfoil in the three study lakes is of concern, but it is not uncommon for lakes in the region. Eurasian water milfoil is an aggressive, non-native species. It often grows in dense mats excluding the establishment of other plants. For example, once the plant reaches the water's surface, it will continue growing horizontally across the water's surface. This growth pattern has the potential to shade other submerged species preventing their growth and establishment. In addition, Eurasian water milfoil does not provide the same habitat potential for aquatic fauna as many native pondweeds. Its leaflets serve as poor substrate for aquatic insect larva, the primary food source of many panfish.

Purple loosestrife is an aggressive, exotic species introduced into this country from Eurasia for use as an ornamental garden plant. Like Eurasian water milfoil, purple loosestrife has the potential to dominate habitats, in this case wetland and shoreline communities, excluding native plants. The stiff, woody composition of purple loosestrife makes it a poor food source substitute for many of the native emergents it replaces. In addition, the loss of diversity that occurs as purple loosestrife takes over plant communities lowers the wetland and shoreline habitat quality for waterfowl, fishes, and aquatic insects. Purple loosestrife was observed in several locations along the Ridinger Lake shoreline.

Like purple loosestrife, reed canary grass is native to Eurasia. Farmers used (and many likely still use) the species for erosion control along ditch banks or as marsh hay. The species escaped via ditches and has spread to many of the wetlands in the area. Swink and Wilhelm (1994) indicate that reed canary grass commonly occurs at the toe of the upland slope around a wetland. Reed canary grass was often observed above the ordinary high water mark around all three study lakes. Like other nuisance species, reed canary grass forms a monoculture mat excluding native wetland/shoreline plants. This limits a wetland's or shoreline's diversity ultimately impacting the habitat's functions.

The presence of Eurasian water milfoil and other exotics is typical in northern Indiana lakes. Of the lakes surveyed by aquatic control consultants and IDNR Fisheries Biologists, nearly every lake supported at least one exotic species (White, 1998a). In fact, White (1998a) notes the absence of exotics in only seven lakes in the 15 northern counties in Indiana. These 15 counties include all of the counties in northeastern Indiana where most of Indiana's natural lakes are located. Of the northern lakes receiving permission to treat aquatic plants in 1998, Eurasian water milfoil was listed as the primary target in those permits (White, 1998b). Despite the ubiquitous presence of nuisance species, lakeshore property owners and watershed stakeholders should continue management efforts to limit nuisance species populations. Management options will be discussed in further detail below.

5.5 Aquatic Plant Management Recommendations

A good aquatic plant management plan takes into account the composition and structure of a lake's current and historical plant community as well as the recreational goals of the lake's users. While development of a complete aquatic plant management plan is beyond the scope of this diagnostic study, the following is a list of recommendations that should form the foundation of any plan. A brief description of aquatic plant management techniques applicable to Ridinger, Robinson, and/or Troy Cedar Lakes follows the list. Lake users should also remember that rooted plants are a vital part of a healthy functioning lake ecosystem; complete eradication of rooted plants is neither desirable nor feasible. A good aquatic plant management plan will reflect these facts. Finally, IDNR Fisheries Biologists should be consulted when developing an aquatic plant management plan for these lakes. These biologists possess local knowledge and specifically knowledge regarding each lakes' quality and historical plant communities that is invaluable for the creation of an aquatic plant management plan for Ridinger, Robinson, and Troy Cedar Lakes.

Ridinger Lake

Plant management on Ridinger Lake should have as its goal increasing the number and abundance of plant species. The lake does not support a very diverse plant community. Similarly, the lake lacks an abundance of plants. While this may be good for some of the desired uses of the lake (swimming, power boating, etc.), it is likely affecting the health of the lake's fish community. As a general rule, aquatic plant management techniques designed to reduce plant abundance should not be employed on Ridinger Lake. The exception to this is the management of Eurasian water milfoil and other exotic emergent species such as purple loosestrife and reed canary grass. An improvement in water quality will be necessary to improve the abundance and species richness for the plant community.

The lack of plants in the lake may be a reflection of successful chemical treatments via large-scale application and/or actions taken by individual property owners. Ridinger Lake is the most developed of the lakes in this study. Individual property owners may be treating the areas in front of their property. The scarcity of plant growth around beaches, piers, and docks supports this hypothesis. Because much of the lake is developed for residential use, the result of many individual treatments is an overall lack of plant growth in the lake. Troy Cedar Lake residents have the luxury of reducing plant growth immediately in front of their property without doing as much harm to the fish community because a large portion of the lake has not been developed for residential use. This undeveloped area provides fish habitat. In contrast, there is little undeveloped lake front on Ridinger Lake to provide habitat for fish if the residents of the lake opt to reduce plant cover in front of their individual properties. Aquatic plant management on Ridinger Lake should include an educational component to provide residents with the information they need to make informed decisions on managing their individual lakefronts.

Ridinger Lake residents should take action to address the Eurasian water milfoil population in the lake. Although the amount of Eurasian water milfoil in Ridinger Lake is not high relative to some other lakes in the region, this species has the potential to proliferate and cover a large portion of the lake. Eurasian water milfoil offers poor habitat to the lake's inhabitants and often interferes with recreational uses of the lake. Spot chemical treatments may be the best management tool at this time to control the spread of the species. Lake users should also educate themselves on the species. Taking precautionary measures such as ensuring that all plant material is removed from their boat propellers following their use prevents the spread of the species. Lake users should also refrain from boating through stands of Eurasian water milfoil. Pieces of the plant as small as one inch in length that are cut by a boat propeller as it moves through a stand of Eurasian water milfoil can sprout and establish a new plant. Signage at the public boat ramp informing visitors of these best management practices would also be useful. It is important to note the IDNR approval is required to post any signs at the public boat ramp.

Robinson Lake
Because Robinson Lake is utilized for different purposes than Ridinger Lake, goals of a plant management plan for Robinson Lake will necessarily be different. The four primary concerns with the aquatic plant community in Robinson Lake are the prevalence of filamentous algae and duckweed, the low species richness (particularly of submerged species), the high density of coontail, and the presence of Eurasian water milfoil. Any aquatic plant management plan for the lake should include the following components to address these four issues:

1. Implement watershed and in-lake management techniques to improve the lake's water quality. The aquatic plant community reflects the relatively poor water quality in Robinson Lake. The presence of dense populations of coontail, watermeal, and filamentous algae, all of which are species that can directly utilize nutrients from the water column, suggests that the lake possesses relatively high nutrient concentrations. The lake's poor water clarity is likely limiting the establishment of a diverse submerged aquatic plant community. Only three species of pondweeds, Sago, long-leaved, and large-leaved pondweed, were observed in Robinson Lake. Both long-leaved and large-leaved pondweed exist as small stands in one location on the lake. Historical and current surveys of other lakes in the region indicate that a much more diverse submerged aquatic plant community is possible. While it is not realistic to expect the return of rarer more sensitive species such as Fries pondweed or minor bladderwort, it is realistic to expect the growth of species as such leafy pondweed, eel grass, and elodea. These species are commonly found in eutrophic lakes in the area. An improvement in Robinson Lake's

water quality and clarity might allow the return of these species, creating a more diverse and healthy aquatic plant community.

2. Because Robinson Lake is primarily a fishing lake, any plant management efforts should manage the lake's aquatic plant community to support fishing opportunities. Robinson Lake supports an extremely dense coontail population. The canopy coverage of this species exceeds 60%. This creates an abundance of cover for prey fish (e.g. bluegills) to hide from predators. The result in situations like this is an explosion in panfish populations and consequent stunting of these fish due to increased competition for limited resources. In other words, the dense stands of coontail may be limiting fishing opportunities on the lake. Control of the coontail may be necessary to achieve the recreational goals for the lake. Harvesting of the coontail, including the proper removal of harvested material, should be given serious consideration as a potential aquatic plant management technique for Robinson Lake. A harvester may be utilized to cut cruising lanes for predators (bass). The removal of coontail from the lake will help remove nutrients from the lake as well.

3. Take action to address the Eurasian water milfoil population in Robinson Lake. While the Eurasian water milfoil population in Robinson Lake is not as large as the coontail population, this species' potential to proliferate and cover a large portion of the lake is immense. Additionally, almost none of the people who use Robinson Lake reside on the lake. So it is likely that the lake's users also launch there boats in other public lakes. This increases the likelihood of spreading Eurasian water milfoil from Robinson Lake to other lakes. At a minimum, the IDNR should post signage at the lake's public access point, instructing lake users how to properly clean their boats to prevent the spread of this nuisance exotic. Similarly, signage may be used to ask lake users to refrain from boating through large stands of Eurasian water milfoil since pieces of the plant as small as one inch in length can sprout and establish a new plant. It is important to note the IDNR approval is required to post any signs at the public boat ramp.

Troy Cedar Lake

As is the case on Ridinger and Robinson Lakes, aggressive aquatic plant removal strategies are not recommended for Troy Cedar Lake at this time. Given the current composition and structure of the plant community in Troy Cedar Lake, any plant management plan developed for the lake should include the following components:

1. Due to sparseness of the vegetative community along the developed eastern shoreline, no or very limited aquatic plant management is recommended at this time in this area. The vegetation present likely does not inhibit most recreational uses of the area. If individual residents feel the amount of plant growth in front of their property is limiting the recreational potential of the lake, these residents might consider management techniques such as hand harvesting of plant material or the use of bottom covers. (Please be aware that permits may be required for these activities. Residents should consult with the IDNR Division of Fish and Wildlife before implementing any of these management methods.) An educational program highlighting the benefits a healthy plant community, including emergent species, might help residents make informed decisions on balancing their desire

for relatively plant-free water in front of their property with the desire for a healthy, productive fish community in the lake.

2. In the undeveloped portions of the lake, no aquatic plant management action is recommended other than treatment of aggressive nuisance and/or exotic species as outlined below. The lake's submerged community is not as dense as other regional lakes, likely providing better habitat for the lake's fish community. Encouragement of a more diverse plant community via watershed and in-lake management efforts will improve the lake's habitat for its fisheries.

3. Implement watershed and in-lake management techniques to improve the lake's water quality. The lake's poor water quality is likely limiting the establishment of a diverse submerged aquatic plant community. Historical surveys of Troy Cedar Lake and other lakes in the region indicate that a much more diverse submerged aquatic plant community is possible. A 1964 survey of Troy Cedar Lake notes the presence of large-leaved pondweed, Illinois pondweed, leafy pondweed, floating leaf pondweed, slender naiad, and stiff pondweed. While it is not realistic to expect the return of rarer more sensitive species such as stiff pondweed, it is realistic to expect the growth of many of the other species. These species are commonly found in eutrophic lakes in the area. An improvement in Troy Cedar Lake's water quality and clarity might allow the return of these species, creating a more diverse and healthy aquatic plant community.

4. Take action to address the Eurasian water milfoil population in the lake. Although the amount of Eurasian water milfoil in Troy Cedar Lake is not high relative to some other lakes in the region, this species has the potential to proliferate and cover a large portion of the lake. Eurasian water milfoil offers poor habitat to the lake's inhabitants and often interferes with recreational uses of the lake. Spot chemical treatments may be the best management tool at this time to control the spread of the species. Lake users should also educate themselves on the species. Taking precautionary measures such as ensuring that all plant material is removed from their boat propellers following their use prevents the spread of the species. Lake users should also refrain from boating through stands of Eurasian water milfoil. Pieces of the plant as small as one inch in length that are cut by a boat propeller as it moves through a stand of Eurasian water milfoil can sprout and establish a new plant. Signage at the public boat ramp informing visitors of these best management practices would also be useful. It is important to note that IDNR approval is required to post any signs at the public boat ramp.

The following is a brief description of aquatic plant management techniques recommended in the list above. A good aquatic plan management plan includes a variety of management techniques applicable to different parts of a lake depending on the lake's water quality, the characteristics of the plant community in different parts of the lake, and lake users' goals for different parts of the lake. Many aquatic plant management techniques, including chemical control, harvesting, and biological control require a permit form the IDNR. Depending on the size and location of the treatment area, even individual residents may need a permit to conduct a treatment. Residents should contact the IDNR Division of Fish and Wildlife before conducting any treatment.

5.5.1 Chemical Control

Herbicides are the most traditional means of controlling aquatic vegetation. Herbicides have been used in the past on Ridinger Lake. In 2002, the Indiana Department of Natural Resources, Division of Fish and Wildlife issued two permits for the treatment of 10 acres (4 ha) and 0.5 acre (0.2 ha) on Ridinger Lake (Jed Pearson, personal communication). No chemical treatment permits were issued for Robinson Lake and the IDNR did not believe any were issued for Troy Cedar Lake in 2002 (Dave Kittaka, personal communication). On Ridinger and Troy Cedar Lakes, it is likely that some residents may have conducted their own spot treatments around piers and swimming areas. It is important for residents to remember that any chemical herbicide treatment program should always be developed with the help of a certified applicator who is familiar with the water chemistry of the target lake. In addition, application of a chemical herbicide may require a permit from the IDNR, depending on the size and location of the treatment area. Information on permit requirements is available from the IDNR Division of Fish and Wildlife or conservation officers.

Herbicides vary in their specificity to given plants, method of application, residence time in the water, and the use restrictions for the water during and after treatments. Herbicides (and algaecides; chara is an algae) that are non-specific and require whole lake applications to work are generally not recommended. Such herbicides can kill non-target plants and sometimes even fish species in a lake. Costs of an herbicide treatment vary from lake to lake depending upon the type of plant species present in the lake, the size of the lake, access availability to the lake, the water chemistry of the lake, and other factors. Typically, in northern Indiana costs for treatment range from $275 to $300 per acre or $680 to $750 per hectare (Jim Donahoe, Aquatic Weed Control, personal communication).

While providing a short-term fix to the nuisances caused by aquatic vegetation, chemical control is not a lake restoration technique. Herbicide and algaecide treatments do not address the reasons why there is an aquatic plant problem, and treatments need to be repeated each year to obtain the desired control. In addition, some studies have shown that long-term use of copper sulfate (algaecide) has negatively impacted some lake ecosystems. Such impacts include an increase in sediment toxicity, increased tolerance of some algae species, including some blue-green (nuisance) species, to copper sulfate, increased internal cycling of nutrients, and some negative impacts on fish and other members of the food chain (Hanson and Stefan, 1984 cited in Olem and Flock, 1990).

Chemical treatment should be used with caution on any of the study lakes since treated plants are often left to decay in the water. This will contribute nutrients to the lakes' water columns which already possesses high levels of nutrients. Additionally, plants left to decay in the water column will consume oxygen. The in-lake sampling conducted during this study showed the water columns in each of the three study lakes was less than 20% oxic. Added oxygen demand in these lakes will reduce the already low volume of lake water with sufficient oxygen to support fish. Spot chemical treatments are recommended only for patches of Eurasian water milfoil.

5.5.2 Mechanical Harvesting

Harvesting involves the physical removal of vegetation from lakes. Harvesting should also be viewed as a short-term management strategy. Like chemical control, harvesting needs to be repeated yearly and sometimes several times within the same year. (Some carry-over from the previous year has occurred in certain lakes.) Despite this, harvesting is often an attractive management technique because it can provide lake users with immediate access to areas and activities that have been affected by excessive plant growth. Mechanical harvesting is also beneficial in situations where removal of plant biomass will improve a lake's water chemistry. (Chemical control leaves dead plant biomass in the lake to decay and consume valuable oxygen.)

Macrophyte response to harvesting often depends upon the species of plant and particular way in which the management technique is performed. Pondweeds, which rely on sexual reproduction for propagation, can be managed successfully through harvesting. However, many harvested plants, especially milfoil, can re-root or reproduce vegetatively from the cut pieces left in the water. Plants harvested several times during the growing season, especially late in the season, often grow more slowly the following season (Cooke et al., 1993). Harvesting plants at their roots is usually more effective than harvesting higher up on their stems (Olem and Flock, 1990). This is especially true with Eurasian water milfoil and curly leaf pondweed. Benefits are also derived if the cut plants and the nutrients they contain are removed from the lake. Harvested vegetation that is cut and left in the lake ultimately decomposes, contributing nutrients and consuming oxygen.

The cost of the harvester is typically the largest single outlay of money. Depending upon the capacity of the harvester, costs can range from $3,500 to over $100,000 (Cooke et al., 1993). Other costs associated with harvesting include labor, disposal site availability and proximity, amortization rate, size of lake, density of plants, reliability of the harvester, and other factors. Depending upon the specific situation, harvesting costs can range up to $650 per acre ($1,600 per hectare, Prodan, 1983; Adams, 1983). Estimated costs of the mechanical harvesting program at Lake Lemon in Bloomington, Indiana averaged $267 per acre ($659 per hectare, Zogorski et al., 1986). In general, however, excluding the cost of the machine, the cost of harvesting is comparable to that for chemical control (Cooke et al., 1993, Olem and Flock, 1990).

Given the rather limited coverage of aquatic plants in Ridinger and Troy Cedar Lakes, large scale mechanical harvesting does not make economic sense on these lakes. Additionally, large scale harvesting should be avoided in areas dominated by Eurasian water milfoil. When small fragments of Eurasian water milfoil break off, they are capable of sprouting roots and becoming established as an individual plant. Large scale harvesting efforts often create many small fragments of plants despite vigilant efforts to capture all cut plant material. Thus, the benefits derived from harvesting (reduction of plant density and removal of potential source of nutrients) Eurasian water milfoil may not outweigh the risks of spreading the species throughout the lakes. The cost of large scale harvesting on Robinson Lake may be too great for consideration by the IDNR. Under new regulations, any large scale harvesting operations will require a permit from the IDNR Division of Fish & Wildlife.

5.5.3 Hand Harvesting

Hand harvesting may be the best option to manage aquatic plants in small areas where human uses are hampered by extensive growths (docks, piers, beaches, boat ramps). In these small areas, plants can be efficiently cut and removed from the lake with hand cutters such as the Aqua Weed Cutter (Figure 57). In less than one hour every 2-3 weeks, a homeowner can harvest 'weeds' from along docks and piers. Depending on the model, hand-harvesting equipment for smaller areas cost from $50 to $1500 (McComas, 1993). To reduce the cost, several homeowners can invest together in such a cutter. Alternatively, a lake association may purchase one for its members. This sharing has worked on other Indiana lakes with aquatic plant problems. Use of a hand harvester is more efficient and quick-acting, and less toxic for small areas than spot herbicide treatments. Depending on the size to be treated, a permit may be required for hand-harvesting. (The IDNR Division of Fish & Wildlife can assist lake residents in determining whether a permit is needed and how to obtain one.)

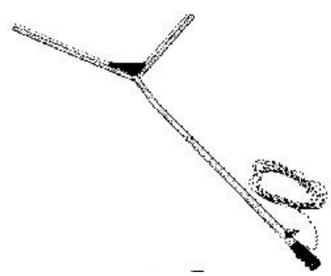


Figure 57. An aquatic weed cutter, designed to cut emergent weeds along the edge of ponds. It has a 48" cutting width, uses heavy-duty stainless steel blades, can be sharpened, and comes with an attached 20' rope and blade covers.

5.5.4 Biological Control

Biological control involves the use of one species to control another species. Often when a plant species that is native to another part of the world is introduced to a new country with suitable habitat, it grows rapidly because its native predators have not been introduced to the new country along with the plant species. This is the case with some of the common pest plants in northeast Indiana such as Eurasian water milfoil and purple loosestrife. Neither of these species is native to Indiana, yet both exist in the Ridinger Lake watershed.

Researchers have studied the ability of various insect species to control both Eurasian water milfoil and purple loosestrife. Cooke et al. (1993) points to four different species that may reduce Eurasian water milfoil infestations: *Triaenodes tarda*, a caddisfly, *Cricotopus myriophylii*, a midge, *Acentria nivea*, a moth and *Litodactylus leucogaster*, a weevil. Recent research efforts have focused on the potential for *Euhrychiopsis lecontei*, a native weevil, to control Eurasian water milfoil. Purple loosestrife biocontrol researchers have examined the potential for three insects, *Gallerucella calmariensis, G. pusilla*, and *Hylobius transversovittatus,* to control the plant.

While the populations of Eurasian water milfoil and purple loosestrife in the study lakes are relatively small and therefore may not be suitable for biological control efforts, it may be worthwhile for Ridinger Lake watershed residents to understand the common biocontrol mechanisms for these two species should the situation on the lake change. Residents should also be aware that under new regulations an IDNR permit is required for the implementation of a biological control program on a lake.

Eurasian Water Milfoil

Euhrychiopsis lecontei has been implicated in a reduction of Eurasian water milfoil in several Northeastern and Midwestern lakes (EPA, 1997). *E. lecontei* weevils reduce milfoil biomass by two means: one, both adult and larval stages of the weevil eat different portions of the plant and two, tunneling by weevil larvae cause the plant to lose buoyancy and collapse, limiting its ability to reach sunlight. The weevils' actions also cut off the flow of carbohydrates to the plant's root crowns impairing the plant's ability to store carbohydrates for over wintering (Madson, 2000). Techniques for rearing and releasing the weevil in lakes have been developed and under appropriate conditions, use of the weevil has produced good results in reducing Eurasian water milfoil. A nine-year study of nine southeastern Wisconsin lakes suggested that weevil activity might have contributed to Eurasian water milfoil declines in the lakes (Helsel et al, 1999). The Indiana Department of Natural Resources is currently conducting field trials on three Indiana lakes.

Cost effectiveness and environmental safety are among the advantages to using the weevil rather than traditional herbicides in controlling Eurasian water milfoil (Christina Brant, EnviroScience, personal communication). Cost advantages include the weevil's low maintenance and long-term effectiveness versus the annual application of an herbicide. In addition, use of the weevil does not have use restrictions that are required with some chemical herbicides. Use of the weevil has a few drawbacks. The most important one to note is that reductions in Eurasian water milfoil are seen over the course of several years in contrast to the immediate response seen with traditional herbicides. Therefore, lake residents need to be patient. Additionally, the weevils require natural shorelines for over-wintering. The prevalence of natural shoreline along Robinson Lake would make this lake an ideal candidate for treatment with the weevils if the Eurasian water milfoil population in that lake expands. The Indiana Department of Natural Resources is currently conducting field trials on three Indiana lakes. Waiting for the independent monitoring results of these field trials may be best before even considering the application of *E. lecontei* weevils in any of the study lakes.

Purple Loosestrife

Biological control may also be possible for inhibiting the growth and spread of the emergent purple loosestrife. Like Eurasian water milfoil, purple loosestrife is an aggressive non-native species. Once purple loosestrife becomes established in an area, the species will readily spread and take over the habitat, excluding many of the native species which are more valuable to wildlife. Conventional control methods including mowing, herbicide applications, and prescribed burning have been unsuccessful in controlling purple loosestrife.

Some control has been achieved through the use of several insects. A pilot project in Ontario, Canada reported a decrease of 95% of the purple loosestrife population from the pretreatment population (Cornell Cooperative Extension, 1996). Four different insects were utilized to achieve this control. These insects have been identified as natural predators of purple loosestrife in its native habitat. Two of the insects specialize on the leaves, defoliating a plant (*Gallerucella calmariensis* and *G. pusilla*), one specializes on the flower, while one eats the roots of the plant (*Hylobius transversovittatus*). Insect releases in Indiana to date have had mixed results. After six years, the loosestrife of Fish Lake in LaPorte County is showing signs of deterioration.

Like biological control of Eurasian water milfoil, use of purple loosestrife predators offers a cost-effective means for achieving long-term control of the plant. Complete eradication of the plant cannot be achieved through use of a biological control. Insect (predator) populations will follow the plant (prey) populations. As the population of the plant decreases, so will the population of the insect since their food source is decreasing.

Because of the limited extent of purple loosetrife along the study lakes, management should focus on hand removal of the species. (This may require educating lake residents in identifying purple loosestrife.) Given the relatively small and scattered distribution of the species, release of a biological control would not be cost effective at this time.

5.5.5 Bottom covers

Bottom shading by covering bottom sediments with fiberglass or plastic sheeting materials provides a physical barrier to macrophyte growth. Buoyancy and permeability are key characteristics of the various sheeting materials. Buoyant materials (polyethylene and polypropylene) are generally more difficult to apply and must be weighted down. Unfortunately, sand or gravel anchors used to hold buoyant materials in place can act as substrate for new macrophyte growth. Any bottom cover materials placed on the lake bottom must be permeable to allow gases to escape from the sediments; gas escape holes must be cut in impermeable liners. Commercially available sheets made of fiberglass-coated screen, coated polypropylene, and synthetic rubber are non-buoyant and allow gases to escape, but cost more (up to $66,000 per acre or $163,000 per hectare for materials, Cooke and Kennedy, 1989). Indiana regulations specifically prohibit the use of bottom covering material as a base for beaches.

Due to the prohibitive cost of the sheeting materials, sediment covering is recommended for only small portions of lakes, such as around docks, beaches, or boat mooring areas. This technique may be ineffective in areas of high sedimentation, since sediment accumulated on the sheeting material provides a substrate for macrophyte growth. The IDNR requires a permit for any permanent structure on the lake bottom, including anchored sheeting.

5.5.6 Preventive Measures

Preventive measures are necessary to curb the spread of nuisance aquatic vegetation. Although milfoil is thought to 'hitchhike' on the feet and feathers of waterfowl as they move from infected to uninfected waters, the greatest threat of spreading this invasive plant is humans. Plant fragments snag on boat motors and trailers as boats are hauled out of lakes (Figure 58). Milfoil, for example, can survive for up to a week in this state; it can then infect a milfoil-free lake when the boat and trailer are launched next. It is important to educate boaters to clean their boats and trailers of all plant fragments each time they retrieve them from a lake.

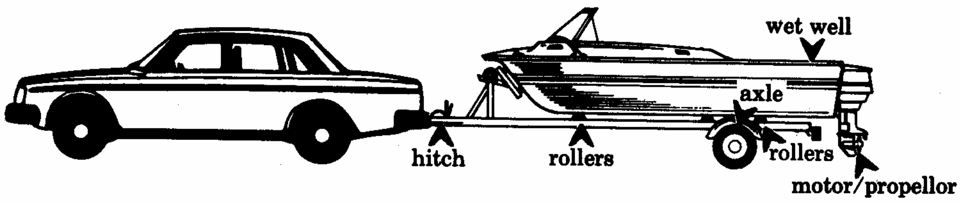


Figure 58. Locations where aquatic macrophytes are often found on boats and trailers.

Educational programs are effective ways to manage and prevent the spread of aquatic nuisance species (ANS) such as Eurasian watermilfoil, zebra mussels, and others. Of particular help are signs at boat launch ramps asking boaters to check their boats and trailers both before launching and after retrieval. All plants should be removed and disposed of in refuse containers where they cannot make their way back into the lake. The Illinois-Indiana Sea Grant Program has examples of boat ramp signs and other educational materials that can be used at the Ridinger, Robinson, and Troy Cedar Lakes. Although Eurasian water milfoil already exists in the study lakes, educational programs and lake signage will help prevent the spread of this nuisance species to other lakes. This is particularly important at Robinson Lake. Since Robinson Lake users do not reside along Robinson Lake, these lake users are extremely likely to use their boats in other lakes in addition to Robinson Lake. Signs addressing any best management practices to prevent the spread of nuisance aquatic species will ultimately help Ridinger, Robinson, and Troy Cedar Lakes as new nuisance (often non-native) species are finding their way to Indiana lakes all the time.

6.0 FISHERIES

6.1 Ridinger Lake

The Indiana Department of Natural Resources (IDNR) conducted its first fishery survey on Ridinger Lake in 1978. Prior to this, limited fisheries management information existed for the lake (Pearson, 1995). In 1981, a major fish kill took place on Ridinger Lake following a large rain event. The IDNR conducted follow up studies in 1981, 1982, and 1983 to determine the kill's impact on the lake's fishery. The two most recent fishery survey occurred in 1995 and 2003 to assess the long-term status of Ridinger Lake's fish community.

Ridinger Lake has an extremely diverse fish community with IDNR fisheries biologists collecting 30 species representing 11 families over the course of six surveys. In 1978, 24 species were collected; gamefish including bluegill, crappie, yellow perch, and various sunfishes dominated the catch. (Fish species collected from Ridinger Lake are included in Appendix H for the 1978, 1981-1983, 1995, and 2003 surveys.) Following the fish kill in 1981, species diversity plummeted to 13 species. The Centrarchid, or sunfish, family suffered the greatest losses with 8 species collected in 1978 absent from the catch in 1981. Bluegill percent community composition declined from nearly 45% to approximately 4%, while crappie populations declined from 10% to near 0% (Figure 59). Other species that were observed in 1978 but absent in the 1981 catch included bowfin, grass pickerel, and brook silversides. Gizzard shad numbers rose in Ridinger Lake following the fish kill, replacing game fish as the most dominant component of the fishery. Reduced predation and forage competition likely allowed this species to increase in number.

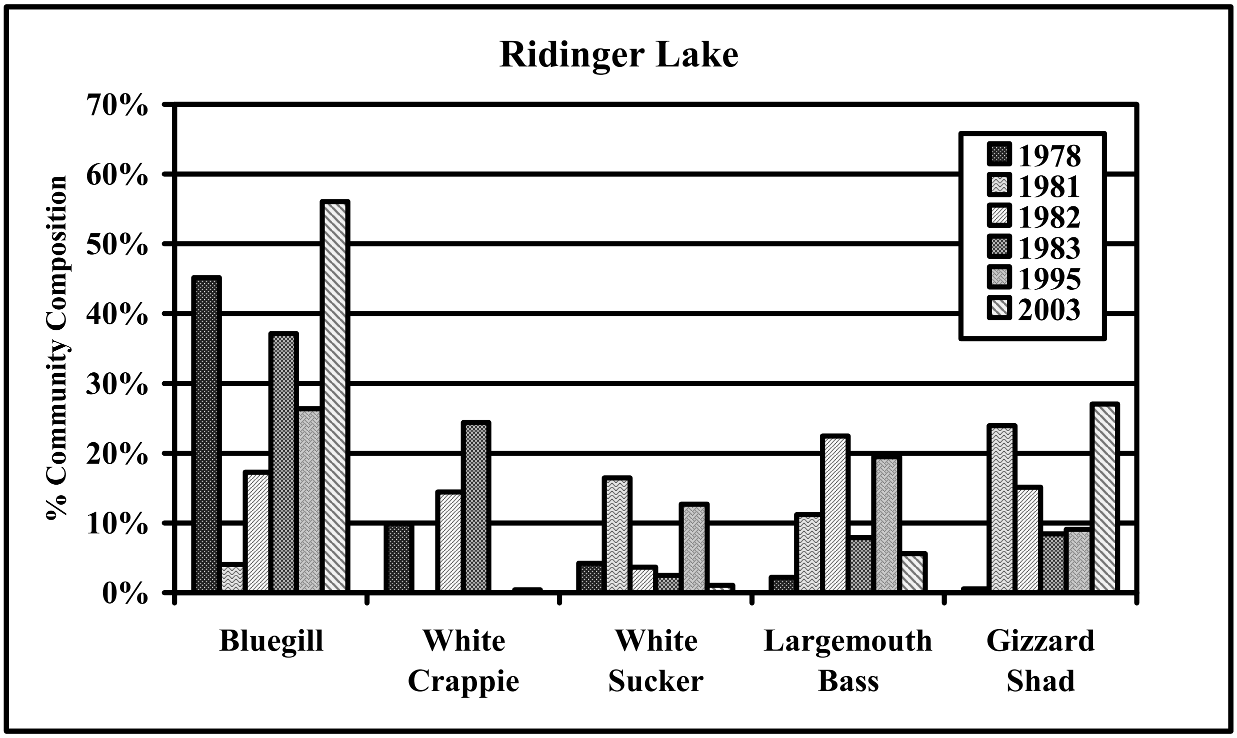


Figure 59. Percent community composition of game and nongame fish species in Ridinger Lake.

By 1982, Ridinger Lake's fish community began to show signs of recovery from the fish kill of the previous year. Species diversity had increased from 13 species in 1981 to 19 species in 1982. Due to the recovery, the IDNR did not take any corrective fish management actions (Pearson, 1995). Sunfish numbers and diversity rose from 1981 levels and continued to do so through the 2003 survey. The bluegill population, however, was still below pre-fish kill level in 1995 but was experiencing higher growth rates. This may have been the result of reduced intraspecies (bluegill) forage competition in the littoral zone. By 2003, the bluegill percent community composition had surpassed the pre-kill levels in 1978. Gizzard shad numbers also continued to rise, although their percent contribution declined (Figure 59). Interestingly, largemouth bass populations appear to have benefited from the fish kill. Largemouth bass percent community composition increased from 2.2% in 1978 to 22.5% in 1982 (Figure 59). This may be attributed to young bluegill entering the population as prey size forage. Above average bass growth rates for the area confirm this theory. However, the 2003 survey shows a reduction in largemouth bass percent community composition to the level observed in 1978. Above average catch and growth rates suggest that the largemouth bas population is still in good condition.

Over the past several years Ridinger Lake has seen a shift in fish biomass. Prior to the 1981 fish kill, gizzard shad, carp, and sucker accounted for 24.6% of the total catch weight (1978 data). Between the 1978 and 1981 surveys, gizzard shad established themselves and became prolific in the lake. By 1982, gizzard shad alone accounted for 27.4% of the total catch weight. Gizzard shad, carp, and sucker accounted for nearly 54% of the total catch weight in 1982. In 1995, gizzard shad, carp, and sucker contribution to the total catch weight climbed to 56%. In 2003, gizzard shad, carp and sucker contribution to the total catch weight declined only slightly to 52.9%. The ratio of gamefish biomass to total fish biomass decreased from 0.5 in 1978 to 0.4 in 1982, 1983, and 1995 after the 1981 fish kill. As trophic status and phosphorus loads increase in warmwater systems, gamefish biomass to total fish biomass often decreases as more tolerant, planktivore fish become established (Maceina, 2001). Ridinger Lake's Secchi disk transparency depths, a potential indicator of trophic status, have steadily declined from a maximum depth of 9.5 feet (2.9 m) in 1978 to 3.5 feet (1.1 m) in 1995. Additionally, gizzard shad abundance may be preventing bluegill populations from returning to 1978 levels. Gizzard shad have been shown to have a negative impact on the bluegill populations through predation or forage competition (Clapp and Wahl, 1995). Bluegill percent community composition had shown improvement following the 1981 fish kill, only declining slightly in 2003 (Figure 59). The IDNR suggested that the selective stocking of other predatory fish species such as musky, pike, or walleye could be utilized to convert more of the lake's productivity back to game fish species (Pearson, 1995 and 2003). However, stocking efforts are only recommended once public access to the lake improves.

6.2 Robinson Lake

In 1993, the IDNR conducted its first general fishery survey to gather baseline information on the Robinson Lake fish community. The IDNR conducted an additional survey on Robinson Lake in 1993 as part of a statewide largemouth bass survey and a regional bluegill survey. In 1996, the IDNR enacted emergency rules on Robinson Lake to manage it as a trophy bass fishery. The IDNR conducted an angler creel survey, largemouth bass survey, and general fishery survey on Robinson Lake in 1996 and 1999 to determine the regulations' impact on the lake's fishery. In 2002, IDNR biologists conducted a fishery survey as part of the Robinson Lake trophy management plan; however a final report documenting this survey was not available at the time of this report. (Preliminary data from the 2002 survey is presented here with permission from Ed Braun, IDNR Fisheries Biologist.)

General Fishery Surveys

The Robinson Lake fish community has shown little fluctuation in community composition during the 1993, 1996, 1999, and 2002 fishery surveys. A total of 29 species representing 11 families have been observed throughout the surveys. (Fish species collected from Robinson Lake are included in Appendix H.) Species diversity ranged from a low of 21 species collected in 1993 to a high of 23 species collected in 1999. Nine species from the Centrarchid, or sunfish, family have been found in Robinson Lake. Bluegill is the most abundant species by number in the lake accounting for 38.2% of the catch in 1993, 32.9% in 1996, 62.7% in 1999, and 37.2% in 2002. Gizzard shad abundance ranged from a high of 29.5% in 1993 (second by number) to a low of 7.5% in 1999 (fourth by number). Largemouth bass was the third most abundant species collected in each of the surveys, accounting for 7.9% of the catch in 1993, 15.3% in 1996, 7.5% in 1999, and 15.2% in 2002 (Figure 60). Gizzard shad is the most abundant nongame species occurring in Robinson Lake followed by white sucker and spotted gar.

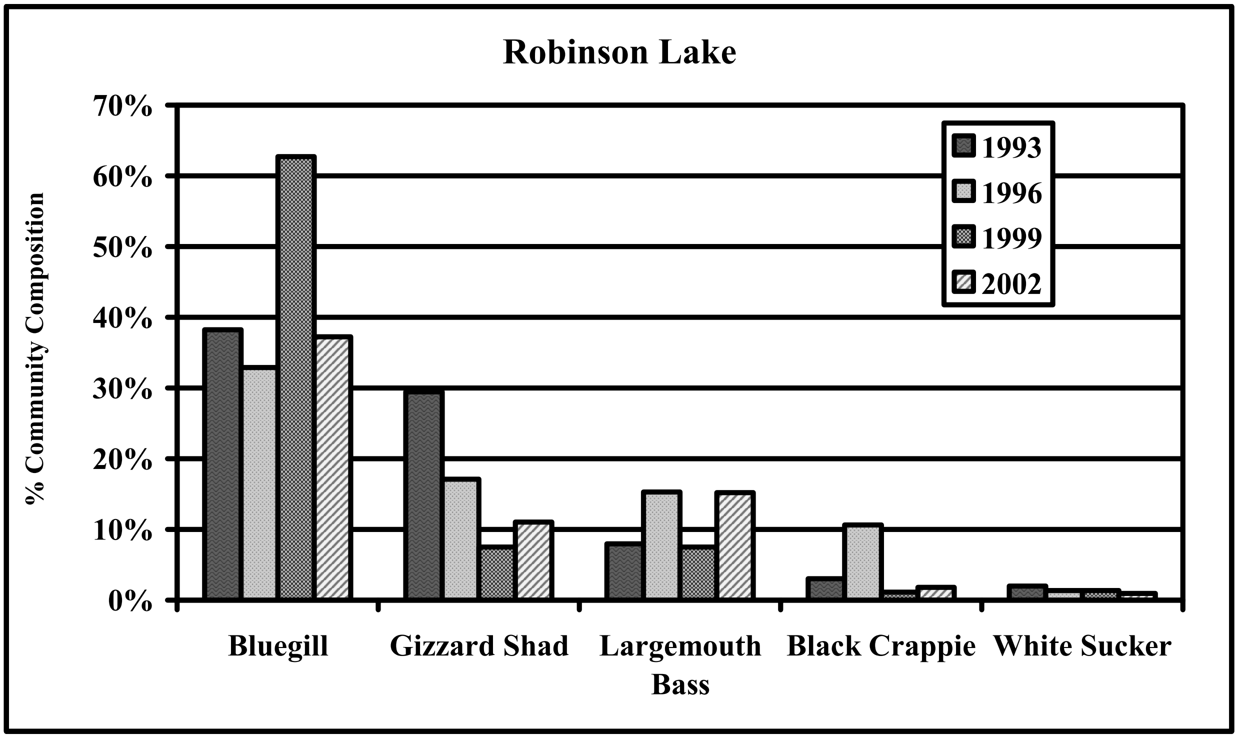


Figure 60. Percent community composition of game and nongame fish species in Robinson

Largemouth Bass Surveys

The 1993 statewide largemouth bass survey found that Robinson Lake supported one of the densest largemouth bass populations in Indiana's natural lakes at 30.4/acre (Braun, 2001). Many of the largemouth bass were large; over 8% of the population was greater than 18 inches (46 cm) in length. In response to these findings, the IDNR enacted emergency rules on Robinson Lake in 1996 to manage the lake as a trophy bass fishery. The largemouth bass bag limit was reduced from six bass per day to two bass per day. Additionally, largemouth bass minimum size length was increased from 12 inches (30 cm) to 18 inches (46 cm). The IDNR conducted follow up largemouth bass surveys on Robinson Lake in 1996, 1999, and 2002. In 1996, the largemouth bass population estimate (≥8 inches) declined from 30.4/acre in 1993 to 20.3/acre. The catch per unit effort (CPUE) of largemouth bass ≥18 inches also declined from 10.4/hour in 1993 to 4.1/hour in 1996. In 1999, the largemouth bass population estimate (≥8 inches) rose to 41/acre. The CPUE of largemouth bass ≥18 inches in 1999 increased to 5.9/hour but was still below the 10/hour trophy management project goal (Table 53). In 2002, the largemouth bass population estimate (≥8 inches) increased from 41/acre in 1999 to 49.4/acre. Additionally, the CPUE of largemouth bass ≥18 inches increased from 5.9/hour in 1999 to 11.3/hour in 2002, thus meeting the management goal of 10/hour.

Table 53. Comparison of Robinson Lake largemouth bass populations in 1993, 1996, and 1999.

	1993	1996	1999	2002
Population estimate	1791	1176	2421	2915
Number of bass per acre	30.4	20.3	41.0	49.4
PSD	51.5	40.5	54.8	74.3
RSD-18	8.1	7.4	4.3	4.7
CPUE (all sizes)	150.4	83.6	177.0	251.6
CPUE (≥18 inches)	10.4	4.1	5.9	11.3

Source: IDNR Quality Largemouth Bass Population at Robinson Lake 1999 Progress Report and Ed Braun, personal communication.

Proportional stock density (PSD), the proportion of fish (largemouth bass) that are considered quality size in a particular stock (Robinson Lake), has fluctuated from a low of 40.5 in 1996 to a high of 74.3 in 2002. Sizes used for "quality" and "stock" are based on angling world record lengths (Anderson and Weithman, 1978). Relative stock density (RSD), the proportion of fish of any designated size group (≥18 inches) in a particular stock, has declined from a high of 8.1 in 1993 to a 4.7 in 2002 (Table 53). The IDNR anticipates that RSD-18 and CPUE of largemouth bass ≥ 18 inches will increase if growth of older year classes does not slow (Braun, 2001).

Creel Surveys

The IDNR conducted an angler creel survey on Robinson Lake in 1996 to assess angler pressure, harvest, and impacts to the fishery prior to the enactment of emergency rules to manage the lake as a trophy largemouth bass fishery. The IDNR conducted a follow up creel surveys in 1999 and 2002 to compare the pre-management regulation conditions to the post-management regulation conditions. The results of the 1996 creel survey documented a total estimated (expanded) fishing effort of 3,562 angler hours (60.4 hrs/ac). In 1999, the total estimated (expanded) fishing effort more than doubled to 8,015 angling hours (135.9 hrs/ac) on Robinson Lake. In 2002, the total estimated (expanded) fishing effort increased to 8,645 angling hours (146.5 hrs/ac). Boat anglers accounted for a majority of the angling population in 1996 (87.9%), 1999 (88.9%), and 2002 (92.1%). Robinson Lake's dense shoreline vegetation limited shoreline fishing opportunities (Braun, 2001). Total estimated harvest in 1996 was 3,155 fish of which 86.8% were bluegill. Total estimated harvest in 1999 climbed slightly to 3,810 fish of which 66.3% were bluegill. Total estimated harvest in 2002 increased to 4,310 of which 70% were bluegill. Estimated harvest of largemouth bass declined from 206 in 1996, prior to trophy management regulations, to 31 largemouth bass in 2002. In 1996, anglers released approximately 871 largemouth bass compared to approximately 2,926 in 2002. Total length of largemouth bass harvested in 1996 ranged from 12 to 18.5 inches (30-48 cm). Total length of largemouth bass harvested in 1999 and 2002 ranged from 18 to 21 inches (46-53 cm).

6.3 Troy Cedar Lake

The IDNR conducted its first fishery survey of Troy Cedar Lake in 1964 in response to declines in fishing quality. In 1977, the IDNR conducted an abbreviated demonstration survey for students from a local school. (Data from the 1977 survey has not been included in the following discussion since the survey did not follow the IDNR's standard protocol, making comparisons to other surveys difficult.) The IDNR surveyed Troy Cedar Lake again in 1981 and 1982 in response to complaints of poor fishing.

Troy Cedar Lake has a diverse fish population comprised of typical lake species such as bluegill and largemouth bass as well as common riverine species such as spotted and longnose gar being present. A total of 26 species representing 9 families have been observed in the lake throughout the surveys. (Fish species collected from Troy Cedar Lake are included in Appendix H.) Ictalurids (catfish), Catostomids (suckers), and Centrarchids (sunfishes) are well represented by numerous species in the lake's fish community. Some genera within these families, however, are only represented by a few individuals. In 1964, bluegill was the most abundant species by number accounting for 37.4% of the total catch followed by largemouth bass (17.3%) and pumpkinseed (12.1%) (Figure 61). By 1981, poor water quality was believed to have caused a decline in the lake's fishery (Braun, 1981). Dissolved oxygen levels at 10 feet (3 m) had fallen from 9.2 mg/L in 1965 to 0.2 mg/L in 1981, limiting habitat availability. Bluegill and pumpkinseed numbers dropped significantly from 1964 to 1981. During the 1981 survey, no bluegill younger than age-2 were collected indicating possible spawning failure in 1980. The pumpkinseed population was no longer a major component of the lake's fishery. In contrast, golden shiner and white sucker numbers and percent community composition began to rise (Figure 61). Golden shiner was the most abundant fish collected in 1981 representing 33.6% of the total catch. Weights were not available for the 1964 survey; however 94% of the fish collected were gamefish. This number had declined to 44% in 1981 with golden shiner, white sucker, spotted gar, and gizzard shad dominating the catch. The ratio of gamefish biomass to total fish biomass was 0.6 in 1981.

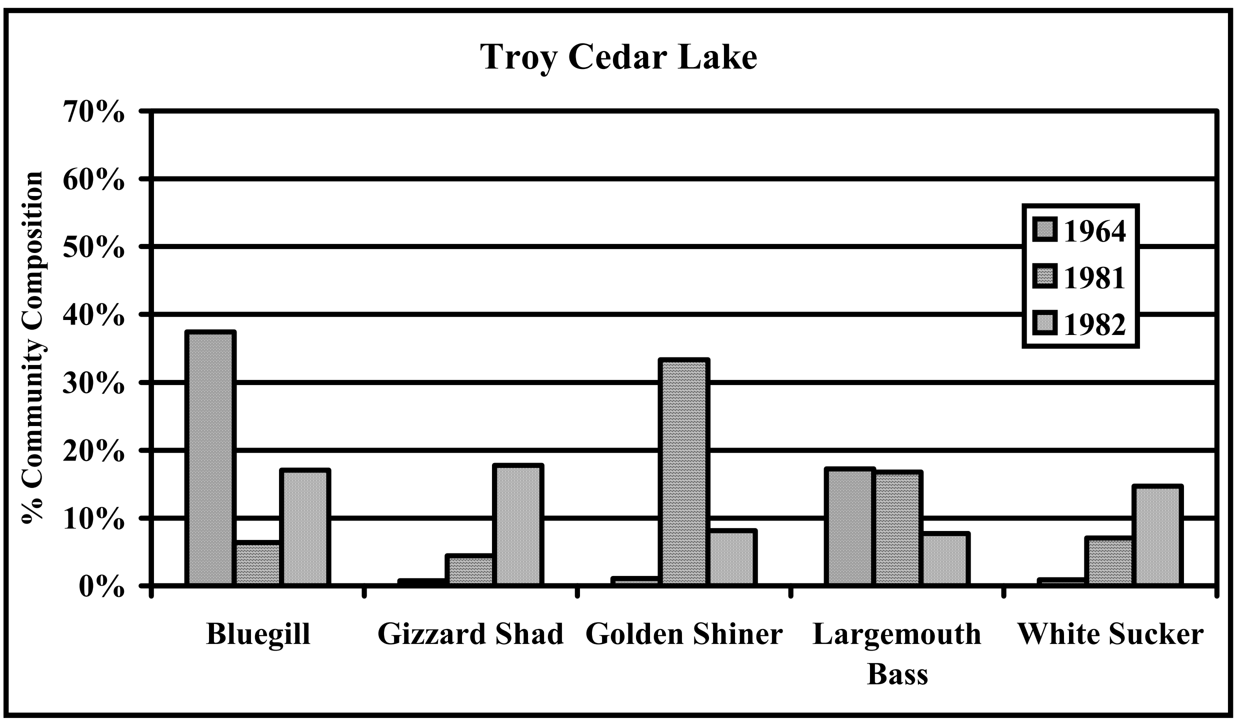


Figure 61. Percent community composition of game and nongame fish species in Troy Cedar Lake.

The IDNR performed a follow up survey in 1982 to determine if the bluegill population was still suppressed. Bluegill numbers rebounded slightly in 1982 with 73 fish being collected. However the bluegill population composed only 17% of the total fishery compared to approximately 34% in 1964 survey (Figure 61). Recruitment was poor with only eight age-1, or those spawned in 1981, fish being collected. Other Centrarchid numbers were similarly low. Largemouth bass decreased from 1981 accounting for 7.7% of the catch compared to 17.3% in 1964 and 16.7% in 1981 (Figure 61). In 1982, gizzard shad was the most abundant fish by number (17.8%) and second most by weight (18.3%). White sucker had become the third most abundant by number (14.7%) and most abundant by weight (33.8%). The ratio of gamefish biomass to total fish biomass declined from a value of 0.6 in 1981 to 0.3 in 1982.

Water quality is most likely limiting the recreational potential of the Troy Cedar Lake fishery. Water quality conditions were slightly better in 1982 compared to 1981; dissolved oxygen levels at 10 feet (3 m) increased from 0.2 mg/L in 1981 to 8.6 mg/L. However, the water's brown color suggested that the lake was receiving heavy sediment loads from the watershed (Braun, 1982). Poor Secchi disk transparency depths, 2.3 feet (0.7 m) in 1982 compared to 8 feet (2.4 m) in 1964, provided further evidence of sediment loading to the lake. The IDNR recommended that the Whitley County Drainage Board install sediment traps to catch sediment from future dredging operations before it enters the lake (Braun, 1981 and 1982). The IDNR also believed the installation of wind powered aeration equipment deserved consideration, but only after a public access site is constructed.

7.0 MODELING

7.1 Water Budget

Water budgets are useful for lakes because they help identify significant water sources that may be important in the management plan. For example, one inlet stream may contribute more water and nutrients than another and this could help direct management efforts. The total amount of water flowing into and out of a lake is used to determine the *hydraulic residence time* and the *hydraulic flushing rate*. The hydraulic residence time is the average time that a given unit of water resides in the lake. The hydraulic flushing rate is the reverse – the number of times the complete volume of water in the lake is exchanged per year. The rate at which water flows through a lake affects turbulence and settling rates of sediments and nutrients. It also helps determine whether the lake's water quality is influenced more by water flowing into the lake or by water already in the lake.

Water enters Ridinger Lake watershed lakes from the following sources:

- direct precipitation to each lake
- channelized flow in streams draining into and from the lakes
- sheet runoff from land immediately adjacent to the lake
- groundwater

Water leaves the watershed from:

- discharge from Ridinger Lake via the Grassy Creek outlet
- evaporation from each lake
- groundwater

There are no discharge gages in the watershed to measure water inputs and the limited scope of this study did not allow for the quantitative determination of annual water inputs or outputs. Therefore, the water budgets for Ridinger, Robinson, and Troy Cedar Lakes were estimated from other records.

- Direct precipitation to the lakes was calculated from mean annual precipitation falling directly on the lakes' surface.
- Runoff from the lakes' watershed was estimated by applying runoff coefficients. A runoff coefficient refers to the percentage of precipitation that occurs as surface runoff, as opposed to that which soaks into the ground. Runoff coefficients may be estimated by comparing discharge from a nearby gaged watershed of similar land and topographic features, to the total amount of precipitation falling on that watershed. The nearest gaged watershed is a U.S.G.S. gaging station on the Tippecanoe River near North Webster, Indiana (Stewart et al., 2002). The 16-year (1986–2002) mean annual runoff for this watershed is 13.32 inches. With mean annual precipitation of 35.52 inches (Staley, 1989), this means that on average, 37.5 % of the rainfall falling on this watershed runs off of the land surface.
- No groundwater records exist for the lakes so it was assumed that groundwater inputs equal outputs or groundwater effects are insignificant compared to surface water impacts. The size of the Ridinger Lake watershed makes this latter assumption plausible.
- Evaporation losses were estimated by applying evaporation rate data to the lake. Evaporation rates are determined at six sites around Indiana by the National Oceanic and Atmospheric Administration (NOAA). The nearest site to the Ridinger Lake watershed is located in Valparaiso, Indiana. Annual evaporation from a 'standard pan' at the Valparaiso site averages 28.05 inches per year. Because evaporation from the standard pan overestimates evaporation from a lake by about 30%, the evaporation rate was corrected by this percentage, yielding an estimated evaporation rate from the lakes' surface of 19.95 inches per year. Multiplying this rate times the surface area of each lake yields an estimated volume of evaporative water loss from the lakes.

Table 54 shows the hydraulic residence time, which results from dividing the amount of water leaving each lake by the individual lake's volume, for Ridinger, Robinson, and Troy Cedar Lakes. Figure 62 diagrams the water inputs and outputs for each of the three study lakes, while Figure 63 illustrates the proportion of water inputs to each lake from various sources. (Appendix I contains the detailed water budget spreadsheet, based on assumptions discussed above, for each of the lakes.) The hydraulic residence times range from only 36 days (0.10 years) for Ridinger Lake to nearly 223 days (0.61 years) for Troy Cedar Lake. This means that water enters Ridinger Lake and stays an average of only 36 days before it leaves. This hydraulic flushing rate is extremely rapid for lakes in this part of the country. In a study of 95 northern temperate lakes in the U.S., the mean hydraulic residence time for the lakes was 2.12 years (Reckhow, 1980). The short hydraulic residence time for all three lakes is due to their large watersheds and low volumes. There are nearly 165 acres of watershed draining into each acre of Ridinger Lake, 75 acres of watershed draining into each acre of Robinson Lake, and 83 acres of watershed draining into each acre of Troy Cedar Lake. Most glacial lakes have a watershed to lake surface area of around 10:1. Lakes in the Ridinger Lake watershed possess ratios that are more typical of reservoirs, where the watershed area to reservoir surface area typically ranges between 100:1 and 300:1 (Vant, 1987).

Table 54. Hydraulic residence times of the Ridinger Lake watershed Lakes.

Lake	Volume (V, in acre-feet)	Discharge (Q) (in acre-feet per year)	Residence Time (V/Q) (in years)
Ridinger	2,572	24,966	0.10
Robinson	1,025	4,950	0.21
Troy Cedar	2,211	3,147	0.61

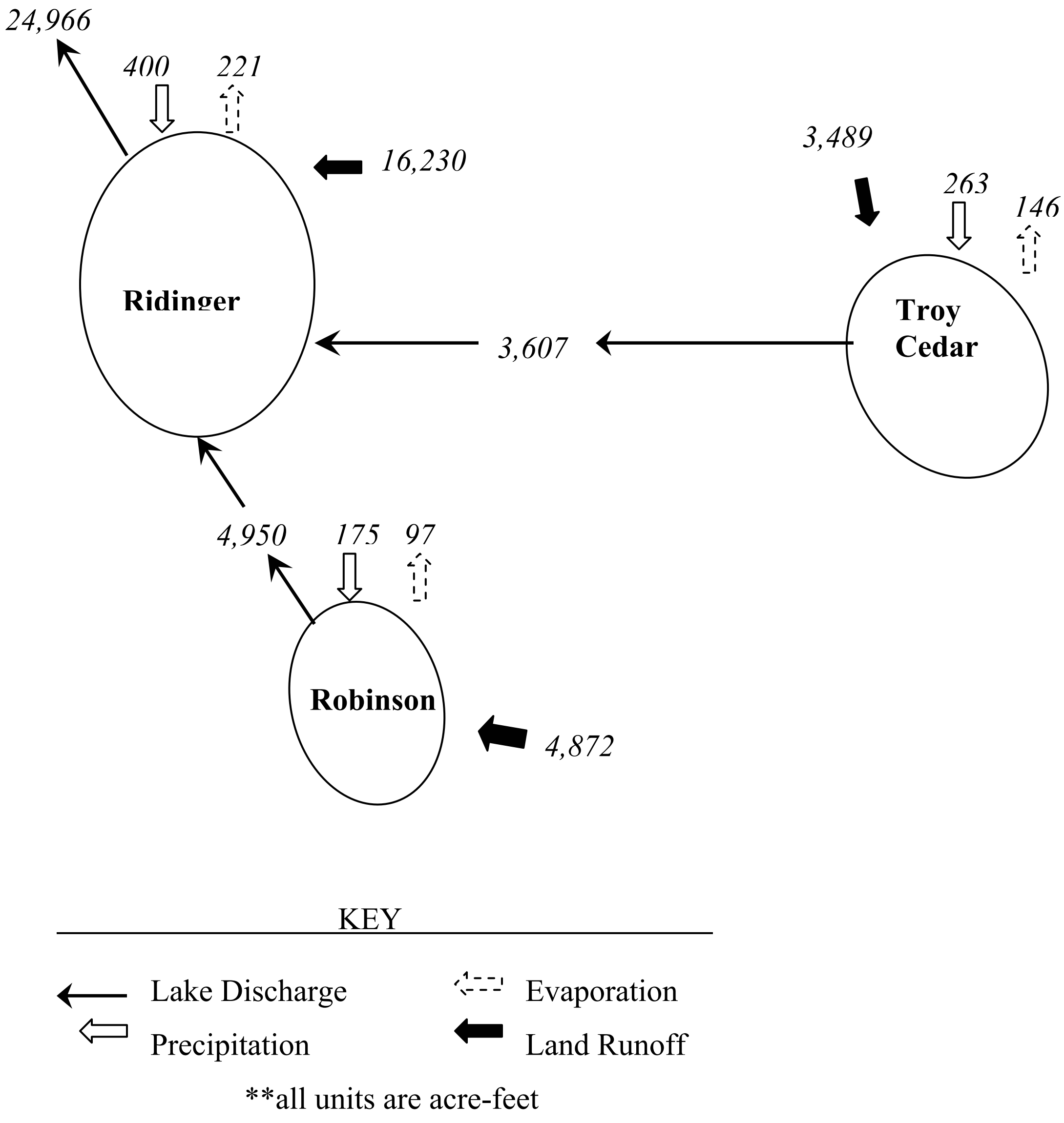
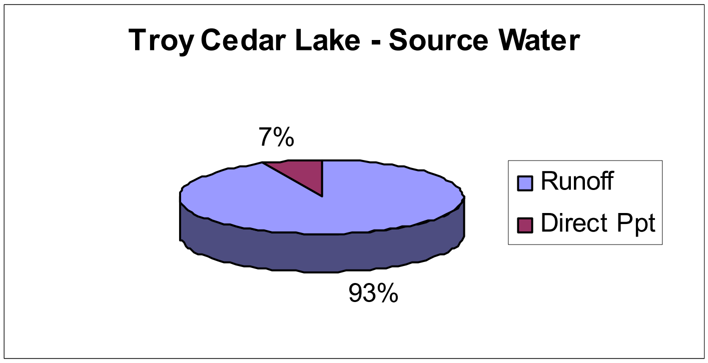
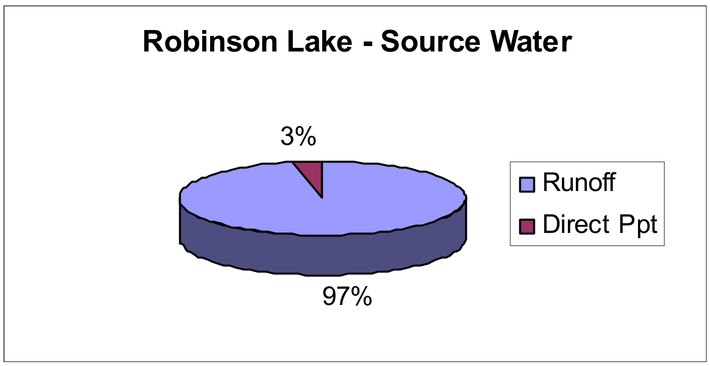


Figure 62. Water Budget Flow Chart for the Ridinger Lake Watershed.





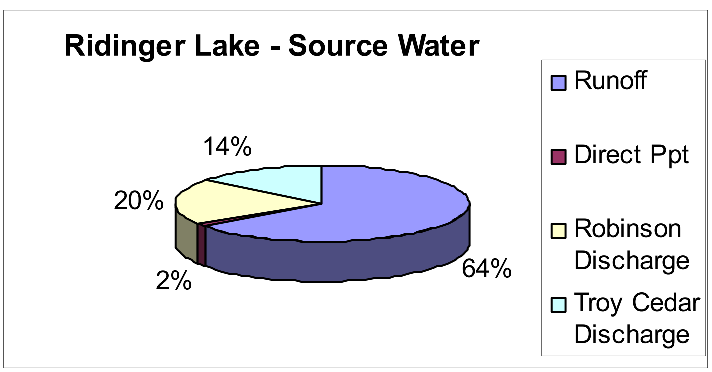


Figure 63. Distribution of water inputs to Ridinger, Robinson, and Troy Cedar Lakes.

7.2 Phosphorus Model

Since phosphorus is the limiting nutrient in Ridinger, Robinson, and Troy Cedar Lakes, a phosphorus model was used to estimate the dynamics of this important nutrient. With its role as the limiting nutrient, phosphorus should be the target of management activities to lower the biological productivity of these lakes.

The limited scope of this study did not allow for the outright determination of phosphorus inputs and outputs. Therefore, a standard phosphorus model was utilized to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies. They used these phosphorus loss rates to calculate phosphorus export coefficients for various land uses. Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. Table 55 shows the phosphorus export coefficients developed by Reckhow and Simpson (1980).

Table 55. Phosphorus export coefficients (units are kg/hectare except the septic category, which are kg/capita-yr).

Estimate Range	Agriculture	Forest	Precipitation	Urban	Septic
High	3.0	0.45	0.6	5.0	1.8
Mid	0.40-1.70	0.15-0.30	0.20-0.50	0.80-3.0	0.4-0.9
Low	0.10	0.2	0.15	0.50	0.3

Source: Reckhow and Simpson, 1980.

To obtain an annual estimate of the phosphorus exported to Ridinger, Robinson, and Troy Cedar Lakes from the lakes' watershed(s), the export coefficient for a particular land use was multiplied by the area of land in that land use category. Mid-range estimates of phosphorus export coefficient values for all watershed land uses (Table 9) were used in this calculation.

Direct phosphorus input via precipitation to the lakes was estimated by multiplying mean annual precipitation in Kosciusko County (0.9 m/yr) times the surface area of the lake times a typical phosphorus concentration in Indiana precipitation (0.03 mg/L). For septic system inputs, the number of permanent homes on each lake was multiplied times an average of 3 residents per home to calculate per capita years. Using a mid-range phosphorus export of 0.5 kg/capita-yr and a soil retention coefficient of 0.75 (this assumes that the drain field retains 75% of the phosphorus applied to it), phosphorus export from septic systems was calculated.

Adding the phosphorus export loads from the watershed, septic systems, and precipitation yielded an estimated 1,458 kg of phosphorus loading to Troy Cedar Lake, annually (Table 56). According to the model, the greatest source of phosphorus loading to Troy Cedar Lake is from row crop agriculture, accounting for over 92% of total watershed loading (Table 56). Row crops were estimated to be the greatest watershed source of phosphorus loading to Robinson (91.4%) and Ridinger (87.0%) Lakes, as well.

Table 56. Results of the phosphorus export model.

Watershed	Total P Loading (kg/yr)	% Row Crop	% Pasture	% Forest
Troy Cedar	1,458	92.4	5.3	1.6
Robinson	2,069	91.4	6.0	2.1
Ridinger[1]	6,631	87.0	9.5	2.2

[1]Not including phosphorus discharge from Troy Cedar and Robinson watersheds

The relationships among the primary parameters that affect a lake's phosphorus concentration were examined employing the widely used Vollenweider (1975) phosphorus-loading model. Vollenweider's empirical model says that the concentration of phosphorus ([P]) in a lake is proportional to the areal phosphorus loading (L, in g/m^2 lake area - year), and inversely proportional to the product of mean depth ($\bar{z}$) and hydraulic flushing rate (ρ) plus a constant (10):

$$[P] = \frac{L}{10 + \bar{z}\rho}$$

During the August 19, 2003 sampling of Troy Cedar Lake, the mean volume weighted phosphorus concentration in the lake was 0.189 mg/L. It is useful to determine how much phosphorus loading from all sources is required to yield a mean phosphorus concentration of 0.189 mg/L in Troy Cedar Lake. Plugging Troy Cedar Lake's mean phosphorus concentration along with its mean depth and flushing rate into Vollenweider's phosphorus loading model and solving for L yields an areal phosphorus loading rate (mass of phosphorus per unit area of lake) of 4.235 g/m^2-yr. This means that in order to get a mean phosphorus concentration of 0.189 mg/L in Troy Cedar Lake, a total of 4.235 grams of phosphorus must be delivered to each square meter of lake surface area per year.

Total phosphorus loading (L_T) is composed of external phosphorus loading (L_E) from outside the lake (watershed, septic systems, and precipitation) and internal phosphorus loading (L_I). Since L_T = 4.235 g/m^2-yr and L_E = 4.049 g/m^2-yr (estimated from the watershed loading in Table 57), then internal phosphorus loading (L_I) equals 0.185 g/m^2-yr. Thus, internal loading accounts for about 4.4% of total phosphorus loading to Troy Cedar Lake.

It is important to check this conclusion that internal phosphorus loading accounts for 4.4% of total phosphorus loading to Troy Cedar Lake. There is evidence in Troy Cedar Lake that soluble phosphorus is being released from the sediments during periods of anoxia. For example, the concentration of total phosphorus in Troy Cedar Lake's hypolimnion on August 19, 2003 was 7.7 times higher than concentrations in the epilimnion (0.363 mg/L vs. 0.047 mg/L). A large portion of this total phosphorus consisted of soluble reactive phosphorus. The source of this hypolimnetic phosphorus is primarily internal loading in most lakes. This internal loading can be a major source of phosphorus in many productive lakes. The modeled estimate of only 4.4% of annual phosphorus loading originating from internal sources is likely underestimated, given the large difference between summertime epilimnetic and hypolimnetic phosphorus concentrations.

The Vollenweider phosphorus loading model was also run using data from Robinson and Ridinger Lakes. Results for all three lakes are included in Table 57. (Appendix J contains detailed phosphorus modeling spreadsheets for each lake.) Note that total loading to Ridinger Lake includes phosphorus in the discharges from Troy Cedar and Robinson lake outlets. For purposes of modeling, it was assumed that 50% of the phosphorus discharged from these lakes was utilized by stream biota and processes before it reached Ridinger Lake. There are no reliable ways to calculate this so the 50% transfer rate is a best professional judgment estimate based on experience.

Table 57. Areal phosphorus loading rates determined from models.

Lake	Total Areal P Loading (g/m^2–yr)[1]	External Areal P Loading (g/m^2–yr)[2]	Internal Areal P Loading (g/m^2–yr)
Ridinger[3]	15.43	14.45	0.98
Robinson	9.83	8.67	1.16
Troy Cedar	4.24	4.05	0.19

[1]estimated from Vollenweider's lake response model
[2]estimated from Reckhow's phosphorus export model and precipitation estimates
[3]includes phosphorus discharge from Troy Cedar and Robinson lakes

The significance of areal phosphorus loading rates is better illustrated in Figure 64 in which areal phosphorus loading is plotted against the product of mean depth times flushing rate. Overlain on this graph is a curve, based on Vollenweider's model, which represents an acceptable loading rate that yields a phosphorus concentration in lake water of 30 μg/L (0.03 mg/L). The areal phosphorus loading rate for each lake is well above the acceptable line.

This figure can also be used to evaluate management needs. For example, areal phosphorus loading to Troy Cedar Lake would have to be reduced from 4.235 g/m^2-yr to 0.67 g/m^2-yr (the downward vertical intercept with the line) to yield a mean lake water concentration of 0.030 mg/L. This represents a reduction in areal phosphorus loading of 3.564 g/m^2-yr to the lake (84%), which is equivalent to a total phosphorus mass loading reduction 1,283 kg P/yr. Similar calculations are shown in Table 58 for the other lakes.

Table 58. Phosphorus reduction required to achieve acceptable phosphorus loading rate and a mean lake concentration of 0.03 mg/L

Lake	Current Total Areal P Loading (g/m^2-yr)	Acceptable Areal P Loading (g/m^2-yr)	Reduction Needed (kg P/yr and %)
Ridinger	15.41	1.99	7,346 (87%)
Robinson	9.83	1.07	2,094 (89%)
Troy Cedar	4.235	0.67	1,283 (84%)

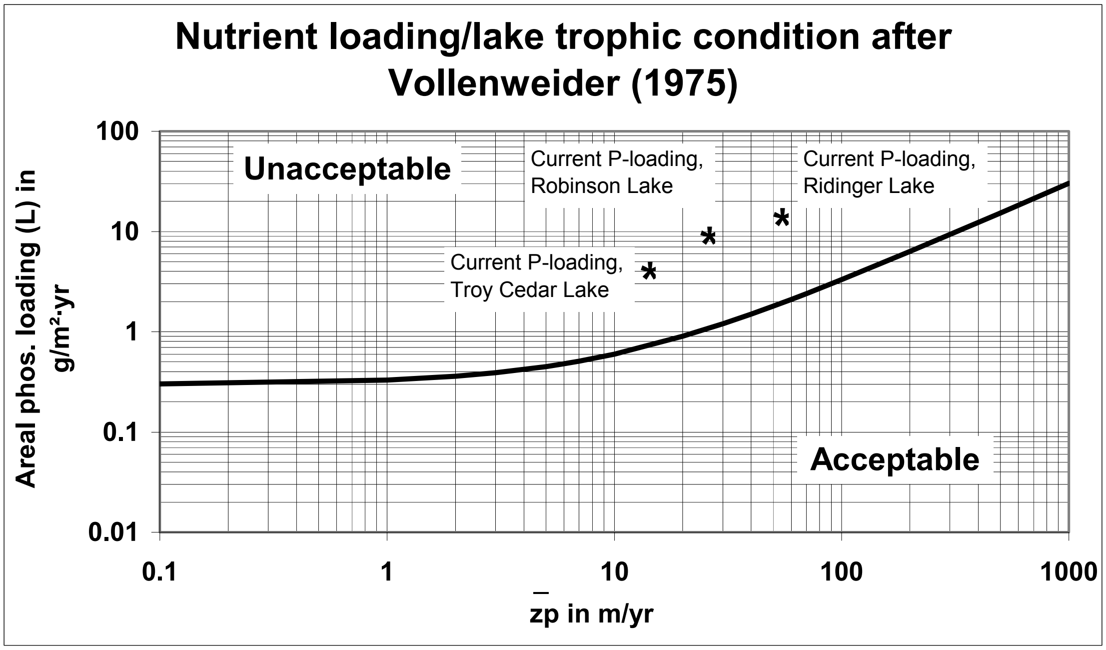


Figure 64. Phosphorus loadings to Ridinger(*), Robinson(*), and Troy Cedar (*) Lakes compared to acceptable loadings determined from Vollenweider's model. The dark line represents the upper limit for acceptable loading.

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 Ridinger, Robinson, and Troy Cedar Lakes.

8.0 MANAGEMENT

Restoration or even minor improvement in a lake's health often requires the implementation of both in-lake and watershed management techniques. Data collected from the Ridinger Lake watershed and from Ridinger, Robinson, and Troy Cedar Lakes themselves shows that this is the case with the study lakes as well. For example, high hypolimnetic soluble reactive phosphorus concentrations in each of the study lakes suggest that phosphorus is being released from the sediments during periods of anoxia. The study lakes may benefit from an alum treatment, a common in-lake treatment, to address the high hypolimnetic phosphorus concentrations. Similarly, high hypolimnetic ammonia concentrations in each of the lakes suggest in-lake treatment such as removal of the organic matter may be warranted.

There is strong evidence, however, that the lakes' watershed exerts a large influence on the health of the study lakes and this influence is likely greater in magnitude than the influence of in-lake processes on the health of the lakes. Ridinger, Robinson, and Troy Cedar Lakes possess relatively short hydraulic residence times. Troy Cedar Lake's residence time is the longest of the three lakes and it is only seven months. Ridinger Lake's residence time is just over one month. The lakes' short residence times mean that water from the watershed is continually replacing the water in each lake. Thus, it is more cost-effective to improve the quality of water entering each lake rather than working on the water quality once the water is in the lake. Phosphorus modeling data add evidence to the idea that the Ridinger Lake watershed exerts a greater influence on the health of the lake than in-lake processes. Phosphorus modeling suggests that 88% to 95% of the phosphorus to each lake comes from external sources rather than internal sources. (It is important to note that the model likely underestimates the amount of internal phosphorus loading. Vollenweider's model does not work as well with lakes possessing short residence times. It is unlikely that is *grossly* underestimates the amount of in internal phosphorus loading, but it does to some minor degree.)

Collectively, the data indicate that management efforts should focus on controlling external sources of pollutants before addressing internal sources of pollutants. In-lake management may need to be explored in the future once external sources of pollutants are controlled. Based on this, the following discussion of management techniques suitable for the Ridinger Lake watershed will focus on watershed management. Several watershed surveys were conducted during the course of this study to identify potential areas of concerns within the Ridinger Lake watershed or areas where management techniques might be employed to improve the water quality in Ridinger, Robinson, and Troy Cedar Lakes. These surveys included a desktop review of existing maps of the watershed, a riparian habitat survey as part of the stream assessment, and a windshield tour of the entire watershed. The following paragraphs discuss management options for the Ridinger Lake watershed. Appendix K provides information on potential funding sources available to help fund the implementation of watershed management projects.

Riparian Restoration and Filter Strip Installation

Healthy, forested riparian zones play a critical role in processing, sequestering, and assimilating pollutants in a stream's water column. Trees and woody vegetation stabilize banks, preventing them from slumping or eroding into the stream. Other herbaceous vegetation in the riparian zone filter pollutants, particularly sediment, in runoff from adjacent lands. Forested riparian zones also indirectly influence the processing and assimilation of nutrients in a stream's water column by determining the species composition of the biotic communities in streams (Ohio EPA, 1999). Because they provide these functions, forested riparian zones are a critical part of a healthy, functioning ecosystem.

Unfortunately, surveys of the Ridinger Lake watershed showed that much of the riparian corridor adjacent to the watershed streams is impaired. In some areas, the damage to watershed streams is severe. Figure 65 shows a portion of Elder Ditch where dredging operations have resulted in the removal of woody vegetation from both sides of the stream. The banks also show signs of slumping that may be due to farming operations occurring right along the stream edge or movement of other heavy machinery along the stream's edge. Figure 66 illustrates a similar situation along Troy Cedar Lake's northern inlet. In addition to the visual evidence noted above, evaluation of the stream's habitat (both in-stream and riparian) using the QHEI suggested that four of the seven watershed streams were so impaired that this impairment prohibits them from supporting the stream's aquatic life beneficial use. Two of the seven streams possessed QHEI scores that IDEM considers to be only partially supportive of the stream's aquatic life use.

Figure 65. View of Elder Ditch showing riparian damage including tree removal and bank slumping. Farming operations also occur right along the stream's edge.

Figure 66. View of Delano Ditch showing the removal of woody riparian vegetation from both sides of the stream.

While restoring the riparian zones along the Ridinger Lake watershed streams to recommended 150-foot (45-m) wide wooded corridors may be unrealistic at this time given the current land use, restoration of reaches along the streams or scaled back restoration should be considered. Isenhart et al. (1997) offers a flexible riparian management model that includes a 45-foot (14-m) wooded buffer and a 21-foot herbaceous buffer adjacent to the wooded buffer. Monitoring studies of Isenhart et al.'s (1997) riparian management system showed a decrease in sediment and nitrate-nitrogen reaching the stream from the adjacent agricultural land. The system also stabilized the stream banks, provided wildlife habitat, and created the opportunity for a more natural energy and nutrient transfer between the stream and its riparian corridor, increasing the potential for a healthy biotic community.

Even scaled back restorations of the riparian zone to a wooded corridor may not be acceptable to many property owners. On these properties, herbaceous filter strips should be installed. Filter strips slow overland flows from adjacent land and reduce the flow volume by increasing infiltration of the runoff. Slower runoff velocities and reduced flow volumes lead to decreased stream bed and bank erosion downstream. Filter strips also help stabilize stream banks, although not to the same extent as wooded riparian buffers.

The most important role of filter strips may, however, be their ability to remove portions of the pollutant load reaching them from adjacent agricultural areas. Many researchers have verified the effectiveness of filter strips in removing sediment from runoff with reductions ranging from 56-97% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999; Lee et al, 2000; Lee et al., 2003). Most of the reduction in sediment load occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus is predominately associated with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentrations like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of dissolved phosphorus, atrazine, and alachlor up to 50% have been documented (Conservation Technology Information Center, 2000). Simpkins et al. (2003) demonstrated 20-93% nitrate-nitrogen removal in multispecies riparian buffers. Short groundwater flow paths, long residence times, and contact with fine-textured sediments favorably increased nitrate-nitrogen removal rates. Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips are most effective when they: 1. are adequately sized to treat the amount of runoff reaching them; 2. include a diverse variety of species; 3. contain species appropriate for filter strips; and 4. are regularly maintained. Filter strip size depends on the purpose of the strip, but should ideally have at least a 30-foot flow path length (the minimum length across which water flows prior to reaching the adjacent waterbody). The variety of species planted in a filter strip depends upon the desired uses of the strip. For instance, if the filter strip will be grazed or if a landowner wishes to attract a diverse bird community, specific seed mixes should be used in the filter strip. The NRCS or an ecological consultant can help landowners adjust filter strip seed mixes to suit specific needs.

The need for riparian zone restoration or minimally filter strip installation is great in the Ridinger Lake watershed. Figure 67 shows the locations in the watershed where riparian zone restoration or filter strip installation or widening is recommended. Property owners should work closely with the Kosciusko County and Whitley County Drainage Boards to ensure riparian restoration needs are balanced with drainage needs and restoration work completed in the watershed will not be disturbed during subsequent dredging operations. Figure 67 also shows the locations where riser filters or protection is needed. Riser filters consist of grass buffers around the riser. These riser filters function similarly to the filter strips described above. For this reason they have been included on Figure 67.

Conservation Reserve Program

Filter strips can be installed by agricultural landowners under the Conservation Reserve Program (CRP). CRP is a cost-share program designed to encourage landowners to remove a portion of their land from agricultural and establish vegetation on the land in an effort to reduce soil erosion, improve water quality, and enhance wildlife habitat. The CRP targets highly erodible land or land considered to be environmentally sensitive. The CRP provides funding for a wide array of conservation techniques including set-asides, filter strips (herbaceous), riparian buffer strips (woody), grassed waterways, and windbreaks. The preceding paragraphs discuss some of the conservation techniques available under the CRP. This section will focus on grassed waterways and set-asides.

Grassed waterways are natural or constructed channels within agricultural fields that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity. Grassed waterways provide similar functions as filter strips. The grassed waterway's vegetation stabilizes the soil beneath it, holding it in place on the landscape. The vegetation also slows runoff water reaching the grassed waterway, reducing the runoff water's erosive power. The vegetation also filters pollutants, particularly sediment from runoff. Like filter strips, the size and shape of the waterway along with what species are planted and how regularly the waterway is maintained determine the ability of the grassed waterway to perform these functions.

Set-asides are simply what the name implies; they are land that "set aside" or removed from agricultural production and planted with herbaceous or woody vegetation. Like grassed waterways, they stabilize the soil on a property. Vegetation on the land set aside in CRP can also filter any runoff reaching it. More importantly, land set aside and planted to prairie or a multi-layer community (i.e. herbaceous, shrub, and tree layers) can help restore a landscape's natural hydrology. Rainwater infiltrates into the soil more readily on land covered with prairie grasses and plants compared to land supporting row crops. This reduces the erosive potential of rain and decreases the volume of runoff. Multi-layer vegetative communities intercept rainwater at different levels, further reducing the erosive potential of rain and volume of runoff.

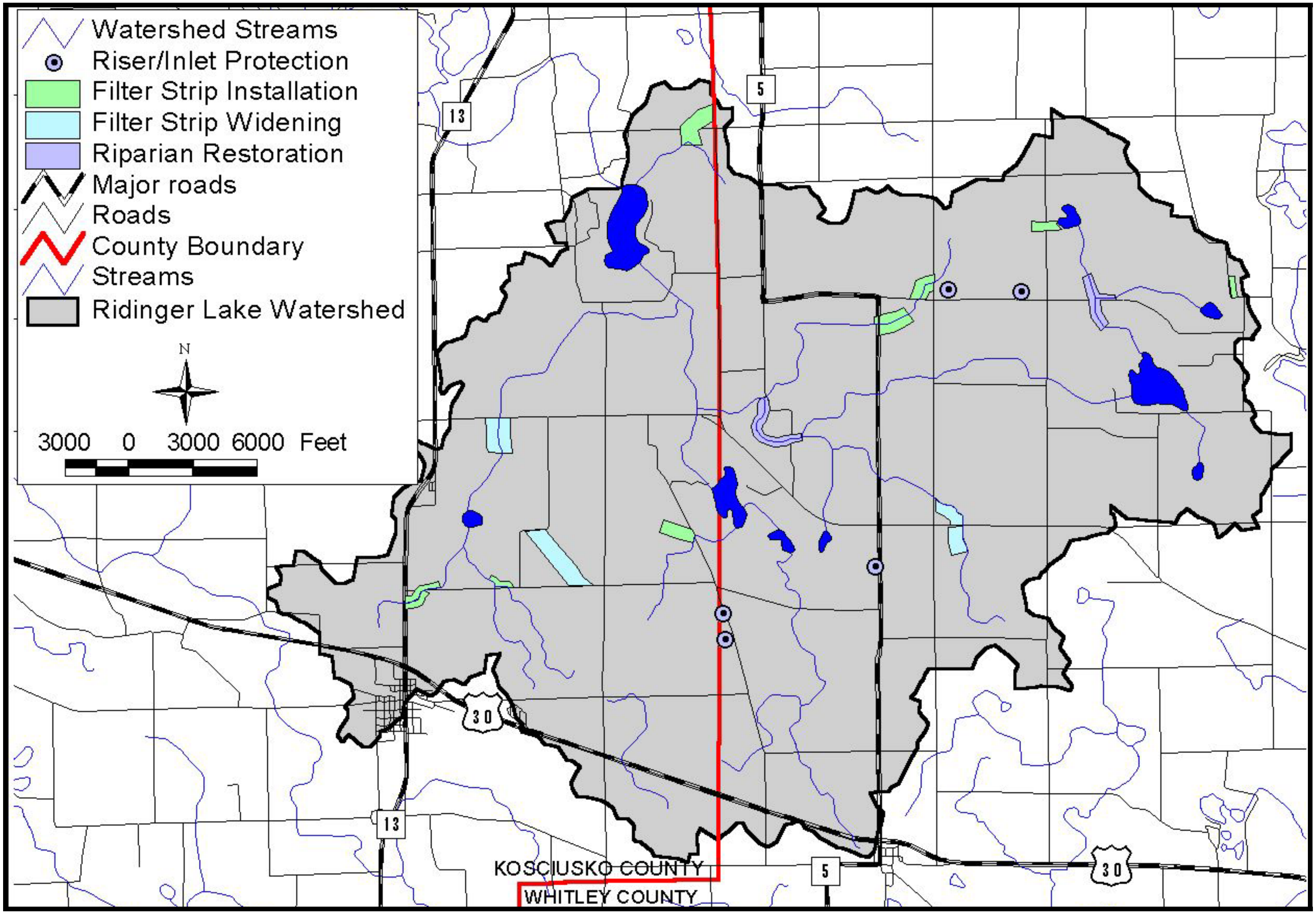


Figure 67. Locations in the Ridinger Lake watershed where riparian restoration or filter strip installation/widening is recommended. Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Given the functions that grassed waterways and set-asides perform, it is not surprising that removing land from production and planting it with vegetation has a positive impact on water quality. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI score is indicative of lower productivity and better water quality.

Field investigations conducted during this study resulted in the identification of several areas where the use of grassed waterways or conversion of at least a portion of a farm field to native prairie or other vegetation would improve water quality (Figure 68). Nearly all of these areas are located in the headwaters of Shanton, Elder, and Mathias Ditches, the three ditches which also possessed the highest areal pollutant loading rates. Many of these areas are also mapped at least partially in Morley or Rawson soils that have severe or very severe limitations for use in agriculture due to the risk of soil erosion. Some small areas, such as an area noted east of Elder Road and south of Elder Ditch, are in soils that have such severe limitations for use in agricultural due to the risk of soil erosion that the soils are considered unsuitable for cultivation. Additionally, during the windshield tour, the presence of rills and the beginning of gully formation was noted in many of these fields. While other areas of the watershed would benefit from enrollment in the CRP program, these areas were prioritized due to the characteristics listed above and, location in the Shanton, Elder, and Mathias Ditch subwatersheds.

Conservation Tillage

Removing land from agricultural production is not always feasible. Conservation tillage methods should be utilized on highly erodible agricultural land where removing land from production is not an option. 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 the phrase “conservation tillage” include no-till, mulch-till, and ridge-till. The crop residue that remains on the landscape helps reduce soil erosion and runoff water 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). In his review of Indiana lakes, Jones (1996) documented lower mean lake trophic state index scores in ecoregions with higher percentages of conservation tillage. A lower TSI score is indicative of lower productivity and better water quality.

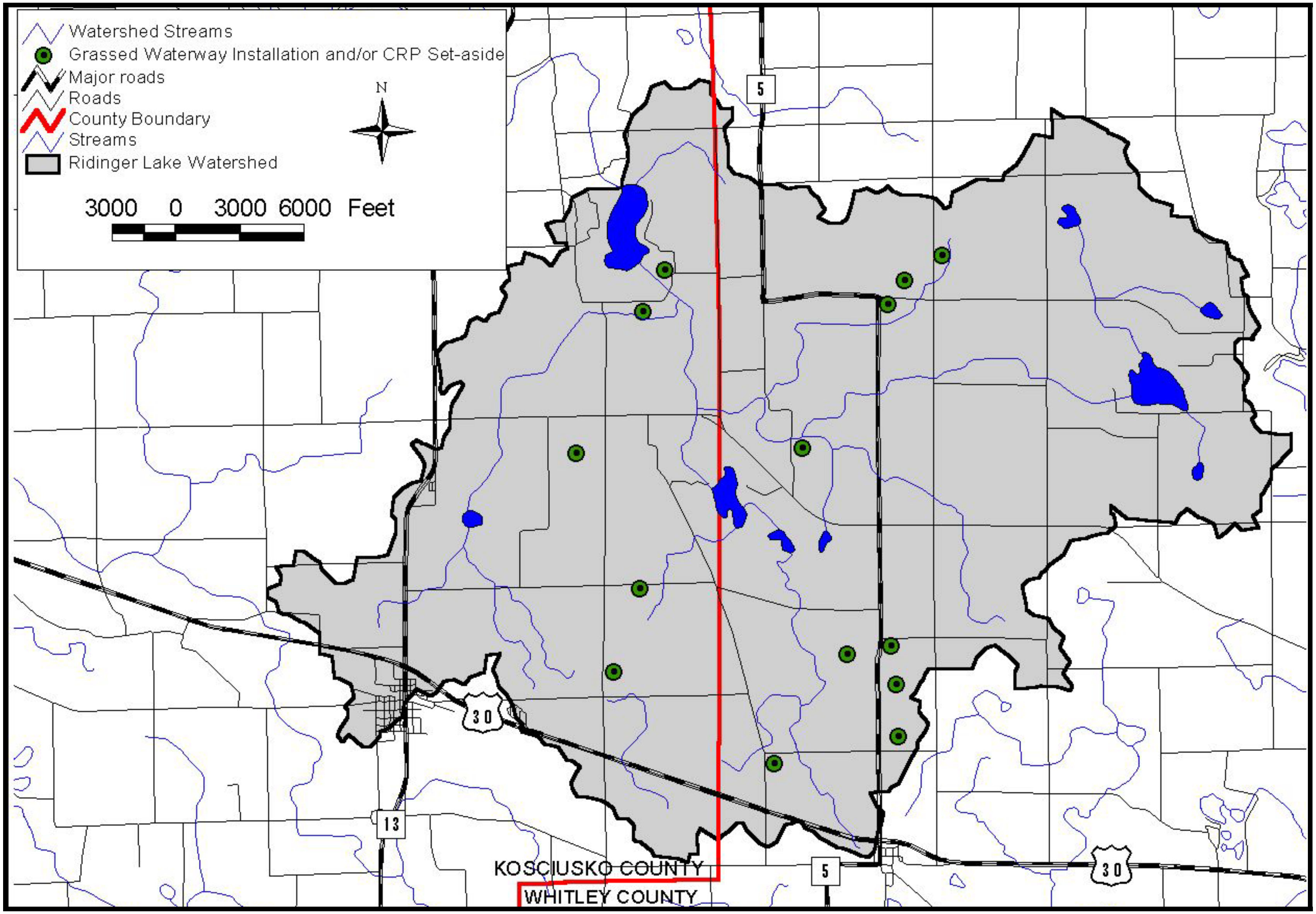


Figure 68. Locations in the Ridinger Lake watershed where grassed waterway installation or set-aside in the Conservation Reserve Program is recommended. Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Although an evaluation of the percentage of crop land on which producers were utilizing conservation tillage methods was beyond the scope of this study, county-wide estimates from tillage transect data provide a reasonable estimate of the amount of crop land on which producers are utilizing conservation tillage methods in the Ridinger Lake watershed. Tillage transect data collected in 2003 for Kosciusko and Whitley Counties showed that the use of no-till methods on Kosciusko County farmland was near the statewide average (for corn and soybeans), while Whitley County ranked near the bottom for corn and near the top for soybeans in the percentage of farmland on which no-till methods are utilized. In 2002, both counties registered an increase in the percentage of corn fields and a decrease in the percentage of soybean fields on which no-till was utilized (Purdue University and IDNR, no date). Collectively, the tillage transect data suggest that, in general, producers in Kosciusko and Whitley Counties could increase their use of no-till methods on farmland in the counties and, therefore, the Ridinger Lake watershed. The areas targeted for CRP implementation noted above should be farmed using no-till methods if removal of the land from production is not a feasible option.

Wetland Restoration

Visual observation and historical records indicate at least a portion of the Ridinger Lake watershed has been altered to increase its drainage capacity. The relative lack of wetlands in the Ridinger Lake watershed compared to the Upper Tippecanoe River watershed lends evidence to this idea. The 1978 Census of Agriculture found that drainage is artificially enhanced on 38% and 45% of the land in Kosciusko and Whitley Counties, respectively (cited in Hudak, 1995). Riser tiles in low spots on the landscape and tile outlets along the Ridinger Lake watershed streams confirm the fact that the landscape has been hydrologically altered. Shoreline development around lakes in areas that are mapped in hydric soils also supports the hypothesis that the landscape has been hydrologically altered.

This hydrological alteration and subsequent loss of wetlands has implications for the watershed's water quality. Wetlands serve a vital role storing water and recharging the groundwater. When wetlands are drained with tiles, the stormwater reaching these wetlands is directed immediately to nearby ditches and streams. This increases the peak flow velocities and volumes in the ditch. The increase in flow velocities and volumes can in turn lead to increased stream bed and bank erosion, ultimately increasing sediment delivery to downstream water bodies. Wetlands also serve as nutrient sinks at times. The loss of wetlands can increase pollutant loads reaching nearby streams and downstream waterbodies.

Restoring wetlands in the Ridinger Lake watershed could return many of the functions that were lost when these wetlands were drained. Figure 69 shows the locations where wetland restoration is recommended. While other areas of the watershed could be restored to wetland conditions, the areas shown in Figure 69 were selected because they are areas where large scale restoration is possible and will likely provide the most water quality improvement benefits due to their proximity to a waterbody.

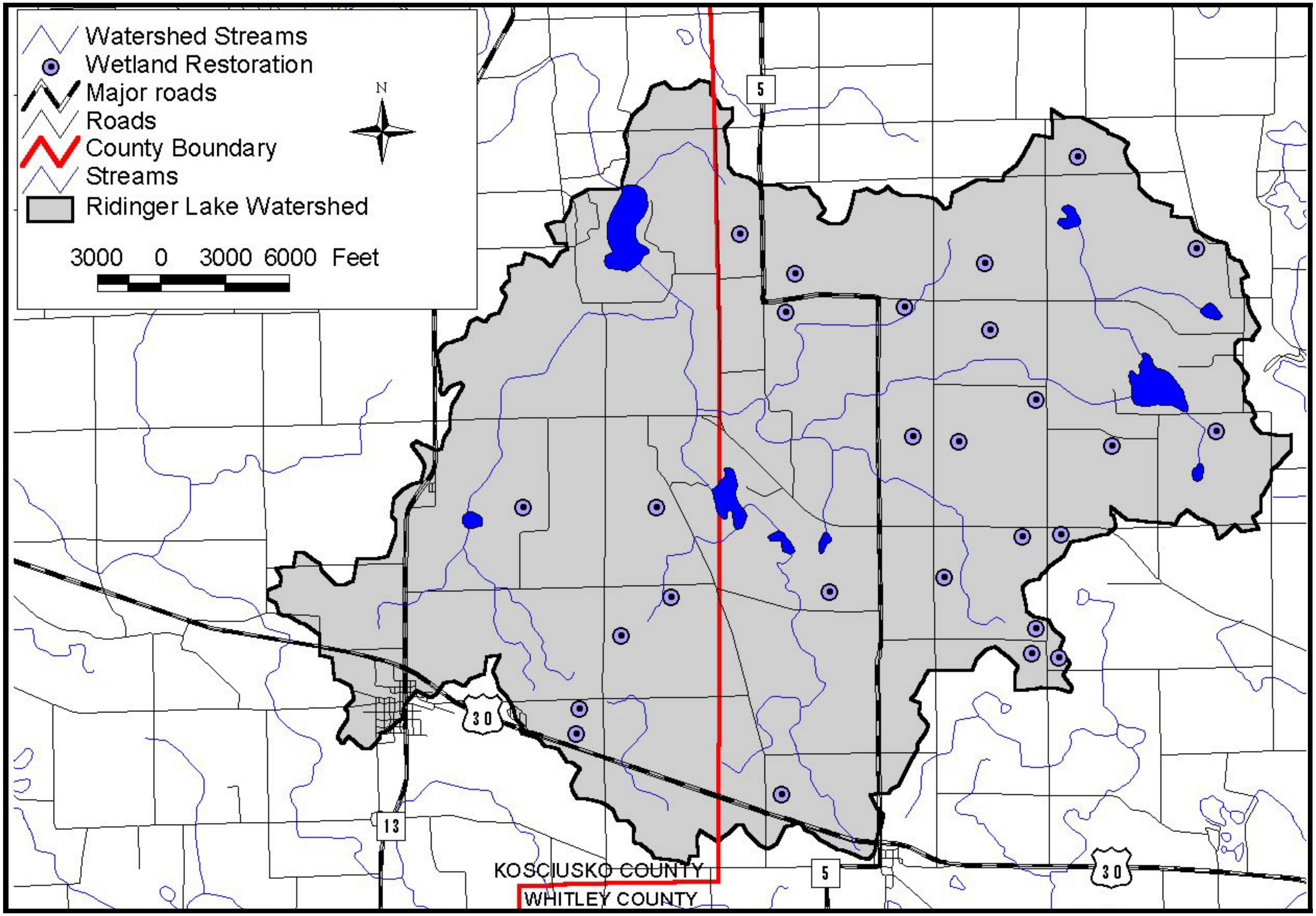


Figure 69. Locations in the Ridinger Lake watershed where wetland restoration is recommended. Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Livestock Fencing

Livestock that have unrestricted access to a lake or stream have the potential to degrade the waterbody's water quality and biotic integrity. Livestock can deliver nutrients and pathogens directly to a waterbody through defecation. Livestock also degrade stream and lake ecosystems indirectly. Trampling and removal of vegetation through grazing of the riparian zones can weaken banks and increase the potential for bank erosion. Trampling can also compact soils in the riparian zone decreasing the area's ability to infiltrate water runoff. Removal of vegetation in the riparian zone also limits the area's ability to filter pollutants in runoff. The degradation of a waterbody's water quality and habitat typically results in the impairment of the biota living in the waterbody.

Livestock have unrestricted access to the Ridinger Lake watershed's streams in several locations (Figure 71). In addition to the locations on Figure 71, three of the special or multiphase projects (Figure 72) involve a livestock fencing component, and it is likely that other locations exist where livestock have unrestricted access to the watershed streams. Figure 70 shows cattle resting in Robinson Lake. These cattle are undoubtedly one source of nutrients that help support the dense watermeal population on the lake. (The green vegetation floating on the lake in Figure 70 is watermeal.) Robinson Lake possessed the highest mean soluble and total phosphorus concentrations of the three study lakes. Although it is not clearly shown in Figure 70, cattle grazing in this area has denuded the shoreline of herbaceous vegetation, thus removing the filtering capacity of the shoreline and allowing nutrients and sediment in runoff to enter the lake untreated. Cattle movement in the lake disturbs the lake's sediments increasing the potential for internal phosphorus loading. Although the lake survey did not include bacteria testing, the cattle are likely contributing pathogens and bacteria to the lake which could affect the lake's inhabitants and its human users.

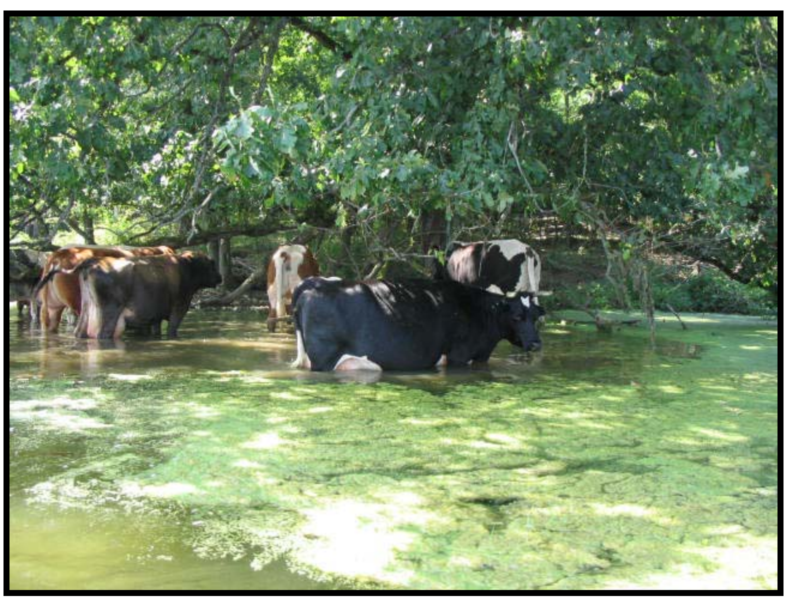


Figure 70. Livestock in Robinson Lake.

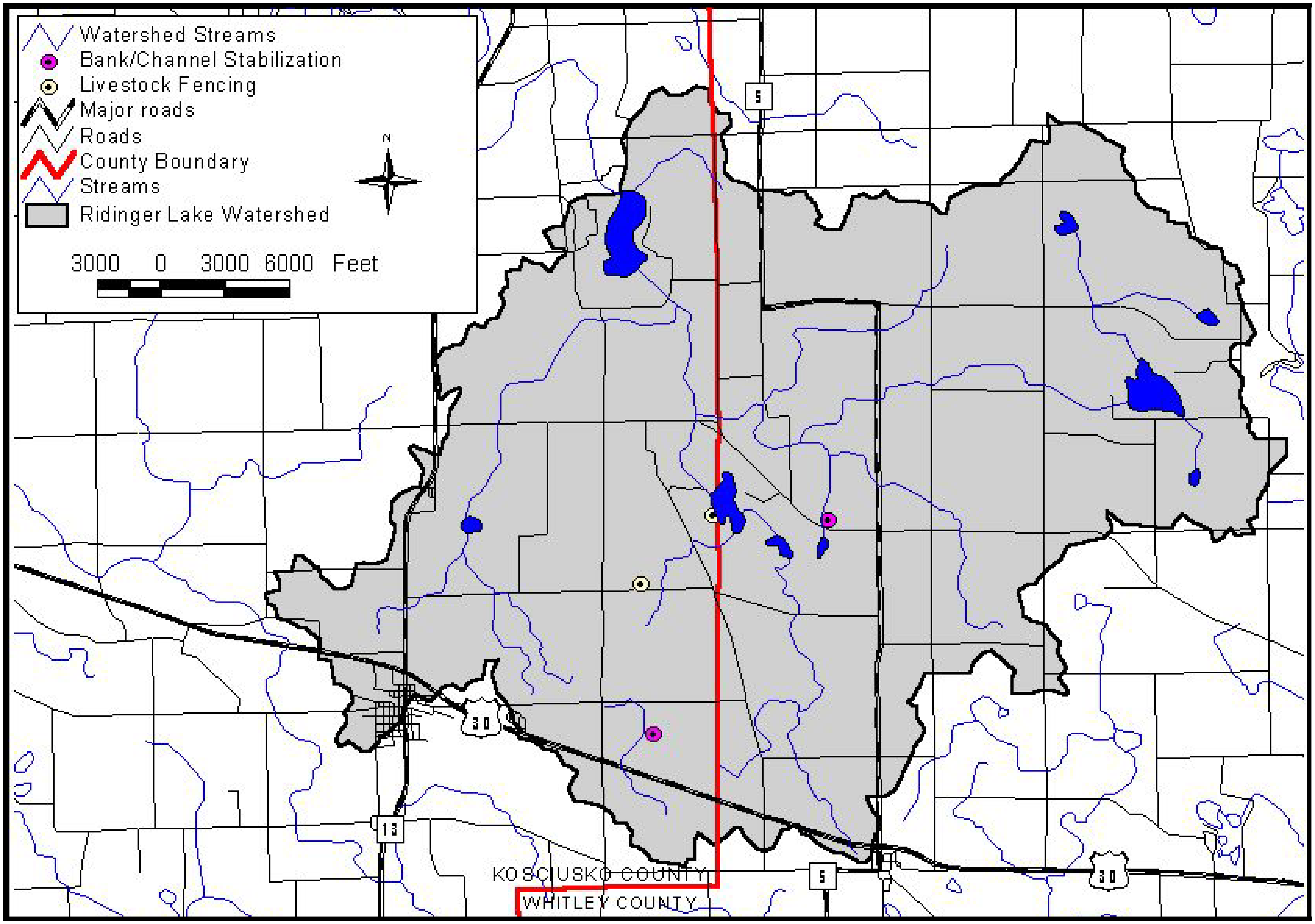


Figure 71. Locations where livestock exclusion fencing and stream bank/channel stabilization is recommended. Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Restoring areas impacting by livestock grazing often involves several steps. First, the livestock in these areas should be restricted from having access to the lake or stream to which they currently have access. If necessary an alternate source of water should be created for the livestock. Second, the riparian zone or lake shoreline where the livestock have grazed should be restored. This may include stabilizing or reconstructing the banks using bioengineering techniques. Minimally, it involves installing filter strips along banks. Finally, if possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading, particularly nitrate-nitrogen loading, to the adjacent waterbody. Complete restoration of these areas will help reduce pollutant loading (particularly nitrate-nitrogen, sediment, and pathogens) to the study lakes. It will also improve the biotic community and habitat quality in the watershed streams.

Streambank and Channel Stabilization and Restoration

Eroding banks add sediment directly to streams. This sediment can impair stream habitat by filling interstitial crevices in a stream's substrate and smothering spawning gravel. This will, in turn, negatively affect the stream's biota. Sediment from eroding stream banks is also transported downstream to the lakes in the watershed where it degrades the lake habitat and can impair recreational uses of the lake. Sediment deltas at lake mouths often support nuisance levels of rooted aquatic plants. Sediment deltas can also restrict boating in the area.

QHEI scores for most of the Ridinger Lake watershed streams show that many of the watershed streams generally suffer from at least moderate levels of bank erosion (See Appendix F). Figure 71 shows some of the areas that would benefit from bank stabilization or restoration. Several of the multiple phase projects also involve bank stabilization (Figure 72). Bioengineering techniques, such as soil encapsulated lifts or willow staking, which utilize vegetation to stabilize stream banks, are recommended in these areas over hard armoring, such as riprap. In addition to reducing sediment loading to a stream, bioengineering techniques often improve riparian habitat, something that cannot be accomplished with riprap alone.

Residential and Commercial Development Erosion Control

Although little residential and commercial development is occurring in the Ridinger Lake watershed compared to other areas of northeast Indiana, some areas particularly those around the watershed's lakes continue to experience development pressure. Active construction sites are a common source of sediment to nearby waterways. Sediment loss from active construction sites can be several orders of magnitude greater than sediment loss from a completed subdivision. Use of appropriate erosion control management techniques on active construction sites is necessary to reduce pollutant loading to nearby waterbodies. During the watershed inspection, several areas were observed where the use of erosion control methods would have prevented or at least minimized the loss of sediment from the site (Figure 73 under Special or Multiple Phase Projects). One of these sites was of particular concern, since gullies had formed transporting sediment to a nearby waterway. Construction vehicles had also tracked sediment onto the road. This sediment on the road was being washed into a nearby waterway. Several erosion control techniques including the installation of silt fencing, creation of a construction entrance, and planting of temporary or permanent ground cover would have helped to minimize sediment loss from this site. Ridinger Lake watershed stakeholders must be vigilant in monitoring development sites, such as this, to ensure erosion control methods are being utilized. Under new regulations, anyone planning to disturb more than an acre of land must file an erosion control plan with the State.

Special or Multiple Phase Projects

Figure 72 shows the locations where a recommended watershed improvement project includes more than one component, such as sites where livestock fencing and stream bank stabilization are recommended. Figure 72 shows one such project where an eroding ravine should be stabilized to reduce sediment loading to Ridinger Lake. Installing grassed waterways or enrolling the field that drains to this ravine in a CRP set-side program would also improve water quality in Ridinger Lake. Figure 73 also maps areas where a special management technique, such as the installation of prairie grasses, is recommended. Finally, the figure highlights sites where a water quality solution might be implemented such as a sediment trap. The management techniques recommended or potential water quality solution at each of the sites mapped on Figure 72 are summarized in Table 59. Most of the management techniques listed in Table 59 and their water quality benefits have been described in the previous paragraphs.

Figure 72. Eroding ravine near Ridinger Lake.

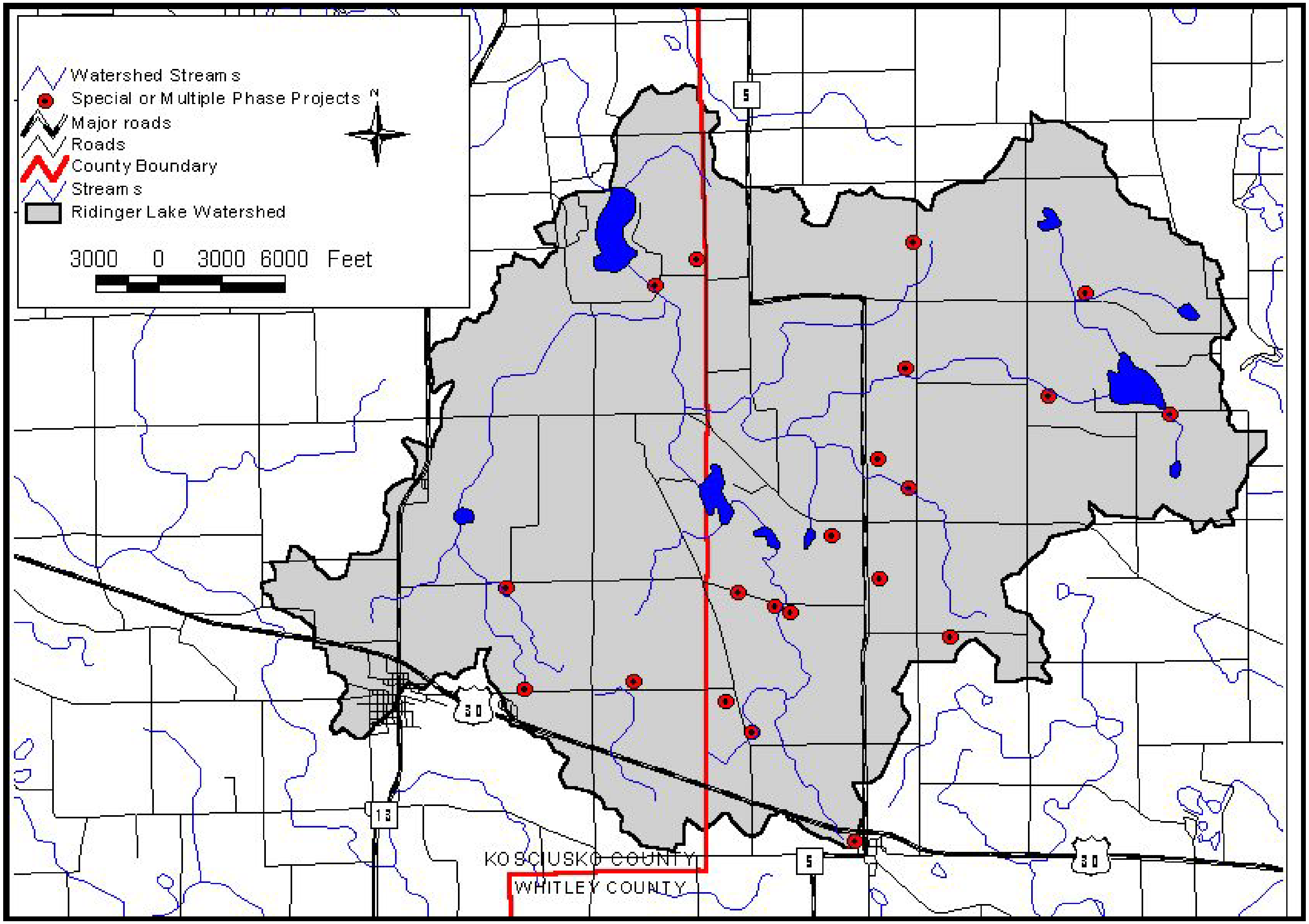


Figure 73. Locations in the Ridinger Lake watershed where implementation of special or multiple phase projects is recommended. Source: See GIS sources appendix (Appendix A). Scale: 1"=7,000'.

Table 59. Special or multiple phase projects in the Ridinger Lake watershed. Locations of the projects corresponds to Figure 73.

Subwatershed	County	Location	Management Required
Shanton Ditch	Kosciusko	South side of CR 150 S, west of Brailer Road	Livestock fencing to restrict access to the stream; bank stabilization; filter strip installation or overall riparian restoration
Shanton Ditch	Kosciusko	North side of CR 250 S, west of CR 900 E	Riser protection; inspection of septic system
Shanton Ditch	Kosciusko	North side of CR 250 S, east of CR 900 E	Stabilization of newly created roadside ditch with check dams and/or erosion control fabric and vegetation
Ridinger Lake	Kosciusko	North side of Adams Road, west of the County Line Road	Grassed waterway installation or other CRP set-aside; minimally use of no-till; ravine/channel stabilization with check dams or other control method
Ridinger Lake	Kosciusko	South side of Adams Road, west of the County Line Road	Off line sediment trap installation
Elder Ditch	Whitley	West side of CR 550 W, north of CR 600 N	Grassed waterway installation or other CRP set-aside; minimally use of no-till; installation of drop structure for inlet protection
Delano Ditch	Whitley	North side of CR 600 N, east of CR 550 W	Potential location for a sediment trap or wetland filter
Elder Ditch	Whitley	West side of CR 650 W, north of CR 500 N	Increase filter strip width and repair gulley damage at the edge of field
Southern Troy Cedar Lake Inlet	Whitley	At the mouth of the inlet and along at east of the inlet south of CR 500 N	Potential location for a sediment trap; increase filter strip width along the inlet; consider CRP set aside or minimally use of no-till
Elder Ditch	Whitley	South side of Troy Cedar Lake Branch of Elder Ditch, east and west sides of CR 550 W	Stream reconstruction by regrading bank slope and stabilizing with bioengineering methods; livestock fencing to restrict access to the stream
Elder Ditch	Whitley	East side of SR 5, north of Lincolnway	Increase stabilization of roadside channel by increasing the size of rock in the channel
Elder Ditch	Whitley	West side of CR 650 W, north of Lincolnway	Increase filter strip on both side of the stream and/or consider wetland filter installation
Elder Ditch	Whitley	South of Lincolnway, west of SR 5	Warm season prairie restoration
Elder Ditch	Whitley	East side of SR 5, south of Lincolnway	Redesign livestock pasture to provide a water source that is separate from the wetland which drains to the headwaters of Elder Ditch

Subwatershed	County	Location	Management Required
Elder Ditch	Whitley	South side of CR 300 N, east of CR 650 W	Install grassed waterways throughout field especially where livestock pasture area drains to stream; riser/inlet structure protection; possibly stabilize bank
Mathias Ditch	Whitley	CR 325 N	Consider paving CR 325 N
Mathias Ditch	Whitley	South side of CR 325 N, west of Mathias Ditch	Erosion control
Mathias Ditch	Whitley	South side of CR 325 N, east of Mathias Ditch	Potential location for sediment trap or wetland filter
Mathias Ditch	Whitley	Southwest corner of Binkley Road and CR 250 N	Erosion control installation, including silt fences and construction entrances, at new construction site; repair of gullies created by the lack of erosion control also needed at this site
Mathias Ditch	Whitley	East side of Binkley Road, north of CR 200 N	Potential location for sediment trap or wetland filter
Mathias Ditch	Whitley	Town of Larwill	Storm drain inserts

Individual Property Management

Individual property owners can take several actions to improve the lakes and streams in the Ridinger Lake watershed. First, 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 lakes and streams. 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 lakes and streams either directly from those residents' lawns along the lakes' shoreline or indirectly via storm drains. This simply fertilizes the rooted plants and algae in the lakes and impairs the biotic communities in both the lakes and streams in the watershed. 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. Alternatively, landowners should consider replacing high maintenance turf grasses with grasses that have lower maintenance requirements such as some fescue (*Festuca*) species.

If a landowner considers fertilizer use necessary, the landowner should apply phosphorus-free fertilizers. Most fertilizers contain both nitrogen and phosphorus. However, the soil usually contains enough natural phosphorus to allow for plant growth. As a consequence, fertilizers with only nitrogen work as well as those with both nutrients. The excess phosphorus that cannot be absorbed by the grass or plants can enter the lakes or streams, again either directly or via storm drains. Landowners can have their soil tested to ensure that their property does indeed have sufficient phosphorus and no additional phosphorus needs to be added. The Purdue University Extension or a local supplier can usually provide information on soil testing.

Shoreline landowners should also avoid depositing lawn waste such as leaves and grass clippings in the lakes and streams as this adds to the nutrient base in these aquatic systems. Pet and other animal waste that enters the watershed lakes and streams also contributes nutrients and pathogens to the waterbodies. All of these substances require oxygen to decompose. This increases the demand on the already oxygen-strained lakes. Yard, pet, and animal waste should be placed in residents' solid waste containers to be taken to the landfill rather than leaving the waste on the lawn or piers to decompose.

Each lake property owner should investigate local drains, roads, parking areas, driveways, and rooftops. Resident surveys conducted on other northern Indiana lakes have indicated that many lakeside houses have local drains of some sort on their properties. These drains contribute to sediment and nutrient loading and thermal pollution to the lakes. Where possible, alternatives to piping the water directly to the lake should be considered. Alternatives include French drains (gravel filled trenches), wetland filters, catch basins, and native plant overland swales.

Residents should disconnect stormwater drainage paths and consider the installation of vegetative filters, rain gardens, gravel infiltration trenches, or other drainage structures that promote infiltration and pollutant treatment over stormwater conveyance. While connecting downspouts with street drains keeps lawns well drained, these direct drainages prevent any pollutant treatment or infiltration (and therefore loss of stormwater volume) that the lawn or natural landscape may provide. Disconnecting these individual stormwater conduits should especially be encouraged in the areas of the watershed where soils are best suited for this.

Individuals should take steps to prevent unnecessary pollutant release from their property. With regard to car maintenance, property owners should clean any automotive fluid (oil, antifreeze, etc.) spills immediately. Driveways and street fronts should be kept clean and free of sediment. Regular hardscape cleaning would help reduce sediment and sediment-attached nutrient loading to the waterbodies in the watershed. Street cleaning would also reduce the watershed loading of heavy metals and other toxicants associated with automobile use. Residents should avoid sweeping driveway silt and debris into storm drains. Rather, any sediment or debris collected during cleaning should be deposited in a solid waste container.

Finally, individual property owners should take steps to minimize the water quality impacts of their on-site waste water treatment systems (i.e. septic systems). Overloaded or leaking septic systems deliver nutrients and other pollutants such as *E. coli* to nearby waterbodies. This can increase the waterbodies' productivity and threaten human health. To address the problems posed by septic systems, properties owners should conduct regular septic tank maintenance. Frequency of septic tanks cleaning depends on the size of the tank and number of persons utilizing it. Jones and Yahner (1994) suggest dividing the size of the septic tank by the product of 100 and the number of persons in the household to determine the frequency of cleaning. For example, if a household of four that does not use a garbage disposal is served by an 800-gallon septic tank, this household should clean its tank every 2 years. (800/(100*4) = 2) Use of a garbage disposal increases solids loading to a septic tank by about 50% so this needs to be considered when calculated cleaning frequency. It is important to distinguish between "cleaning" which means the removal of solids and effluent from the tank and "pumping" which refers to removal of only the liquid effluent from the tank. Where necessary, systems should be upgraded to ensure they can handle any increases in waste stream that have occurred over the years (i.e. modernization of home, increases in residence time, etc.) Water conservation measures such as using low-flow toilets or taking shorter showers will also decrease loading to septic systems.

Those are the minimum steps that should be taken to prevent an increase in pollution from septic systems. Alternatives that actually reduce the waste stream should also be considered. For example, wastewater wetlands typically produce cleaner effluent at the end of a leach field than traditional systems. This is particularly true during the summer months, when plants in such a wetland operate at peak evapotranspiration capacity. Very little effluent leaves the wetlands. This reduction in effluent release corresponds with the peak times for potential algae blooms in the lake. The wetland is working hardest to prevent nutrients from reaching the lake at the exact time when nuisance algae blooms could develop if sufficient nutrients are present. Leach fields of wastewater wetlands are smaller than traditional leach fields making them more attractive on lots where limited space is available. Finally, because of the relative isolation of some of the areas in the Ridinger Lake watershed, the installation of a sanitary sewer system is not likely to be economically feasible in the near future. However, new subdivisions might utilize an expanded waste water wetland to treat all waste water from this area rather than relying on individual septic systems.

9.0 RECOMMENDATIONS

Data collected during this study indicate that management efforts should first focus on watershed improvement and implement in-lake management techniques only after external sources of pollutants, particularly phosphorus and sediment, have been controlled. Each of the lakes has a relatively short hydraulic residence time. Ridinger Lake's is especially short at 36 days. This means that every 36 days the entire volume of water in Ridinger Lake is flushed and replaced with new water from its inlet. Thus, improving the water entering Ridinger Lake is more cost-effective than treating the water that exists in the lake since the lake is continually replenished with new water from its watershed. The same is true for Robinson and Troy Cedar Lakes.

Nearly 100 management actions were identified in the Ridinger Lake watershed over the course of this study. Data collected during the study suggest that management efforts in the Shanton Ditch and Elder Ditch subwatersheds should be prioritized over other areas in the Ridinger Lake watershed. These ditches possessed the greatest pollutant loading rates. In addition, when drainage area is taken into account, Shanton Ditch still exhibits some of the highest areal pollutant loading rates and Elder Ditch's pollutant loading rates were of concern. The ditches also possessed two of the lowest three QHEI scores indicating poor in-stream and riparian habitat in these ditches. Impaired habitat can affect a stream's ability to process and assimilate pollutant loads. Collectively, this evidence suggests work in these two subwatersheds should receive a higher priority over other areas in the watershed.

Management efforts in the Mathias Ditch subwatershed draining to Robinson Lake should receive priority after projects in the Shanton Ditch and Elder Ditch subwatersheds. When drainage size is taken into account, Mathias Ditch has high areal pollutant loading rates, especially for total phosphorus, relative to other subwatersheds in the Ridinger Lake subwatershed. Focusing on the Mathias Ditch subwatershed is particularly important if watershed stakeholders decide improvement of Robinson Lake is a high priority. Work done in the Mathias Ditch subwatershed will have less of an impact on Ridinger Lake compared to watershed work conducted in the Shanton Ditch and Elder Ditch subwatersheds.

Regardless of the location in the watershed, there were several water quality concerns that require immediate attention. These projects should receive the highest priority due to their proximity to one of the study lakes or streams and the ecological damage occurring or that has occurred at these sites. There are six projects that meet this definition. They are listed first in the recommendations list below.

When implementing any of the following recommendations, watershed stakeholders should remember that the restoration of Ridinger, Robinson, and Troy Cedar Lakes and their watershed will require a long-term, concerted effort. The lake and watershed characteristics of the study lakes do not point to a single "smoking gun" responsible for the observed increase in productivity or poor water quality. Thus, the installation of a single buffer strip, restoration of a single wetland, utilization of conservation tillage on a single field, or implementation of erosion control methods on a single residential construction site will have little noticeable effect on study lakes' water quality. Restoration of Ridinger, Robinson, and Troy Cedar Lakes to a more natural, eutrophic condition from their current hypereutrophic condition will only be achieved by the implementation of these recommendations across the watershed over the long term.

The following is a list of prioritized recommendations for improving water quality in the Ridinger Lake watershed. The prioritization is based on the current ecological conditions of the study lakes and their watershed. These conditions may change as land and lake uses change. Watershed stakeholders may also wish to prioritize these management recommendations differently to accommodate specific needs or desired uses of the lakes and streams in the Ridinger Lake watershed. It is also important for watershed stakeholders to know that action need not be taken in this order. Some of the smaller, less expensive recommendations, such as the individual property owners recommendations, may be implemented while funds are being raised to implement some of the larger projects. Many of the larger projects will require feasibility studies to ensure landowner willingness to participate in the project and regulatory approval of the project.

Specific Recommendations

1. Restoration of the Elder Ditch corridor where ditch cleaning has been particularly damaging such as the area upstream and downstream of Elder Road. Restoration in this area includes stream bank stabilization through the use of bioengineering techniques and revegetation of the riparian corridor, preferably with woody vegetation.

2. Restricting access of livestock to Robinson Lake. An alternate source of water should be created for the livestock, and the lake shoreline where the livestock have grazed should be restored. Ideally, a constructed wetland or other treatment of drainage from the livestock's pasture should be installed to limit nutrient input to Robinson Lake from runoff.

3. Stabilization of the eroding ravine leading to the southeast corner of Ridinger Lake. Work at this site will include working with the property owner of the adjacent land to utilize grassed waterways or set aside a portion of the land in CRP.

4. Restoration of Troy Cedar Lake's northern inlet's corridor where ditch cleaning has damaged the riparian zone. Restoration may include stream bank stabilization through the use of bioengineering techniques and revegetation of the riparian corridor, preferably with woody vegetation.

5. Restricting access of livestock to Shanton Ditch's headwaters tributaries. An alternate source of water should be created for the livestock, and the stream bank where the livestock have grazed should be restored. This may include stabilizing or reconstructing the banks using bioengineering techniques. If possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading particularly, nitrate-nitrogen loading, to the adjacent stream.

6. Restrict livestock access to the Troy Cedar Branch of Elder Ditch on the east and west sides of CR 550W. An alternate source of water should be created for the livestock, and the stream bank where the livestock have grazed should be restored. This may include stabilizing or reconstructing the banks using bioengineering techniques. If possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading particularly, nitrate-nitrogen loading, to the Troy Cedar Branch of Elder Ditch.

Watershed-Scale Recommendations

1. Restore riparian zones along the streams in the Ridinger Lake watershed where possible; minimally, install filter strips along these streams. Target areas shown on Figure 67. In addition to the areas listed in the *Specific Recommendations* above, stream corridors in the Shanton Ditch and Elder Ditch subwatersheds should receive high priority.

2. Restore as many wetlands as possible in the Ridinger Lake watershed, targeting those areas shown in Figure 69. Watershed stakeholder should try to restore wetland acreage so that the percentage of the Ridinger Lake watershed covered by wetlands equals or exceeds the percentage of land in the greater Upper Tippecanoe River basin that is covered by wetlands.

3. Restrict the direct access of livestock to watershed streams. Reconstruct/stabilize banks where damage from livestock trampling and grazing has occurred. Target areas listed above in the *Specific Recommendations* and those shown on Figure 73 first. Prioritize work in the Shanton Ditch and Elder Ditch subwatersheds over work in other areas.

4. Utilize the conservation reserve program to implement grassed waterways and remove land mapped in highly erodible soils from agricultural production. Target areas shown in Figure 68 first. Higher priority should also be given to land in the headwaters of the Shanton Ditch and Elder Ditch subwatersheds.

5. Monitor and improve erosion control techniques on residential and commercial development sites. Bring areas of concerns to appropriate authorities. Management efforts should focus on areas listed in Figure 73 where the active construction sites exist and lack of erosion control techniques were observed.

6. Increase the usage of no-till conservation tillage on corn fields in the Whitley County portion of the watershed and on both soybean and corn fields in the Kosciusko County portion of the watershed.

7. Plant vegetative filter areas around unprotected risers shown in Figure 67.
8. Post informational signage at the boat launches on each of the lakes to inform lake users of best management practices to prevent the spread of aquatic nuisance species, particularly Eurasian water milfoil.

9. Implement individual property owner management techniques. These apply to all watershed property owners rather than simply those who live adjacent to Ridinger and Troy Cedar Lakes.

- a. Reduce the frequency and amount of fertilizer and herbicide/pesticide used for lawn care.
- b. Use only phosphorus-free fertilizer. (This means that the middle number on the fertilizer package listing the nutrient ratio, nitrogen:phosphorus:potassium is 0.)
- c. Consider re-landscaping lawn edges, particularly those along the watershed's lakes and streams, to include low profile prairie species that are capable of filtering runoff water better than turf grass.
- d. Consider planting native emergent vegetation along shorelines or in front of existing seawalls to provide fish and invertebrate habitat and dampen wave energy.
- e. Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
- f. Properly maintain septic systems. Systems should be pumped regularly and leach fields should be properly cared for.
- g. Examine all drains that lead from roads, driveways, or rooftops to the watershed's lakes and/or streams; consider alternate routes for these drains that would filter pollutants before they reach the water.
- h. Obey no-wake zones.
- i. Clean boat propellers after lake use and refrain from dumping bait buckets into the lake to prevent the spread of exotic species.

Additional Considerations
1. Work with the Kosciusko and Whitley County Drainage Boards to balance drainage needs with the benefits provided by healthy riparian zones.

2. Implement watershed restoration techniques within the framework established in the Upper Tippecanoe River Watershed Management Plan.

3. Become an active volunteer in the Indiana Clean Lakes Program volunteer monitoring program. The three study lakes currently lack volunteers. Volunteer monitoring is easy and does not take much time. The CLP staff provides the training and equipment needed to participate in the program. The data collected by the volunteer monitor will be extremely useful

in tracking long-term trends in the lake water quality and measuring the success of any restoration measures implemented in the watershed.

4. In the future, consider installation of a sewer system or alternate waste water treatment system around the Ridinger and Troy Cedar Lakes.

5. Continue implementation of recommendations made in previous watershed studies.

6. Following implementation of several watershed management techniques, re-assess the lakes and determine whether in-lake management should be considered.

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APPENDICES

APPENDIX A:

GEOGRAPHIC INFORMATION SYSTEMS (GIS)
MAP DATA SOURCES

Appendix A. Geographic Information Systems (GIS) map data sources.

Figure 2. The Ridinger Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 3. Topographical relief of the Ridinger, Robinson, Troy Cedar Lakes watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Relief coverage is the U.S. Geological Survey National Elevation Data set.

Figure 4. Ridinger Lake subwatersheds.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Watershed boundaries were delineated based using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI.

Figure 5. Robinson Lake subwatersheds.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Watershed boundaries were delineated based using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI.

Figure 6. Troy Cedar Lake subwatersheds.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Watershed boundaries were delineated based using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI.

Figure 7. The major soil associations covering the Ridinger Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Soil associations digitized from McCarter, 1977 and Reusch, 1990.

Figure 11. Land use in the Ridinger Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Land use comes from the USGS Indiana Land Cover Data Set. The data set was corrected based on field investigations conducted in 2002.

Figure 12. Wetlands in the Ridinger Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Wetland location source is U.S. Fish and Wildlife Service National Wetland Inventory GIS coverage.

Figure 13. Stream sampling sites.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 65. Locations in the Ridinger Lake watershed where riparian restoration or filter strip installation/widening is recommended.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 66. Locations in the Ridinger Lake watershed where grassed waterway installation or set-aside in the Conservation Reserve Program is recommended.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 67. Locations in the Ridinger Lake watershed where wetland restoration is recommended.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 69. Locations in the Ridinger Lake watershed where livestock exclusion fencing and stream bank/channel stabilization are recommended.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 70. Locations in the Ridinger Lake watershed where implementation of special or multiple phase projects is recommended.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

APPENDIX B:

DETAILED SUBWATERSHED LAND USE DATA

Appendix B. Subwatershed land use in the Ridinger Lake watershed.

Land Use	Shanton Ditch Subwatershed	Mathias Ditch Subwatershed	Elder Ditch Subwatershed	Immediate Ridinger Lake Subwatershed	Watershed
Deciduous Forest	598.7*	620.8	1,016.6	396.4	2,632.5
Evergreen Forest	3.2	1.3	1.3	1.1	7.0
Mixed Forest	0.4	0.2	0.0	0.4	1.1
High Intensity Residential	10.7	0.0	0.0	0.0	10.7
High Intensity Commercial	9.6	0.2	0.0	10.1	19.9
Low Intensity Residential	110.1	10.3	2.5	98.5	221.5
Emergent Herbaceous Wetlands	35.9	16.6	58.1	9.2	119.9
Woody Wetlands	102.3	195.7	339.2	54.6	691.9
Open Water	18.3	84.5	156.9	138.4	398.1
Pasture/Hay	907.4	523.7	1,719.7	243.3	3,394.1
Row Crops	3,464.0	3,129.9	6,907.6	1,182.0	14,683.6
Total	**5,260.9**	**4,583.4**	**10,202.0**	**2,134.1**	**22,180.3**

*All areas are in acres.

Robinson Lake watershed.

Land Use	Mathias Ditch Subwatershed	Western Inlet Subwatershed	Immediate Robinson Lake Subwatershed	Watershed
Deciduous Forest	391.2*	112.6	33.1	537.0
Mixed Forest	0.2	0.0	0.0	0.2
Evergreen Forest	0.2	0.4	0.0	0.7
High Intensity Commercial	0.2	0.0	0.0	0.2
Low Intensity Residential	9.7	0.0	0.2	9.9
Pasture/Hay	271.3	215.9	19.6	506.8
Row Crops	1909.9	1156.6	18.2	3,084.7
Open Water	20.9	2.0	57.7	80.6
Emergent Herbaceous Wetlands	10.9	4.3	0.0	15.2
Woody Wetlands	109.0	27.1	22.9	159.0
Total	**2723.7**	**1519.0**	**151.6**	**4,394.3**

*All areas are in acres.

Troy Cedar Lake watershed.

Land Use	Northern Inlet Subwatershed	Southern Inlet Subwatershed	Immediate Troy Cedar Lake Subwatershed	Watershed
Deciduous Forest	192.6*	53.0	27.2	272.8
Evergreen Forest	0.0	0.2	0.4	0.7
Low Intensity Residential	0.0		1.7	1.7
Pasture/Hay	180.8	55.5	75.2	311.6
Row Crops	1,265.9	605.1	303.2	2,174.2
Open Water	33.3	7.5	98.1	138.9
Emergent Herbaceous Wetlands	23.3	3.1	5.8	32.2
Woody Wetlands	184.2	12.1	19.2	215.5
Total	**1,880.0**	**736.4**	**530.9**	**3,147.4**

*All areas are in acres.

APPENDIX C:

ENDANGERED, THREATENED, AND RARE SPECIES LIST, RIDINGER LAKE WATERSHED

January 28, 2003

ENDANGERED, THREATENED AND RARE SPECIES,
HIGH QUALITY NATURAL COMMUNITIES, AND SIGNIFICANT NATURAL AREAS DOCUMENTED FROM THE
ROBINSON-RIDINGER-TROY CEDAR LAKES WATERSHED, KOSCIUSKO AND WHITLEY COUNTIES, INDIANA

TYPE	SPECIES NAME	COMMON NAME	STATE	FED	LOCATION	DATE	COMMENTS
LORANE							
Vascular Plant	ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	T32NR08E 12	1920	
Vascular Plant	CAREX ATLANTICA SSP ATLANTICA	ATLANTIC SEDGE	ST	**	T32NR08E 12	1917	
Vascular Plant	CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	T32NR08E 12	1917	
Vascular Plant	CAREX LIMOSA	MUD SEDGE	SE	**	T32NR08E 12	1917	
Vascular Plant	ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	T32NR08E 12	1917	
Vascular Plant	POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	T32NR08E 12	NO D	
NORTH WEBSTER							
Vascular Plant	POTAMOGETON EPIHYDRUS	NUTTALL PONDWEED	SE	**	T32NR07E 01	1962	
PIERCETON							
Bird	ARDEA HERODIAS	GREAT BLUE HERON	**	**	T32NR08E 18 NEQ SEQ SWQ	1990	
Mammal	LYNX RUFUS	BOBCAT	SE	**	T32NR08E 18	1990	
Vascular Plant	CAREX ALOPECOIDEA	FOXTAIL SEDGE	SE	**	T32NR08E 18	1985	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX D:

ENDANGERED, THREATENED, AND RARE SPECIES LIST, KOSCIUSKO AND WHITLEY COUNTIES, INDIANA

November 12, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ACTAEA RUBRA	RED BANEBERRY	SR	**	S2	G5
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARETHUSA BULBOSA	SWAMP-PINK	SX	**	SX	G4
ASTER BOREALIS	RUSHLIKE ASTER	SR	**	S2	G5
BIDENS BECKII	BECK WATER-MARIGOLD	SE	**	S1	G4G5T4
CAREX AUREA	GOLDEN-FRUITED SEDGE	SR	**	S2	G5
CAREX BEBBII	BEBB'S SEDGE	ST	**	S2	G5
CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	S1	G5
CAREX DISPERMA	SOFTLEAF SEDGE	SE	**	S1	G5
CAREX ECHINATA	LITTLE PRICKLY SEDGE	SE	**	S1	G5
CAREX FLAVA	YELLOW SEDGE	ST	**	S2	G5
CAREX PSEUDOCYPERUS	CYPERUS-LIKE SEDGE	SE	**	S1	G5
CORNUS AMOMUM SSP AMOMUM	SILKY DOGWOOD	SE	**	S1	G5T?
CORNUS CANADENSIS	BUNCHBERRY	SE	**	S1	G5
CYPRIPEDIUM CALCEOLUS VAR PARVIFLORUM	SMALL YELLOW LADY'S-SLIPPER	SR	**	S2	G5
CYPRIPEDIUM CANDIDUM	SMALL WHITE LADY'S-SLIPPER	SR	**	S2	G4
DROSERA INTERMEDIA	SPOON-LEAVED SUNDEW	SR	**	S2	G5
ELEOCHARIS GENICULATA	CAPITATE SPIKE-RUSH	ST	**	S2	G5
ERIOPHORUM ANGUSTIFOLIUM	NARROW-LEAVED COTTON-GRASS	SR	**	S2	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
ERIOPHORUM VIRIDICARINATUM	GREEN-KEELED COTTON-GRASS	SR	**	S2	G5
GERANIUM ROBERTIANUM	HERB-ROBERT	ST	**	S2	G5
JUGLANS CINEREA	BUTTERNUT	WL	**	S3	G3G4
LATHYRUS OCHROLEUCUS	PALE VETCHLING PEAVINE	SE	**	S1	G4G5
LEMNA PERPUSILLA	MINUTE DUCKWEED	SX	**	SX	G5
MALAXIS UNIFOLIA	GREEN ADDER'S-MOUTH	SE	**	S1	G5
MATTEUCCIA STRUTHIOPTERIS	OSTRICH FERN	SR	**	S2	G5
MYRIOPHYLLUM VERTICILLATUM	WHORLED WATER-MILFOIL	ST	**	S2	G5
PANICUM BOREALE	NORTHERN WITCHGRASS	SR	**	S2	G5
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
POTAMOGETON EPIHYDRUS	NUTTALL PONDWEED	SE	**	S1	G5
POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	S1	G4
POTAMOGETON OAKESIANUS	OAKES PONDWEED	SE	**	S1	G4
POTAMOGETON RICHARDSONII	REDHEADGRASS	ST	**	S2	G5
POTAMOGETON STRICTIFOLIUS	STRAIGHT-LEAF PONDWEED	SE	**	S1	G5
PRUNUS PENSYLVANICA	FIRE CHERRY	SR	**	S2	G5
SCIRPUS SUBTERMINALIS	WATER BULRUSH	SR	**	S2	G4G5
SELAGINELLA APODA	MEADOW SPIKE-MOSS	SE	**	S1	G5
SPARGANIUM ANDROCLADUM	BRANCHING BUR-REED	ST	**	S2	G4G5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
STENANTHIUM GRAMINEUM	EASTERN FEATHERBELLS	SE	**	S1	G4G5
TOFIELDIA GLUTINOSA	FALSE ASPHODEL	SR	**	S2	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 12, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4
VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	S2	G5
WOLFFIELLA FLORIDANA	SWORD BOGMAT	SX	**	SX	G5
ZANNICHELLIA PALUSTRIS	HORNED PONDWEED	SE	**	S1	G5
ZIGADENUS ELEGANS VAR GLAUCUS	WHITE CAMAS	SR	**	S2	G5T4T5
MOLLUSCA: BIVALVIA (MUSSELS)					
ALASMIDONTA VIRIDIS	SLIPPERSHELL MUSSEL	**	**	S2	G4G5
EPIOBLASMA OBLIQUATA PEROBLIQUA	WHITE CAT'S PAW PEARLYMUSSEL	SE	LE	S1	G1T1
EPIOBLASMA TORULOSA RANGIANA	NORTHERN RIFFLESHELL	SE	LE	S1	G2T2
LAMPSILIS FASCIOLA	WAVY-RAYED LAMPMUSSEL	SSC	**	S2	G4
LAMPSILIS OVATA	POCKETBOOK	**	**	S2	G5
LIGUMIA RECTA	BLACK SANDSHELL	**	**	S2	G5
PLEUROBEMA CLAVA	CLUBSHELL	SE	LE	S1	G2
PTYCHOBRANCHUS FASCIOLARIS	KIDNEYSHELL	SSC	**	S2	G4G5
QUADRULA CYLINDRICA CYLINDRICA	RABBITSFOOT	SE	**	S1	G3T3
TOXOLASMA LIVIDUS	PURPLE LILLIPUT	SSC	**	S2	G2
TOXOLASMA PARVUM	LILLIPUT	**	**	S2	G5
VILLOSA FABALIS	RAYED BEAN	SSC	**	S1	G1G2
VILLOSA LIENOSA	LITTLE SPECTACLECASE	SSC	**	S2	G5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
EUPHYDRYAS PHAETON	BALTIMORE	**	**	S2S4	G4
EUPHYES BIMACULA	TWO-SPOTTED SKIPPER	SR	**	S2	G4
EURISTRYMON ONTARIO	NORTHERN HAIRSTREAK	WL	**	S2S4	G4
HESPERIA LEONARDUS	LEONARDUS SKIPPER	SR	**	S2	G4
LYCAENA HELLOIDES	PURPLISH COPPER	**	**	S2S4	G5
PIERIS OLERACEA	VEINED WHITE	SE	**	S1	G5T4
ARTHROPODA: INSECTA: LEPIDOPTERA (MOTHS)					
HEMILEUCA SP 3	MIDWESTERN FEN BUCKMOTH	**	**	S1?	G3G4
LYTROSIS PERMAGNARIA	A LYTROSIS MOTH	ST	**	S2	GU
FISH					
ACIPENSER FULVESCENS	LAKE STURGEON	SE	**	S1	G3
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
HYBOPSIS AMBLOPS	BIGEYE CHUB	**	**	S2	G5
NOTROPIS HETEROLEPIS	BLACKNOSE SHINER	**	**	S2	G5
PERCINA EVIDES	GILT DARTER	SE	**	S1	G4
AMPHIBIANS					
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
HEMIDACTYLIUM SCUTATUM	FOUR-TOED SALAMANDER	SE	**	S2	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
NECTURUS MACULOSUS	MUDPUPPY	SSC	**	S2	G5
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
NERODIA ERYTHROGASTER NEGLECTA	COPPERBELLY WATER SNAKE	SE	**	S2	G5T2T3
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
BOTAURUS LENTIGINOSUS	AMERICAN BITTERN	SE	**	S2B	G4
CHLIDONIAS NIGER	BLACK TERN	SE	**	S1B,SZN	G4
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
CISTOTHORUS PLATENSIS	SEDGE WREN	SE	**	S3B,SZN	G5
DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S3B	G4
FALCO PEREGRINUS	PEREGRINE FALCON	SE	E(S/A)	S2B,SZN	G4
GRUS CANADENSIS	SANDHILL CRANE	SE	**	S2B,S1N	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
MNIOTILTA VARIA	BLACK-AND-WHITE WARBLER	SSC	**	S1S2B	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
RALLUS ELEGANS	KING RAIL	SE	**	S1B,SZN	G4G5
RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S3B,SZN	G5
VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER	SE	**	S1B	G4
MAMMALS					
CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
WETLAND - BEACH MARL	MARL BEACH	SG	**	S2	G3
WETLAND - BOG ACID	ACID BOG	SG	**	S2	G3
WETLAND - BOG CIRCUMNEUTRAL	CIRCUMNEUTRAL BOG	SG	**	S3	G3
WETLAND - FEN	FEN	SG	**	S3	G3

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
WETLAND - FEN FORESTED	FORESTED FEN	SG	**	S1	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?
WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	S2	GU

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM WHITLEY COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
BIDENS BECKII	BECK WATER-MARIGOLD	SE	**	S1	G4G5T4
CAREX ALOPECOIDEA	FOXTAIL SEDGE	SE	**	S1	G5
CAREX ATLANTICA SSP ATLANTICA	ATLANTIC SEDGE	ST	**	S2	G5T4
CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	S1	G5
CAREX LIMOSA	MUD SEDGE	SE	**	S1	G5
COELOGLOSSUM VIRIDE VAR VIRESCENS	LONG-BRACT GREEN ORCHIS	ST	**	S2	G5T5
ELEOCHARIS EQUISETOIDES	HORSE-TAIL SPIKERUSH	SE	**	S1	G4
ERIOCAULON AQUATICUM	PIPEWORT	SE	**	S1	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
PHLOX OVATA	MOUNTAIN PHLOX	SE	**	S1	G4
PLANTAGO CORDATA	HEART-LEAVED PLANTAIN	SE	**	S1	G4
POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	S1	G4
POTAMOGETON PRAELONGUS	WHITE-STEM PONDWEED	SE	**	S1	G5
POTAMOGETON RICHARDSONII	REDHEADGRASS	ST	**	S2	G5
POTAMOGETON ROBBINSII	FLATLEAF PONDWEED	ST	**	S2	G5
POTAMOGETON STRICTIFOLIUS	STRAIGHT-LEAF PONDWEED	SE	**	S1	G5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
UTRICULARIA MINOR	LESSER BLADDERWORT	SE	**	S1	G5
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4
MOLLUSCA: GASTROPODA					
CAMPELOMA DECISUM	POINTED CAMPELOMA	SSC	**	S2	G5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
POANES VIATOR VIATOR	BIG BROAD-WINGED SKIPPER	SR	**	S2	G5T4
FISH					
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
AMPHIBIANS					
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	SE	**	S3B,SZN	G5
STURNELLA NEGLECTA	WESTERN MEADOWLARK	SSC	**	S2B	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM WHITLEY COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
MAMMALS					
LYNX RUFUS	BOBCAT	SE	**	S1	G5
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
WETLAND - FEN	FEN	SG	**	S3	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX E:

MACROINVERTEBRATE FAMILIES LIST FOR THE RIDINGER LAKE WATERSHED STREAMS

Appendix E. Number and type of macroinvertebrates found in Ridinger Lake watershed streams.

Order	Family	Shanton Ditch (Site 2)	Robinson Lake outlet (Site 3)	Elder Ditch (Site 4)	Doke Ditch (Site 5)	Mathias Ditch (Site 6)
Amphipoda	Talitridae	2	16	2	2	
Bivalvia	Corbiculidae	1				
Coleoptera	Dytiscidae	1	3			1
Coleoptera	Elmidae	2		7	4	5
Coleoptera	Haliplidae				2	1
Crustacea	Cambaridae				1	
Diptera	Chironomidae	18	14	29	7	33
Diptera	Dixidae				1	
Diptera	Simuliidae		4			23
Diptera	Tabanidae				2	
Ephemeroptera	Baetidae		5	11	3	16
Ephemeroptera	Caenidae		2	1		
Ephemeroptera	Heptageniidae	5	1	2		1
Gastropoda	Ancylidae				13	
Gastropoda	Hydrobidae				8	
Gastropoda	Planorbidae				7	
Hempitera	Belostomatidae		2			
Hempitera	Corixidae	2			10	
Hempitera	Gerridae		1	17	8	4
Hempitera	Mesoveliidae		1			
Hemiptera	Pleidae		2			1
Hempitera	Veliidae	5			1	2
Hirudinea	Glossiphoniidae			1	6	1
Isopoda	Asellidae	13	33	44	1	
Megaloptera	Corydalidae	1				
Megaloptera	Sialidae	3			8	
Odonata	Aeshnidae			2	4	1
Odonata	Calopterygidae	1	1			1
Odonata	Coenagrionidae	4	1	1		
Odonata	Corduliidae				1	
Platyhelminthes	Planaria		3	1		
Trichoptera	Hydropsychidae	58	10	8	10	12
Trichoptera	Lepidostomatidae				1	
Trichoptera	Philopotamidae		1	1		
Trichoptera	Polycentropodidae			1		
Number of individuals		**116**	**100**	**128**	**100**	**102**
Number of taxa		**14**	**17**	**15**	**21**	**14**

APPENDIX F:

QUALITATIVE HABITAT EVALUATION INDEX (QHEI) DATA SHEETS FOR RIDINGER LAKE WATERSHED STREAMS

STREAM: Ridinger Lake outlet (Site 1) **RIVER MILE:** ______ **DATE:** 8/13/2003 **QHEI SCORE** 53

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) — SUBSTRATE SCORE 12

TYPE			POOL	RIFFLE			TYPE	POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[x]	[ ]	GRAVEL(7)	x	
[ ]	[ ]	BOULDER(9)			[x]	[ ]	SAND(6)	x	
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)	x		[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all)
- [ ] LIMESTONE(1)
- [x] TILLS(1)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)
- [ ] RIP/RAP(0)
- [ ] HARDPAN(0)

SILT COVER (one)
- [ ] SILT-HEAVY(-2)
- [x] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)
- [x] EXTENSIVE(-2)
- [x] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: — COVER SCORE 8

TYPE (Check all that apply)
- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [x] DEEP POOLS(2)
- [ ] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [x] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) — CHANNEL SCORE 7.5

SINUOSITY
- [ ] HIGH(4)
- [ ] MODERATE(3)
- [x] LOW(2)
- [ ] NONE(1)

DEVELOPMENT
- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [ ] FAIR(3)
- [x] POOR(1)

CHANNELIZATION
- [ ] NONE(6)
- [ ] RECOVERED(4)
- [x] RECOVERING(3)
- [ ] RECENT OR NO RECOVERY(1)

STABILITY
- [ ] HIGH(3)
- [x] MODERATE(2)
- [x] LOW(1)

MODIFICATION/OTHER
- [ ] SNAGGING
- [ ] RELOCATION
- [ ] CANOPY REMOVAL
- [ ] DREDGING
- [ ] ONE SIDE CHANNEL MODIFICATION
- [ ] IMPOUND
- [ ] ISLAND
- [ ] LEVEED
- [x] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) — RIPARIAN SCORE 7.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
x	x	WIDE >150 ft.(4)
		MODERATE 30-150 ft.(3)
		NARROW 15-30 ft.(2)
		VERY NARROW 3-15 ft.(1)
		NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
x		FOREST, SWAMP(3)			URBAN OR INDUSTRIAL(0)
	x	OPEN PASTURE/ROW CROP(0)			SHRUB OR OLD FIELD(2)
		RESID.,PARK,NEW FIELD(1)			CONSERV. TILLAGE(1)
		FENCED PASTURE(1)			MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
		NONE OR LITTLE(3)
x	x	MODERATE(2)
		HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY — NO POOL = 0 — POOL SCORE 8

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [x] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [x] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1)
- [ ] FAST(1)
- [x] MODERATE(1)
- [x] SLOW(1)
- [x] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH
- GENERALLY >4 in. MAX.>20 in.(4)
- [ ] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [x] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [ ] UNSTABLE (Gravel, Sand)(0)
- [x] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [ ] EXTENSIVE(-1)
- [x] MODERATE(0)
- [ ] LOW(1)
- [ ] NONE(2)
- [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 7.89 — % POOL ____ — % RIFFLE ____ — % RUN 100 — GRADIENT SCORE 10

STREAM: Shanton Ditch (Site 2) **RIVER MILE:** ______ **DATE:** 8/13/2003 **QHEI SCORE** 44

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 6

TYPE			POOL	RIFFLE				POOL	RIFFLE
		BLDER/SLAB(10)				x	GRAVEL(7)	x	
		BOULDER(9)					SAND(6)		
		COBBLE(8)	x				BEDROCK(5)		
		HARDPAN(4)					DETRITUS(3)		
x		MUCK/SILT(2)	x				ARTIFIC(0)		

SUBSTRATE ORIGIN (all)

	LIMESTONE(1)		RIP/RAP(0)
x	TILLS(1)		HARDPAN(0)
	SANDSTONE(0)		
	SHALE(-1)		
	COAL FINES(-2)		

SILT COVER (one)

x	SILT-HEAVY(-2)		SILT-MOD(-1)
	SILT-NORM(0)		SILT-FREE(1)

Extent of Embeddedness (check one)

x	EXTENSIVE(-2)		MODERATE(-1)
	LOW(0)		NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 11

TYPE (Check all that apply)

	UNDERCUT BANKS(1)	X	DEEP POOLS(2)		OXBOWS(1)
x	OVERHANGING VEGETATION(1)		ROOTWADS(1)		AQUATIC MACROPHYTES(1)
	SHALLOWS (IN SLOW WATER)(1)		BOULDERS(1)	X	LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

	EXTENSIVE >75%(11)
X	MODERATE 25-75%(7)
	SPARSE 5-25%(3)
	NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 9

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
[ ] HIGH(4)	[ ] EXCELLENT(7)	[ ] NONE(6)	[ ] HIGH(3)
[ ] MODERATE(3)	[ ] GOOD(5)	[X] RECOVERED(4)	[X] MODERATE(2)
[x] LOW(2)	[ ] FAIR(3)	[ ] RECOVERING(3)	[ ] LOW(1)
[ ] NONE(1)	[X] POOR(1)	[ ] RECENT OR NO RECOVERY(1)	

MODIFICATION/OTHER

[ ] SNAGGING	[ ] IMPOUND
[ ] RELOCATION	[ ] ISLAND
[ ] CANOPY REMOVAL	[ ] LEVEED
[ ] DREDGING	[ ] BANK SHAPING
[X] ONE SIDE CHANNEL MODIFICATION	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 5.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
		WIDE >150 ft.(4)
		MODERATE 30-150 ft.(3)
x	X	NARROW 15-30 ft.(2)
		VERY NARROW 3-15 ft.(1)
		NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
		FOREST, SWAMP(3)			URBAN OR INDUSTRIAL(0)
		OPEN PASTURE/ROW CROP(0)		X	SHRUB OR OLD FIELD(2)
X		RESID.,PARK,NEW FIELD(1)			CONSERV. TILLAGE(1)
		FENCED PASTURE(1)			MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
		NONE OR LITTLE(3)
X	X	MODERATE(2)
		HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 6

MAX.DEPTH (Check 1)

	>4 ft.(6)
x	2.4-4 ft.(4)
	1.2-2.4 ft.(2)
	<1.2 ft.(1)
	<0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)

	POOL WIDTH>RIFFLE WIDTH(2)
X	POOL WIDTH=RIFFLE WIDTH(1)
	POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)

	TORRENTIAL(-1)		EDDIES(1)
	FAST(1)		INTERSTITIAL(-1)
	MODERATE(1)		INTERMITTENT(-2)
X	SLOW(1)		

COMMENTS:

RIFFLE SCORE 2

RIFFLE/RUN DEPTH

	GENERALLY >4 in. MAX.>20 in.(4)
x	GENERALLY >4 in. MAX.<20 in.(3)
	GENERALLY 2-4 in.(1)
	GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE

	STABLE (e.g., Cobble,Boulder)(2)
	MOD.STABLE (e.g., Pea Gravel)(1)
X	UNSTABLE (Gravel, Sand)(0)
	NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS

X	EXTENSIVE(-1)		NONE(2)
	MODERATE(0)		NO RIFFLE(0)
	LOW(1)		

COMMENTS:

6) GRADIENT (FEET/MILE): 4.22

% POOL 10 % RIFFLE 5 % RUN 85 **GRADIENT SCORE** 4

STREAM: Robinson Lake outlet (Site 3) **RIVER MILE:** ______ **DATE:** 8/13/2003 **QHEI SCORE** 47

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 11

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)	x	x
[ ]	[ ]	BOULDER(9)			x	x	SAND(6)	x	x
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)	x		[ ]	[ ]	ARTIFIC(0)		x

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [x] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [x] SILT-MOD(-1) [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [x] EXTENSIVE(-2) [x] MODERATE(-1) [ ] LOW(0) [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: **COVER SCORE** 11

TYPE (Check all that apply)

- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [x] SHALLOWS (IN SLOW WATER)(1)
- [x] DEEP POOLS(2)
- [ ] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [ ] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [x] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 8.5

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [x] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [ ] FAIR(3) [x] POOR(1)

CHANNELIZATION: [x] NONE(6) [ ] RECOVERED(4) [x] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [ ] MODERATE(2) [x] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [x] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 4.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
x	x	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	x	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
x	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
x	x	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 7

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [x] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [ ] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [x] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [x] MODERATE(1) [x] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 3

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [x] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [x] UNSTABLE (Gravel, Sand)(0) [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [x] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 0.88 **% POOL** 15 **% RIFFLE** 5 **% RUN** 80 **GRADIENT SCORE** 2

STREAM: Elder Ditch (Site 4) **RIVER MILE:** ______ **DATE:** 8/13/2003 **QHEI SCORE** 30

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 5

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		x
[ ]	[ ]	BOULDER(9)			[x]	[ ]	SAND(6)	x	
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[x]	[ ]	MUCK/SILT(2)	x		[ ]	[ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all)

- [ ] LIMESTONE(1)
- [ ] RIP/RAP(0)
- [x] TILLS(1)
- [ ] HARDPAN(0)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)

SILT COVER (one)

- [x] SILT-HEAVY(-2)
- [ ] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)

- [x] EXTENSIVE(-2)
- [ ] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: recently cleared stream banks of all wooded vegetation

2) INSTREAM COVER:

COVER SCORE 4

TYPE (Check all that apply)

- [ ] UNDERCUT BANKS(1)
- [ ] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [x] DEEP POOLS(2)
- [ ] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [x] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 5

SINUOSITY

- [ ] HIGH(4)
- [ ] MODERATE(3)
- [x] LOW(2)
- [ ] NONE(1)

DEVELOPMENT

- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [ ] FAIR(3)
- [x] POOR(1)

CHANNELIZATION

- [ ] NONE(6)
- [ ] RECOVERED(4)
- [ ] RECOVERING(3)
- [x] RECENT OR NO RECOVERY(1)

STABILITY

- [ ] HIGH(3)
- [ ] MODERATE(2)
- [x] LOW(1)

MODIFICATION/OTHER

- [ ] SNAGGING
- [ ] RELOCATION
- [x] CANOPY REMOVAL
- [ ] DREDGING
- [x] ONE SIDE CHANNEL MODIFICATION
- [ ] IMPOUND
- [ ] ISLAND
- [ ] LEVEED
- [x] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 2.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[x]	[ ]	NARROW 15-30 ft.(2)
[ ]	[x]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[x]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[x]	[x]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 7

MAX.DEPTH (Check 1)

- [ ] >4 ft.(6)
- [x] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)

- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [x] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)

- [ ] TORRENTIAL(-1)
- [ ] FAST(1)
- [x] MODERATE(1)
- [x] SLOW(1)
- [ ] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH

- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [ ] GENERALLY >4 in. MAX.<20 in.(3)
- [x] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE

- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [x] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS

- [x] EXTENSIVE(-1)
- [ ] MODERATE(0)
- [ ] LOW(1)
- [ ] NONE(2)
- [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 5.75

% POOL 10 % RIFFLE 5 % RUN 85 **GRADIENT SCORE** 6

STREAM: Doke Ditch (Site 5) **RIVER MILE:** ______ **DATE:** 8/13/2003 **QHEI SCORE** 54

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 12

TYPE	POOL	RIFFLE
[ ] [ ] BLDER/SLAB(10)		
[ ] [ ] BOULDER(9)		
[ ] [ ] COBBLE(8)	x	x
[ ] [ ] HARDPAN(4)		
[ ] [ ] MUCK/SILT(2)	x	
[x] [ ] GRAVEL(7)		x
[x] [ ] SAND(6)		x
[ ] [ ] BEDROCK(5)		
[ ] [ ] DETRITUS(3)		
[ ] [ ] ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [x] TILLS(1) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2) [ ] RIP/RAP(0) [ ] HARDPAN(0)

SILT COVER (one): [ ] SILT-HEAVY(-2) [ ] SILT-NORM(0) [x] SILT-MOD(-1) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] LOW(0) [x] MODERATE(-1) [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 10

TYPE (Check all that apply)

- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [x] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [ ] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [ ] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [x] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 13

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [x] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [x] FAIR(3) [ ] POOR(1)

CHANNELIZATION: [x] NONE(6) [ ] RECOVERED(4) [ ] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [x] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 9

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	
x	x	WIDE >150 ft.(4)
		MODERATE 30-150 ft.(3)
		NARROW 15-30 ft.(2)
		VERY NARROW 3-15 ft.(1)
		NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY (most predominant per bank)

L	R	
x	x	FOREST, SWAMP(3)
		OPEN PASTURE/ROW CROP(0)
		RESID.,PARK,NEW FIELD(1)
		FENCED PASTURE(1)
		URBAN OR INDUSTRIAL(0)
		SHRUB OR OLD FIELD(2)
		CONSERV. TILLAGE(1)
		MINING/CONSTRUCTION(0)

BANK EROSION (per bank)

L	R	
		NONE OR LITTLE(3)
x	x	MODERATE(2)
		HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 3

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [x] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [ ] POOL WIDTH=RIFFLE WIDTH(1) [x] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [x] MODERATE(1) [x] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 1

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [x] GENERALLY 2-4 in.(1) [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [x] UNSTABLE (Gravel, Sand)(0) [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [x] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.32

% POOL ____ % RIFFLE ____ % RUN ____ **GRADIENT SCORE** 6

STREAM: Mathias Ditch (Site 6) **RIVER MILE:** ______ **DATE:** 8/13/2003 **QHEI SCORE** 61

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 12

TYPE			POOL	RIFFLE	TYPE			POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[x]	[ ]	GRAVEL(7)		x
[ ]	[ ]	BOULDER(9)			[x]	[ ]	SAND(6)		x
[ ]	[ ]	COBBLE(8)		x	[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)			[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

SUBSTRATE ORIGIN (all)
- [ ] LIMESTONE(1)
- [x] TILLS(1)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)
- [ ] RIP/RAP(0)
- [ ] HARDPAN(0)

SILT COVER (one)
- [ ] SILT-HEAVY(-2)
- [x] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)
- [ ] EXTENSIVE(-2)
- [x] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

COMMENTS: ______

2) INSTREAM COVER:

COVER SCORE 13

TYPE (Check all that apply)
- [x] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [x] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [x] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [x] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS: ______

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 16

SINUOSITY
- [ ] HIGH(4)
- [x] MODERATE(3)
- [ ] LOW(2)
- [ ] NONE(1)

DEVELOPMENT
- [ ] EXCELLENT(7)
- [x] GOOD(5)
- [ ] FAIR(3)
- [ ] POOR(1)

CHANNELIZATION
- [x] NONE(6)
- [ ] RECOVERED(4)
- [ ] RECOVERING(3)
- [ ] RECENT OR NO RECOVERY(1)

STABILITY
- [ ] HIGH(3)
- [x] MODERATE(2)
- [ ] LOW(1)

MODIFICATION/OTHER
- [ ] SNAGGING
- [ ] RELOCATION
- [ ] CANOPY REMOVAL
- [ ] DREDGING
- [ ] ONE SIDE CHANNEL MODIFICATION
- [ ] IMPOUND
- [ ] ISLAND
- [ ] LEVEED
- [ ] BANK SHAPING

COMMENTS: ______

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 7

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[x]	WIDE >150 ft.(4)
[x]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[x]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[x]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[ ]	[x]	MODERATE(2)
[x]	[ ]	HEAVY OR SEVERE(1)

COMMENTS: ______

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 6

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [ ] 2.4-4 ft.(4)
- [x] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [x] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1)
- [x] FAST(1)
- [x] MODERATE(1)
- [x] SLOW(1)
- [ ] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS: ______

RIFFLE SCORE 3

RIFFLE/RUN DEPTH
- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [ ] GENERALLY >4 in. MAX.<20 in.(3)
- [x] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [x] MOD.STABLE (e.g., Pea Gravel)(1)
- [ ] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [ ] EXTENSIVE(-1)
- [x] MODERATE(0)
- [x] LOW(1)
- [ ] NONE(2)
- [ ] NO RIFFLE(0)

COMMENTS: ______

6) GRADIENT (FEET/MILE): 4.32

% POOL ______ % RIFFLE ______ % RUN ______ **GRADIENT SCORE** 4

STREAM: Troy Cedar Lake inlet (Site 7) **RIVER MILE:** ______ **DATE:** 8/13/2003 **QHEI SCORE** 19

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 1

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[ ]	[ ]	SAND(6)		
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[x]	[x]	MUCK/SILT(2)			[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all):
- [ ] LIMESTONE(1)
- [x] TILLS(1)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)
- [ ] RIP/RAP(0)
- [ ] HARDPAN(0)

SILT COVER (one):
- [x] SILT-HEAVY(-2)
- [ ] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one):
- [x] EXTENSIVE(-2)
- [ ] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: **COVER SCORE** 5

TYPE (Check all that apply)
- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [ ] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [X] AQUATIC MACROPHYTES(1)
- [ ] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [X] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 4

SINUOSITY
- [ ] HIGH(4)
- [ ] MODERATE(3)
- [ ] LOW(2)
- [x] NONE(1)

DEVELOPMENT
- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [ ] FAIR(3)
- [X] POOR(1)

CHANNELIZATION
- [ ] NONE(6)
- [ ] RECOVERED(4)
- [ ] RECOVERING(3)
- [X] RECENT OR NO RECOVERY(1)

STABILITY
- [ ] HIGH(3)
- [ ] MODERATE(2)
- [X] LOW(1)

MODIFICATION/OTHER
- [ ] SNAGGING
- [ ] RELOCATION
- [X] CANOPY REMOVAL
- [ ] DREDGING
- [X] ONE SIDE CHANNEL MODIFICATION
- [ ] IMPOUND
- [ ] ISLAND
- [ ] LEVEED
- [X] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 5.3

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[x]	[X]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[X]	[X]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[X]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[X]	[X]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 0

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [ ] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [x] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1)
- [ ] FAST(1)
- [ ] MODERATE(1)
- [ ] SLOW(1)
- [ ] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH
- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [ ] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [X] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [ ] UNSTABLE (Gravel, Sand)(0)
- [X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [ ] EXTENSIVE(-1)
- [ ] MODERATE(0)
- [ ] LOW(1)
- [ ] NONE(2)
- [X] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 3.76 **% POOL** ______ **% RIFFLE** ______ **% RUN** 100 **GRADIENT SCORE** 4

APPENDIX G:

MACROPHYTE SURVEY DATA SHEETS

Aquatic Vegetation Reconnaissance Sampling

Waterbody Cover Sheet

Field	Value
Surveying Organization:	JFNew
Waterbody Name:	Ridinger Lake
Lake ID:	
County:	Kosciusko County
Date:	8/28/03
Habitat Stratum:	IL
Ave. Lake Depth (ft):	21 ft
Lake Level:	NA
Crew Leader:	M. Giolitto
Recorder:	S. Namestnik
Method:	
Secchi Depth (ft):	2.0 ft
Total # of Plant Beds Surveyed:	14
Total # of Species:	36

GPS Metadata

Datum:	Zone:	Accuracy:

Littoral Zone Size (acres): 25 ac

- ❑ Measured
- ✓ Estimated

Littoral Zone Max. Depth (ft): 6.0 ft

- ❑ Measured
- ❑ Estimate (historical Secchi)
- ✓ Estimated (current Secchi)

Notable Conditions:

Abbreviation	**Plant Species**	**Common Name**
ACE SAI*	*Acer saccharinum*	Silver maple
ACO CAL	*Acorus calamus*	Sweet flag
ALGA**		Filamentous algae
ASC INC	*Asclepius incarnata*	Swamp milkweed
CEDE	*Ceratophyllum demersum*	Coontail
CEP OCC	*Cephalanthus occidentalis*	Buttonbush
CH?AR	*Chara species*	Chara species
DEC VER	*Decodon verticillatus*	Water willow
ELCA	*Elodea canadensis*	Common waterweed
LE?MN	*Lemna* species	Duckweed species
LEE ORY	*Leersia oryzoides*	Rice cutgrass
LEMI	*Lemna minor*	Lesser duckweed
MYSP	*Myriophyllum spicatum*	Eurasian water milfoil
NAGU	*Najas guadalupensis*	Southern naiad
NLPW	Narrow leaved *Potamogeton* species	Narrow leaved pondweed species
NUAD	*Nuphar advena*	Spatterdock
NYOD	*Nyphaea odorata*	White waterlily
PEVI	*Peltandra virginica*	Arrow arum
POCO	*Pontedaria cordata*	Pickerel weed
POFO	*Potamogeton foliosis*	Leafy pondweed
POL HYS	*Polygonum hydropiperoides*	Swamp smartweed
PONO	*Potomogeton nodosus*	Long-leaf pondweed
POPU	*Potomogeton pusillus*	Small pondweed
RUM VER	*Rumex verticillatus*	Swamp dock
SAL NIG	*Salix nigra*	Black willow
SAU CER	*Saururus cernuus*	Lizard's tail
SCI PUN	*Scirpus pungens*	Chairmaker's rush
SCI VAC	*Scirpus validus*	Soft-stem bulrush
SPA EUR	*Sparganium eurycarpum*	Giant burreed
SPPO	*Spirodela polyrrhiza*	Giant duckweed
STPE	*Stuckenia pectinata*	Sago pondweed
TYAN	*Typha angustifolia*	Narrow-leaved cattail
TYLA	*Typha latifolia*	Broad-leaved cattail
WO?LF	*Wolffia* species	Watermeal species
WOL COL	*Wolffia columbiana*	Columbia watermeal
ZODU	*Zosterella dubia*	Water stargrass

*Six letter acronyms from Plants of the Chicago Region Database.

**Four letter acronyms from Shuler and Hoffmann (2002).

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew

DATE: 8/28/03

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 01	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.06 ac.					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 15				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:4	E:1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUAD	3			
NYOD	3			
NAGU	2		1	
CEDE	1			
PONO	1		1	
WO?LF	1			
SPPO	1			
LE?MN	1			
ALGA	1			
ELCA	1			
LEE ORY	1			
SPA EUR	1			
POCO	1			
ZODU	1		1	
STPE	1		1	

Individual Plant Bed Survey

Comments: The plant bed is located between the boat ramp and the Jellystone Park beach. The maximum lakeward extent of the plant bed is 45 feet while the average width of the bed is 25 feet. The bed extends approximately 100 feet along the shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	DATE: 8/28/03

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 02	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 900 sq. ft.					Latitude: NA
Substrate: 3	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 6				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:1	E:4	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POCO	4			
SCI VAC	1			
NUAD	1			
NYOD	1			
CEDE	1			
LEE ORY	1			

Individual Plant Bed Survey

Comments:Plant bed 02 starts at the northern edge of the Jellystone Park beach and extends approximately 60 feet along the shoreline. The maximum lakeward extent of the plant bed is approximately 20 feet while the average lakeward extent is 15 feet. Purple loosestrife occurs along the shoreline immediately north of the edge of plant bed 02.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 03	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 1.7 ac.					Latitude: NA
Substrate: 3	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 11				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:2	F:3	E:3	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POCO	3			
NUAD	3			
ALGA	2			
MYSP	2			
CEDE	2			
SPA EUR	1			
SAL NIG	1			
LEMI	1			
CEP OCC	1			
STPE	1			
NAGU	1		1	

Individual Plant Bed Survey

Comments: Plant bed 03 extends from south of the lake's outlet stream around to the north shore of the lake. The maximum lakeward extent of the plant bed is approximately 100 feet while the average width of the plant bed is about 40 feet. Bed extends along approximately 1825 feet of shoreline. Reed canary grass occurs on the north edge of the lake, east of the outlet.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew | **DATE: 8/28/03**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 04	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.6 ac.					Latitude: NA
Substrate: 3	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 13				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:2	F:1	E:1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
ALGA	2			
MYSP	2			
CEDE	2			
STPE	2			
LEMI	1			
PONO	1		1	
ZODU	1		1	
NAGU	1		1	
SPA EUR	1			
POFO	1		1	
NLPW	1		1	
CH?AR	1			
POCO	1			

Individual Plant Bed Survey

Comments: Reed canary grass occurs in scattered patched along the shoreline of the plant bed. The maximum lakeward extent of the plant bed is approximately 60 feet, while the average extent of the plant bed is about 40 feet. The bed parallels the shore for approximately 600 feet.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 05	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 975 sq. ft.					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 14				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:1	E:3	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POCO	3			
STPE	2			
CEDE	2			
NAGU	2		1	
TYAN	1			
CEP OCC	1			
PONO	1		1	
WOL COL	1			
CH?AR	1			
LEMI	1			
ZODU	1		1	
POFO	1			
NLPW	1		1	
ALGA	1			

Individual Plant Bed Survey

Comments: The maximum lakeward extent of the plant bed is approximately 20 feet, while the average extent is about 15 feet. Plant bed 05 extends approximately 65 feet along the shoreline through an area including a number of docks and piers.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 06	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.3 ac.					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 13				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:1	E:3	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
STPE	2			
CEDE	2			
POCO	2			
PONO	2		1	
TYAN	2			
ALGA	1			
NYOD	1			
TYLA	1			
CH?AR	1			
NAGU	1		1	
PEVI	1			
SCI PUN	1			
ACO CAL	1			

Individual Plant Bed Survey

Comments: The maximum lakeward extent of the plant bed is approximately 25 feet, while the average width is 15 feet. The bed parallels approximately 965 feet of shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 07	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.5 ac.					Latitude: NA
Substrate: 3	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 14				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:3	F:3	E:2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUAD	3			
WOL COL	3			
LEMI	2			
STPE	2			
POCO	2			
CEDE	2			
MYSP	2			
ALGA	2			
PEVI	1			
SPA EUR	1			
ASC INC	1			
NYOD	1			
CEP OCC	1			
SPPO	1			

Individual Plant Bed Survey

Comments: Reed canary grass occurs along much of the perimeter of plant bed 07. The maximum lakeward extent of the plant bed is approximately 55 feet, while the average extent is about 35 feet. The plant bed extends about 600 feet along the shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew | **DATE: 8/28/03**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 08	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.1 ac.					Latitude: NA
Substrate: 6	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 17				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:2	F:2	E:2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUAD	2			
STPE	2			
LEMI	2			
WOL COL	2			
NAGU	2		1	
ALGA	2			
POCO	2			
CEDE	2			
CH?AR	2			
NYOD	1			
SPA EUR	1			
SPPO	1			
SCI VAC	1			
PEVI	1			
PONO	1		1	
SCI PUN	1			
NLPW	1			

Individual Plant Bed Survey

Comments: Plant bed 08 occurs at the mouth of a channel. Several docks and piers interrupt the plant bed. Some areas of the bed are sparsely vegetated. The maximum extent of the plant bed is approximately 50 feet, while the average extent of the plant bed is about 25 feet. These distances are from the shoreline (not the channel) lakeward. The plant bed borders approximately 225 feet of shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 09	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.3 ac.					Latitude: NA
Substrate: 3	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 15				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:1	E:2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POCO	2			
CEDE	2			
MYSP	2			
STPE	2			
SAU CER	2			
PONO	1		1	
SCI VAC	1			
ALGA	1			
LEMI	1			
SAL NIG	1			
CEP OCC	1			
WOL COL	1			
NAGU	1		1	
SPA EUR	1			
POFO	1		1	

Individual Plant Bed Survey

Comments: Clumps of reed canary grass are located along portions of the shoreline. Several docks interrupt the plant bed. Vegetation is sparse throughout the plant bed. The maximum lakeward extent of the plant bed is approximately 30 feet. The average lakeward extent of the plant bed is about 20 feet. The bed borders approximately 660 feet of shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/28/03**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 10	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 1.6 ac.					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 17				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:3	E:2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUAD	3			
POCO	2			
MYSP	2			
ALGA	2			
CEDE	2			
SPA EUR	2			
STPE	2			
PONO	2		1	
SAU CER	1			
TYLA	1			
LEMI	1			
SPPO	1			
NYOD	1			
WOL COL	1			
ZODU	1		1	
POFO	1		1	
SCI VAC	1			

Individual Plant Bed Survey

Comments: The maximum lakeward extent of the plant bed is approximately 85 feet, while the average lakeward extent of the plant bed is approximately 45 feet. The plant bed borders approximately 1585 feet of shoreline, much of which is undeveloped.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 11	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.9 ac.					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 14				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:1	E:1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
MYSP	2			
CEDE	2			
ALGA	1			
LEMI	1			
STPE	1			
SPPO	1			
ZODU	1		1	
POPU	1		1	
WOL COL	1			
PEVI	1			
PONO	1		1	
CEP OCC	1			
POFO	1		1	
NAGU	1		1	

Individual Plant Bed Survey

Comments: Plant bed 11 runs along much of the southern shoreline of the lake. Reed canary grass occurs in small patches along the shoreline of plant bed 11. Plant cover throughout much of the bed is sparse. The maximum lakeward extent of the plant bed is approximately 40 feet, while the average extent is about 25 feet. The plant bed extends along approximately 1550 feet of shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION

Plant Bed ID: 12	Waterbody Name: Ridinger Lake			
Bed Size: 0.3 ac.				
Substrate: 2	Waterbody ID:			
Marl?	Total # of Species: 11			
High Organic?	**CanopyAbundance at Site**			
	S:1	N:2	F:2	E:1

SITE COORDINATES

Center of the Bed
Latitude: NA
Longitude: NA

Max. Lakeward Extent of Bed
Latitude: NA
Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUAD	2			
WOL COL	2			
CEDE	2			
MYSP	2			
ALGA	1			
LEMI	1			
SPPO	1			
STPE	1			
ACE SAI	1			
POCO	1			
PEVI	1			

Individual Plant Bed Survey

Comments: Plant bed 12 covers the southwest corner of the lake. Vegetation throughout the plant bed is sparse. The maximum lakeward extent of the bed is approximately 55 feet, while the average lakeward extent is 35 feet. Plant bed 12 follows approximately 450 feet of shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew | **DATE: 8/28/03**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 13	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 0.4 ac.					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 21				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:2	E:1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
ALGA	2			
CEDE	2			
MYSP	2			
NAGU	2		1	
STPE	2			
NUAD	2			
POFO	1		1	
SAU CER	1			
PEVI	1			
SPA EUR	1			
LEMI	1			
SPPO	1			
WOL COL	1			
POPU	1		1	
DEC VER	1			
POL HYS	1			
RUM VER	1			
POCO	1			
PONO	1		1	
NYOD	1			
NLPW	1			

Individual Plant Bed Survey

Comments: The maximum lakeward extent of the plant bed is approximately 50 feet, while the average extent of the plant bed is 30 feet. The plant bed borders apprxoimately 550 feet of shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/28/03**

SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 14	Waterbody Name: Ridinger Lake				Center of the Bed
Bed Size: 1.3 ac.					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 9				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:1	N:1	F:2	E:1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NYOD	2			
STPE	2			
NAGU	2		1	
ALGA	1			
CEDE	1			
PEVI	1			
LEMI	1			
NUAD	1			
NLPW	1			

Individual Plant Bed Survey

Comments: Plant bed 14 is sparsely vegetated. The maximum lakeward extent of the plant bed is approximately 45 feet, while the average extent is about 30 feet. Plant bed 14 borders approximately 1950 feet of shoreline.

REMINDER INFORMATION

Substrate
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Reconnaissance Sampling

Waterbody Cover Sheet

Surveying Organization: JFNew

Waterbody Name: Robinson Lake

Lake ID:

County: Kosciusko/Whitley County

Date: 8/28/03

Habitat Stratum: IL

Ave. Lake Depth (ft): NA

Lake Level: 851.09 ft

Crew Leader: M. Giolitto

GPS Metadata

Datum:

Zone:

Accuracy:

Recorder: S. Namestnik

Method:

Secchi Depth (ft): 2.7 ft

Total # of Plant Beds Surveyed: 1

Total # of Species: 26

Littoral Zone Size (acres): 16 ac

- ❑ Measured
- ✓ Estimated

Littoral Zone Max. Depth (ft): 8.1 ft

- ❑ Measured
- ❑ Estimate (historical Secchi)
- ✓ Estimated (current Secchi)

Notable Conditions:

Abbreviation	**Plant Species**	**Common Name**
ALGA*		Filamentous algae
CEDE	*Ceratophyllum demersum*	Coontail
CEP OCC**	*Cephalanthus occidentalis*	Buttonbush
CYP RIV	*Cyperus rivularis*	Shining flatsedge
CYP STR	*Cyperus strigosis*	Straw-color flatsedge
JUAM	*Justicia americana*	Water willow
LE?MN	*Lemna* species	Duckweed species
LEE ORY	*Leersia oryzoides*	Rice cutgrass
MYSP	*Myriophyllum spicatum*	Eurasian water milfoil
NUAD	*Nuphar advena*	Spatterdock
NYOD	*Nymphaea ordata tuberosa*	White water lily
PEVI	*Peltandra virginica*	Arrow arum
PHA ARU	*Phalaris arundinacea*	Reed canary grass
POAM	*Potamogeton amplifolius*	Large-leaved pondweed
POCO	*Pontederia cordata*	Pickerel weed
POL COC	*Polygonum coccinium*	Water heartsease
POL HYS	*Polygonum hydropiperoides*	Water smartweed
POL PER	*Polygonum persicaria*	Lady's thumb
PONO	*Potamogeton natans*	Long-leaf pondweed
SAL INT	*Salix interior*	Sandbar willow
SCI PUN	*Scirpus pungens*	Chairmaker's rush
SPA EUR	*Sparganium eurycarpum*	Giant burreed
SPPO	*Spirodela polyrhiza*	Giant duckweed
STPE	*Stuckenia pectinata*	Sago pondweed
TYLA	*Typha latifolia*	Broad-leaf cattail
WO?LF	*Wolffia* species	Watermeal species

*Four letter acronym system from Shuler and Hoffmann (2002).
**Six letter acronym system from the Plants of the Chicago Region Database.

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew

DATE: 8/28/03

SITE INFORMATION

Plant Bed ID:	Waterbody Name: Robinson Lake			
Bed Size:				
Substrate: 2 (6 in part)	Waterbody ID:			
Marl?	Total # of Species: 26			
High Organic?	**CanopyAbundance at Site**			
	S: 2	N: 4	F: 2	E: 1

SITE COORDINATES

Center of the Bed

Latitude: NA

Longitude: NA

Max. Lakeward Extent of Bed

Latitude: NA

Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CEDE	4			
WO?LF	3			
ALGA	3			
NUAD	3			
NYOD	3			
LE?MN	2			
POCO	2			
MYSP	2			
PEVI	2			
PONO	1			
POAM	1			
SPPO	1			
STPE	1			
TYLA	1			
JUAM	1			
PHA ARU	1			
POL COC	1			
CYP RIV	1			
CYP STR	1			
LEE ORY	1			
POL HYR	1			
POL PER	1			

Individual Plant Bed Survey

Comments: The bed entirely rings the lake. Reed canary grass was observed in several clumps around the edge of the lake. Filamentous algae coated a lot of the plants. The maximum lakeward extension of the plant bed is approximately 85 feet, while the average width of the plant bed is about 30 feet. Cows were observed in the lake at two locations along the western edge of the lake.

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/28/03**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 01	Waterbody Name: Robinson Lake				Center of the Bed
Bed Size:					Latitude: NA
Substrate: 2 (6 in part)	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 26				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 2	N: 4	F: 2	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
SAL INT	1			
CEP OCC	1			
SPA EUR	1			
SCI PUN	1			

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Reconnaissance Sampling

Waterbody Cover Sheet

Surveying Organization: JFNew

Waterbody Name: Troy Cedar Lake

Lake ID:

County: Whitley County

Date: 8/28/03

Habitat Stratum: IL

Ave. Lake Depth (ft): 24.7 ft

Lake Level: 905.41 ft

GPS Metadata

Datum:

Zone:

Accuracy:

Crew Leader: M. Giolitto

Recorder: S. Namestnik

Method:

Secchi Depth (ft): 2.0 ft

Total # of Plant Beds Surveyed: 2

Total # of Species: 23

Littoral Zone Size (acres): 14 ac

❑ Measured

✓ Estimated

Littoral Zone Max. Depth (ft): 6 ft

❑ Measured

❑ Estimate (historical Secchi)

✓ Estimated (current Secchi)

Notable Conditions:

Abbreviation	Plant Species	Common Name
ALGA*		Filamentous algae
CEDE	*Ceratophyllum demersum*	Coontail
CEP OCC**	*Cephalanthus occidentalis*	Buttonbush
DEC VER	*Decodon verticillatus*	Water willow
LEE ORY	*Leersia oryzoides*	Rice cutgrass
LEMI	*Lemna minor*	Lesser duckweed
LOB CAR	*Lobelia cardinalis*	Cardinal flower
MYSP	*Myriophyllum spicatum*	Eurasian water milfoil
NAGU	*Najas guadalupensis*	Southern naiad
NUAD	*Nuphar advena*	Spatterdock
NYOD	*Nymphaea odorata*	White waterlily
PHA ARU	*Phalaris arundinacea*	Reed canary grass
POCO	*Pontederia cordata*	Pickerel weed
POL COC	*Polygonum coccineum*	Water heartsease
PONO	*Potamogeton nodosus*	Long-leaf pondweed
SCI PUN	*Scirpus pungens*	Chairmaker's rush
SCI VAC	*Scirpus validus*	Softstem bullrush
SPA EUR	*Sparganium eurycarpum*	Giant burreed
STPE	*Stuckenia pectinata*	Sago pondweed
TYAN	*Typha angustifolia*	Narrow-leaf cattail
TYLA	*Typha latifolia*	Broad-leaf cattail
VAAM	*Vallisneria americana*	Eel grass
WOL COL	*Wolffia columbiana*	Columbia watermeal

*Four letter acronym system from Shuler and Hoffmann (2002).
**Six letter acronym system from the Plants of Chicago Region Database.

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					DATE: 8/28/03
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 01	Waterbody Name: Troy Cedar Lake				Center of the Bed
Bed Size:					Latitude: NA
Substrate: 2, 5	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 23				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 1	N: 1	F: 3	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUAD	3			
NYOD	2			
SCI PUN	2			
MYSP	2			
CEDE	2			
ALGA	2			
PHA ARU	1			
POL COC	1			
DEC VER	1			
SCI VAC	1			
LEE ORY	1			
TYAN	1			
TYLA	1			
CEP OCC	1			
SPA EUR	1			
LOB CAR	1			
STPE	1		1	
PONO	1		1	
POCO	1			
VAAM	1			
NAGU	1		1	
LEMI	1			

Individual Plant Bed Survey

Comments: This bed rings the western, northern, and most of the eastern portion of the lake. Reed canary grass was observed in several clumps along the western and northern shoreline. The maximum lakeward extension of the plant bed is approximately 125 feet, while the average width of the plant bed is about 40-45 feet.

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/28/03**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 01	Waterbody Name: Troy Cedar Lake				Center of the Bed
Bed Size:					Latitude: NA
Substrate: 2, 5	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 23				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 1	N: 1	F: 3	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
WOL COL	1			

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/28/03**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 02	Waterbody Name: Troy Cedar Lake				Center of the Bed
Bed Size:					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 10				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 1	N: 1	F: 2	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUAD	2			
MYSP	2			
VAAM	2			
SCI PUN	1			
TYAN	1			
CEDE	1			
POCO	1			
SCI VAC	1			
DEC VER	1			
TYLA	1			

Individual Plant Bed Survey

Comments: The bed covers the eastern shoreline of the lake. Multiple piers, boats, and recreational structures were located throughout the plant bed. The maximum lakeward extent of the plant bed is approximately 55 feet, while the average width of the plant bed is about 40 feet. This plant bed is much more sparse than plant bed 01.

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

APPENDIX H:

FISH SPECIES LIST
FOR RIDINGER, ROBINSON, AND TROY CEDAR LAKES

Appendix H. Fish species presence in the Ridinger Lake watershed.

Fish species collected from Ridinger Lake (1978-1985). An X indicates the presence of the species during the survey date. Source: IDNR fisheries surveys.

Common Name	Scientific Name	1978	1981	1982	1983	1995	2003
Gars	***Lepisosteidae***						
Spotted Gar	*Lepisosteus oculatus*	X	X	X	X	X	X
Catfishes	***Ictaluridae***						
Brown Bullhead	*Ameiurus nebulosus*	X	X	X	X	X	
Yellow Bullhead	*Ameiurus natalis*	X	X	X	X	X	X
Black Bullhead	*Ameiurus melas*						X
Channel Catfish	*Ictaluris punctatus*			X	X	X	X
Herrings	***Clupeidae***						
Gizzard Shad	*Dorosoma cepedianum*	X	X	X	X	X	X
Bowfins	***Amiidae***						
Bowfin	*Amia calva*	X			X		
Pikes	***Esocidae***						
Grass Pickerel	*Esox americanus*	X			X		
Northern Pike	*Esox lucius*				X		
Minnows	***Cyprinidae***						
Carp	*Cyprinus carpio*	X	X	X	X	X	X
Golden Shiner	*Notemigonus crysoleucas*	X	X	X	X	X	X
Bluntnose Minnow	*Pimephales notatus*			X			
Suckers	***Catostomidae***						
Spotted Sucker	*Minytrema melanops*	X	X	X	X	X	X
White Sucker	*Catostomus commersoni*	X	X	X	X	X	X
Lake Chubsucker	*Erimyson sucetta*	X	X	X	X	X	X
Quillback	*Carpiodes cyprinus*		X	X			
Siversides	***Atherinidae***						
Brook Silverside	*Labidesthes sicculus*	X		X		X	
Temperate Basses	***Moronidae***						
White Bass	*Morone chrysops*				X	X	X
Sunfishes	***Centrarchidae***						
Bluegill	*Lepomis macrochirus*	X	X	X	X	X	X
Largemouth Bass	*Micropterus salmoides*	X	X	X	X	X	X
Redear Sunfish	*Lepomis microlophus*	X		X	X	X	
Black Crappie	*Pomoxis nigromaculatus*	X			X	X	X
Warmouth	*Lepomis gulosus*	X				X	X
Pumpkinseed	*Lepomis gibbosus*	X			X	X	X
Green Sunfish	*Lepomis cyanellus*	X		X			
Hybrid Sunfish	*Lepomis sp.*	X					
White Crappie	*Pomoxis annularis*	X		X	X		X
Longear Sunfish	*Lepomis megalotis*	X			X		X
Perches	***Percidae***						
Logperch	*Percina caprodes*	X				X	
Yellow Perch	*Perca flavescens*	X	X	X	X	X	X

Fish species collected from Robinson Lake (1993-1999). An X indicates the presence of the species during the survey date. Source: IDNR fisheries surveys.

Common Name	Scientific Name	1993	1996	1999	2003
Gars	***Lepisosteidae***				
Spotted Gar	*Lepisosteus oculatus*	X	X	X	X
Catfishes	***Ictaluridae***				
Brown Bullhead	*Ameiurus nebulosus*	X	X	X	X
Yellow Bullhead	*Ameiurus natalis*	X	X	X	X
Channel Catfish	*Ictalurus punctatus*	X		X	
Black Bullhead	*Ameiurus melas*	X	X	X	
Slender Madtom	*Noturus exilis*	X	X		
Bowfins	***Amiidae***				
Bowfin	*Amia calva*	X	X	X	X
Herrings	***Clupeidae***				
Gizzard Shad	*Dorosoma cepedianum*	X	X	X	X
Pikes	***Esocidae***				
Grass Pickerel	*Esox americanus*	X	X	X	
Northern Pike	*Esox lucius*				X
Minnows	***Cyprinidae***				
Carp	*Cyprinus carpio*		X	X	X
Golden Shiner	*Notemigonus crysoleucas*	X	X	X	X
Suckers	***Catostomidae***				
Spotted Sucker	*Minytrema melanops*		X	X	X
White Sucker	*Catostomus commersoni*	X	X	X	X
Quillback	*Carpiodes cyprinus*			X	
Lake Chubsucker	*Erimyson sucetta*				X
Siversides	***Atherinidae***				
Brook Silverside	*Labidesthes sicculus*	X	X	X	X
Temperate Basses	***Moronidae***				
White Bass	*Morone chrysops*			X	
Sunfishes	***Centrarchidae***				
Bluegill	*Lepomis macrochirus*	X	X	X	X
Largemouth Bass	*Micropterus salmoides*	X	X	X	X
Redear Sunfish	*Lepomis microlophus*	X	X	X	X
Black Crappie	*Pomoxis nigromaculatus*	X	X	X	X
Warmouth	*Lepomis gulosus*	X	X	X	X
White Crappie	*Pomoxis annularis*	X	X		X
Pumpkinseed	*Lepomis gibbosus*		X		
Hybrid Sunfish	*Lepomis sp.*		X	X	X
Spotted Sunfish	*Lepomis punctatus*			X	X
Longear Sunfish	*Lepomis megalotis*				X
Perches	***Percidae***				
Logperch	*Percina caprodes*	X			
Yellow Perch	*Perca flavescens*	X	X	X	X

Fish species collected from Troy Cedar Lake (1964-1982). An X indicates the presence of the species during the survey date. Source: IDNR fisheries surveys.

Common Name	Scientific Name	1964	1977	1981	1982
Gars	***Lepisosteidae***				
Spotted Gar	*Lepisosteus oculatus*	X		X	X
Longnose Gar	*Lepisosteus osseus*	X			
Catfishes	***Ictaluridae***				
Brown Bullhead	*Ameiurus nebulosus*	X		X	X
Yellow Bullhead	*Ameiurus natalis*	X	X	X	X
Channel Catfish	*Ictalurus punctatus*			X	X
Black Bullhead	*Ameiurus melas*			X	
Madtom sp.	*Noturus sp.*			X	
Bowfins	***Amiidae***				
Bowfin	*Amia calva*	X		X	X
Herrings	***Clupeidae***				
Gizzard Shad	*Dorosoma cepedianum*	X	X	X	X
Pikes	***Esocidae***				
Grass Pickerel	*Esox americanus*	X		X	X
Northern Pike	*Esox lucius*	X			
Minnows	***Cyprinidae***				
Carp	*Cyprinus carpio*	X	X	X	X
Golden Shiner	*Notemigonus crysoleucas*	X		X	X
Suckers	***Catostomidae***				
Spotted Sucker	*Minytrema melanops*			X	
White Sucker	*Catostomus commersoni*	X		X	X
Quillback	*Carpiodes cyprinus*			X	X
Lake Chubsucker	*Erimyson sucetta*	X	X	X	X
Sunfishes	***Centrarchidae***				
Bluegill	*Lepomis macrochirus*	X	X	X	X
Largemouth Bass	*Micropterus salmoides*	X	X	X	X
Redear Sunfish	*Lepomis microlophus*	X	X		
Black Crappie	*Pomoxis nigromaculatus*	X	X	X	X
Warmouth	*Lepomis gulosus*	X		X	
Pumpkinseed	*Lepomis gibbosus*	X	X	X	
Green Sunfish	*Lepomis cyanellus*			X	
Longear sunfish	*Lepomis megalotis*	X		X	X
Perches	***Percidae***				
Yellow Perch	*Perca flavescens*	X		X	X

APPENDIX I:

WATER BUDGET

Appendix I. Water Budgets for lakes in the Ridinger Lake watershed.

WATER BUDGET FORM FOR LAKES	
Watershed	**Ridinger Lake**
Watershed size (ac)	14,639
Mean Watershed Runoff (ac-ft/yr)	16,230
Lake Volume (ac-ft)	2,572
Closest gaged stream	Tippe R @ N. Webster
Stream watershed (mi2)	49.3
Stream watershed (acres)	31,552
Mean annual Q (cfs)	48.32
Mean annual Q (ac-ft/yr)	34,982
Mean ppt (in/yr)	35.52
Mean watershed ppt (ac-ft/yr)	93394
Watershed C	0.37456
Pan evaporation (in/yr)	28.05
Pan evaporation coefficient	0.70
Lake Surface Area (acres)	135
Estimated lake evaporation (ac-ft)	221
Direct precipitation to lake (ac-ft)	400
	= input data
	= output data
Water Budget Summary	
Direct precipitation to lake (ac-ft)	400
Runoff from watershed (ac-ft)	16,230
Discharge from Troy Cedar Lake (ac-ft)	3,607
Discharge from Robinson Lake (ac-ft)	4,950
Evaporation (ac-ft)	221
TOTAL LAKE OUTPUT (ac-ft)	24,966
Hydraulic Residence Time (yr)	0.10
Watershed Area:Lake Area	108.4

WATER BUDGET FORM FOR LAKES	
Watershed	**Robinson Lake**
Watershed size (ac)	4,394
Mean Watershed Runoff (ac-ft/yr)	4,872
Lake Volume (ac-ft)	1,025
Closest gaged stream	Tippe R @ N. Webster
Stream watershed (mi2)	49.3
Stream watershed (acres)	31,552
Mean annual Q (cfs)	48.32
Mean annual Q (ac-ft/yr)	34,982
Mean ppt (in/yr)	35.52
Mean watershed ppt (ac-ft/yr)	93,394
Watershed C	0.37456
Pan evaporation (in/yr)	28.05
Pan evaporation coefficient	0.70
Lake Surface Area (acres)	59
Estimated lake evaporation (ac-ft)	97
Direct precipitation to lake (ac-ft)	175
	= input data
	= output data
Water Budget Summary	
Direct precipitation to lake (ac-ft)	175
Runoff from watershed (ac-ft)	4,872
Evaporation (ac-ft)	97
TOTAL LAKE OUTPUT (ac-ft)	4,950
Hydraulic Residence Time (yr)	0.21
Watershed Area:Lake Area	74.5

WATER BUDGET FORM FOR LAKES	
Watershed	**Troy Cedar Lake**
Watershed size (ac)	3147
Mean Watershed Runoff (ac-ft/yr)	3489
Lake Volume (ac-ft)	2211
Closest gaged stream	Tippe R @ N. Webster
Stream watershed (mi2)	49.3
Stream watershed (acres)	31552
Mean annual Q (cfs)	48.32
Mean annual Q (ac-ft/yr)	34982
Mean ppt (in/yr)	35.52
Mean watershed ppt (ac-ft/yr)	93394
Watershed C	0.37456
Pan evaporation (in/yr)	28.05
Pan evaporation coefficient	0.70
Lake Surface Area (acres)	89
Estimated lake evaporation (ac-ft)	146
Direct precipitation to lake (ac-ft)	263
	= input data
	= output data

Water Budget Summary	
Direct precipitation to lake (ac-ft)	263
Runoff from watershed (ac-ft)	3489
Evaporation (ac-ft)	146
TOTAL LAKE OUTPUT (ac-ft)	3607
Hydraulic Residence Time (yr)	0.61
Watershed Area:Lake Area	35.4

APPENDIX J:

PHOSPHORUS MODEL

`Phosphorus Loading - Lake Response Model				
LAKE:	**Ridinger**		**DATE:**	2/2/2004
COUNTY:	Kosciusko			
STATE:	Indiana			
INPUT DATA		**Unit**		
Area, Lake	135	acres		
Volume, Lake	2572	ac-ft		
Mean Depth	19.1	ft		
Hydraulic Residence Time	0.10			
Flushing Rate	9.71	1/yr		
Mean Annual Precipitation	0.90	m		
[P] in precipitation	0.03	mg/l		
[P] in epilimnion	0.059	mg/l		
[P] in hypolimnion	0.736	mg/l		
Volume of epilimnion	1913	ac-ft		
Volume of hypolimnion	659	ac-ft		
Land Use (in watershed)	**Area**	--------	**P-export Coefficient**	
Deciduous Forest	738.0	hectare	0.2	kg/ha-yr
Emergent Herbaceous Wetlands	29.3	hectare	0.1	kg/ha-yr
Evergreen Forest	2.3	hectare	0.15	kg/ha-yr
High Intensity Residential	4.3	hectare	1.5	kg/ha-yr
High Intensity:Commercial/Ind	8.0	hectare	1.3	kg/ha-yr
Low Intensity Residential	85.0	hectare	0.6	kg/ha-yr
Mixed Forest	0.4	hectare	0.175	kg/ha-yr
Pasture/Hay	1042.8	hectare	0.6	kg/ha-yr
Row Crops	3815.7	hectare	1.5	kg/ha-yr
Woody Wetlands	128.5	hectare	0.1	kg/ha-yr
Septic Systems	--------	--------	0.50	kg/ha-yr
	5854.23			
Other Data				
Soil Retention coefficient	0.75	--------		
# Permanent Homes	95	homes		
Use of Permanent Homes	1.0	year		
# Seasonal Homes	0	homes		
Use of Seasonal Homes	0.25	year		
# Seasonal Homes	0	homes		
Use of Seasonal Homes	0.09	year		
Avg. Persons Per Home	3	persons		
OUTPUT				
P load from watershed	6580.8	kg/yr		
P load from precipitation	14.78	kg/yr		
P load from septic systems	35.63	kg/yr		
Total External P load	6631.3	kg/yr		
P load from Troy Cedar	420.45			
P load from Robinson	842.60			
Areal P loading	14.449	g/m2-yr		
Predicted P from Vollenweider	0.218	mg/l		
Back Calculated L total	15.432	g/m2-yr		
Estimation of L internal	0.983	g/m2-yr		
% of External Loading	93.6	%		
% of Internal Loading	6.4	%		

Phosphorus Loading - Lake Response Model				
LAKE:	**Robinson**		**DATE:**	2/2/2004
COUNTY:	Kosciusko			
STATE:	Indiana			
INPUT DATA		**Unit**		
Area, Lake	59	acres		
Volume, Lake	1025	ac-ft		
Mean Depth	17.4	ft		
Hydraulic Residence Time	0.21			
Flushing Rate	4.83	1/yr		
Mean Annual Precipitation	0.90	m		
[P] in precipitation	0.03	mg/l		
[P] in epilimnion	0.037	mg/l		
[P] in hypolimnion	0.944	mg/l		
Volume of epilimnion	755	ac-ft		
Volume of hypolimnion	271	ac-ft		
Land Use (in watershed)	**Area**	--------	**P-export Coefficient**	
Deciduous Forest	217.4	hectare	0.2	kg/ha-yr
Emergent Herbaceous Wetlands	6.2	hectare	0.1	kg/ha-yr
Evergreen Forest	0.3	hectare	0.15	kg/ha-yr
High Intensity Residential	0.0	hectare	1.5	kg/ha-yr
High Intensity:Commercial/Ind	0.1	hectare	1.3	kg/ha-yr
Low Intensity Residential	4.0	hectare	0.6	kg/ha-yr
Mixed Forest	0.1	hectare	0.175	kg/ha-yr
Pasture/Hay	205.2	hectare	0.6	kg/ha-yr
Row Crops	1248.9	hectare	1.5	kg/ha-yr
Woody Wetlands	64.4	hectare	0.1	kg/ha-yr
Septic Systems	--------	--------	0.50	kg/ha-yr
	1746.45			
Other Data				
Soil Retention coefficient	0.75	--------		
# Permanent Homes	35	homes		
Use of Permanent Homes	1.0	year		
# Seasonal Homes	0	homes		
Use of Seasonal Homes	0.25	year		
# Seasonal Homes	0	homes		
Use of Seasonal Homes	0.09	year		
Avg. Persons Per Home	3	persons		
OUTPUT				
P load from watershed	2049.5	kg/yr		
P load from precipitation	6.46	kg/yr		
P load from septic systems	13.13	kg/yr		
Total External P load	2069.09	kg/yr		
Areal P loading	8.666	g/m2-yr		
Predicted P from Vollenweider	0.244	mg/l		
Back Calculated L total	9.833	g/m2-yr		
Estimation of L internal	1.168	g/m2-yr		
% of External Loading	88.1	%		
% of Internal Loading	11.9	%		

Phosphorus Loading - Lake Response Model				
LAKE:	**Troy Cedar**		**DATE:**	2/2/2004
COUNTY:	Kosciusko			
STATE:	Indiana			
INPUT DATA		**Unit**		
Area, Lake	89	acres		
Volume, Lake	2211	ac-ft		
Mean Depth	24.8	ft		
Hydraulic Residence Time	0.61			
Flushing Rate	1.63	1/yr		
Mean Annual Precipitation	0.90	m		
[P] in precipitation	0.03	mg/l		
[P] in epilimnion	0.047	mg/l		
[P] in hypolimnion	0.363	mg/l		
Volume of epilimnion	1214	ac-ft		
Volume of hypolimnion	997	ac-ft		
Land Use (in watershed)	**Area**	--------	**P-export Coefficient**	
Deciduous Forest	110.4	hectare	0.2	kg/ha-yr
Emergent Herbaceous Wetlands	13.0	hectare	0.1	kg/ha-yr
Evergreen Forest	0.3	hectare	0.15	kg/ha-yr
High Intensity Residential	0.0	hectare	1.5	kg/ha-yr
High Intensity:Commercial/Ind	0.0	hectare	1.3	kg/ha-yr
Low Intensity Residential	0.7	hectare	0.6	kg/ha-yr
Mixed Forest	0.0	hectare	0.175	kg/ha-yr
Pasture/Hay	126.1	hectare	0.6	kg/ha-yr
Row Crops	880.3	hectare	1.5	kg/ha-yr
Woody Wetlands	87.2	hectare	0.1	kg/ha-yr
Septic Systems	--------	--------	0.50	kg/ha-yr
	1218.03			
Other Data				
Soil Retention coefficient	0.75	--------		
# Permanent Homes	50	homes		
Use of Permanent Homes	1.0	year		
# Seasonal Homes	15	homes		
Use of Seasonal Homes	0.25	year		
# Seasonal Homes	0	homes		
Use of Seasonal Homes	0.09	year		
Avg. Persons Per Home	3	persons		
OUTPUT				
P load from watershed	1428.6	kg/yr		
P load from precipitation	9.75	kg/yr		
P load from septic systems	20.16	kg/yr		
Total External P load	1458.52	kg/yr		
Areal P loading	4.049	g/m2-yr		
Predicted P from Vollenweider	0.181	mg/l		
Back Calculated L total	4.235	g/m2-yr		
Estimation of L internal	0.185	g/m2-yr		
% of External Loading	95.6	%		
% of Internal Loading	4.4	%		

APPENDIX K:

POTENTIAL FUNDING SOURCES

FUNDING SOURCES

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Community groups 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. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)

LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a single project or $300,000 for all projects on a lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with landowners who implement various BMPs. Both the LARE programs are recommended as a project funding source for the Ridinger Lake watershed. More information about the LARE program can be found at http://www.in.gov/dnr/soilcons/programs/lare.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must meet specific criteria such as being listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement. To qualify for implementation projects, there must be a watershed management plan for the receiving waterbody. This plan must meet all of the current 319 requirements. This diagnostic study serves as an n excellent foundation for developing a watershed management plan since it satisfies several, but not all, of the 319 requirements for a watershed management plan. More information about the Section 319 program can be obtained from http://www.in.gov/idem/water/planbr/wsm/319main.html.

Section 104(b)(3) NPDES Related State Program Grants
Section 104(b)(3) of the Clean Water Act gives authority to a grant program called the National Pollutant Discharge Elimination System (NPDES) Related State Program Grants. These grants provide money for developing, implementing, and demonstrating new concepts or requirements that will improve the effectiveness of the NPDES permit program that regulates point source discharges of water pollution. Projects that qualify for Section 104(b)(3) grants involve water pollution sources and activities regulated by the NPDES program. The awarded amount can vary by project and there is a required 5% match. For more information on Section 104(b)(3) grants, please see the IDEM website at: http://www.in.gov/idem/water/planbr/wsm/104main.html.

Section 205(j) Water Quality Management Planning Grants
Funds allocated by Section 205(j) of the Clean Water Act are granted for water quality management planning and design. Grants are given to municipal governments, county governments, regional planning commissions, and other public organizations for researching point and non-point source pollution problems and developing plans to deal with the problems. According to the IDEM Office of Water Quality website: "The Section 205(j) program provides for projects that gather and map information on non-point and point source water pollution, develop recommendations for increasing the involvement of environmental and civic organizations in watershed planning and implementation activities, and implement watershed management plans. No match is required. For more information on and 205(j) grants, please see the IDEM website at: http://www.in.gov/idem/water/planbr/wsm/205jmain.html.

Other Federal Grant Programs
The USDA and EPA award research and project initiation grants through the U.S. National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program
The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture and is administered by the Natural Resources Conservation Service. Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program
The Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Currently, the program offers continuous sign-up for practices like grassed

waterways and filter strips. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

Grassland Reserve Program

The Grassland Reserve Program (GRP) is funded by the USDA and is administered by the NRCS. GRP is a voluntary program that provides funding the restoration or improvement of natural grasslands, rangelands, prairies or pastures. To qualify for the program the land must consist of at least a 40 acre contiguous tract of land, be restorable, and provide water quality or wildlife benefit. Landowners may enroll land in the Grassland Reserve Program for 10, 15, 20, or 30 years or enter their land into a 30-year permanent easement. Landowners receive payment of up to 75% of the annual grazing value. Restoration cost-share funds of up to 75% for restored or 90% for virgin grasslands are also available.

Community Forestry Grant Program

The U.S. Forest Service through the Indiana Department of Natural Resources Division of Forestry provides three forms of funding for communities under the Community Forestry Grant Program. Urban Forest Conservation Grants (UFCG) are designed to help communities develop long term programs to manage their urban forests. UFCG funds are provided to communities to improve and protect trees and other natural resources; projects that target program development, planning, and education are emphasized. Local municipalities, not-for-profit organizations, and state agencies can apply for $2,000-20,000 annually. The second type of Community Forestry Grant Program, the Arbor Day Grant Program, funds activities which promote Arbor Day efforts and the planting and care of urban trees. $500-1000 grants are generally awarded. The Tree Steward Program is an educational training program that involves six training sessions of three hours each. The program can be offered in any county in Indiana and covers a variety of tree care and planting topics. Generally, $500-1000 is available to assist communities in starting a county or regional Tree Steward Program. Each of these grants requires an equal match.

Forest Land Enhancement Program (FLEP)

FLEP replaces the former Forestry Incentive Program. It provides financial, technical, and educational assistance to the Indiana Department of Natural Resources Division of Forestry to assist private landowners in forestry management. Projects are designed to enhance timber production, fish and wildlife habitat, soil and water quality, wetland and recreational resources, and aesthetic value. FLEP projects include implementation of practices to protect and restore forest lands, control invasive species, and preserve aesthetic quality. Projects may also include reforestation, afforestation, or agroforestry practices. The IDNR Division of Forestry has not determined how they will implement this program; however, their website indicates that they are working to determine their implementation and funding procedures. More information can be found at http://www.in.gov/dnr/forestry.

Wildlife Habitat Incentive Program

The Wildlife Habitat Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost-share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost-share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices, innovative approaches to enhance environmental investments like carbon sequestration or market-based credit trading, and groundwater and surface water conservation are also eligible for EQIP cost-share.

Small Watershed Rehabilitation Program

The Small Watershed Rehabilitation Program provides funding for rehabilitation of aging small watershed impoundments that have been constructed within the last 50 years. This program is newly funded through the 2002 Farm Bill and is currently under development. More information regarding this and other Farm Bill programs can be found at http://www.usda.gov/farmbill.

Farmland Protection Program

The Farmland Protection Program (FPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals of FPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature

Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent to or within administered conservation areas.

Partners for Fish and Wildlife Program
The Partners for Fish and Wildlife Program (PFWP) is funded and administered by the U.S. Department of the Interior through the U.S. Fish and Wildlife Service. The program provides technical and financial assistance to landowners interested in improving native habitat for fish and wildlife on their land. The program focuses on restoring wetlands, native grasslands, streams, riparian areas, and other habitats to natural conditions. The program requires a 10-year cooperative agreement and a 1:1 match.

North American Wetland Conservation Act Grant Program
The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish, and other wildlife. The match for this program is on a 1:1 basis.

National Fish and Wildlife Foundation (NFWF)
The National Fish and Wildlife Foundation is administered by the U.S. Department of the Interior. The program promotes healthy fish and wildlife populations and supports efforts to invest in conservation and sustainable use of natural resources. The NFWF targets six priority areas which are wetland conservation, conservation education, fisheries, neotropical migratory bird conservation, conservation policy, and wildlife and habitat. The program requires a minimum of a 1:1 match. More information can be found at http://www.nfwf.org/about.htm.

Bring Back the Natives Grant Program
Bring Back the Natives Grant Program (BBNG) is a NFWF program that provides funds to restore damaged or degraded riverine habitats and the associated native aquatic species. Generally, BBNP supports on the ground habitat restoration projects that benefit native aquatic species within their historic range. Funding is jointly provided by a variety of federal organizations including the U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Department of Agriculture and the National Fish and Wildlife Foundation. Typical projects include those that revise land management practices to remove the cause of habitat degradation, provide multiple specie benefit, include multiple project partners, and are innovative solutions that assist in the development of new technology. A 1:1 match is required; however, a 2:1 match is preferred. More information can be obtained from http://www.nfwf.org.

Native Plant Conservation Initiative
The Native Plant Conservation Initiative (NPCI) supplies funding for projects that protect, enhance, or restore native plant communities on public or private land. This NFWF program typically funds projects that protect and restore of natural resources, inform and educate the surrounding community, and assess current resources. The program provides nearly $450,000 in funding opportunities annually awarding grants ranging from $10,000-50,000 each. A 1:1 match is required for this grant. More information can be found at http://www.nfwf.org/programs/grant_apply.htm.

Freshwater Mussel Fund
The National Fish and Wildlife Foundation and the U.S. Fish and Wildlife Service fund the Freshwater Mussel Fund which provides funds to protect and enhance freshwater mussel

resources. The program provides $100,000 in funding to approximately 5-10 applicants annually. More information can be found at http://www.nfwf.org/programs/grant_apply.htm.

Non-Profit Conservation Advocacy Group Grants

Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

U.S. Environmental Protection Agency Environmental Education Program

The USEPA Environmental Education Program provides funding for state agencies, non-profit groups, schools, and universities to support environmental education programs and projects. The program grants nearly $200,000 for projects throughout Illinois, Indiana, Michigan, Minnesota, Wisconsin, and Ohio. More information is available at http://www.epa.gov/region5/ened/grants.html.

Core 4 Conservation Alliance Grants

Core 4 provides funding for public/private partnerships working toward Better Soil, Cleaner Water, Greater Profits and a Brighter Future. Partnerships must consist of agricultural producers or citizens teaming with government representatives, academic institutions, local associations, or area businesses. CTIC provides grants of up to $2,500 to facilitate organizational or business plan development, assist with listserve or website development, share alliance successes through CTIC publications and other national media outlets, provide Core 4 Conservation promotional materials, and develop speakers list for local and regional use. More information on Core 4 Conservation Alliance grants can be found at http://www.ctic.purdue.edu/CTIC/GrantApplication.pdf.

Indianapolis Power and Light Company (IPALCO) Golden Eagle Environmental Grant

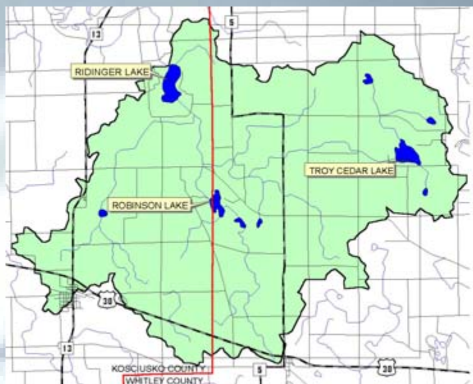
The IPALCO Golden Eagle Grant awards grants of up to $10,000 to projects that seek improve, preserve, and protect the environment and natural resources in the state of Indiana. The award is granted to approximately 10 environmental education or restoration projects each year. Deadline for funding is typically in January. More information is available at http://www.ipalco.com/ABOUTIPALCO/Environment/Golden_Eagle.html

Nina Mason Pulliam Charitable Trust (NMPCT)

The NMPCT awards various dollar amounts to projects that help people in need, protect the environment, and enrich community life. Prioritization is given to projects in the greater Phoenix, AZ and Indianapolis, IN areas, with secondary priority being assigned to projects throughout Arizona and Indiana. The trust awarded nearly $20,000,000 in funds in the year 2000. More information is available at www.nmpct.org

Understanding Your Watershed:

- ★ The Ridinger Lake watershed forms the headwaters of the Barbee Lakes sub-basin within the headwaters of the Upper Tippecanoe River Watershed.

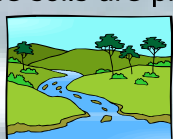


- ★ Ridinger Lake's watershed encompasses approximately 22,100 acres in Kosciusko and Whitley Counties. Ridinger Lake's watershed is extremely large relative to the size of the lake.

- ★ Land use in the watershed is mostly agricultural:

Agriculture	81%	Open Water	2%
Forested	12%	Wetlands	4%
Residential	~1%		

- ★ Morley soils are the most common soils found in the central and eastern portions of the watershed. Miami, Wawasee, and Riddles soils are the most common in the western portion of the watershed. All of these soils are prone to erosion.



For additional information on how to keep your lake and watershed clean and healthy contact:

Lake and River Enhancement Program
Indiana Department of Natural Resources
(IDNR) Division of Soil Conservation
402 West Washington Street Room 265
Indianapolis, Indiana 46204
(317) 233-3870

Tippecanoe Environmental Lake and
Watershed Foundation (TELWF)
P.O. Box 55
North Webster, Indiana 46555
(574) 834-3242
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Barbee Lakes Property Owners Association
North Webster, Indiana 46555

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Ridinger Lake Watershed Diagnostic Study
Kosciusko and Whitley Counties

The Ridinger Lake Watershed Diagnostic Study is a comprehensive examination of Ridinger, Robinson, and Troy Cedar Lakes and their surrounding watershed. In 2003, with funding from the Indiana Department of Natural Resources Lake and River Enhancement Program, the Barbee Lakes Property Owners Association hired the team of JFNew and Indiana University to conduct the study. The purpose of the study was to evaluate historical trends in the lakes' water quality, describe the existing condition of the lakes and their watershed, identify problems, and make recommendations to address these problems. This fact sheet summarizes the study results and presents some suggestions for improving water quality in the Ridinger Lake watershed.

The Watershed Streams:

- ★ There are three main streams and several smaller tributaries in the watershed. Elder Ditch, Shanton Ditch, and Mathias Ditch are the primary streams.

Elder Ditch

Shanton Ditch

Mathias Ditch

- ★ Elder Ditch and Shanton Ditch possess the highest pollutant levels. Both streams also deliver high levels of pollutants to Ridinger Lake. Phosphorus in Mathias Ditch is also of concern.

- ★ The streams' habitat conditions are poor and biological communities living in these streams are impaired.

The Three Lakes:

- ★ Ridinger Lake is best classified as a eutrophic to hypereutrophic lake, while Robinson and Troy Cedar Lakes are classified as eutrophic lakes.

- ★ All three lakes have poorer water clarity and higher nutrient concentrations than most Indiana lakes.

- ★ Historical records show a decrease in Ridinger and Troy Cedar Lakes' water clarity over the past 20-30 years. Trophic state index scores, however, are better now than in the 1970's.

- ★ Eurasian water milfoil, coontail, and sago pondweed are the most common rooted plants in the three lakes. These plants are tolerant of poor water quality conditions.

How to Manage the Lakes:

Ridinger and Robinson Lakes have very short residence times: 36 days in Ridinger and 77 days in Robinson. This means that every 36 (or 77) days the entire volume of water in Ridinger (or Robinson) Lake is flushed and replaced with new water from the lake's inlets. Therefore, to have clean lakes, we have to focus on cleaning the watershed water entering these lakes. Troy Cedar Lake's residence time is a little longer. Management efforts for Troy Cedar Lake should focus on both watershed and in-lake processes.

Management Actions:

- ★ Nearly 100 management actions were identified in the watershed. Because of the high pollutant loads identified in Shanton Ditch and Elder Ditch, management actions should focus on these subwatersheds first.

- ★ Possible management actions include:
  - ♦ Restoring streams corridors and stabilize banks. Planting stream edges.
  - ♦ Restricting livestock access to lakes and streams.
  - ♦ Restoring wetlands.
  - ♦ Increasing the use of no-till conservation tillage and CRP enrollment.
  - ♦ Monitoring/improving erosion control on development sites.

- ★ Specific locations where these actions should be implemented are listed in the study.

What You Can Do Yourself:

- ★ Become an lake monitoring volunteer with the Indiana Clean Lakes Program.
- ★ Use only phosphorus-free fertilizer.
- ★ Plant native plants along shorelines.
- ★ Keep lawn clippings, leaves, and animal waste out of the water.
- ★ Clean/pump septic systems regularly.
- ★ Use idle speeds in shallow water.
- ★ Clean boat propellers after lake use; do not dump bait buckets into the water.