Aquatic Enhancement
& Survey, Inc.

# Lake Diagnostic Study
# Lake James, Snow Lake, Big Otter and Little Otter Lakes
# Steuben County, Indiana

Prepared by:

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For the:

Lake James Association, Snow Lake Cottagers Association,
North Otter Lakes Association.

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## Executive Summary

The James Lake Chain is a series of interconnected glacial lakes near Angola Indiana. This study examines four of those lakes including Lake James (1229 surface acres), Snow Lake (412 surface acres), Big Otter Lake (68 surface acres), and Little Otter Lake (31 surface acres). The lake chain is accessible to the general public at two Indiana Department of Natural Resources Public Access sites, and several private and pay ramps. Boaters, fisherman, and water skiers access the lakes through these sites. Swimmers and kayakers/canoeists can also access Lake James through Pokagon State Park, a large wooded state park containing recreational facilities and a state-owned hotel and conference center. An extended watershed area of approximately 26,290 acres drains through the lakes. This watershed contains several large lakes and marshes as well as significant areas of residential and commercial development, agriculture, woodland, and wetlands.

This report was prepared for the Lake James Association, Snow Lake Cottagers Association, and North Otter Lakes Association (Big and Little Otter Lakes) through cost share grant funding provided by the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program. Residents and lake users are concerned about changes in water quality and increasing pressures placed on the lakes by boat traffic and residential and commercial development.

The purposes of this study were to: ●Collect and compile information on the current and historical, chemical, physical, and biological characteristics of the James Chain Lakes and their watersheds. ●Use the information to look for trends in water quality and the causes of recent water-quality problems including reports of algal blooms and excessive plant growth. ●Explore the biological, social, and recreational implications of past, present, and future watershed land-use and water-quality at the James Chain. ●Recommend a set of possible steps toward protecting and improving water-quality, aquatic biological integrity, and recreational-use at the Lake James Chain.

Work conducted for the study included measurement of a variety of water quality parameters for four major tributaries to the chain and three minor tributaries. Water samples from each lake were also collected and analyzed. In-lake measurements were made to generate temperature, oxygen, pH, and conductivity profiles for the lakes. Land use and land cover for the lakes' immediate watershed was mapped and annual phosphorus input to the lakes was estimated. Major tributary drainage ways and eroded areas in the watershed were also examined to locate sediment and nutrient sources to the lakes. The presence and location of destructive non-native wetland species was noted for possible future control measures. Annual phosphorus contributions to the watershed were estimated using National Pollution Discharge Elimination System (NPDES) data to assess possible affects on lake health. Types of shoreline/seawalls were mapped to note areas where erosion or seawall type may be a factor with regard to water quality.

Overall water quality and clarity on the chain was good in 2005 but total phosphorus levels in the four lakes were much higher than expected. Mean water-column Total phosphorus levels were .08 parts per million (ppm), .13 ppm, 2.07 ppm, and .6 ppm for Lake James, Snow Lake, Big Otter Lake, and Little Otter Lake respectively. Phosphorus levels predicted from watershed land uses and contributions from upstream lakes were .022 ppm, .024 ppm, .032 ppm, and .031 ppm for James, Snow, Big Otter and Little Otter respectively. Possible contributors to these elevated nutrient levels include internal phosphorus loading from the lakes' own sediments, resuspension and disturbance of shallow-water sediments and nutrients by wave action, or wastewater effluents in the watershed.

Sampling from the chain's tributaries during both rain event and baseline conditions showed low phosphorus loading in 2005. However, several areas of erosion and streambed instability were noted in the watershed along with some eroded areas along the shore of Lake James.

A review of past IDNR fisheries reports indicates that all four lakes offer good sportfishing to area anglers with largemouth bass, bluegill and northern pike being important in the fishery. Lake James also contains a significant population of smallmouth bass.

A user survey distributed by the lake associations as part of this study was completed and returned by 769 James Chain residents. Respondents from Lake James indicated that fast boating and skiing/tubing were their preferred lake activities followed closely by fishing and swimming. Resident respondents from both Snow Lake and Big Otter preferred low speed boating/cruising followed by fast boating, fishing, skiing/tubing and personal watercraft use. Little Otter Lake residents preferred cruising and fishing equally as the favored activity followed by fast boating and swimming. Among resident fisherman on all four lakes bluegill were the species sought most often followed by bass. On Lake James perch ranked third followed by walleye, pike, and crappie. On Snow Lake perch were also third followed by walleye/crappie, then pike. Among Big Otter anglers perch also ranked third followed by pike/walleye. Most residents of the chain ranked their water quality as "good" and indicated that water quality at their lake has stayed about the same since they've owned property there. Most also indicated that they felt it was very important that their lake association work toward protecting water quality.

Based on the information collected the following recommendations are presented**:** ●Stabilize eroding areas in the Croxton Ditch, Walter's Lake Drain, Follet Creek, and Crooked Creek watersheds. ●Investigate the possibility of restoring wetlands in the Croxton Ditch and Walter's Lakes Drain Watersheds. ●Stay proactive with regard to filling and draining of wetlands and the practice of proper erosion control techniques on disturbed lands within the watershed. ●Preserve existing water-bodies, wetlands, and other beneficial land uses in the watershed. ●Control the spread of non-native wetland and aquatic plants that can degrade the ecology of the lakes and the function of beneficial wetland areas in the watershed. ●Network with other Lake Associations and Lake Property Owners in the watershed about protecting and improving water quality. ●Investigate the possibility of conducting a monitoring study to determine the impact of major watershed wastewater effluents on the lakes. ●Work toward upholding local regulations that limit and regulate development and funneling. ●Work to maintain the limits of the present watershed and avoid the redirection of stormwater drainage from other watersheds into the James Chain watershed. ●Make Efforts to keep the association memberships informed of goals, progress, and ways to help the lakes ●Work to educate lakeside and watershed property owners about the proper management of their own lands including the use of phosphorus-free fertilizers, proper irrigation, erosion control, and shoreline preservation. ●Work with the USDA Natural Resources Conservation Service, Steuben County Soil and Water Conservation District, and local landowners to establish vegetative cover and other best management practices on highly erodible agricultural areas that may contribute sediments and nutrients to the lakes and watershed wetlands. ●Continue with Volunteer Secchi monitoring on each lake. During years without IDEM sponsored water quality sampling initiate expanded association sponsored monitoring to include, oxygen and temperature profiles, epilimnion and hypolimnion total phosphorus measurement, and surface water chlorophyll a measurement. Use data collected to calculate an annual Carlson's Trophic State Index score for each lake.

While evidence shows that eutrophication has taken place on the James Chain, water quality and the chain's fishery remain relatively good overall. The recent connection of many of the Lake James and Snow Lake residences to a wastewater treatment facility outside the watershed may have a significant positive influence on water quality. If the James Chain associations become dedicated to making steady progress in other problem areas in the watershed and maintain an active advocacy for the regulation ofn high impact land development and lake-use, prospects for improving and protecting water quality on the chain are good.

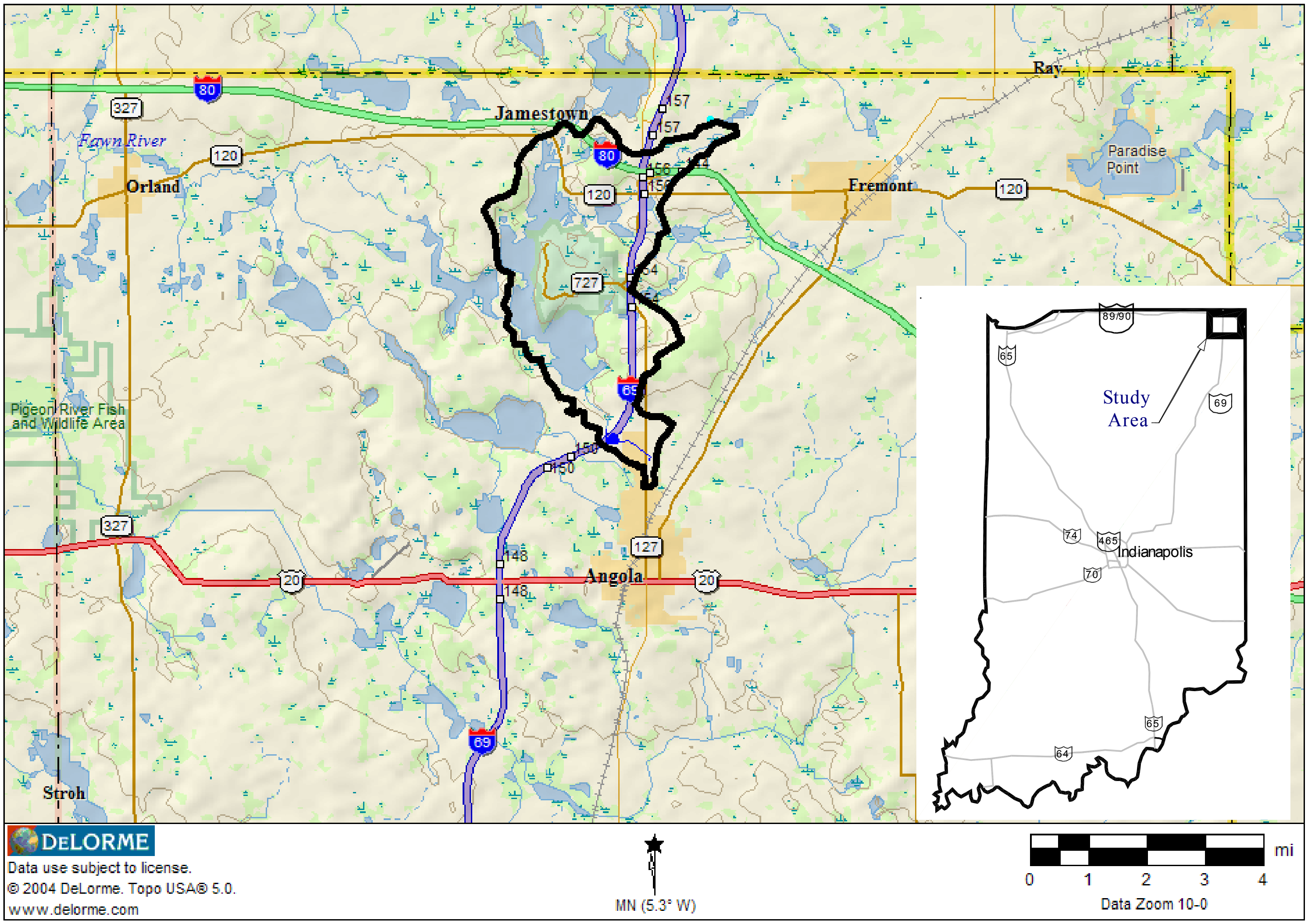



Figure 1 Study Area Location

# 1. Introduction to the Lake James Chain and its Watershed

The James Chain of Lakes consists of several interconnected glacial lake basins just northwest of Angola in northeastern Indiana. (see figure 1) This work examines four of those lakes , Little Otter Lake, Big Otter Lake, Snow Lake and Lake James, hereafter collectively referred to as the James Chain. (see figure 2) At the east end of the chain, Little Otter Lake is approximately 31 acres. Its shape is roughly ovate and it lies in an east to west orientation. The lake's shoreline is partially developed with approximately 25 single family homes and cottages. Much of the Little Otter Lake shoreline is also emergent and scrub shrub wetlands. It receives flow from Marsh Lake to the east through a large wetland to the east via Follet Creek and flows into Big Otter Lake at its northwest End. Big Otter Lake lying just to the northeast of Little Otter is approximately 68 acres in size and roughly rectangular. There are two excavated channels off of Big Otter Lake. One is located in the lake's northeast corner one in the northwest corner. Drainage from a small tributary (Walter's Lakes Drain) enters Big Otter Lake through the northeast channel. A small intermittent tributary also enters the northwest channel. Both contain docking areas for channel-side homes and an IDNR public access site is also located on the northeast channel. The Big Otter basin contains a single small sunken island just southwest of its center. There are approximately 52 homes along Big Otters north, east, and south sides.

The lake's west side is emergent wetland. Big Otter's outlet is at its west end where it flows approximately one half mile through an emergent wetland as Follet Creek before entering Snow Lake. Snow Lake is approximately 412 surface acres in size. It is roughly triangular in shape lying in a North-South orientation just south of Indiana State Road 120 and the 80/90 Indiana Toll Road. Snow Lake contains several sand bars, sunken islands, marshy islands, and peninsulas. It has several thousand feet of riparian wetlands along its shoreline totaling approximately 127 acres. These wetlands are largely cattail marsh with some scrub shrub and wooded wetland habitat also present. Nearly all riparian uplands around Snow Lake have been developed with approximately 164 developed acres containing approximately 312 homes and cottages. To extend the area available for lakeside development two large channel systems, North Snow Bay and Sprague Addition, have been constructed off of the north and southeast part of the lake respectively. Four other small channels have been constructed at various points along the lake's shoreline and dredging activity along the central-western portion of the lake's shoreline deepened the shoreline and disconnected a wetland peninsula making it an island. A small Creek (Crooked Creek) also drains a chain of lakes to the north of Snow Lake into the northeast part of the Snow Lake basin. Snow Lake drains to Lake James through a short channel at its southern tip. At 1229 acres Lake James is the largest lake in the chain and the fourth largest natural lake in Indiana. Lake James is distinctly divided into three basins (Upper, Middle, and Lower). It contains two islands, several sunken islands and several distinct bays. A small attached glacial basin (Krielbaum Lake) is attached to Lake James upper basin through a short channel. Several small channels have been excavated along the Lake James shoreline with two larger constructed channels systems containing multiple homes in the Glen Eden and Lagoona Park Subdivisions along the Eastern and South shoreline of Lake James lower basin respectively. Lake James Largest Tributary, Croxton Ditch enters the lake at the Lagoona Park channel system at the lake's southern tip. Lake James drains to Jimmerson Lake through a channel along the eastern shore of its middle basin.

The general public can access the chain through three IDNR public access sites. One is located on Jimmerson Lake just downstream of Lake James and a second is located on a channel off the Northeast portion of Big Otter Lake. A third is located on Marsh Lake, just upstream and to the East of Little Otter Lake, but due to an "electric motor only" rule on marsh lake and a limited sized steel culvert that must be traversed to pass beneath I-69 on Follet Creek, passage to Little Otter Lake is limited to smaller boats. All three sites have concrete boat ramps. The access sites at Jimmerson Lake and Big Otter Lake were both established in the year 2000 and marked the beginning of general public access to the chain for the majority of boaters. There is also rental, and subdivision common area slip space available at several locations on Lake James for boaters who do not own lake property directly on the lake. There are currently also three locations on the chain that offer launch ramp access for a fee. One pay ramp is owned by a bait shop on the channel located between Lake James and Jimmerson Lake, another is located at a bait and tackle store at the Follet Creek inlet on Little Otter Lake, and a third is located at a marina facility on the east side of the narrows between Lake James middle and upper basins. The general public can also gain access to Lake James at Pokagon State Park located on Lake's James' east shore. Swimming is offered at Pokagon's beach on Lake James and at a beach adjacent to the state owned Potawatomi Inn hotel.

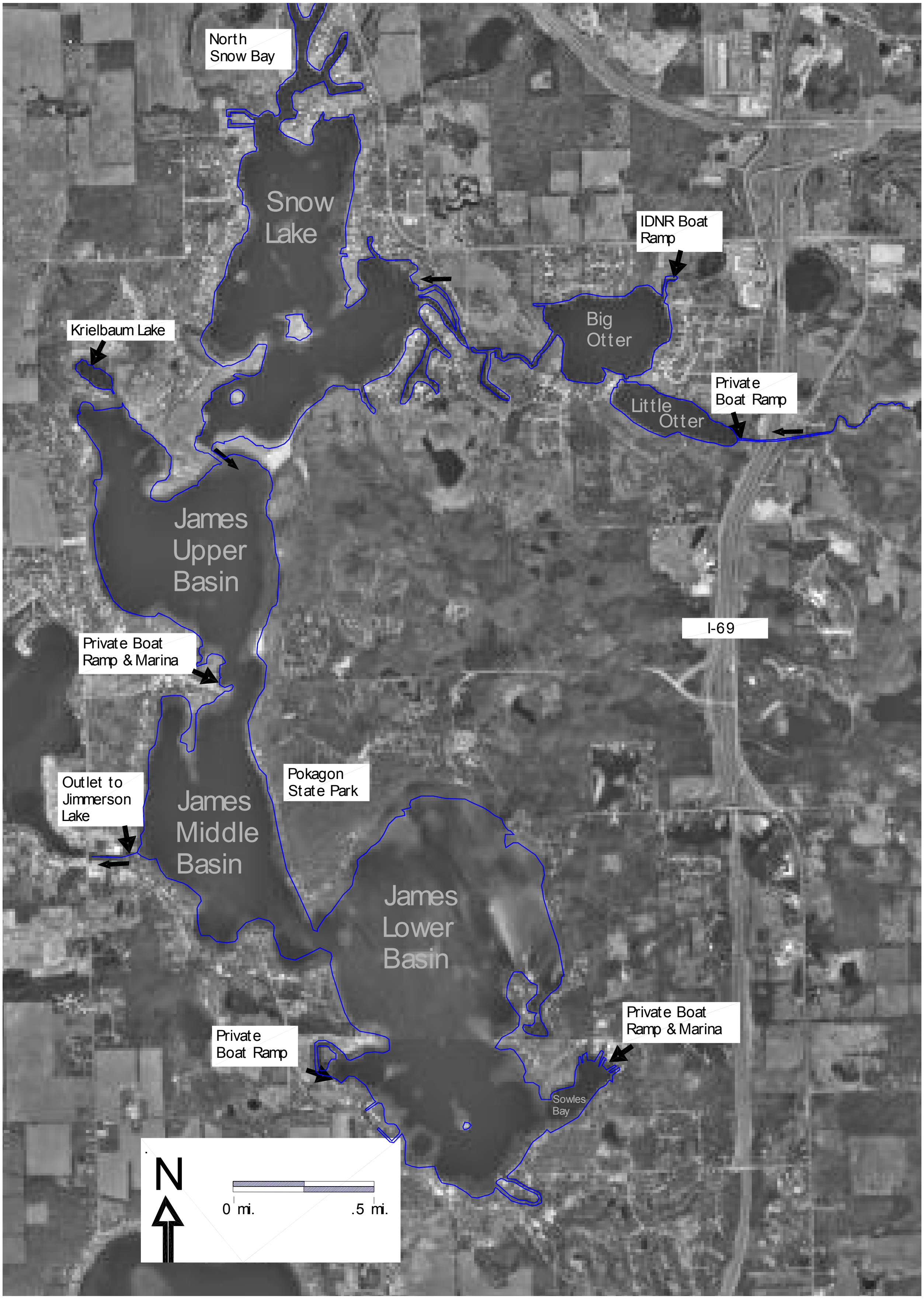



**Figure 2 Satellite Photo of the Upper James Chain (photo source USGS)**

Canoes and kayaks can also be launched at the beach area at Pokagon State Park and slip space is available for hotel guests during the summer. Swimming, fishing, boating, waterskiing, and sailing are all popular activities on the Lake James Chain. Several bass tournaments and bass club outings take place on the chain each season. All three lakes have active homeowner's associations which publish newsletters, hold fundraisers, and have maintained marine patrols on Snow Lake and Lake James through Indiana Department of Natural Resources Lake and River Enhancement (LARE) grant funding. Snow Lake has also developed an Aquatic Plant Management Plant with assistance from the LARE program.

Most of the James Chain watershed lies within Steuben County Indiana. Steuben County is divided into five major watersheds with the eastern edge of the County containing the Fish Creek and St. Joe River watersheds, draining toward Lake Erie via the Maumee River. Roughly the Western three quarters of the county drain toward Lake Michigan via the Crooked Creek, Pigeon Creek, and Turkey Creek watersheds which are tributary to the St. Joseph River. The James Chain and its extended watershed form the headwaters of the Crooked Creek watershed. The total surface area draining through the James Chain is approximately 26,290 acres. The watershed extends from Kinderhook, Michigan at it's northern tip to the City of Angola in the south.(see fig. 3) Its eastward limit is just east of Fremont and its westward limit is just west of Lake James. Included in the watershed is the City of Fremont, Indiana, much of the northern part of Angola Indiana, and businesses and trucking depots that have been established at Jamestown near the intersection of Interstate 69 and the 80/90 Toll Road. For the purposes of this study the immediate watershed for the four principal lakes has been examined for land use and land cover taken downstream of Lake George, Walter's Lakes, and Marsh Lake. The small watersheds for Long Beach Lake, Lake Charles East, Lake Charles West, and Green Lake Have been included in land use and land cover data collection.

Water flow exits the James Chain along the west shoreline of Lake James Middle Basin. It flows west through a navigable channel, passing beneath a concrete bridge at County Road North 300 West and into Jimmerson Lake. Jimmerson Lake overflows over a concrete dam at Nevada Mills forming Crooked Creek. Crooked Creek then flows roughly northwest through the county becoming the Fawn River near Orland in the northwest corner of Steuben County. After passing just north of Orland the Fawn River flows due west meandering back and forth across the Michigan-Indiana state line, eventually joining with the St. Joseph River (tributary to Lake Michigan) at Constantine Michigan.

## 1.1 Statement of Project Purpose

This study was undertaken with joint funding provided by The Snow Lake Cottager's Association, Lake James Association, North Otter Lakes Association and the Indiana Department of Natural Resources Division of Fish and Wildlife Lake and River Enhancement Program (L.A.R.E.).

Project goals were as follows:

- Collect and compile information on the current and historical, chemical, physical, and biological characteristics of the James Chain Lakes and their watersheds.
- Use the above information to look for trends in water quality and the causes of recent water-quality problems including algal blooms and excessive plant growth.
- Explore the biological, social, and recreational implications of past, present, and future watershed land-use and water-quality at The James Chain.
- Recommend a set of possible steps toward protecting and improving water-quality, aquatic biological integrity, and recreational-use at The Lake James Chain.

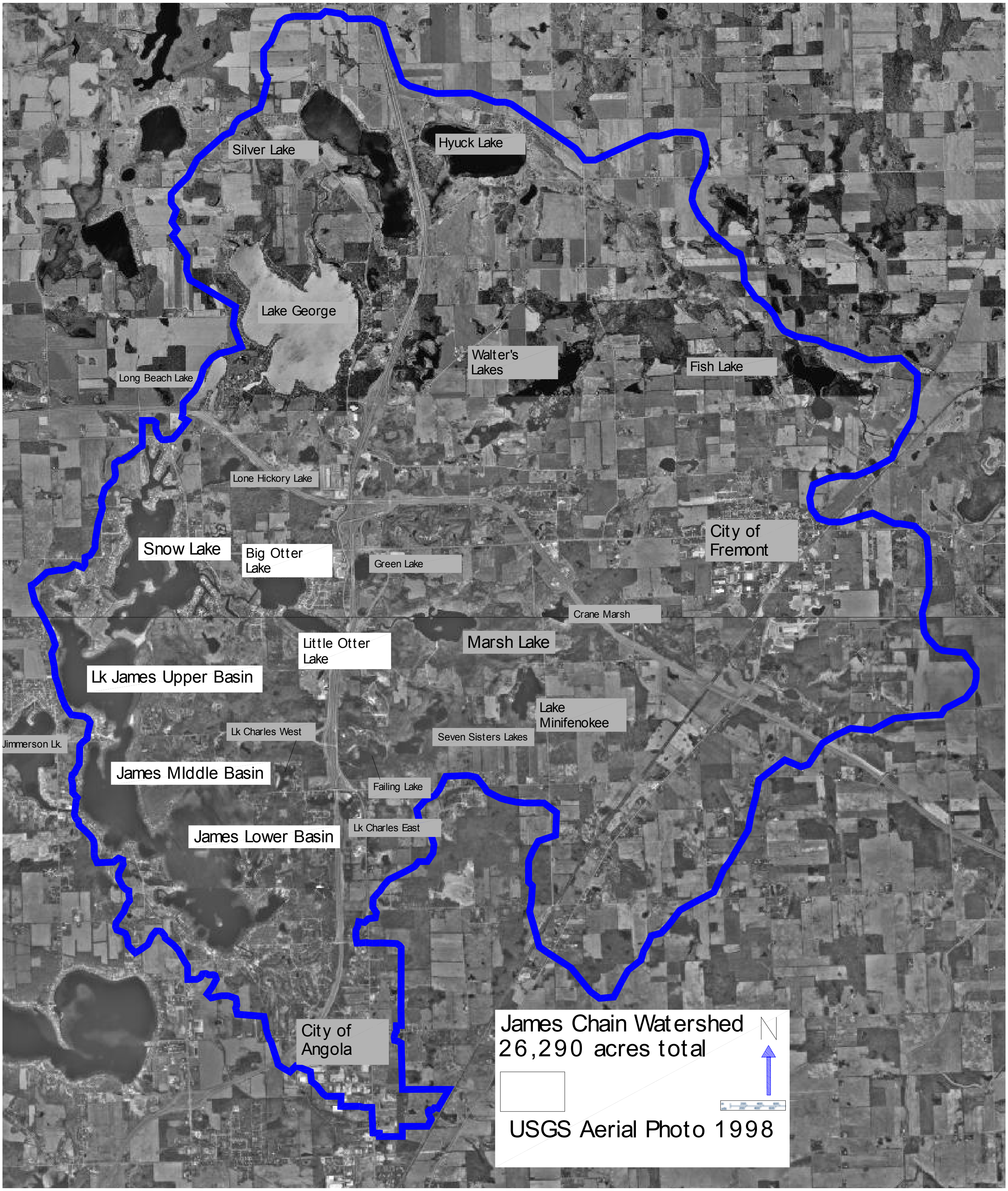



**Figure 3 Satellite Photo of the Upper James Chain Watershed**

### 1.2 Historical Perspective

Like most northeastern Indiana lakes the lakes of the James Chain were formed by large glaciers present in Northern Indiana during the late Pleistocene era, approximately ten thousand years ago. Kettle Lakes like those of the James Chain were formed by large blocks of glacial ice which broke free of the main glacier and were left on the landscape or buried in outwash deposits for a period after the recession of the main glacial edge. As these ice blocks melted they filled their respective depressions in the soil with their melt-water, leaving northeastern Indiana dotted with natural lakes and marshes. The lakes in the James Chain have probably always been hydrologically connected through a network of emergent wetlands and small stream channels between them, but channels connecting the lakes have been widened or deepened enough to allow for the passage of watercraft between the lakes.

The lands surrounding the James Chain were first surveyed in 1831 by E. H. Lytle D.S. This survey information is available through the Indiana State Archive. These surveys were performed to establish section lines and property boundaries prior to the arrival of European settlers. Information recorded in the original survey included the nature of the land and timber on interior section lines. The size and species of bearing trees was also recorded during the surveys to aid in future locating of section and quarter section corners. Basic maps were draw up including rough depictions of marshes, lakes, and streams along with the section lines. It appears that the original watershed for the James Chain contained a mixture of oak savanna, prairie, woodland, wet prairie, marsh, and swamp. Tree species recorded included White and Black Oak, Hickory, Poplar, Elm, Ash, Sycamore, Willow, Beech, Maple, Poplar, Hackberry, and Dogwood. The sizes of bearing trees noted by the surveyors ranged between four and thirty-eight inches in diameter with twenty inch trees being common. Oak barrens (savanna) and rolling barrens (rolling prairie) were commonly listed for the James Chain area and were probably the main type of land cover present. (see Fig. 4) These areas may have been maintained in an open herbaceous (non-woody) plant assemblage through the influence of periodic natural fires started by lightning or fires started by native peoples present in presettlement times. The area probably served as hunting grounds for the Potawatomi Indians who sometimes used burns as a hunting and game habitat management technique. Due to land-use changes and modern fire suppression most James Chain watershed areas not currently in residential, commercial, or agricultural use now contain forest or woody shrubs. Settlement of Steuben County began around the time of the 1831 surveys. Most settlement of Jamestown Township which encompasses the northern half of Lake James, Snow Lake, and the Otter Lakes occurred between 1831 and 1836. (Flaim Cupp 1995) Settlement and conversion of lands to agricultural use continued to progress through the 1800's with a population of 779 listed for Jamestown in 1870. By 1884 nearly all (12,999.84 acres) of the lands in Jamestown were listed for assessment by the township. By the late 1800's most of the area's lands were being converted to agriculture. With land at a premium, attempts at draining many area lakes and wetlands were taking place.

**Figure 4 Oak Barren (savanna) like those originally present on much of the James Chain watershed**

Around the turn of the century A. W. Fruechtenicht, a German immigrant from Fort Wayne became a leader in preventing the drainage of area lakes. Fruechtenicht fought to maintain water levels at Lake James and also Sylvan Lake by working closely with county and state officials, and playing an instrumental part in the building of a dam at Nevada Mills (Jimmerson Lake) which controls the level of the James Chain to this day. (Flaim Cupp 1995) The establishment of cottages on the Lake James Chain had begun by the end of the 19th century. The plat drawing for Spring Point subdivision on Lake James lower basin is dated 1895 followed soon by the map for Lake James Park (Paltytown) in 1899. (see fig. 5) In 1903 an electric railroad line was established from Angola to Paltytown on the southwest shore of Lake James lower basin. Regular service was begun in 1904. This allowed Paltytown to serve as an origin for the development of Lake James. The roads to the lake at that time were poor so residents would take the railroad line to Paltytown and travel to various parts of the lake by boat. A dance hall, pavilion, amusement park, hotel were also operated at Paltytown during the summer months. The railroad continued to operate until 1918. By the 1920's automobiles had become the principle means of travel to the lake. By 1930 Lake James' shoreline already had 29 platted subdivisions and at least four platted subdivisions were located on the east shore of Snow Lake (fig. 8). In 1925 the residents of Steuben County purchased 580 acres along the east shores of Lake James and Snow Lake and presented it as a Christmans gift to the State of Indiana. Another 127 acres were added to the property by the State for a total area of 707 acres. On these parcels in 1926 construction of Pokagon State park and the state owned Potawatomi Inn began. Pokagon State Park currently has 1203 acres of woods and wetlands on the shores of Lake James and Snow Lake.

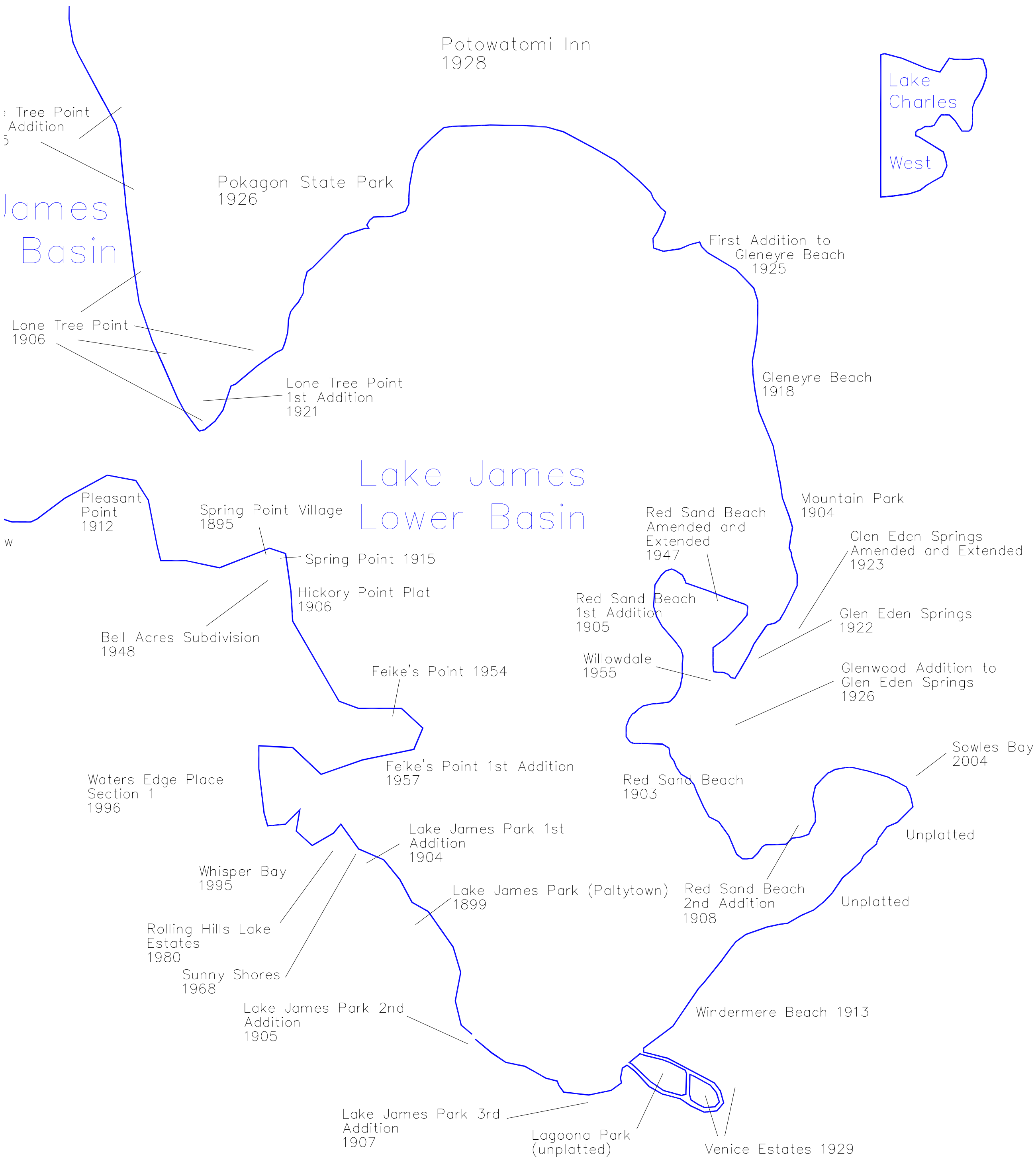



**Figure 5 Steuben County Plat Dates for Lake James Lower Basin Subdivisions**

Big and Little Otter Lakes appear to have been relatively undeveloped on 1938 air photos with the first subdivision, North Otter Lake subdivision on Big Otter Lake being platted in 1948 (see fig. 9). Residential development of all four lakes continues to the present day.

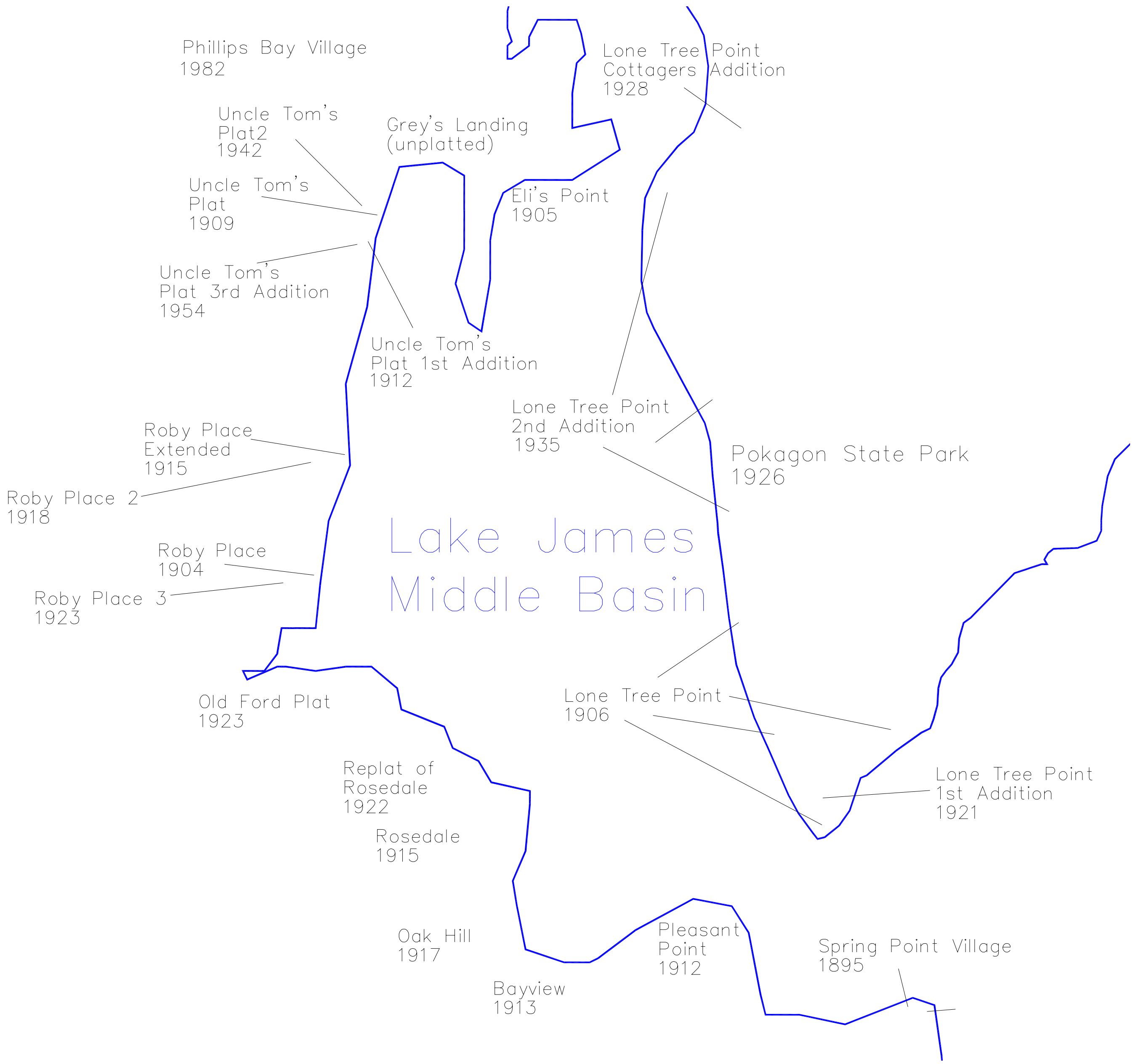



**Figure 6 Steuben County Plat Dates for Lake James Middle Basin**

Nearly all the chain's upland riparian (shoreline) ground outside Pokagon State Park has been developed. Most recent development has proceeded by locating new dwellings on off-lake uplands while providing resident access to the lakes by extending dockage through riparian wetlands. Attempts to provide access to off-lake development through designated lakeside lots are ongoing, but have met resistance in the Steuben County Plan Commission's regulations regarding funneling. Other recent development has also sought to utilize previously constructed shallow channels which may be deepened to provide docking areas for residences.

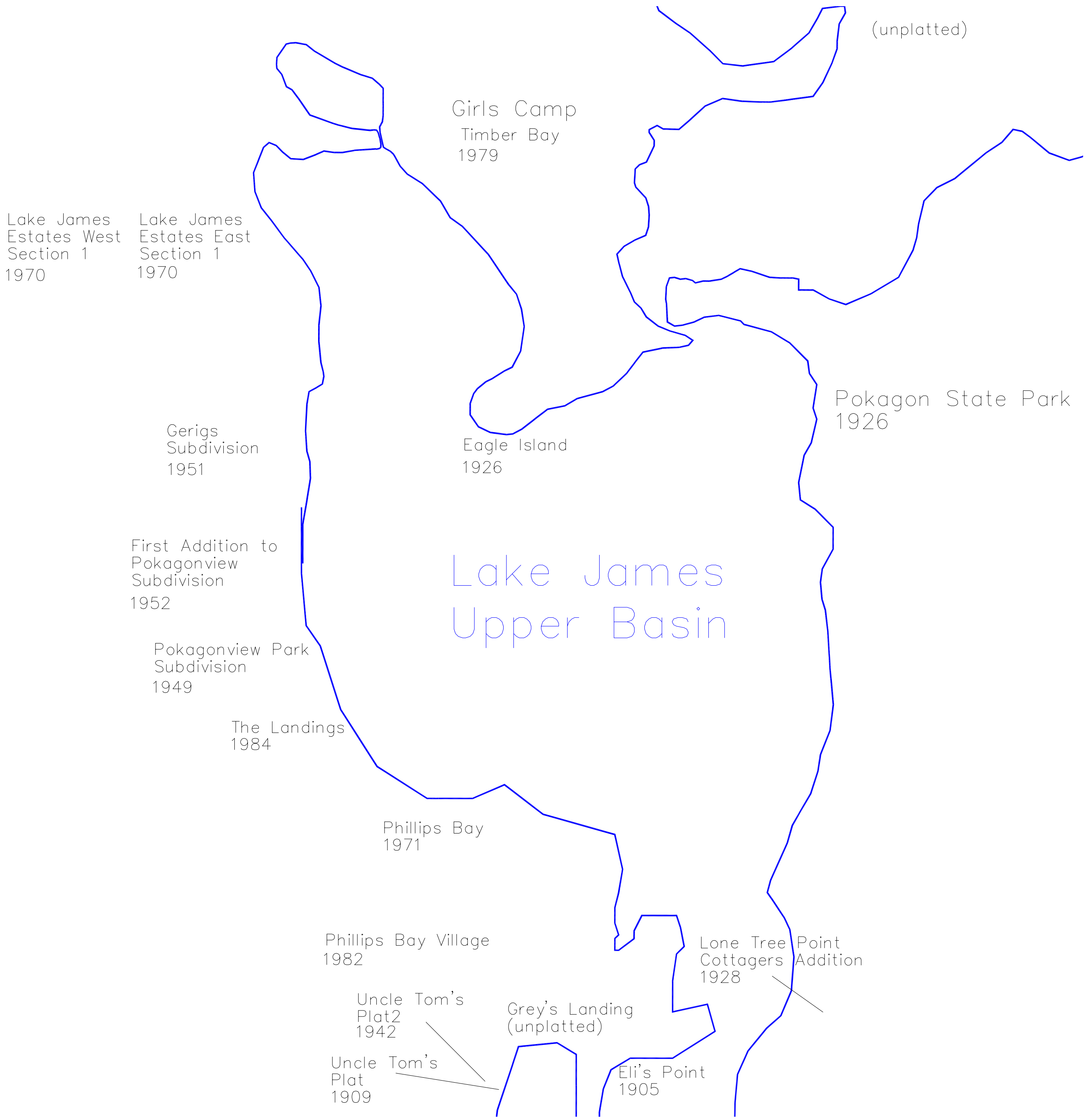



**Figure 7 Steuben County Plat Dates for Lake James Upper Basin**

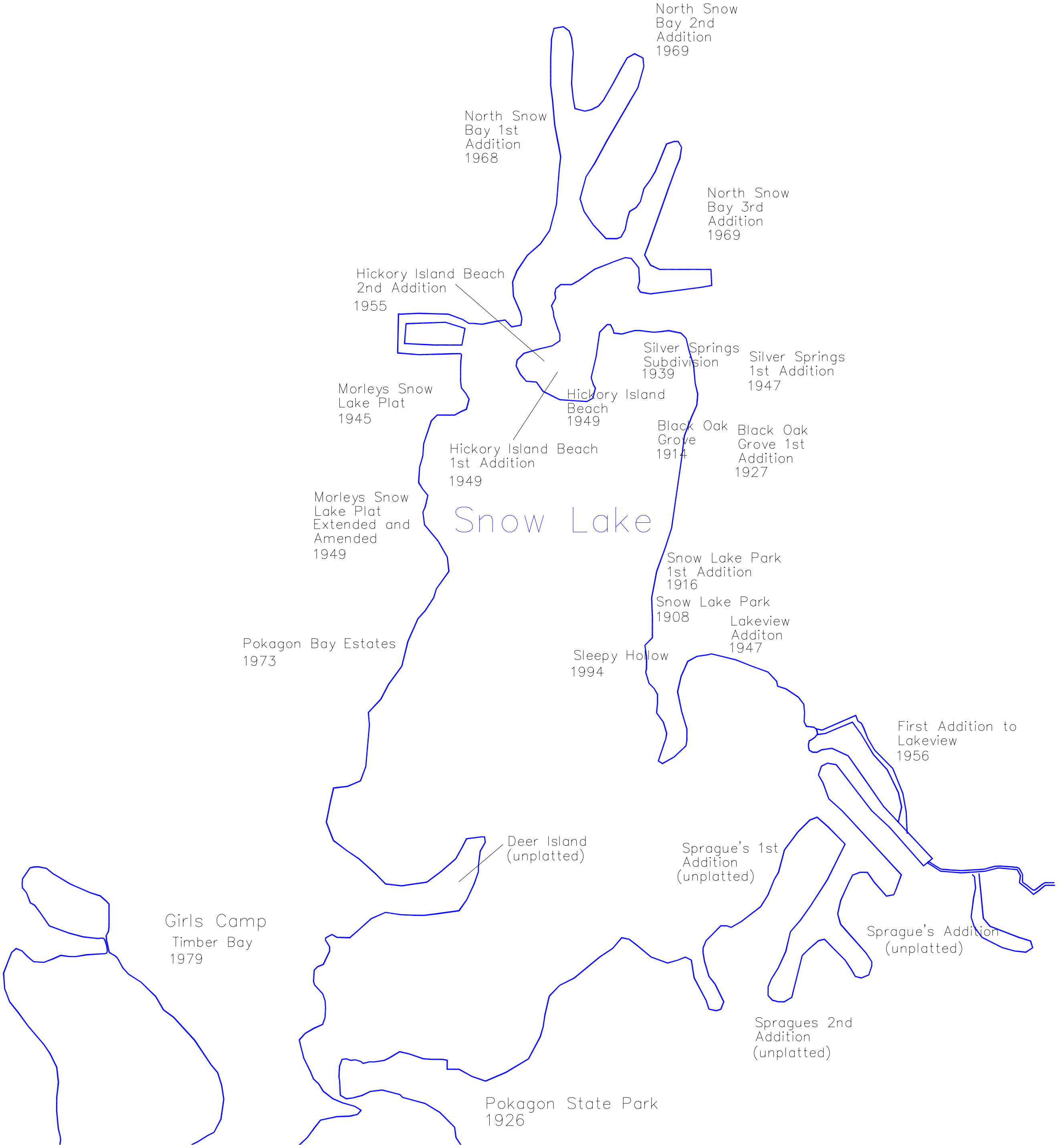



**Figure 8 Steuben County Plat Dates for Snow Lake Subdivisions**

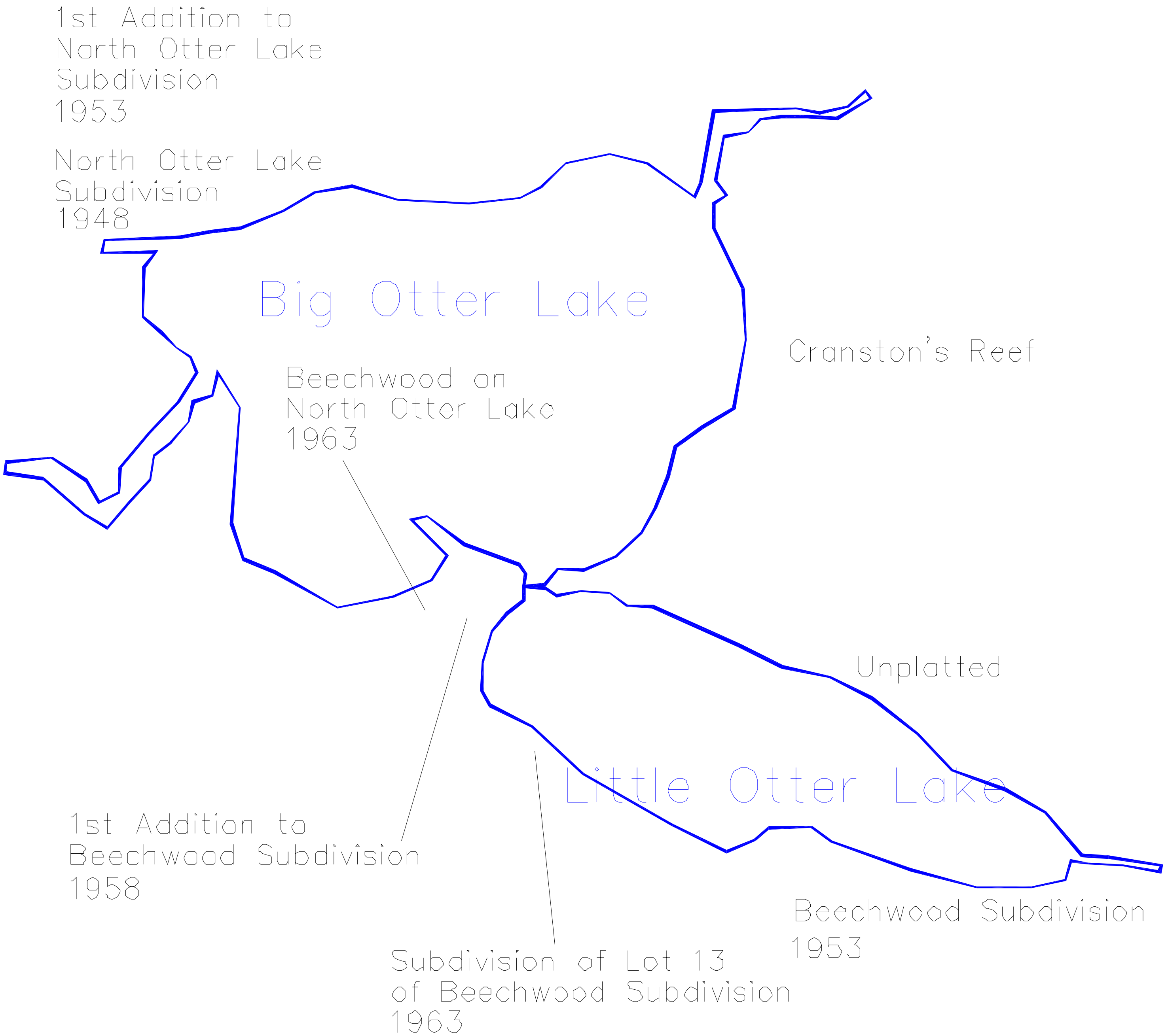



**Figure 9 Steuben County Plat Dates for Big and Little Otter Lakes**

# 2. Lake Characteristics

## 2.1 Morphometry

Morphometry refers to the physical structure of a lake basin. Lake basin physical structure is important because of the way it affects lake mixing, stratification, and biological productivity. The basic morphometry of the individual James Chain basins is summarized below:

Lake James Morphometry

| | |
|---|---|
| Surface area sq feet | 53,516,229.51 |
| Surface area sq meters | 4,971,820.41 |
| area acres | 1228.56 |
| area hectares | 497.18 |
| mean depth ft | 27.00 |
| mean depth meters | 8.23 |
| maximum depth ft | 88.00 |
| maximum depth meters | 26.82 |
| relative depth % | 1.07 |
| volume ac-ft | 33,171.22 |
| volume cu-ft | 1,444,938,196.8 |
| volume gallons | 10,837,036,475.8 |
| maximum length ft | 10,586.11 |
| maximum length meters | 3226.65 |
| maximum width ft | 5512.22 |
| maximum width meters | 1680.12 |
| mean width ft | 5055.33 |
| mean width meters | 1540.86 |
| shoreline length ft | 92,604.86 |
| shoreline length meters | 28,225.96 |
| shoreline development | 3.57 |

**Table 1 Lake James Basic Morphometric Parameters**

Lake James is morphometrically complex with several marshy peninsulas and sunken islands so it provides a variety of biological habitat. It is divided into three distinct basins with one very distinct bay in it's Southeast corner (Sowles Bay) and an additional attached basin (Krielbaum Lake) in the northwest corner of its upper basin (see fig. 10) The total surface area of Lake James is approximately 1229 acres. All three basins are characterized by a deeper central area with a steep step up onto shallower surrounding sand, gravel, or marl bottomed flats of various widths around the lake's edge. All three basins also contain multiple sunken islands or sand bars with the lower basin also containing a single upland island. The upper basin of Lake James is it's deepest with a maximum depth of 88 feet (fig. 11) followed by the middle basin at 76 feet (fig. 12) and the lower basin at 70 feet (fig. 13). Sowles Bay off the southeast corner of James lower basin has a maximum depth of 35 feet and Krielbaum Lake's maximum depth is 20 feet.

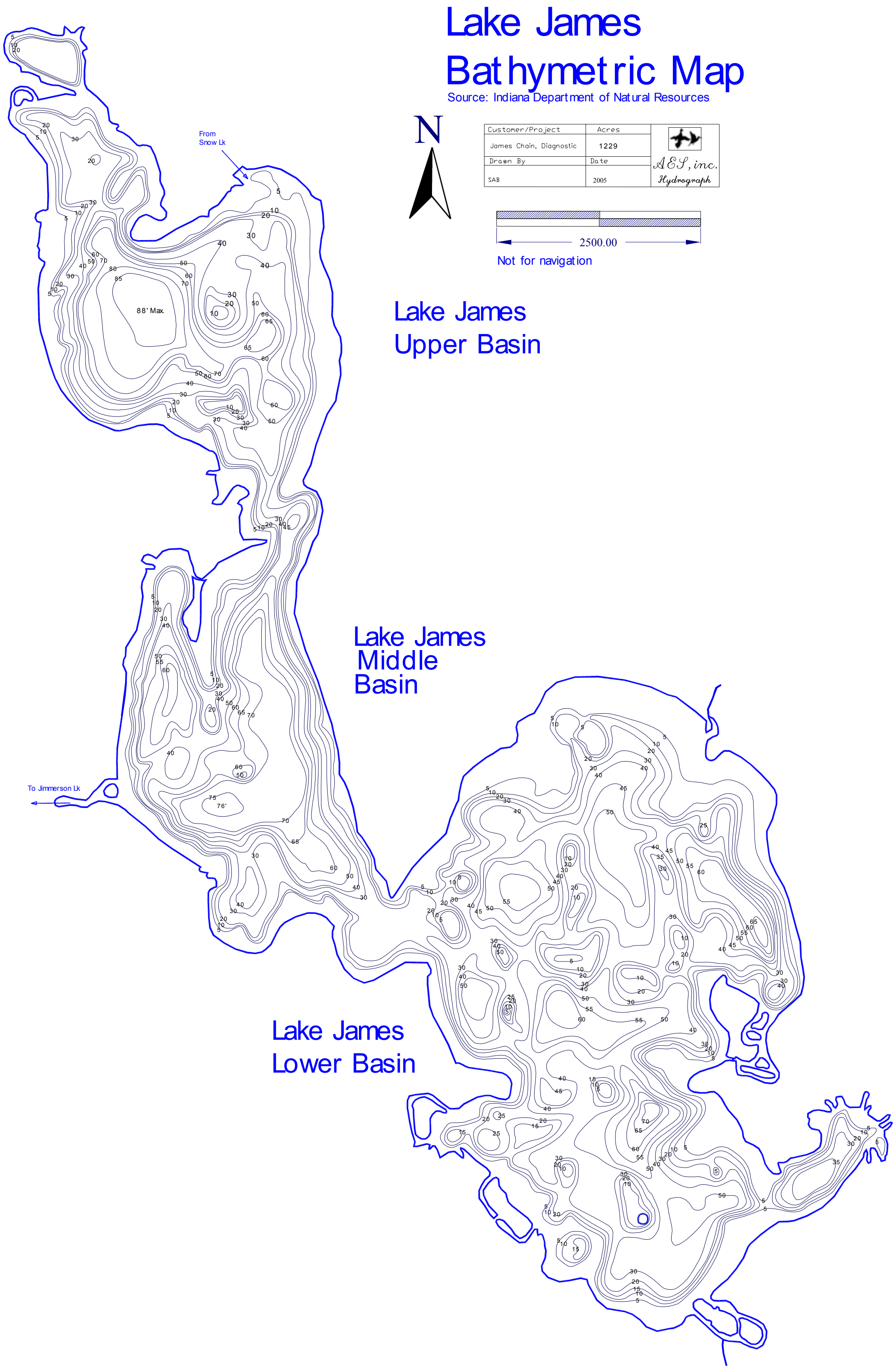



**Figure 10 Lake James Bathymetry**

James has a mean depth of 8.23 meters (27 feet). The *relative depth* of a lake is the ratio of the maximum depth as a percentage of the mean diameter of the lake at the surface, expressed as a percentage. Most lakes have a relative depth of less than two percent. Very deep lakes with a small surface area usually have a relative depth of over four percent. Although it is a relatively deep lake for Indiana, Lake James is also relatively large in terms of it's surface area giving it a relative depth of 1.07 percent. Lake James contains approximately 33,171 acre-feet of water or approximately 10 billion 837 million gallons of water. The *maximum length* of Lake James (farthest distance that wind can act upon the surface of the water without interference from land) is 3226 meters (10586 feet). James' *maximum width* (perpendicular to the maximum length) is 1680 meters (5512 feet). The length of Lake James' shoreline is approximately 28225.96 meters (92605 feet). James' *Shoreline Development* (ratio of shoreline length to the shoreline length of a perfectly circular lake of equal size) is 3.57. The shoreline development of a perfectly circular lake being 1 this is an indication of Lake James irregular shoreline having a good potential for biological productivity due to a relatively long length of interface between the terrestrial and aquatic habitats for the size of the lake. Lake James' shoreline development is increased considerably by the presence of the various channels, bays, and peninsulas.

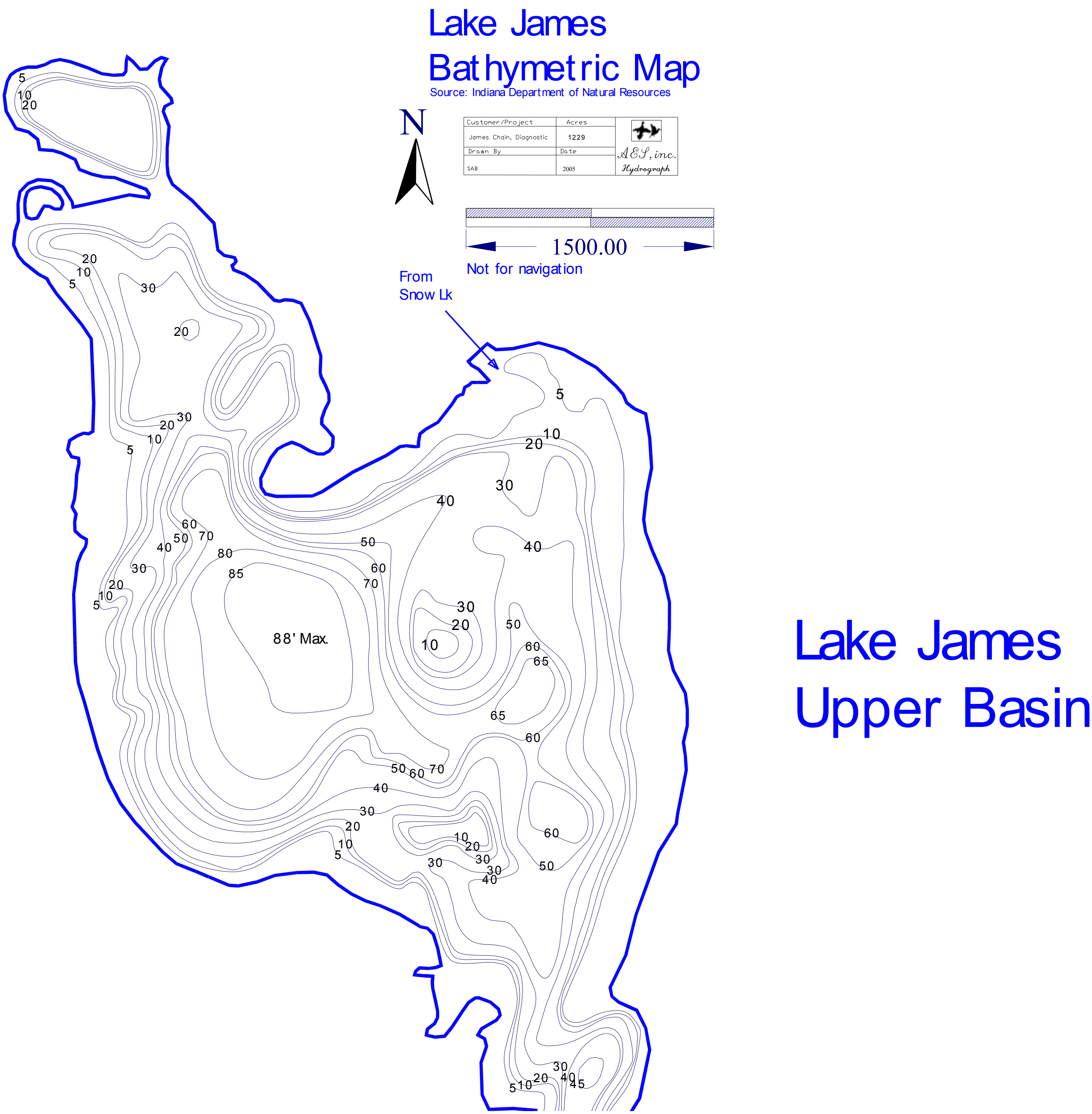



**Figure 11 Lake James Upper Basin Bathymetry**

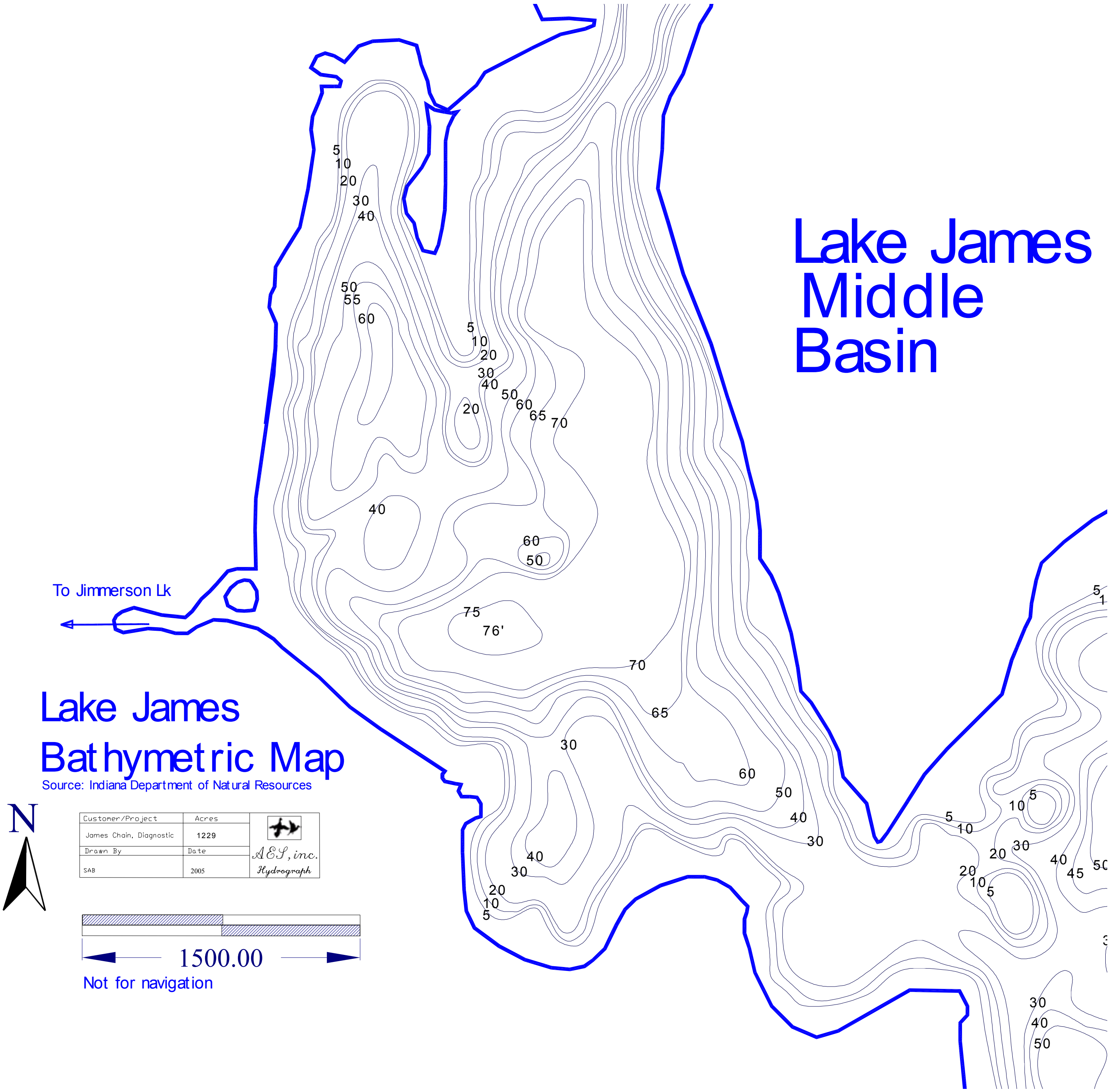



**Figure 12 Lake James Middle Basin Bathymetry**

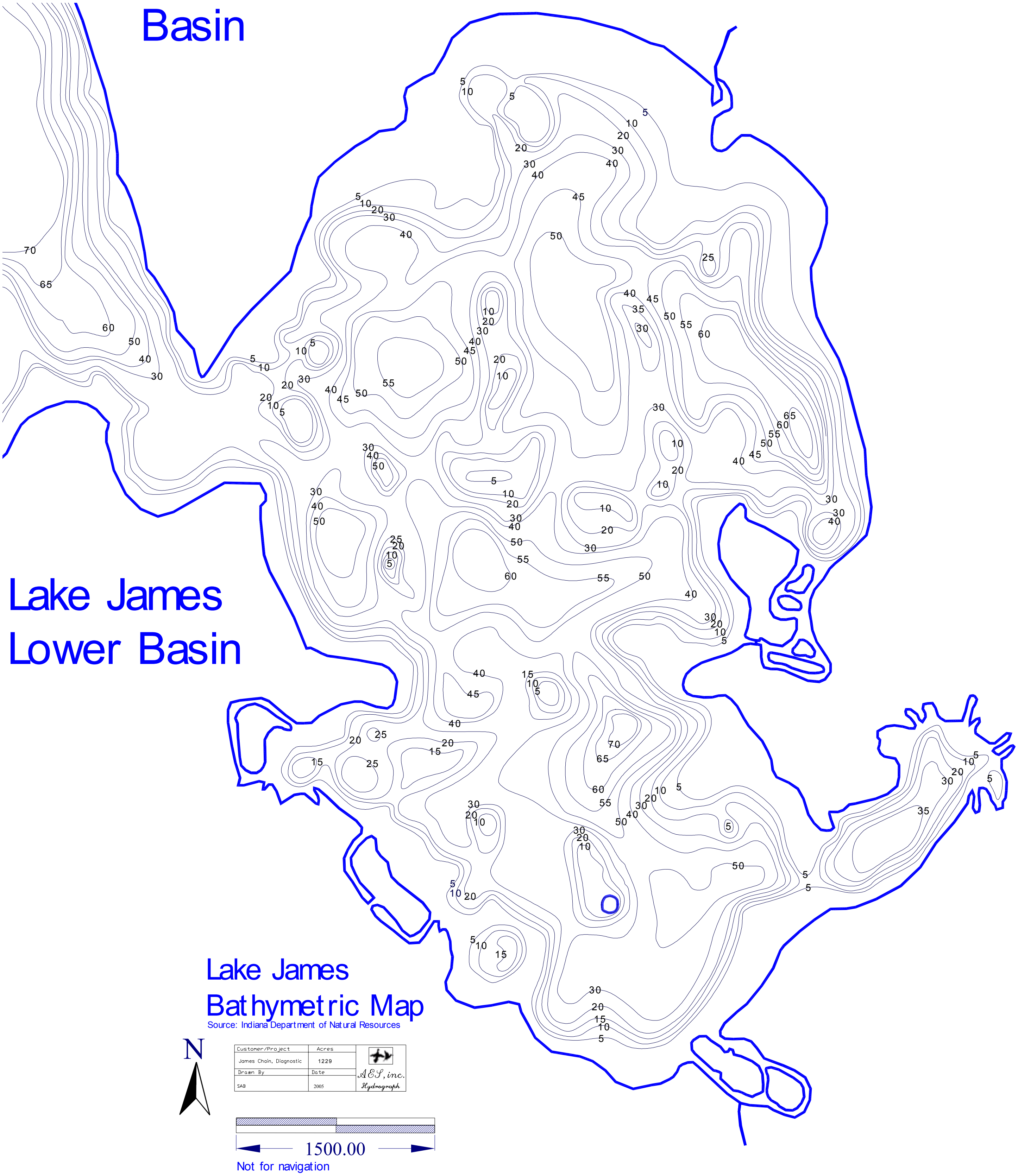



**Figure 13 Lake James Lower Basin Bathymetry**

Snow Lake Morphometry

| | |
|---|---|
| Surface area sq feet | 17,957,171.34 |
| Surface area sq meters | 1,668,275.81 |
| area acres (islands not incl.) | 412.24 |
| area hectares | 166.83 |
| mean depth ft | 28.00 |
| mean depth meters | 8.53 |
| maximum depth ft | 84.00 |
| maximum depth meters | 25.60 |
| relative depth % | 1.76 |
| volume ac-ft | 11,542.72 |
| volume cu-ft | 502,800,797.44 |
| volume gallons | 3,771,005,980.83 |
| maximum length ft | 6940.53 |
| maximum length meters | 2115.47 |
| maximum width ft | 3894.95 |
| maximum width meters | 1187.18 |
| mean width ft | 2587.29 |
| mean width meters | 788.61 |
| shoreline length ft | 54,284.98 |
| shoreline length meters | 16,546.06 |
| shoreline development | 3.61 |

**Table 2 Snow Lake Basic Morphometric Parameters**

Snow Lake is also relatively morphometrically complex, containing several sand bars, sunken islands, marshy islands, and peninsulas. (See fig. 14) With a mean depth of 8.53 meters (28 feet) and a maximum depth of 25.60 meters (84 feet) Snow Lake is relatively deep for a northeast Indiana Lake. Several acres of manmade channels are connected to the north and southeast shorelines of the lake. Along most shorelines and around Snow Lake's submersed islands and sandbars is a broad shallow littoral flat that drops off into deeper waters. In most areas this littoral shelf is 100 to 300 feet wide and sand, gravel, or marl bottomed. In some calm backwater areas and areas near tributary inlets the lake bottom is primarily silt and muck. Along the lake's middle-eastern shoreline the bottom is primarily sand and gravel. The total surface area of Snow Lake is approximately 412 acres. Snow Lake has a relative depth of 1.76 percent and contains approximately 11,543 acre-feet of water or approximately 3 billion 771 million gallons of water. The maximum length of Snow Lake is 2116 meters (6941 feet). Snow's maximum width (perpendicular to the maximum length) is 1187 meters (3895 feet). The length of Snow Lake's shoreline is approximately 16,546 meters (54,285 feet). Snow Lake's Shoreline Development is close to that of Lake James at 3.61. This is an indication of Snow Lake also having a good potential for biological productivity due to a relatively long length of interface between the terrestrial and aquatic habitats for the size of the lake.


**Figure 14 Snow Lake Bathymetry**

Big Otter Lake Morphometry

| | |
|---|---|
| Surface area sq feet | 2,943,916.87 |
| Surface area sq meters | 273,498.83 |
| area acres (islands not incl.) | 67.58 |
| area hectares | 27.35 |
| mean depth ft | 26.00 |
| mean depth meters | 7.92 |
| maximum depth ft | 38.00 |
| maximum depth meters | 11.58 |
| relative depth % | 1.96 |
| volume ac-ft | 1757.16 |
| volume cu-ft | 76541,838.52 |
| volume gallons | 574,063,788.87 |
| maximum length ft | 2368.94 |
| maximum length meters | 722.05 |
| maximum width ft | 1834.48 |
| maximum width meters | 559.15 |
| mean width ft | 1242.71 |
| mean width meters | 378.78 |
| shoreline length ft | 8959.88 |
| shoreline length meters | 2730.97 |
| shoreline development | 1.47 |

**Table 3 Big Otter Lake Basic Morphometric Parameters**

Big Otter Lake is comparatively uncomplicated in terms of its morphometry but does contain some shoreline irregularities, two excavated channels, and one sunken island. (see fig. 15) Its surface area is approximately 68 acres. With a mean depth of 7.92 meters (26 feet) and a maximum depth of 11.58 meters (38 feet) Big Otter Lake has typical depth characteristics for a northeast Indiana lake of its size. Along most shorelines and around Big Otter's submersed island a relatively narrow littoral area drops off sharply into deeper waters. In most areas this littoral shelf is 15 meters wide or less and sand, silt, or marl bottomed. Big Otter Lake has a relative depth of 1.96 percent and contains approximately 1757 acre-feet of water or approximately 574 million gallons of water. The maximum length of Big Otter Lake is 722 meters (2369 feet). Big Otter's maximum width (perpendicular to the maximum length) is 559 meters (1835 feet). The length of Big Otter's shoreline is approximately 2731 meters (8960 feet) long. Big Otter's Shoreline Development is 1.47. Big Otter Lake has a moderate potential for biological productivity along its shoreline due to a moderately short length of interface between the terrestrial and aquatic habitats for the size of the lake.

Little Otter Lake Morphometry

| | |
|---|---|
| Surface area sq feet | 1,334,022.06 |
| Surface area sq meters | 123,934.70 |
| area acres | 30.62 |
| area hectares | 12.39 |
| mean depth ft | 21.00 |
| mean depth meters | 6.40 |
| maximum depth ft | 37.00 |
| maximum depth meters | 11.28 |
| relative depth % | 2.84 |
| volume ac-ft | 643.12 |
| volume cu-ft | 28,014,463.26 |
| volume gallons | 210,108,474.45 |
| maximum length ft | 2405.57 |
| maximum length meters | 733.22 |
| maximum width ft | 749.29 |
| maximum width meters | 228.38 |
| mean width ft | 554.56 |
| mean width meters | 169.03 |
| shoreline length ft | 5685.96 |
| shoreline length meters | 1733.08 |
| shoreline development | 1.39 |

**Table 4 Little Otter Lake Basic Morphometric Parameters**

Little Otter lake has a relatively simple morphometry with few shoreline and bottom contour irregularities. (see fig. 15) Its surface area is approximately 31 acres. With a mean depth of 6.4 meters (21 feet) and a maximum depth of 11.28 meters (37 feet) Little Otter Lake is slightly deeper than most northeast Indiana lakes of its size. It's characterized by a very limited littoral area. The littoral shelf around Little Otter is relatively narrow, being less than ten meters wide in most places and sand, silt, or marl bottomed. Wetland shorelines drop off immediately into deep water along much of the west end of the lake. The exception is at the east end of the lake near the Follet Creek inlet where a thick clay and silt sedimentation has taken place building a gradually sloping littoral shelf. Little Otter Lake has a relative depth of 2.84 percent and contains approximately 643 acre-feet (210 million gallons) of water. The maximum length of Little Otter Lake is 733 meters (2406 feet). Little Otter's maximum width (perpendicular to the maximum length) is 228 meters (749 feet). The length of Little Otter's shoreline is approximately 1733 meters (5686 feet). Little Otter's Shoreline Development is 1.39. Little Otter Lake has only a moderate potential for biological productivity in terms of shoreline irregularities due to a moderately short length of interface between the terrestrial and aquatic habitats for the size of the lake.

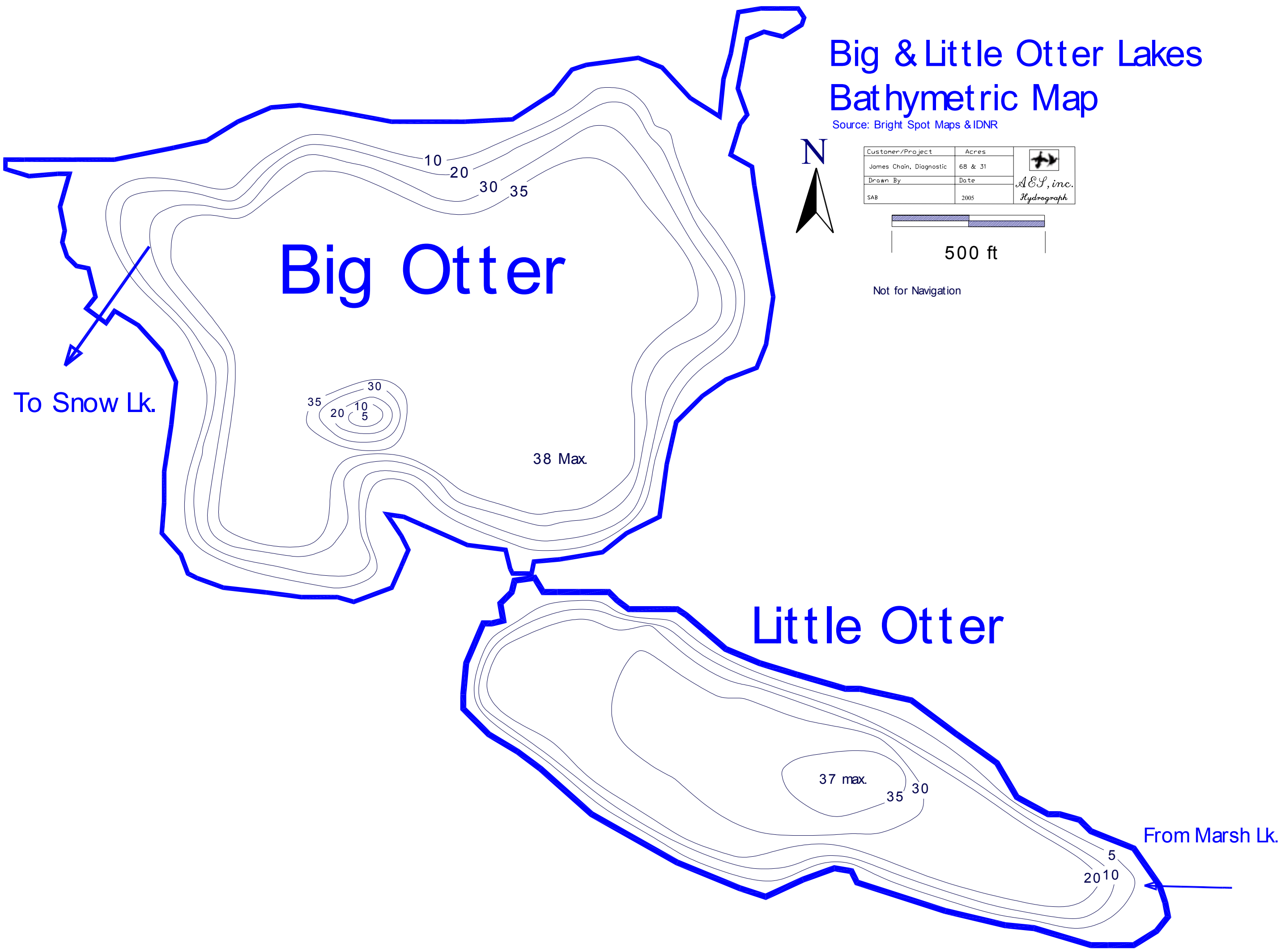



**Figure 15 Big and Little Otter Lakes Bathymetry**

## 2.2 Shorelines

A lake's shorelines can be important with respect to the biological integrity of the lake and the lakes water quality. Glacial stones, gravel, woody structure, and wetland vegetation all provide habitat for certain types of juvenile and adult fish and benthic macroinvertebrates. Riparian wetlands and emergent shoreline vegetation can provide a natural buffering or filtering effect for lake-bound runoff. Stones, woody structure, and wetland vegetation can help buffer wind driven or boat-caused wave energy and stabilize shoreline soils prone to erosion. A survey of the James Chain's shoreline types was performed by traversing the shoreline in a boat carrying a WAAS enabled hand-held GPS unit. Waypoints were recorded at each significant change in shoreline types and then converted to computer aided drawing coordinates and placed on a map of the lakes. The shorelines of The James Chain were classified according to the following types:

| Shoreline Type | Description |
|---|---|
| Turfgrass/unprotected | Lawn to the waters edge at the time of the survey, few or no added stones, rip rap or other structures to armor the shoreline |
| Glacial Stone | A significant amount of added natural rounded stones or stone/concrete rip rap present to armor the shoreline against erosion |
| Concrete Seawall | Poured or placed flat concrete structure at or near the waterline at the time of the survey |
| Emergent Vegetation | A significant amount of native emergent plants present on, along or just lake ward of the shoreline |
| Railroad Ties/wooden | Stacked or driven railroad ties, landscape timbers or wooden seawall |
| Sand Beach | Relatively Level sandy substrate present at and just above the waterline lacking significant indication of erosion |
| Natural Wooded | Timber grows to the lakes edge. Fallen trees, root systems, shrubs etc. and some emergent vegetation provide soil stabilization |
| Corrugated Steel Sheet Pile | Driven steel seawall |
| Eroding | Shows obvious signs of loss of soil to the lake waters |

**Table 5 Descriptions of Shoreline Classifications Used in the Survey**

Originally the James Chain shorelines were probably dominated by emergent vegetation. Today this shoreline still contains significant amounts of emergent vegetation but many developed areas have been armored with glacial stone or concrete seawalls. Wetland shoreline plants are a positive asset with respect to water quality on the Lake James Chain and should be encouraged where possible. In areas susceptible to erosion by wave action glacial stone is the preferred method of artificial shoreline armoring. The complex habitat offered by the stones is more beneficial to fish and wildlife than most other forms of shoreline armoring and the many angles of refraction presented by the stone help dissipate energy from waves striking the shore rather than reflecting wave energy back lake-ward like concrete seawalls. Some shoreline areas are also dominated by unprotected turfgrass. A few of these areas also contain some amount of emergent vegetation or an uncut strip of grasses along the lakes edge. Both are assets from a water quality standpoint and should be encouraged. As an added benefit Canada geese that cause problems for residents at the lake can be deterred by an uncut strip of vegetation along the shoreline. This acts to provide a barrier to accessing lawns for grazing. On December 11, 2005 237 Canada Geese were noted to be using the James Upper Basin during partial ice cover. Several mated pairs of geese were also noted on the chain in the spring of 2005. In areas where possible, leaving an emergent vegetation or uncut buffer strip can help alleviate problems with grazing Canada Geese. Shoreline erosion was relatively minor across all shoreline types on the James Chain with the exception of some steep banked crumbling spoil deposit areas near the mouth of North Snow Bay and some steep eroded shoreline areas at Pokagon State Park. ( fig. 16)

**Figure 16 Sediment from Erosion along the Pokagon Shoreline Leaves its Signature in a Plant Free Area on the Lake Bottom**

The lack of obvious erosion on the James Chain is probably attributable to several thousand feet of shoreline being armored with glacial stone or concrete seawalls. Erosion from boat traffic passing through the channels between the lakes has widened the channels over the years and brought complaints from some residents. Small islands on Snow Lake and Lake James have also eroded over the years, likely from wind and wake driven waves. Use of glacial stone to help absorb wave energy along shorelines may help slow this process. Enforcing an idle speed limit will be the best way to prevent erosion and disturbance of wetland shorelines in channel areas. Enforcing the existing ten mile per hour speed limit on Big and Little Otter Lake can help protect wetland shorelines in those areas. Encouraging the planting and growth of emergent vegetation, and encouraging the establishment of tall vegetated shoreline buffer strips along James Chain Lakes' edges will help to prevent the development of shoreline erosion in the future. In areas requiring shoreline armoring the use of glacial stone should be encourage over concrete, wooden, or steel seawalls. Emergent vegetation plantings can also be used in combination with glacial stone to provide further buffering of wave energy in some areas. Refacing of concrete seawalls with glacial stones can also help absorb wave action. A single refacing with glacial stones on concrete seawalls is now allowed without IDNR permitting for this reason.

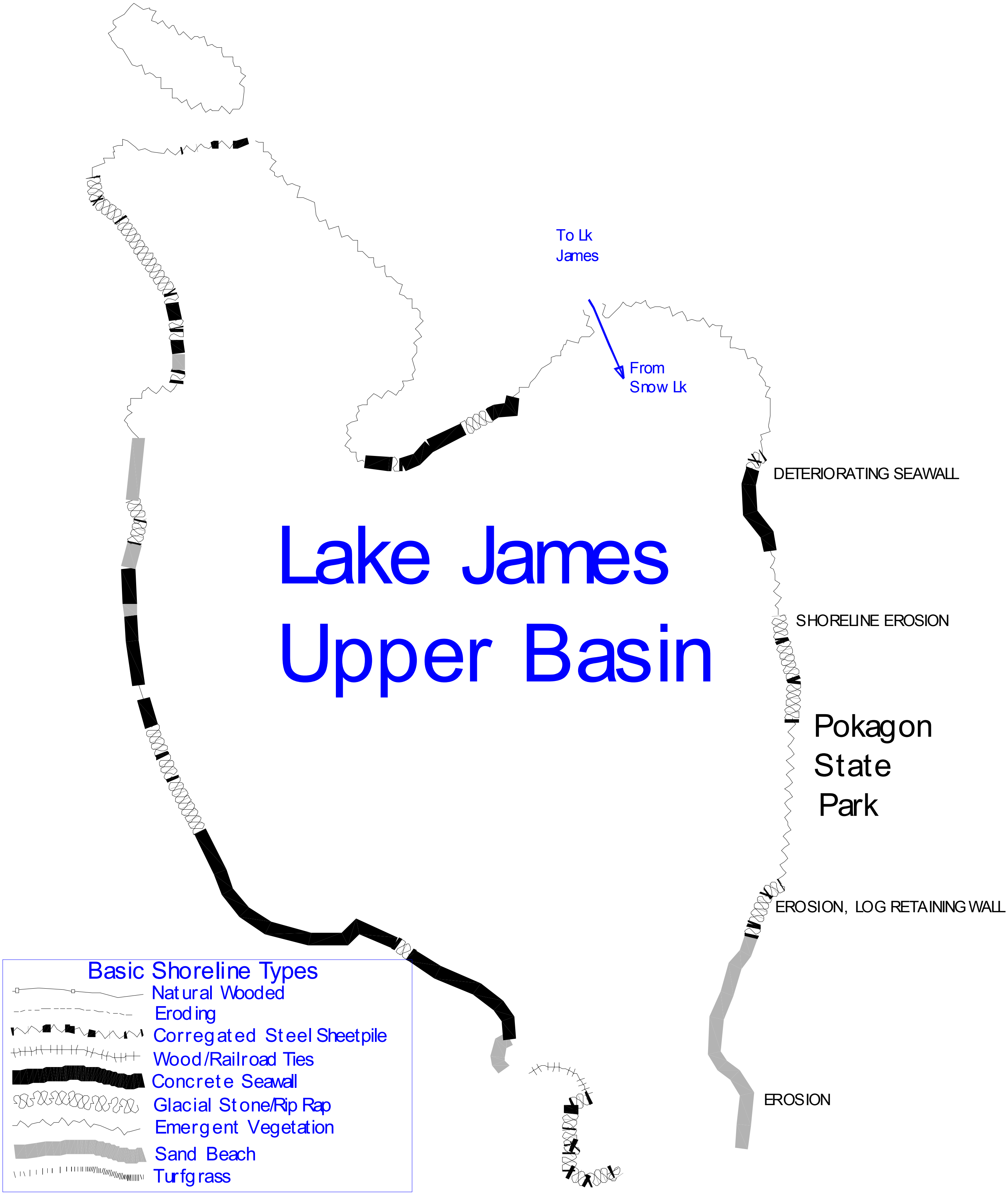



**Figure 17 Lake James Upper Basin Shoreline Types**

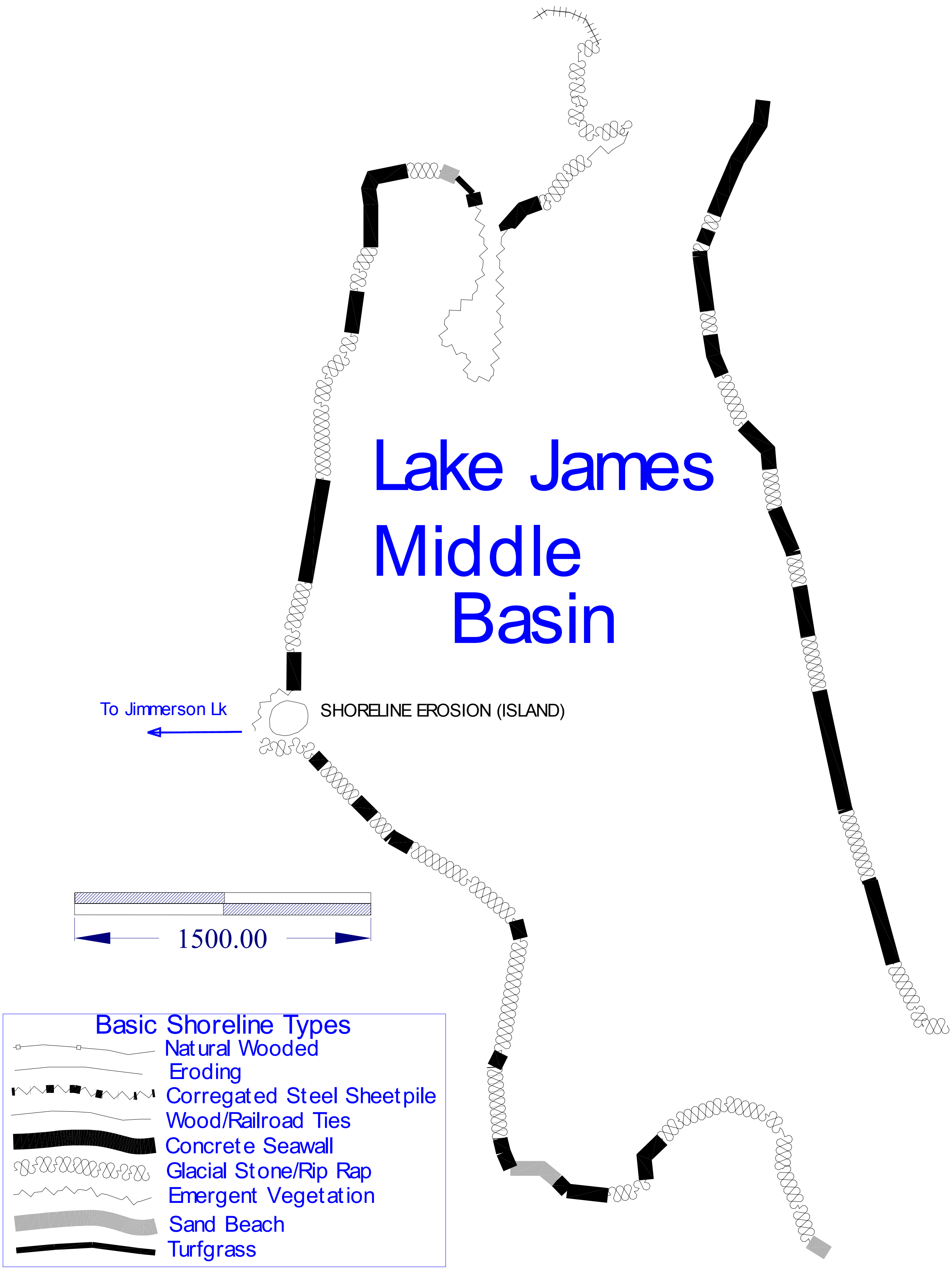



**Figure 18 Lake James Middle Basin Shoreline Types**

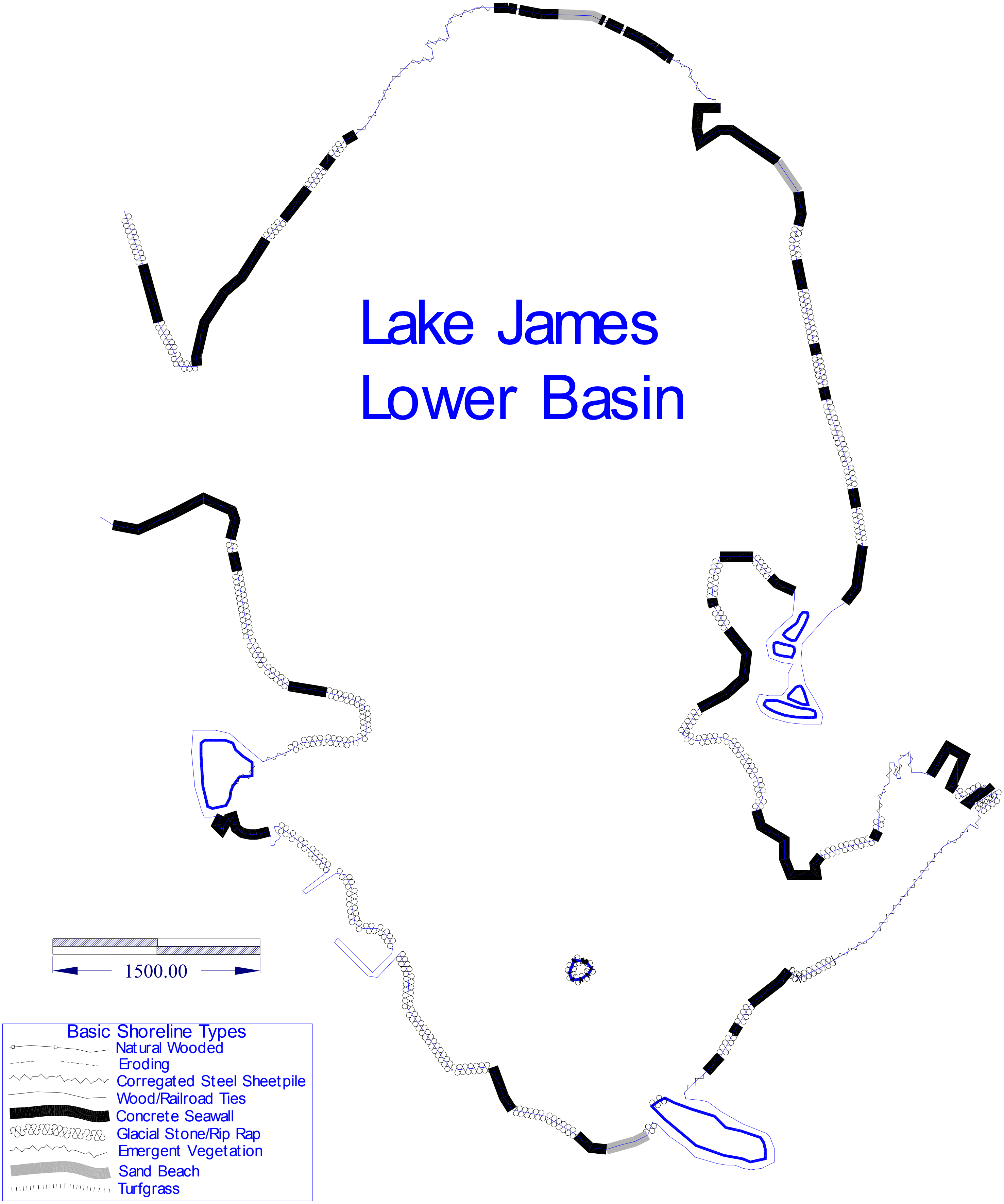



**Figure 19 Lake James Lower Basin Shoreline Types**

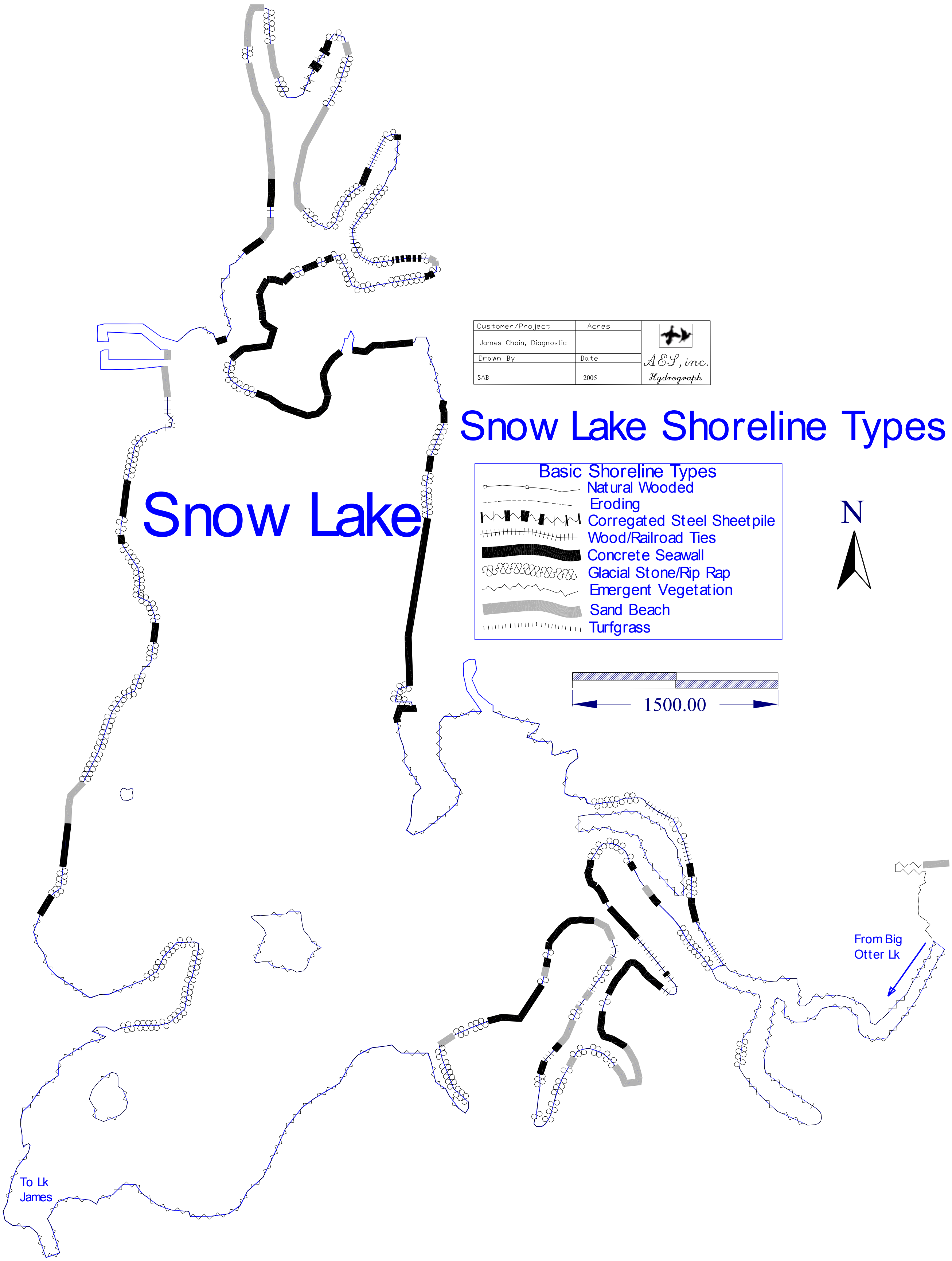



**Figure 20 Snow Lake Shoreline Types**

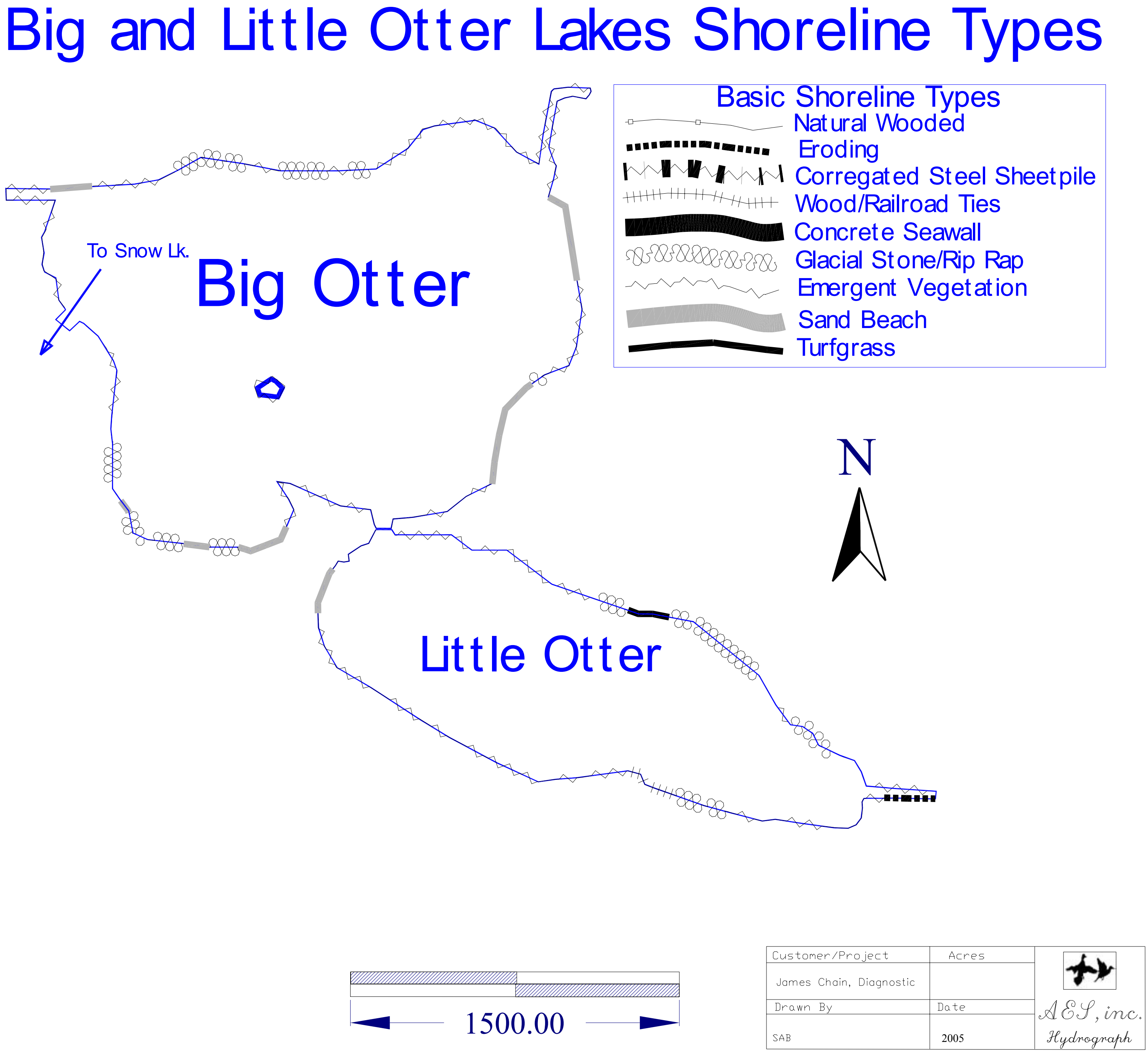



**Figure 21 Big and Little Otter Shoreline Types**

## 2.3 The Lake James Chain Fisheries

The Lake James Fishery

Fishing is a very popular activity on all the James Chain lakes in both summer and winter. The chain supports several bass tournaments each season. Lake James is noted for being a productive Northern Pike fishery and both Lake James and Snow Lake are very popular with ice-fisherman seeking Bluegills and Crappie. IDNR general fisheries surveys are on file for Lake James for 1975, 1989 and 2000. General surveys are performed on freshwater public lakes to evaluate the fishery and provide any management recommendations accordingly. Information summarized from the IDNR general fisheries surveys is below.

In June 2-5, 1975 IDNR fisheries biologists used a combination of gill netting, trap netting and nighttime electrofishing to collect fish from Lake James. 574 fish representing 20 species were collected. Bluegill were dominant by number at 22.5%, yellow perch were second most numerous at 16.4%, followed by rock bass 11.7%, and yellow bullhead 10.6%. Lake James bluegills were characterized by above average condition factors (relative plumpness) and average growth rates. Bluegills ranged in size from 3 to 10 inches in length with 82.6% being a harvestable size of 6 inches or larger. 94 Yellow Perch were collected. Growth rates and condition factors were average. 62% of the perch were a harvestable size of 8 inches or longer in size. Fisheries biologists noted that Lake James was one of the few remaining natural lakes that supports a sustaining rock bass and smallmouth bass fishery. 61% of the rock bass collected were seven inches or larger. Seven Smallmouth Bass collected ranged in size from nine to 16.5 inches. The biologists classified the fishery as excellent being characterized by many desirable species with a large percentage of fish being of a harvestable size. It was recommended that due to the adequate forage base, large size of the lake, and satisfactory water quality, Lake James should be stocked with walleye fry beginning in 1976. Stocking was recommended to also include Snow and Jimmerson Lakes.

On May 15-19 of 1989 another general fisheries survey was conducted on Lake James. The survey again utilized a combination of gill nets, trap nets, and nighttime electrofishing. 1344 fish representing 23 species were collected. By number, yellow bullhead were dominant at 19.3%, bluegill at 18.2% and yellow perch at 10.8%, followed by Brown bullhead 9.4% and largemouth bass 8.9%. Over 93% of the 260 yellow and brown bullheads collected 8 inches or larger and considered harvestable size. It was noted that timing (mid to late May) of collection may have been somewhat responsible for the large number of bullheads as they become very active at that time. Bluegill comprising 18.2% of the sample by number ranged in length from 1.8 inches to 8.9 inches. Bluegill growth rates and weights were average for northeast Indiana. 30.6% of the bluegill collected were 6 inches or larger and considered harvestable size. This was down from 82% in 1975. A total of 145 yellow perch were collected and ranged in length from 3.1 inches to 10.8 inches. Growth rates were average for age I and II fish but below average for the older year classes. Only 4.1% were a catchable size of eight inches or longer. This was also down from the figure of 62% harvestable size in 1975. Largemouth Bass collected ranged in length from 5.5 to 16.8 inches. 7.6% were a harvestable size of 14 inches or larger. Bass growth rates and weights were average. It was concluded that Lake James supports a good population of sportfish with bullhead, yellow perch and largemouth bass being dominant. It was noted that bullheads active in the evening could be an excellent opportunity to introduce youngsters to the sport of fishing and could offer good table fare. Northern Pike and Largemouth Bass populations were noted to have increased with Lake James supporting one of the largest pike populations in Northeast Indiana. It was noted that water quality at Lake James was good and the efforts on the part of residents to address wastewater through a treatment cluster system were commendable. It was also noted that some nutrients and sediments were entering Lake James through Croxton Ditch and land use practices in that waterway should be addressed. Aquatic vegetation was not noted to be a problem and no fish disease or parasites were noted. The recommendation was made that IDNR continue working to acquire land and construct a public access site on Lake James.

On 6/12-16 of 2000 another IDNR general survey of Lake James was performed. Bluegill were the most numerous fish collected comprising 52 percent of the sampling by number. They ranged in length from 1.5 to 9.3 inches. 207 Largemouth Bass were collected comprising 11.3 percent of the sample. The Bass ranged in length from 3.8 to 16.4 inches. Only 6.3 percent were of a harvestable size of 14 inches or larger. Growth rates were average. Electrofishing catch rates for largemouth bass had increased from 79.3 fish per hour in 1989 to 118.3 fish per hour in 2000. Rock bass were third most abundant in the survey at 8.7 percent. Their lengths ranged from 2.5 to 10.2 inches. Rock Bass growth rates and weights were average. Just over 26 percent were of a harvestable size of eight inches or larger. It was summarized that the lake supported a good sport fishery dominated by bluegill and largemouth bass. It was noted that numerous other sport fish species were also available in numbers and sizes suitable to provide angling opportunity. Selected Lake James fishery data is provided in tables 6,7,8, and 9.

Walleye on the James Chain

Walleye fry were stocked in the James Chain in 1976, 1978, and 1980. In apring of 1980 and 1982 Lake James was stocked with 142,695 1.2 to 3.2 inch walleye fingerlings. In 1982 195,191 fish of an average length of 1.5 inches were stocked in Lake James. Follow up sampling was performed using gill nets. Some walleye collected showed excellent growth rates but the sampling indicated inconsistent survival. Anglers continued to catch some walleye in Lake James, Snow Lake and other lakes in the chain. This indicated that the fish had migrated throughout the chain, possibly resulting in a lower than normal stocking density. In 1986 fisheries biologist performed walleye spot check sampling to investigate reports of walleye being caught. No Walleye were recovered in the sampling, but biologists did find one walleye dead on the surface of Lake James. In June of 2003 the James Chain was again stocked with Walleye. 112,880 fingerlings were stocked in Lake James. 37,790 were stocked downstream of Lake James in Jimmerson Lake. Snow Lake received 36,600 fingerlings. In June of 2004 the stocking was repeated with Lake James receiving 122,871, Jimmerson Lake receiving 48,217, and Snow Lake receiving 50,750. Subsequent fall electrofishing was performed to gauge walleye survival. The sampling failed to produce any walleye from the stocking so the program has been discontinued. It is unknown why recent walleye stockings on the James Chain appear to have been unsuccessful. Adult walleye were collected in the sampling so the chain apparently either has been stocked to some extent privately or a remnant population of reproducing walleye is present in the James Chain.

| Number Collected | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | 129 | 245 | 955 |
| Hybrid bluegill | 0 | 1 | 5 |
| Longear sunfish | 0 | 1 | 0 |
| Yellow perch | 94 | 145 | 81 |
| Rock bass | 67 | 89 | 160 |
| Yellow bullhead | 61 | 260 | 118 |
| Warmouth | 42 | 74 | 50 |
| Longnose gar | 36 | 1 | 17 |
| Spotted gar | 0 | 0 | 17 |
| Largemouth bass | 32 | 119 | 207 |
| Brown bullhead | 26 | 127 | 13 |
| Redear sunfish | 24 | 52 | 61 |
| Pumpkinseed | 12 | 51 | 34 |
| Bowfin | 9 | 6 | 6 |
| Golden shiner | 7 | 10 | 3 |
| Spottail shiner | 0 | 1 | 3 |
| Grass pickerel | 7 | 7 | 1 |
| Smallmouth bass | 7 | 18 | 37 |
| Northern pike | 7 | 81 | 30 |
| Black crappie | 7 | 37 | 26 |
| Green sunfish | 4 | 9 | 10 |
| Lake chubsucker | 2 | 9 | 0 |
| White sucker | 1 | 0 | 0 |
| Common carp | 0 | 0 | 2 |
| Logperch | 0 | 0 | 1 |
| Walleye | 0 | 1 | 0 |
| Brook silverside | Abundant | Abundant | Present |
| | | | |
| Sampling Effort | | | |
| Night Electrofishing hrs | 2 | 1.5 | 1.75 |
| Gill net lifts | 12 | 16 | 14 |
| Trap net lifts | 0 | 12 | 7 |

**Table 6 Lake James Summary of General Survey Fish Collection By Species**

| Condition/Weights | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | Above avg. | Avg. | Avg. |
| Yellow Perch | Avg. | Bel. Avg. | Bel. Avg. |
| Rock Bass | Avg. | Avg. | Avg. |
| Largemouth Bass | Avg. | Avg. | Avg. |
| Redear Sunfish | Above avg. | Avg. | Avg. |
| Northern Pike | Avg. | Avg. | N/R |
| Black Crappie | Avg. | Avg. | N/R |

**Table 7 Condition/Weights Per Length of Selected Lake James Fish Species (N/R denotes not reported in IDNR report text)**

| Growth rates | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | Avg. | Avg. | Avg. |
| Yellow Perch | Avg. | Avg./Below Avg. | Bel. Avg. |
| Rock Bass | Avg. | Avg. | Avg. |
| Largemouth Bass | Avg. | Avg. | Avg. |
| Redear Sunfish | Above avg. | Above avg. | Above avg. |
| Northern Pike | Avg. | Avg. | N/R |
| Black Crappie | Avg. | Above avg. | N/R |

**Table 8 Growth Rates of Selected Lake James Fish Species**

| Percent catchable size | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | 82.6 | 30.6 | 13.4 |
| Yellow Perch | 62.8 | 62 | 45 |
| Rock Bass | 82.2 | 27 | 26 |
| Largemouth Bass | 6.3 | 6.3 | 6.3 |
| Redear Sunfish | 91.8 | 83 | 74.2 |
| Northern Pike | 100 | 65 | N/R |
| Black Crappie | 43 | 81 | 50 |

**Table 9 Percent of Lake James Collected Fish considered to be of harvestable/catchable size by species**

The Snow Lake Fishery

The Indiana Department of Natural Resources has conducted general fisheries surveys on Snow Lake in 1975, 1989, and 2000 through a combination of gill netting, trap netting and D.C. electrofishing. Gill net sampling for Cisco was also conducted in 1955, 1975, 1994, and 2000. In November of 1980 gill netting was performed to spot check for walleye possibly present from a stocking in connected Lake James in June of that year. Snow Lake was stocked by IDNR with 930,000 walleye fry in the spring of 1976, 1978, and 1980.

In the 1975 survey 725 fish representing 21 species were collected with the dominant species by number being bluegill 38.5%. The dominant species by weight was longnose gar (33.3%). Bluegills collected from Snow Lake were deemed to be in above average condition and have an average growth rate for northeast Indiana lakes. 61.6% of collected bluegills were of a harvestable size (6 inches or larger). The largest bluegill collected was 9.5 inches. The perch population was deemed to be excellent with 52.8 percent being of catchable size. The largest perch collected was 11.5 inches. Condition factors and growth rates were average. Rock bass ranked third in relative abundance and exhibited average growth and above average condition. Of 63 rock bass collected 96% were a catchable size of 6 inches or larger. The biologists estimated that the rock bass population in Snow Lake was one of the largest in northern Indiana and recommended that it be exploited by anglers. Twenty largemouth bass were collected with the largest being 20 inches. Condition and growth factors were average. Two of the bass collected (10%) were 14 inches or larger. Other game species collected included Redear sunfish, crappie, northern pike, smallmouth bass, and bullhead. It was noted that a large gar population was present with twenty seven Longnose Gar collected comprising 33% of the fish population by weight. Snow Lake was deemed to contain an excellent sport fishery with ten game species present and a large percentage of harvestable sized fish. It was recommended that Snow Lake be stocked with 3000 walleye fry per acre during alternate years starting in 1976. It was noted that Snow was not a large enough lake to warrant stocking alone but should be included because of its connection to larger Lake James and the presence of a large forage base in the lake's Yellow Perch, Lake Chubsuckers, and Brook Silversides. Four species of submersed and three species of emergent plants were noted. Submersed species included Watermilfoil (species not noted), Curlyleaf pondweed, Bladderwort, and Coontail. The dominant plant was Watermilfoil. It was also noted that control would only be required in channels to facilitate boat traffic.

In November of 1980 a spot check for Walleye was performed that consisted of a total of 264 hours of gill netting with two to four 250 foot experimental mesh nets. The purpose of the check was to sample for walleye that had migrated to Snow Lake from a June 1980 stocking of 142,695 walleye in Lake James. Netting effort was .85 hours per surface acre but effective netting effort was substantially less due to much of the net mesh sizes being too large to catch young-of-the-year walleye. No Walleye were caught. It was recommended that walleye surveys be repeated in the fall of 1981 and 1982 to see if a walleye fishery develops from the 1980 Lake James stocking.

The third general survey on Snow Lake took place from June 19-22 or 2000 and again included gill netting, trap netting, and nighttime D.C. electrofishing. A total of 1237 fish representing 25 species were collected. Bluegill were the dominant species numerically (44%) and largemouth bass were dominant by weight. (21.2%) The largest bluegill collected was 9.5 inches. A total 544 bluegill were collected almost matching the combined total of the 1989 and 1975 surveys (576). Harvestable sized fish of six inches or larger comprised 28.4% of the sample. The percent harvestable fish was 21% and 35.8% in 1989 and 1975 respectively. 209 largemouth bass were collected ranking them second numerically. The largest was 20.6 inches. Bass of harvestable size (14 inches or larger) made up 9.1% of the sample. This was similar to 1975 (10%), and 1989 (8.9%). Growth rates of age II+, III+, and IV+ bass were below average, all other age groups exhibited average growth. All bass weights were average. Redear sunfish comprised 15.6% of the sample by number. 193 redear were collected with 94.3% being of a catchable size of 6 inches or larger. Weights and growth rates were average. 40 yellow perch were collected comprising 3.2% of the catch numerically. The largest was 9.4 inches. Seven black crappie were collected and comprised only .6% of the catch by number. Two walleye of (20.2 and 23.8 inches) were also collected. These fish were apparently the offspring of walleye from the 1980 and 1982 stockings in Lake James. A 12 inch size limit had been established for largemouth bass in 1990 with the limit being set at 14 inches in the fall of 1998. It was estimated that the average density of stock size largemouth bass (eight inches or larger) had increased 88% percent since the 1990 size limit was imposed. The number of bass per acre 12 inches or larger in length had increased 167% from an average of 3.1 before the size limit to 8.3 in 2000. Snow lake was deemed to support a healthy sportfish population dominated by bluegill, largemouth bass and Redear. Yellow perch black crappie, bullheads, rock bass, and northern pike provided other opportunities to anglers. Yellow perch were seen to have undergone a general decline over time at Snow Lake but the Largemouth Bass population had increased. The report also indicated that water quality was generally good and noted the connection of many of the lakes residences to a waste collection cluster system and a centralized sewage collection plant in Fremont, Indiana. It was also noted that a new centralized collection plant had been approved for Steuben county and would include all the Snow Lake residences. The presence of zebra mussels was also noted. The mussels although not an ecological problem at that time, can present a hazard to swimmers who can cut their feet on the sharp shells. Aquatic vegetation was not found to be a problem. The biologist recommended that walleye fingerlings be stocked in Snow Lake as part of an effort to establish a walleye fishery in the Lake James Chain. No additional management was requested. Survey data is presented in tables 10, 11, 12, and 13.

| Number Collected | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | 279 | 297 | 544 |
| Largemouth bass | 20 | 89 | 209 |
| Redear sunfish | 26 | 121 | 193 |
| Warmouth | 57 | 27 | 49 |
| Yellow bullhead | 61 | 48 | 43 |
| Black bullhead | 1 | 0 | 0 |
| Yellow perch | 104 | 56 | 40 |
| Rock bass | 63 | 23 | 26 |
| Longnose gar | 27 | 21 | 25 |
| Brown bullhead | 10 | 14 | 16 |
| Spotted gar | 9 | 10 | 16 |
| Pumpkinseed | 18 | 16 | 13 |
| Lake chubsucker | 6 | 9 | 9 |
| Northern pike | 4 | 26 | 9 |
| Common Shiner | 0 | 0 | 8 |
| Black crappie | 5 | 14 | 7 |
| Golden shiner | 4 | 11 | 7 |
| Bowfin | 11 | 2 | 4 |
| Hybrid bluegill | 0 | 0 | 4 |
| Logperch | 0 | 0 | 4 |
| Common carp | 0 | 1 | 3 |
| Grass pickerel | 5 | 7 | 2 |
| Smallmouth bass | 3 | 1 | 2 |
| Walleye | 0 | 6 | 2 |
| Green sunfish | 12 | 15 | 0 |
| White bass | 0 | 1 | 0 |
| Central Mudminnow | 0 | 0 | 1 |
| Steelcolor shiner | 0 | 0 | 1 |
| Brook silverside | abundant | abundant | 0 |
| | | | |
| | | | |
| Sampling Effort | | | |
| Night Electrofishing hrs | 2 | 1 | 1.25 |
| Gill net lifts | 9 | 9 | 9 |
| Trap net lifts | 0 | 6 | 5 |

**Table 10 Snow Lake Summary of General Survey Fish Collection By Species**

| Condition/Weights | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | Above avg. | Avg. | Avg. |
| Yellow Perch | Avg. | Below Avg. | N/R |
| Rock Bass | Above avg. | N/R | N/R |
| Largemouth Bass | Avg. | Avg. | Avg. |
| Redear Sunfish | Avg. | Avg. | Avg. |

**Table 11 Condition/Weights Per Length of Selected Snow Lake Fish Species**

| Growth rates | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | Avg. | Below avg. | Avg. |
| Yellow Perch | Avg. | Below avg. | N/R |
| Rock Bass | Avg. | N/R | N/R |
| Largemouth Bass | Avg. | Above avg. | Age 2,3,4 below avg, Age 4+ avg. |
| Redear Sunfish | Avg. | Below avg. age 2,3,4 Above avg. age 5,6 | Avg. |

**Table 12 Growth Rates of Selected Snow Lake Fish Species**

| Percent catchable size | June 1975 | May 1989 | June 2000 |
|---|---|---|---|
| Bluegill | 61.6 | 21 | 28.4 |
| Yellow Perch | 52.8 | 52 | N/R |
| Largemouth Bass | 10 | 8.9 | 9.1 |
| Redear Sunfish | 80.8 | 84 | 94.3 |

**Table 13 Percent of Snow Lake Collected Fish considered to be of harvestable/catchable size by species**

## The Big Otter Lake Fishery

One notable characteristic of the Big Otter Lake fishery is its northern pike production. Big Otter Lake has been surveyed by IDNR in 1984 and 2000. The 1984 report indicates that the channel and associated marshes in the northeast corner of the lake are used extensively by Northern Pike for spawning during the spring months. This area provided a major portion of the adult Northern Pike needed for egg collection for hatching Pike at Fawn River State Hatchery in Orland, Indiana. In the 1984 general fisheries survey for Big Otter Lake biologists utilized gill netting, trap netting, and collected a total of 634 fish. These represented 19 species. Bluegill were most abundant by number comprising 41.8 percent of fish collected. The bluegill ranged in length from two to nine inches. Thirty three percent were of a harvestable size of six inches or larger. The bluegills showed average or above average growth rates and condition. Largemouth bass were second most abundant comprising 9.5 percent of fish collected. They ranged from 3.5 inches to 19.5 inches. Of the 60 bass collected 8.3 percent were of a harvestable size of 14 inches or larger. Growth rates of the bass were above average. Bass weights per length were average. Yellow Perch were third most abundant comprising 8.5 percent of fish collected. Perch ranged from 3.5 to 10.5 inches. Weights per length of the fish were average, but growth rates were below average. Of 54 collected perch only six were of a harvestable size of eight inches or larger. It was concluded that Big Otters perch were not contributing much to the sportfishery. The 1984 survey report concluded that Big Otter Lake supported a good population of sportfish with Bluegill, Largemouth Bass, Yellow Perch and Yellow Bullhead dominating the fish population. All of these but perch were noting to provide good sportfishing opportunities with Northern Pike and Black Crappie also contributing. Vegetation was not noted to be a problem and no fish diseases or parasites were observed. It was noted that considerable development had taken place around the lake's northeast channel and tributary that provided a spawning area for Northern Pike and reports of obstructions to fish passage would be investigated. The report also noted that future development that would be detrimental to the fishery should be prevented. At that time collection of northern pike for egg harvesting took place in the northeast tributary (Walter's Lakes Drain) on the north side of State Road 120. It is unknown the extent to which this tributary is currently used by Pike as a limestone structure has been installed on the north side of 120. This rock structure does become inundated at times of high water levels and may not be a barrier to fish passage at that time. Northern Pike are no longer collected by IDNR at this location. No additional fish management recommendations were made in the 1984 report.

Big Otter Lake underwent a general fisheries survey again using gill netting, trap netting, and nighttime electrofishing to collect fish on June 26-28 of 2000. The survey collected 1124 fish representing 17 species. Bluegill were again dominant numerically. Bluegills comprised 82.7 percent of fish collected were bluegills. Largemouth Bass were second numerically at five percent. Pumpkinseeds were third most numerous at 3.6 percent of the sample. Bluegills collected ranged in length from 1.5 to 8.5 inches. 26.7% of the sampled bluegills were of harvestable size of six inches or larger. Growth weights and rates were average. Largemouth Bass collected ranged in length from 4.6 to 19.1 inches. Harvestable sized bass (14 inches or larger) comprised 7.3 percent of the sample. Age II+, III+, and IV+ showed below average growth rates while growth rates for all other ages were average. The number of Largemouth Bass collected per electrofishing hour had increased to 106 per hour over 60 per hour in 1984. Additional gamefish collected included 19 yellow perch up to 9.3 inches, nine northern pike up to 35.4 inches and three Crappie up to 8.3 inches in length. Sampling was also performed in the spring of 2000 to establish a population estimate for Largemouth Bass at Big Otter and Little Otter Lake. In 1990 a state size limit of 12 inches was established and a was subsequently increased to 14 inches in 1998. Biologists were collecting bass population estimates for comparison with data from Indiana Lakes before the size limits were established. Big and Little Otter were sampled as one lake using 9.18 hours of nighttime electrofishing. The bass population was estimated by marking bass with a fin clip and calculating the population estimate based on the number of recaptures using the Schnabel method. One thousand thirty seven bass were collected. The total bass population was estimated at 2778 fish. The population of stock-sized bass (8 inches or larger) was estimated at 2418 fish. Bass eight to 11.5 inches comprised 55.4% of the stock size fish population compared to a 72.9% average for medium sized natural lakes in Indiana prior to the size limit. Average stock size bass density from medium sized lakes before the establishment of a size limit was 11.4 per acre. The stock size bass density in the Otter Lakes was estimated at 23.5 per acre. This represented a 106% increase since implementation of a 12 inch size limit. Bass density for 12 inch or larger fish increased 239 percent from an average of 3.1 prior to the size limit to 10.5 inches in the 2000 surveys. Catch rate-per-hour was also higher than pre-limit. For medium sized lakes before the limit the rate was 64 bass per hour. At the Otter Lakes in 2000 121 bass per hour were collected for an increase of 89 percent. Biologists summarized that Big Otter Lake supported good sport fish populations, dominated by Bluegill and Largemouth Bass. It was stated that Northern Pike continued to supplement the fishery. While few Crappie were collected in the survey it was noted that a good fishery for them had been reported at Big Otter Lake. No parasites or fish diseased were noted and shoreline erosion was seen to be minimal. No fish management activities were recommended. Selected data from the Big Otter fish surveys is presented in table 14.

| Number Collected | June 1984 | June 2000 |
|---|---|---|
| Bluegill | 265 | 929 |
| Largemouth bass | 60 | 56 |
| Redear sunfish | 12 | 0 |
| Warmouth | 42 | 9 |
| Yellow bullhead | 52 | 13 |
| Black bullhead | 0 | 0 |
| Yellow perch | 0 | 19 |
| Rock bass | 8 | 1 |
| Longnose gar | 3 | 2 |
| Brown bullhead | 15 | 0 |
| Spotted gar | 6 | 18 |
| Pumpkinseed | 23 | 40 |
| Lake chubsucker | 15 | 8 |
| Northern pike | 8 | 9 |
| Common Shiner | 0 | 0 |
| Black crappie | 27 | 3 |
| Golden shiner | 5 | 3 |
| Bowfin | 19 | 6 |
| Hybrid bluegill | 0 | 0 |
| Logperch | 0 | 0 |
| Common carp | 1 | 2 |
| Grass pickerel | 2 | 2 |
| Smallmouth bass | 0 | 0 |
| Walleye | 0 | 0 |
| Green sunfish | 17 | 0 |
| White bass | 0 | 0 |
| Central Mudminnow | 0 | 4 |
| Steelcolor shiner | 0 | 0 |
| Brook silverside | 0 | 0 |
| | | |
| | | |
| Sampling Effort | | |
| Night Electrofishing hrs | 1 | .5 |
| Gill net lifts | 8 | 4 |
| Trap net lifts | 8 | 2 |

**Table 14 Big Otter Summary of General Survey Fish Collection by Species**

The Little Otter Lake Fishery

Little Otter Lake was also surveyed in 1984 and 2000. The 1984 survey was conducted on June 11-13, 1984. Gill netting, trap netting, and night electrofishing were used to collect a total of 273 fish representing 17 species. Bluegills dominated the fishery by number. They comprised 41.4 percent of the sample. Largemouth Bass were second most abundant at 18.3 percent. Warmouth were third most abundant comprising 7.7 percent of the fish collected. Bluegill collected ranged from two to nine inches in length. Growth rates and weights were average to slightly above average. Twenty-seven percent were of a harvestable size of 6 inches or larger. Largemouth bass collected ranged in length from three to 20.5 inches. Weights per length were average and growth rates were above average. Fourteen percent of the bass were of a harvestable size of 14 inches or larger. Other important fish collected included Northern Pike up to 40 inches in length. Pike dominated the sampling by weight (33.5 percent). It was noted that pike offered good fishing at Little Otter and also utilized the lake as a migratory path to spawning areas upstream in Marsh Lake and Follet Creek. Follet Creek east of Little Otter Lake was once a collection site for Northern Pike brood stock during the early spring breeding period. In summary it was noted that Little Otter as a marl-bottomed lake with a narrow littoral zone fit the profile of a lake of low productivity in terms of sportfish. Despite this Little Otter supported good populations of Bluegill, Largemouth Bass, and Northern Pike. It was concluded that Pike, Bass, and Bluegill offered good fishing opportunities. Aquatic vegetation was not noted to be a problem with the exception of the east shore near the inlet (Follet Creek). No fish diseases or parasites were noted and shoreline erosion was observed to be minimal. Fish management activities were not deemed necessary based on the results of the survey.

Little Otter Lake was again surveyed on June 28-29 of 2000 utilizing trap-netting, gill netting and electrofishing. A total of 237 fish were collected representing 17 species. Bluegill were again most numerous at 41.4 percent and also represented the largest weight (32 percent). Largemouth Bass were second in number and comprised 18.2 percent of fish collected by number. Pumpkinseeds were third most numerous at 3.1 percent. Northern Pike were second most dominant by weight at 33.5 percent. Collected Bluegills ranged from 1.8 to 8.5 inches. 25.3 percent of Bluegills collected were of harvestable size of six inches or longer. Largemouth Bass collected ranged from 1.4 to 15.6 inches in length. Just over 10 percent were of a harvestable length of 14 inches or larger. Growth rates were below average for age II+, III+, and IV+ bass. Growth rates were average for all other age classes. Four Northern Pike were collected ranging from 23.3 to 34 inches. It was summarized that Little Otter Lake continues to support a good sport fishery with Bluegills and Bass being dominant. The Bass population was noted to have increased over the 1984 survey, a probably result of the establishment of the 14 inch size limit. Pike continued to be present and compliment the sportfishing. While few Crappies were again collected it was noted that Little Otter is known to produce good Crappie fishing for area anglers. It was speculated that the low number of Crappie collected was a result of the lakes narrow littoral zone making the setting of shallow water gill nets difficult. Aquatic vegetation was seen to be limited by the lake's limited littoral zone with the exception of the Follet Creek delta area. No fish diseases or parasites were noted and shoreline erosion was minimal. No fish management activities were recommended. Selected fish data is presented in table 15.

| Number Collected | June 1984 | June 2000 |
|---|---|---|
| Bluegill | 113 | 288 |
| Largemouth bass | 50 | 29 |
| Redear sunfish | 0 | 0 |
| Warmouth | 21 | 5 |
| Yellow bullhead | 10 | 3 |
| Black bullhead | 0 | 0 |
| Yellow perch | 7 | 4 |
| Rock bass | 0 | 0 |
| Longnose gar | 0 | 1 |
| Brown bullhead | 14 | 1 |
| Spotted gar | 5 | 6 |
| Pumpkinseed | 9 | 11 |
| Lake chubsucker | 5 | 0 |
| Northern pike | 6 | 4 |
| Common Shiner | 0 | 0 |
| Black crappie | 0 | 1 |
| Golden shiner | 4 | 2 |
| Bowfin | 7 | 1 |
| Hybrid bluegill | 2 | 0 |
| Logperch | 0 | 0 |
| Common carp | 2 | 1 |
| Grass pickerel | 6 | 0 |
| Smallmouth bass | 0 | 0 |
| Walleye | 0 | 0 |
| Green sunfish | 12 | 0 |
| White bass | 0 | 0 |
| Central Mudminnow | 0 | 1 |
| Steelcolor shiner | 0 | 0 |
| Brook silverside | Present | 0 |
| White sucker | 0 | 1 |
| | | |
| Sampling Effort | | |
| Night Electrofishing hrs | .75 | .5 |
| Gill net lifts | 4 | 2 |
| Trap net lifts | 2 | 1 |

**Table 15 Little Otter Lake Summary of General Survey Fish Collection by Species**

Largemouth and Smallmouth Bass Management on the James Chain

A survey to establish Largemouth and Smallmouth Bass population estimates and an angler creel survey were also conducted at the James Chain in the spring of 2000. Nighttime electrofishing was used on two nights per week for four consecutive weeks covering the entire Shoreline each week. This was a mark and recapture study utilizing a fin clip to mark the bass. The survey included Lake James, Snow Lake, Big Otter Lake, Little Otter Lake, and Jimmerson Lake (just downstream of Lake James). Recaptured fish were noted to produce a population estimate utilizing the Schnabel method. During Late April and May of 2000 nighttime D.C. electrofishing was utilized to mark and release a total 9782 largemouth bass. 481 smallmouth bass were also collected from Lake James. Very few smallmouth were collected from the other lakes in the chain. The bass population estimates below were produced for the lakes in this study. Big and Little Otter were sampled in combination as one lake.

| **Bass Size** | **James** | **Snow** | **Big and Little Otter** |
|---|---|---|---|
| All LMB (largemouth bass) | 13651 | 8812 | 2778 |
| ≥ 8" | 10031 | 7817 | 2418 |
| ≥ 12" | 2617 | 3967 | 1080 |
| ≥ 14" | 687 | 1906 | 475 |
| ≥ 18" | 74 | 137 | 96 |
| Est. Stock size (8"-18") largemouth bass per acre | 9 | 21 | 24 |

**Table 16 Largemouth bass population estimates for the study lakes 2000. (IDNR 2000)**

In 1990 IDNR placed a minimum harvest size limit of 12 inches on largemouth bass. This was increased to 14 inches in 1998. Baseline bass data collected from 34 Indiana lakes (not including the James Chain) before and after the imposition of the size limits indicates that the number of stock size bass per acre in Lakes James, Snow and the Otters has increased 5%, 88%, and 106% respectively. It was noted that the 14 inch minimum length limit on the Lake James Chain Bass populations needs to be in effect for several more years before any impact can be determined directly. IDNR creel surveys were also conducted by three creel clerks interviewing anglers five days per week from May 5 through October 31, 2000. Objectives were to determine an estimate of total fishing pressure, fish harvest, fishing pressure by tournament anglers, and the number of bass caught and released. Anglers fished a total of 66,771 hours on the James Chain (34 hours per acre). On a statewide basis fishing pressure below 50 hours per acre is considered low. Fishing pressure for the lakes included in this study was 19 hours per acre on Lake James, 33 hours per acre at Snow Lake, and 103 hours per acre at the Otter Lakes. The total fish harvest for this period was 46,062 with bluegill (38,392), redear (2886), and black crappie (2167) dominating the catch 570 largemouth bass and 47 smallmouth bass were harvested. During 2000 thirty bass tournaments were held. 70% were organized by Indiana Bass clubs, 23% by Ohio clubs, and 7% by Michigan clubs. Only two of the bass tournaments were held by non-residents when the bass season in their own home state was currently closed. A total of 1069 bass tournament anglers fished 8680 hours representing 13% of the chains total fishing pressure. Tournaments averaged 19 boats and 37 anglers. Tournament anglers weighed in a total of 750 legal size bass, an average of 25 per tournament. Tournament anglers had a catch rate of .78 bass per hour, slightly less than non-tournament bass anglers at .82 per hour. It was concluded that the James Chain provides good sportfishing opportunities dominated by bluegill and largemouth bass. The harvest of bass was considered to be relatively small, while catch-and-release bass fishing was considered to be significant. Total fishing pressure on the chain overall was considered to be low while fishing pressure on the Otters specifically was approaching the high range. Lake James was seen to attract smaller local club tournament fishing in comparison to the larger events documented at Lake Wawasee. Further information on the bass study and creel surveys is available from IDNR, Fawn River State Hatchery, 6889 North State Road 327, Orland, IN 46776.

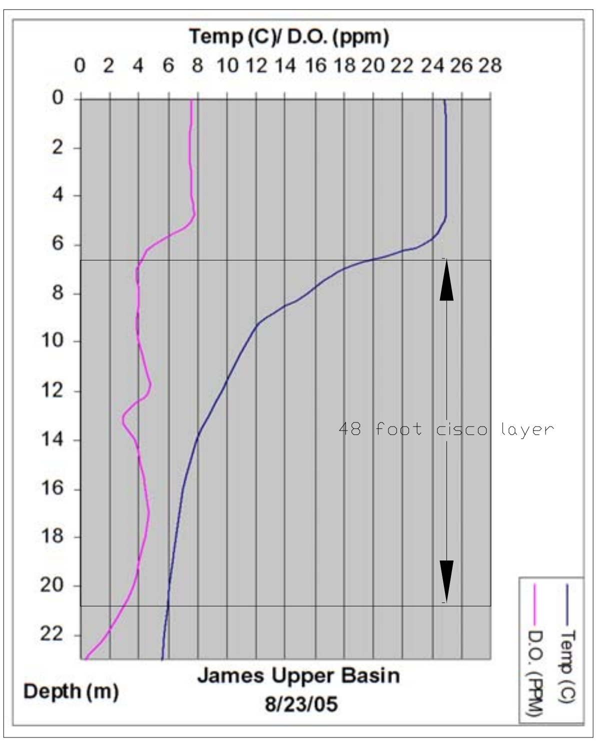
**Figure 22 Cisco, a type of whitefish, were once common on Big Otter, James, and Snow Lake**

Cisco in the Lake James Chain

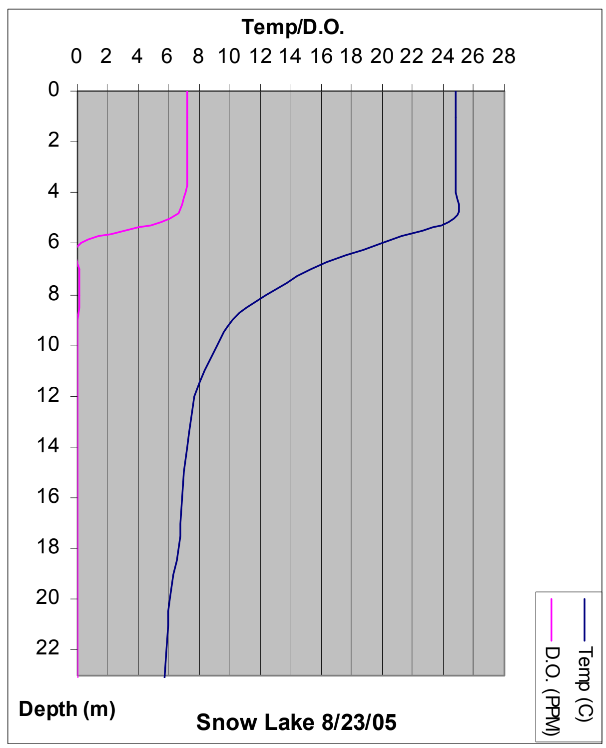
All four of the lakes examined in this study once supported a population of Cisco. These fish are currently thought to have been extirpated from the James Chain lake basins examined in this study. The Cisco, *Coregonus artedi*, also called "lake herring" is a native fish belonging to the Family Salmonidae (fig 22). The salmonid family includes the trouts, salmons, chars, and whitefishes. As a member of the genus *Coregonus* the cisco is a close relative of the lake whitefish. These silver colored fish grow to a size of approximately twenty two inches. Cisco habitat in Indiana has experienced an extensive decline during the twentieth century as Indiana's Lakes and rivers have undergone water quality changes, presumably in response to altered habitat conditions associated with eutrophication. The cisco along with the lake sturgeon is one of only two lake fishes currently listed as a species of special concern by IDNR. In his 1955 paper *Distributional Ecology of the Cisco in Indiana* David G. Frey attempted to assemble information on the species and map the extent of current and previous habitat in the state. Frey drew on a number of resources summarizing existing reports of the occurrence of the species in the literature dating from 1871 to 1945. In addition, Lake and Stream Survey results of 1951 and 1952 and the results of a 1951 survey of licensed cisco fisherman were utilized. Frey also examined the literature for information on factors governing geographic and summer bathymetric distribution of the species. Since Frey's work IDNR fisheries managers have maintained an active program to update the population status of the cisco and work toward the preservation of the species (Gulish 1973-75, Hudson 1998, James 1975, Koza 1994, Pearson

2001) IDNR currently uses targeted gill net surveys to asses cisco populations, classifying cisco as “extirpated”, “probably extirpated”, “rare”, or “common” based on gill net catch rates and water quality data. (Pearson 2001) refined Frey’s list by excluding erroneous or unreliable reports and adding cisco habitat since discovered. At present ciscos are thought since 1955 to have occurred naturally in at least forty six Northern Indiana Lakes. Populations have died out in thirty of those lakes (65%), with populations in four additional lakes being listed as “probably extirpated” and the status in one lake being unknown.(Pearson 2001) A cisco population has been successfully established through privately stocked fish in one man-made pit-lake in Kosciusko county (Dillards Pit) and IDNR has successfully reestablished a breeding population within the James Chain's extended watershed in Green Lake that was thought to originally contain the species. That leaves a total of 13 Indiana cisco lakes. Status of the cisco in Indiana lakes is currently classified according to catch-per-unit effort. One effort consists of one daily lift of 250 feet of gill net fished in the cisco layer. In lakes where IDNR personnel achieve a return of one cisco catch-per-unit effort or more, cisco are classified as “common”. In lakes in which catch rates are less than one CPUE, but in which at least one cisco was caught the fish are classified as “rare”. Lakes which return no netted cisco, but have a cisco layer (cool well-oxygenated habitat) at the time of sampling receive a “probably extirpated” status. In lakes in which no cisco are caught and no cisco layer is present, cisco are classified “extirpated”. Of the thirteen Indiana cisco lakes left, the status of the fish is “rare” in six of those lakes and “common” in seven. Steuben County Lakes where cisco have been extirpated include Lake James, Jimmerson, Snow Lake, Big Otter, and Marsh Lake. In Steuben county the species is currently listed as “rare” in Clear, Gooseneck, Little Lime, and Meserve lakes. Only Gage, Failing, and Green lakes are in the “common” classification in Steuben County. Cisco’s spawn in November and December over a variety of bottom substrates, usually in water less than ten feet deep.(Pearson 2001) Fishing for ciscos on the fall and winter spawning grounds with gill nets was once a popular activity among a significant number of Indiana Sportsmen. Gill nets were used on the James Chain to harvest ciscos in the past. Use of gillnets for cisco fishing was discontinued by 1976 (James 1975) and by the 1980’s only Crooked Lake (Noble/Whitley county) remained as a popular hook-and-line Fall cisco fishery. The popularity of cisco fishing at Crooked Lake has now dropped off significantly as declining numbers of the fish in that lake have diminished catches. (Pearson 2001) The cisco remains as an important indicator of stable, high quality aquatic habitat in Indiana. Lake residents who have cisco populations in their waters are assured of exceptional water quality worth preservation.

While the exact mechanisms of cisco extirpation are not well understood, many former cisco lakes in Indiana can be shown to now lack necessary summertime habitat for the species. This is the case with Snow Lake and Big Otter. As a fish species physiologically suited to cold, oxygen rich waters, the cisco was already perched precariously at the southern tip of its natural presettlement range in Indiana. Frey listed Shriner Lake in Whitley county as the Southernmost known natural occurrence of the Coregonids. Cisco still occur in a large numbers of inland lakes in other areas of the glaciated United States, but habitat has been significantly reduced in other states as well. Required habitat for the species can be reasonably defined as; waters of a temperature of twenty degrees Celsius (68°F) or less and a dissolved oxygen concentration of 3 parts-per-million (mg/L) or more. These requirements confine the fish to deeper cooler parts of Indiana Lakes during the summer months. However, decreasing hypolimnetic oxygen levels originating at the lake bottom typically assign a maximum depth of suitable habitat in middle or late summer. This effectively confines the fish to a limited vertical strata restricted by high temperatures at the upper limit and low oxygen at the lower extent. This is called the “cisco layer." The relative thickness of the cisco layer, and it's year to year stability within a given lake is presumed to largely determine habitat suitability. An understanding of basic lake functioning is essential for linking the effects of watershed and lake character to the presence or absence of cisco habitat and associated water quality characteristics. The shrinkage and disappearance of cisco habitat can occur in lakes as increased nutrient loads boost biological productivity in the water columns upper strata. It has been well demonstrated that aquatic systems tend to support much increased numbers of phytoplankton (tiny planktonic plants that float in the water column) in response to increasing phosphorus levels (Schindler 1974)(Vollenweider 1968). As watershed land use changes and increased in-lake disturbances boost dissolved phosphorus levels planktonic biomass increases. As increasing numbers of planktonic organisms complete their life cycle and die they lose their buoyancy and sink into the lower strata of the lake where decomposition occurs. As bacterial decomposers in the hypolimnion (deepest lake layer) respire and oxidation of the fallen detritus occurs, oxygen in the hypolimnion is consumed. Meanwhile the phytoplankton near the lake's surface boosts oxygen levels through photosynthesis. As the summer months progress surface waters warm, pushing the upper limit of the cisco habitat downward while the hypolimnetic oxygen deficit creeps upward.




Lake James Upper Basin Cisco Layer




Snow Lake Showed no Cisco Layer in 2005

In many lakes this process is mitigated somewhat by the development of an oxygen maxima near or just below the thermocline. This reverse heterograde condition occurs in lakes of intermediate productivity where water clarity allows a significant amount of oxygen producing planktonic photosynthesis to occur near the substantially cooler waters of the thermocline. The higher affinity for dissolved gases possessed by the colder waters allows the accumulation of relatively high levels of dissolved oxygen at that level. In Lake James this effect can only be seen as a slight increase in oxygen at the top of the thermocline. In the majority of Indiana

Lakes the hypolimnetic oxygen deficit will overlap the upper thermal limit of the cisco layer at some point during summer or early autumn effectively eliminating coldwater fisheries habitat. This occurred on Snow Lake and Big Otter Lake in 2005 when no cisco layer was present. A profile provided by the North Otter Lakes association for 7/18/29 showed a cisco Layer of 14 feet. A 7/25/73 profile shows a six foot cisco layer. Letters provided by the North Otter Lakes Association from 1976 indicate the Association circulated a petition complaining of nutrient discharge violations contributing to profound bluegreen algal blooms that year. It's not very likely that Big Otters Cisco population would have survived this time period. IDNR cisco survey data lists the species as common in 1955 but extirpated in 1975 and thereafter. Repeated sampling for Cisco on Big Otter in 1994 and 2000 failed to produce any fish. Snow Lake apparently followed roughly the same path of extirpation with the fish being "common" in 1955 and "extirpated" thereafter. Lake James being larger and enjoying some isolation from much of the watershed through the filtering effect of the rest of the chains lakes was slower to respond. Cisco were listed as common in Lake James in 1955, rare in 1975, "probably extirpated" in 1994, and "extirpated" in 2000. In a few cases Indiana cisco populations have demonstrated the ability to survive complete disappearances of their habitat for a period of time but (Frey 1955) and IDNR water quality data indicates that the persistence of the species correlates strongly with the extent and stability of habitat occurrence. Ciscos have also apparently disappeared from some lakes where habitat appears to be ample for the years on record. Lake James fits into this category. In 1976, 1988, 1994 and presently Lake James appears to have a cisco layer in all three basins. Short term habitat instability, changes is zooplankton prey populations, recruitment problems, or other poorly understood water quality declines may be significant factors in the continuing decline of the species in these lakes. One problem with tracking cisco layer changes is that much of the profile data has been collected in July. Cisco layers on some lakes tend to be minimal during late august and early september. It's also possible that rapid changes in oxygen levels take place on a daily basis that are missed in normal sampling.

## 2.4 Aquatic Plants in the James Chain Basins

To assemble general aquatic plant community data for this report Tier I reconnaissance surveys (IDNR 2004) were performed in 2005. In this qualitative survey a boat was used to cruise the lakes littoral zones in a zigzag pattern, making rake tosses and using visual observation to divide the lakes littoral zone into numbered plant bed units based on like plant species, composition and density. Information collected at each plant bed includes, species, species number, substrate, depth, and bed location. A numeric score of one through four is assigned for each species as a measure of abundance within the bed. For plant beds with a plant canopy, a canopy score of one through four is assigned. Canopy abundance scores are recorded as they apply to submersed, non-rooted floating, rooted floating, and emergent vegetation.

### The Lake James Aquatic Plant Community

Like most Indiana glacial lakes Lake James' plant community in the open lake (non-channel) areas is largely stratified by depth. This is probably primarily due to the mechanical activity of wind and wave action sorting sediment particle size by depth and the availability of light. With finer silts and associated organic materials settling into dredged depressions, channels and

deeper lake areas the substrate becomes optimal for plant growth in these regions. With the exclusion of
growth in the light-poor deeper regions the optimal strata for growing plant biomass on Lake James appears to be between the 4.5 and twelve foot depth contours. Mapped tier one plant beds were chosen on the basis of plant community differences as they appeared with lateral movement around the lakes littoral zones. Within each plantbed however a common depth-related stratification occurred. Chara, a type of low growing algae, tended to dominate the plant community to between the roughly 1.5 to 4.5 foot depth contour. Dominance beyond 4.5 feet shifted to Illinois pondweed, Vallisneria, and Sago pondweed. From seven feet to fifteen feet deep Variable watermilfoil is dominant. Beyond the 15 foot contour only Chara grew in most areas. Chara was found to be growing to a depth of 36.5 feet in some areas. The Variable milfoil forms a tall and often narrow weedline along the lakes contour breaks which tend to be steep. Tall Illinois pondweed and Valisneria plants tended to share this weedline with Variable milfoil. Substrates were dominated by sand, marl, and gravel. Some shallow areas in the upper and lower basins area have a very gravelly substrate that supports no plants. Lake James has an extremely diverse plant community. 23 submersed and two free-floating plants species were noted in the survey. (table 17) One species of Arrowhead was commonly found growing as a submersed plant in waters up to five feet deep. Peak diversity occurred in Sowles Bay (plantbed 18, fig 25). All plantbeds were heavily dominated by native plants. Three species of non-native (introduced) plants were noted. Eurasian watermilfoil, a potentially invasive non-native plant occurred in 22 of the 43 plantbeds (51%). Curlyleaf pondweed, another potentially invasive non-native species was noted in 11 plant beds (26%). Spiny naiad, also non-native, was found but was not common. The majority of aquatic plants noted were beneficial native species that have value in providing fishery habitat and food for waterfowl. A potential problem could occur if Eurasian milfoil becomes significantly more prominent and interferes with the native plant community, but the plant does not appear to be growing invasively in Lake James presently in most areas. Excessive plant growth typically presents problems to boaters on Lake James only in channel areas. Whitestem pondweed *Potamogeton praelongus* an Indiana state listed threatened species is relatively common in Lake James and was found in plantbeds 12, 18, 20, and 33. Richardson's pondweed *Potamogeton richardsonii* an Indiana state listed "rare" species and is also common in some areas. Richardson's pondweed was observed growing in plantbeds 2, 12, 14, 18, 26, 33, and 36. Lake James has probably provided habitat to these relatively uncommon species of plants due to its good water quality, and relative lack of disturbance. This coupled with the high diversity of the lake's plant community and the popularity of the lake as a fishery make the Lake James aquatic plant community a resource worth protecting. Protecting the water quality of the lake along with selectively controlling invasive competitor species should they ever gain dominance can aid in protecting these plants. Periodic examination of the lake's plant community and development of an aquatic plant management plan will be recommendation of this report.

| |
|---|
| Sago pondweed |
| Chara |
| Illinois pondweed |
| Vallisneria |
| Great bladderwort |
| Variable watermilfoil |
| Eurasian watermilfoil |
| Spiny naiad |
| Coontail |
| Curlyleaf pondweed |
| Flatstem pondweed |
| Richardson's pondweed* |
| Sagittaria sp. (Arrowhead) (submersed) |
| Longleaf pondweed |
| Floatingleaf pondweed |
| Southern naiad |
| Whitestem pondweed*(v) |
| Watermeal |
| Duckweed |
| Variable pondweed |
| Small pondweed |
| Leafy pondweed(v) |
| Elodea |
| Filamentous algae |
| Needle rush |
| Water buttercup |
| Largeleaf pondweed |

**Table 17 Submersed Plant Species Noted in Lake James**

*rare, threatened, endangered listed species

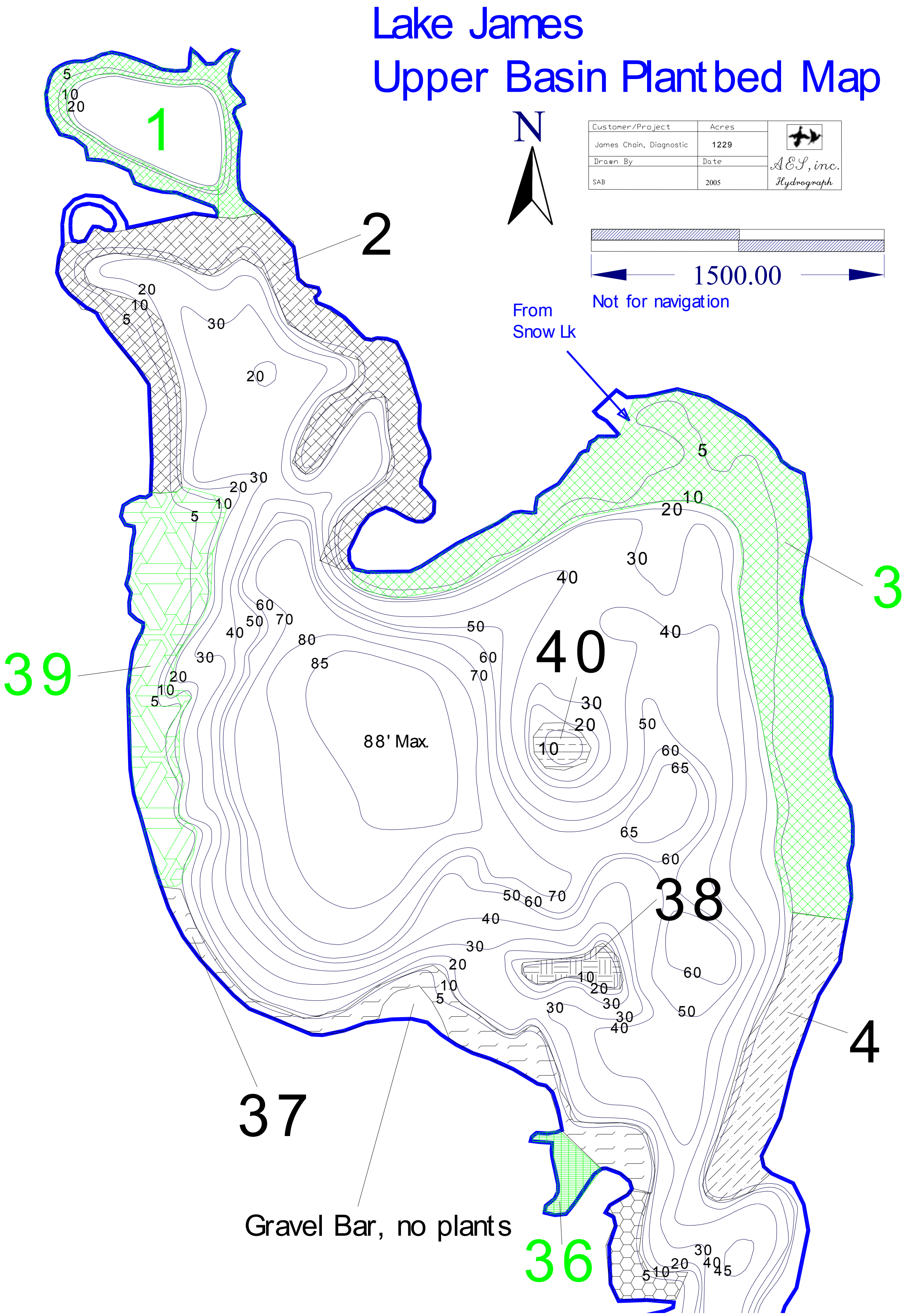



**Figure 23 Lake James Upper Basin Plantbed Map**

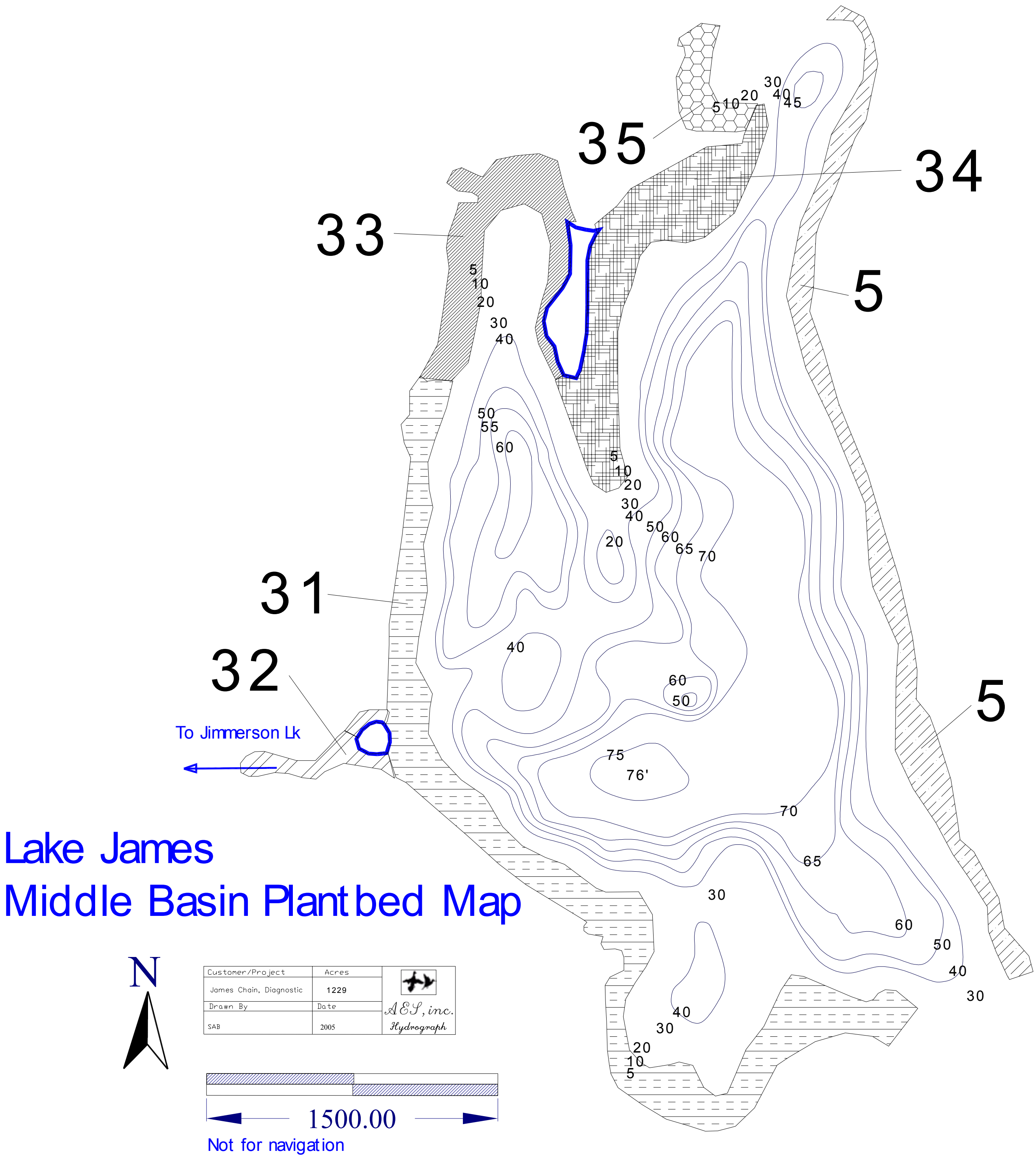



**Figure 24 Lake James Middle Basin Plantbed Map**

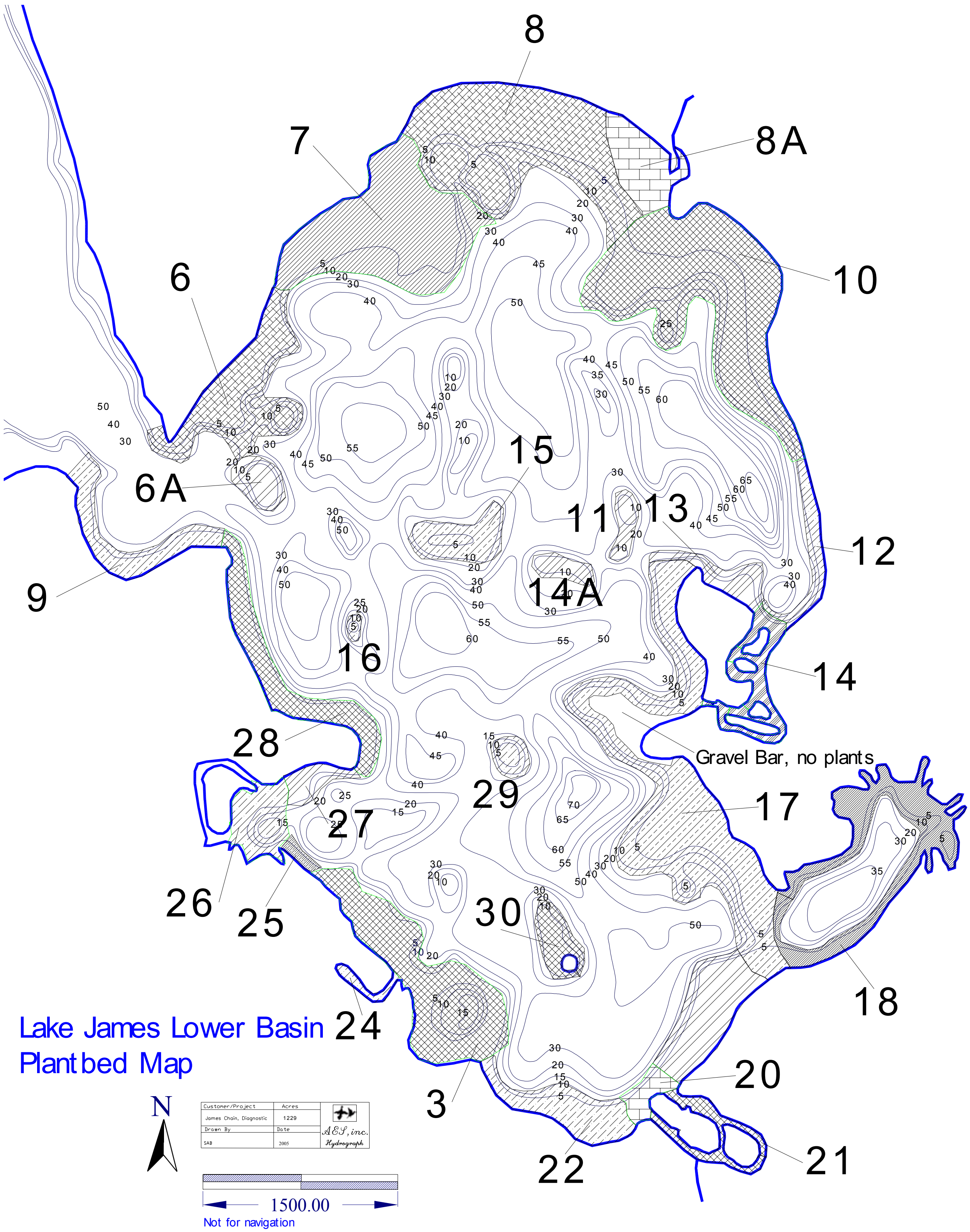



**Figure 25 Lake James Lower Basin Plantbed Map**

## The Snow Lake Aquatic Plant Community

Snow Lake's plant community is also largely stratified by depth. The optimal depth for growing plant biomass on Snow Lake appears to be between the 4.5 and ten foot depth contours. Tier one plant beds mapped on September 15 and 16 of 2005 were chosen roughly on the basis of plant community differences as they appeared with lateral movement around the lakes littoral ring. Within each plantbed however a common depth-related stratification occurred. Chara tended to dominate the plant community to roughly the five foot depth contour. Dominance beyond five shifted to Variable watermilfoil. The Variable milfoil forms a tall and often narrow weedline along the contour break. Tall Illinois pondweed and Vallisneria plants tended to share this weedline with Variable milfoil. Plants were found growing to a maximum depth of 18 feet with most growth occurring shallower than 14 feet. When it occurred in waters shallower than four feet Variable milfoil tended to form very dense colonies, some of which had achieved surface mats. Shallow areas were dominated by a low-meadow type growth of Chara. Substrates were dominated by sand with silt, muck, gravel, and marl. Rich silts and mucks were most common in inlet and channel areas. Some areas along the lakes east-central section are dominated by gravel. Richardson's pondweed, a rare species and Whitestem pondweed, a threatened species were also observed in Snow Lake. Richardson's pondweed was observed growing in plantbeds 5, 9A, 10, 12, 17, 22, 23, 25, 26, and 28. Whitestem pondweed was observed growing in plantbeds 2, 6, 17, 25, 26, and 29. Diversity was good with 19 submersed species observed and also a species of Sagittaria (arrowhead) growing as a submersed plant . Aquatic moss was also noted. The Snow Lake Cottagers Association has taken steps to manage the lake's aquatic plant community by obtaining funding from the LARE program and developing an Aquatic Plant Management Plan. (Aquatic Enhancement 2006) As on Lake James treatment of both native and non-native aquatic vegetation is needed on some of Snow Lake's channels to maintain navigability. Some shoreline areas are also treated to reduce plants. The Snow Lake Cottagers Association should follow recommendations outlined in their Aquatic Plant Management Plan to protect the lake's primarily native and beneficial plant community. Maintaining good water quality, preventing or controlling dominance by non-native plants, and periodically reassessing the lake's plant community will be important.

| |
|---|
| Sago pondweed |
| Chara |
| Illinois pondweed |
| Vallisneria |
| Great bladderwort |
| Variable watermilfoil |
| Eurasian watermilfoil |
| Spiny naiad |
| Coontail |
| Curlyleaf pondweed |
| Flatstem pondweed |
| Richardson's pondweed* |
| Sagittaria sp. (Arrowhead) (submersed) |
| Longleaf pondweed |
| Floatingleaf pondweed |
| Southern naiad |
| Whitestem pondweed*(v) |
| Variable pondweed |
| Small pondweed |
| Elodea |
| Filamentous algae |

**Table 18 Submersed Plant Species Noted in Snow Lake**

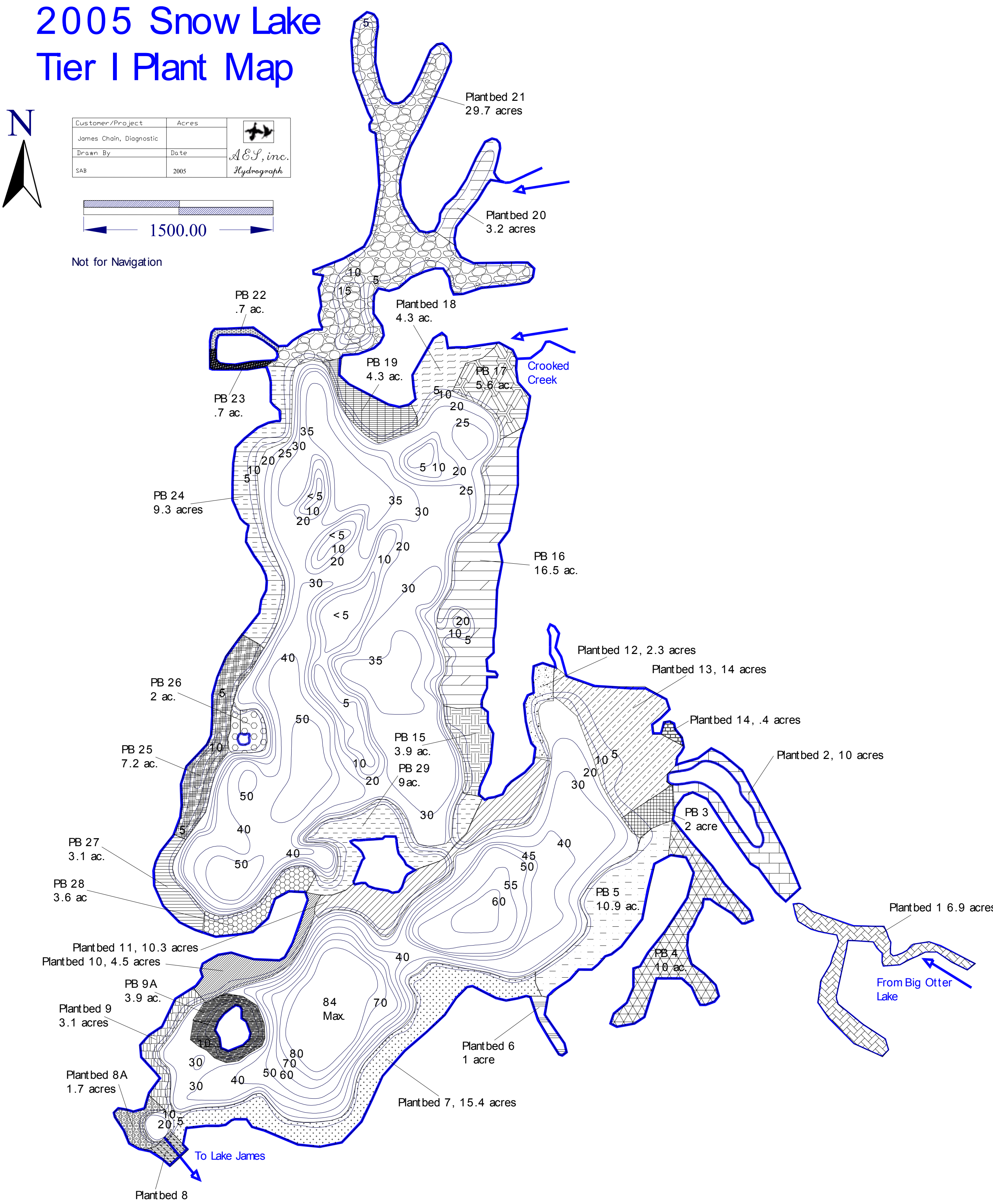



**Figure 26 Snow Lake Plantbed Map**

## The Big Otter Lake Plant Community

Six Tier one plantbeds were mapped for Big Otter Lake. Peak Diversity occurred in plantbed two where 15 species of submersed aquatic plant were noted. In all 18 species of submersed aquatic plant were noted. Substrates were dominated by sand with silt. The northeast and northwest channels had silty organic substrates. State listed Richardson's pondweed and Whitestem pondweed were also noted in Big Otter Lake. Whitestem pondweed was found growing in plantbed four. Richardson's pondweed was noted in plantbed three. Eurasian watermilfoil and Curlyleaf pondweed, potentially invasive species were present but not dominant. Big Otter Lake has a plant community that is primarily native and beneficial to fish and wildlife. Some non-native and native plant growth interferes with boating and swimming on the north and east sides of Big Otter Lake. Aquatic Herbicides have been used to reduce this problem. These treatments are unlikely to have a negative effect on Big Otter Lakes native plant community as a whole. Preserving water quality and detecting and preventing dominance by non-native plants will be the best way to preserve Big Otter Lakes beneficial native plant community. Periodic reassessment of the lake's plant community will be a recommendation of this report.

| |
|---|
| Sago pondweed |
| Chara |
| Illinois pondweed |
| Vallisneria |
| Great bladderwort |
| Variable watermilfoil |
| Eurasian watermilfoil |
| Coontail |
| Curlyleaf pondweed |
| Flatstem pondweed |
| Richardson's pondweed* |
| Longleaf pondweed |
| Southern naiad |
| Whitestem pondweed*(v) |
| Water Stargrass |
| Small pondweed |
| Leafy Pondweed |
| Filamentous algae |

**Table 19 Submersed Plants Noted in Big Otter Lake**

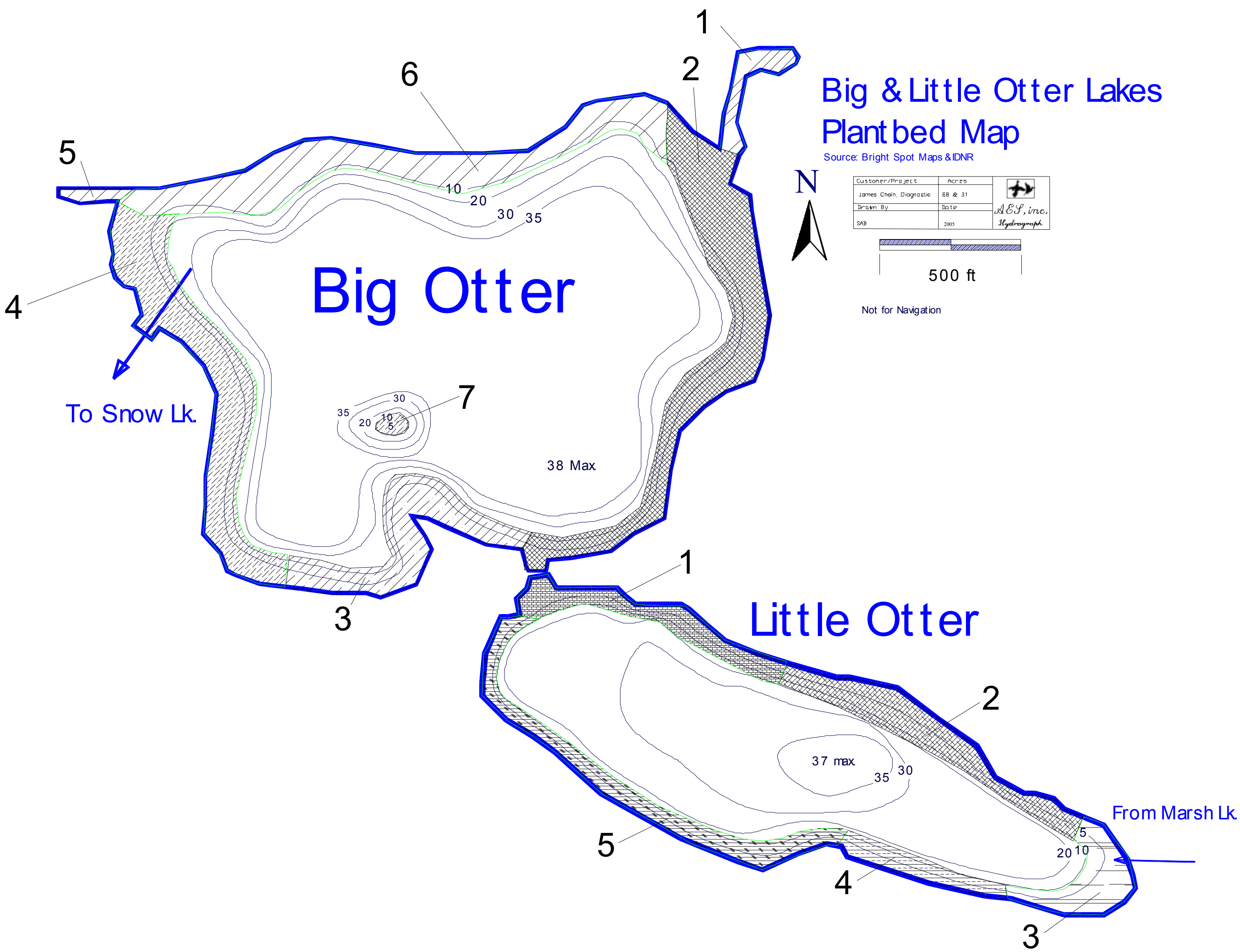



**Figure 27 Big and Little Otter Lake Plantbed map**

The Little Otter Lake Aquatic Plant Community

Five Tier one plantbeds were mapped for Little Otter Lake. Peak Diversity occurred in plantbed two where 11 species of submersed aquatic plant were noted. Poorest diversity occurred in plantbed three where only two species of submersed plant were noted. Diversity in plantbed three is probably impaired by sediment and nutrient inputs from Follet Creek. Substrates were silty and high in organic material in this area. Springtime dominance by Curlyleaf pondweed, an invasive species, occurs in this area. Despite having a very narrow littoral zone Little Otter Lake has a diverse aquatic plant community. In all, 17 species of submersed aquatic plant were noted. Substrates were dominated by sand, also being silty in some areas. State listed Whitestem pondweed was noted in Little Otter Lake. Whitestem pondweed was found growing in plantbed four. Eurasian watermilfoil and Curlyleaf pondweed, potentially invasive species were present but not dominant in most areas. Little Otter Lake has a plant community that is primarily native and beneficial to fish and wildlife. Some non-native and native plant growth interferes with boating, especially near the inlet where Curlyleaf pondweed can be dominant in the spring and early summer. Aquatic Herbicides have been used to reduce this problem. These treatments are unlikely to have a negative effect on Big Otter Lakes native plant community. Preserving water quality and detecting and preventing dominance by non-native plants will be the best way to preserve Little Otter Lake's beneficial native plant community. Periodic reassessment of the lake's plant community will be a recommendation of this report.

| |
|---|
| Sago pondweed |
| Chara |
| Illinois pondweed |
| Vallisneria |
| Great bladderwort |
| Variable watermilfoil |
| Eurasian watermilfoil |
| Coontail |
| Curlyleaf pondweed |
| Flatstem pondweed |
| Water Buttercup |
| Longleaf pondweed |
| Southern naiad |
| Whitestem pondweed* |
| Elodea |
| Leafy Pondweed |
| Filamentous algae |

**Table 20 Submersed Plants Noted in Little Otter Lake**

## Background Information on Eurasian watermilfoil

The lakes in the James Chain like many Indiana lakes have been colonized by the aquatic plant, Eurasian Watermilfoil *Myriophyllum spicatum* . A native plant of Europe, Asia, and north Africa Eurasian milfoil in the U.S. was first documented growing in a pond in Washington D.C. in 1942. The plant was probably intentionally introduced to the United States (Couch and Nelson 1985) and has now spread to forty-five of the lower forty-eight states and the Canadian provinces of British Columbia, Ontario, and Quebec. At least 160 glacial lakes in Northern Indiana now contain the plant (IDNR 1997). Eurasian watermilfoil is capable of spreading and reproducing by fragmentation. This has hastened its invasion by allowing introduction to occur from plant fragments attached to boat trailers. Spread can also occur from plant fragments which enter a lake from upstream in flowing tributaries. Once established, most localized reproduction occurs by stolon formation with more distant colonization occurring through fragmentation (Aiken et al 1979, Madsen et al 1988). Under experimental conditions it has been demonstrated that up to 46% of fragments that settle on aquatic substrate become established (Madsen etal 1997). Obviously fragments produced by powerboat traffic can increase the rate of spread. Eurasian watermilfoil can be an extremely invasive and fast growing aquatic plant given proper conditions. It often tends to gain a strong foothold colonizing areas of ecological disturbance such as dredged shoreline areas, regions of excessive sedimentation, and nutrient enriched lakes. Eurasian watermilfoil can be an extremely destructive inhabitant in some lakes because of its invasive nature. Displacement of more beneficial native species often takes place as the fast growing milfoil achieves a dense canopy over native plant beds, depriving the slower growing species of sunlight. The resulting loss of diversity and increase in habitat complexity can cause a variety of trophic changes in an overgrown aquatic system including reduced predatory success and growth of picivorous gamefish (Strange et al 1975) and reduced growth of panfish (Crowder and Cooper 1982). In shallow lakes milfoil biomass can become extensive enough to cause winter or summer fishkills as plant material decomposes during periods of low light in late summer or extensive snow and ice cover in winter. Milfoil infestations commonly cause problems for boaters, swimmers, and fisherman as dense growths of the plant reach the surface and grow laterally forming unsightly vegetative mats. Many thousands of dollars per year are spent in Indiana on control programs, with extensive treatments taking place locally on Crooked Lake (Steuben) and Hamilton Lake. Lake responses to milfoil infestation vary greatly. In some lakes Eurasian milfoil shows limited growth, competing side by side with native plants as an integrated member of the floral community, causing problems only in limited areas. The Lakes in the James Chain currently fall into this category having been impacted minimally by Eurasian milfoil. In other cases the plant quickly displaces native plant communities becoming a major nuisance within the first five years of colonization. Curlyleaf pondweed also has the potential to become highly invasive and interfere with the growth of beneficial native species. Should Eurasian watermilfoil or Curlyleaf pondweed become dominant and disrupt the native aquatic plant communities in the James Chain the following summary of control options would apply.

## 2.6 Options for Controlling Invasive Exotic Aquatic Plants

•Insect Biological Control:
A North American Weevil *Euhrychiopsis lecontie*, may be associated with natural declines in Eurasian milfoil at northern lakes (Sheldon 1994, Bratager et al. 1996, Weinberg 1995). In recent years the weevils have been marketed and stocked as a biological control agent with varying results. Historically associated with the native milfoils, the insects are capable of grazing on Eurasian milfoil as well, while not affecting the majority of native vegetation. A control program involves breeding the weevils in captivity, collecting them and then physically attaching the insects to the target plants in the field. The stocked weevils sometimes produce a modest reduction in milfoil biomass among targeted plants during the first season. In most cases restocking must occur every year to maintain control, in many cases no reduction in plants is noted at all after stocking. Interest in the use of the milfoil weevils has been high. They are often viewed as a natural control method that will be less environmentally damaging than more effective forms of control. At present, the high cost and relatively low reductions in plant biomass associated with weevil stocking programs has severely limited their popularity as a control mechanism.

•Harvesting:
Their are several models of machines produced for cutting and removal of aquatic vegetation from lakes. Contractors who own the machines generally hire on to cut plants on an hourly basis with organizations that can provide a set minimum hours of work to cover mobilization costs. Most harvesters are constructed like a floating combine. The floating machine is driven and steered with paddle wheels. An underwater cutting bar cuts plant stems and a driven belt carries the cuttings to the back of the machine where they are deposited in a hopper. When the machines hopper is full the machine operator offloads the aquatic cuttings in a designated area or into the back of a truck for disposal. One advantage of harvesting is the actual removal of plant material and associated nutrients from the lake. Unfortunately, only a very small percentage of a lakes nutrient load is invested in plant biomass at any given time. In most cases the cutting

will have to be repeated each season and often multiple cuttings per season are needed to control plant regrowth. A major disadvantage of harvesters is the amount of biological disturbance introduced to the lake during the cutting process. Eurasian watermilfoil maintains the ability to recover very quickly from cutting. Native plants which cannot recover as readily from the harvesting encounter a selective disadvantage. The end result can be a shift in plant biomass away from more beneficial native plants, toward Eurasian watermilfoil. Whereas Eurasian milfoil can reproduce through fragmentation, the potential for free floating cut plants to spread growth by settling in other parts of the lake also must be considered. Aquatic plant cutters also tend to entrain a large number of small fish, turtles, and other aquatic organisms which will be removed from the lake if not screened out by the operator. Because of these problems weed harvesting has become subject to regulation and permitting by the Indiana Department of Natural Resources. Harvesters are often the only effective option for controlling excessive growths of stout native plants that do not respond well to other control methods. They are also often employed in areas where regulatory permitting excludes the use of pesticides.

•Control of Eurasian watermilfoil and Curly-leaf Pondweed with Aquatic Contact Herbicides:

Several aquatic contact herbicides are available for use in Indiana lakes. Aquatic pesticide applications on Indiana public lakes are subject to review and permitting on a seasonal basis with the Indiana Department of natural Resources. In addition aquatic applicators for hire must be licensed through the office of the Indiana State Chemist. In aquatic herbicide applications chemical products are typically dispersed over target plants as liquid or granular formulations using specialized boat-mounted equipment. Most contact herbicides function by eroding the cell membranes of plant tissue disrupting plant functioning. Control is usually achieved quickly with susceptible plant species often dropping out in less than one week. Aquatic herbicide choices are somewhat limited as EPA approved products must not cause damage to untargeted organisms, provide a hazard to lake users, or leave harmful residues in the environment. Because of these requirements most contact herbicides have a short half-life in an aquatic environment, being lost to soil adhesion, photodegradation, or bacterial decomposition shortly after application. By both accident and design, most aquatic contact herbicides are selectively effective against obnoxious exotic species with Eurasian milfoil, and Curly-leaf pondweed being especially susceptible. Stout native species such as some of the larger native pondweeds and most of the native milfoils largely remain unaffected by open-lake and lake-channel applications. This provides the advantage of allowing selective control, dropping out invasive exotics and leaving the native plant community to recover and capitalize on available light. Selective susceptibility needs to be considered when making herbicide choices so that appropriate plant community effects occur. Contact herbicides tend to leave plant root structures intact so regrowth often begins shortly after treatment. Multiple treatments can be needed in some cases to maintain full-season control. Use of some herbicides requires that lake activities such as swimming or lawn irrigation be restricted near the treatment area during a post treatment waiting period. Water-use restrictions generally apply within 100 feet of the application area. Waiting periods for swimming and other water-uses vary between zero and 30 days depending on the product used.

•Aquatic Plant Control with 2-4-D Granular Translocated Aquatic Herbicide:

Granular formulations of 2-4-D herbicide have been used for many years to control Eurasian watermilfoil. In lawn, agricultural, and aquatic applications 2-4-D is used to selectively control plants which are biologically classified as "broadleaves". Aquatic plants in this category include Eurasian and Native milfoils and Coontail *Ceratophyllum echinatum*. 2-4-D is a translocated or "systemic" aquatic herbicide. It is absorbed by target plants and transported through their vascular systems, affecting remote parts of the plant including the root structure. This offers the theoretical advantage of actually killing more plants and providing longer term control. Well-timed 2-4-D applications in some cases provide seasonal control of Eurasian watermilfoil with regrowth occurring the following season. Occasionally reapplication is needed within the same season. With milfoil infestations, 2-4-D offers the advantage of being highly selective for milfoil with the pondweeds, and most other native plants remaining completely unaffected. Granular 2-4-D use typically restricts swimming near the treatment area for one day, and requires a waiting period on the use of lake water for lawn irrigation, so ornamental and garden plants will not be damaged.

•Aquatic Plant Control with Trichlopyr Translocated Aquatic Herbicide:
Available in a liquid formulation as Renovate 3® aquatic herbicide, trichlopyr offers broadleaf specific systemic control of aquatic plants in a liquid herbicide. This offers the advantage of easier handling and application over 2-4-D. Results have been similar to use of 2-4-D. Improved application techniques and the use of adjuvants show some promise of possible providing multi-seasonal control with the use of Trichlopyr. The current labels allows the restricted use of dosed lake water to be adjusted in accordance with lake-water assay results, greatly reducing the time of restriction in most cases.

•Aquatic Plant Control with Fluridone Translocated Aquatic Herbicide:
Two aquatic herbicide formulations containing fluridone are currently available under the trade names Avast!® and Sonar®. Fluridone is an extremely effective aquatic herbicide at very small concentrations in lakes and ponds, while it displays a relatively low toxicity to fish and mammals. Unlike most other aquatic herbicides it's also environmentally persistent, often remaining in the dosed waterbody in minute, but measurable amounts over the course of several months. Fluridone is absorbed by plant shoots from water, and from hydrosoil by the roots of aquatic vascular plants. In susceptible plants, fluridone inhibits the formation of carotene. In the absence of carotene chlorophyll is rapidly photodegraded causing plants to become chlorotic (whiteish) and eventually drop out. Like many other herbicides fluridone is capable of a high degree of selective control at proper dosages. Within the assemblage of plants in The James Chain Curly-leaf pondweed, Eurasian watermilfoil, and Elodea (a native plant) are most susceptible. For control of Eurasian milfoil fluridone is introduced into a lake at the calculated rate of six to twelve parts-per-billion. Assays are often performed within the first two weeks after initial dosing to assess a hit or miss on a target concentration. A second dosage is often used to maintain the target concentration for a period of 60 to 90 days as the product is allowed to work. At a 6 PPB dosage rate fluridone is typically highly selective for Eurasian watermilfoil and Curly-leaf pondweed. Control typically lasts the entire season with occasional carryover effects during the second season. At dosages of 10 to 12 PPB Eurasian watermilfoil control is typically complete by the end of the first season and often extends through the second season, but a variety of native plants may be impacted. One major advantage of Fluridone use is its persistence and slow activity. During the extended treatment period the product mixes throughout the upper strata of the entire lake basin, allowing it to reach all exotic target plants in contact with the water. This also means that consideration must be given to possible impacts

downstream from the target lake. Because of its slow rate of activity fluridone also offers the advantage of providing for gradual breakdown of target plants, providing a more gradual release of nutrients than faster acting herbicides. This decreases the chances of developing oxygen deficits or excessive algal blooms in shallow lakes. Because of the high cost of fluridone herbicides, their use is often reserved for lakes with extensive littoral areas showing profound mat-forming infestations and severely impaired recreational use. The only water-use restriction associated with fluridone is a wait on the use of lake water for lawn and garden irrigation of 14 to 30 days.

•Aquatic Plant Control with Triploid Grass Carp (White Amur):
The Asiatic Grass Carp *Ctenopharyngodon idella* have become popular as an introduced exotic biological control for rooted aquatic plants in ponds and southern U.S. lakes. Grass Carp are native to river systems of Russia and China. The species was first imported to the southern United States in 1963. Like most biological controls herbivorous grass carp have remained extremely popular despite some problems associated with their use. Stocking of grass carp was initially illegal in many states including Indiana. Because grass carp are a possibly detrimental exotic species, resource managers feared a destructive establishment of viable wild populations. This process had already occurred with the common carp which remains a destructive influence in our aquatic habitats. Proponents of the plant-eating fish argued that viable breeding habitat for the carp was not present in the United States. That argument was refuted when viable reproduction was noted in the 1980's in tributaries to the Mississippi. When a technique was developed for producing genetically altered triploid grass carp stock with greatly reduced fertility, laws in many states including Indiana were changed to allow stocking of the sterile fish in private waters. The possibility still exists for fish producers to bypass the necessary hatchery process and market fertile fish. Illegally stocked fertile grass carp have been found in some locations. Use of any grass carp remains illegal in twelve states including Michigan. Despite remaining controversy, some regulatory agencies encourage their use in ponds and lakes publishing stocking guidelines and even offering the fish for sale. Grass carp have been introduced into thousands of private ponds and many larger reservoirs in the southern United States with mixed results. Often stockings in large waterbodies bring either complete eliminations of vegetation or very little decline at all (Cassani 1995). Grass Carp are selective feeders and unfortunately tend to prefer most native plant species over Eurasian watermilfoil. Results of grass carp stocking vary with the plant species assemblage present in stocked waters and variations in lake morphometry. In general, stocking at low rates can be expected to produce a shift in plant biomass away from preferred species food plants, toward unpreferred. At high stocking rates the fish will consume all rooted aquatic vegetation in the system. This causes a shift in plant biomass toward planktonic and filamentous algae as fish waste and feeding activity boosts lake nutrient levels. At sustained high numbers, the fish will consume filamentous algae, emergent aquatic plants, and even terrestrial vegetation within their reach at the lake's edge. Shoreline erosion can become a problem when this occurs. At the end result of sustained high stocking rates lake plant biomass will be maintained in planktonic algae, which the fish are unable to utilize as a food source. This can obviously lead to water clarity problems and unstable oxygen levels, especially in the temperate northern U.S. Successful use of grass carp on ponds and in large southern lakes often trades water clarity for alleviation of rooted plant problems. This technique can be effectively employed where water clarity and high oxygen levels are not a priority. In the case of the James Chain where water quality and clarity is a high priority, use of herbivorous fish as a management technique would not be wise or legal.

•Benthic Barriers for Aquatic Plant Control

Sheets of plastic or rubber material have been used to exclude aquatic plant growth. Usually owners of small ponds or swimming areas will employ this technique by placing the liner on the bottom and depositing sand or pea gravel on the liner. One drawback with this technique is the tendency for gasses to build up beneath impermeable liner material pushing it up from the bottom. This occurs as decomposition in the lake sediments produces hydrogen sulfide and carbon dioxide gasses. Using mesh liners or permeated liners can alleviate this problem somewhat, but obviously will allow plants to a grow through the liner. Bottom liners also effectively exclude areas of benthic habitat and are generally not permitted by IDNR in public lakes for this reason.

□Table of Aquatic Plant Management alternatives

| Option | Benefits | Drawbacks |
|---|---|---|
| No Control | No dollar cost, No water-use restrictions | Further loss of plant diversity, degraded fish & wildlife value, possible further Sportfish stunting, Impeded recreational use, aesthetic problems |
| Biocontrol Weevils | No swimming restrictions, No watering restrictions | Often ineffective, Cost prohibitive |
| Biocontrol Grass Carp | No water-use restrictions, possible multi-season control | Results not-predictable, illegal in Indiana public waters, may cause water clarity/quality problems, limited selectivity |
| Harvesting | No water-use restrictions, Removes some nutrients from lake | May hasten spread Eurasian milfoil through fragmentation and hydrosoil disturbance, Expensive, May result in regrowth within same season, Requires plant disposal site, Non-selective |
| Benthic liners | No water-use restrictions, possible multi-seasonal control | Impairs benthic habitat, Not generally permitted in Indiana Public Waters, Not feasible in deep water, Inherent maintenance problems |
| Aquatic Pesticides (2-4-D) | Highly selective control, Very effective | Intermediate expense, difficult application, Swimming and irrigation restrictions, Generally provides one season's control |
| Aquatic Pesticides(Renovate) | Highly selective control, Very effective | Expensive- materials expense, Swimming and irrigation restrictions, Generally provides one season's control, |
| Aquatic Pesticides (Sonar a.s.) | Highly selective control, Very effective, Multi-seasonal control | Expensive product, irrigation restriction, possible damage to non-target vegetation |
| Aquatic Pesticides (contact herbicides) (diquat dibromide or endothols) | Some selectivity, Very effective, fast acting, least expensive application | Generally provides on season's control, Possible regrowth in late season, Swimming, Irrigation, and possible fish consumption restrictions |

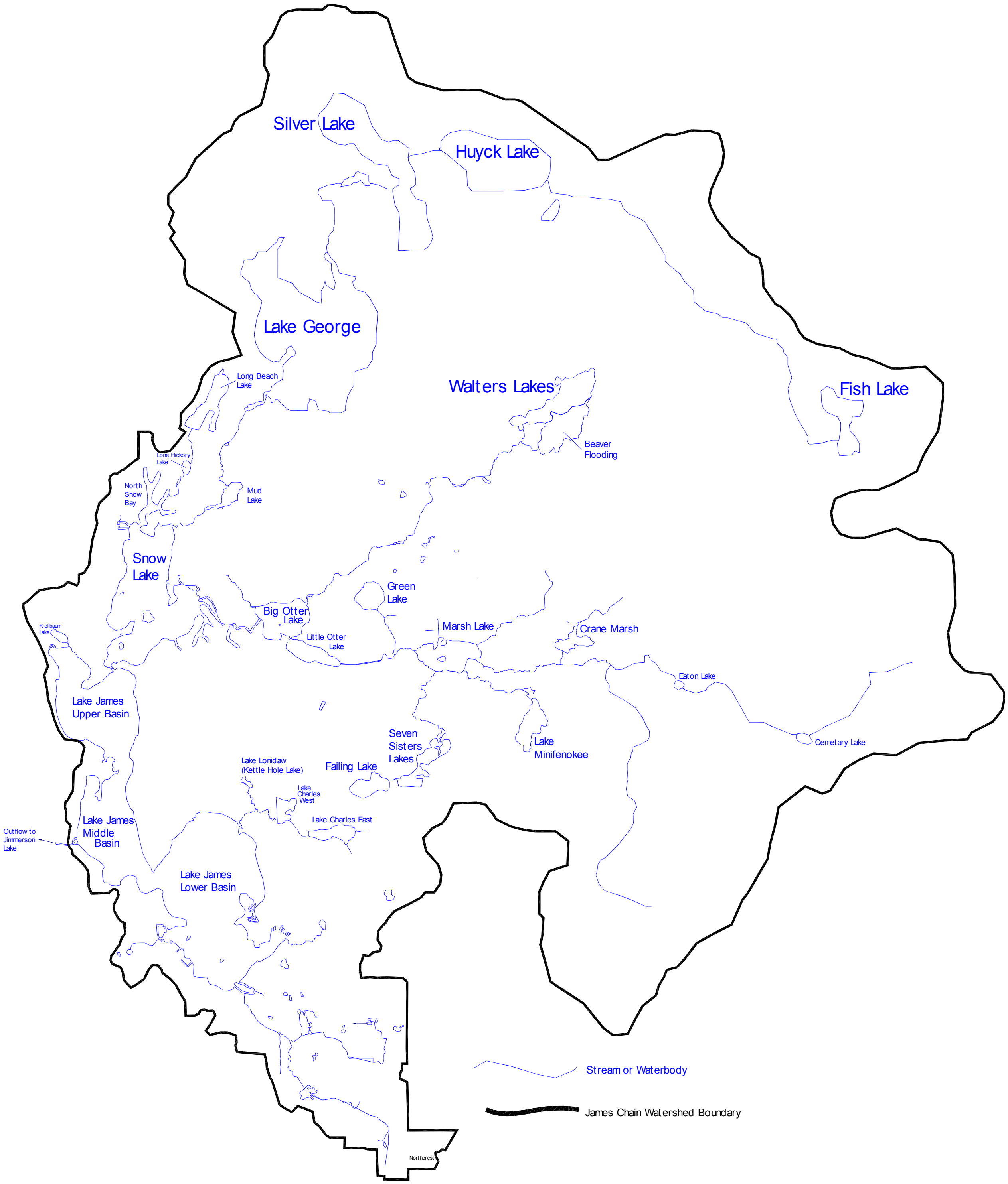



**Figure 28 The James Chain Watershed**

## 3. Lake James Chain Watershed Characteristics

A watershed is defined as the area that drains to a waterbody. Examining watersheds is important in lake management because the nature of watershed lands often largely determines the

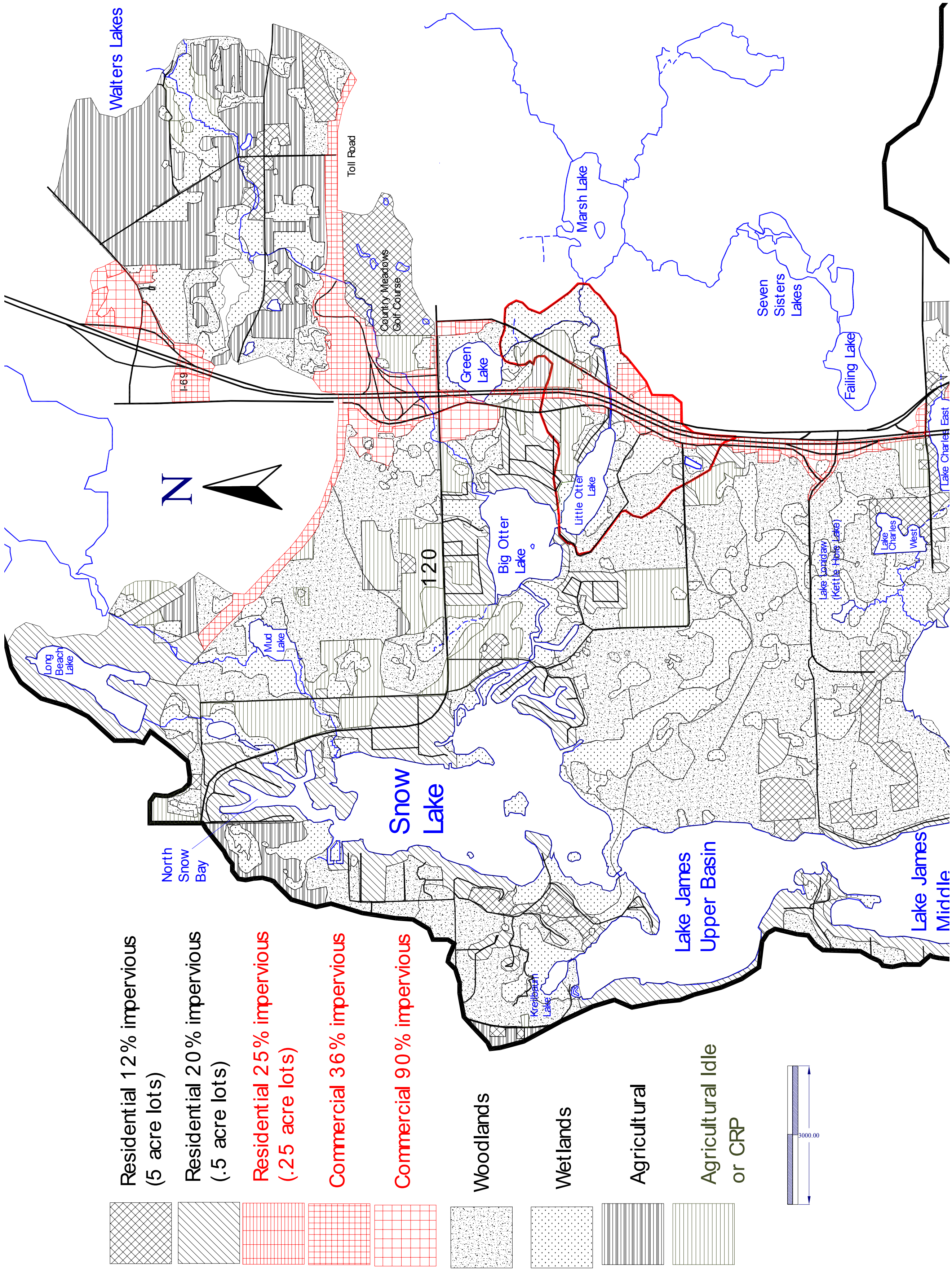



**Figure 29 Land Use and Land Cover in the North Half of the Study Watershed**

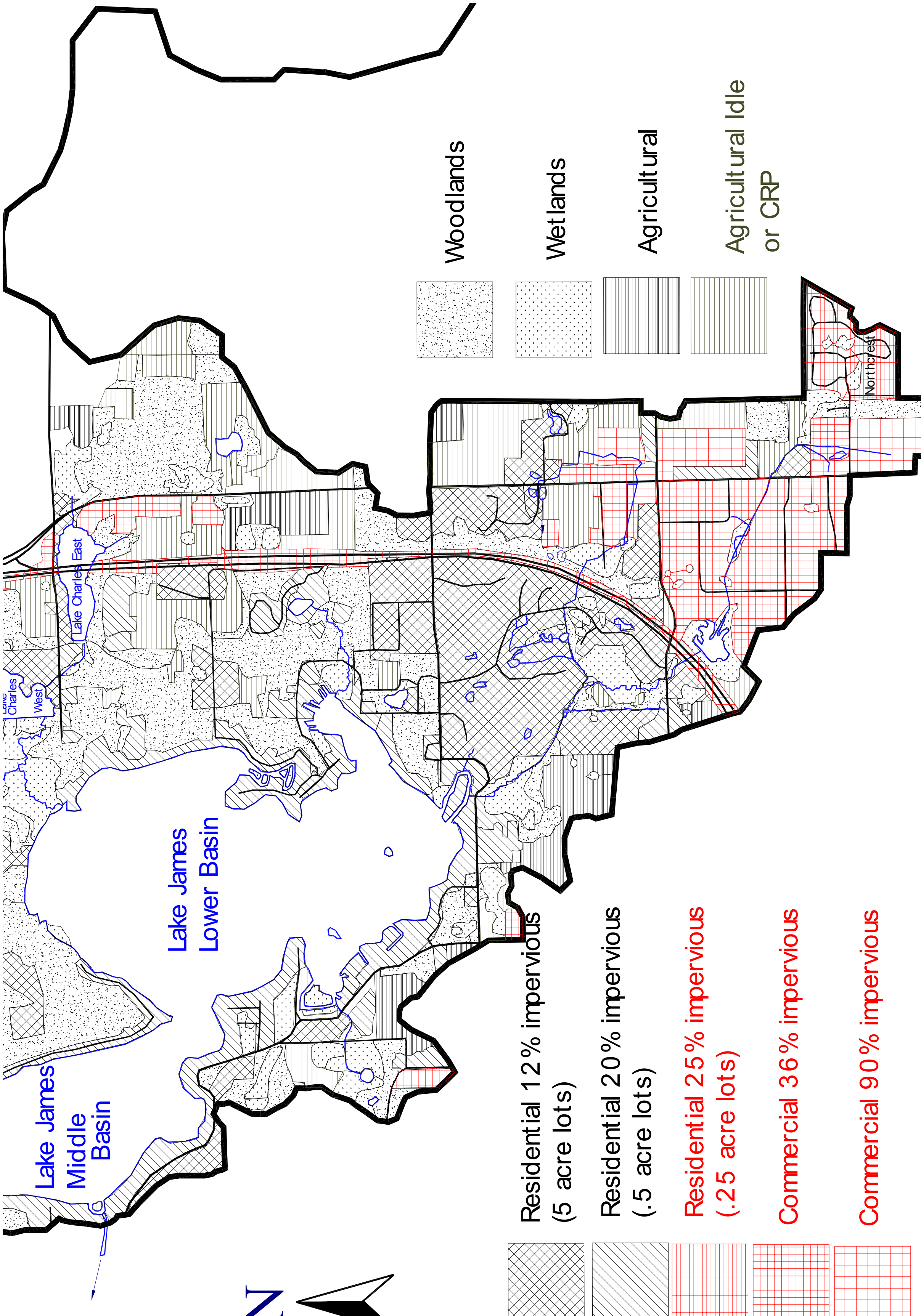



**Figure 30 Land Use and Land Cover in the South Half of the Study Watershed**

character of waters they drain to. Rainfall and snow-melt runoff bring eroded soil, nutrients and other pollutants into lakes and streams. An area of approximately 26,290 acres drains through the Lake James Chain (fig 28). Watershed land uses near the lakes are dominated by woodlands, wetlands, and residential and commercial development with much of the outlying watershed upstream of Marsh Lake, Lake George and Big Otter Lake being agricultural. For this study land use and land cover was mapped for the immediate 6481 total acres lying within the subwatersheds for Green Lake (64 acres), Lake Charles East (406 acres), Little Otter Lake (260 acres), Big Otter Lake (1454 acres), Snow Lake (1493 acres), and Lake James (3160 acres). (fig 29,30)

| Subwatersheds | square feet | acres |
|---|---|---|
| Overall watershed | 1,145,218,803.00 | 26,290.61 |
| Lake George | 352,038,225.00 | 8081.69 |
| Big Otter Lake | 65,968,734.00 | 1514.43 |
| Walter's Lakes | 49,515,190.00 | 1136.71 |
| Green Lake | 2,794,901.00 | 64.16 |
| Little Otter | 13,187,758.00 | 302.75 |
| Lake Charles Est. | 17,661,724.00 | 405.46 |
| Lake James | 188,275,764.00 | 4322.22 |
| Marsh Lake | 372,656,269.00 | 8555.01 |
| Snow Lake | 83,044,708.00 | 1906.44 |
| | | |
| | Total | 26,288.87 |

**Table 21 James Chain Subwatershed Areas**

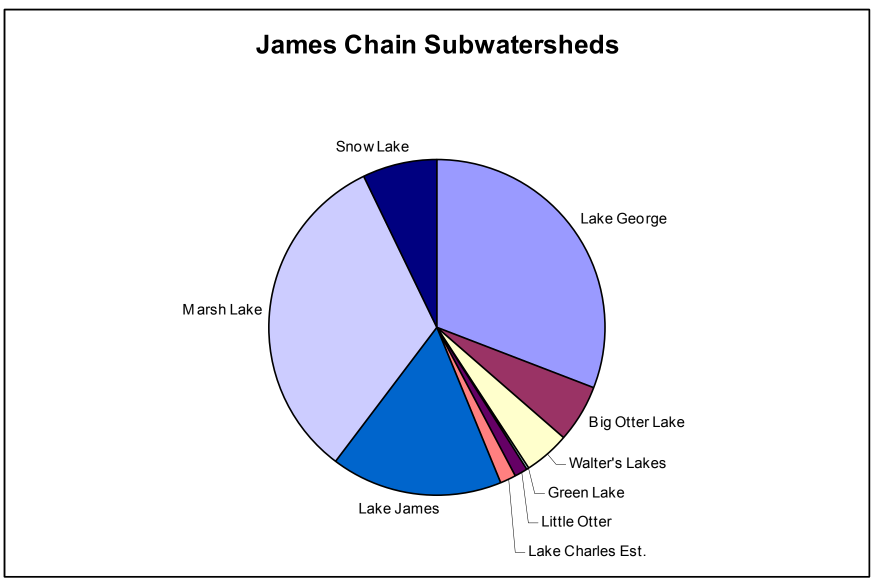



**Figure 31 James Chain Subwatershed Area Chart**

Land uses were categorized using satellite photos with field checks also used on some areas. Developed areas were categorized into five groups by their approximate percentage of impervious surface (pavement and rooftops). These groups ranged from residential areas with approximate five acre lot sizes and 2 percent impervious surfaces to commercial areas with 90% impervious surfaces. Agricultural areas were divided into those which are actively tilled and those which are idle or contain a cover crop of grasses. The main land use on the 4751 acres of land in the studied subwatersheds is woodlands (41 percent). This is owed in large-part to the woodland acreage within Pokagon State Park. Wetland acreage is the second most common land use (24 percent). The many riparian and isolated wetlands within the James Chain watershed are a great asset to the watershed, providing filtration of soil and nutrients present in rain and snow-melt runoff, especially during the growing season when wetland plants utilize nutrients for growth. Residential areas with lot sizes of approximately one half acre are the third most common land use (20 percent). These areas have approximately 20 percent impervious surfaces such as concrete or rooftops. Fourth most common are residential areas with large lots of approximately five acres and two percent impervious areas. Idle farmlands or CRP fields containing grasses are the fifth most common land use and account for 14 percent of the area. Commercial areas with 36 percent impervious surfaces were fifth most common comprising 13 percent of the study area. Active agricultural areas accounted for 12 percent of the area. Commercial areas with large rooftops, parking lots and approximately 90 percent impervious surfaces comprise three percent of the area and small residential lots of approximately one quarter acre and 25 percent impervious surfaces comprise one percent of the area.

| Land Use | Acres | Percentage |
|---|---|---|
| Agriculture | 547.90 | 12% |
| Idle/crp (grasses) | 676.14 | 14% |
| Commercial 36% | 614.51 | 13% |
| Commercial 90% | 126.78 | 3% |
| Residential .25 ac. lots | 51.20 | 1% |
| Residential .5 ac. lots | 936.72 | 20% |
| Residential 5 ac. lots | 725.47 | 15% |
| Wooded | 1964.11 | 41% |
| Wetlands | 1124.63 | 24% |
| Total Lands | 4750.93 | 100% |

**Table 22 Watershed Land Use Areas and Percentages**

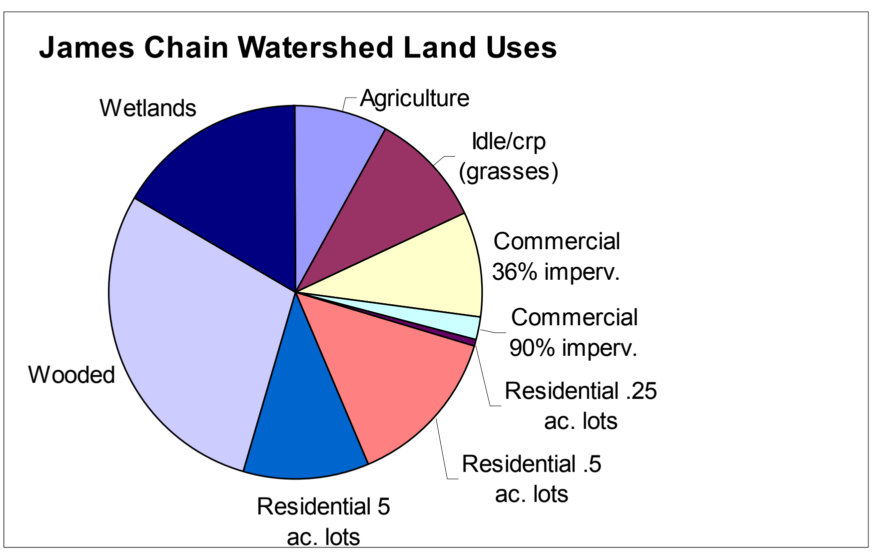



**Figure 32 Land Uses in the James Chain Watershed**

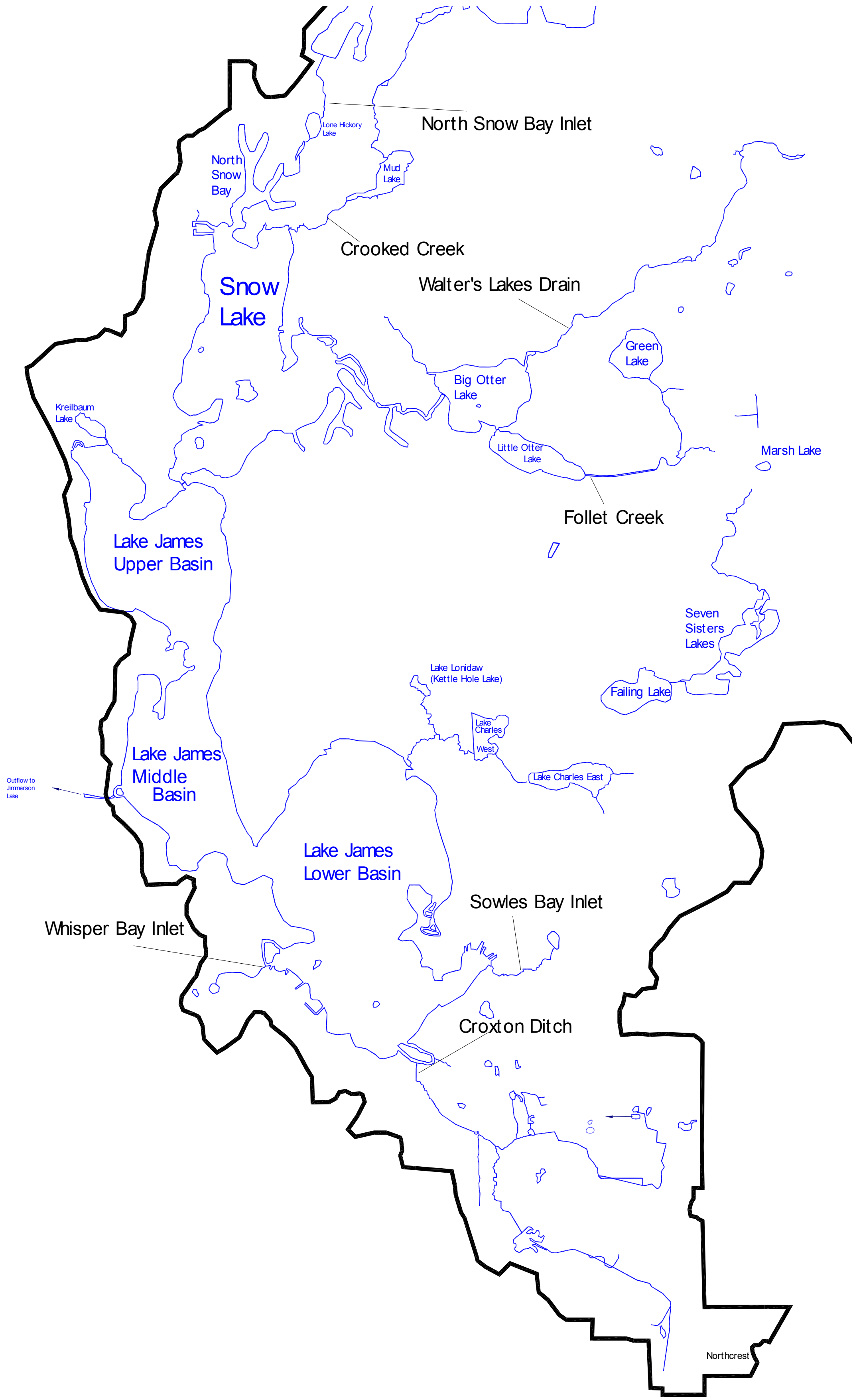



**Figure 33 James Chain Tributaries Sampled in 2005**

## 3.1 Tributaries and Their Watersheds

Because tributaries provide conduits for nutrient and sediment runoff, and wastewater effluents their water quality has implications for the water quality of the lakes they drain to. A total of seven tributaries were sampled for this study. The chains four major tributaries, Crooked Creek, Walter's Lake Drain, Follet Creek, and Croxton Ditch were sampled and analyzed for 12 parameters during baseline flow conditions and also during one rain event. Three of the chain’s smaller unnamed tributaries were also sampled for total phosphorus and total suspended solids during baseline flow conditions and one rain event.

| Parameter | E-coli, CFU/100ml | Total Phos. (ppm) | TSS | Orth. Phos | Turb | Dissolved Phos. | Amm. | Nitrate/ Nitrite | TKN | D.O. | Temp. | Cond. (uS) /cm | pH | CFM Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Croxton Ditch | 157 | .027 | n/d | <.007 | 2.8 | .023 | .04 | .26/.01 | .56 | 8.07 | 17.3 | 609 | 7.85 | 61.74 |
| Follet Creek | 10 | <.007 | 2.8 | n/d | n/d | n/d | n/d | n/d | n/d | 5.27 | 25.2 | 735 | 7.95 | 718.73 |
| Walter's Lakes Drain | 81 | .085 | n/d | .058 | 3.20 | .682 | .03 | .01/.01 | .48 | 8.21 | 17.3 | 685 | 7.8 | 177.85 |
| Crooked Creek | 8 | <.094 | n/d | .013 | .40 | n/d | .03 | .01/.01 | .80 | 4.55 | 24.2 | 460 | 7.61 | 346 |
| St. Joseph River Watershed Mean IDEM 2000-2005 stream data | 1895.58 (MPN) | .382 | 35.87 | n/d | 17.41 | n/d | 1.19 | 3.52 | 2.28 | 7.14 | 19.91 | 764.2 | n/d | _ |

**Table 23 8/17/05 Lake James Chain Baseline Flow Data from Major Tributaries with mean comparison data from St. Joseph River Watershed Streams (IDEM probabilistic stream data)**

| Parameter | Total Phos. (ppm) | TSS | D.O. | Temp. | Cond. (uS) /cm | CFM Flow |
|---|---|---|---|---|---|---|
| Sowles Bay Trib. | .034 | 8.4 | 9.66 | 14.3 | 765 | 4.17 |
| Whisper Bay Trib. | .037 | 3.6 | n/d | n/d | n/d | 26.61 |
| North Snow Bay Trib. | .054 | 6.0 | n/d | n/d | n/d | No meas. |
| IDEM St Joseph River Watershed Mean | .382 | 35.87 | 7.14 | 19.91 | 764.19 | _ |

**Table 24 8/17/05 Lake James Chain Baseline Flow Data from Minor Tributaries with mean comparison data from St. Joseph River Watershed Streams (IDEM probabilistic stream data)**

Baseline flow data for the James Chain's major and minor tributaries was collected on August 17 (table 22,23). Total Phosphorus levels in samples collected from Croxton Ditch and Follet Creek were quite low. Follet Creek's sample fell below a Total Phosphorus lab detection limit of .007 parts-per-million (PPM). Walter's Lake drain showed a slightly higher total phosphorus measurement of .085 ppm and Crooked Creek showed the highest measurement at .094 ppm. These measurements were low relative to other Indiana streams in the broader St. Joseph River watershed. Randomly collected probabilistic data provided by the Indiana Department of Environmental Management in 2000 and 2005 (125 samples) showed a mean total phosphorus concentration of .382 ppm. Orthophosphorus, the form most readily available to spur algae growth and affect water quality was relatively low for the Walter's Lake Drain and Crooked Creek samples. Dissolved phosphorus was highest from the Walter's Lake Drain sample.

Since it should be included as a component of the total phosphorus measurement and was far higher this result is assumed to be in error. Dissolved Phosphorus and Orthophosphorus data from the probabilistic data set were unavailable for comparison. Nitrate+Nitrite, Ammonia and suspended solids measurements were well below the mean for other streams in the probabilistic data. Dissolved oxygen levels on Walter's Lakes Drain and Croxton Ditch were considered slightly above normal for Indiana streams. Crooked Creek and Follet Creek were slightly below the norm for Dissolved Oxygen. The highest E-coli level measured was 157 colony forming units (CFU) for Croxton Ditch. This may still fall within acceptable levels. E-coli standards for primary-contact recreational waters (where uses such as swimming are permissible) vary among public agencies. The bacterial water quality standard for full body contact recreation in Indiana is based on E.coli, as recommended by the EPA. The geometric mean of 5 samples over a 30-day period is required to be less than 125 CFU/100 mL, with no sample testing higher than 235 CFU/100 mL. Monitoring results for E. coli are usually given in terms of number of E. coli colony forming units (or CFU) in 100 mL of water. All samples were well below the mean E-coli count from the probabilistic data set from other Indiana Streams of 1895.58 (MPN). Obviously many streams in the probabilistic data have very elevated E-coli levels. Conductivities were near or slightly below the average for the probabilistic data set, indicating average or below average concentrations of dissolved ions in James Chain tributaries. Baseline flow samples collected from minor tributaries at Sowles Bay (Lake James), Whisper Bay (Lake James), and North Snow Bay (Snow Lake) were quite low in total phosphorus and total suspended solids compared to other Indiana streams. Dissolved oxygen, and conductivity was measured at the Sowles Bay tributary during baseline flow conditions. Dissolved oxygen was relatively high compared to the average for other area streams while conductivity was average.

| Parameter | E-coli, CFU/ml 9/23/05 | Total Phos. (ppm) | Turb (NTU) | Dissolved Phos. (ppm) | Amm. (ppm) | Nitrate/ Nitrite (ppm) | TKN (ppm) | D.O. (ppm) | Temp. (C) | Cond. (uS)/cm | pH | CFM Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Croxton Ditch | 650 | .043 | 8 | .034 | .06 | .41/ <.01 | .48 | 7.20 | 18.5 | 780 | 7.85 | 81.73 |
| Follet Creek | 325 | .034 | 2.80 | .122 | .05 | .48/.01 | .64 | 7.85 | 22.3 | 713 | 7.85 | 486.36 |
| Walter's Lakes Drain | 1600 | .048 | 7.7 | .043 | .04 | .25/.01 | .40 | 7.32 | 18 | 737 | 7.32 | 99.74 |
| Crooked Creek | 443 | .058 | 3.6 | .059 | <.01 | <.01/ <.01 | .64 | 6.15 | 22.9 | 449 | 7.75 | 160.00 |
| St. Joseph River Watershed Mean IDEM 2000-2005 stream data | 1895.58 (MPN) | .382 | 17.41 | n/d | 1.19 | 3.52 | 2.28 | 7.14 | 19.91 | 764.19 | n/d | _ |

**Table 25 6/5/05 Lake James Chain Rain Event Flow Data from Major Tributaries with mean comparison data from St. Joseph River Watershed Streams (IDEM probabilistic stream data), event rainfall .24 inches in approx. 2 hrs. (E-coli 9/23/05 )**

| Parameter | Total Phos. (ppm) | Turb | Dissolved Phos. | Amm. | Nitrate/ Nitrite | TKN | pH | CFM Flow |
|---|---|---|---|---|---|---|---|---|
| Sowles Bay Trib. | .047 | 7.9 | .05 | .02 | .30/.01 | .48 | 7.93 | 13.84 |
| Whisper Bay Trib. | .044 | 4.5 | .049 | .08 | .66/ <.01 | .48 | 7.82 | 34.28 |
| North Snow Bay Trib. | .057 | 4.5 | .078 | .06 | .01/.01 | .56 | 7.59 | 4.5 |
| IDEM St Joseph River Watershed Mean | .382 | 17.41 | n/d | 1.19 | 3.52 | 2.28 | n/d | _ |

**Table 26 6/5/05 Lake James Chain Rain Event Flow Data from Minor Tributaries with mean comparison data from St. Joseph River Watershed Streams (IDEM probabilistic stream data), event rainfall .24 inches in approx. 2 hrs.**

Rain event tributary data was collected on 6/5/05 (table 25,26). Phosphorus and nitrogen parameter levels were again well below average on all the major and minor tributaries sampled. This was probably the result of a relatively dry season in general and a rain event of only .24 inches prior to sampling. Rain event significant enough to produce a large amount of runoff during the 2005 season were few. Turbidity was also well below average, but E-coli levels were somewhat elevated on all four major tributaries, especially Walter's Lake Drain which showed a level of 1600 CFU. While this is still below the average from the IDEM data set of 1895.58 it is still cause for concern. Swimming would not be advisable in a body of water with this count. The source of this contamination is unknown. The Walter's Lake Drain watershed does contain a small wastewater treatment facility but it is separated from the streambed by a large wetlands. Pasture ground draining to Walter's Lake drain just north of the 80/90 toll road may be an area to further investigate elevated E-coli levels in this watershed. Elevated levels on the other tributaries could be related to Canada Geese, pets, or septic systems in the watershed, especially on Croxton Ditch and its tributaries which flow through a golf course and housing development prior to entering Lake James.

Historical Tributary Data: Walter's Lakes Drain, Follet Creek, Crooked Creek

Data from James Chain tributaries has been collected by various sources over the years. Association members have carried out volunteer monitoring through RC&D and Hoosier Riverwatch on Follet Creek at Snow Lake and Crooked Creek at State Road 120 (just upstream of Snow Lake) for several seasons. The table below contains selected volunteer monitoring data for Crooked Creek. The Otter Lakes have apparently experienced water quality problems in the past due to nutrients and sediments entering the lakes via Follet Creek and Walter's Lakes Drain. Interstate 69 was constructed over Follet Creek just upstream of Little Otter Lake in the 1960's. During construction the course of the creek was altered significantly. Sediment introductions during this time lead to the eventual dredging of the East End of Little Otter Lake. Beginning in or about 1970 the Otter Lakes residents also experienced severe problems with algae growth and petitioned the Indiana State Board of Health Water Pollution Control Division with concerns about contributions from the Fremont and Indiana Toll Road Wastewater Treatment Plants. In response to this some tributary data was collected for Big and Little Otter Lakes by the State of Indiana. A data sheet provided by the lake residents dated May 21, 1970 suggests that the phosphorus concentration of Follet Creek waters entering Little Otter Lake may have been as high as .7 ppm at that time. The source of the 1970 data is unknown, but presumed to be the State Board of Health that was working with the lake residents at the time. Table 28 below contains selected tributary data collected by the Board of Health in 1976. At that time Follet Creek had a total phosphorus concentration of .06 ppm compared to 2005 measurements of .034 ppm (rain event) and less than .007 ppm (baseline). The 1976 measured phosphorus concentration for Walter's Lake Drain was below a lab detection limit of .03 ppm. The 2005 rain event and baseline flow measurements were .048 ppm and .085 respectively. A 1976 correspondence from the Indiana State Board of Health acknowledged the presence of severe blue-green algal blooms on Big and Little Otter Lakes at that time and expressed concern over a possible increase in nutrient enrichment of Snow Lake as a result of a proposed channel to be built through the wetlands between Big Otter and Snow Lake. At that time boat passage was difficult at best and also deterred by the existence of a low bridge between Big Otter and Snow Lake. A portage was necessary to even complete the journey with a row boat. When a higher bridge was constructed at some point thereafter more boats made the journey and prop and wake erosion eventually resulted in the open-water channel that's present today. A query of Indiana State Water Quality Data did not produce any further data for Walter's Lakes Drain, Follet Creek, or Crooked Creek.

| Volunteer Sampling Date, Crooked Creek | Fecal Coliform CFU/ml | Total Phos. (ppm) | Turb JTU | Nitrate/ Nitrite | D.O. | Temp | pH |
|---|---|---|---|---|---|---|---|
| 7/20/96 Time 1045 | 0 | .05 | 5 | .15 | 7 | 24 | 8.1 |
| 7/20/96 Time 1350 | 0 | .04 | 5 | 0 | 8 | 26 | 7.5 |
| 9/21/96 Time 1005 | 0 | .12 | 0 | .135 | 6 | 15 | 7.2 |
| 9/21/96 Time 1220 | 0 | .20 | 0 | .10 | 7 | 17 | 7.4 |
| 7/19/97 Time 958 | 0 | .04 | 13 | .09 | 7 | 25 | 7.5 |
| 9/27/97 Time 940 | 0 | .04 | 5 | .09 | 5 | 17 | 7.7 |
| 6/13/98 Time 2:21 | 0 | .02 | 15 | 0 | 7 | 21 | 7.5 |
| 9/19/98 Time 820 | 0 | .04 | 10 | .15 | 5 | 22 | 7.3 |
| 6/5/99 | 0 | .04 | 15 | 0 | 7 | 24 | 7.7 |
| 9/18/99 | 0 | .02 | 15 | 0 | 7 | 17 | 7.5 |
| 7/24/00 | 0 | .05 | 15 | .2 | 7 | 24 | 7.1 |
| 9/17/00 | 0 | .04 | 5 | .09 | 5 | 17 | 7.7 |
| 6/4/01 | 1 | .04 | 15 | 0 | 7 | 15 | 7.6 |
| 10/15/01 | 0 | .04 | 13 | .09 | 7 | 16 | 7 |
| 5/24/02 | 2 | .02 | 5 | 0 | 8 | 15 | 7.5 |
| 9/24/02 | 2 | .02 | 5 | 0 | 7 | 14 | 7.5 |
| 5/2/03 | 9 | .02 | 15 | 0 | 7 | 9 | 8.1 |
| 9/26/03 | 9 | .04 | 5 | 0 | 10 | 15 | 7 |
| 4/26/04 | 6 | .04 | 20 | 0 | 7 | 14 | 8 |
| 9/25/04 | 5 | .05 | 5 | 0 | 5 | 18 | 7.6 |
| 4/20/05 | 7 | | | | | | |

**Table 27 Volunteer Sampling Data from Crooked Creek (Trib. to Snow Lake)**

| | Total Phos., mg/L | Sol. P. | NH 3-N | NO3-N & NO2-N | TKN | Tot. P. Loading Kg./day |
|---|---|---|---|---|---|---|
| Walter's Lake Drain 5/19/76 | <.03 | <.03 | 0.2 | <.1 | .6 | <.29 |
| Follet Creek (upstream of Little Otter) 5/19/76 | .06 | .06 | .1 | .1 | .7 | 2.04 |

**Table 28 Selected State Board of Health Tributary Data**

## Historical Tributary Data: Croxton Ditch

Water quality data for Croxton Ditch has also been collected by number of sources. A sample collected and analyzed by the Indiana State Board of health on May 19, 1976 showed total phosphorus and soluble phosphorus concentrations of less than .03 parts-per-million. The daily loading at the time of that sample was calculated to be less than .11 kilograms per day. Total Phosphorus and Total Suspended Solids Data is available from an IDNR Lake Enhancement funded study for the Croxton Ditch watershed.(Hill 1989). The 1989 Study also utilized water quality data from sampling performed by the Steuben County Health Department at County Road 275 North (near Lagoona Park) from 1973 through 1977. Additional data was produced by samples collected in 1987 and 1988 by Tri-State University (5 yearly samples). This sampling was funded by the Steuben County Lakes Council. Annual total phosphorus concentration averages for the samples collected from 1973 through 1977 were all below .05 ppm showing relatively low phosphorus concentrations. The data collected in 1987 and 1988 showed much higher Phosphorus concentrations. Most of the data was collected during or after rainfall events and reflected significant soil erosion occurring in the Angola Industrial Park at that time. The table below contains Total Phosphorus Data from the 1988 study.

| 1988 Total P (ppm) | 5/23 | 6/16 | 7/14 | 7/19 | 7/26 | 8/15 | 8/19 | 8/27 |
|---|---|---|---|---|---|---|---|---|
| State Rd. 127 | .50 | .20 | .50 | .02 | | .34 | .17 | |
| 200 N | .45 | .16 | .21 | .05 | | .40 | .03 | .09 |
| 275 N | .50 | .095 | .06 | .09 | .70 | .27 | .06 | .10 |
| Sowles Lateral @ I-69 | | | | | | | | .63 |
| Pond @ 14 green (country club) | | | | | | | | .09 |
| West Edge Of # 1 Fairway | | | | | | | | .14 |
| Confluence with Sowle Lateral | | | | | | | | .04 |
| Rainfall (in) | 1.98 | | .34 | .10 | | .46 | .18 | |

**Table 29 Total Phosphorus Data from the 1989 Study of Croxton Ditch (Hill 1989)**

The eroding areas noted in the 1989 study have since been stabilized by vegetative cover and also isolated by the restoration of an in-line wetland upstream of I-69. This appears to be reflected in the measurement of .043ppm total phosphorus in the June 6 2005 sample collected at 275 North after a rain event. At present nutrient and sediment sources located downstream of I-69 (outlined in the next section) may be of higher importance with regard to regard to water quality than the areas that produced the increased pollution during the 1980’s. It is noteworthy however that the 2005 rain event was not great in volume and occurred during a relatively dry season and may not have resulted in a large amount of runoff (.24 inches of rain fell in approximately 2 hours).

Croxton Ditch Current Conditions

Croxton Ditch, a first order tributary to Lake James originates in the City of Angola running approximately 10,000 feet Southwest to it's mouth in the Lagoona Park channel system at the southern tip of Lake James Lower Basin. (see fig. 34) It's joined by Sowle Lateral, a smaller tributary approximately 3000 feet upstream of Lake James. Croxton Ditch, along with Sowle Lateral is a Steuben

County legal drain maintained by the Steuben County Drainage Board and County Surveyor's office as the John Croxton Maintenance Unit. The entire streamcourse has been extensively modified and channelized to facilitate drainage with nearly all watershed areas East of I-69 being in commercial, industrial, and residential development. The stream currently originates in subsurface lines receiving storm runoff from extensively paved areas along U.S. 127 (North Wayne St.) in the City of Angola. The ditch becomes open several hundred feet East of 127. Most of the ditch banks in this reach are steep but reasonably well vegetated and stable. Native emergent and submersed aquatic plants have extensively colonized the ditch. Purple loosestrife, an invasive non-native wetland plant common on the Lake James Chain does not appear to be present growing along the ditch in this reach. West of 127 Croxton passes for approximately 2400 feet through an industrial park where it picks up surface and subsurface-tile drainage from parking lots and business lawns. A short stretch of meanders has been built into the stream in the central part of this area by the Steuben County Surveyor's Office as a mitigation for road construction activities in an adjacent watershed. Invasive Phragmites (Giant Reedgrass), an invasive species, have begun to colonize a small portion of this reach.

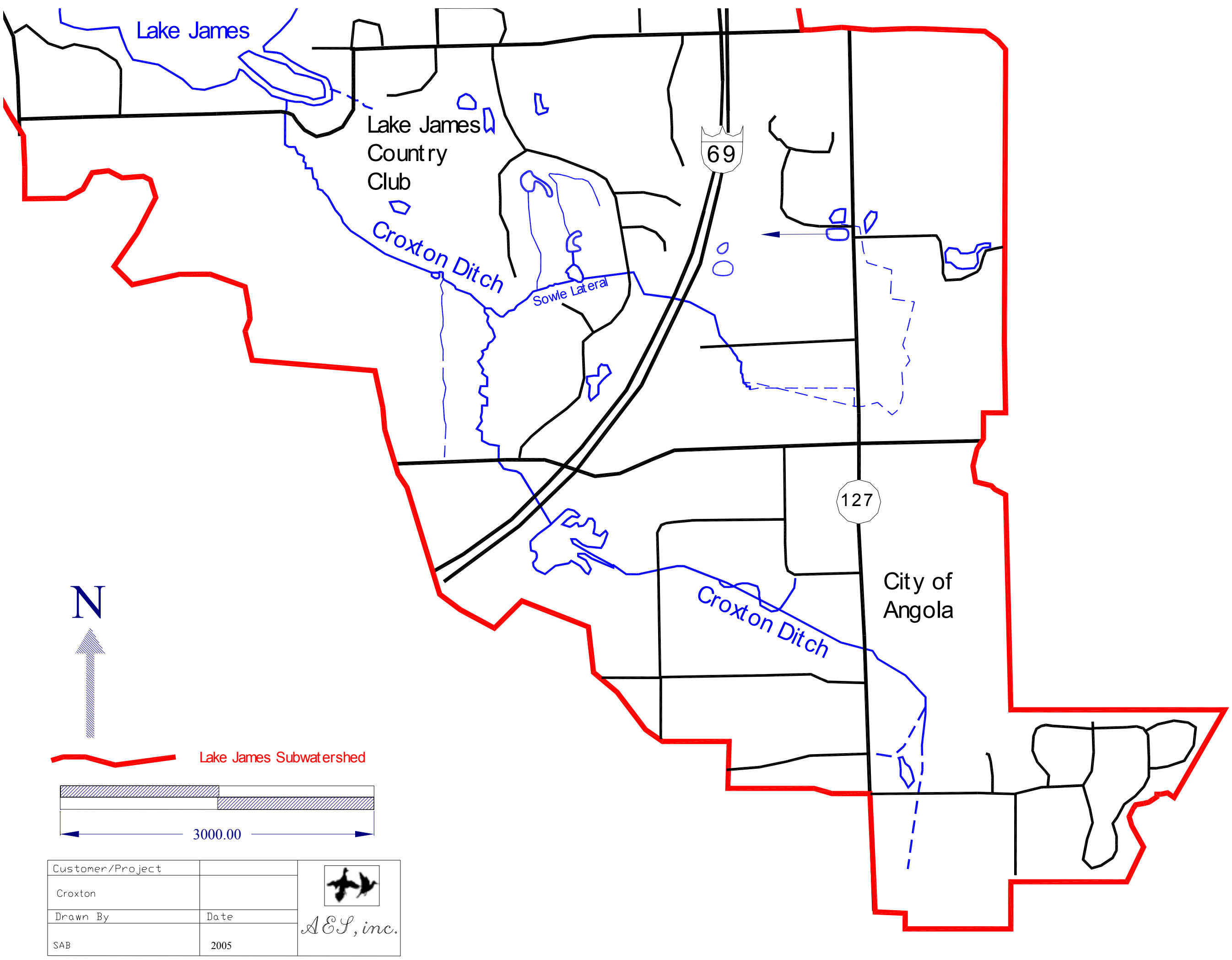



**Figure 34 The Croxton Ditch Watershed**

Figure 35 The origin of Croxton Ditch as a surface drainage, just East of 127 in Angola

Figure 36 Most Ditchbanks along Croxton in the City of Angola are relatively stable and well vegetated or protected with limestone.

Figure 37, A constructed wetland in the Croxton Ditch drainage just East of Interstate 69 is a restored remnant of Croxton's original headwater marsh delineated on the 1831 surveyor's map. Purple loosestrife (an invasive non-native plant common in the lower part of the watershed) has apparently not yet colonized Croxton this far upstream from the lakes.

Just prior to passing beneath Interstate 69 Croxton ditch enters a constructed wetland. (see fig 37) This shallow impoundment built on a preexisting emergent wetland, created approximately 5.5 acres of shallow-water emergent and open water habitat behind a limestone gabion control structure. This flooding was created by the Steuben County Surveyor's office to moderate drainage from the City of Angola and mitigate for construction activities elsewhere in the watershed. Vegetation present is primarily native but Invasive Phragmites have lightly colonized the West edge of this wetland. Purple loosestrife did not appear to be present in this marsh in 2005.

On the West Side of Interstate 69 Croxton Ditch picks up highway drainage and flows northwest passing adjacent to several residences. In this reach Croxton also runs through a previously channelized streambed. Evidence of channel instability and erosion begins to increase considerably in this reach. (fig. 38,39) After passing beneath County Road West 200 North Croxton runs in a Southerly direction through a mixed forested, scrub shrub wetland. The streambanks are not well vegetated in this stretch due to shading from trees shrubs, and some erosion is evident. Approximately 2000 feet downstream of Interstate 69 Croxton Ditch is joined by Sowle Lateral (running from the east) and turns to run in a southwesterly direction. Beyond this point the watershed is dominated by a golf course and its associated housing community. Approximately 450 feet downstream from the junction with Sowle Lateral another small tributary ditch joins Croxton ditch running from the north. (fig. 40) This ditch follows a more or less strait course parallel to Croxton from County Road 200 north and probably

Figure 38,   Approximately 1200 feet Downstream of Interstate 69 Severe bank erosion is evident along Croxton Ditch

Figure 39 Sediment crumbles from the Croxton streambank between Interstate 69 and the Lake James Country Club

was installed to help facilitate drainage of now idle/forested former wetlands between the two drainages. This ditch also receives groundwater seepage from higher ground on the edge of the adjacent golf course. Parts of this ditch show bank erosion as well.

Figure 40, Small tributary ditch that parallels Croxton running south from 200 North, joining Croxton 2450 feet south of 200 North.

Just downstream from joining with this ditch Croxton Ditch takes a meander through a small impoundment that has filled with sediment. (fig. 41,42) Purple loosestrife plants become very common along the streams edge downstream from this point. Exploring options for restoring or enhancing prior converted wetlands and streambed and restoring the function of the small impoundment in this drainway will be recommendations of this report. Future work should look at the best way to establish a streambed through this area capable of handling expected flows while remaining relatively stable and minimizing the transport of sediment and associated nutrients downstream to Lake James. Given time Croxton ditch would carve it's own more stable streambed through this area by removing and transporting soil downstream to the Lagoona Park Channels at the southern tip of Lake James. The key will be to look for a feasible way to foster this process while minimizing the sediment transport.

Figure 41 A small impoundment that appears to have become filled with sediment from the upstream eroding reach of Croxton Ditch.   Purple loosestrife was noted in this area but not seen upstream of this reach.

Figure 42, A concrete overflow sets the pool level in this small pond and appears to have settled somewhat

After passing through the small impoundment Croxton Ditch runs in a strait northwest direction across the golf course that surrounds much of the lower drainage area. (fig 43)   A small connected excavated pond lying just to the south of the stream serves as an irrigation draw for the golf course.   The streambanks in this reach show some evidence of crumbling and instability, but are well vegetated above the waterline.   A series of rockpiles probably act to moderate flow, but the streamflow is beginning to breach one of the rockpiles by eroding the bank.   Purple loosestrife plants are numerous along this reach.

Figure 43, Croxton runs northwest across a golf course that along with associated housing additions occupies much of the lower watershed.   Purple loosestrife is abundant along this reach.

At approximately 1500 feet upstream from Lake James Croxton Ditch turns slightly more northerly.   The stream runs though a mixed scrub shrub/emergent wetland with excavation/channelization spoils having been piled to build up the East bank.   Some instability and erosion is evident in this area with areas of both the west bank and previously removed spoils on the east bank eroding. (fig. 44)   Opportunities for wetland or streambank restoration in this area should be explored.   The James Chain associations should work with the Steuben County Drainage Board to explore options.

Figure 44 As Erosion occurs along the lower reach of Croxton Ditch previously removed spoils on the east bank rejoin the stream.

The last 400 feet of Croxton ditch runs in a straight northerly direction before passing under County Road 275 North and entering the Lagoona Park channel system. Streambanks are well vegetated in this area and water movement is generally slow as the lake level backs up into the stream. The stream bottom is extremely soft and supports emergent vegetation. (fig 45) This reach is occasionally subject to beaver damming although none was occurring during the 2005 study period. The Lagoona Park Channels have experienced ongoing problems with sedimentation and the excessive growth of aquatic plants. Aquatic Herbicides are used to control plant growth at Lagoona Park but levels of control effectiveness are limited by shallow depths and the influence of suspended sediment and water movement from the Croxton Ditch Inflow.

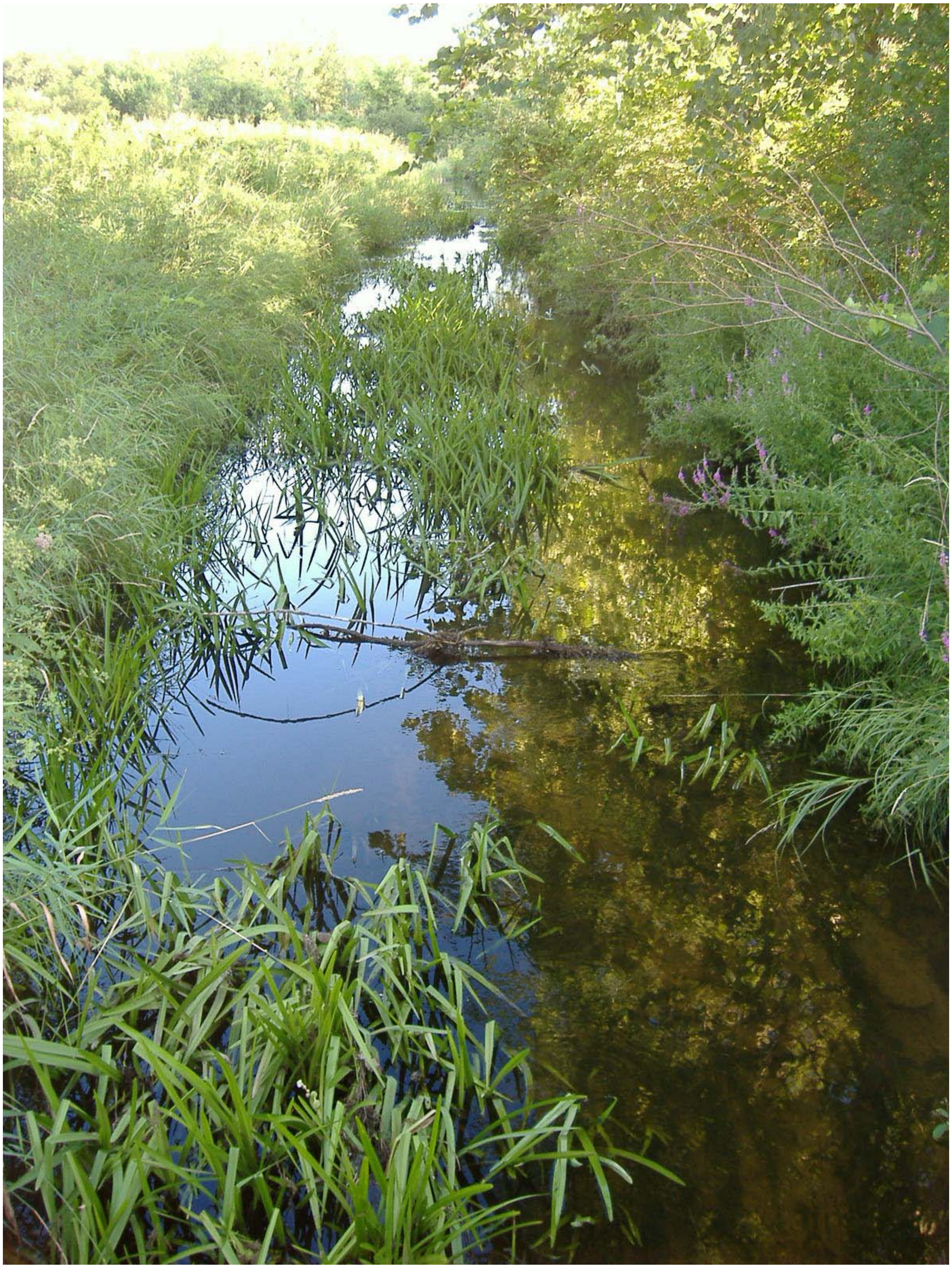


Figure 45 Lower Croxton flows are moderated by the backup of lake water. The stream supports emergent vegetation. Purple loosestrife was abundant along the west shore of this stream reach.

## Croxton Ditch and Sowle Lateral Historical Perspective

Surveyor's maps from 1831 show that Croxton Ditch and a single adjoining tributary stream ran a meandering course through relatively broad marshy corridors on rolling prairie or oak savanna. (fig. 47) Historical air photos show that by 1938 extensive channelization had taken place to facilitate drainage. (fig. 46) At that time the length of these streams as open ditches was close to the current, but both have since been extended with subsurface stormwater lines through part of the City of Angola. The streamcourses delineated on the 1831 surveyors map for the area indicate that both originated in wetlands near the present day Interstate 69 Corridor. (fig. 47) The site of the present day constructed Croxton Ditch marsh was shown as the original headwater marsh of the stream. The 1831 map also suggests that the course of Croxton may have been moved significantly. In the case of Croxton the origin of the stream matches very closely the spot where it currently enters the constructed marsh but the first 2000 feet of the ditch south of County Road 200 is shown running approximately 500 feet west of its current location.

Figure 46 1938 Air Photo of the Croxton Ditch watershed. The dark area just below center is the site of the restored marsh in the Croxton Streamcourse

This location seems to be supported by the signature of a meandering band of dark (hydric) soils running approximately 500 feet west of the location of the present ditch on the 1938 air photos. (fig. 46) The original course of Sowle lateral is more difficult to discern. The original survey shows the stream taking a more southerly course with its origin in a marsh corridor that extended just south of present day 200 North. Remnants of this marsh are still present on both sides of County Road 200 North. An obvious lack of detail and occasional inaccuracies on the part of the drafters of the original survey maps complicates the process of determining the original streamcourses but significant early drainage changes to facilitate agriculture and development are evident. At least 30 acres of wetlands have been lost in Croxton ditch and Sowle Lateral watershed to drainage or fill for agriculture and development. Channelization and excavation of the streambeds, the addition of two tributary ditches extending northward from Sowle Lateral, and the construction of Interstate 69 have caused the majority of wetland loss.

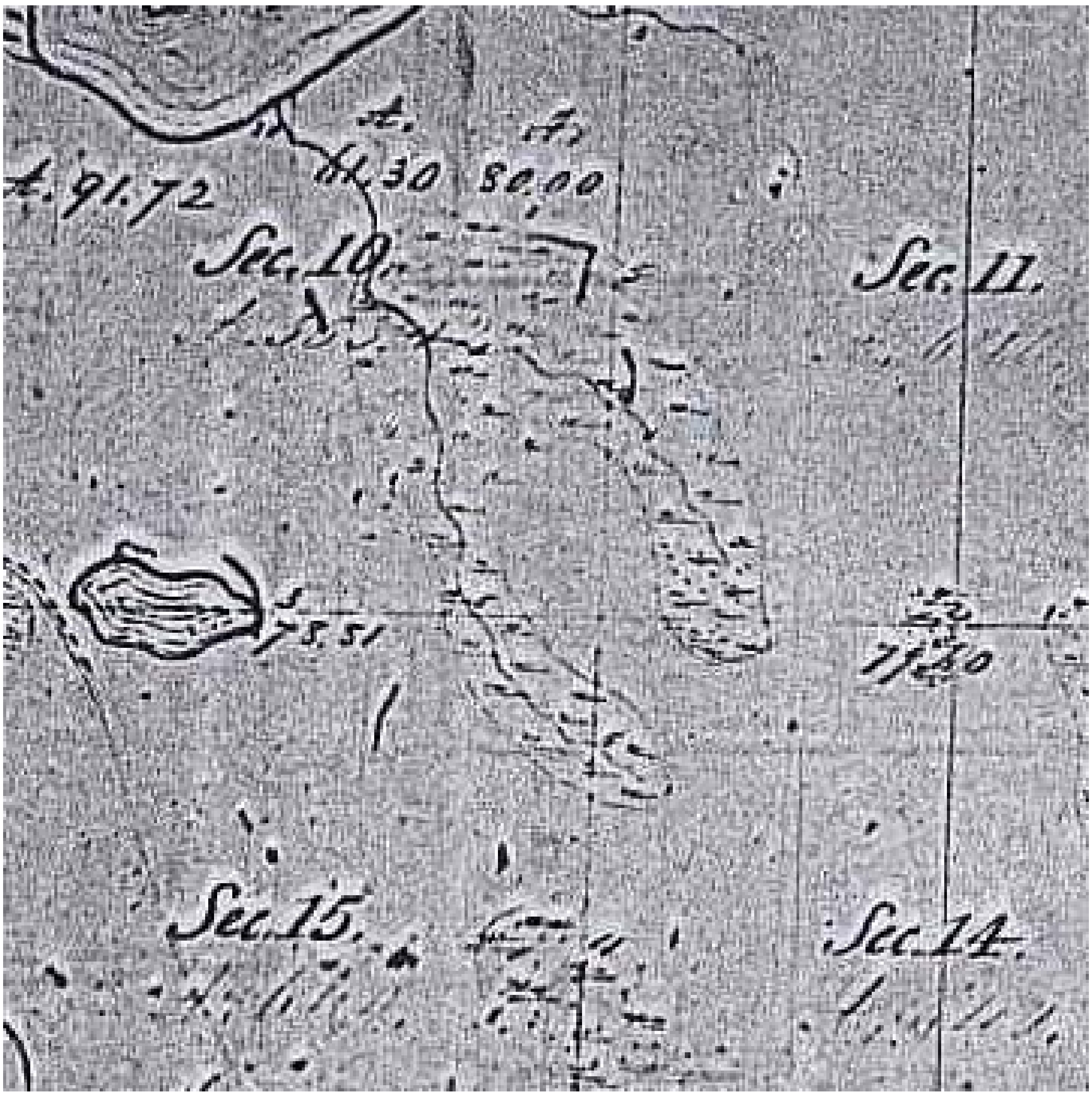



Figure 47 1831 Survey map of the Croxton-Sowle Lateral watershed, Indiana State Archive, E.H. Lytle. D.S. 1831

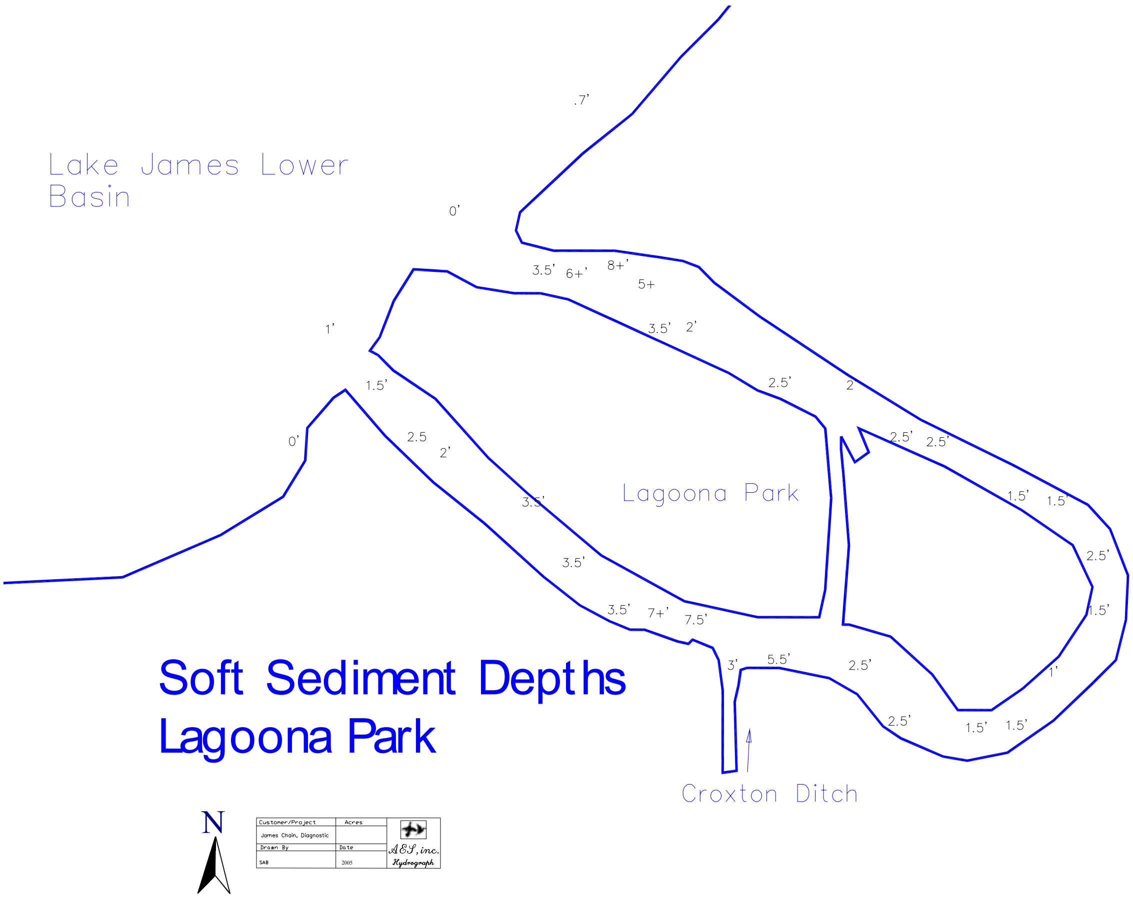



**Figure 48 Soft Sediment Depths at Lagoona Park on Lake James**

Sedimentation in the Lagoona Park Channels

Lagoona Park has a long history of sedimentation and aquatic plant growth problems. In June of 2005 a section of 1.5 inch PVC pipe was used to probe the bottom of the Lagoona Park channel system and nearby lake bottom at 33 random points (fig 48). The purpose of this was to determine roughly the extent to which the channels could be deepened by hydraulic dredging to increase their navigability. Sediments that can be penetrated by a 1.5 inch PVC pipe can typically be loosened and removed effectively by a hydraulic dredge. Deepening the channels could create a better passage for large boats, decrease the amount of sediment disturbed by navigation and decrease the amount of light available to bottom-growing aquatic plants. The average depth of the 3 acre channel system is 4.5 feet. Sediment depths within the channel varied from one half foot to over eight feet. (probing beyond 8 feet was limited by the probe length) The channel contains an average sediment depth of 3.8 feet. Sedimentation drops off rapidly outside the channel system with an average of only 1.2 inches of soft sediment on the lake bottom outside the channel mouths. The probing indicated that approximately 18,392 cubic yards of sediment could be removed from the channel system by hydraulic dredging. Once erosion issues upstream in the Croxton Ditch streambed have been address the Lake James residents may want to consider deepening this channel system.

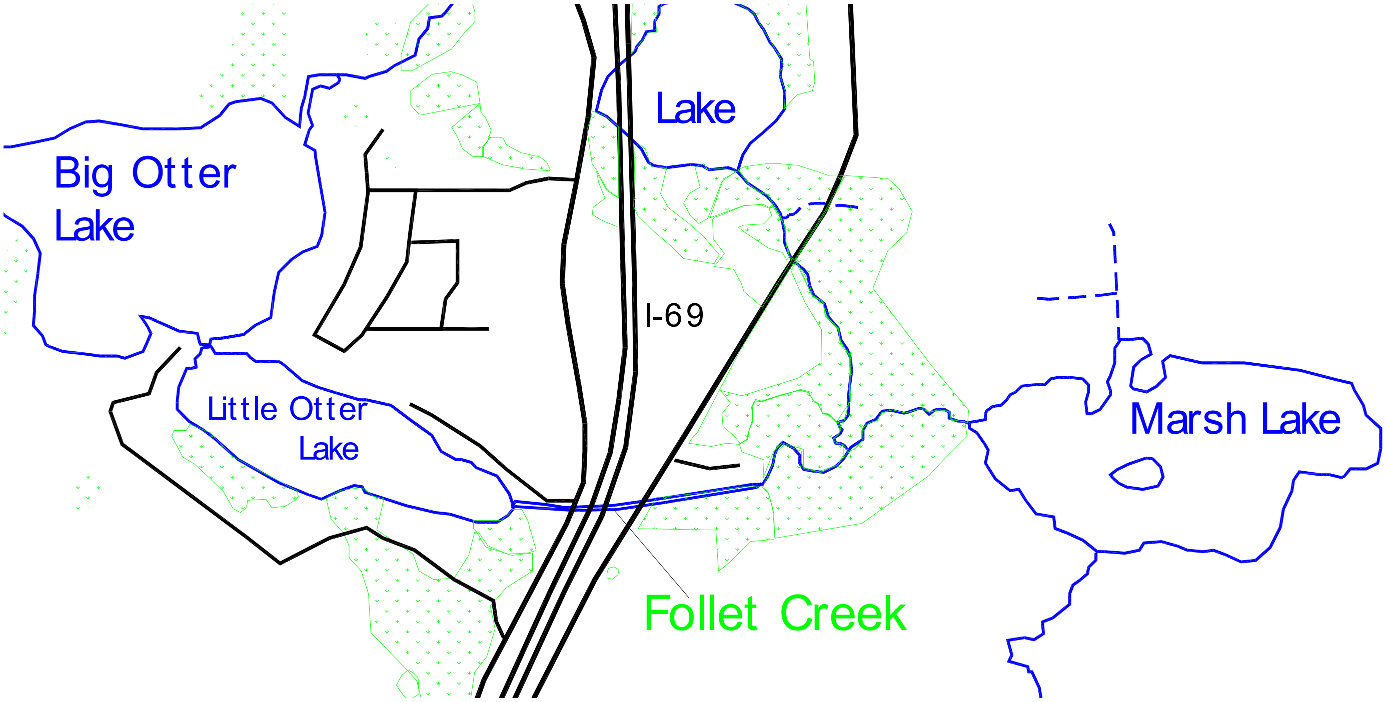



**Figure 49 Follet Creek**

Follet Creek Current Conditions

Follet Creek flows due West from Marsh Lake approximately 3600 feet before joining with Little Otter Lake at its East end serving as the outlet for Marsh Lakes large watershed. Approximately the first 1500 feet of Follet Creek follows a natural meandering course through an emergent wetland. (fig. 49,50)

**Figure 50 Follet Creek in the Marsh Lake Wetlands**

For approximately the next 2100 feet Follet Creek runs through a dredged and channelized section containing channelfront homes. This section appears to have been moved southward when Interstate 69 was constructed, placing the stream adjacent to a steep wooded bank near its passage below the interstate. Some erosion and bank crumbling is occurring in this area. (fig. 51) This stretch of Follet Creek has also likely received soil runoff from an eroded area to the north. (fig. 52) Addressing erosion in this area will be a recommendation of this report.

**Figure 51 Some Bank Crumbling is Occurring Along Follet Creek Near I-69**

**Figure 52 Severe Erosion in the Follet Creek/Marsh Lake Watershed**

## Sedimentation at the Follet Creek Delta

Sedimentation has been a problem at the Follet Creek delta in Little Otter Lake. Navigation in and around the creek mouth is difficult and a buildup of rich organic sediments has occurred. Problems with invasive aquatic plants have also been experienced in this area. Air photos from 1938 seem to indicate a shallow area has always existed at this delta, but the problem has probably increased over the years. In June of 2005 a section of 1.5 inch PVC pipe was used to probe the bottom of the Follet Creek delta area and nearby lake bottom at 14 random points. (fig. 53) The purpose of this was to determine roughly the extent to which the delta area could be deepened by hydraulic dredging to increase navigability. This area serves as a launching, docking, and fishing area for a bait shop and campground. Several homes along the north shore of Little Otter Lake also have frontages in this area. Deepening this region could create a better passage for boats, decrease the amount of sediment disturbed by navigation in Little Otter Lake and decrease the amount of light available to bottom-growing aquatic plants. The average depth of the 1.2 acre probed area is 5.4 feet. Sediment depths within the channel varied from zero to 5.5 feet. The creek bottom is soft sediment from the lake to a point approximately 130 feet upstream. Sediment depths in the delta area ranged from 3.5 to eleven plus feet (the deepest that could be probed with the equipment used). The sediment was composed primarily of clays with dark organic muck in the surface layer. Soft sediment depths in the creek and delta area averaged 5.6 feet. The probing indicated that at least 10,850 cubic yards of sediment could be removed from the delta area by hydraulic dredging. Once erosion issues upstream in the Follet Creek streambed and watershed have been addressed, the Little Otter Lake residents may want to consider the possibility of deepening this area.

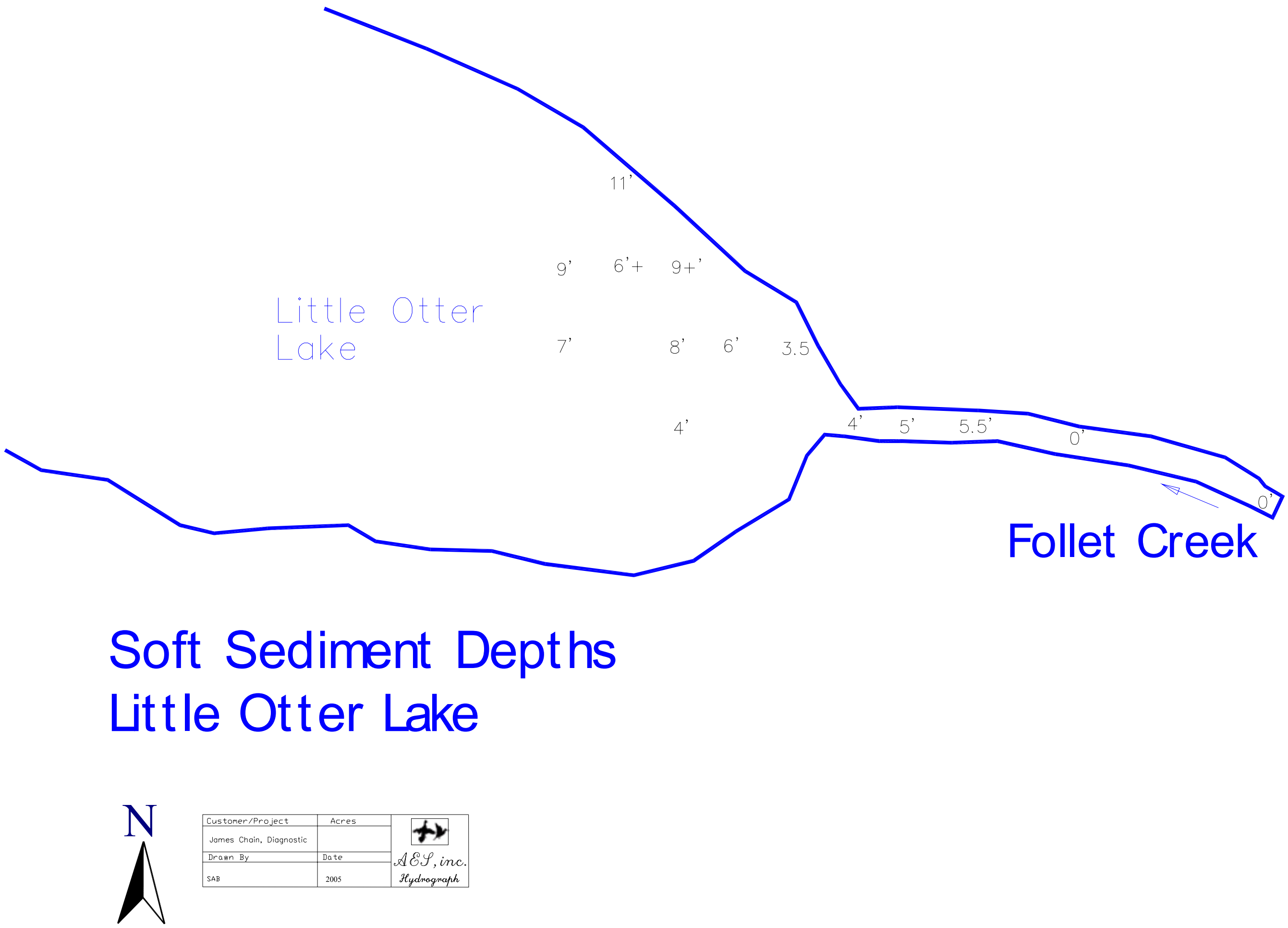



**Figure 53 Soft Sediment Depths in the Follet Creek Delta**

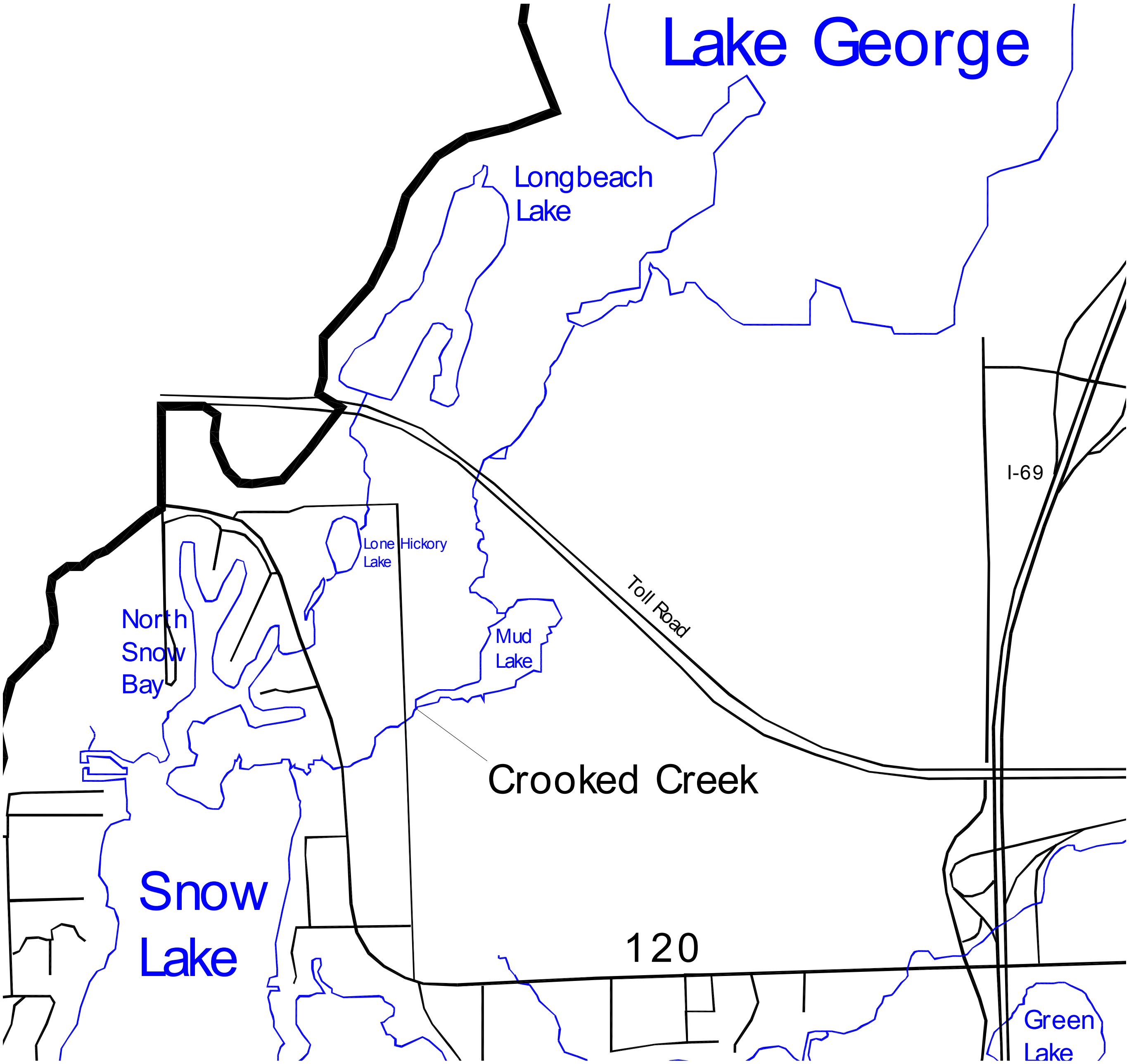



**Figure 54 Crooked Creek**

Crooked Creek Current Conditions

Crooked Creek drains Lake George and its large watershed into the northeastern bay of Snow Lake. It follows an approximate 7600 foot course running roughly southwest from a concrete overflow structure at Lake George. The first reach of the stream passes through some residential lots near the Lake George outlet. Some slow bank erosion is evident in this channelized reach upstream of Jamestown Road. (fig. 55) Downstream from Jamestown road the stream's edges have been stabilized with the use of glacial stone. Beyond this point Crooked Creek follows a natural course through a series of scrub-shrub wetlands, and a small impoundment before crossing beneath the 80/90 toll road. Below the toll road the stream passes through a small marshy lake before passing beneath state road 120 and winding through a riparian cattail marsh into Snow Lake. Concerns in the Crooked Creek watershed include the presence of Purple Loosestrife and Phragmites, two invasive non-native wetland plants occurring in the Crooked Creek wetlands. Road and road-bank erosion is also occurring in the Crooked Creek watershed. (figs. 58 and 61 respectively) The wetlands in this drainway are a valuable asset. Protecting them from invasive species and the effects of erosion will be a recommendation of this report.

**Figure 55 Banks are vegetated but show some signs of erosion in the initial reach of Crooked Creek**

**Figure 56 Crooked Creek at CR 175W Looking Downstream**

**Figure 57 Crooked Creek at CR 175W Looking Upstream**

**Figure 58 Erosion of CR 175W into the Crooked Creek Wetland Corridor**

**Figure 59 Small Impoundment in Crooked Creek at CR 150, Just Upstream of the 80/90 Toll Road**

**Figure 60 Crooked Creek Looking Upstream from CR 150W**

**Figure 61 Roadside Bank Erosion in the Crooked Creek Watershed Along CR 150W**

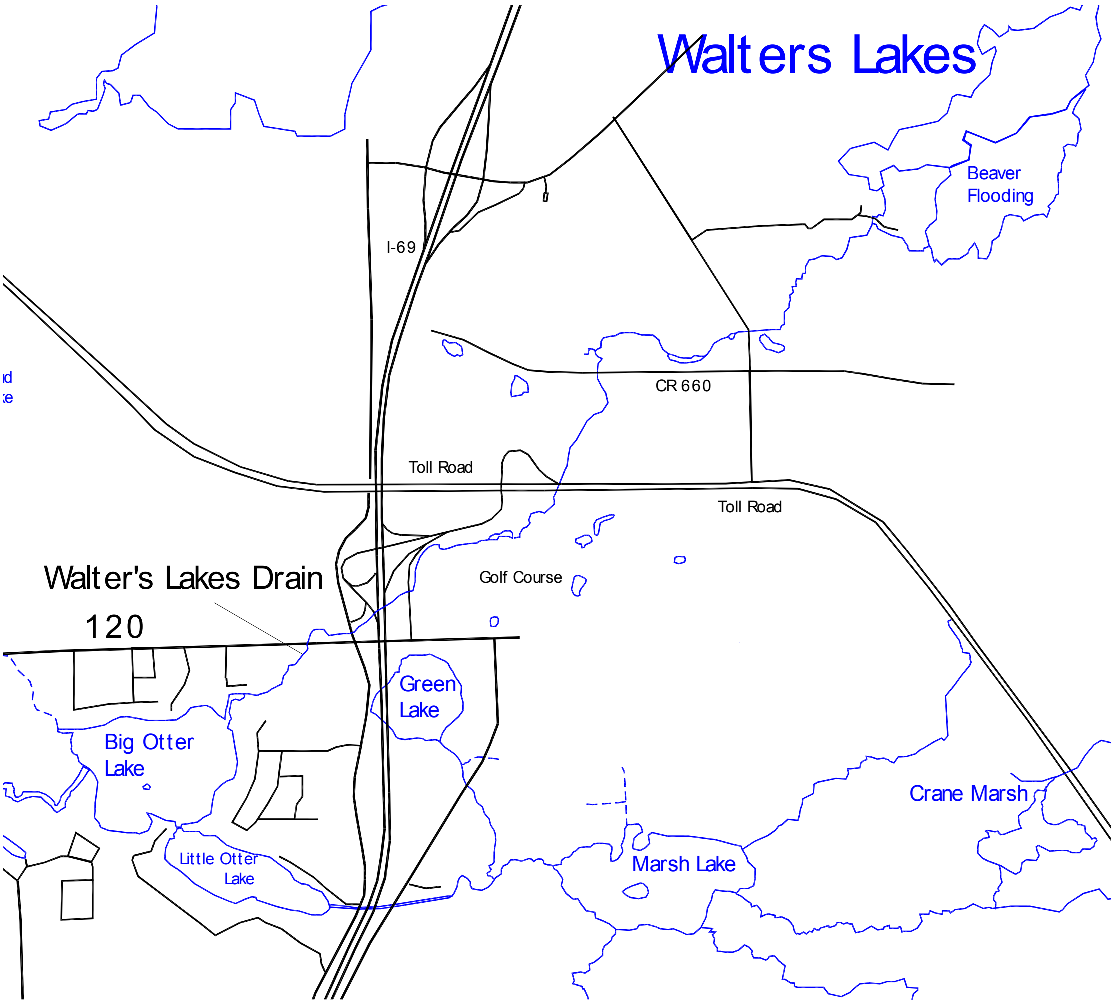



**Figure 62 Walter's Lakes Drain**

Walter's Lakes Drain Current Conditions

Walter's Lakes drain runs approximately 14,000 feet in a southwest direction draining Walter's Lake's and their watershed to Big Otter Lake (fig 62). Walter's Lakes, the streams origin, is composed of several small glacial basins linked by riparian marshes. Currently a beaver flooding and/or fill placed at the outlet has inundated all the basins and increased the surface area of the lake considerably. Maintenance or filling and damming activity near the beaver dam at Walter's Lakes and the setting of the lake level have been issues of contention among the riparian property owners. Downstream of the beaver flooding the stream flows through a marshy corridor and into a larger impounded marsh. This waterbody is maintained by a property owner with the use of a concrete overflow structure to produce waterfowl habitat. Leaks in this structure have lowered water levels in this marsh. Many of the agricultural fields draining to this reach of Walter's lake drain are also being maintained in vegetative cover as wildlife habitat. The James Chain residents may want to consider working with landowners to maintain stable, beneficial wildlife habitat in this area. No Purple loosestrife or Phragmites were noted in this area. After this impounded marsh the stream passes through a small impounded pond that currently sets the water level in the upstream marsh. (fig 63) After passing through this marsh Walter's Lakes

**Figure 63 A small impoundment that currently sets the water level in an impounded Walter's Lakes Drain marsh**

Drain flows through a narrow brushy corridor through agricultural lands for several thousand feet. With sloping tilled ground draining toward the stream filter strips may be used in this area to reduce sediment and nutrient contributions to the stream. After passing through two additional small residential impoundments a 2000 foot reach of Walter's Lake Drain winds through a large wetland. This wetland is a mix of wooded, scrub shrub, and emergent wetland habitat. No obvious channelization, dredging, or erosion, is evident in this reach. After leaving this area and crossing beneath West 660 North Walter's Lake Drain flows roughly south and enters a ditched and channelized reach where it collects drainage from sloping pasture ground. No signs of erosion are present in this reach. As it nears the 80/90 Toll Road the stream is joined by a newly reconstructed drainage ditch running through a wooded wetland. Highway storm drainage is directed to the stream just prior to it entering the culvert beneath the 80/90 toll road. Some erosion of the highway construction fill is apparent in this reach. Passing beneath the toll road running due south Walter's Lake's Drain turns roughly southwest and runs through a golf course. Bank erosion is occurring in this area where the stream has been located adjacent to steeply banked wooded areas. Before leaving the golf course the stream flows through a small impoundment. The stream flow has breached the concrete overflow structure on this impoundment. Whereas this pond serves as a settling basin for the steams sediment load the James Chain residents should consider working with this landowner to repair the ponds overflow and protect the pond. No Purple loosestrife or Phragmites were noted to be growing along the streambanks in this area. Downstream of this impoundment the stream follows a constructed path through the 80/90 Toll Road and Interstate 69 junction before entering a large marsh flowing due West just north of State Road 120. Colonization of this marsh by Purple

Loosestrife is extensive and Phragmites are also present adjacent to state road 120. Within the marsh the stream turns South and flows over a limestone rock structure before crossing beneath State Road 120, passing through a second marsh and entering a constructed channel attached to the northeast corner of Big Otter Lake. This second marsh generally displays varying water levels and is subject to repeated inundation and drying. Investigating the possibility of stabilizing water levels in this marsh will be a recommendation of this report. The constructed channel this stream passes through before entering Big Otter Lake contains a considerable amount of organic sediments. The IDNR public access site is located on this channel. The James Chain residents may want to consider including this area in any future dredging to create a sediment trap and isolate soils and associated nutrients that may otherwise contribute to the degradation of the lakes.

### 3.2 Benthic Macroinvertebrates in the James Chain Major Tributaries

Sites on Croxton ditch, Crooked Creek, Walter's Lake Drain, and Follet Creek were sampled for benthic macroinvertebrates. Macroinvertebrates were collected at each site, preserved, and later identified in the lab to family level in order to calculate the m-IBI or Macroinvertebrate Index of Biotic Integrity. The m-IBI is a tool used nationwide to investigate water quality in a stream and is one of a number of protocols used by the Indiana Department of Environmental Management to keep track of the quality of Indiana’s surface waters. The index provides a numerical score for each sampling event that when coupled with a numerical score for the habitat quality at the site can give investigators information about the quality of the stream. Though the main thrust of this study was to collect baseline data, those samples collected with a kick net are applicable to IDEM methods so comparison to other data in the county can be made. (adapted from Interfluv Inc. 2005)

### Methods

All samples were collected using EPA Rapid Bioassessment Protocols for Wadeable Streams. In streams that contained riffles, a 500 micron net was used for kick sampling at the riffle. In areas where riffles were not present, a 500 micron D-frame net was used to perform multi-habitat sampling through the site. At each site a Qualitative Habitat Evaluation Index was performed, based on IDEM protocol. Each sample was preserved in a mixture of 80% alcohol and brought back to the lab for identification. All samples were identified to family level, and vouchers of each were saved in separate vials for curation. A 15 minute pick was also performed on the sample, in keeping with IDEM protocols, and preserved for curation. The m-IBI is calculated based on Indiana specific metrics and scores developed by IDEM for riffle kick samples. A table illustrating the metrics is shown below. Each metric receives a score and then they are averaged for a possible 0 (lowest) to the highest possible score of 8.

| Scoring Criteria for the Family Level<br>Macroinvertebrate Index of Biotic Integrity (mIBI) for<br>Riffle KICK Samples<br>Calibrated from Transformed Data Distribution of the 1990-1995<br>Using 100-Organism Subsamples (IDEM- BSS Section) | | | | | |
|---|---|---|---|---|---|
| | **Classification Scores** | | | | |
| | **0** | **2** | **4** | **6** | **8** |
| Family Level HBI | ≥ 5.63 | 5.06 – 5.62 | 4.55 – 5.05 | 4.09 – 4.54 | ≤ 4.08 |
| Number of Taxa | ≤ 7 | 8 - 10 | 11 – 14 | 15 - 17 | ≥ 18 |
| Number of Individuals | ≤ 79 | 80 – 129 | 130 – 212 | 213 – 349 | ≥ 350 |
| Percent Dominant Taxa | ≥ 61.6 | 43.9 – 61.5 | 31.2 – 43.8 | 22.2 – 31.1 | ≤ 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 | 55 – 146 | 20 - 54 | 7 - 19 | ≤ 6 |
| Total Number of Individuals to Number of Squares Sorted | ≤ 29 | 30 - 71 | 72 – 171 | 172 - 409 | ≥ 410 |

**Table 30 mIBI scoring criteria, Interfluv Inc. 2005**

## Discussion

The goal of this study is simply to gather baseline data for areas of interest. However, some coarse analysis is allowable in order to place the results in a larger context. The results of the study are shown below (orange) along with historical m-IBI data (yellow) collected by IDEM in Steuben Co. Because riffles were not present on the reaches of Follet Creek and Croxton Ditch sampled a multi-habitat approach was used instead of riffle kicks. These samples are called out. Though the m-IBI is calculated for these two sites, since they are not the same as IDEM protocols, comparison is questionable.

| Stream Name | Location | QHEI Score (100 possible) | m-IBI Score (8 possible) |
|---|---|---|---|
| Pigeon Creek | CR 400 S | 63 | 4.6 |
| Black Creek | SR 1 | 55 | 3.2 |
| Pigeon Creek | D/S SR 27 Bridge | 72 | 3.4 |
| Eaton Creek | D/S CR 100 E | 41 | 3.2 |
| Crooked Creek | D/S Nevada Mills Dam | 76 | 3.6 |
| Pigeon Creek | SR 327 DNR Access | 46 | 2.8 |
| Turkey Creek | SR 327 | 52 | 2.2 |
| Fish Creek | CR 40 S | 62 | 4.4 |
| Black Creek | SR 1 | 69 | 4.2 |
| Fish Creek No 2 | CR 775 S | 53 | 5.6 |
| Concorde Creek (ref. reach) | Orland Rd | 65.25 | 1.8 |
| Concorde Creek (Orland Rd) | Orland Rd | 69.5 | 3.6 |
| Concorde Creek (Butler's Woods) | U/S Lake Gage | 58 | 5.4 |
| **Crooked Creek | N of SR 120 | 50 | 4.2 |
| Walter's Lake Drain Trib- Big Otter Lk. | N of SR 120 | 58 | 2.0 |
| Follett Creek | Just W of I-69 | 40 | 2.2 |
| **Croxton Ditch | W 275 N | 39 | 2.4 |

| Legend (shading) | |
|---|---|
| Gray | = Data collected for another Steuben Co. Study in 2005 |
| Yellow | = IDEM Historical Data |
| Orange | = Data from this study |

**data collected using multi-habitat approach

**Table 31 Benthos and QHEI results**

A high m-IBI score for a stream is an indication of a system with less habitat impairment and an indicator of good general water quality based on the invertebrate species found in the stream. Crooked Creek scored highest in the sampling followed by Croxton Ditch, Follet Creek, and Walter's Lake Drain. The Qualitative Habitat Index score is based on visual observations of habitat irrespective of the organisms present. Walter's Lake Drain scored highest on the QHEI. Part of this was the result of the stone substrate present, however this was artificial limestone placed in the stream in past construction project and was probably somewhat misleading. Crooked Creek scored next highest on the QHEI followed by Follet Creek and Croxton Ditch.

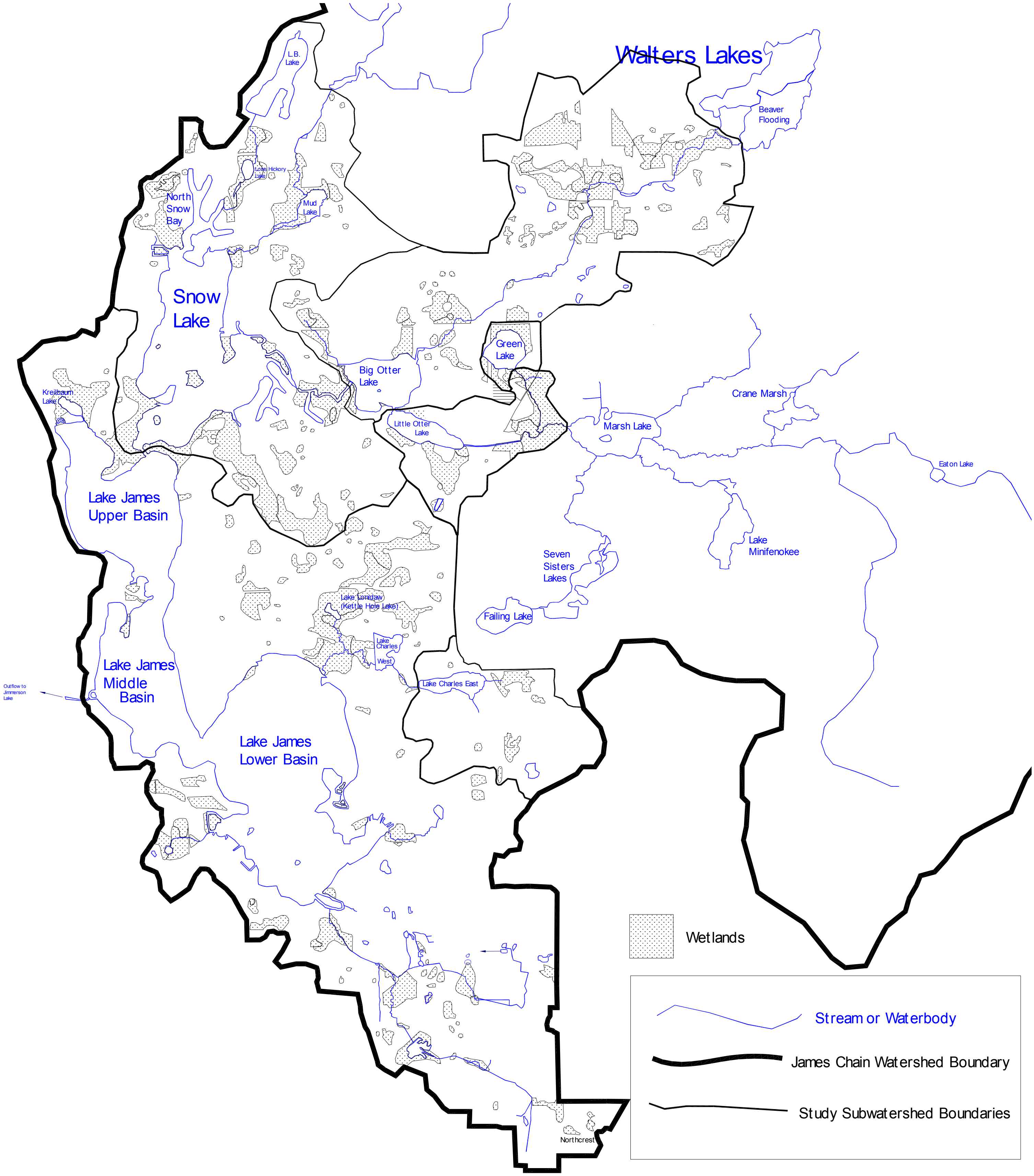



**Figure 64 Wetlands in the James Chain Watershed**

### 3.3 Wetlands

The James Chain's watershed has retained some of its most valuable natural features with 1125 acres of wetlands comprising 24 percent of the study area. (fig. 64) More importantly, these wetlands serve as filtration basins for much of the lake's drainage area including agricultural acreage in the Walter's Lakes Drain watershed and developed areas in the City of Angola. Wetland protection will be a major key to water quality protection at the Lake James Chain. These areas are largely a combination of forested, scrub-shrub, and emergent wetlands.

There have been significant losses of wetlands in the watershed. Wetland losses were estimated using satellite photos, historic air photos, the presence of hydric soil types, and field checks. Hydric soil types present in areas without current wetlands are often a strong indicator of lost (drained) wetland acreage (hydric soils map fig 65). Hydric soil types are those having qualities that indicate that water has been present at or near the soil surface for a significant period of time. For this work 58 separate areas of wetland losses were mapped totaling 443 acres (fig 66). This is a loss of 28% of the estimated original wetlands. On many Indiana watersheds agricultural drainage accounts for most wetland losses. The two largest components of wetland loss in the James Chain watershed appear to be the deposit of fill for development, and the dredging of channel systems. The North Snow Bay, Cranston's Reef, Sprague Addition, Lagoona Park and other lakeshore subdivisions were created or expanded through dredging or filling of riparian wetland areas. Other major components of wetland losses include development in the City of Angola and the construction of Interstate 69. It will be important for the James Chain Association to seek protection of remaining wetland areas through the establishment of conservation easements, deed restrictions, or other agreements available to cooperative property owners. Establishment of filter strips and other vegetative cover on key agricultural field borders adjacent to wetland areas can help maintain optimal wetland function. Preventing the invasion of native wetland plant communities by non-native plants will also be important and will be a recommendation of this report. Opportunities to work with landowners to restore wetlands lost in the watershed should also be explored.

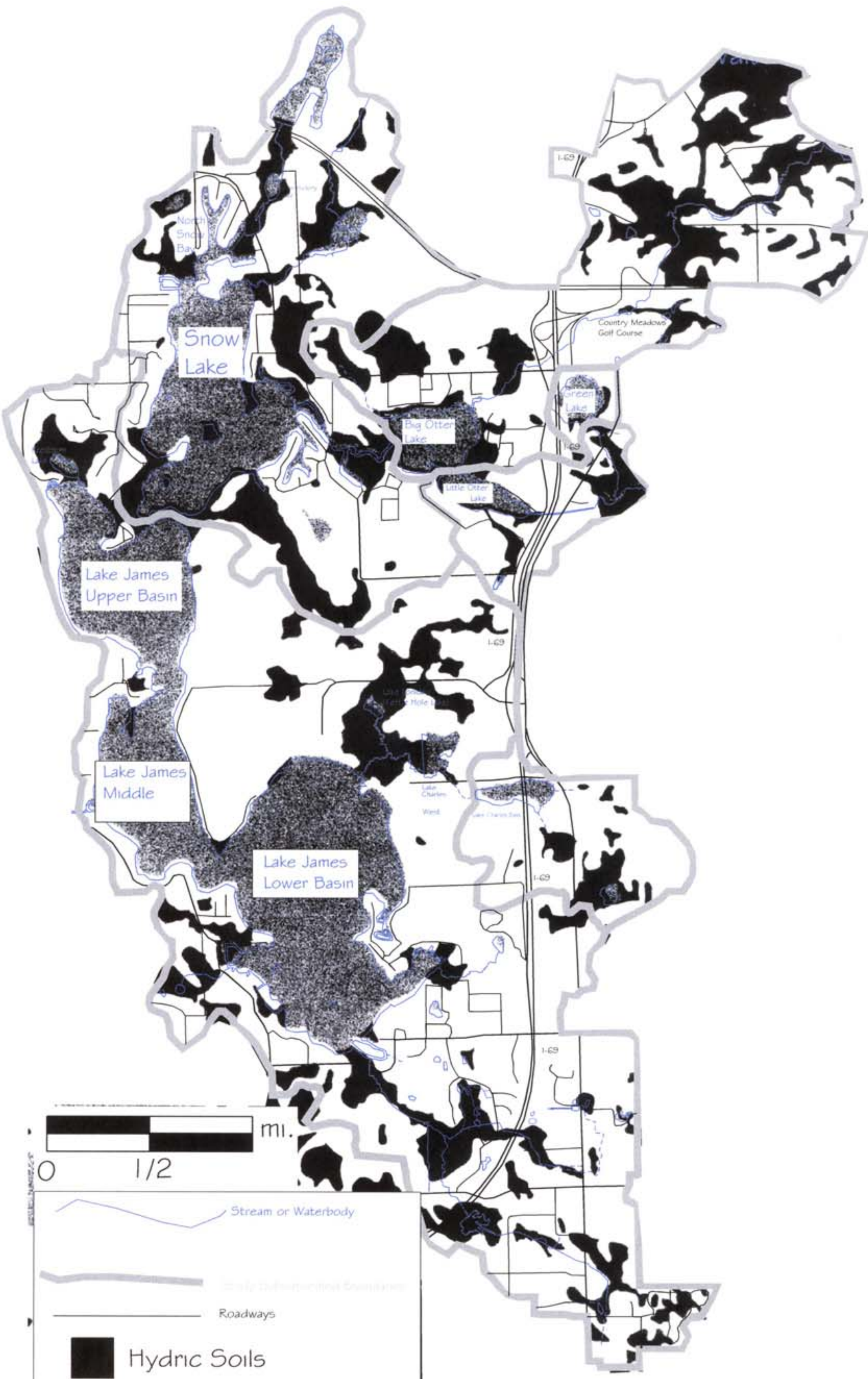



**Figure 65 Hydric Soils (includes current wetlands) in the James Chain Watershed (USDA, NRCS data)**

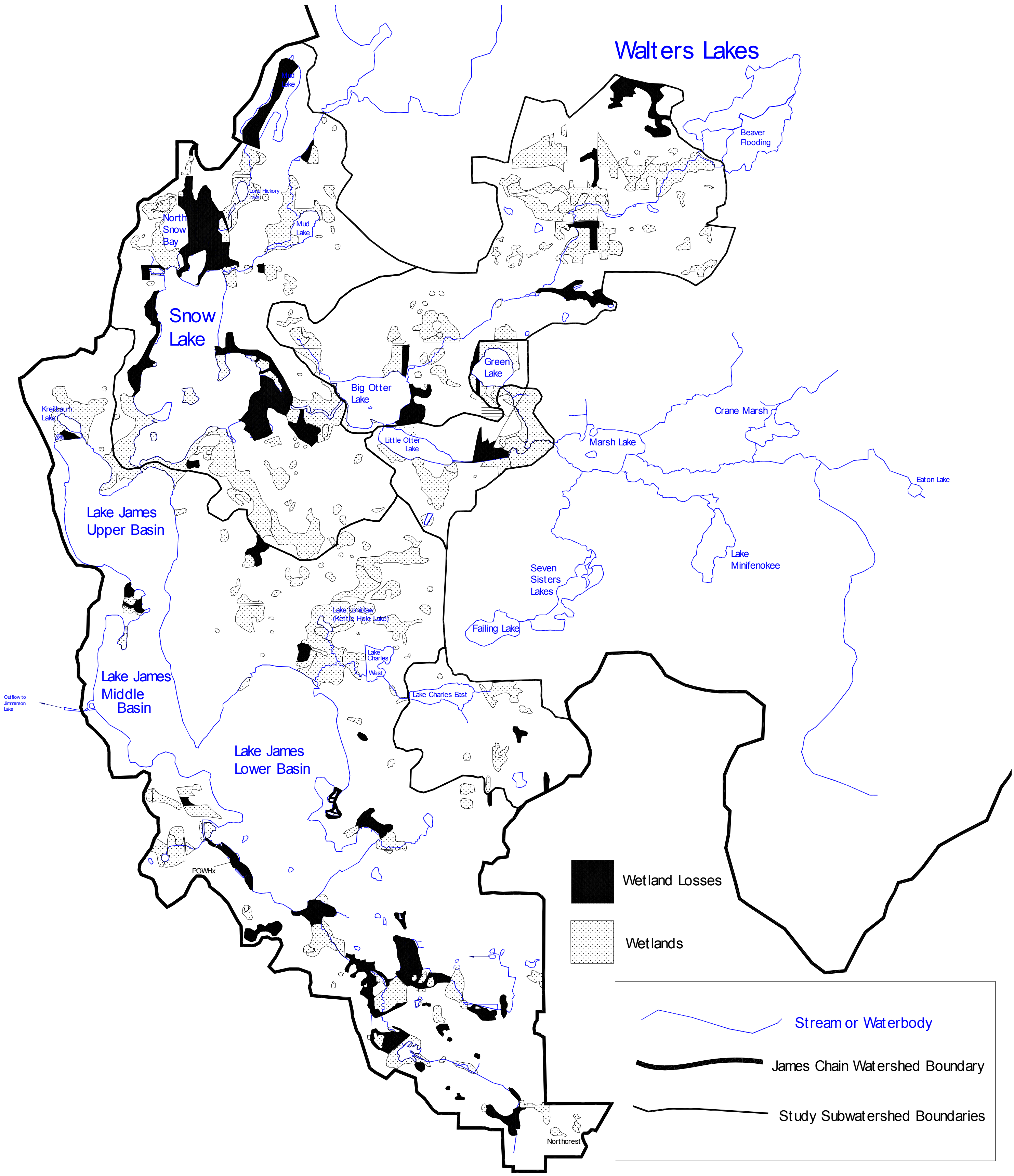



**Figure 66 Study Area Wetlands and Wetland Losses**

Figure 67 Purple Loosestrife, an invasive non-indigenous wetland plant

### 3.4 Invasive Wetland Plants, Implications and Control Options

Purple loosestrife *Lythrum salicaria* an invasive non-native (European) wetland plant has colonized virtually all the riparian wetlands on the James Chain. However this plant has not yet appeared in many of the wetlands located away from the lakes. Since each of these plants is capable of producing 2.2 million seeds annually, it is likely that the plants could spread upstream to the rest of the watershed's wetlands. Because the spread of this plant to off-lake wetlands could potentially degrade the function of the watershed's wetland plant communities the James Chain residents may want to consider a control program to protect wetlands not yet affected. A reduction in plant diversity and habitat degradation may result if these plants are allowed to spread. Purple loosestrife is not generally utilized as a food source by North American wildlife and carries little value in our native wetland plant assemblages. Once allowed to become established in area wetlands it is unlikely that this plant will ever be completely eradicated. In some cases the stocking of non-native insects that forage on Purple Loosestrife can be successful in reducing colonization by the plant. Lake residents should be informed as to the ecological significance of this plant and encouraged to assist in the control efforts on their own property through association meetings and newsletters. Croxton Ditch and Sowle Lateral were walked in their entirety to check for Purple Loosestrife colonization of their streambanks and associated wetlands. The Walter's Lakes Drain was walked in its entirety upstream of Interstate 69 to its origin. Crooked Creek was checked from road right-of-ways and noted to be colonized by Purple Loosestrife to its origin at Lake George. Along Croxton ditch and Sowle Lateral Purple Loosestrife was noted to be growing on the streambanks to within several hundred feet of Interstate 69. No purple loosestrife was noted in either drainway beyond Interstate 69. Every wetland in the Croxton Ditch watershed in the City of Angola was checked and no Purple Loosestrife was noted. Concentrating control efforts along these stream corridors on the northwest side of Interstate 69 may be able to delay or prevent spread to the upstream wetlands and stream corridors.

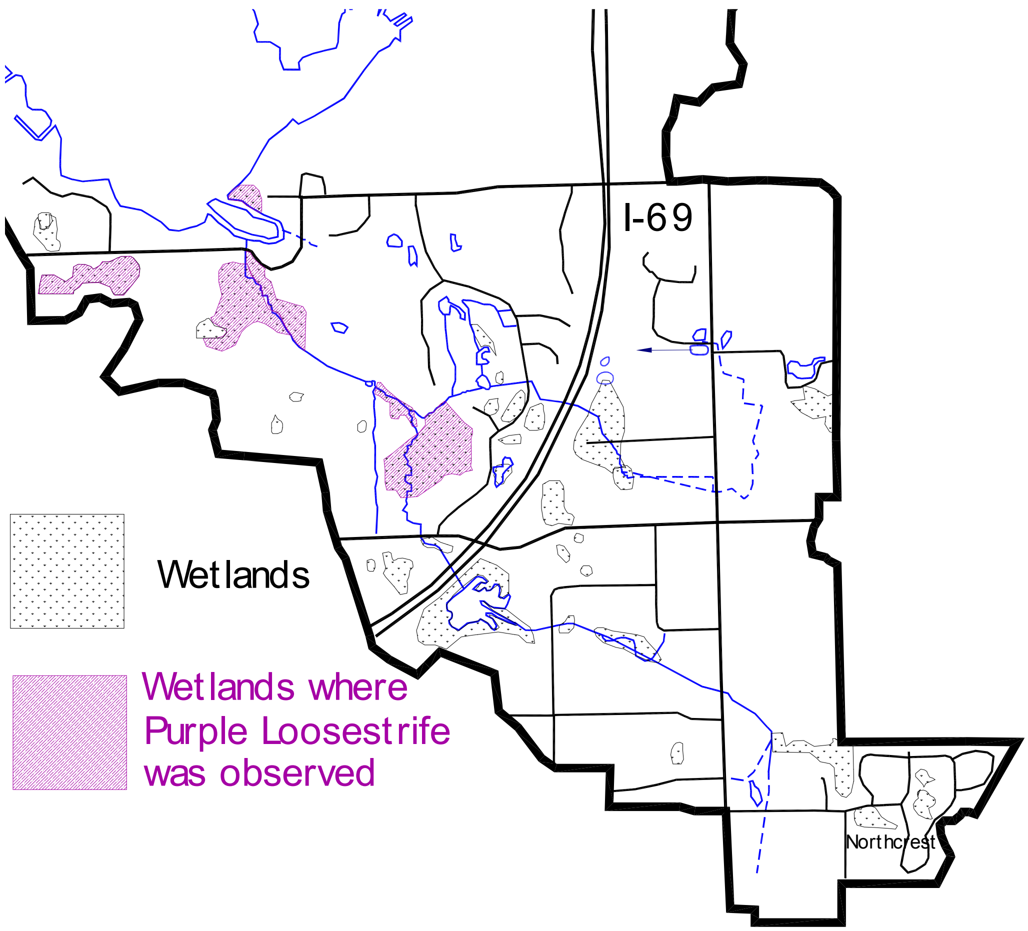



**Figure 68 Wetlands in the Croxton Watershed where purple loosestrife was observed**

In the Walter's Lakes Drain watershed no purple loosestrife was noted in the stream or it's riparian wetlands from Country Meadows Golf Course upstream to Walter's Lakes (fig 69). An owner of a marsh near Walter's Lakes indicated he had noted purple flowers growing in the marsh but none of the plants were found in a check of the area in question. Controlling purple loosestrife in the area of Interstate 69 may delay or prevent the introduction of this plant to extensive upstream wetlands in the Walter's Lakes watershed.

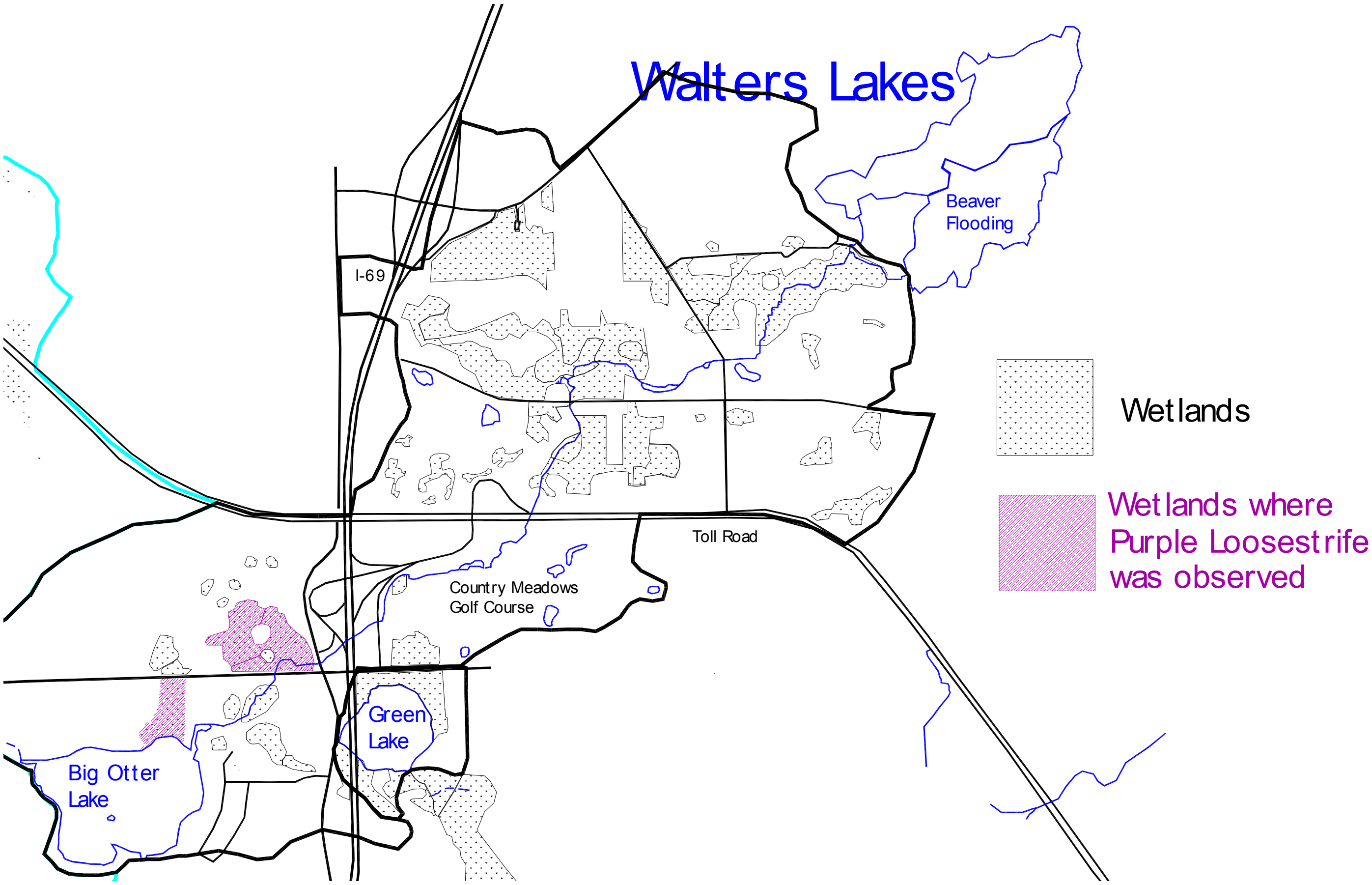



**Figure 69 Wetlands in the Walter's Lakes Drain where Purple loosestrife was noted**

**Figure 70 Phragmites (Giant Reed Grass)**

Giant Reed Grass *Phragmites australis* (fig. 70), another invasive non-native wetland species has also begun to colonize the James Chain watershed. A native non-invasive strain of the same plant is also present in some of the watershed's marshes. Because Invasive Phragmites are very tall showy plants (up to 14 feet) they are typically very easy to spot. Colonization of the James Chain watershed appears to be progressing very slowly. Phragmites, like Purple loosestrife plants, have the ability to crowd out native wetland plant assemblages adversely affect wetland function and wildlife value. Invasive Phragmites have been located growing in the Crooked Creek, Walter's Lakes Drain, and Croxton Ditch watersheds. Some plants are also present within Pokagon State Park and around the Lower Basin of Lake James. In the Crooked Creek watershed scattered Phragmites are present in a scrub shrub wetland just north of the State Road 120 stream crossing. (fig. 71) Larger colonies are present in a wetland on the north side of the 80/90 Toll Road just east of the Crooked Creek stream crossing. Colonization in the Walter's Lake Drain watershed appears to be limited to a single colony growing on the North side of State Road 120 just east of the Walter's Lake Drain stream crossing. (fig. 72) In the Croxton Ditch Watershed a small colony is present just upstream of Lagoona Park on Lake James. (fig. 73) Phragmites have also begun to colonize the restored wetland in Croxton Ditch just upstream of Interstate 69. Five additional small colonies have begun to grow in the Croxton watershed within the City of Angola. On the Lower Basin of Lake James small Phragmites colonies were found growing in an off-lake wetland near the East Central portion of the Basin and a few plants were found adjacent to a channel in Sowles Bay. A few additional plants were also found growing in wetland adjacent to County Road 200 West on the Edge of the Lake James watershed. Colonization of the James Chain watershed by Phragmites is progressing very slowly. Less than ten acres of wetlands appear to be impacted. If cooperation from area landowners is gained it is likely that an aggressive treatment program utilizing EPA approved herbicides can prevent the continuing spread of the plants.

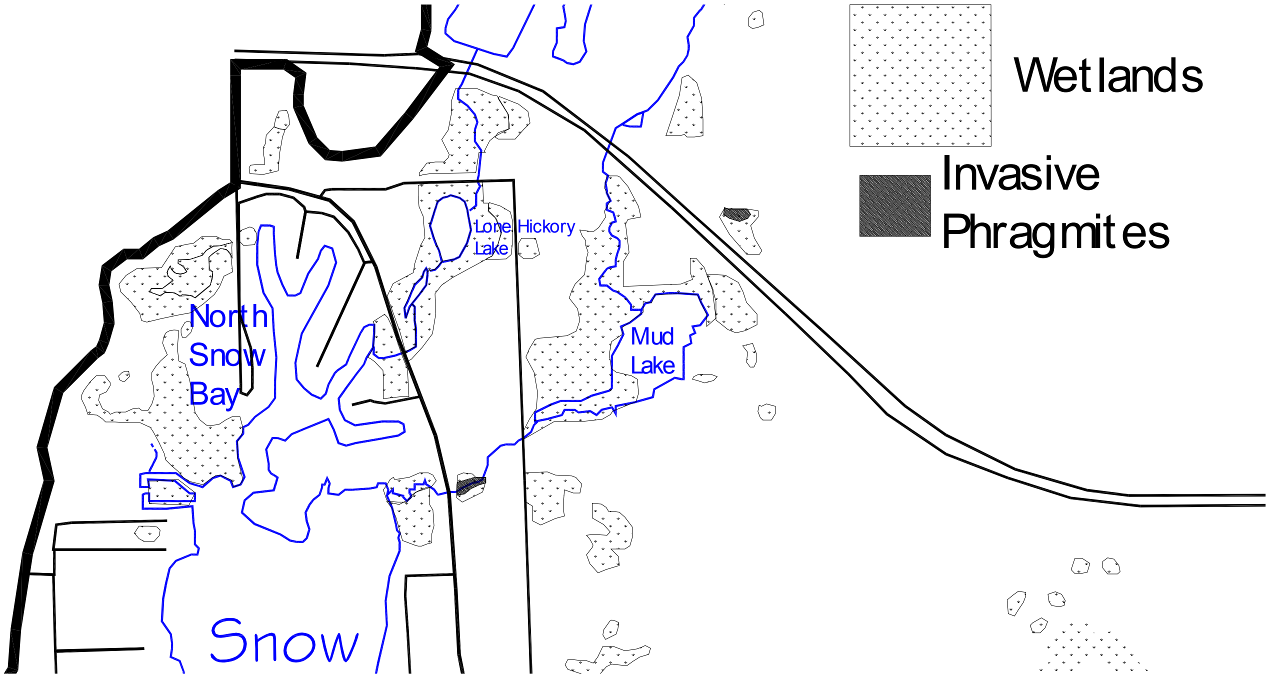



**Figure 71 Invasive Phragmites colonies in the Crooked Creek Watershed**

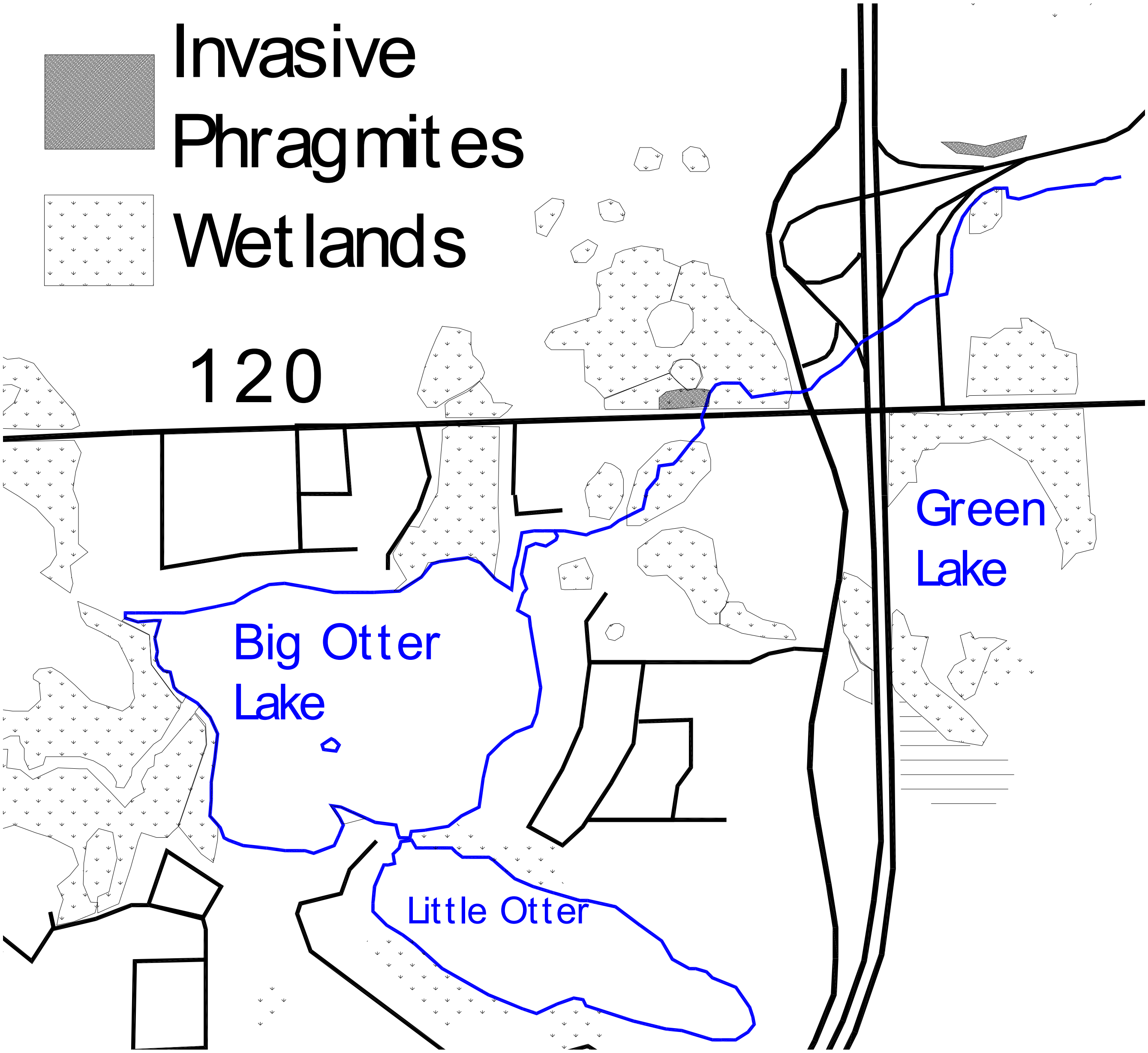



**Figure 72 Invasive Phragmites in the Walter's Lake Drain Watershed**

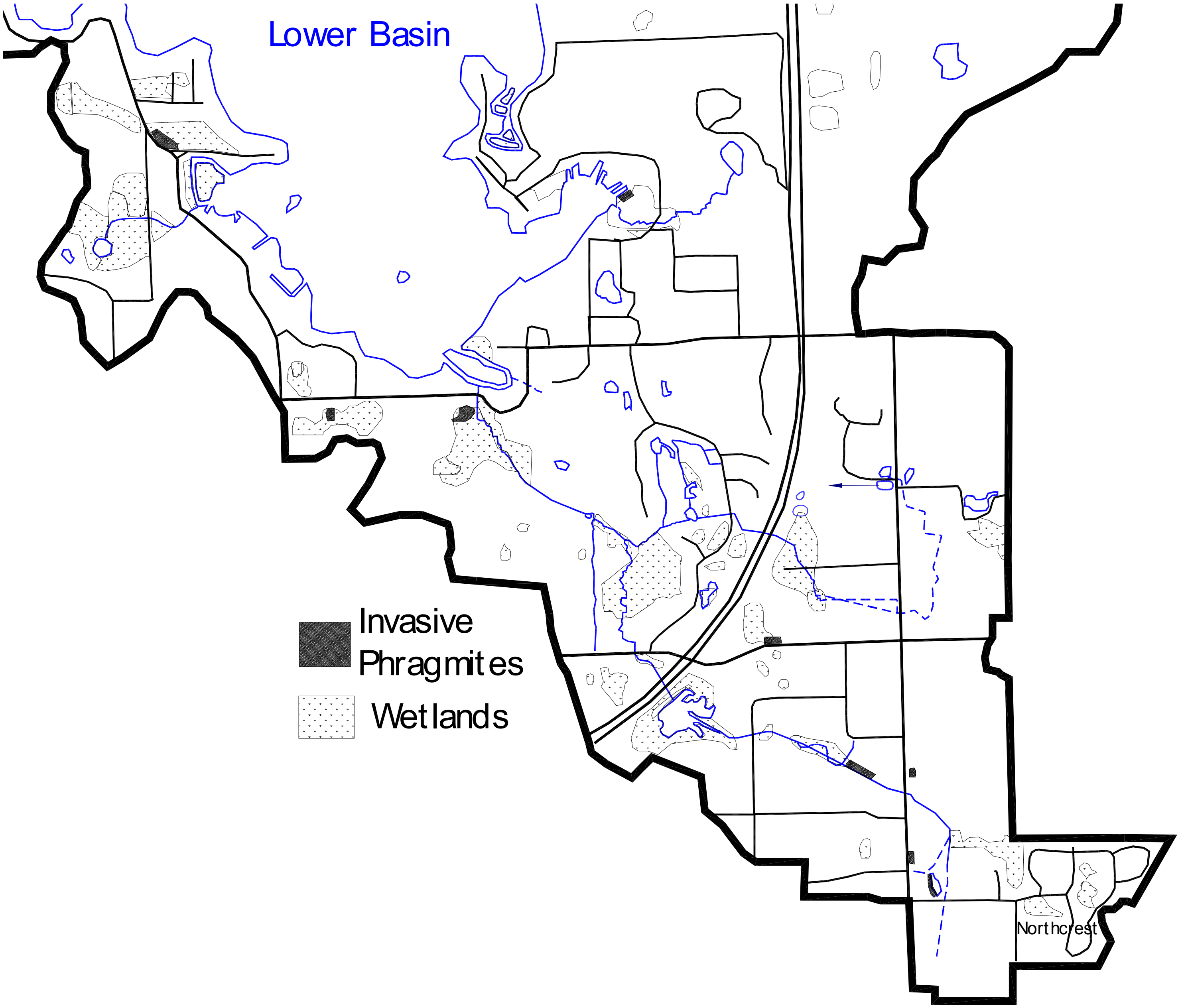



**Figure 73 Invasive Phragmites Colonies in the Croxton Ditch Watershed and Lake James Lower Basin**

## 3.5 Septic Systems, Waste Disposal, and Discharge Effluents in the Watershed

The James Chain has contained many cottages and homes since the early part of the twentieth century. All dwellings originally had private septic systems. Private septic systems near lakes often leach nutrients into lake waters and contribute to declines in water quality. In the early 1980's the Steuben Regional Waste District was organized in response to sewage disposal problems around several lakes in Steuben County. From 1985 to 1991, 19 onsite cluster systems were installed around several Lake Communities using a combination of Federal E.P.A. construction grants and State grant funds. The Cluster system arrangement incorporated the use of individual homeowner septic tanks with a pumping chamber and an individual effluent pump for each home served. The individual effluent pumps pump wastewater effluent from the individual pumping chambers through small diameter sewer pipe to a forced main that transports the effluent to the respective drain field. Drain fields located around the lakes were either gravity fed subsurface soil absorption fields or pressure dosed fields. Lacking the capacity to handle additional user input and increasing user volumes resulting from an increase in year-round lake residents the Steuben Lakes Regional Waste District began planning to discontinue use of the Cluster system in favor of a central collection and treatment works. Construction of the new plant began in 2002. Until recently approximately 27 percent of Lake James 650 homes were users of the cluster system with the remainder still utilizing private systems. On Snow Lake approximately 75 percent of the 312 homes present were either users of the cluster system or connected to the Town of Fremont Municipal Wastewater Plant to the East. With the recent completion of a new Steuben Lakes Regional Waste District wastewater plant nearly all homes on Lake James are now connected to off-site treatment facilities. The one exception, Lone Tree point still utilizes a cluster system drain field located within Pokagon State Park. The Potawatomi Inn located at Pokagon State Park and other park facilities are users of Pokagon's own wastewater treatment plant with an effluent draining to Snow Lake. All homes on the West Side of Snow Lake will also soon be users of the new treatment plant. The majority of homes on North Snow Bay, the northeast side of Snow Lake and at Sprague Addition are either connected to a cluster system drain field or connected to the Fremont Treatment Plant. Most Big Otter Lake homes are still using private on-site systems with a few homes using the Fremont Plant. All Little Otter Lake Homes are still using private on-site septic systems. The elimination of most lakeside septic systems on the James Chain will undoubtedly be a positive step that eliminates a significant component of nutrient loading in the watershed, lake residents should however bear in mind that it can also encourage increased development affecting the future of the lakes in alternate ways.

The Indiana Department of Environmental Management (IDEM) has issued five discharge permits for facilities located in the James Chain watershed. Permit number 0050318 was issued to the Indiana Department of Highways, Toll Road Division for a small treatment plant located at an 80/90 Toll Road plaza in the Walter's Lakes Drain Watershed. This plant has been out of operation for several years. The toll plaza is now a user of the Fremont Wastewater Plant. Permit number 0054011 was issued to Western Consolidated Technologies in Fremont Indiana. This is a small industrial cooling water discharge in the Marsh Lake watershed. Permit number 0032891 was issued to the Angola Travelers Mall Truck Stop located near the Junction of Interstate 69 and the 80/90 Toll Road. The Traveler's Mall operates a small wastewater treatment facility draining through a large wetland to the Walter's Lake Drain watershed. Permit number 0030309 is held by the Pokagon State Park Wastewater Treatment Plant. Based on information provided by Pokagon State Park personnel this small plant contributes approximately 30 kilograms of phosphorus to the Snow Lake watershed annually. Permit number 0022942 is held by the Town of Fremont Wastewater Treatment Plant. According to data provided by Treatment plant personnel this facility contributes approximately 220 kilograms of phosphorus to the Marsh Lake watershed annually. The James Chain residents should work with the operators of these facilities to insure that permit pollution allowances are adhered to. A monitoring study could also be useful in creating a better understanding of phosphorus contributions to the chain by assessing seasonal phosphorus removal rates for wetland areas that receive the effluents.

### 3.6 Soils and Agriculture

Information from the *Soil Survey of Steuben County Indiana* was used to characterize soils in the James Chain Watershed. The soil survey was prepared by the USDA, Soil Conservation Service (now called Natural Resource Conservation Service) in cooperation with Purdue University Agricultural Experiment Station and Indiana Department of Natural Resources, Soil and Water Conservation Committee. Through and extensive effort in field work, laboratory testing, and air photo interpretation the survey delineated soil units on maps and aerial photos as an aid to developers, farmers, builders, engineers and resource managers. Two types of soil units are delineated in the survey with "general" map units representing major associations of Steuben County soil types on a county map. Detailed soil units are delineated on air photos and labeled according to the characteristics of soils or combinations of soils within each respective unit.

The James Chain and most of its watershed falls within the Kosciusko-Ormas-Boyer major soil unit. This unit is nearly level to strongly sloping, well drained, loamy and sandy soils that are moderately deep or deep over sand and gravel on outwash plains and moraines. This description is very applicable to the James Chain watershed where the glaciers have created steep relief around edges of many lake and wetland depressions with moderately sloping areas in between. The Kosciusko series dominates most areas with well drained sandy loams over very coarse sandy and gravelly parent material. Hydrology and accumulation of organic material in the area wetlands has established primarily Houghton muck and Histosols ponded soils in these areas. Soil permeability makes much of the area only fair in terms of agricultural production because of the limited moisture retention of the soils. The combination of coarse soil composition and strongly sloping relief makes some of the watershed susceptible to erosion. Many of the most severe slopes are wooded or idle, with others in CRP or hayfields, especially near the lakes. Approximately 417 acres of highly erodible lands in the study area were in agricultural production (corn, beans, or wheat) or idle/CRP in the 2005 season. (fig 74) Working with local landowners to increase conservation reserve lands and Best Management Practices in highly erodible areas will be a recommendation of this report. Much of the eroded soil loss from these areas is attenuated by the watersheds wetland basins prior to finding a hydrologic connection to the lakes. For this reason much of the emphasis must be placed on preventing soil contributions to the wetlands to preserve their long-term function for removal of both soil attached and dissolved nutrient loads in watershed runoff and value as wildlife habitat.

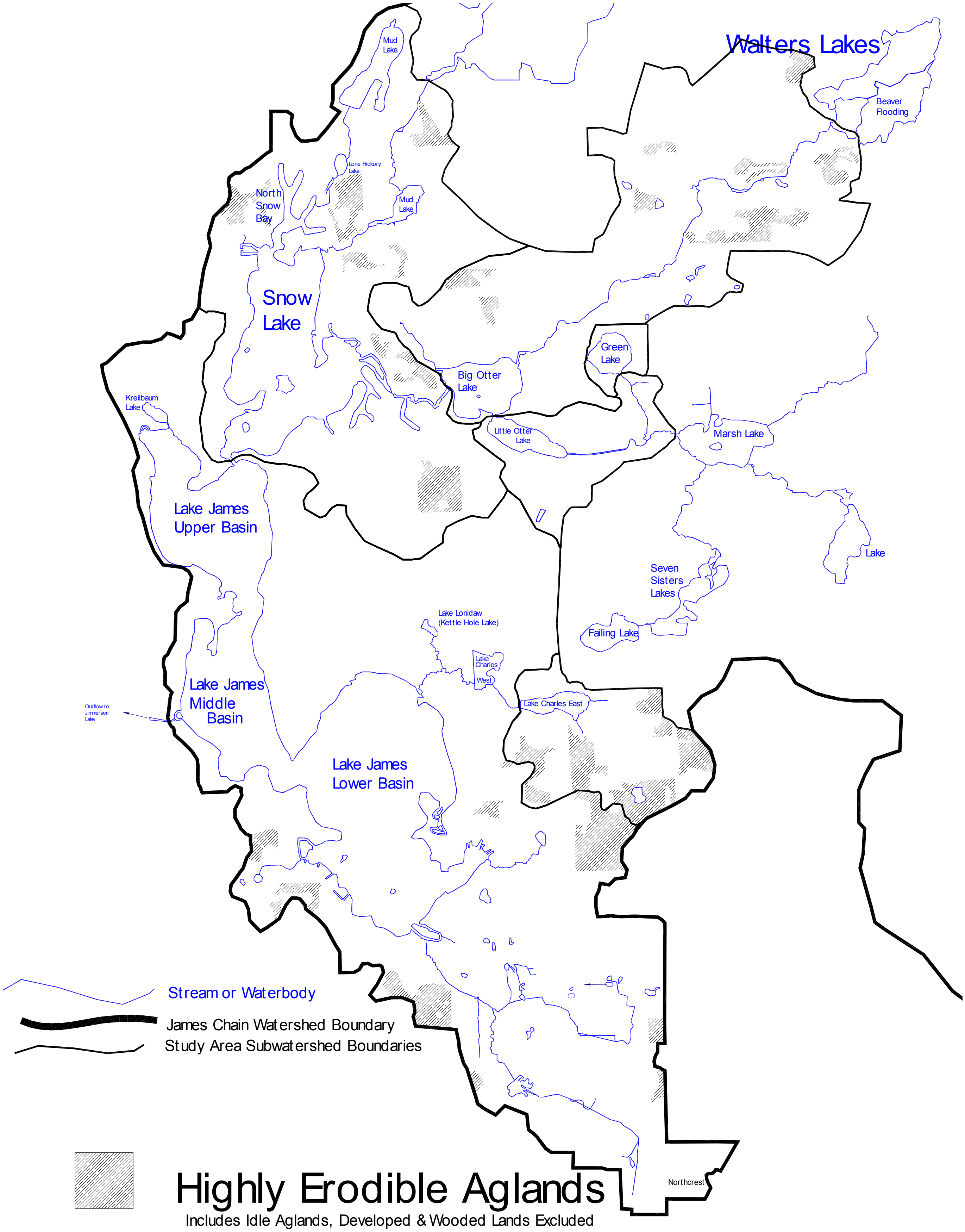



**Figure 74 Highly Erodible Aglands in the James Chain Watershed**

# 4. Phosphorus and Water Quality in the James Chain Lakes

With regard to water quality phosphorus is studied and measured more than any other nutrient. A huge volume of literature exists on the fate and effects of increased phosphorus levels in living aquatic systems. This is because relatively small changes in phosphorus levels can have profound effects on an aquatic ecosystem, with changes in functioning at all trophic levels. Phosphorus levels elevated just ten parts per billion or so can in some cases be enough to boost algal populations and cause blooms associated with poor water clarity. This is because phosphorus is typically the limiting factor in the growth of planktonic algae. An algae “bloom” is a rapid increase in algal populations in a short period of time. Repeated algae blooms or an elevated biomass of algae over a long period of time has ramifications at all levels of ecosystem functioning. More immediately evident is the destruction of water clarity, quickly affecting the aesthetic and recreational value of a lake. The term “eutrophication” is often used to describe increasing phosphorus levels accompanied by corresponding higher primary productivity. To some extent natural lakes like those in the James Chain undergo eutrophication naturally over time as soil and organic materials migrate to these depressions in the landscape driven by rainfall, wind, and snow-melt runoff. The materials become committed to the lakes sediments and eventually lead to a filling-in and finally succession into a bog or wetland, and ultimately upland. Examples of glacial depressions in each of these states can be found in Steuben County. Human land uses and urban development can be said to simply hasten this process of natural “eutrophication” or lake succession. However, a human induced rapid introduction of soil borne and dissolved pollutants takes place in a mere millisecond on the geological time scale that would typically govern this process outside human influence. Because of this, ecosystem adjustment does not occur as it naturally would, and systems can become unstable, exhibiting signs of disturbance, shifts to disturbance oriented species, and unstable water chemistry and fish populations. It is often useful to classify lakes by their degree of eutrophication, taking one or more chemical or biological characteristics as a measure of lake character. The terms Oligotrophic, Mesotrophic, Eutrophic, and Hypereutrophic are often used to characterize lakes in various states of nutrient enrichment. (table 4-1)

**Table 4-1 Basic Classification of Lakes based on “trophic” condition (biological productivity)** (adapted from Jones 1996)

Oligotrophic- clear water, very low levels of nutrients (total phosphorus <.006ppm) support few algae, dissolved oxygen is present in the hypolimnion, can support salmonid (trout and cisco) fisheries.

Mesotrophic- water less clear, moderate levels of nutrients (total phosphorus .01-.03ppm), support healthy algal populations, decreasing dissolved oxygen in the hypolimnion, loss of salmonids.

Eutrophic- transparency less than two meters, relatively high concentrations of nutrients (total phosphorus >.035ppm, no dissolved oxygen in hypolimnion during summer, weeds and algae abundant.

Hypereutrophic- transparency less than 1 meter, no dissolved oxygen in hypolimnion, extremely high nutrient concentrations (total phosphorus > .08ppm) support thick algal scums, very dense weeds.

## 4.1 Water Quality Indexes

### The Indiana Trophic State Index

The Indiana Trophic State Index is a multi-parameter eutrophication index developed in the early 1970’s as a tool to characterize problem Indiana lakes and define the reasons or sources behind complaints from lake users. (Jones 1996) In the mid 1970’s the ITSI began to be used as a means of numerically ranking Indiana public lakes. Data is collected and scored according to the following table:

| Parameter & Range | Eutrophy Points | Lake James | Snow | Big Otter | Little Otter |
|---|---|---|---|---|---|
| **Total Phosphorus (mg/L or PPM) mean of epilimnion & hypolimnion** | | | | | |
| A. AT LEAST .O3 | 1 | | | 0 | 0 |
| B. .04-.05 | 2 | | | | |
| C. .06-.19 | 3 | 3 | 3 | | |
| D. .2-.99 | 4 | | | | 4 |
| E.1.0 OR MORE | 5 | | | 5 | |
| **Soluble Phosphorus (PPM)** | | | | | |
| A. AT LEAST .O3 | 1 | | | | |
| B. .04-.05 | 2 | | | | |
| C. .06-.19 | 3 | 3 | 3 | 3 | |
| D. .2-.99 | 4 | | | | 4 |
| E.1.0 OR MORE | 5 | | | | |
| **Organic Nitrogen (PPM)** | | | | | |
| A.AT LEAST .5 | 1 | | | 1 | |
| B. .6-.8 | 2 | | | | |
| C. .9-1.9 | 3 | 3 | 3 | | |
| D. 2.0 OR MORE | 4 | | | | 4 |
| **Nitrate (PPM)** | | | | | |
| A. AT LEAST .3 | 1 | 0 | 0 | 0 | 0 |
| B. .4 TO .8 | 2 | | | | |
| C. .9 TO 1.9 | 3 | | | | |
| D. 2.0 OR MORE | 4 | | | | |
| **Ammonia (PPM)** | | | | | |
| A. AT LEAST .3 | 1 | 0 | | | |
| B. .4 TO .5 | 2 | | 2 | | |
| C. .6 TO .9 | 3 | | | 3 | |
| D. 1.0 OR MORE | 4 | | | | 4 |
| **Dissolved Oxygen: Percent saturation at 5 feet from surface** | | | | | |
| A. 114% OR MORE | 0 | 0 | 0 | 0 | 0 |
| B. 115% TO 119% | 1 | | | | |
| C. 120% TO 129% | 2 | | | | |
| D. 130% TO 149% | 3 | | | | |
| E. 150% OR MORE | 4 | | | | |
| **Dissolved Oxygen: Percent of water column with at least .1PPM** | | | | | |
| A. 28% OR LESS | 4 | | 4 | | |
| B. 29% TO 49% | 3 | | | | |
| C. 50% TO 65% | 2 | | | 2 | 2 |
| D. 66% TO 75% | 1 | | | | |
| E. 76% TO 100% | 0 | 0 | | | |
| **Light Penetration (secchi disk)** | | | | | |
| A. FIVE FEET OR LESS | 6 | | | | |
| B. GREATER THAN FIVE FEET | 0 | 0 | 0 | 0 | 0 |
| Light Transmission (photocell)-percent light transmission at 3ft | | | | | |
| A. 0 TO 30% | 4 | | | | |
| B. 31%-50% | 3 | | | | |
| C. 51%-70% | 2 | 2 | 2 | 2 | 2 |
| D. 71% AND UP | 0 | | | | |
| **Total plankton per liter sampled from a single vertical tow between** | | | | | |
| **the 1% light level and the surface** | | | | | |
| A. Less than 3000 organisms/L | 0 | | | | |
| B. 3000-6000 | 1 | | | | |
| C.6001-16,000 | 2 | | | | |
| D. 16,001-26,000 | 3 | | | | |
| E. 26,001-36,000 | 4 | | | | |
| F. 36,001-60,000 | 5 | | | | |
| G. 60,001-95,000 | 10 | | | | |
| H. 95,001-150,000 | 15 | | | | |

| | | Lake James | Snow | Big Otter | Little Otter |
|---|---|---|---|---|---|
| I. 150,001-500,000 | 20 | | | | |
| J. Greater than 500,000 | 25 | 25 | 25 | 25 | 25 |
| **K Blue Green Dominance: additional points** | 10 | 10 | | 10 | 10 |
| | | Lake James Total Points | Snow Total Points | Big Otter Total Points | Little Otter Total Points |
| | | 46 | 42 | 51 | 55 |

0 to 25 points Oligotrophic
26 to 50 points Mesotrophic
51 to 75 points Eutrophic

**Table 32 2005 season ITSI scoring for the James Chain Lakes**

ITSI scoring based on 2005 data placed Lake James and Snow Lake in the "Mesotrophic" category indicating an intermediate level of nutrient enrichment. The scoring placed both Big Otter Lake and Little Otter Lake in the "Eutrophic" category indicating a high amount of nutrient enrichment. The majority of the Eutrophy points in the 2005 scores resulted from the high algal counts, especially with regard to blue green algae. This is probably a result of improved accuracy in algal counting and identification over techniques used when past ITSI scores were developed. With Secchi depths between 7.7 and 14.8 feet measured on the lakes in reality all four lakes probably belong at the upper end of the Oligotrophic (low nutrient) category or lower end of the Mesotrophic category.

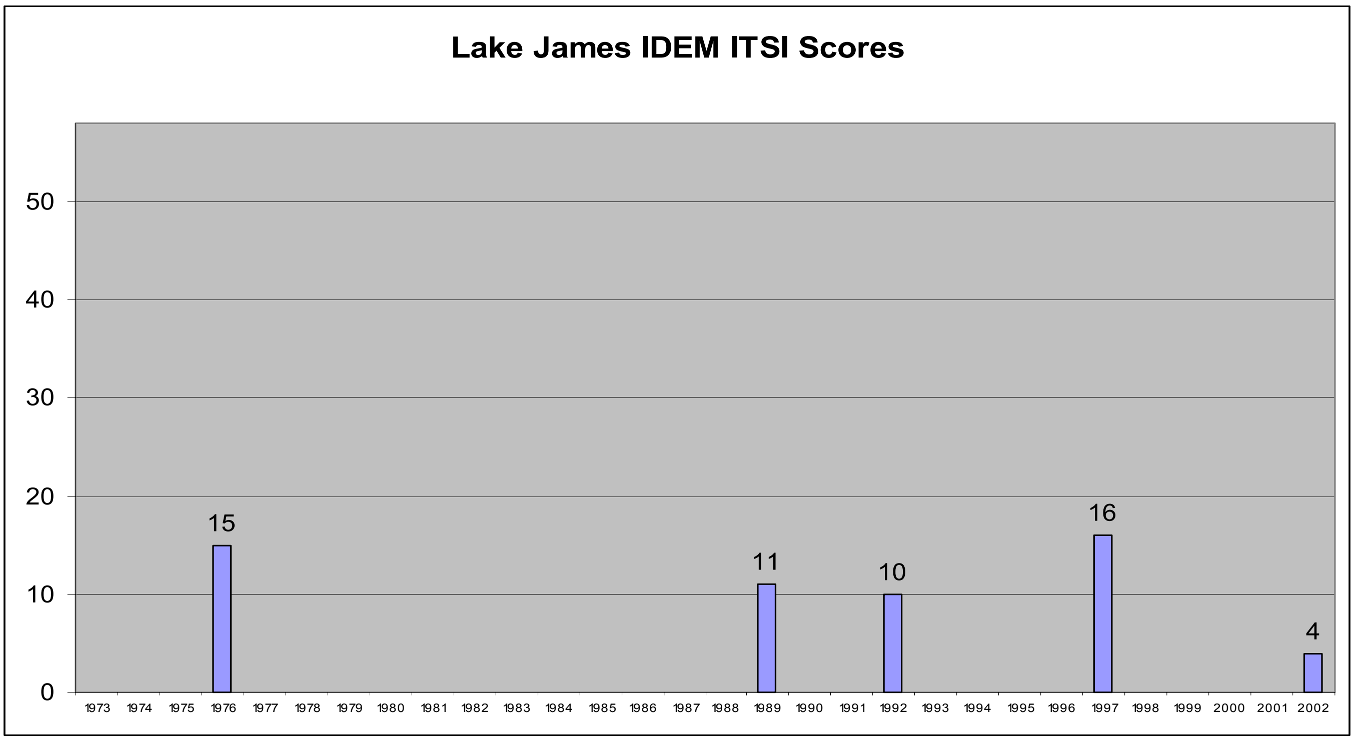



**Figure 75 IDEM ITSI Scores for Lake James**

Water Quality Trends

Lake James

A bar chart of total phosphorus measurements for Lake James show that concentrations have been relatively high since 1976 without an obvious trend other than a possible lessening in total phosphorus in the 1990's (fig 76). For this particular parameter the James Chain Lake Associations may wish to consider collecting a measurement on an annual basis during years that

IDEM/SPEA does not conduct sampling. This may assist in producing a clearer statistical picture of water quality trends.

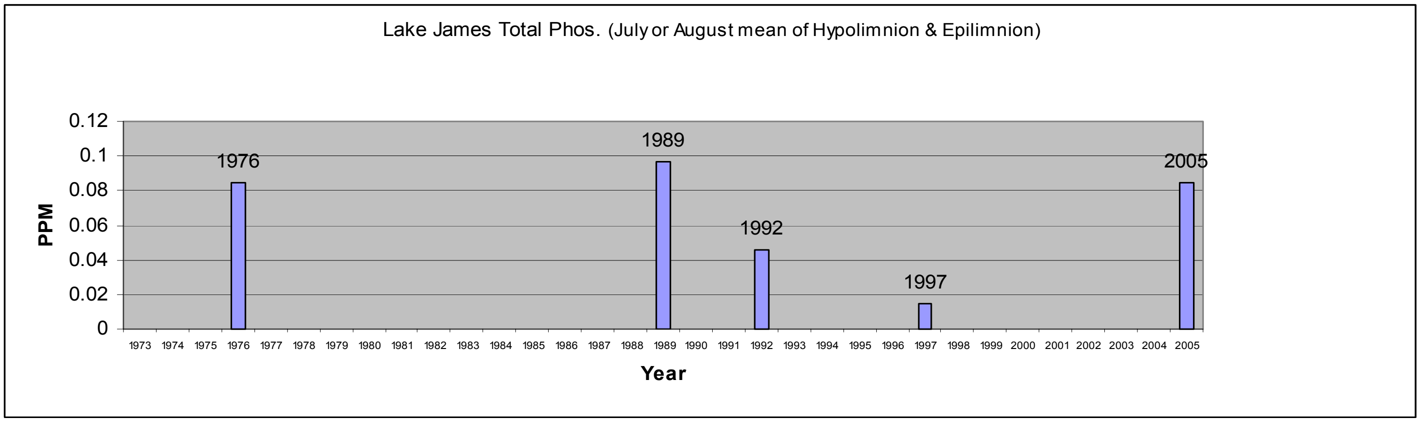



**Figure 76 Lake James Total Phosphorus (July or August Mean of Hypolimnion & Epilimnion, IDEM/SPEA/Current Study Data)**

July average Secchi disk measurements for years on record appear to show a trend toward less summertime water clarity in Lake James. (fig 77) 2002 showed a midsummer period that was especially turbid with a July 14, 2002 measurement of 3.2 feet. Lake James surface waters typically contain enough total phosphorus to potentially produce algal blooms, but a relatively small amount of that phosphorus is present as orthophosphorus the and thus is unavailable to spur algae growth. This may mean the potential for algal blooms is high if biological or chemical instability occurs and shifts the balance of phosphorus in useable form as it likely did in 2002. In addition to limiting phosphorus introductions, steps such as maintaining a healthy and diverse native aquatic plant community may be important in maintaining the necessary balance to keep the good water clarity typical of Lake James.

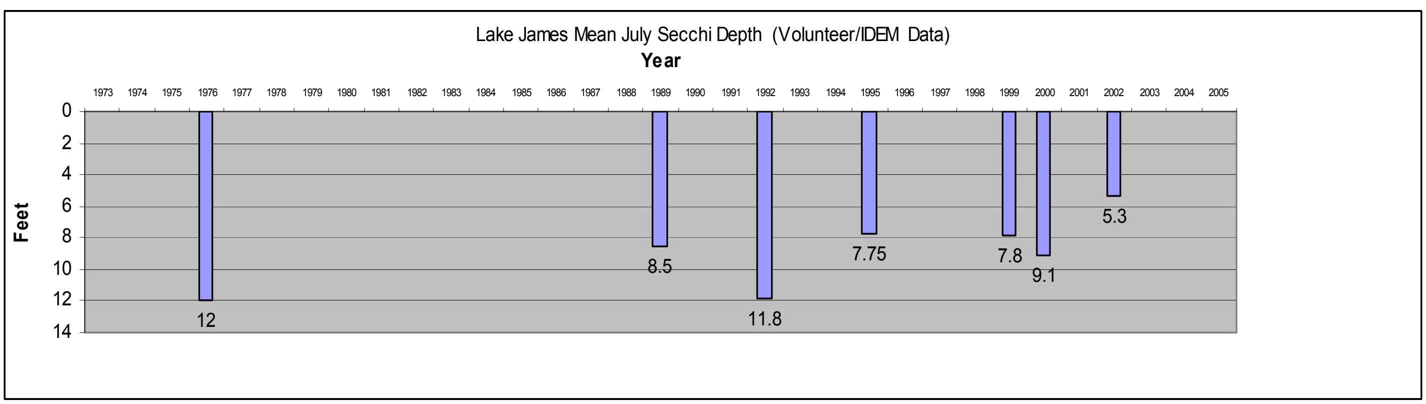



**Figure 77 Lake James Secchi Measurements (Mean of July Measurements, IDEM/SPEA/LJA Volunteer Data)**

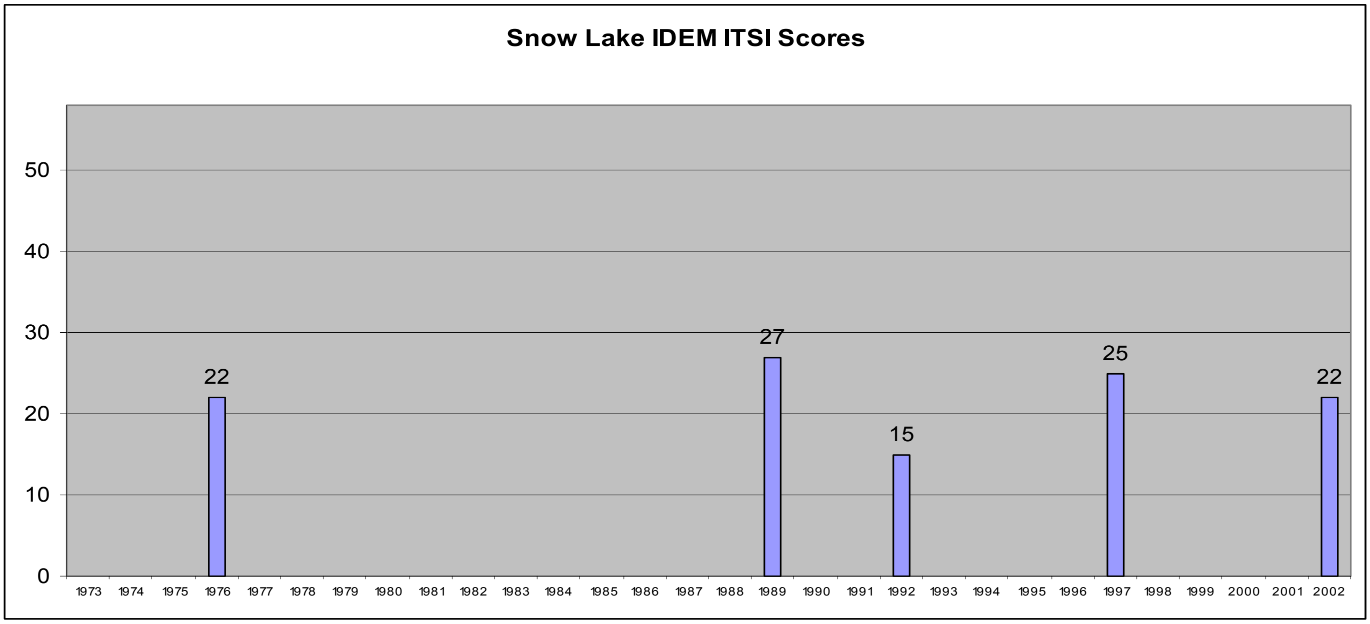



**Figure 78 IDEM ITSI Scores for Snow Lake**

Snow Lake

Snow Lakes ITSI since initial scoring in 1976 appears to be relatively stable. Like Lake James, however, Snow Lake also appears to show a trend toward less water clarity when July Secchi data is examined (fig 80) with a trend in mean total phosphorus less obvious with available data.(fig 79) It is possible that a source of turbidity other than planktonic algae may play a role in the decreased water clarity. Suspended sediments mobilized by increased summertime boat traffic are one possibility.

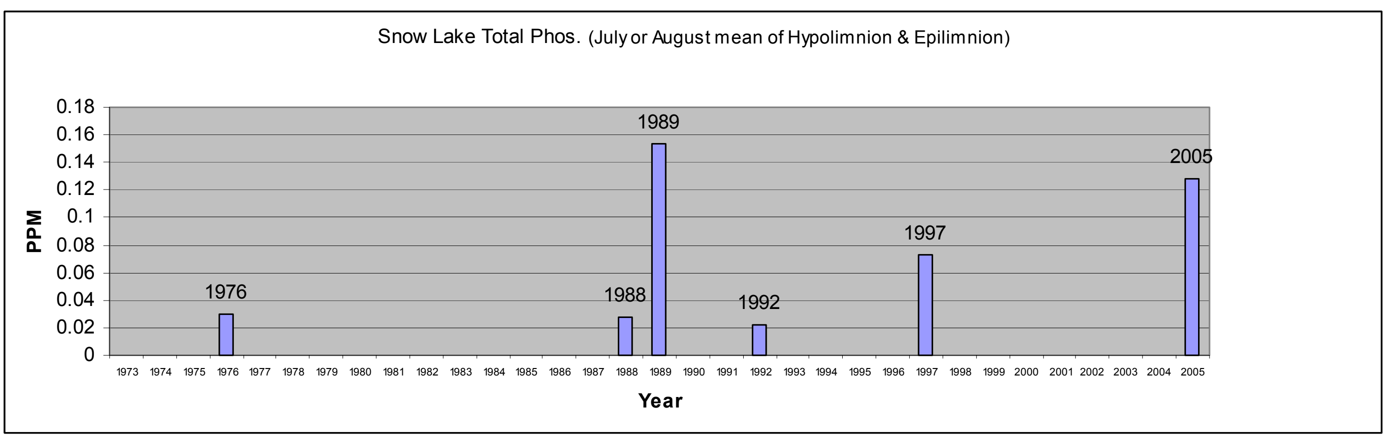



**Figure 79 Snow Lake Total Phosphorus (July or August Mean of Hypolimnion & Epilimnion, IDEM/SPEA/Current Study Data)**

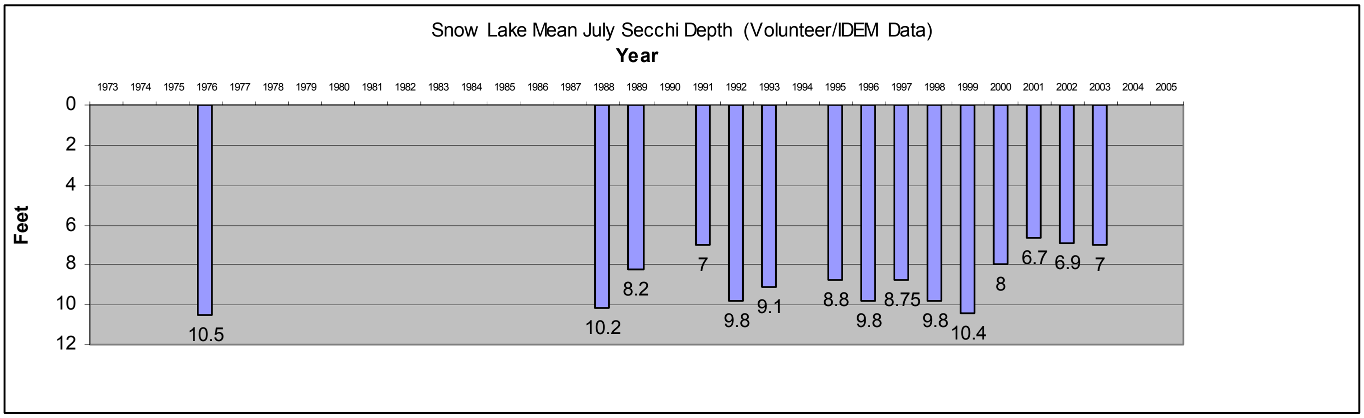



**Figure 80 Snow Lake Secchi Measurements (Mean of July Measurements, IDEM/SPEA/LJA Volunteer Data)**

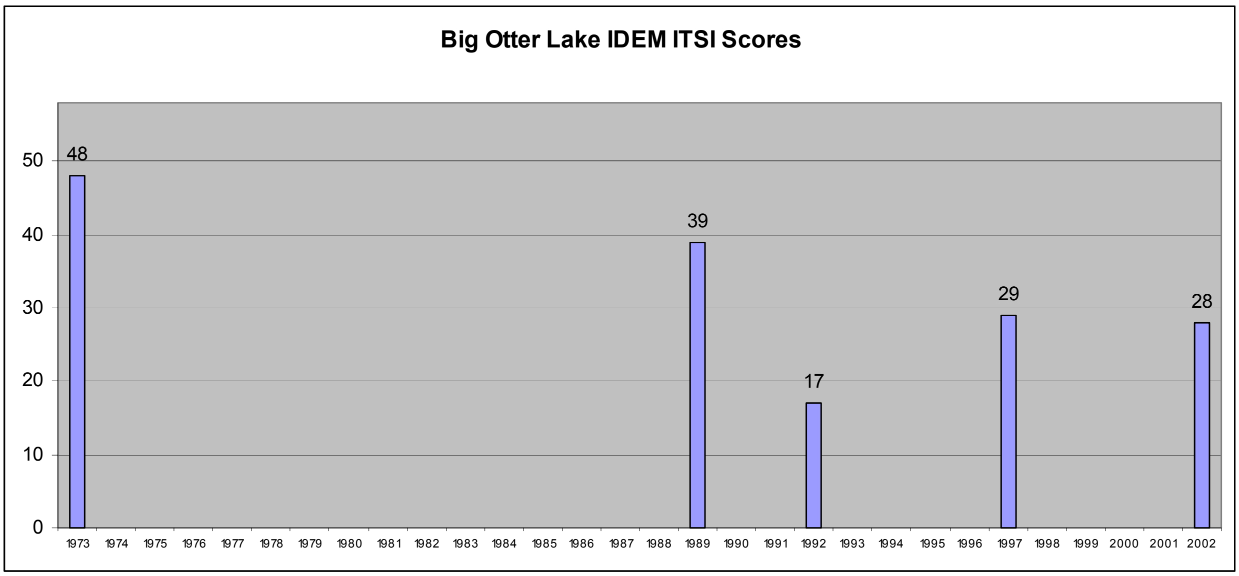



**Figure 81 IDEM ITSI Scores for Big Otter Lake**

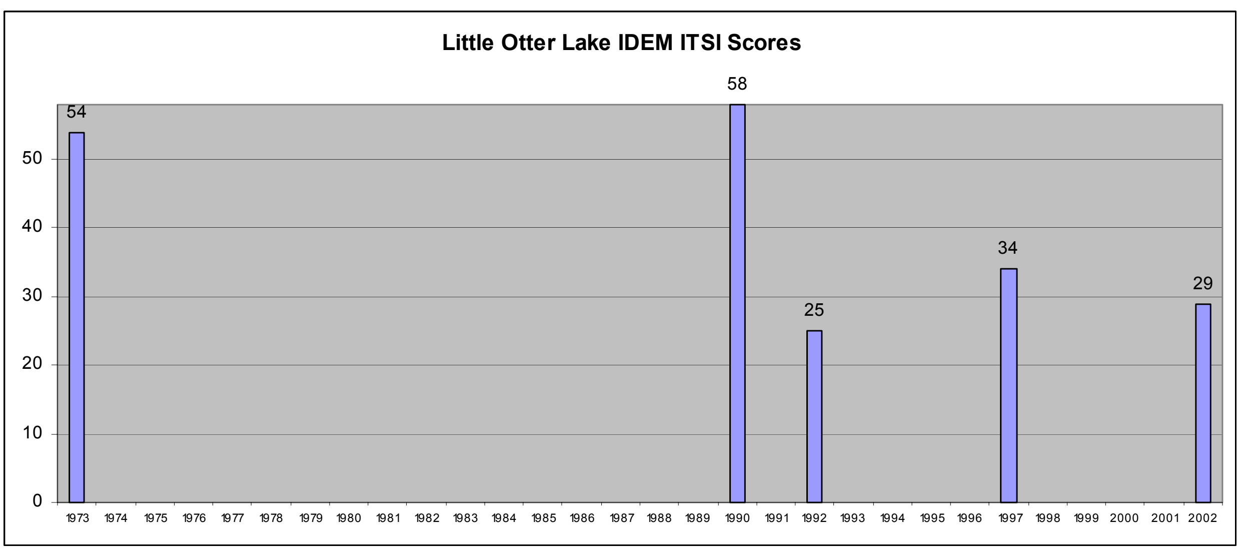



**Figure 82 IDEM ITSI Scores for Little Otter Lake**

Big and Little Otter

In terms of ITSI scores Big and Little Otter both appear to show a trend toward improved water quality since the 1970's (figs 81,82). With limited data available since 1973 a trend in mean total phosphorus is difficult to discern on either of the Otter Lakes (figs 83, 85), but a gradual trend toward better summer water clarity is apparent from the available Secchi data (figs. 84,86). This trend in opposition to those on Snow Lake and Lake James could be an indication that the lesser lakeside development and no-wake speed limit present on these smaller basins are significant factors determining summer water clarity. The Otters don't experience the resuspension of sediments and associated nutrient exchange likely occurring on Snow Lake and Lake James in response to powerboat traffic. While Both Otters do receive sediments mobilized by boats navigating at their tributary mouths, the bulk of boat-traffic related sediments and nutrients eroded from the Follet Creek wetlands are carried downstream away from the Otters. A considerable amount of material has traveled downstream to Snow Lake to produce the current depth and width of the Follet Creek channel between the lakes.

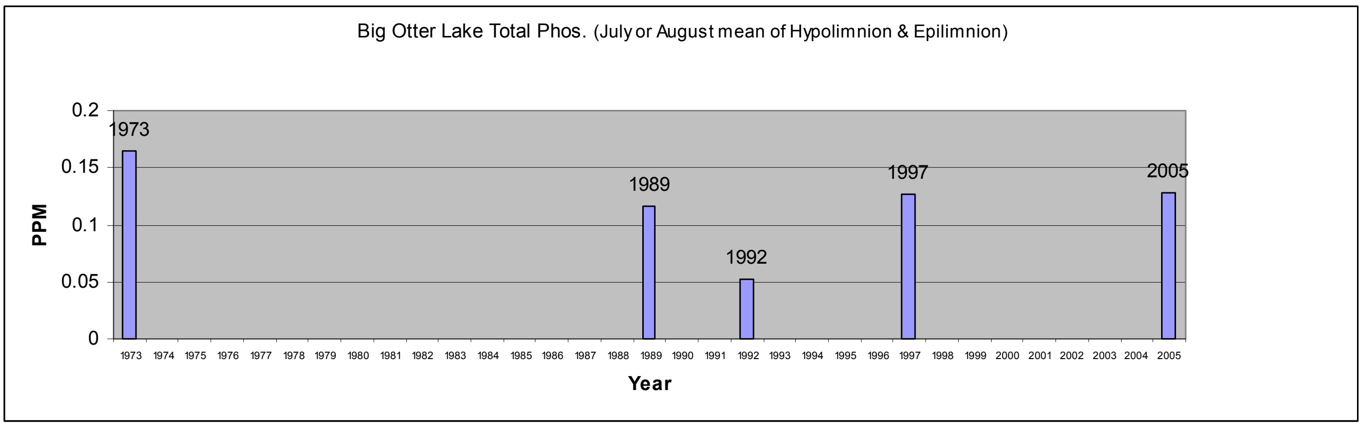



**Figure 83 Big Otter Lake Total Phosphorus (July or August Mean of Hypolimnion & Epilimnion, IDEM/SPEA/Current Study Data)**

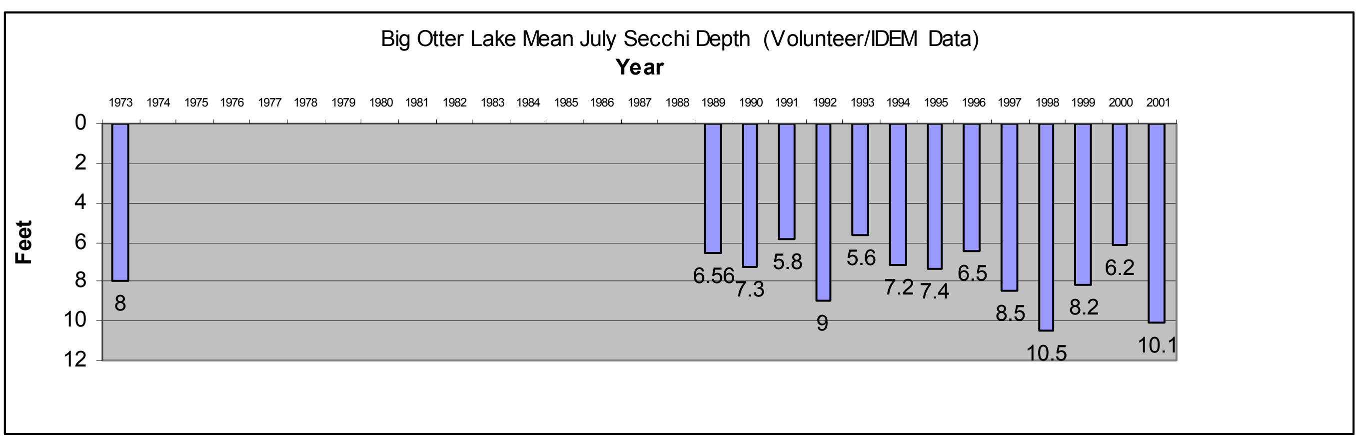



**Figure 84 Big Otter Lake Secchi Measurements (Mean of July Measurements, IDEM/SPEA/LJA Volunteer Data)**

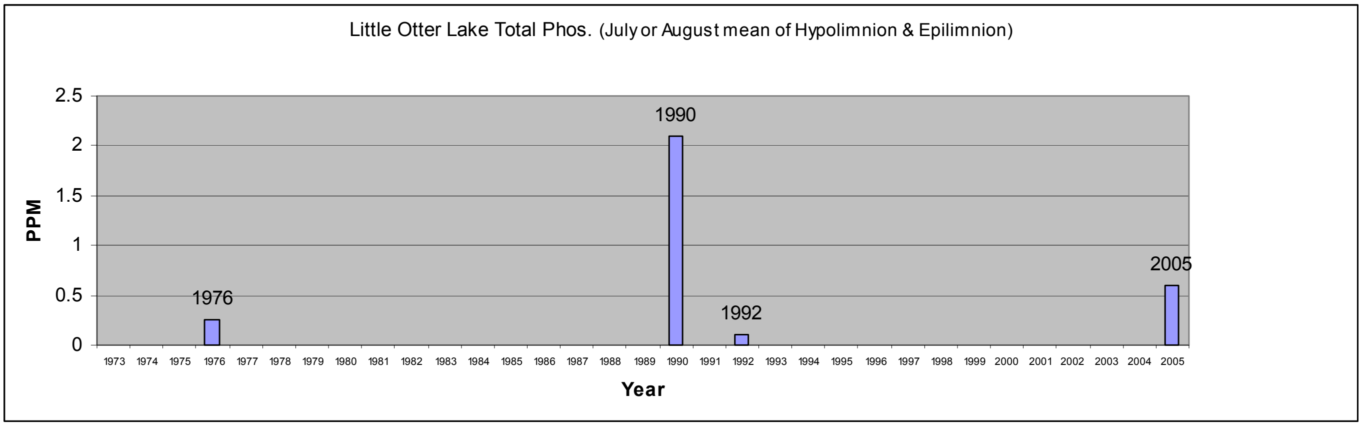



**Figure 85 Little Otter Lake Total Phosphorus (July or August Mean of Hypolimnion & Epilimnion, IDEM/SPEA/Current Study Data)**

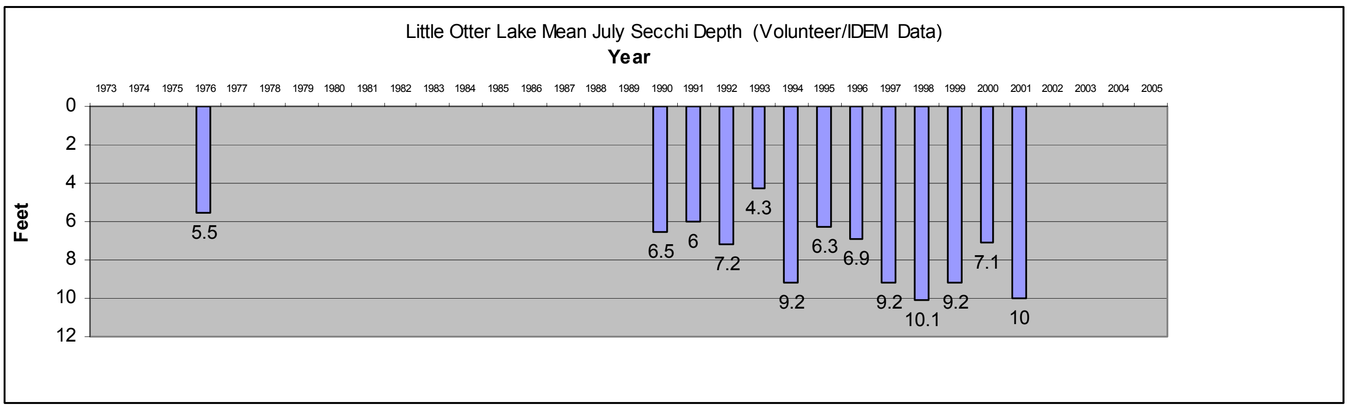



**Figure 86 Little Otter Lake Secchi Measurements (Mean of July Measurements, IDEM/SPEA/LJA Volunteer Data)**

## Carlson's Trophic State Index

Carlson's Trophic State Index is another very commonly used multi-parameter index. The index scores three commonly measured parameters on a scale produced from the set of lakes used to form the index. This can be useful in revealing variations in parameter relationships within a particular lake in comparison with Carlson's lake set.

| | Secchi | Secchi (m) | Total P ppm | Total P ppb | Chl a ppb | Score | **Mean Lk Score** |
|---|---|---|---|---|---|---|---|
| James | 14.8 | 4.5 | 0.09 | 90 | 2.1 | 2.1 | |
| Score | 38 | | 69 | | 38 | | **48** |

| | Secchi | Secchi (m) | Total P ppm | Total P ppb | Chl a ppb | Score | **Mean Lk Score** |
|---|---|---|---|---|---|---|---|
| Snow | 9.9 | 3.0 | 0.07 | 70 | 4.1 | 4.1 | |
| Score | 44 | | 65 | | 44 | | **51** |

| | Secchi | Secchi (m) | Total P ppm | Total P ppb | Chl a ppb | Score | **Mean Lk Score** |
|---|---|---|---|---|---|---|---|
| Big Otter | 7.7 | 2.3 | 0.36 | 360 | 0.1 | 0.1 | |
| Score | 48 | | 89 | | 8 | | **48** |

| | Secchi | Secchi (m) | Total P ppm | Total P ppb | Chl a ppb | Score | **Mean Lk Score** |
|---|---|---|---|---|---|---|---|
| Little Otter | 12.2 | 3.7 | 0.078 | 78 | 3.6 | 3.6 | |
| Score | 41 | | 67 | | 43 | | **50** |

**Table 33 Carlson's TSI data for the James Chain Lakes in 2005**

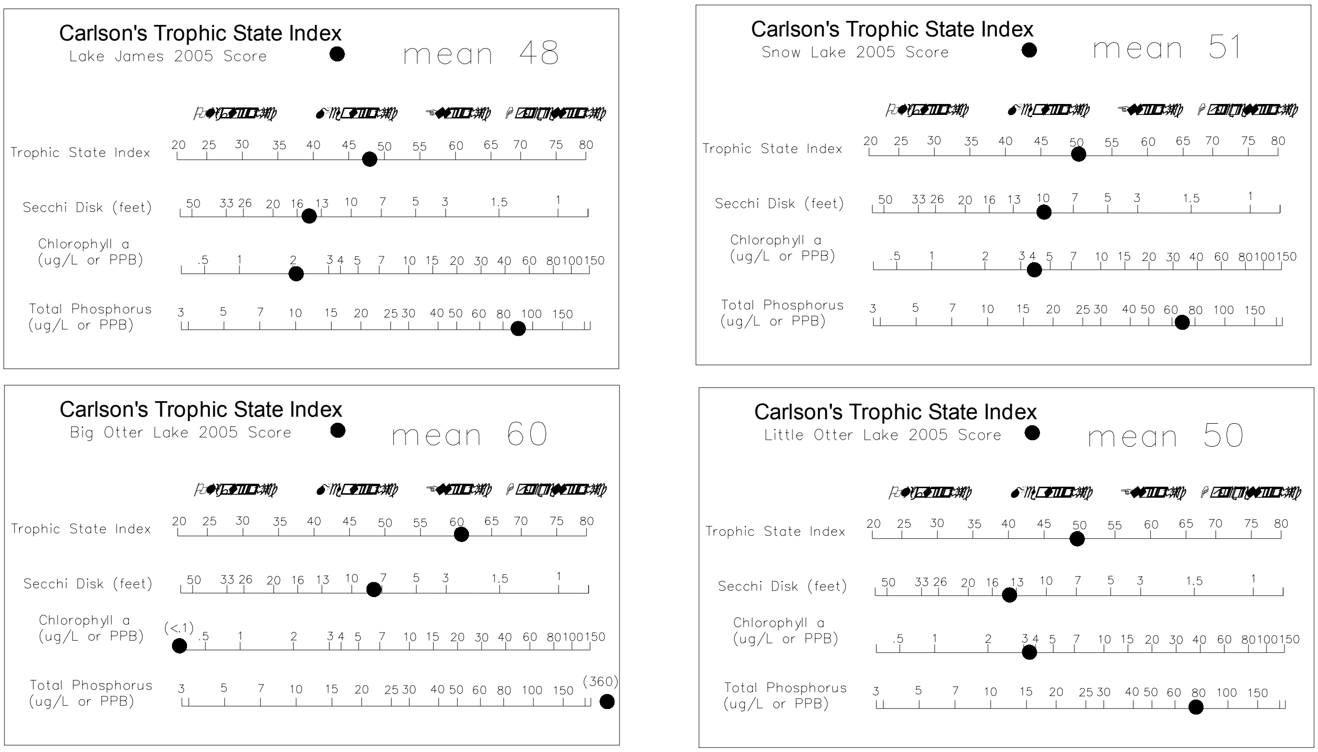



**Table 34 Carlson's TSI Index Scales for the James Chain Lakes in 2005**

By examining the respective Carlson's scores produced by each parameter separately we can see that in each case total phosphorus measurements provided a considerably inflated score over Secchi depth and Chlorophyll a. On James Secchi depth provided a score of 38 placing the lake between the "oligotrophic" and "mesotrophic" category. This was backed up by a 38 score produced by Chlorophyll a. A high surface water total phosphorus measurement of .09 ppm however gave James a score of 69 putting it into the hypereutrophic category. Results were similar on Snow Lake where both Secchi depth and Chlorophyll a measurements scored Snow as mesotrophic, while the total phosphorus measurement indicated a eutrophic condition. We can see that in 2005 James and Snow were functioning very differently than Carlson's set of lakes did. In this case the scores provided by Secchi depth and Chlorophyll a are probably a better measure of lake trophic state than total phosphorus. On Big Otter Secchi depth indicated a score of 48 in the mesotrophic category while a very low chlorophyll a measurement scored the lake as oligotrophic. Total phosphorus was above the hypereutrophic part of the scale. Again total phosphorus did not appear to be an accurate measure of eutrophication. Like James and Snow, Little Otter scored as mesotrophic with the exception of total phosphorus which placed Little Otter between the eutrophic and hypereutrophic categories. With each of the basins apparently not reflecting their relatively high total phosphorus levels as most lakes would the potential may exist for algal blooms to occur in response to a change in ecosystem function that would bring a more full utilization of the phosphorus present by algal populations. In addition to limiting phosphorus introductions to the lakes, in-lake management strategies such as maintaining a healthy, and diverse native aquatic and wetland plant community may be important to maintaining good water clarity in the relatively phosphorus-rich waters of the chain.

## 4.2 The James Chain Water Budgets

To gain insight into the sources of nutrients to the lakes it's helpful to produce estimated phosphorus budgets for the four lakes in the James Chain. Because most phosphorus enters the lakes in rain and snow melt runoff it is first necessary to establish water budget figures for each lake in the chain and each major lake upstream of the James Chain based on what we know about the lakes, their watersheds, and climatic conditions in the area. The subwatersheds for which runoff figures were calculated are shown in Figure 87.

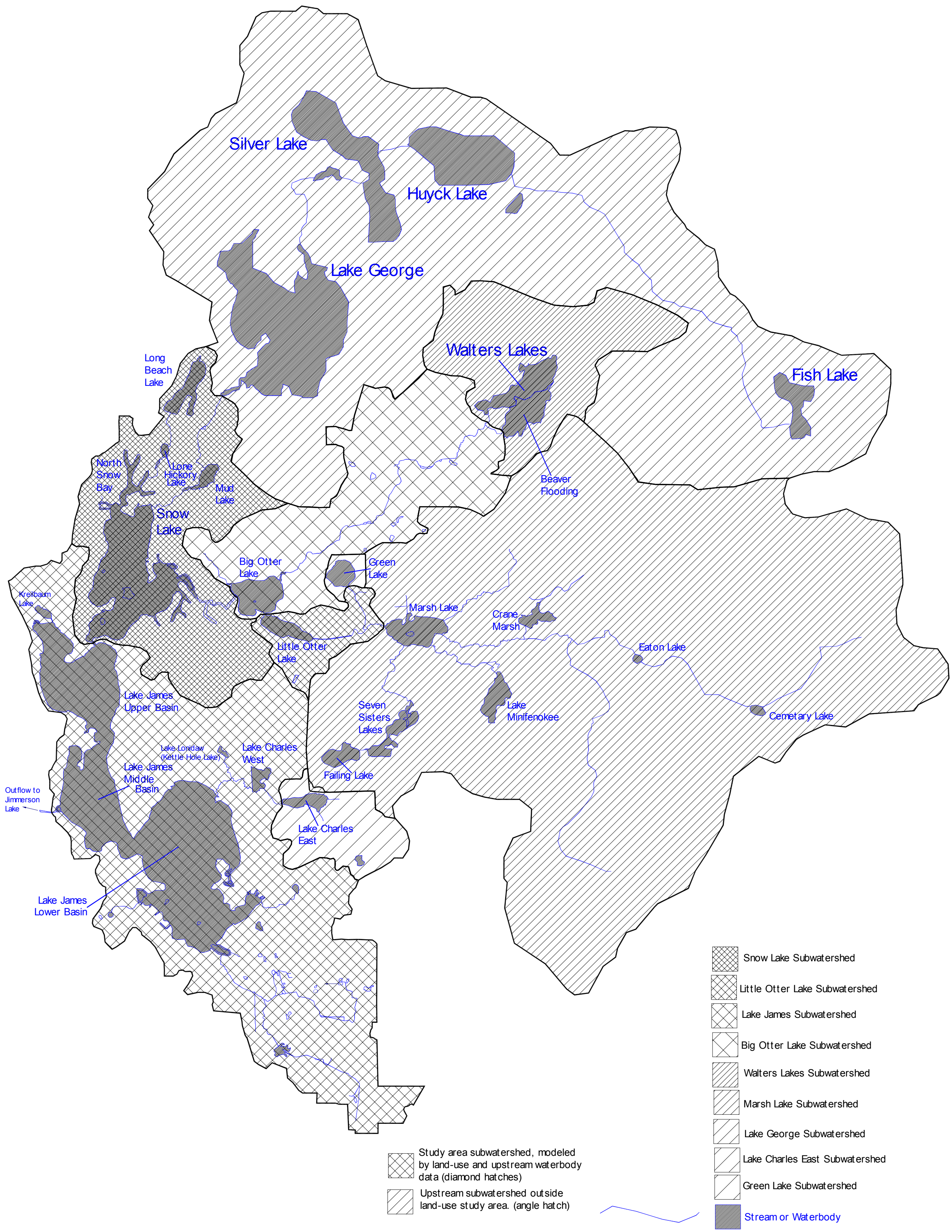



**Figure 87 James Chain Subwatersheds Used in Water Budget Calculations**

Calculation of Lake George Water Budget

To quantify sources and losses of water for Lake George, a water budget was produced. The calculation of the respective water budget components is outlined below.

**Direct Rainfall Input**
Yearly direct precipitation to the lake was calculated using Angola rainfall records obtained from the Midwestern Regional Climatic Center in Champaign, Illinois. Mean annual precipitation of 38.89 inches for the period 1990 to 2001 was used.

Annual Direct Precipitation to Lake George

| | 1990-2001 Records | |
|---|---|---|
| Surface Area (acres) | Mean Annual Precip.(in) | Ann. Direct Precip. Vol. (acre-feet) |
| 509 | 38.89 | 1649.58 |

**Table 35 Calculation of Annual Direct Precipitation to Lake George (Annual Acre-Feet)**

**Surface Runoff Input**
Because there is no U.S. Geological Survey operated a stream-flow gauging station on Lake George to tell us how much water flows through the lake in response to precipitation, outlet outflow data from another nearby watershed of similar soil types and precipitation was used. This figure will be used to calculate contributions to the lake's water budget from surface rain and snow melt runoff. The U.S.G.S. operated a stream-flow gauging station on the outlet from Lime Lake and Lake Gage in Steuben County between 1969 and 1986. This provided outflow data specific to the same general watershed (Fawn River) within the same general soil unit. A mean annual outflow figure for the period of record provided a starting point for runoff calculations. Runoff for the entire 17.5 square mile watershed was recorded at 6.25 inches annually. Dividing the runoff figure by mean annual precipitation for the same period of record produced a runoff coefficient of .17. Annual outflow for the period 1989 to 1999 was predicted at 6160 acre-feet with the U.S.G.S. coefficient. Because the U.S.G.S. outflow figure omits runoff that evaporates on that watershed's lakes, and includes direct rainfall to the lakes, the predicted outflow was adjusted by those amounts and a refined runoff coefficient of .14 was generated. This coefficient was then utilized in predicting the drainage from the 7555 acres of land in Lake's George's watershed at 3427.83 acre feet of water.

Annual Watershed Rain and Snow Melt Runoff to Lake George

| Watershed | Watershed Land Acreage | Ann. Drainage Vol. (acre-feet) |
|---|---|---|
| Lake | 7555 | 3427.83 |
| | | |
| Runoff Coefficient | 0.14 | |
| Annual Precip. (in) | 38.89 | |

**Table 36 Calculation of Annual Rain/Snow Melt Runoff to Lake George**

This produces a total annual input figure of 5077 acre feet of water.

Annual Water Input to Lake George

| Lake Water Input | Mean annual volume (ac-ft) | Percentage |
|---|---|---|
| Direct rainfall to lake | 1649.58 | 32.49% |
| Rain/snow runoff | 3427.83 | 67.51% |
| Total Water Input | 5077.413583 | 100.00% |

**Table 37 Summary of Annual Sources of Water Input to Lake George**

**Mean Annual Evaporative Losses**

Evaporative losses for the lake were estimated using pan evaporation data for Prairie Heights Indiana obtained through the National Climatic Data Center in Asheville North Carolina. Mean annual pan evaporation for the year of most complete record (1996) was 31.11 inches. Because actual evaporative losses from lakes occurs at approximately .74[1] the rate of standard measured pan evaporation, this figure was adjusted to 23.02 inches and used to calculate mean annual evaporative losses for the 509 acre surface area of Lake George.

Annual Evaporation from Lake George

| Surface Area (acres) | Mean Annual Evap.(in) | Annual Evap. volume (acre-feet) |
|---|---|---|
| 509 | 23.02 | 976.43 |

**Table 21 Calculation of Annual Evaporative Losses from Lake George (figures in Annual Acre-feet)**

This allows us to calculate that approximately 4101 acre feet of water flow from Lake George to Snow Lake Annually.

Annual Water Losses from Lake George

| Lake Water Losses | Mean annual Volume (ac-ft) | Percentage |
|---|---|---|
| Evaporation | 976.43 | 19.23% |
| Overflow to Downstrm. | **4100.98** | 80.77% |
| Total Losses | 5077.41 | 100.00% |

**Table 38 Summary of Annual Water Losses from Lake George**

[1] .74 is mean of data reported in (Linacre 1994)

Repeating the same calculations for the other upstream watersheds draining to the James Chain produces the following table of upstream watershed data. This data can then be used to establish estimates for the water budgets for the lakes in the James Chain individually.

| Watershed | Lake George | Walter's Lakes | Green Lake | Marsh Lake | Lake Charles East | Total |
|---|---|---|---|---|---|---|
| Total direct precip. and runoff water input (acre-feet) | 5077.41 | 881.36 | 98.98 | 4049.11 | 245.74 | 10352.60 |
| Total evaporative water losses (acre-feet) | 976.43 | 251.65 | 48.09 | 115.33 | 41.30 | 1432.80 |
| Output to James Chain (acre-feet) | 4100.98 | 629.71 | 50.89 | 3933.78 | 204.44 | 8919.80 |

**Table 39 Annual Water Budget Figures for Lakes Immediately Upstream of the James Chain**

Repeating the water budget calculations for each of the respective lakes in the James Chain while adding the input from the above upstream lakes produces the following data for the James Chain Lakes:

Annual Water Input to Little Otter Lake

| Lake Water Input | Mean annual volume (ac-ft) | Percentage |
|---|---|---|
| Direct rainfall to lake | 99.23 | 2.36% |
| Rain/snow runoff | 123.47 | 2.93% |
| Input from upstream watershed(s)(Marsh/Green) | 3984.67 | 94.71% |
| Total Water Input | 4207.37 | 100.00% |

**Table 40 Summary of Annual Sources of Water Input to Little Otter Lake**

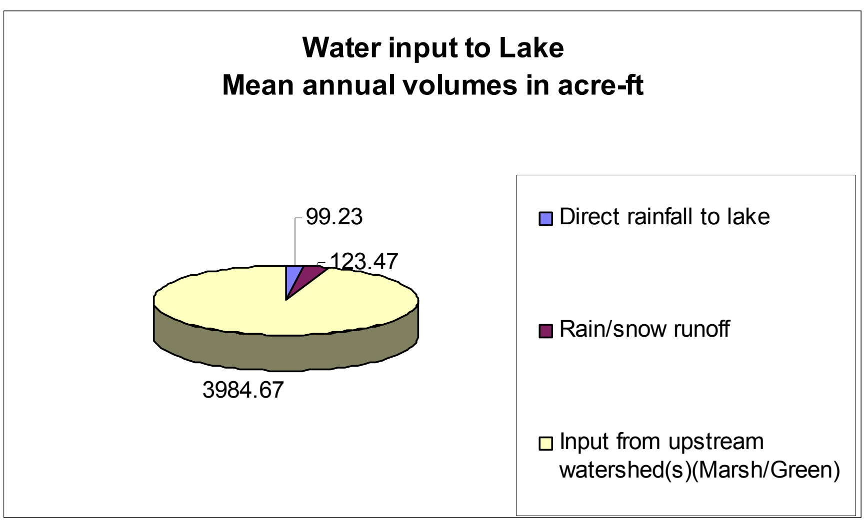



**Figure 88 Pie Chart of Annual Water Input Sources for Little Otter Lake**

Annual Water Losses from Little Otter Lake

| Lake Water Losses | Mean annual Volume (ac-ft) | Percentage |
|---|---|---|
| Evaporation | 58.74 | 1.47% |
| Overflow to Downstrm. | 3925.93 | 98.53% |
| Total Losses | 3984.67 | 100.00% |

**Table 41 Summary of Annual Water Losses from Little Otter Lake**

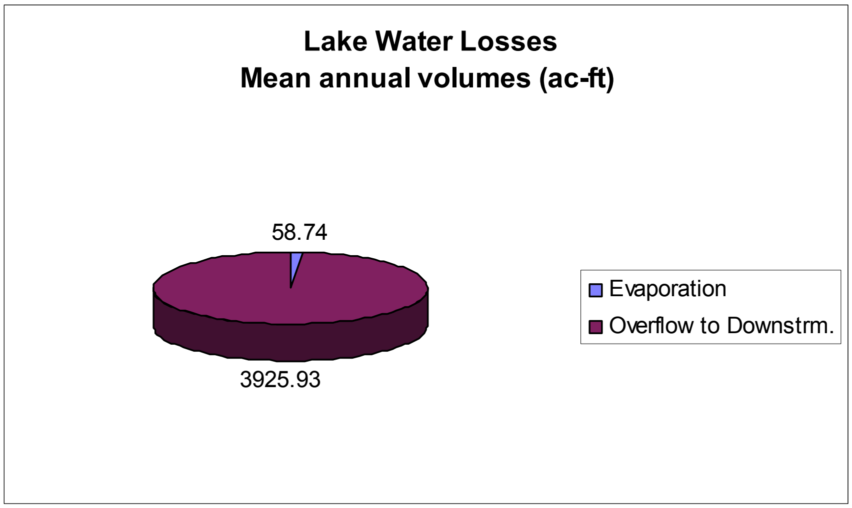



**Figure 89 Pie Chart of Annual Water Losses for Little Otter Lake**

Knowing the amount of Little Otter Lakes annual outflow and the lakes volume we can now calculate the hydraulic residence time of the lake.

| Volume (acre-feet) | Mean Ann. Outflow (ac-ft) | Hydraulic Residence time (years) (volume / mean annual outflow) |
|---|---|---|
| 643.02 | 3925.93 | 0.16 (58 days) |

**Table 42 Hydraulic Residence Time Calculation for Little Otter Lake**

Solving in the same manner for Big Otter Lake collecting runoff from its approximately 1464.5 acre subwatershed and receiving outflow from the Walter's Lakes and Little Otter Lake (Follet Creek) subwatersheds produces the following water budget data:

| Lake Water Input | Mean annual volume (ac-ft) | Percentage |
|---|---|---|
| Direct rainfall to lake | 219.02 | 4.03% |
| Rain/snow runoff | 664.47 | 12.22% |
| Input from upstream (Walter's Lakes) | 629.71 | 11.58% |
| Input from upstream (Little Otter Lake) | 3925.93 | 72.18% |
| Total Water Input | 5439.12 | 100.00% |

**Table 43 Summary of Annual Sources of Water Input to Big Otter Lake**

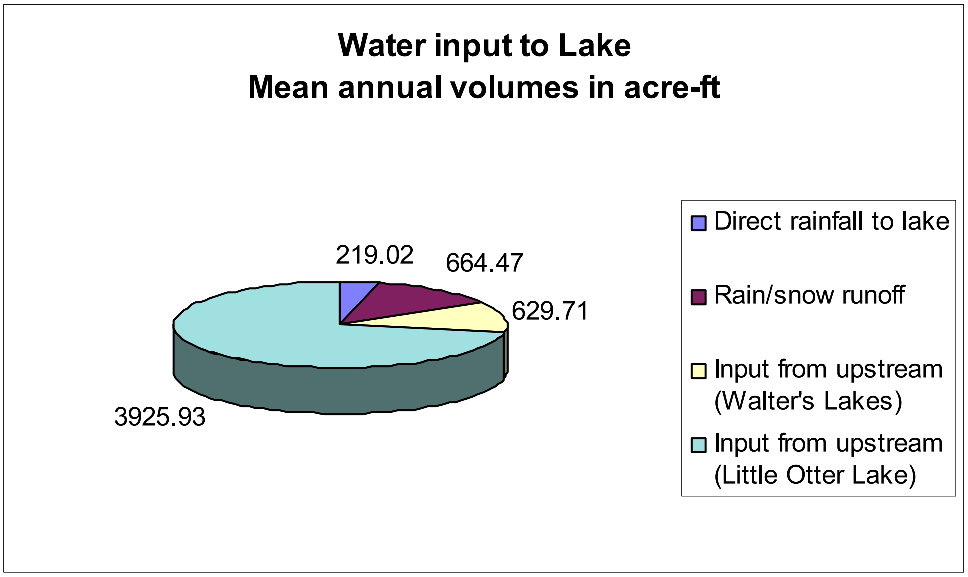



**Figure 90 Pie Chart of Annual Water Input Sources to Big Otter Lake**

| **Lake Water Losses** | Mean annual Volume (ac-ft) | Percentage |
|---|---|---|
| Evaporation | 129.64 | 2.38% |
| Overflow to Downstrm. | 5309.48 | 97.62% |
| Total Losses | 5439.12 | 100.00% |

**Table 44 Summary of Annual Water Losses from Big Otter Lake**

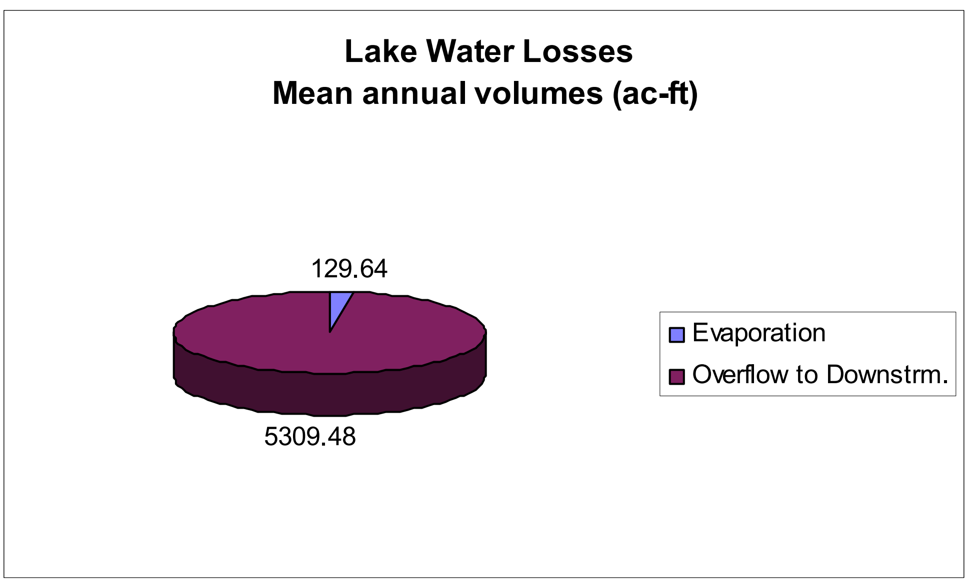



**Figure 91 Pie Chart of Annual Water Losses from Big Otter Lake**

We can now calculate the hydraulic residence time for Big Otter Lake.

| Volume (acre-feet) | Mean Ann. Outflow (ac-ft) | Hydraulic Residence time (years) (volume / mean annual outflow) |
|---|---|---|
| 1757.16 | 5309.48 | 0.33 (120 days) |

**Table 45 Hydraulic Residence Time Calculation for Big Otter Lake**

Again solving in the same manner for Snow Lake collecting runoff from its approximately 1494.20 acre subwatershed and receiving outflow from Big Otter Lake via Follet Creek and Lake George through Crooked Creek produces the following water budget and hydraulic residence data:

| Lake Water Input | Mean annual volume (ac-ft) | Percentage |
|---|---|---|
| Direct rainfall to lake | 1336.00 | 11.69% |
| Rain/snow runoff | 677.94 | 5.93% |
| Input from upstream (Big Otter Lake) | 5309.48 | 46.47% |
| Input from upstream (Lake George) | 4100.98 | 35.90% |
| Total Water Input | 11,424.40 | 100.00% |

**Table 46 Summary of Annual Sources of Water Input to Snow Lake**

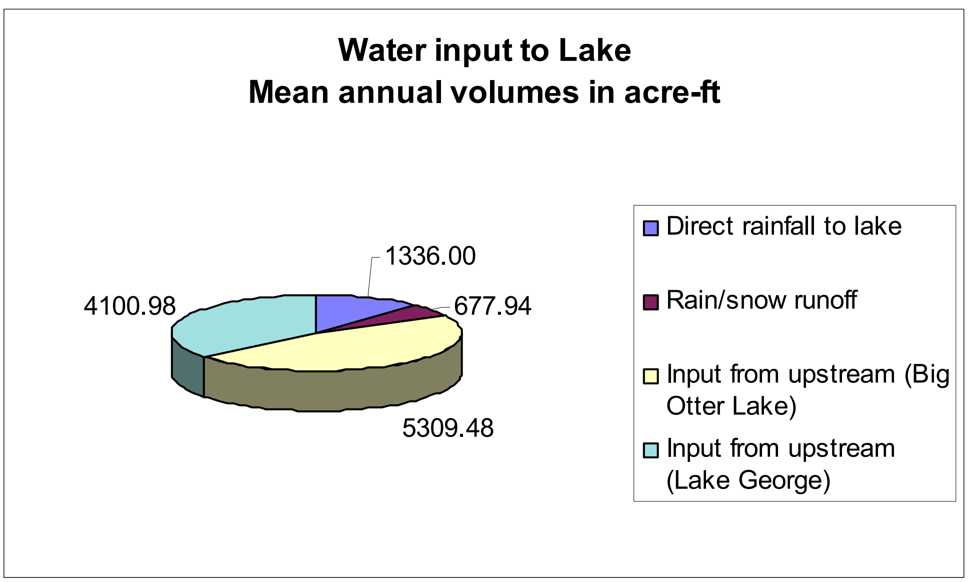



**Figure 92 Pie Chart of Annual Water Input Sources to Snow Lake**

| Lake Water Losses | Mean annual Volume (ac-ft) | Percentage |
|---|---|---|
| Evaporation | 790.81 | 6.92% |
| Overflow to Downstrm. | 10,633.59 | 93.08% |
| Total Losses | 11,424.40 | 100.00% |

**Table 47 Summary of Annual Water Losses from Snow Lake**

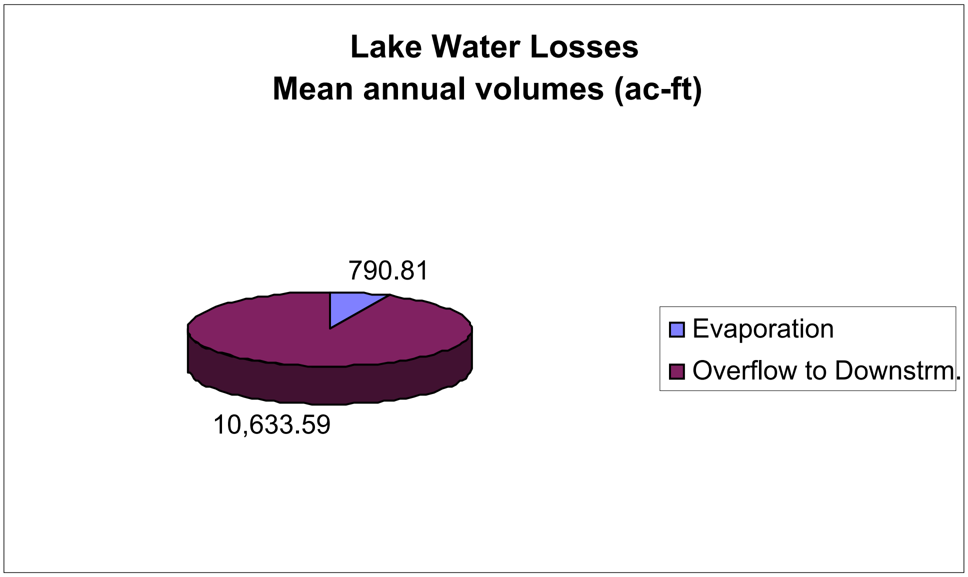



**Figure 93 Pie Chart of Annual Water Losses from Snow Lake**

| Volume (acre-feet) | Mean Ann. Outflow (ac-ft) | Hydraulic Residence time (years) (volume / mean annual outflow) |
|---|---|---|
| 11,542.72 | 10,633.59 | 1.09 (398 days) |

**Table 48 Hydraulic Residence Time Calculation for Snow Lake**

Solving in the same manner for Lake James collecting runoff from its approximately 3093.66 acre subwatershed and receiving outflow from Lake Charles East and Snow Lake produces the following water budget data. Lake Charles East's water output was estimated because phosphorus data for Lake Charles East is collected annually. Its water budget figure and total phosphorus data will be used later in the Lake James phosphorus model.

| Lake Water Input | Mean annual volume (ac-ft) | Percentage |
|---|---|---|
| Direct rainfall to lake | 3981.56 | 24.54% |
| Rain/snow runoff | 1403.65 | 8.65% |
| Input from upstream (Lake Charles East) | 204.44 | 1.26% |
| Input from upstream (Snow Lake) | 10,633.59 | 65.55% |
| Total Water Input | 16,223.23 | 100.00% |

**Table 49 Summary of Annual Water Input Sources from Lake James**

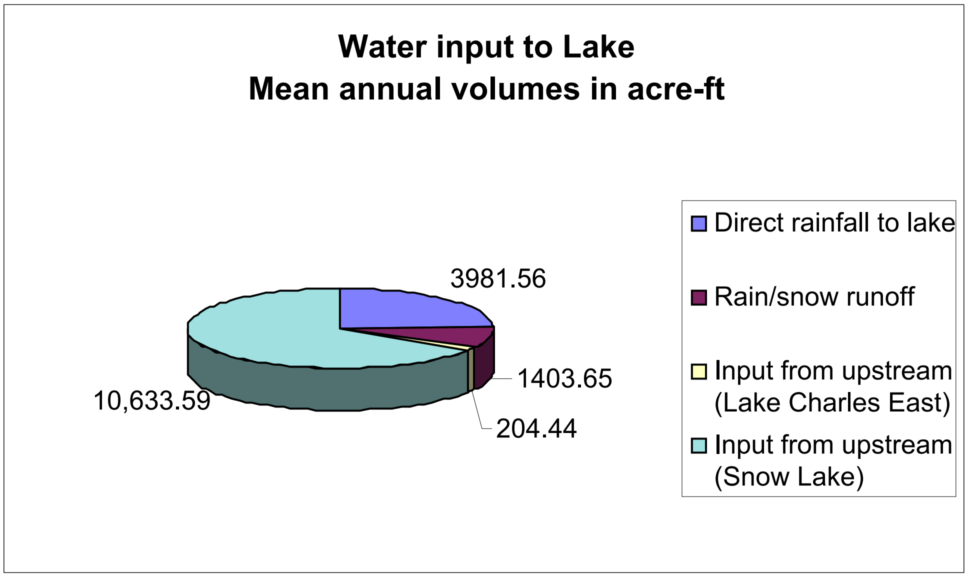



**Figure 94 Pie Chart of Annual Water Input Sources for Lake James**

| Lake Water Losses | Mean annual Volume (ac-ft) | Percentage |
|---|---|---|
| Evaporation | 2356.79 | 14.53% |
| Overflow to Downstrm. | 13,866.45 | 85.47% |
| Total Losses | 16,223.23 | 100.00% |

**Table 50 Summary of Annual Water Losses for Lake James**

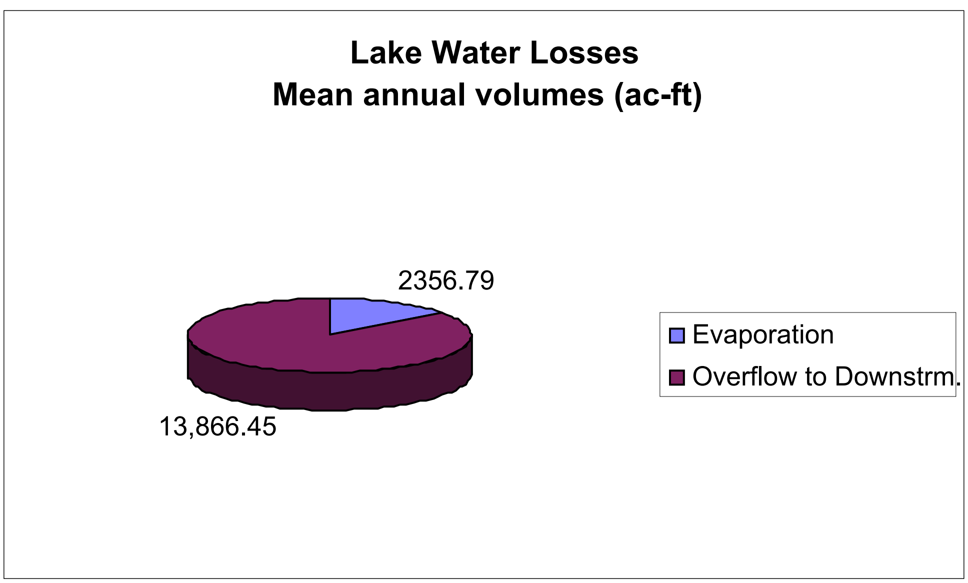



**Figure 95 Summary of annual water losses from Lake James**

| Volume (acre-feet) | Mean Ann. Outflow (ac-ft) | Hydraulic Residence time (years) (volume / mean annual outflow) |
|---|---|---|
| 33,171.22 | 13,866.45 | 2.39 (872 days) |

**Table 51 Hydraulic Residence Time Calculation for Lake James**

## 4.3 Phosphorus Budgets for the Lake James Chain

It is helpful in lake management to estimate mean in-lake phosphorus levels using land-use data for the lake's watershed. Once a prediction is made it can be compared with actual data to indicate the presence of possible nutrient sources or sinks not previously noted in the watershed, but important from a management perspective. For instance if a predicted in-lake phosphorus level is much lower than actual, there may be point sources of nutrients to the lake that have been missed. Similarly a much lower level of phosphorus than predicted may indicate some mechanism of phosphorus removal at work in that waterbody such as the scrubbing activity marl precipitation in a very calcerous lake's water column. Predictions of mean in-lake summertime total phosphorus levels are possible with the use of runoff coefficients established by past experimental direct measurements of phosphorus entering a lake or stream from various land use/land cover. Mathematical models produced by the experimental measurement of phosphorus contributions from various soil types, agricultural cropping and tillage types, etc are also available. Once this "nutrient budget" is established we can use another model based on lake nutrient functioning to predict the mean summertime in-lake total phosphorus levels for that lake based on the nutrient budget. Because modeling of nutrient contributions from the watersheds of all 15 significant upstream lakes and marshes in the watershed was beyond the scope of this report, nutrient contributions from lakes just upstream of the James Chain were estimated using known phosphorous data from those waterbodies and their calculated water budgets. Land-use and land cover data from the immediate watersheds of each of the four James Chain lakes was then added to inputs from the upstream lakes to produce their phosphorus budgets.

### Phosphorus budget for Little Otter Lake

To optimize the efficacy of watershed changes to be undertaken to reduce nutrient and sediment loading it is helpful to estimate phosphorus inputs to the lake from various sources. Mathematical models were used to estimate phosphorus contributions to Little Otter Lake utilizing existing demographic, land-use, soil, and water budget data. Calculation of the components of the phosphorus budget is outlined below.

**•Estimated Phosphorus Loading from Lakeside Septic Systems**

Annual phosphorus (P) loading for Little Otter Lake from septic systems was estimated using basic demographic information. Estimated annual phosphorus contributions to the lake from septic systems were calculated with the following equation:

Annual P load (kg) = (person-years)(wastewater phos. per person yr)(.59)

Where: •person-years =[(3.5 average occupants per household)(average days at lake per yr)]/365
55 days at the lake per year was used for vacation homes (est. 7), 365 days for year round lake homes (est. 2). Vacation home users were assumed to use their lake property during summer weekends and vacation periods totaling approx.55 days annually. Homes several hundred feet from the lake's edge were excluded as soil nutrient retention is likely to be high with few nutrients reaching the lake.

•wastewater phos. per person year = average mass of phosphorus in wastewater produced per person in one year, 1.48 kg (Reckhow 1980[2])

•.59 allows for 41% retention of phosphorus in the soil (Metcalf etal 1979[3])

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2 mean of reported data pp. 89
3 as reported in Reckhow 1990

Summing the respective calculated annual phosphorus loads for the vacation homes and year-round homes on Little Otter Lake yields an estimated annual phosphorus load of 17.75 kilograms per year.

| Septic Load | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| part-t 73% | residents/per | days per yr | capita days | Cap-years | P. pr cap-yr | Total P | reten. coeff | ann. P. (kg) |
| 12.00 | 3.50 | 55.00 | 2310.00 | 6.33 | 1.48 | 9.37 | 0.59 | 5.53 |
| full time 27% | residents/per | days per yr | capita days | Cap-years | P. pr cap-yr | Total P | reten. coeff | ann. P. (kg) |
| 4.00 | 3.50 | 365.00 | 5110.00 | 14.00 | 1.48 | 20.72 | 0.59 | 12.22 |
| | | | | | | | total load | 17.75 |

**Table 52 Calculation of Estimated Annual Septic Phosphorus Loading to Little Otter Lake**

## Estimated Phosphorus Loading from Watershed Runoff

A large component of lake phosphorus loading in Indiana is typically contained in watershed runoff (non-point source pollution). Much of the phosphorus in rain and snow melt runoff typically enters the aquatic system either attached to soil particles, or dissolved in inflowing waters. In Indiana's watersheds where agriculture, construction, and other sources of erosion are found the soil attached component often represents the bulk of phosphorus introduced. For this reason reduction of soil erosion is often a critical component of watershed management. The use of conservation tillage or "no till" farming has helped greatly in reducing the soil attached component in agricultural areas by leaving crop residues on the soil surface where they inhibit erosion. This can, however, boost the dissolved nutrient runoff component as decomposing crop residues on the soil surface yield dissolved nutrients. For this study, the soil-attached and dissolved phosphorus components of the phosphorus budget were estimated separately, to produce a clearer picture of relative contributions. The soil attached component of the phosphorus budget was calculated using the following equations:

### Sediment Attached Nutrient Load (Reckhow 1990)

$LS_k = 0.001\ Cs_k\ X_k\ SD_k$

Where: $LS_k$ = annual sediment attached nutrient load for area k (kg)

0.001 is a units conversion constant

$Cs_k$ = concentration of nutrient in eroded soil from area k(mg/kg) Calculated from regional data (Mills et al. 1985)(Haith and Tubbs 1981).

$X_k$ = soil loss from area k (tons/ha/year) Calculated using Universal Soil Loss Equation Below (Wischmeier and Smith 1978)

$SD_k$ = sediment delivery ratio (dimensionless) Estimated by Drainage Area (SCS 1983)

**Universal Soil Loss Equation (Wischmeier and Smith 1978)**

$X_k = 1.29 \quad RE \quad K \quad LS \quad C \quad P$

Where: X = Soil Loss (tons/hectare/year)
1.29 is a units conversion constant
RE = rainfall erosivity (MJ-mm/ha-h) Calculated value of runoff & rainfall erosive energy, regional value from Steuben NRCS
K = soil erodibility (dimensionless) Mean of Steuben soil type K values from NRCS (Steuben County Soil Survey 1979)
LS = topographic factor (dimensionless) quantifies land slope and length, values used are mean LS by soil type supplied by Steuben NRCS
C = cover and management factor/ cropping factor, quantifies erosion resistance from plant canopy, crop residues, etc. Steuben county agricultural values from Steuben NRCS. Non-agricultural cover factors from (Wischmeier 1978)
P = supporting practice factor, quantifies effect of protective practices of contouring or terracing, the value of 1 was used in the absence of these.

Wetland filtration of Little Otter Lake's runoff may mediate the soil attached nutrient component of the lakes phosphorus budget. It's likely that some component of soil runoff remains in lakeside wetlands indefinitely, but wetlands sometimes act as a source for nutrients in addition to acting as a sink. Often a component of soil attached and dissolved nutrients entering the wetland in the spring and summer may become incorporated into the tissues of growing plants, or settle in the wetlands attached to calcium carbonate (marl) that precipitates in the wetlands in response to the growth of submersed aquatic plants and algae. However a component of these nutrients will also re-mobilize as plant materials senesce and decompose in the fall and winter releasing phosphorus. This process can be important in changing the timing of nutrient introductions so they have less impact on the lake during the growing season when water quality is more reflective of increased nutrients and also more critical in terms of the lakes biology and recreational value. Because the net effect of this on the lake's annual phosphorus load is difficult to determine, for the purposes of this study the net annual loss of nutrients in watershed ponds or wetlands is assumed to be negligible.

Because field by field analysis is beyond the scope of this report, agricultural fields in the watershed were assumed to be in typical farming practices in the area as provided by the USDA. Specifically in 75% Corn-Beans rotation and 25% Corn-Bean-Wheat crop rotation with Corn being field cultivated/residue incorporated and no-till farming during bean and wheat seasons. Agricultural land in the Little Otter watershed is currently idle so a very small soil loss results.

| Cropping | Square Ft. | Acres | Hectares | Constant | RE | K | LS | C | P | Soil Loss tn/yr |
|---|---|---|---|---|---|---|---|---|---|---|
| C-B | | 0.00 | 0.00 | 1.29 | 140.00 | 0.22 | 0.81 | 0.100 | 1.00 | 0.00 |
| C-B-W | | 0.00 | 0.00 | 1.29 | 140.00 | 0.22 | 0.81 | 0.088 | 1.00 | 0.00 |
| Hay-CRP | 1,930,006 | 44.31 | 17.93 | 1.29 | 140.00 | 0.22 | 0.81 | 0.010 | 1.00 | 5.77 |

**Table 53 Estimated Annual Soil Loss for the Little Otter Watershed**

The equation estimates that 5.77 tons of soil will be transported to the Little Otter Lake from the immediate watershed. This is estimated to result in .44 kilograms of soil attached phosphorus being delivered to Little Otter Lake. Since soil losses from the other land-uses in the Little

Otter Lake watershed are expected to be minimal an equation for estimating dissolved nutrient loading will be applied to those areas. This same equation will also be used to establish an estimated dissolved phosphorus runoff component for agricultural areas. Dissolved Nutrient Loading in the Little Otter Lake watershed was estimated using the following equation:

Dissolved Nutrient Load (Haith and Tubbs 1981)(Mills et al. 1985)

$LD_k = 0.1\ Cd_k\ Q_k\ A_k$

Where: $LD_k$ = The dissolved nutrient load (kg) from each source area k

0.1 is a units conversion contant

$Cd_k$ = average nutrient concentration in runoff from land-use k in mg/l (Reckhow 1990)

$Q_k$ = surface water runoff from area k (cm) Calculated using annual rainfall and land-use runoff coefficients(Dunne et al. 1978 & Chow et al. 1988 as adapted by Reckhow 1990)(Camp et al 1988 as adapted by Reckhow 1990)

$A_k$ = area of k (ha)

| Land Use | sq ft | acres | hectares | constant | Nutrient con. | Ann Prec. cm | Runoff coef | Ann load kg |
|---|---|---|---|---|---|---|---|---|
| Ag, hay/crp | 1,930,006 | 44.31 | 17.93 | 0.10 | 0.15 | 99.09 | 0.10 | 2.67 |
| Ag,C,cb | | 0.00 | 0.00 | 0.10 | 0.26 | 99.09 | 0.15 | 0.00 |
| Ag,B,cb | | 0.00 | 0.00 | 0.10 | 0.80 | 99.09 | 0.15 | 0.00 |
| Ag,C,cbw | | 0.00 | 0.00 | 0.10 | 0.26 | 99.09 | 0.15 | 0.00 |
| Ag,B,cbw | | 0.00 | 0.00 | 0.10 | 0.80 | 99.09 | 0.15 | 0.00 |
| Ag,W,cbw | | 0.00 | 0.00 | 0.10 | 0.80 | 99.09 | 0.15 | 0.00 |
| Wetlands | 3,579,302 | 82.17 | 33.25 | 0.10 | 0.01 | 99.09 | 0.10 | 0.33 |
| | | 0.00 | 0.00 | 0.10 | | | | 0.00 |
| Wooded | 2,050,398 | 47.07 | 19.05 | 0.10 | 0.01 | 99.09 | 0.10 | 0.17 |
| Drain field | 0 | 0.00 | 0.00 | 0.10 | 0.15 | 99.09 | 0.20 | 0.00 |
| Res 5 ac | | 0.00 | 0.00 | 0.10 | 0.38 | 99.09 | 0.08 | 0.00 |
| Res 1/2 ac | 1,303,003 | 29.91 | 12.11 | 0.10 | 0.38 | 99.09 | 0.22 | 10.03 |
| Res 1/4 ac | | 0.00 | 0.00 | 0.10 | 0.38 | 99.09 | 0.26 | 0.00 |
| | | 0.00 | 0.00 | 0.10 | | | | 0.00 |
| Com 36% | 2,474,493 | 56.81 | 22.99 | 0.10 | 0.20 | 99.09 | 0.36 | 16.40 |
| Com 90% | | 0.00 | 0.00 | 0.10 | 0.20 | 99.09 | 0.86 | 0.00 |

**Table 54 Calculation of Dissolved Phosphorus from Little Otter Watershed Land Uses**

The model estimates the annual delivery of 29.6 kilograms of dissolved phosphorus to Little Otter Lake from combined watershed runoff. This is a relatively small nutrient load for a watershed of this size. The relatively large amount of wetlands in the watershed and lack of significant acreage in agricultural production helps limit soil-attached and dissolved contributions. The largest source in terms of dissolved phosphorus is commercial areas with approximately 36 percent impervious areas (pavement).

## Estimated Phosphorus Loading from Atmospheric Sources

Direct atmospheric loading of phosphorus to a lake's surface occurs both from the deposit of dry windborne dusts, and rain scavenged particulates and soluble gases. Seasonal variability is high with peak deposits typically occurring during spring and fall agricultural fertilization and tillage. (Andren et al., 1977) Atmospheric deposits to Little Otter Lake were estimated by applying the experimentally determined atmospheric deposition data for another Midwest watershed to the Little Otter watershed area.

| Atmospheric Watrsh acre | Watrsh hec | P per hec kg | Total load |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 260.27 | 104.11 | 0.125 | 13.01 |

**Table 55 Calculation of atmospheric phosphorus deposit to Little Otter Lake**

Using an atmospheric total phosphorus input rate of .125 kg/ha/yr (Burwell et al 1975[4]) for the 260 acres of land in Little Otter Lake's immediate watershed produced an annual atmospheric loading figure of approximately 13 kilograms. Atmospheric phosphorus can be limited by utilizing agricultural, construction, and road maintenance practices that minimize wind erosion and the suspension of dusts.

## Estimated Phosphorus Loading from Marsh Lake

Phosphorus loading to Little Otter Lake from Marsh Lake and its watershed was calculated using the measured mean in-lake total phosphorus levels from IDEM water quality data and the annual outflow figure calculated as part of the Marsh Lake water budget.

| avg con. ppm | acre ft outpt | cubic ft outp | Ann load kg |
|---|---|---|---|
| 0.027 | 3933.78 | 171,355,456.80 | 131.03 |

**Table 56 Calculation of Phosphorus Contributions from Marsh Lake**

The calculation estimates that an annual loading of 131 kilograms of phosphorus from Marsh Lake will occur. The Estimated Little Otter Lake Phosphorus budget components are summarized as follows:

All Watershed Loads

| Source | Annual Phos. Load (kg) | Annual Phos. Load % |
|---|---|---|
| Lakeside Septic Systems | 17.75 | 9% |
| Dis. P Runoff Agri/idle | 2.67 | 1% |
| Atmospheric P | 13.01 | 7% |
| Soil Attach P Runoff Ag. | 0.44 | 0% |
| Dis. P Runoff Residential | 10.03 | 5% |
| Dis. P Runoff Commercial | 16.40 | 9% |
| Dis. P Runoff Wetlands | 0.33 | 0% |
| Dis. P Runoff Woodlands | 0.17 | 0% |
| Loading from Marsh Lk | 131.03 | 68% |
| | | 0% |
| | | 0% |
| Total | 191.83 | 100% |

**Table 57 Little Otter Lake's Annual Phosphorus Budget**

[4] as reported in Reckhow 1980

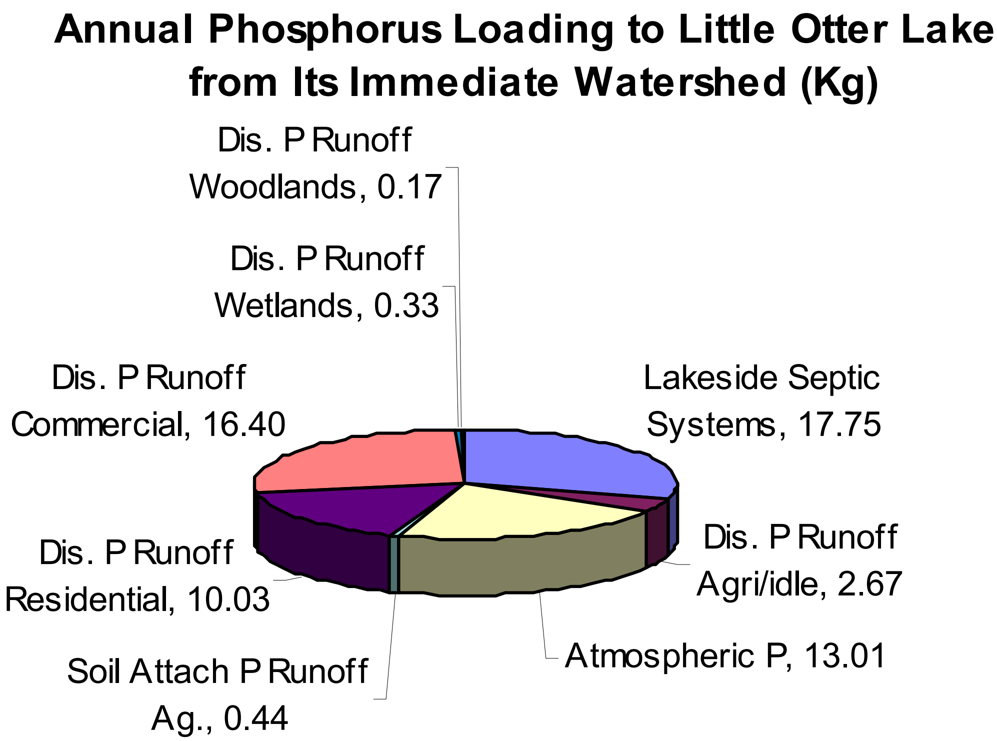



**Figure 96 Phosphorus Budget Pie Chart for Little Otter Lake**

The estimates indicate that the majority of Little Otter Lake's annual phosphorus load (68%) is contributed by inflows from Marsh Lake. The second largest contribution is shared by runoff from commercial lands (9%) and lakeside septic systems (9%). The estimates indicate that the water quality of Marsh Lake has a large affect on Little Otter Lake. It's also notable that connection of homes on Little Otter Lake to a wastewater treatment facility outside the watershed could eliminate nine percent of the phosphorus load.

Repeating the above calculations for the other Lakes in the James Chain Using septic loading figures from before the connection of Lake James and Snow Lake residents to the new Steuben Lakes Regional Waste District wastewater treatment facility produces the following annual phosphorus budget figures:

Big Otter Lake

| **Source** | Annual Phos. Load (kg) | Annual Phos. Load % |
|---|---|---|
| Lakeside Septic Systems | 60.29 | 14% |
| Dis. P Runoff Agri/idle | 133.61 | 30% |
| Atmospheric P | 72.70 | 16% |
| Soil Attach P Runoff Ag. | 38.42 | 9% |
| Dis. P Runoff Residential | 46.38 | 10% |
| Dis. P Runoff Commercial | 92.21 | 21% |
| Dis. P Runoff Wetlands | 1.21 | 0% |
| Dis. P Runoff Woodlands | 0.70 | 0% |
| Total | 445.52 | 100% |

**Table 58 Big Otter Lake's Phosphorus Budget**

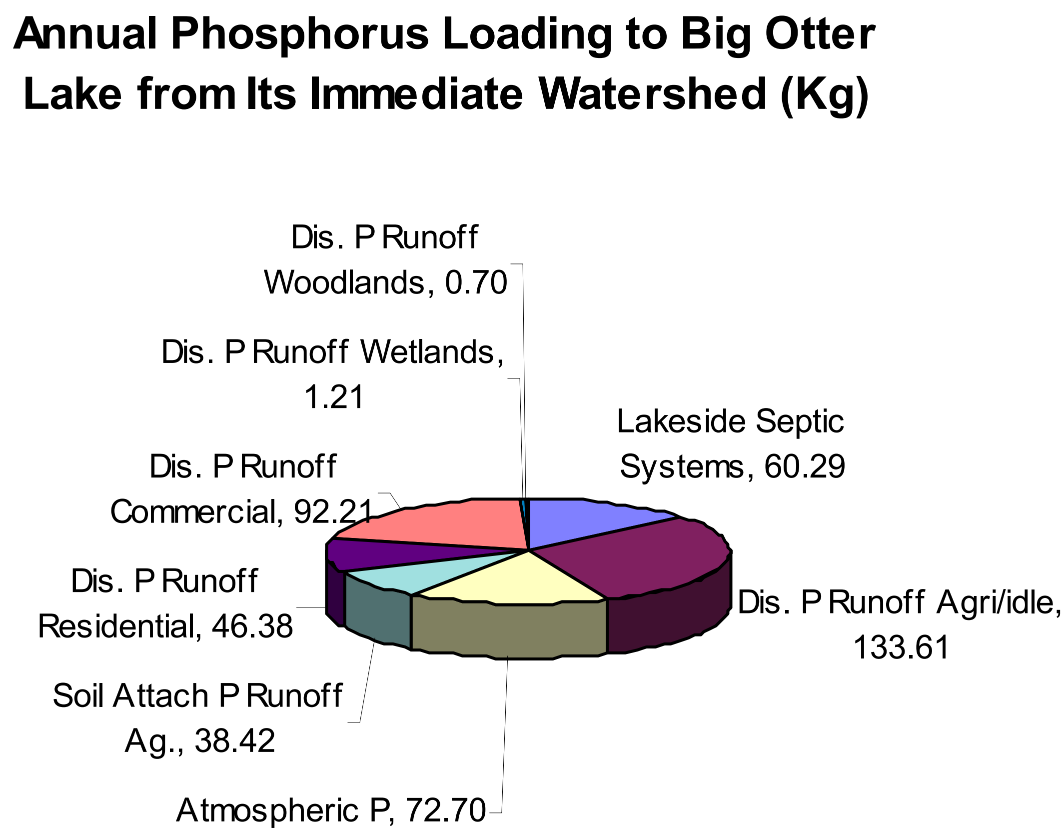



**Figure 97 Phosphorus Budget Pie Chart for Big Otter Lake**

Snow Lake

| Source | Annual Phos. Load (kg) | Annual Phos. Load % |
|---|---|---|
| Lakeside Septic Systems | 90.43 | 13% |
| Dis. P Runoff Agri/idle | 23.69 | 3% |
| Atmospheric P | 74.66 | 10% |
| Soil Attach P Runoff Ag. | 5.60 | 1% |
| Dis. P Runoff Residential | 139.70 | 19% |
| Dis. P Runoff Commercial | 6.70 | 1% |
| Dis. P Runoff Wetlands | 1.32 | 0% |
| Dis. P Runoff Woodlands | 1.77 | 0% |
| Lk George | 166.95 | 23% |
| Big Otter Lk | 209.60 | 29% |
| | | 0% |
| Total | 720.42 | 100% |

**Table 59 Snow Lake's Phosphorus Budget**

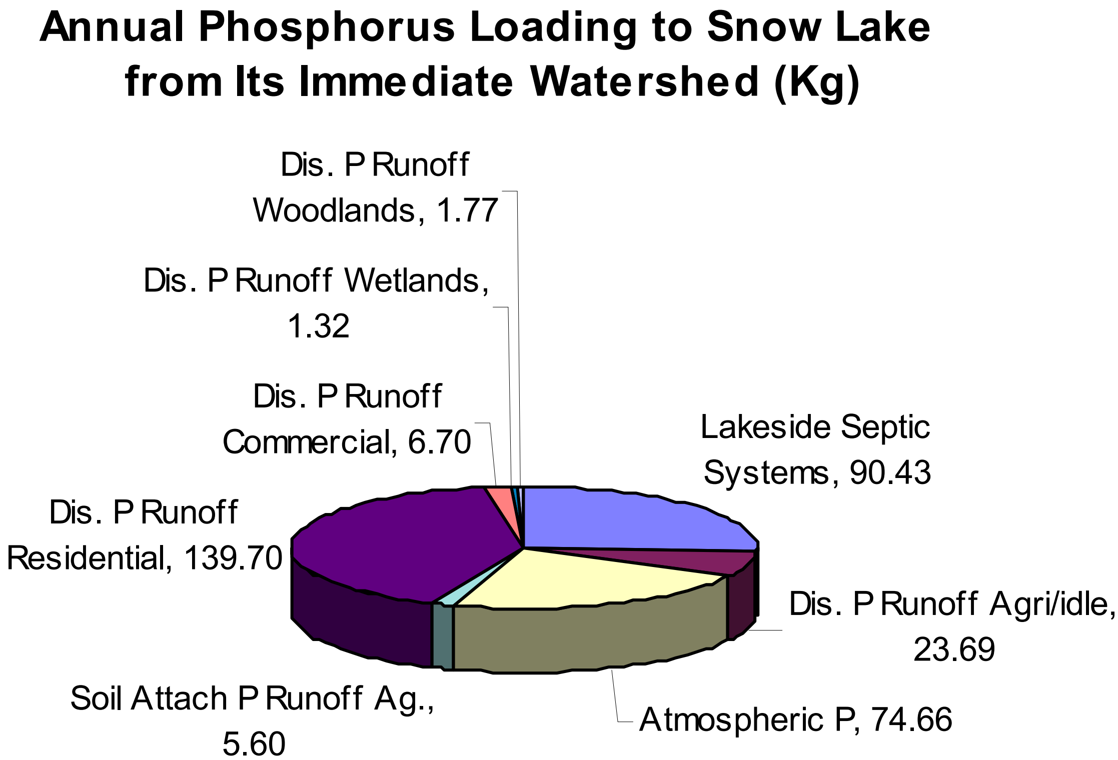



**Figure 98 Phosphorus Budget Pie Chart for Snow Lake**

Lake James

| Source | Annual Phos. Load (kg) | Annual Phos. Load % |
|---|---|---|
| Lakeside Septic Systems | 541.83 | 36% |
| Dis. P Runoff Agri/idle | 51.41 | 3% |
| Atmospheric P | 157.98 | 11% |
| Soil Attach P Runoff Ag. | 13.42 | 1% |
| Dis. P Runoff Residential | 217.49 | 15% |
| Dis. P Runoff Commercial | 134.45 | 9% |
| Dis. P Runoff Wetlands | 1.53 | 0% |
| Dis. P Runoff Woodlands | 3.94 | 0% |
| Snow Lake | 166.95 | 11% |
| Lk Charles E. | 209.60 | 14% |
| | | 0% |
| Total | 1498.60 | 100% |

**Table 60 Annual Phosphorus Budget for Lake James**

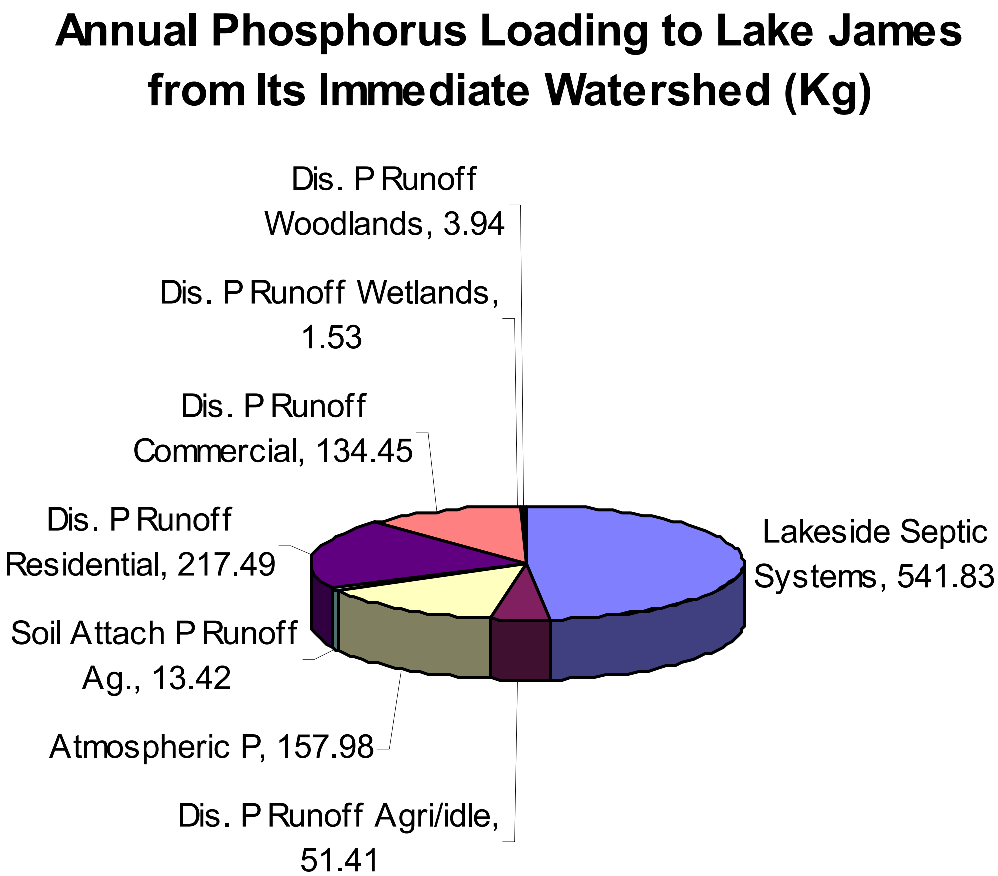



**Figure 99 Phosphorus Budget Pie Chart for Lake James**

**Predicted Phosphorus Concentration for Little Otter Lake**
Utilizing the estimated annual phosphorus loading, and other limnological data, a prediction of long-term average in-lake phosphorus levels can be made. (Vollenweider 1975) defined the following relationship:

$$P = \frac{Lp}{10 + z\rho}$$

Where: **P** =mean summertime in-lake concentration of total phosphorus (mg/L)
**Lp** = areal phosphorus loading (g/m$^2$ lake area per year)
**10** is a constant
**z** = mean depth
ρ = hydraulic flushing rate or dilution rate = 1/hydraulic residence time in yrs.

| Total ann P loading (kg) | Lake Area (sq. M) | areal loading (g/sq-m) | Mean Depth | Dilution Rate | Predicted Phos. (mg/l) |
|---|---|---|---|---|---|
| 191.83 | 123,914.85 | 1.55 | 0.16 | 6.25 | 0.031 |

**Table 61 Calculation of Predicted in-lake Phosphorus for Litte Otter Lake**

The model predicts a phosphorus concentration of .031 milligrams per liter for Little Otter Lake.

Repeating the above for the other lakes produces the following table.

| Lake | Predicted In-Lake Total Phosphorus prior to 2005 (PPM) | Predicted In-Lake T.P. after connection to new SLRWD plant (PPM) | Measured T.P. in 2005 (PPM) |
|---|---|---|---|
| Little Otter | .031 | .031 | .60 |
| Big Otter | .032 | .032 | 2.07 |
| Snow | .024 | .022 | .13 |
| James | .022 | .013 | .08 |

**Table 62 Predicted In-Lake Phosphorus levels for the Lake James Chain**

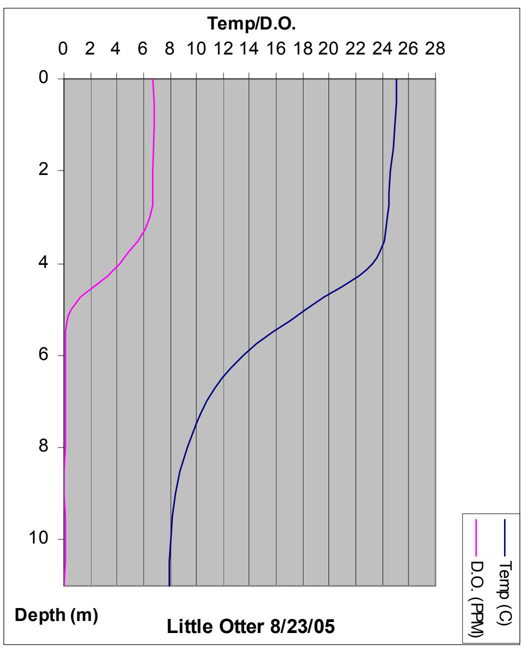
Note the decreased Predicted Phosphorus levels with the input data adjusted for the connection of Lakeside homes to the new wastewater treatment plant. Snow Lake and Lake James are both likely to benefit with the decrease being greatest in James where a large number of homes were connected. Measured phosphorus levels in 2005 were much higher than predicted. The source of the these nutrients is unknown. Internal loading could have been occurring releasing nutrients for the lakes' own sediments. Loading from resuspension of sediments from shallow water during high boat-traffic period could also be a factor. The model estimates that the effluent from the Pokagon treatment plant could potentially raise the total phosphorus level in Snow Lake .001 ppm and Lake James .0005 ppm if all the effluent phosphorus was to enter the lake. Some retention in the wetlands on Snow Lake is likely. Investigating this retention will be a recommendation of this report.

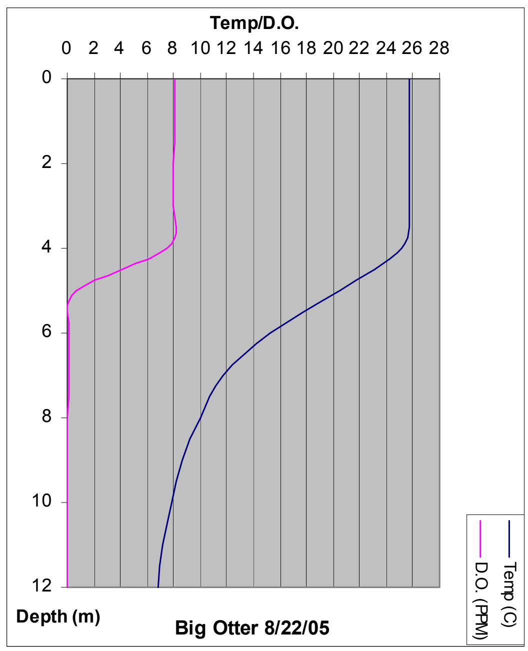
## 4.4 Lake Sampling in 2005

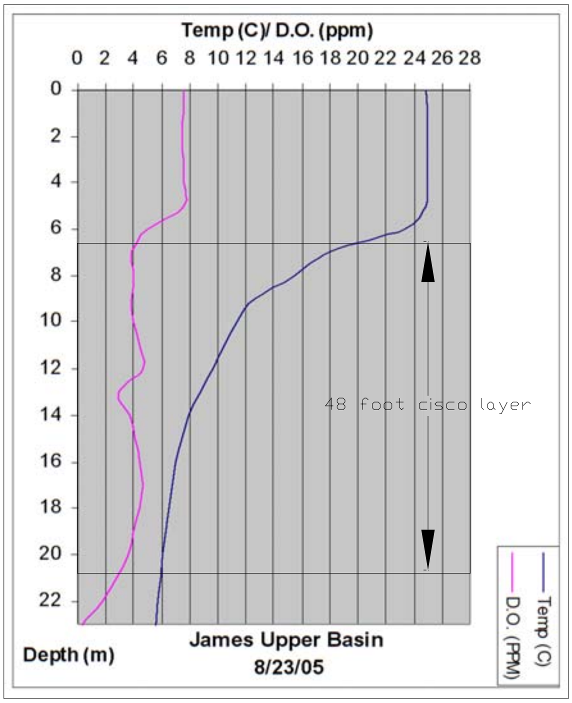
| Parameter/Date | E-coli, | Total Phos. | Dissolve d Phos. | Ortho phos. | Ammon. | Nitrate+ Nitrite | TKN | Chloro phyll a | Secchi |
|---|---|---|---|---|---|---|---|---|---|
| units | CFU/100ml | pm | ppm | ppm | ppm | ppm | ppm | ppb | ft |
| James Upper Basin Epilimnion | 16 | .092 | .036 | < .007 | .01 | .2 | 1.04 | 2.1 | 14.8 |
| James Upper Basin Hypolimnion | <1 | .077 | .11 | .055 | .58 | <.2 | 1.48 | | |
| Snow Epilimnion | <1 | .079 | nd | .007 | <.01 | <.01 | .96 | 4.1 | 9.9 |
| Snow Hypolimnion | <1 | .176 | .181 | .084 | .80 | <.2 | 1.6 | | |
| Big Otter Epilimnion 8/24 | <1 | .36 | <.007 | <.007 | .03 | <.01 | 1.12 | <.1 | 7.7 |
| Big Otter Hypolimnion 8/24 | <1 | 3.78 | .39 | .268 | 1.55 | <.01 | <.01 | | |
| Little Otter Epilimnion | <1 | .078 | .051 | .067 | .01 | <.2 | 1.12 | 3.6 | 12.2 |
| Little Otter Hypolimnion | 1 | 1.112 | .735 | .679 | 3.13 | <.2 | 4.16 | | |

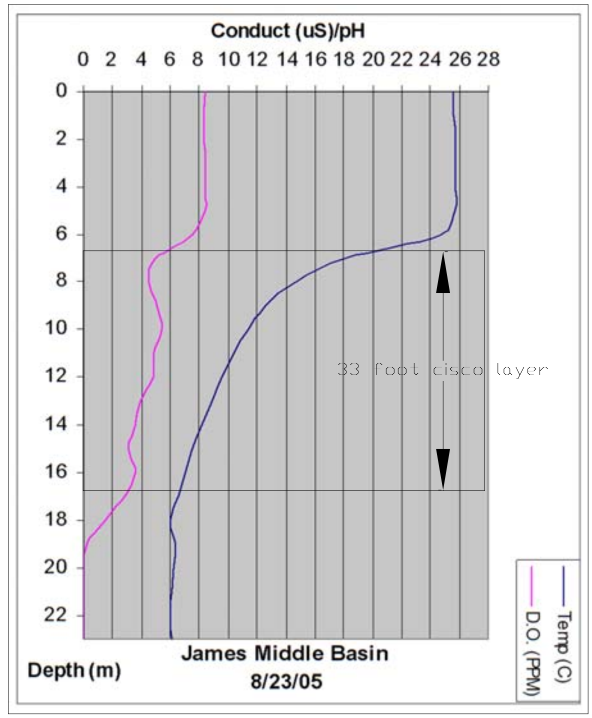
**Table 63 8/23/05 Sampling Data from the Lake James Chain Basins**

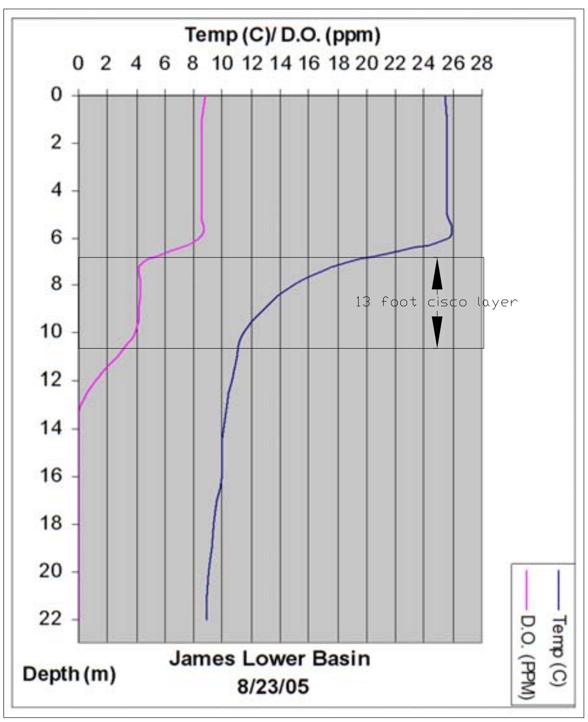
Samples were collected from the epilimnion (surface) and hypolimnion of each Lake on August 23 and 24 of 2005. E-coli measurements were normal. For water to meet the EPA recreation standards, the geometric mean of 5 samples over a 30-day period is required to be less than 125 CFU/100 mL, with no sample testing higher than 235 CFU/100 mL. (Purdue University Website www.ecn.purdue.edu ) With 16 CFU/100ml (colony forming units per 100 ml) being the highest measurement the lake waters would easily pass this standard at the sites sampled. All phosphorus measurements were unusually high. In lakes like those in the James Chain generally considered "mesotrophic" or exhibiting characteristics of moderate phosphorus enrichment, Total Phosphorus concentrations tend to average .027 ppm with the typical range being .011ppm to .096ppm (Vollenweider 1979). The lakes in the James Chain were near or above the upper end of this scale in 2005. The total phosphorus concentrations for Lake James were below the .102 average for 57 Steuben County Lakes sampled in 1992.(IDEM 1996) Snow Lakes total phosphorus was just above the average and Big and Little Otter were both well above the average. Orthophosphorus, the form most readily available to spur the algae growth that causes poor water clarity was considerably lower in concentration than total phosphorus in Lake James and Snow Lake surface waters. In most natural waters the ionic orthophosphate levels are typically less than 5% of the total phosphorus level (Tarapchak, et al., 1982 as reported in, Wetzel 1983). Good water clarity seemed to indicate this in these basins as well. Apparently the majority of phosphorus present was not bioavailable and therefore had little impact on water clarity. In terms of the orthophosphorus concentration Little Otter Lake was the exception however, with the measurement indicating that 85% of the total phosphorus was present as orthophosphorus. Orthophosphorus concentrations on Lake James and Snow Lake were below a .058 ppm mean for 57 Steuben County lakes (IDEM 1996) while levels in Big and Little Otter Lakes were well above that mean. Temperature and oxygen profiles taken on Lake James showed the presence of coldwater fish habitat in all three basins and Kreilbaum Lake. Oxygen levels were relatively good in deeper water. With the 2005 data having been collected in late August, this indicates that coldwater fish habitat was likely present for the duration of the season. Big Otter, Little Otter, and Snow had little oxygen present below the thermocline and had no coldwater fishery habitat. Ammonia concentrations in Lake James and Snow Lake (averages for the hypolimnion and eplimnion) were well below the .604 ppm average for 57 Steuben County Lakes, while again Big and Little Otter ran well above the mean. All four lakes were well below the 57 Steuben County lake mean of 1.233 for Nitrate/Nitrite levels. Conductivity and pH profiles were normal on all basins. pH measurements fell between 8.4 and 7.4. The (pH) range of a majority of open lakes is between six and nine.(Wetzel 1983) Calcareous hard-water lakes commonly are buffered strongly at pH values above 8. (Wetzel 1983) The lakes of the James Chain like many Northeast Indiana lakes are very well buffered by their relatively hard waters and will often show a pH above 8 in their surface waters.

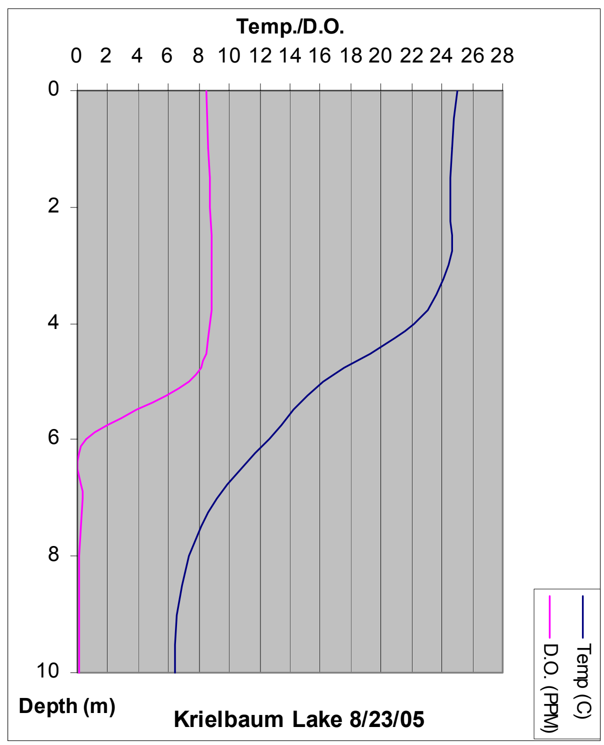


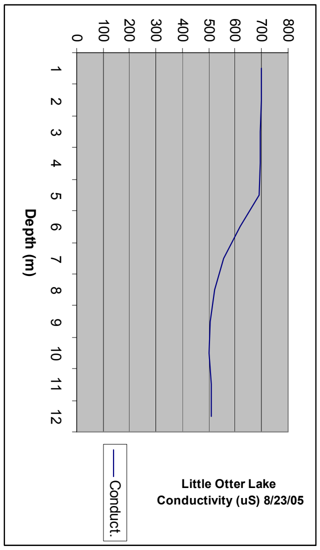



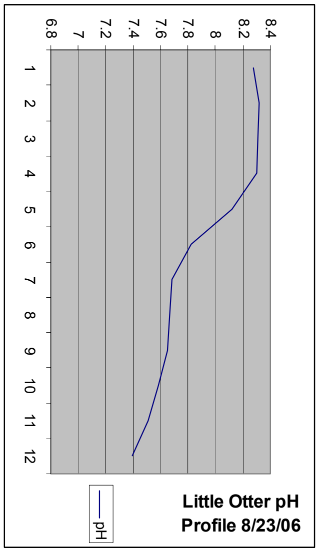

Temp (C)/ D.O. (ppm)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 2 4 6 8 10 12 14 16 18 20 22
48 foot cisco layer
Depth (m)
James Upper Basin
8/23/05
Temp (C)
D.O. (PPM)

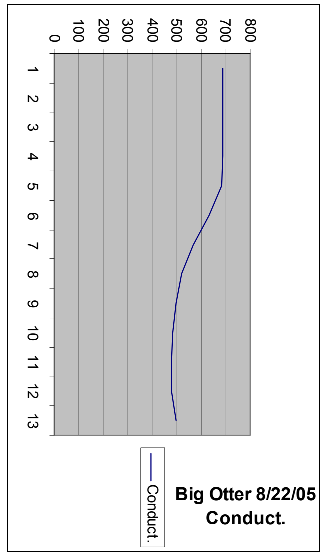

Conduct (uS)/pH
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 2 4 6 8 10 12 14 16 18 20 22
33 foot cisco layer
Depth (m)
James Middle Basin
8/23/05
Temp (C)
D.O. (PPM)

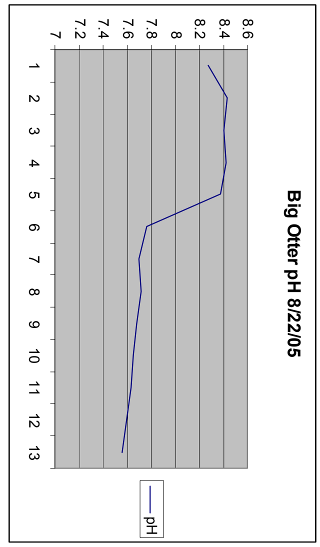

Temp (C)/ D.O. (ppm)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 2 4 6 8 10 12 14 16 18 20 22
13 foot cisco layer
Depth (m)
James Lower Basin
8/23/05
Temp (C)
D.O. (PPM)

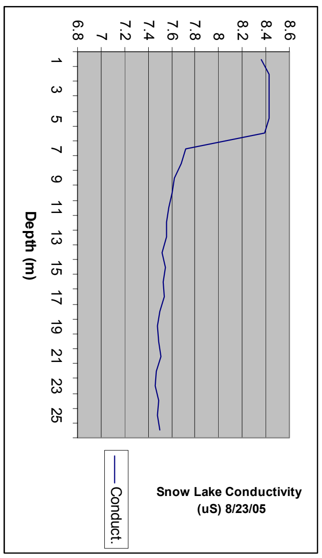

Temp./D.O.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 2 4 6 8 10
Depth (m)
Krielbaum Lake 8/23/05
Temp (C)
D.O. (PPM)

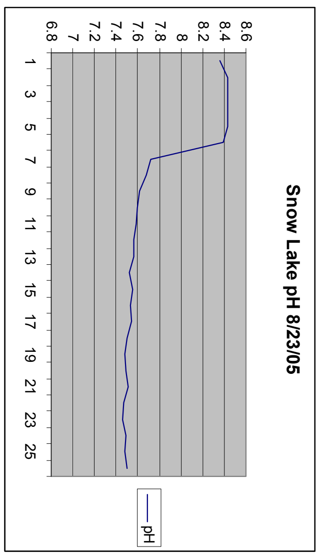

Little Otter Lake Conductivity (uS) 8/23/05
Depth (m)
Conduct.

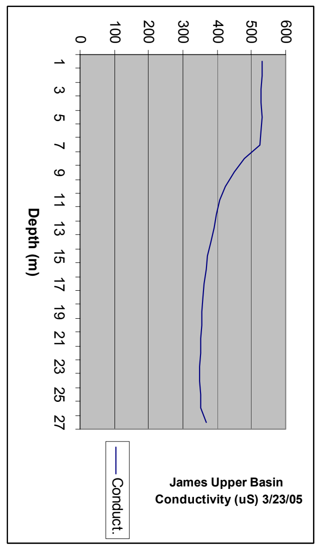

Little Otter pH Profile 8/23/06
pH

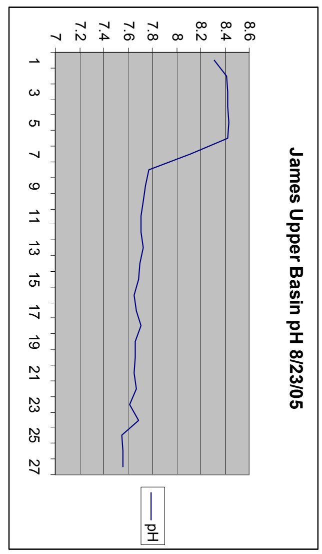

Big Otter 8/22/05 Conduct.
Conduct.

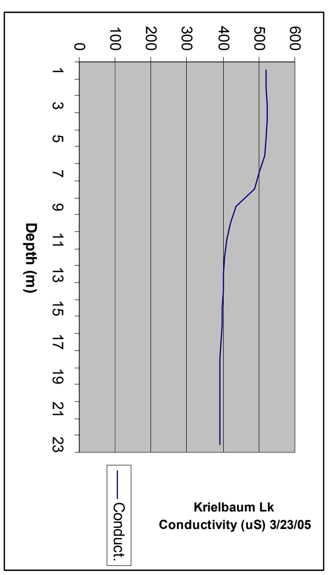

Big Otter pH 8/22/05
pH


Snow Lake Conductivity (uS) 8/23/05
Depth (m)
Conduct.


Snow Lake pH 8/23/05
pH


James Upper Basin Conductivity (uS) 3/23/05
Depth (m)
Conduct.


James Upper Basin pH 8/23/05
pH


Krielbaum Lk Conductivity (uS) 3/23/05
Depth (m)
Conduct.

## 5. The James Chain User Survey

The mailer card below was sent to the databases the three James Chain Associations. 769 respondents returned the cards. Results and discussion are below:

Dear Lake James Chain resident; To better protect the lakes and preserve the value and beauty of the surrounding properties, your lake associations would like to collect some basic information. Please complete this survey form and drop it in the mail. Thank you.

**Please "X" the appropriate boxes below:**

1. I own or occupy property at/with access to ☐ Snow Lake ☐ Lake James ☒ Big Otter Lake ☐ Little Otter Lake ☐ None of the lakes

2. How long have you owned/occupied property at the lake? ☒ 0-5 yrs ☐ 5-10 yrs ☐ 10-15 yrs ☐ 15-20 yrs ☐ more than 20 yrs

3. Which do you enjoy most often. (please mark only one) ☐ Fishing ☐ Fast Boating (above 10mph) ☒ Low speed boating/cruising ☐ Ski/tube/wakeboarding ☐ kayaking/canoeing ☐ sailing ☐ Personal Watercraft (jet skiis etc.) ☐ Swimming ☐ Other____________________

4. If you or your neighbors have fished/netted for or caught Cisco on the lake chain in the past, on which lake(s)____________________
Approximately what year or time period did you see the last cisco taken on those lakes?____________________

5. If you fish, what species do you seek most often ?
☒ I don't fish ☐ Bluegill/Redear ☐ Black Crappie ☐ LM/SM Bass ☐ Walleye ☐ Perch ☐ Northern Pike ☐ Other____________________

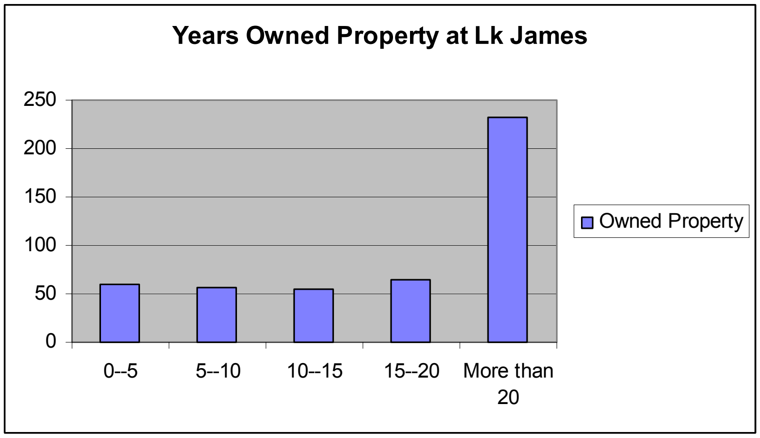
6. How would you rate the water quality/clarity on your lake?
☐ Excellent, ☐ Good, ☒ Fair, ☐ Poor

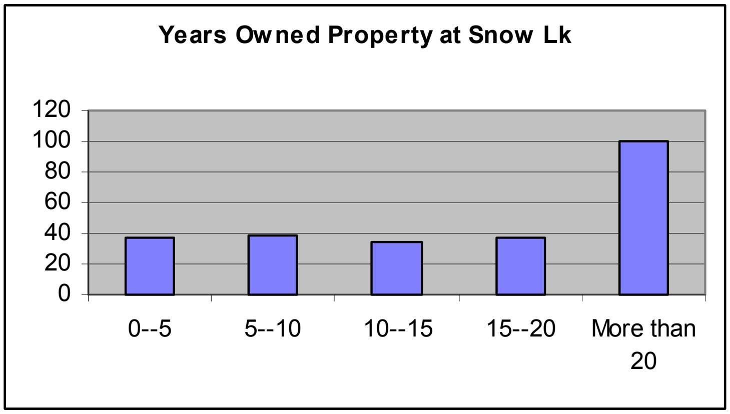
7. Since you have owned/occupied property at the lake has the water quality/clarity
☐ Improved ☒ Worsened ☐ Remained about the same

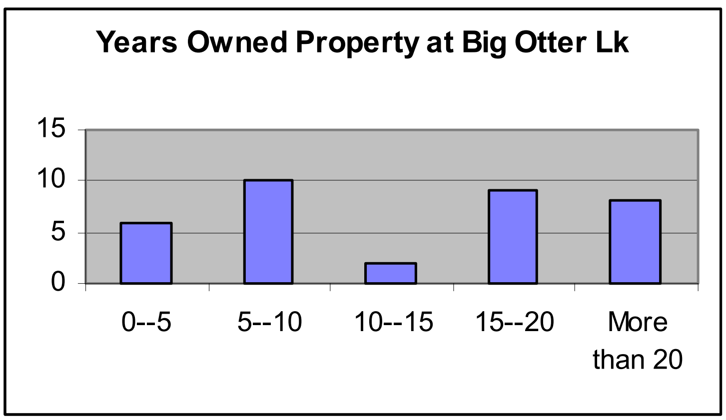
8. How important do you feel it is that your association seeks protection and improvement of water quality? ☒ Very ☐ Somewhat ☐ Not important

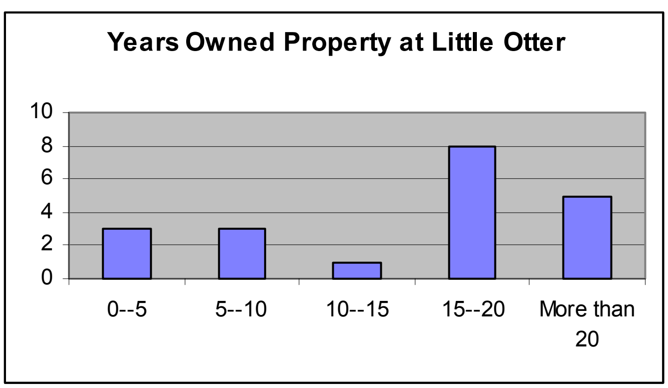
9. Are you a member of your association? Y ☒ N ☐ If not why?
____________________

10. Would you like to see a Sportsman's Club formed on the James Chain to help foster management of fish and wildlife on the lakes? ☒ Yes ☐ No ☐ No opinion

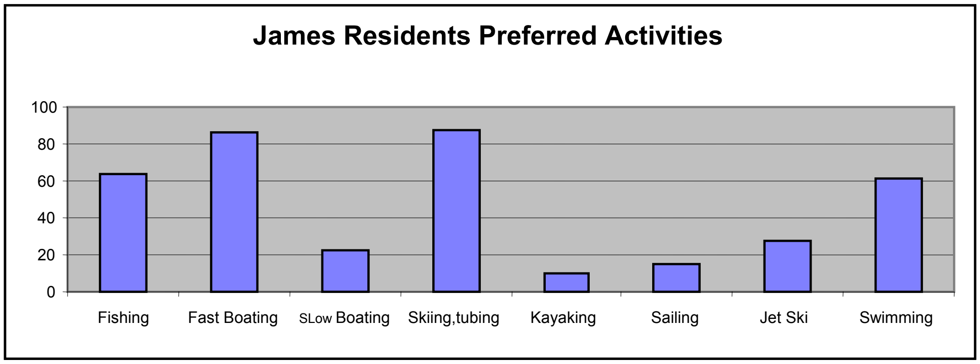

Years Owned Property at Lk James
250
200
150
100
50
0
0--5
5--10
10--15
15--20
More than 20
Owned Property

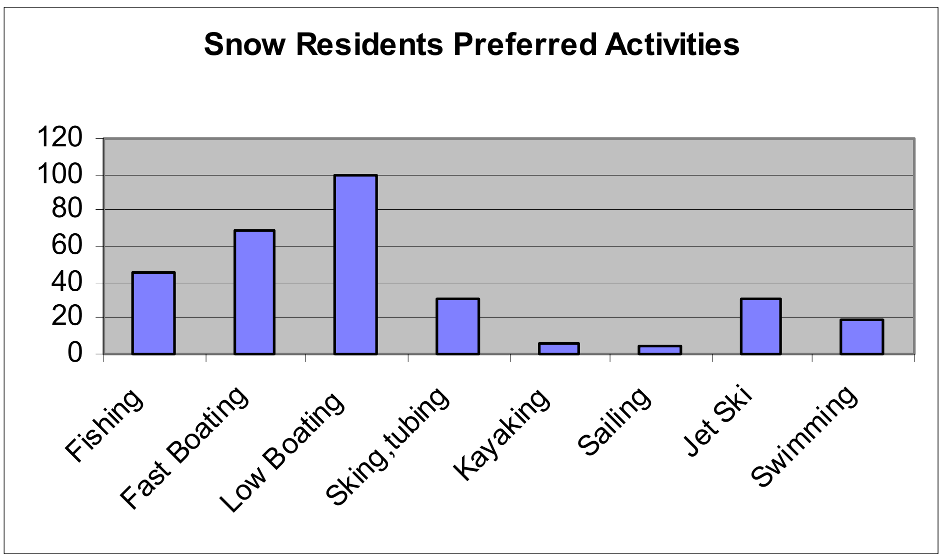

Years Owned Property at Snow Lk
120
100
80
60
40
20
0
0--5
5--10
10--15
15--20
More than 20

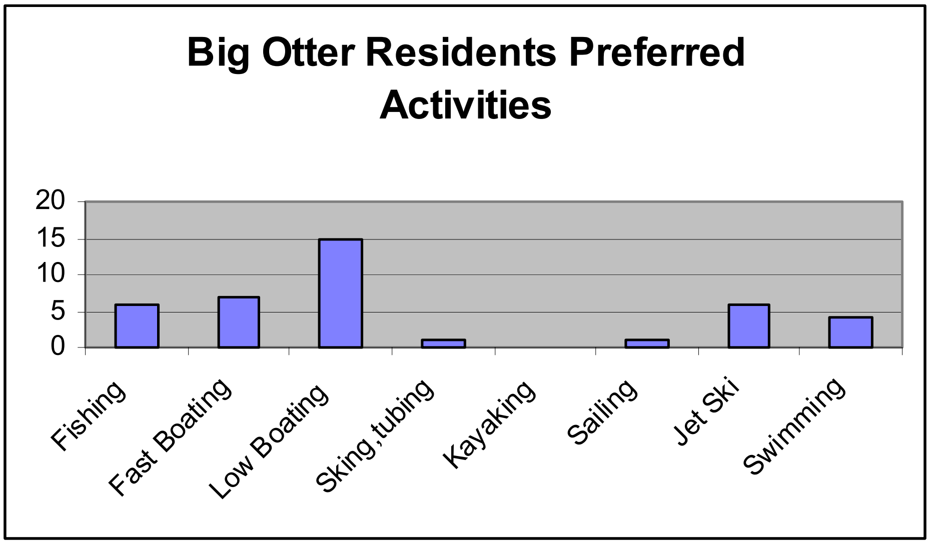

Years Owned Property at Big Otter Lk
15
10
5
0
0--5
5--10
10--15
15--20
More than 20

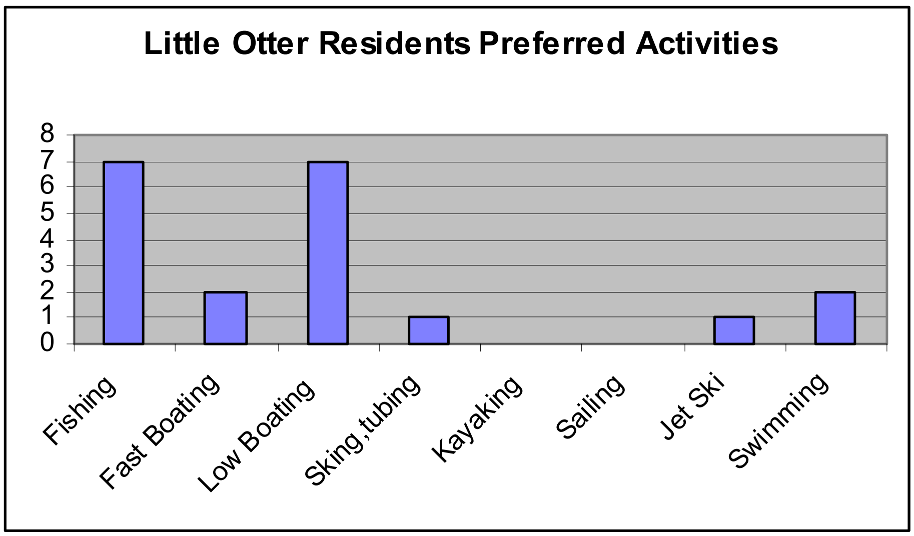

Years Owned Property at Little Otter
10
8
6
4
2
0
0--5
5--10
10--15
15--20
More than 20

Lake James and Snow Lake have a large percentage of long-time residents with 50 percent of James respondents and 41 percent of Snow Lake respondents reporting that they have owned property at the lake for 20 years or more.   At Big and Little Otter Lakes residents were more proportionately distributed in terms of years spent at the lake.

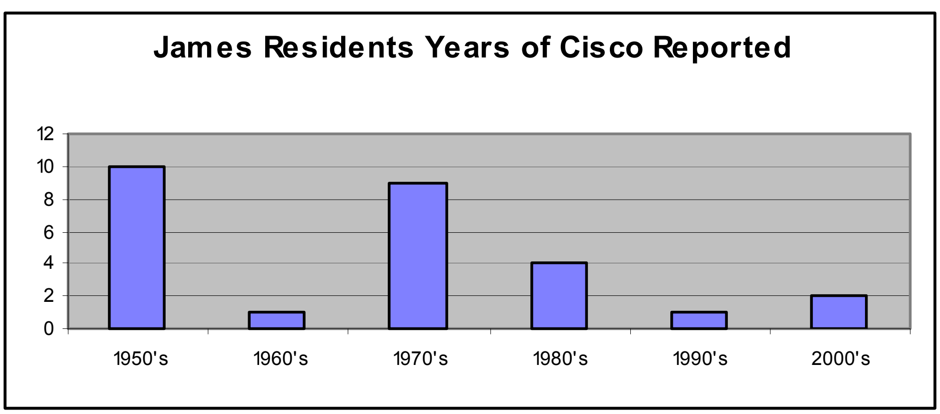


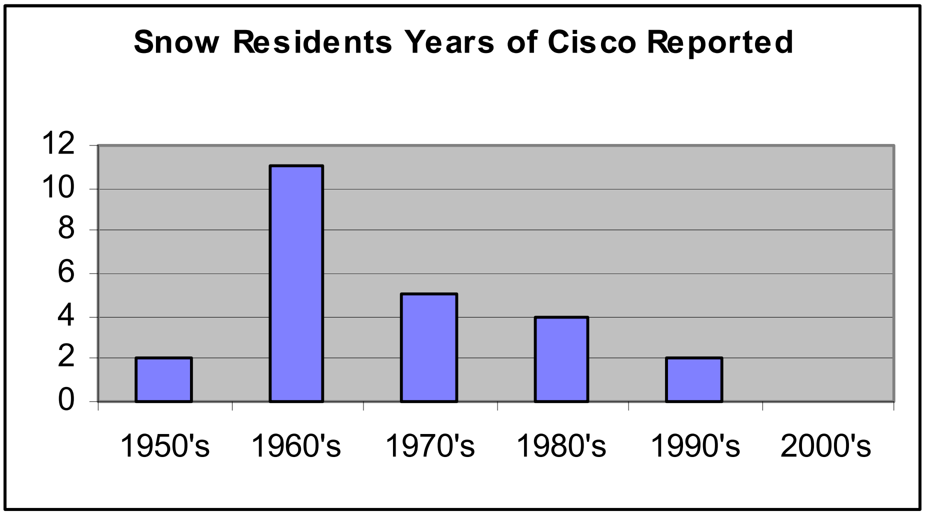



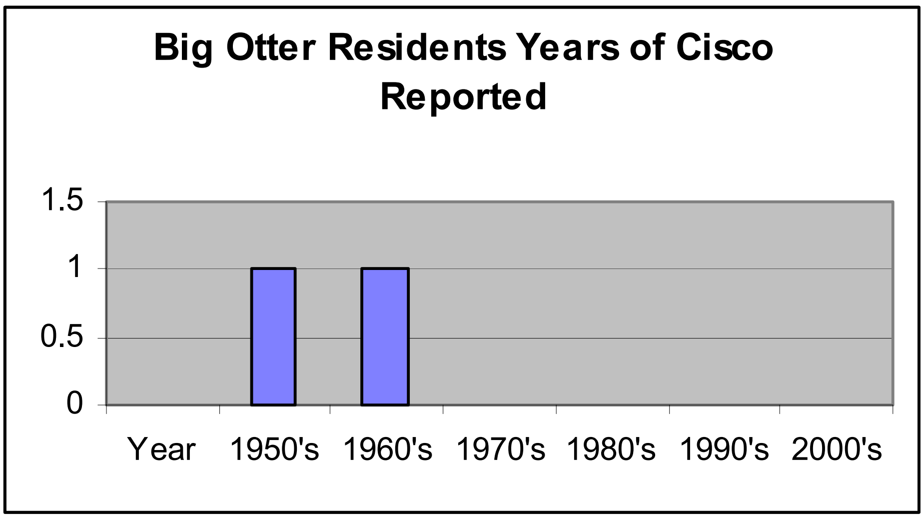


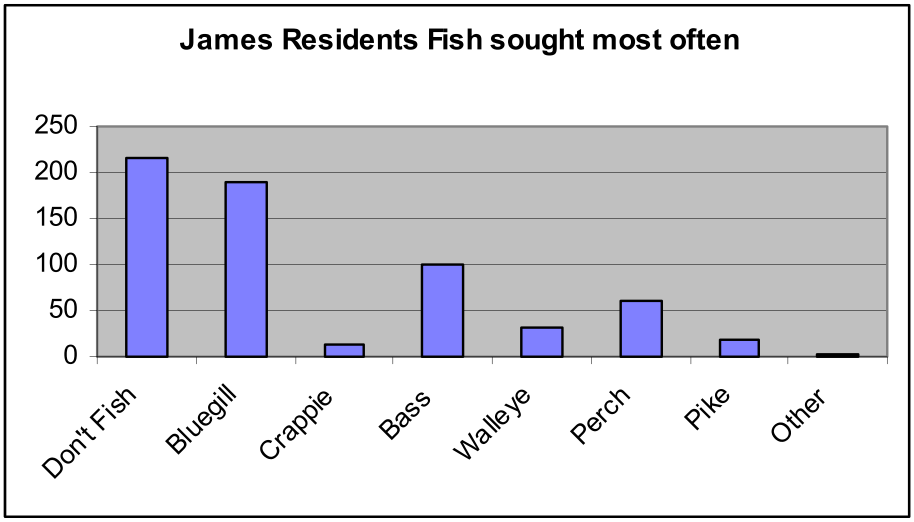

James and Snow residents tended to prefer lake activities that involve the use of watercraft at speed. (fast boating and skiing/tubing) Little Otter and Big Otter residents tended to choose low speed cruising (listed as “low boating” on the bar charts) and fishing higher in importance.

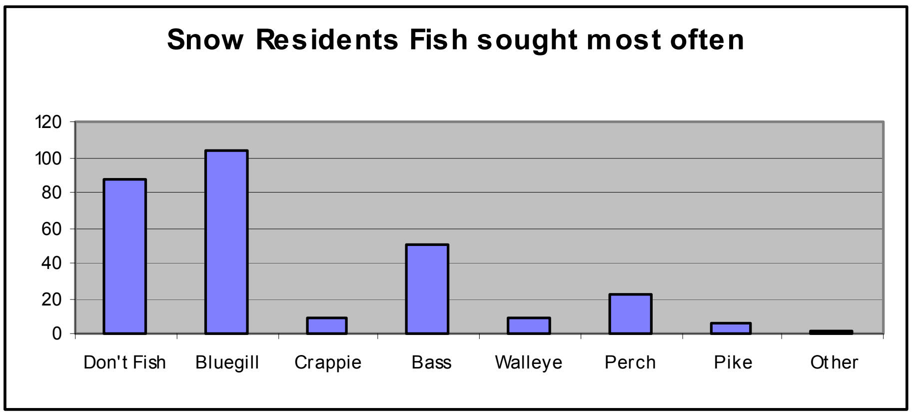


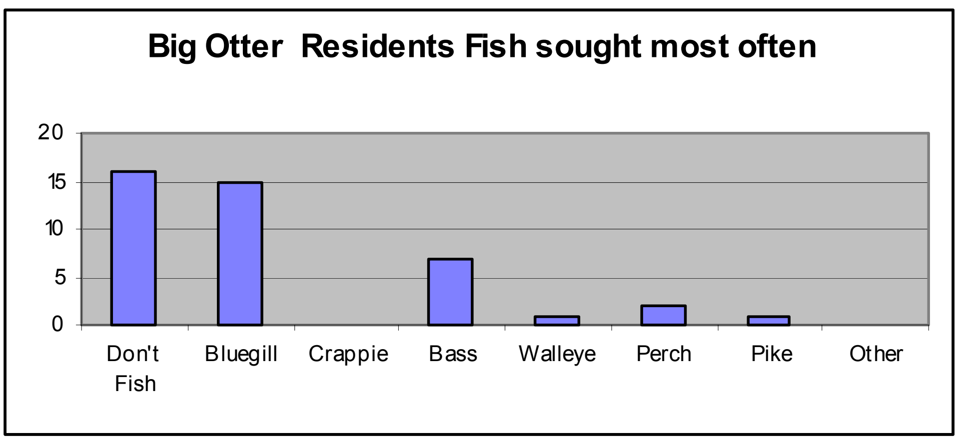


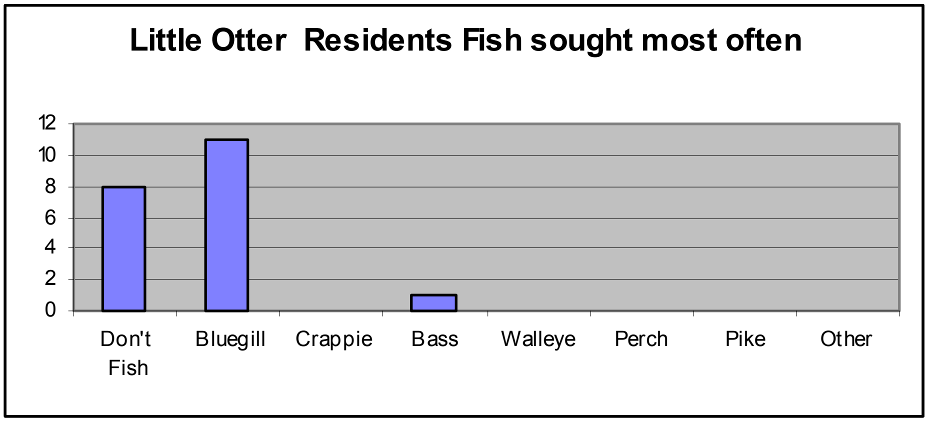




Respondents were asked to report the last approximate date they knew of cisco being caught on the lake chain as a possible additional measure of the timing of their disappearance. Peak reports for Lake James were the 1950's and 1970's at 10 and 11 respondents respectively. Lake James also had reports from the 1980's, 1990's, and 2000's. For Snow Lake reports peaked at 11 for the 1960's declining to five in the 1970's. Four were also received for the 1980's and two for the 1990's from Snow Lake residents. The 1980's and 1990's reports could be the result of remnants from one or more basins in the chain, fish that made the passage from one of the other lakes on the chain that still contain cisco, or misidentification by anglers. One report for the 1950's and one report for the 1960's was recorded for Big Otter Lake.

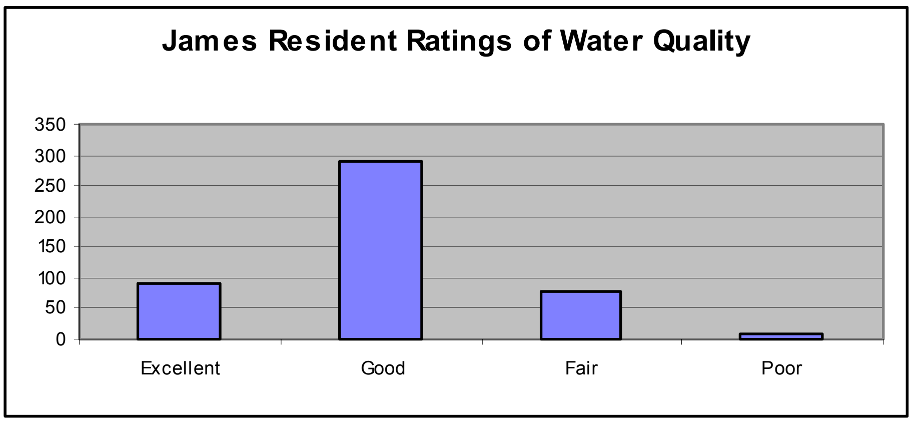

James Residents Fish sought most often
250
200
150
100
50
0
Don't Fish
Bluegill
Crappie
Bass
Walleye
Perch
Pike
Other

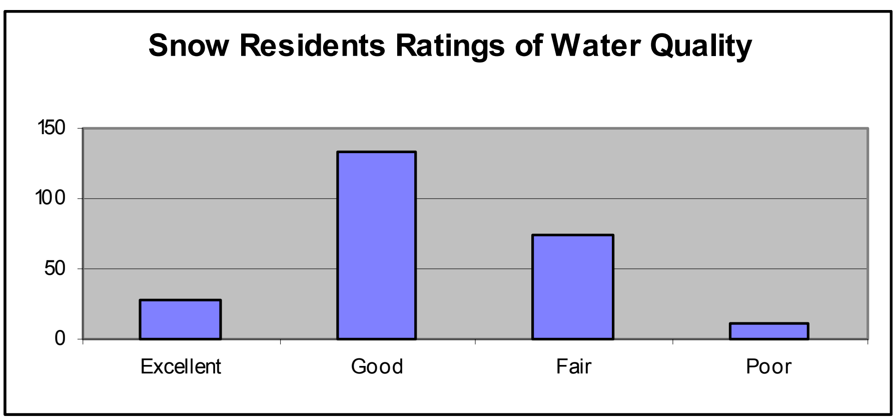

Snow Residents Fish sought most often
120
100
80
60
40
20
0
Don't Fish
Bluegill
Crappie
Bass
Walleye
Perch
Pike
Other

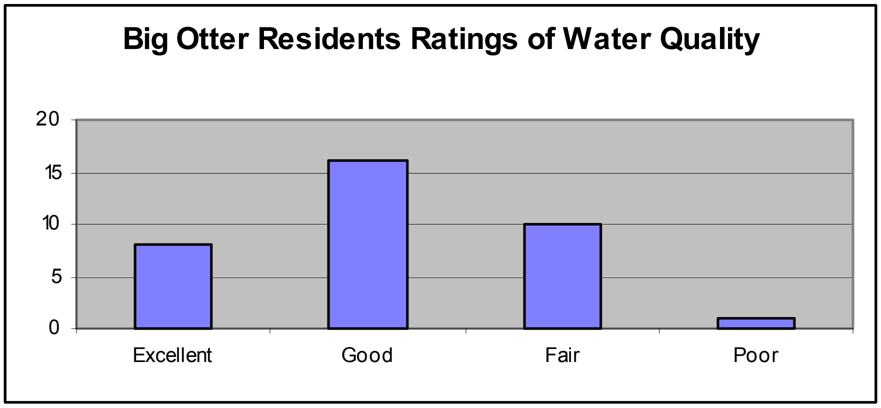

Big Otter Residents Fish sought most often
20
15
10
5
0
Don't Fish
Bluegill
Crappie
Bass
Walleye
Perch
Pike
Other

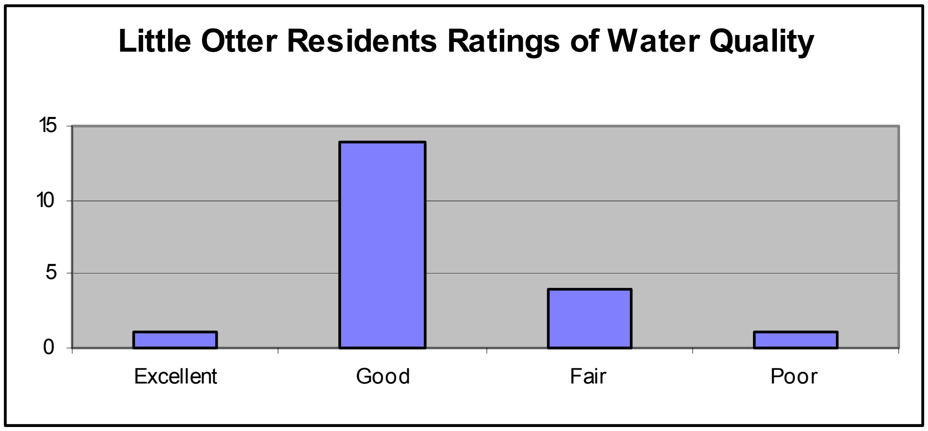



Across all four lakes bluegill ranked first as the fish species sought most often by angling residents. Bass ranked second at each lake. Perch ranked third at James, Snow, and Big Otter. Choices at Snow and James also included walleye, northern pike, and crappie. One respondent from Big Otter chose walleye as the species sought most often and one chose northern pike.

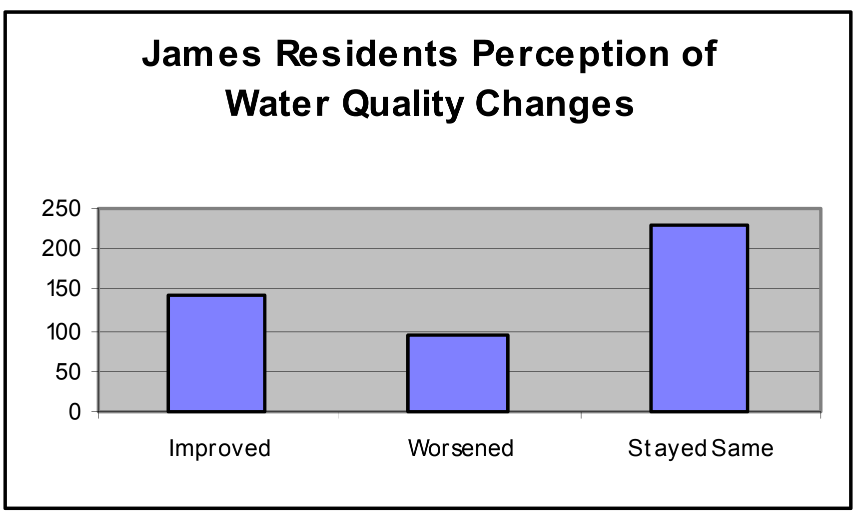


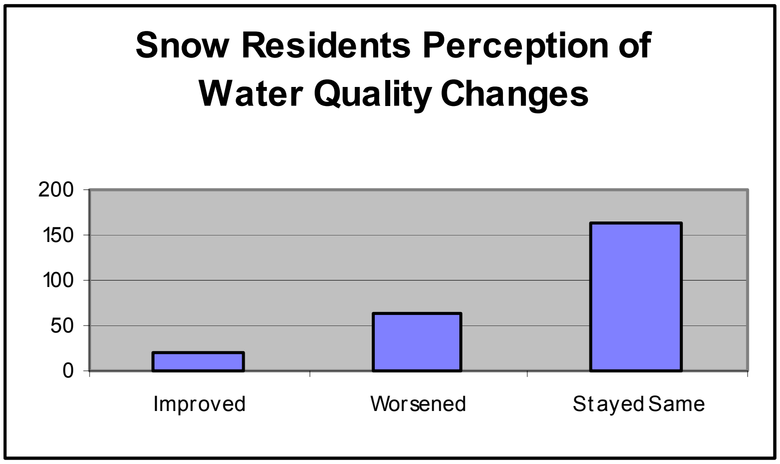



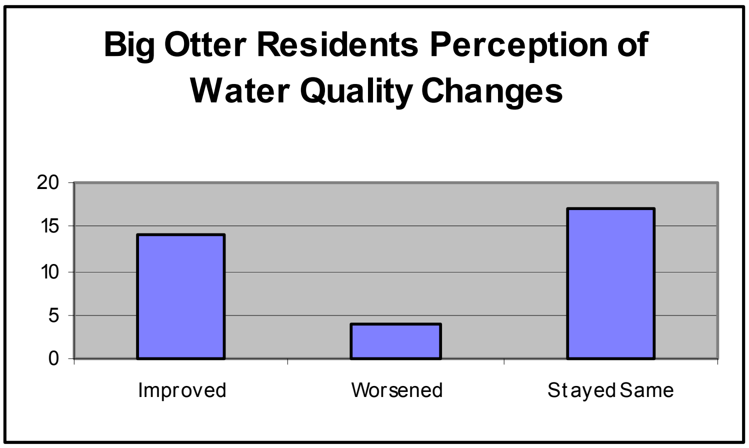


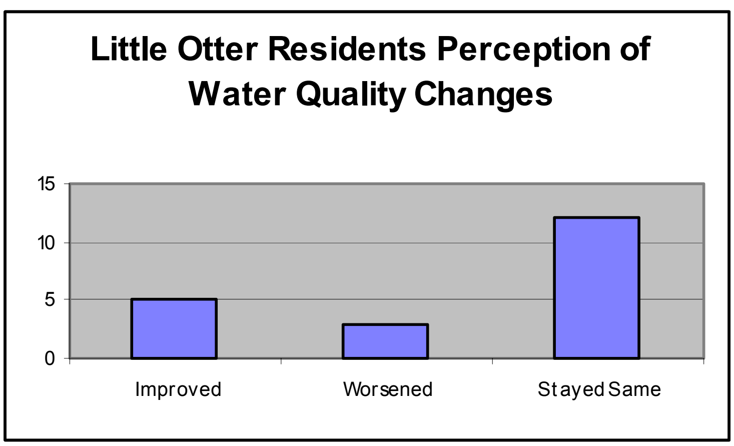




When asked to rate the water quality/clarity with the choices of "excellent, good, fair, poor" at their lake the "good" category was most popular across all four lakes. Perceptions of water quality were similar among the four lakes with very few respondents rating their lake in the "poor" category.



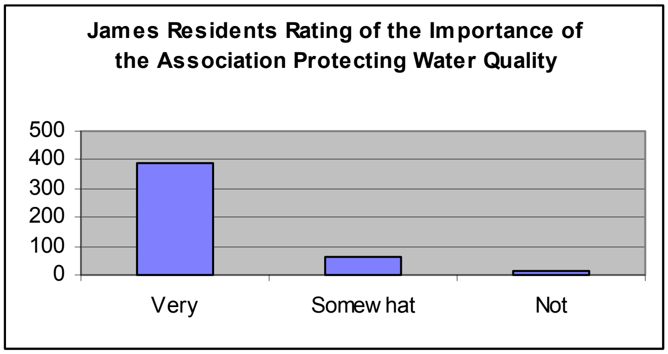


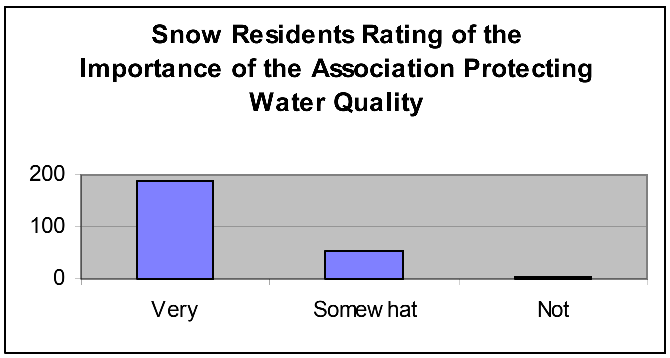



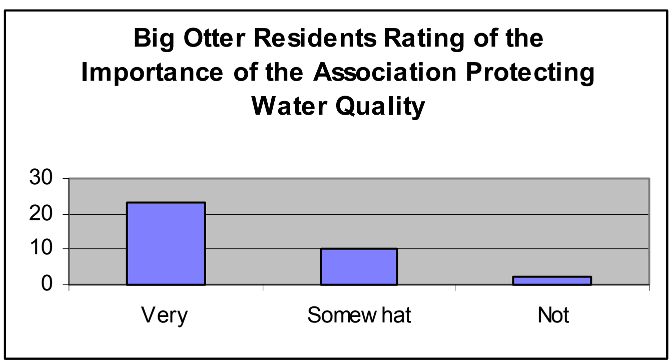



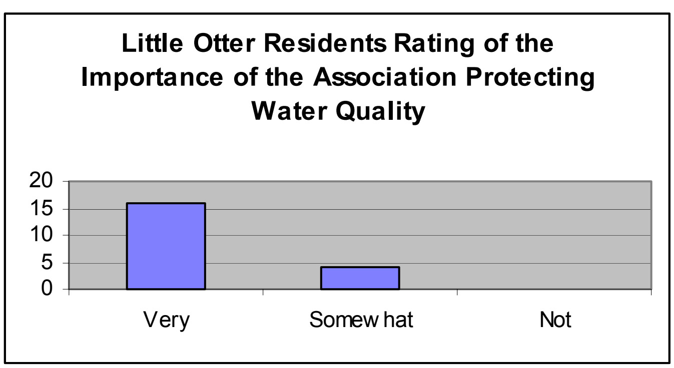

When asked to characterize water quality/clarity changes since acquiring their property 49 percent of James respondents indicated the water quality had stayed the same. Twenty percent indicated it had worsened and 31 percent said it had improved. Most Snow residents also thought water quality had stayed the same (66%). Twenty six percent thought it had worsened, and eight percent indicated an improvement. The "stayed the same" category was also most popular on Big and Little Otter at 49 percent and 60 percent respectively. Forty percent of Big Otter residents indicated an improvement while only 25 percent of Little Otter residents did. Eleven percent of Big Otter residents indicated a change for the worse and 15 percent of Little

Otter residents did also.  James and Big Otter residents stood out as the most likely to have sensed an improvement. This seems to match Secchi data that shows improving water clarity at the Otters. e Snow Lake was characterized by having the smallest proportion of residents indicating improvement.

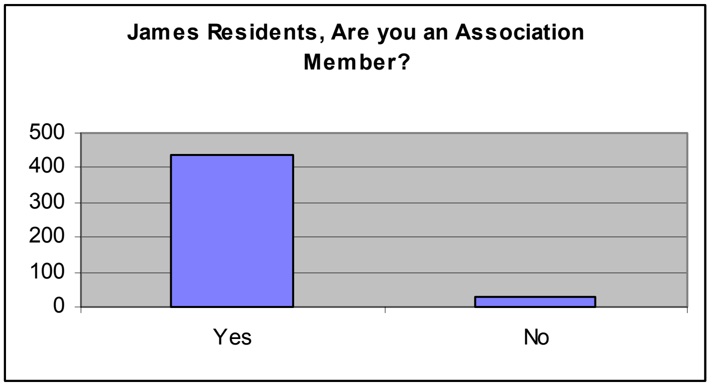


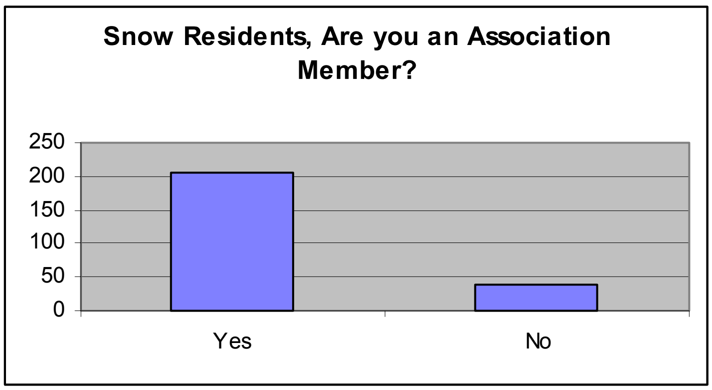



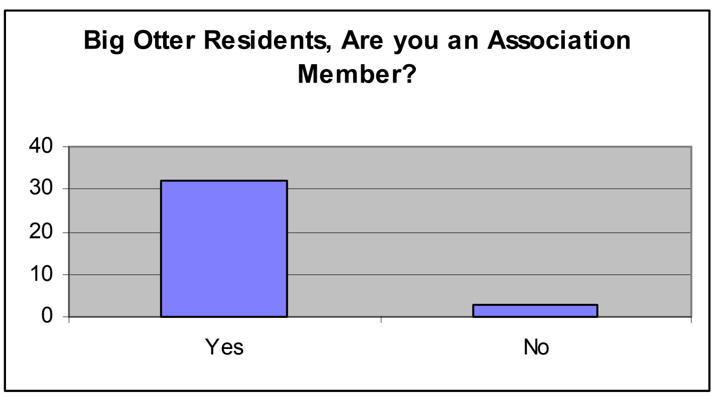



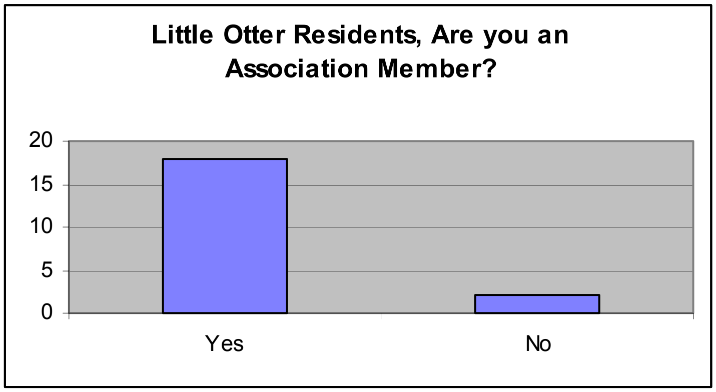



The majority of respondents from all four lakes felt that it was very important for their association to work to protect water quality. Respondents marking the "very important" category were highest at Lake James (84%) and lowest at Big Otter (66%).

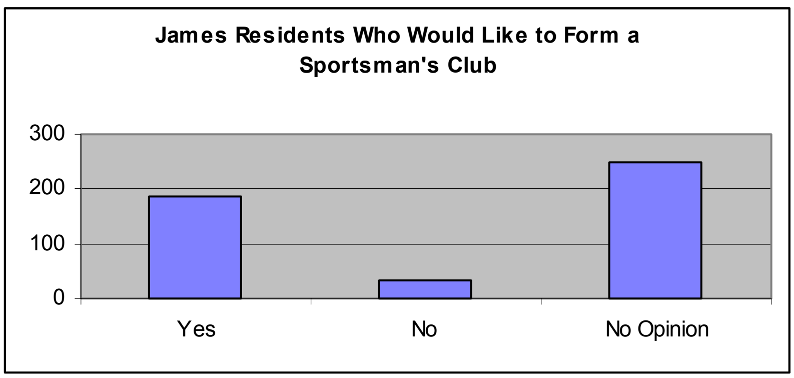


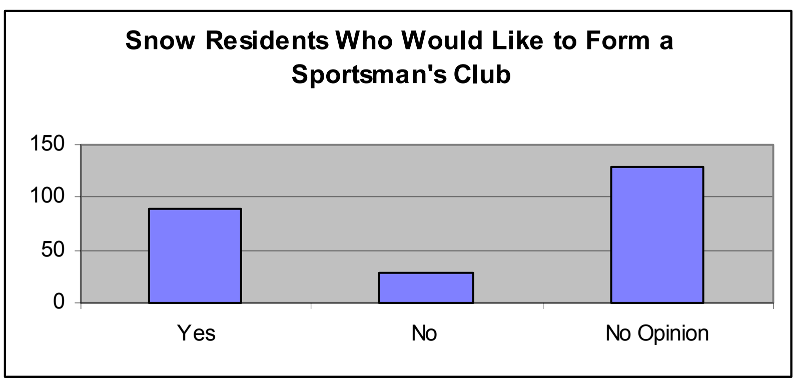



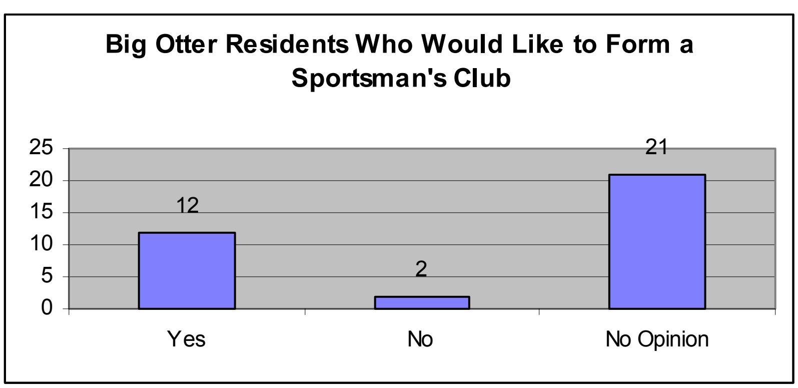



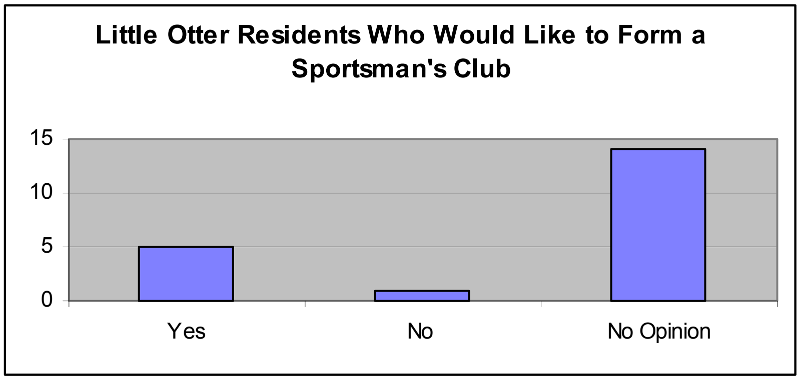



Respondents were largely association members. This can sometimes be overstated if association mailing lists are used to mail the surveys. Future surveys should seek input from non-members and members alike through the construction of a complete mailing list or door to door surveying.






When asked if they would like to see a sportsman's club formed to help foster the management of fish and wildlife on the lakes the highest number of respondents on all four lakes chose "no opinion". Interest was highest on Lake James (40%) second at Snow Lake (36%), third at Big Otter (34%), and lowest at Little Otter (25%).

Overall results seem to indicate that residents of the James Chain do not perceive a profound decline in water quality and perceive their water quality as being good. Residents do however appear to be very concerned about protecting their existing good water quality and managing fish and wildlife resources on the chain. The James Chain Association should take advantage of this sentiment and present options to residents for lending their time and assistance in working toward these goals.

## 6. Boating Use of the James Chain Lakes

Lake Association volunteers were utilized to collect weekend and weekday boating data from the James Chain. Volunteers counted boats at 9:00 a.m., 12:00 p.m. and 3:00 p.m. recording the type of boat and categorizing each craft as anchored, low speed, or high speed. High speed was defined as "making a significant wake". Results are shown below in figures 100 and 101.

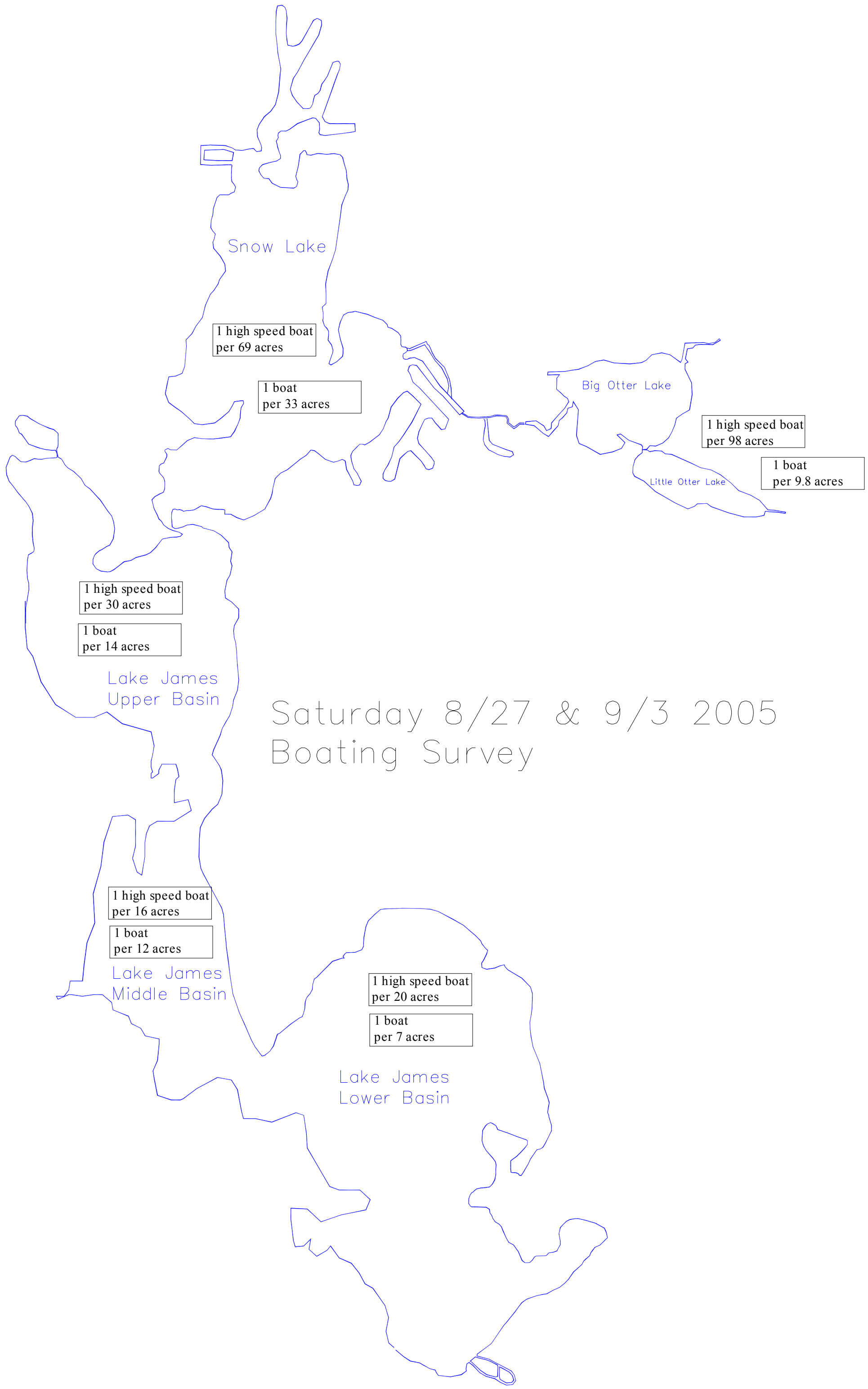



**Figure 100 James Chain Weekend Boating Data 2005**

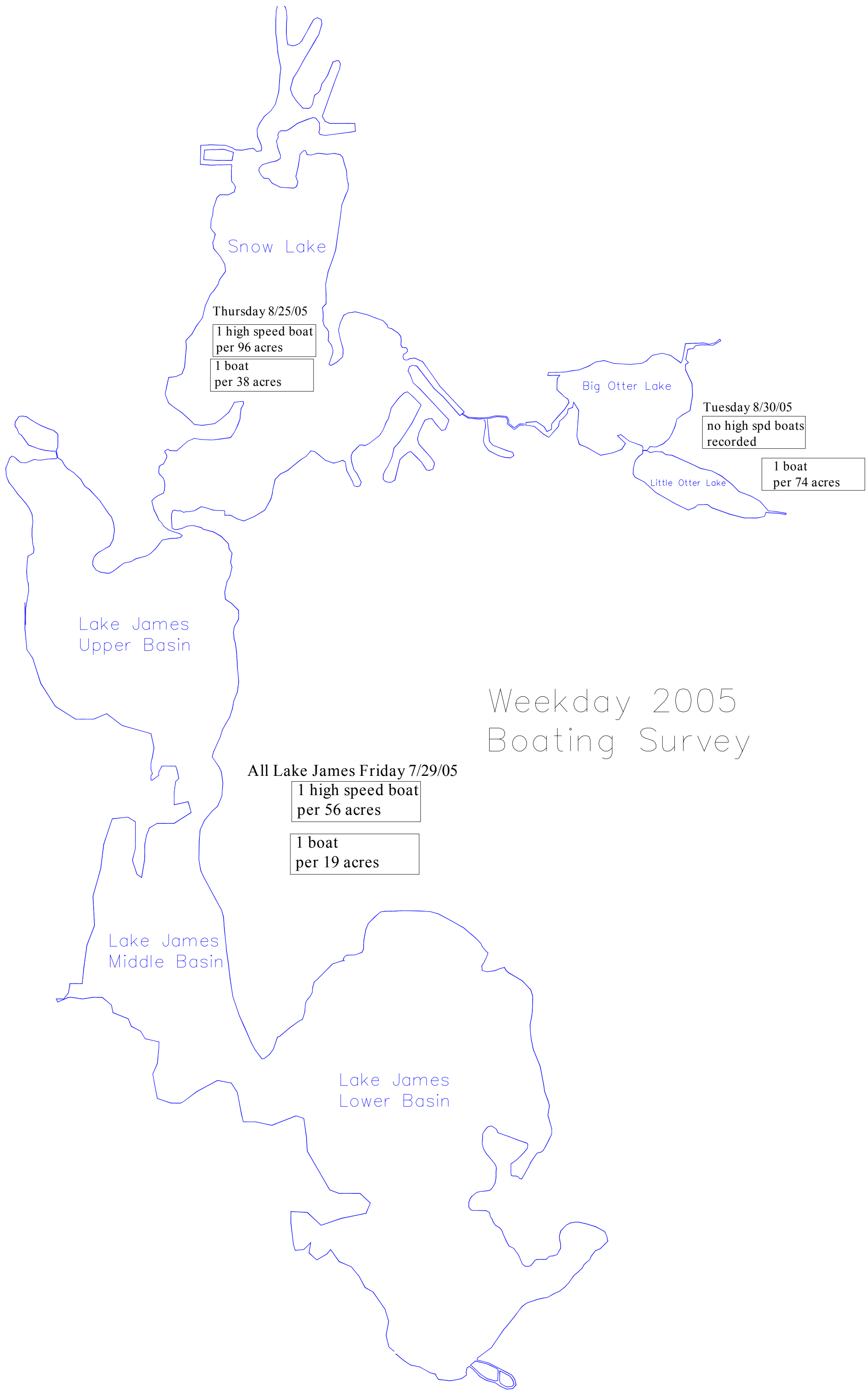



**Figure 101 James Chain Weekday Boating Data 2005**

An *acres of water per high speed boat*, and an *acres per boat* figure was calculated from the data for a weekend day and weekday. Lake James saw the heaviest boat traffic. On Saturday September 3rd (Labor Day weekend) one high speed boat per 20 acres was recorded on James Lower Basin and one boat per seven acres. The Lower Basin acres per boat figure was probably inflated considerably due to a sandbar located at the north end of the basin being the chain's principal gathering place for boaters. James Middle Basin was the most congested in terms of high speed boating with one high speed boat per 16 acres. The Upper Basin had one high speed boat per 30 acres with one boat per 14 acres. Congestion on Snow Lake was much less severe at one high speed boat per 69 acres and one boat per 14 acres. Boaters from the rest of the chain may be gravitating toward Lake James for the promise of more room for high speed cruising when the smaller lakes are actually less congested. Snow Lake is also more broken up by islands than James on an acre by acre basis and has a considerable amount of it's acreage in no-wake channel systems so the acres per high speed boat figure may be slightly affected by parts of Snow Lake being less suitable to high speed travel. Big and Little Otter Lakes were surveyed as one lake for boating use. As expected weekend high speed boating use was lighter on these lakes. Smaller size and a 10 mile-per-hour/no wake law cause high speed boaters to gravitate toward the chains larger basins. One high speed boat per 98 acres was recorded on the weekend for the Otter Lakes. Surface-acres-per-boat was low however, probably reflecting the gravitation of fisherman and cruisers to these calmer waters. One boat per 9.8 acres was recorded on the weekend for the Otter Lakes. The James Chain Associations can utilize this data for comparison with future collected boat traffic data to asses changing trends on the lakes. Few users of the chain would deny that boat traffic can be excessive at times especially on Lake James. Wave energy from boat wakes has biological ramifications for the lake as well. Increased turbidity is quite visible along the chains lakeshore as wakes stir sediments in the shallows. This induces the suspension of sediments that can cloud the water and exchange nutrients with the lake's waters and also discourages the establishment of beneficial aquatic vegetation. Refacing concrete seawalls that typically reflect and amplify wave energy with glacial stone can help alleviate this problem. The passage of boats has widened the chains channels and eroded wetland areas. Strict enforcement of no-wake zones in channels should be practiced to avoid further damaging the chains riparian wetlands. The establishment of evening and morning speed limits has been used successfully at nearby Lake George to relieve boat traffic and provide appeal to a broader number of lake users and could probably provide similar benefits on the Lake James Chain. While the James Chain lake user survey indicated that residents granted high importance to their associations working to protect water quality it also indicated that high speed cruising and skiing/tubing was a high priority for James and Snow residents, so the establishment of speed restrictions is likely to be a contentious issue.

## 7. Recommendations

**-Stabilize eroding areas along the shore of Lake James and in the Croxton Ditch, Walter's Lake Drain, Follet Creek, and Crooked Creek watersheds.** Soil and associated nutrients from erosion is a source of nutrients and sediments to the James Lake Chain. Investigate the possibility of working with landowners and Steuben County drainage officials to modify and stabilize eroding areas. Lake and River Enhancement or other funding sources may be available. Once the input of sediments to the watershed tributaries is reduced the James Chain Associations should consider applying to the Indiana Department of Natural Resources Lake and River Enhancement program for cost share funding to further study and hydraulically dredge impacted areas such as Lagoona Park, the Public access area on Big Otter Lake or the Follet Creek Delta on Little Otter Lake.

**-Investigate the possibility of restoring wetlands in the Croxton Ditch and Walter's Lakes Drain Watersheds.** Areas of previous and current wetlands may be restored or enhanced to provide filtration for watershed runoff once eroding sections of stream are stabilized. An engineering feasibility study can further determine the suitability of these areas for future restoration projects.

**-Stay proactive in preventing the filling and draining of wetlands and insuring the practice of proper erosion control techniques on disturbed lands within the watershed.** Correspond with regulatory agencies to see that existing regulations are enforced. Soil runoff from construction sites can provide a source of nutrients to the James Lake Chain or degrade watershed wetlands and decrease their function with regard to water quality.

**-Preserve existing waterbodies, wetlands, and other beneficial land uses in the watershed.** Some owners of private wetlands or woodlands may be interested in preserving their property through conservation easements, deed restrictions, or other methods. Work with the Steuben County Lakes Council, or other local land trusts to secure watershed wetlands and woodlands and prevent future filling, draining and development of these areas. Work with upstream owners of constructed ponds and marshes to help maintain and manage these areas to provide a beneficial filtering effect for lake-bound tributary waters.

**-Control the Spread of non-native wetland and aquatic plants that can degrade the ecology of the lakes and function of beneficial wetland areas in the watershed.** With the limited extent of the current colonization by invasive Phragmites the James Chain Associations may be able to effectively prevent the spread of this plant throughout the watershed. Preventing the spread of Purple Loosestrife to unaffected wetlands in the watershed may also be possible by controlling plants in selected areas by cutting, pulling, or spraying. Areas that are already severely colonized may enjoy some success with biocontrols. With the exception of limited channel and shoreline areas the James Chain does not currently have a significant problem with non-native invasive submersed aquatic plants. However, potentially invasive plants such as Eurasian watermilfoil can eventually pose a problem if they become more prevalent in the lakes' plant communities. Snow Lake already has an established plant management plan through the Lake and River Enhancement Program. Establishment of an Aquatic Plant Management plan through the Lake and River Enhancement program on the other three lakes in the chain and periodic updates to keep track of plant community changes can help detect and control future problems. Examination of the lake's aquatic plant communities on a five year interval should be sufficient.

**-Network with other Lake Associations and Lake Property Owners in the watershed about protecting and improving water quality.** The James Chain Associations need to keep in mind that they are part of a larger watershed and water quality in the James Chain is dependent on the quality of inflowing water it receives from upstream.

**-Investigate the possibility of conducting a monitoring study to determine the impact of major wastewater effluents on the lakes.** Connection of many lakeside residences to the Steuben Lakes Regional Waste District treatment facility may have a noticeable affect on water quality. A monitoring program to determine the impact of treatment effluents still present in the watershed can help clarify the implications of these facilities for water quality. This can be a further step in limiting nutrient input to the lake chain. Funding for suitable monitoring activities may be available from the Lake and River Enhancement Program or other sources.

-**Work toward upholding local regulations that limit and regulate development and funneling.** While the transport of wastewater out of the James Chain watershed is a positive step for water quality it also makes increased development of the lakes area more likely. Increasing development and boat traffic on the lakes can also impact water quality and increase nutrients in the James Chain and have implications for water quality.

**-Work to maintain the limits of the present watershed.** With increasing area development the tributaries to the James Chain are an attractive conduit for accepting stormwater. The James Chain Associations should work toward preventing an increase to their drainage area and seek to maximize retention and attenuation of stormwaters from urban, commercial, and residential areas.

**-Make Efforts to keep the association memberships informed of goals, progress, and ways to help the lakes through the association meetings and newsletter.** Keeping lake residents interested will help generate the assistance necessary to complete steps toward improving and protecting water quality.

**-Work to educate lakeside and watershed property owners about the proper management of their own lands including the use of phosphorus-free fertilizers, proper irrigation, erosion control, and shoreline preservation.**

**-Work with the USDA Natural Resources Conservation Service, Steuben County Soil and Water Conservation District, and local landowners to establish vegetative cover and other best management practices on highly erodible agricultural areas that may contribute sediments and nutrients to the lakes and watershed wetlands.**

**-Continue with Volunteer Secchi monitoring on each lake. During years without IDEM sponsored water quality sampling initiate expanded association sponsored monitoring to include, oxygen and temperature profiles, epilimnion and hypolimnion total phosphorus measurement, and surface water chlorophyll a measurement. Use data collected to calculate an annual Carlson’s Trophic State Index score for each lake.**

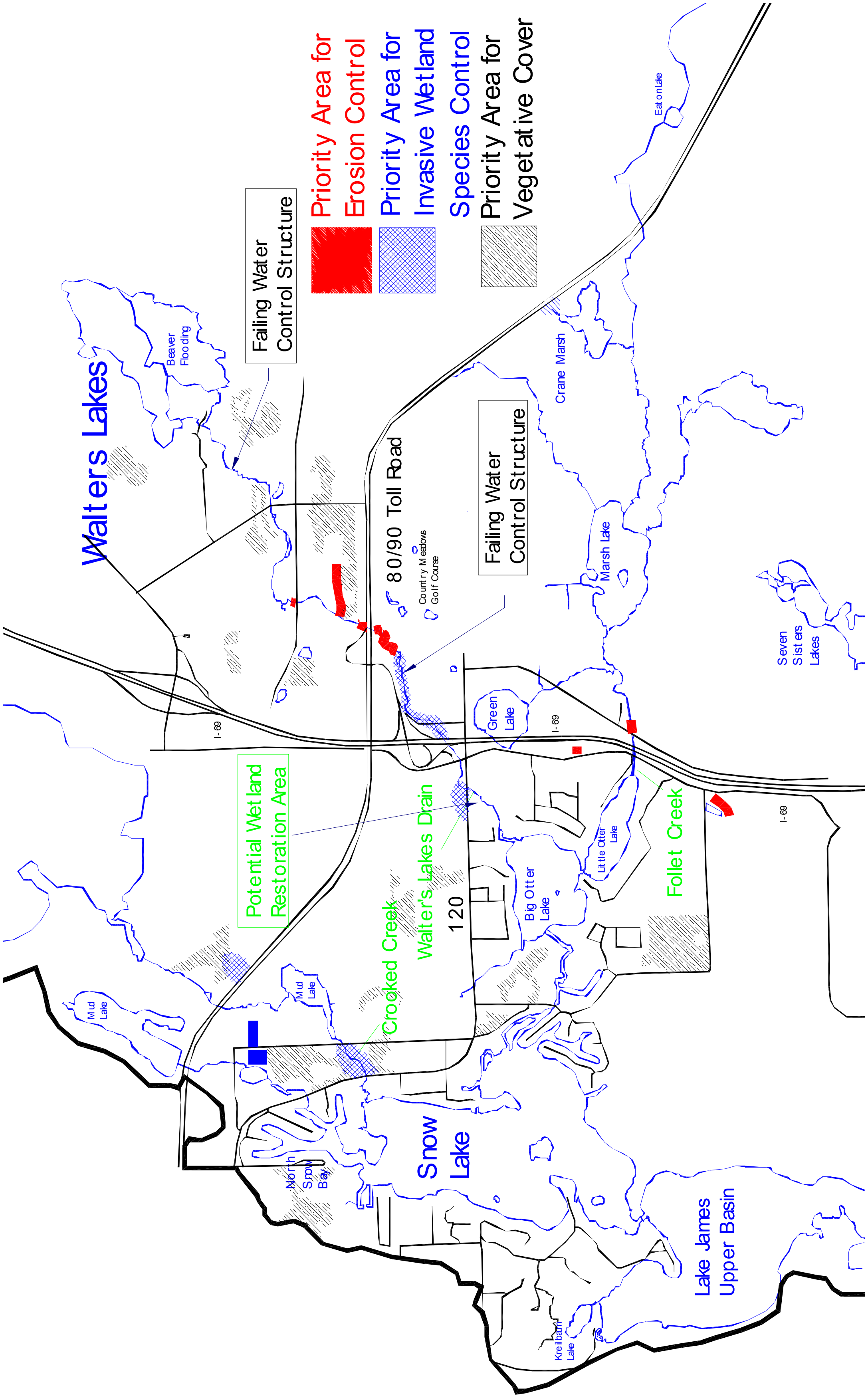



**Figure 102 Recommendations Map, Northern Watershed Area**

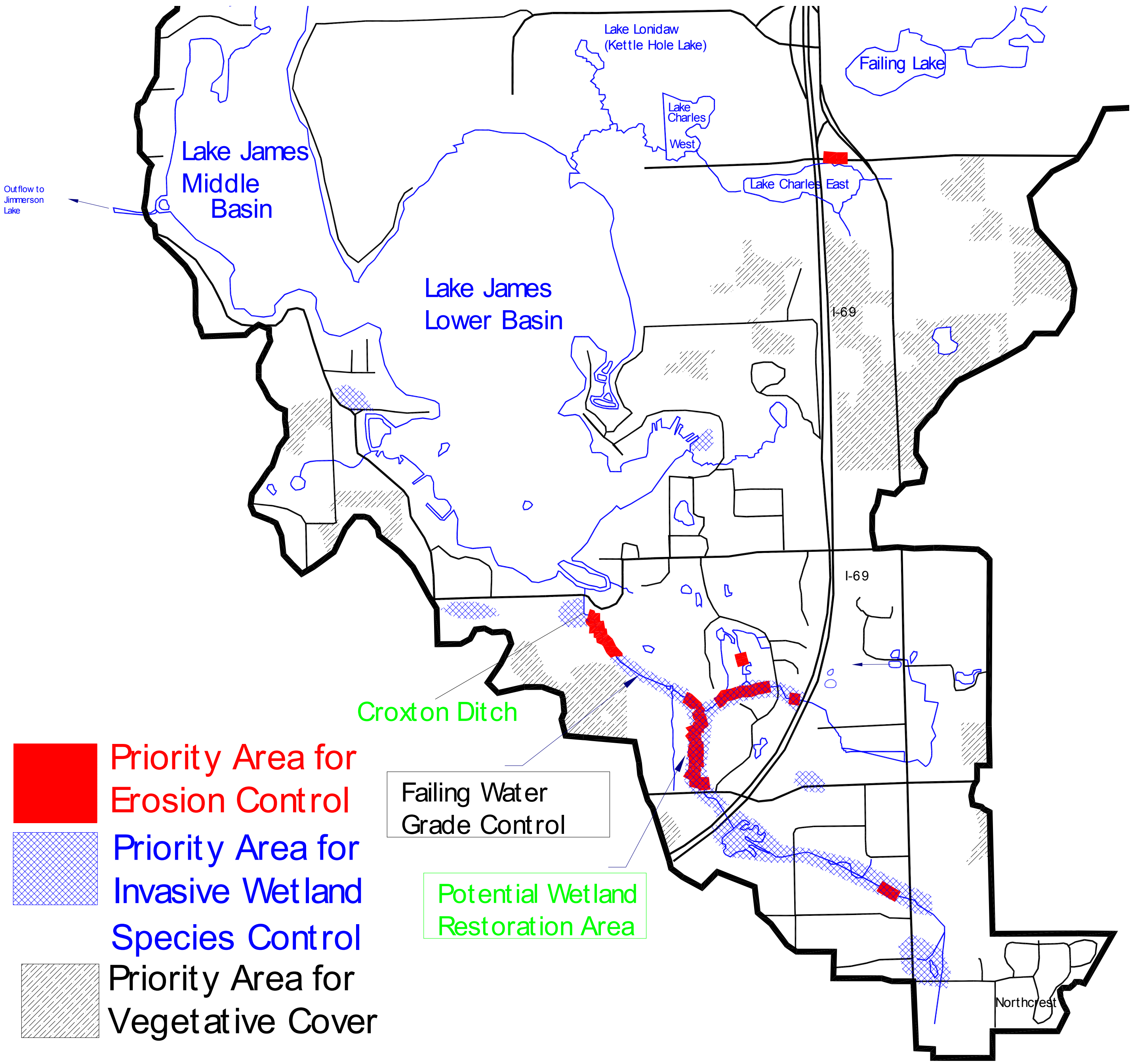



**Figure 103 Recommendation Map, Southern Watershed area**

## Glossary

**acre-foot** a unit of water volume equal to one acre of water one foot deep

**analyte** substance targeted for detection and quantification in lab analysis

**anoxia** a condition of no oxygen

**benthic** of or associated with the lake or stream bottom

**benthic macroinvertebrates** small organisms living in close association with the lake or stream bottom/sediments

**biogenic meromixis** incomplete lake mixing in response to biologically influenced water chemistry in the lower strata

**biomass** weight or quantity of a biological entity

**breakline** a lake contour which marks a steep decline

**broadleaf** a broad category of plants with a set of common biological characteristics, generally excludes the grasses

**detritus** dead plant, animal, or other organic debris

**dimictic** describes a lake whose waters destratify and mix twice annually

**epilimnion** the uppermost layer of the water column

**eutrophication** phosphorus enrichment and associated changes within a lake

**extirpated** ecologically displaced or caused to disappear or become extinct

**GPS** an acronym for "global positioning system" , an array of satellites which broadcast to earthbound electronic receivers allowing mathematical determination of geographic location (latitude & longitude)

**herbivore** an organism which utilizes plants as food

**humus** soil borne decaying organic material

**hypolimnion** deepest layer of the stratified water column

**littoral zone** the productive shallower portion of a lake where light is available to aquatic plants

**macrophyte** large vascular aquatic plant (non-planktonic)

**marl** calcium carbonate, present in solution in lake water or as a precipitate

**meromixis** a lake mixing regime in which a mixing period is incomplete, involving only part of the water column (usually the lower hypolimnion)

**metalimnion** middle layer of the stratified water column

**mixolimnion** portion of the water column (usually upper) which undergoes mixing in a case of meromixis (see meromixis)

**monoculture** an area of plant growth dominated by or exclusively containing a single species

**monolimnion** portion of the water column (usually lower) which remains unmixed in a case of meromixis (see meromixis)

**omnivore** describes an animal which utilizes both animal and vegetable matter as food

**pelagic** of or related to open waters, not closely associated with shoreline or benthic (bottom) habitat

**periphyton** layer of organisms which colonize the surface of a submersed object

**photic zone** upper lake strata where significant sunlight penetrates the waters

**photodegredation** chemical decomposition in response to exposure to light or sunight

**phytoplanktivorous** describes an organism which preys on phytoplankton

**phytoplankton** tiny plants which float in the water column

**piscivore** describes an organism which preys on fish

**plankton** tiny plants and animals which float in the water column

**riparian** of, connected to, or associated with the shoreline of a lake or stream

**strata** distinct layers

**stratification** separation into or condition of being in; distinct layers as with the epilimnion, metalimnion, and hypolimnion

**systemic** describes a pesticide or other substance which acts on an organism internally, usually undergoing internal vascular transport

**thermocline** middle layer of a stratified lake, the area of most rapid temperature decline with increasing depth

**translocated** see systemic

**trophic** of or having to do with feeding, the biological production of food or the food chain/web

**water column** the vertical extent of water from the lake surface to bottom

**zooplanktivorous** describes an organism which utilizes zooplankton as prey

**zooplankton** tiny animals which float in the water column

## Lake Management, conferences, classes, and workshops

James Chain residents can attend the following events to learn more about lake management and converse with other lake associations and lake management industry professionals.

**November 8-10, 2006** 26th International Symposium of the North American Lake Management Society, Indianapolis, IN, More information is available at www.indianalakes.org or by calling 260-665-8226

**March 30, 31, 2007** Indiana Lakes Management Society annual conference, Bloomington, IN, More information is available at www.indianalakes.org or by calling 260-665-8226

**October 2007,** Several Indiana lake workshops offered by the Indiana Lakes Management Society, dates to be announced. More information is available at www.indianalakes.org or by calling 260-665-8226

## Sources of local, state, and federal funding and information

Funding assistance for wetland and grassland restoration is available from:

Ducks Unlimited
Great Lakes/Atlantic Regional Office
331 Metty Drive, Suite #4
Ann Arbor, MI 48103
734-623-2000

Pheasants Forever, Northeast Indiana Chapter
Habitat Officer, Dave Hurley
1003 County Road 8
Corunna, IN 46730

National Wild Turkey Federation
Indiana Regional Director, Greg Larrison
2977 Bell Road, Newburgh, IN 47630

Other help for watershed improvements can be obtained from:

Indiana Department of Natural Resources
Division of Fish and Wildlife Room W265
402 W. Washington Street
Indianapolis, IN 46204-2739
317-233-5468

Steuben County Soil and Water Conservation District
Peachtree Plaza 200
1220 N 200 W
Angola, IN 46703-9171
260-665-3211, Ext. 3

USDA Natural Resources Conservation Service
1220 N 200W
Angola, IN 46703

Wood-Land-Lakes RC&D
Peachtree Plaza 200
1220 N 200 W -Ste J
Angola, IN 46703
260-665-3211, Ext. 5

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**Pan Evaporation coefficient**- Linacre, E.T. 1994. Estimating U.S. Class-A pan evaporation from few climate data. *Water International 19*, 5 - 14.

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**Flow data, Lime Lake Outlet**- U.S. Geological Survey, Water Resources Division, 5957 Lakeside Boulevard, Indianapolis, IN 46278-1996

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## Appendix A, National Heritage Database List of Rare, Threatened, or Endangered Species in the Watershed Study Area

**DNR** Indiana Department of Natural Resources

Mitchell E. Daniels, Jr., Governor
Kyle J. Hupfer, Director

Division of Nature Preserves
402 W. Washington St., Rm W267
Indianapolis IN 46204-2739

December 8, 2005

Mr. Scott Banfield
Aquatic Enhancement & Survey, Inc.
PO Box 1036
Angola, IN 46703

Dear Mr. Banfield:

I am responding to your request for information on the endangered, threatened, or rare (ETR) species, high quality natural communities, and natural areas documented from a the Wall Lake watershed, Lagrange and Steuben counties, and Lake James watershed, Steuben County, Indiana. The Indiana Natural Heritage Data Center has been checked and enclosed you will find information on the ETR species documented from the project area.

For more information on the animal species mentioned, please contact Katie Smith, Nongame Supervisor, Division of Fish and Wildlife, 402 W. Washington Room W273, Indianapolis, Indiana 46204, (317)232-4080.

The information I am providing does not preclude the requirement for further consultation with the U.S. Fish and Wildlife Service as required under Section 7 of the Endangered Species Act of 1973. You should contact the Service at their Bloomington, Indiana office.

U.S. Fish and Wildlife Service
620 South Walker St.
Bloomington, Indiana 47403-2121
(812)334-4261

At some point, you may need to contact the Department of Natural Resources' Environmental Review Coordinator so that other divisions within the department have the opportunity to review your proposal. For more information, please contact:

Kyle Hupfer, Director
Department of Natural Resources
attn: Christie Kiefer
Environmental Coordinator
Division of Water
402 W. Washington Street, Room W264
Indianapolis, IN 46204
(317)232-4160

## Endangered, Threatened and Rare Species and High Quality Natural Communities documented from the Lake James watershed, Steuben Counties, Indiana

| TYPE | SPECIES NAME | COMMON NAME | FED | STATE | TOWN RANGE | DATE | COMMENTS |
|---|---|---|---|---|---|---|---|
| Mammal | Lynx rufus | Bobcat | | | 038N013E 15 SEQ SEQ SWQ | 11/15/1993 | |
| High Quality Natural Community | Wetland - beach marl | Marl Beach | | SG | 038N013E 28 SWQ NWQ | 8/30/1983 | |
| Vascular Plant | Gnaphalium macounii | Winged Cudweed | | SX | 038N013E 2 MI NE OF LAKE JAMES | 9/10/1930 | |
| **BIG OTTER LAKE (NORTH OTTER LAKE)** | | | | | | | |
| Fish | Coregonus artedi | Cisco | | SSC | 038N013E 27 SEQ NEQ | 1955 | |
| **GREEN LAKE** | | | | | | | |
| Fish | Coregonus artedi | Cisco | | SSC | 038N013E 26 NWQ NEQ | 1998 | |
| Reptile | Sistrurus catenatus catenatus | Eastern Massasauga | C | SE | 038N013E 26 SWQ NWQ NEQ | 8/22/1994 | |
| Vascular Plant | Scirpus subterminalis | Water Bulrush | | SR | 038N013E 26 NEQ NWQ | 1982-07 | |
| **KRIELBAUM (KRIEGBAUMS) LAKE** | | | | | | | |
| Fish | Coregonus artedi | Cisco | | SSC | 038N013E 28 SWQ SWQ NWQ | 1974 | |
| **LAKE JAMES** | | | | | | | |
| Bird | Rallus elegans | King Rail | | SE | 038N013E LAKE JAMES | 7/18/1939 | |
| Bird | Chlidonias niger | Black Tern | | SE | 037N013E LAKE JAMES | 1948 | |
| Fish | Coregonus artedi | Cisco | | SSC | 038N013E 33 | 1975 | |
| **LAKE JAMES AREA** | | | | | | | |
| Mammal | Condylura cristata | Star-nosed Mole | | SSC | 038N013E LAKE JAMES AREA | 1941-06 | |
| **LAKE JAMES-SOWLES BAY** | | | | | | | |
| Reptile | Clemmys guttata | Spotted Turtle | | SE | 037N013E 03 | 6/14/1989 | |
| **SNOW LAKE** | | | | | | | |
| Fish | Coregonus artedi | Cisco | | SSC | 038N013E 28 NEQ & NWQ SEQ | 1955 | |
| Reptile | Clemmys guttata | Spotted Turtle | | SE | 038N013E 22 | 1989 | |

### BEECHWOOD NATURE PRESERVE

| TYPE | SPECIES NAME | COMMON NAME | FED | STATE | TOWN RANGE | DATE | COMMENTS |
|---|---|---|---|---|---|---|---|
| Vascular Plant | Aster borealis | Rushlike Aster | | SR | 038N013E 26 EH SWQ SWQ | 9/21/1967 | |

### BEECHWOOD NATURE PRESERVE ADDITION 2

Fed: LE = Endangered; LT = Threatened

State: SE = state endangered; ST = state threatened; SR = state rare; SSC = state species of special concern; SX = state extirpated; SG = state significant; WL = watch list; badger has been delisted but still is a protected nongame animal

Endangered, Threatened and Rare Species and High Quality Natural Communities documented from the Lake James watershed, Steuben Counties, Indiana

| TYPE | SPECIES NAME | COMMON NAME | FED | STATE | TOWN RANGE | DATE | COMMENTS |
|---|---|---|---|---|---|---|---|
| High Quality Natural Community | Forest - upland mesic | Mesic Upland Forest | | SG | 038N013E 26 SWQ | 1980 | |
| High Quality Natural Community | Wetland - swamp forest | Forested Swamp | | SG | 038N013E 26 SWQ | 1997-06 | |

**POKAGON STATE PARK**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Amphibian | Hemidactylium scutatum | Four-toed Salamander | | SE | 038N013E 34 | 1954-05 | |
| Bird | Rallus limicola | Virginia Rail | | SE | 038N004E 13 NEQ SEQ SWQ | 6/29/2003 | |
| Bird | Gallinula chloropus | Common Moorhen | | SE | 038N013E 34 SWQ NEQ | 7/7/2002 | |
| Bird | Gallinula chloropus | Common Moorhen | | SE | 037N013E 34 SEQ | 6/29/2003 | |
| Bird | Certhia americana | Brown Creeper | | | 038N013E 34 | 6/7/2001 | |
| Bird | Cistothorus platensis | Sedge Wren | | SE | 038N013E 33 | 6/18/1993 | |
| Bird | Cistothorus palustris | Marsh Wren | | SE | 038N013E 27 | 1994-SU | |
| Bird | Cistothorus palustris | Marsh Wren | | SE | 038N013W 34 NWQ | 6/29/2003 | |
| Bird | Dendroica cerulea | Cerulean Warbler | | SSC | 038N013E 33 | 1994-SU | |
| Reptile | Emydoidea blandingii | Blanding's Turtle | | SE | 038N013E 26 | NO DATE | |
| Reptile | Clonophis kirtlandii | Kirtland's Snake | | SE | 038N013E 27 | 1986 | |
| Reptile | Sistrurus catenatus catenatus | Eastern Massasauga | C | SE | 038N013E 27 SH | 1993 | |
| Vascular Plant | Conioselinum chinense | Hemlock Parsley | | SE | 038N013E 34 | 1914-09 | |
| Vascular Plant | Arabis missouriensis var. deamii | Missouri Rockcress | | SE | 038N013E 34 | 1916-06 | |
| Vascular Plant | Lonicera canadensis | American Fly-honeysuckle | | SX | 038N013E 34 | 1952-05 | |
| Vascular Plant | Cypripedium calceolus var. parviflorum | Small Yellow Lady's-slipp | | SR | 038N013E 34 SWQ NWQ SEQ | 1998-05 | |

MARSH IN POKAGON STATE PARK

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bird | Rallus limicola | Virginia Rail | | SE | 038N013E 04 NWQ SWQ | 1993-SP | |

POKAGON STATE PARK CAMPGROUND #4

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reptile | Sistrurus catenatus catenatus | Eastern Massasauga | C | SE | 038N013E 28 | 8/15/1994 | |

**POTAWATOMI NATURE PRESERVE**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bird | Lophodytes cucullatus | Hooded Merganser | | | 038N013E 34 NEQ | 6/8/2003 | |
| Bird | Grus canadensis | Sandhill Crane | | SSC | 038N013E 34 SEQ | 6/14/2003 | |
| Reptile | Sistrurus catenatus catenatus | Eastern Massasauga | C | SE | 038N013E 34 SWQ NWQ SEQ & NEQ SWQ & SWQ SWQ NEQ | 8/16/1993 | |
| High Quality Natural Community | Forest - upland mesic | Mesic Upland Forest | | SG | 038N013E 34 | 1980 | |
| High Quality Natural Community | Forest - upland mesic | Mesic Upland Forest | | SG | 038N013E 34 WH NWQ NWQ | NO DATE | |

Fed: LE = Endangered; LT = Threatened
State: SE = state endangered; ST = state threatened; SR = state rare; SSC = state species of special concern; SX = state extirpated; SG = state significant; WL = watch list; badger has been delisted but still is a protected nongame animal

Endangered, Threatened and Rare Species and High Quality Natural Communities documented from the Lake James watershed, Steuben Counties, Indiana

| TYPE | SPECIES NAME | COMMON NAME | FED | STATE | TOWN RANGE | DATE | COMMENTS |
|---|---|---|---|---|---|---|---|
| High Quality Natural Community | Wetland - fen | Fen | | SG | 038N013E 34 SEQ SEQ | 1988 | |
| High Quality Natural Community | Wetland - marsh | Marsh | | SG | 038N013E 34 | 1980 | |
| High Quality Natural Community | Wetland - marsh | Marsh | | SG | 038N013E 34 SWQ SEQ | 1988 | |
| High Quality Natural Community | Wetland - marsh | Marsh | | SG | 038N013E 34 SH NEQ | 1988 | |
| High Quality Natural Community | Wetland - meadow sedge | Sedge Meadow | | SG | 038N013E 34 NWQ SEQ | NO DATE | |
| High Quality Natural Community | Wetland - swamp forest | Forested Swamp | | SG | 038N013E 34 WH NWQ NWQ | NO DATE | |
| High Quality Natural Community | Wetland - swamp forest | Forested Swamp | | SG | 038N013E 34 SEQ NEQ | 1988 | |
| High Quality Natural Community | Wetland - swamp forest | Forested Swamp | | SG | 038N013E 34 NEQ NEQ | 1988 | |
| Insect: Lepidoptera | Dasychira cinnamomea | A Moth | | SR | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Macrochilo absorptalis | A Moth | | SR | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Macrochilo hypocritalis | A Noctuid Moth | | SR | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Melanomma auricinctaria | Huckleberry Eye-spot Mot | | SR | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Capis curvata | A Noctuid Moth | | ST | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Chortodes inquinata | Tufted Sedge Moth | | ST | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Chortodes enervata | The Many-lined Cordgrass | | ST | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Iodopepla u-album | A Noctuid Moth | | SR | 038N013E 34 SEQ | 2001 | |
| Insect: Lepidoptera | Leucania multilinea | | | ST | 038N013E 34 SEQ | 2001 | |
| Vascular Plant | Hypericum pyramidatum | Great St. John's-wort | | ST | 038N013E 34 SEQ SEQ NEQ | 2/3/1988 | |
| Vascular Plant | Circaea alpina | Small Enchanter's Nightsh | | SX | 038N013E 34 | 7/18/1927 | |
| Vascular Plant | Actaea rubra | Red Baneberry | | SR | 038N013E 34 | 1998-05 | |
| Vascular Plant | Sorbus decora | Northern Mountain-ash | | SX | 038N013E 34 | 1933-09 | |
| Vascular Plant | Carex pedunculata | Longstalk Sedge | | SR | 038N013E 34 SWQ NEQ | 5/25/1988 | |
| Vascular Plant | Eriophorum viridicarinatum | Green-keeled Cotton-grass | | SR | 038N013E 34 | 5/26/1927 | |
| Vascular Plant | Coeloglossum viride var. virescens | Long-bract Green Orchis | | ST | 038N013E 34 | 1927-05 | |
| Vascular Plant | Platanthera hyperborea | Leafy Northern Green Orcl | | ST | 038N013E 34 NWQ SEQ | 7/27/1982 | |

Fed: LE = Endangered; LT = Threatened

State: SE = state endangered; ST = state threatened; SR = state rare; SSC = state species of special concern; SX = state extirpated; SG = state significant; WL = watch list; badger has been delisted but still is a protected nongame animal

| TYPE | SPECIES NAME | COMMON NAME | FED | STATE | TOWN RANGE | DATE | COMMENTS |
|---|---|---|---|---|---|---|---|
| Vascular Plant | Poa alsodes | Grove Meadow Grass | | SR | 038N013E 34 NEQ NEQ | 5/25/1988 | |
| Vascular Plant | Poa paludigena | Bog Bluegrass | | WL | 038N013E 34 SWQ NEQ | 5/25/1988 | |
| LAKE LONIDAW | | | | | | | |
| Insect: Odonata | Cordulegaster bilineata | Brown Spiketail | | SE | 038N013E 34 SEQ | 6/20/1997 | |
| Insect: Odonata | Sympetrum semicinctum | Band-winged Meadowhaw | | SR | 038N013E 34 SEQ | 10/13/1996 | |
| LOST SWAMP | | | | | | | |
| High Quality Natural Community | Wetland - swamp forest | Forested Swamp | | SG | 038N013E 34 SWQ SEQ | 1988 | |
| POTAWATOMI | | | | | | | |
| Vascular Plant | Cypripedium candidum | Small White Lady's-slippei | | WL | 038N013E 34 SWQ NEQ | 5/28/1986 | |

**POTAWATOMI NATURE PRESERVE (ORIGINAL)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| High Quality Natural Community | Forest - upland dry-mesic | Dry-mesic Upland Forest | | SG | 038N013E 34 SEQ | 1980 | |
| High Quality Natural Community | Wetland - fen | Fen | | SG | 038N013E 34 NEQ SWQ | NO DATE | |
| Insect: Odonata | Aeshna mutata | Spatterdock Darner | | ST | 038N013E 34 | 6/20/1997 | |
| Vascular Plant | Salix serissima | Autumn Willow | | ST | 038N013E 34 | 7/7/1928 | |
| Vascular Plant | Zigadenus elegans var. glaucus | White Camas | | SR | 038N013E OR 037N013E | 1902-08 | |
| Vascular Plant | Cypripedium candidum | Small White Lady's-slippei | | WL | 038N013E 34 SWQ NWQ SEQ | 6/1/1994 | |

**WING HAVEN NATURE PRESERVE**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reptile | Sistrurus catenatus catenatus | Eastern Massasauga | C | SE | 038N013E 35 SEQ SEQ | 1993 | |

Fed: LE = Endangered; LT = Threatened
State: SE = state endangered; ST = state threatened; SR = state rare; SSC = state species of special concern; SX = state extirpated; SG = state significant; WL = watch list; badger has been delisted but still is a protected nongame animal

# Appendix B, Interfluv. Inc.   Stream Sampling Report

# Stueben County, Indiana

## Stream Macroinvertabrate Sampling

September 30, 2005

Prepared for:

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# Stueben County, Indiana
## Stream Macroinvertabrate Sampling

### Introduction

Two Lake Diagnostic studies are ongoing on Lake Gage and the James Chain of Lakes in Stueben County, Indiana. The studies are being funded by the LARE program, a DNR sponsored Lake and River Enhancement Program with the goal of improving the quality of Indiana's surface water resources. As part of these two studies, macroinvertabrate sampling within streams tributary to the lakes is required to detail existing baseline conditions, prior to the implementation of any projects recommended in the baseline study phase.

Seven sites were sampled for the two studies. Macroinvertabrates were collected at each site, preserved, and later identified in the lab to family level in order to calculate the m-IBI or Macroinvertabrate Index of Biotic Integrity. The m-IBI is a tool used nationwide to investigate water quality in a stream and is one of a number of protocols used by the Indiana Department of Environmental Management to keep track of the quality of Indiana's surface waters. The index provides a numerical score for each sampling event that when coupled with a numerical score for the habitat quality at the site can give investigators information about the quality of the stream. Though the main thrust of this study was to collect baseline data, those samples collected with a kick net are applicable to IDEM methods so comparison to other data in the county can be made.

### Methods

Detailed information about each site and the field methods used can be found in the appendix along with the data. All samples were collected using EPA Rapid Bioassessment Protocols for Wadeable Streams. In streams that contained riffles, a 500 micron net was used for kick sampling at the riffle. In areas where riffles were not present, a 500 micron D-frame net was used to perform multi-habitat sampling through the site. At each site a Qualitative Habitat Evaluation Index was performed, based on IDEM protocol.

Each sample was preserved in a mixture of 80% alcohol and brought back to the lab for identification. All samples were identified to family level, and vouchers of each were saved in separate vials for curation. A 15 minute pick was also performed on the sample, in keeping with IDEM protocols, and preserved for curation.

The m-IBI is calculated based on Indiana specific metrics and scores developed by IDEM for riffle kick samples. A table illustrating the metrics is shown below. Each metric receives a score and then they are averaged for a possible 0 (lowest) to the highest possible score of 8.

| Scoring Criteria for the Family Level Macroinvertebrate Index of Biotic Integrity (mIBI) for Riffle KICK Samples Calibrated from Transformed Data Distribution of the 1990-1995 Using 100-Organism Subsamples (IDEM- BSS Section) | | | | | |
|---|---|---|---|---|---|
| | **Classification Scores** | | | | |
| | **0** | **2** | **4** | **6** | **8** |
| Family Level HBI | ≥ 5.63 | 5.06 – 5.62 | 4.55 – 5.05 | 4.09 – 4.54 | ≤ 4.08 |
| Number of Taxa | ≤ 7 | 8 - 10 | 11 – 14 | 15 - 17 | ≥ 18 |
| Number of Individuals | ≤ 79 | 80 – 129 | 130 – 212 | 213 – 349 | ≥ 350 |
| Percent Dominant Taxa | ≥ 61.6 | 43.9 – 61.5 | 31.2 – 43.8 | 22.2 – 31.1 | ≤ 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 | 55 – 146 | 20 - 54 | 7 - 19 | ≤ 6 |
| Total Number of Individuals to Number of Squares Sorted | ≤ 29 | 30 - 71 | 72 – 171 | 172 - 409 | ≥ 410 |

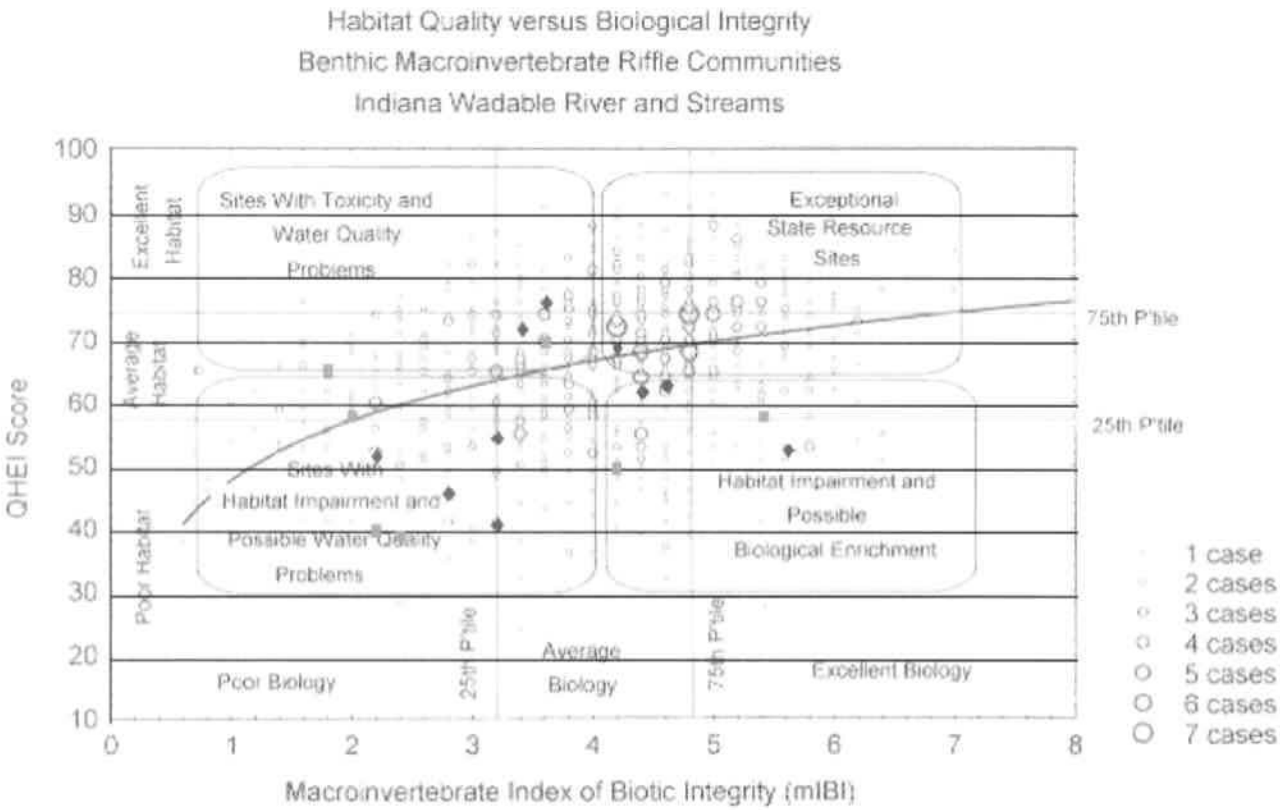
## Discussion

The goal; of this study is simply to gather baseline data for areas of interest. However, some coarse analysis is allowable in order to place the results in a larger context. The results of the study are shown below (orange) along with historical m-IBI data (yellow) collected by IDEM in Stueben Co. Two sites sampled using multi-habitat methods instead of riffle kicks are called out. Though the m-IBI is calculated for these two sites, since they are not the same as IDEM protocols, comparison is questionable.

| Stream Name | Location | QHEI Score (100 possible) | m-IBI Score (8 possible) |
|---|---|---|---|
| Pigeon Creek | CR 400 S | 63 | 4.6 |
| Black Creek | SR 1 | 55 | 3.2 |
| Pigeon Creek | D/S SR 27 Bridge | 72 | 3.4 |
| Eaton Creek | D/S CR 100 E | 41 | 3.2 |
| Crooked Creek | D/S Nevada Mills Dam | 76 | 3.6 |
| Pigeon Creek | SR 327 DNR Access | 46 | 2.8 |
| Turkey Creek | SR 327 | 52 | 2.2 |
| Fish Creek | CR 40 S | 62 | 4.4 |
| Black Creek | SR 1 | 69 | 4.2 |
| Fish Creek No 2 | CR 775 S | 53 | 5.6 |
| **Croxton Ditch | W 275 N | 39 | 2.4 |
| Concorde Creek (Orland Rd) | Orland Rd | 69.5 | 3.6 |
| Concorde Creek (Butler's Woods) | U/S Lake Gage | 58 | 5.4 |
| **Crooked Creek | N of SR 120 | 50 | 4.2 |
| Unnamed Trib- Big Otter Lk. | N of SR 120 | 58 | 2.0 |
| Follett Creek | Just W of I-69 | 40 | 2.2 |
| Concorde Creek (ref. reach) | Orland Rd | 65.25 | 1.8 |

= IDEM Historical Data
= Data from this study
**data collected using multi-habitat approach

Below is a graph for all eco-regions in Indiana that illustrates the purpose of the m-IBI and QHEI in guiding additional investigations into water quality. Although it is beyond the scope of this project, the riffle community data above can be applied to this graphic and some inferences drawn as to the health of the stream and possible impairments that may exist. The results of the data from IDEM for Steuben Co.(blue) and from this study (pink) have been overlain in order to compare the data.




Stueben Co. IDEM results in BLUE Results of this study in PINK
Graphic produced by IDEM Biological Studies Section, 1999. Data includes all Indiana stream samples.

This type of rough comparison is appropriate for the level of analyses that this study requires. However, it is important to normalize each sample with others in the same *eco-region* in order to proceed with a more in depth analysis. In other words, a QHEI score of 100 in one eco-region may be the same as a QHEI score of 80 in another, simply because of geologic or other landscape level controls beyond any anthropogenic influences.