WAWASEE AREA CONSERVANCY FOUNDATION
WATER QUALITY SUMMARY REPORT

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WATER QUALITY SUMMARY

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EXECUTIVE SUMMARY

The purpose of the project is to provide a summarization of water quality data collected from eight studies in the Lake Wawasee watershed from the 1970s through current. The Wawasee Area Conservancy Foundation (WACF) intends to use the summary to understand the water quality trends for distribution to the community.

To complete the summary, the studies were analyzed individually and then compared. The analysis indicated fecal coliform and nutrients are generally the parameters of concern while the Turkey Creek and Dillon Creek outflows are generally the sites of concern. The overall water quality of Lake Wawasee is good. Going forward, sampling is recommended at Odgen Island, Conklin Bay, Marineland Gardens, Turkey Creek outflow, Turkey Creek Indian Village, Dillon Creek outflow, South Shore, Kanata Manayunk, and Papakeechie outlet. Efforts should be made to continue sampling at such sites to develop trends. Also, parameters such as dissolved oxygen, nitrate, total phosphorus, orthophosphate, and fecal coliform should continue to be sampled.

WAWASEE AREA CONSERVANCY FOUNDATION
WATER QUALITY SUMMARY

I. PROJECT DESCRIPTION AND PURPOSE

The proposed project involved the summarization of water quality data collected by the Wawasee Area Conservancy Foundation (WACF) in the Lake Wawasee watershed. Area maps of Lake Wawasee and the surrounding area are provided in Appendix A. The WACF has pulled together information from the 1970's forward from a conglomeration of studies within the Lake Wawasee watershed. The purpose of this project is to provide a summary of the water quality within Lake Wawasee's watershed. The summary is to be concise and is to provide graphical representations.

II. RATIONALE / METHODOLOGY

The data analyzed by this report includes:

1) A report conducted in the Summer of 1971 by Cameron E. Gifford, Michael Melampy, William Bishop, and Margaret Hollinger entitled " A Summary of a Chemical and Bacteriological Survey of Lakes Wawasee and Syracuse";
2) A report conducted in the Summer of 1982 by Karl A. Keiper entitled "Chemical and Bacteriological Survey, Lakes Syracuse and Wawasee";
3) Watershed water quality sampling from the Spring and Summer of 1995 provided in Section VII of "Lake Enhancement Diagnostic/Feasibility Study for the Wawasee Area Watershed" ;
4) The Kosciusko County Health Department Wawasee Lake Study in July 1995 provided in Section IX of "Lake Enhancement Diagnostic/Feasibility Study for the Wawasee Area Watershed";
5) Kosciusko County Stream Monitoring Watershed Study from the Fall of 1996 to the Spring of 1998
6) Public Water System Reports conducted in August of 1998 by Turner Technologies testing community water for E. Coli;
7) Data from 1989 to 2003, by the Indiana Clean Lakes Program; and
8) The Hoosier Riverwatch's Standard Chemical Monitoring Data Sheets from 2000 through 2003 completed by WACF members.

The data sets highlight the following parameters, respectively:

1) Dissolved oxygen, nitrate, total phosphorus, fecal
2) Temperature, pH, dissolved oxygen, fecal, nitrate, ammonia nitrogen (NH3-N), orthophosphate, total phosphorus
3) Total phosphorus, orthophosphate, ammonia and ammonium nitrogen (NH_3 + NH_4-N), total kjeldahl nitrogen, nitrite and nitrate nitrogen (NO_2 + NO_3-N), total suspended solids
4) Depth, water temperature, dissolved oxygen, E. coli, nitrite, ammonia, orthophosphate, pesticides (atrazine)
5) Dissolved oxygen, percent saturation of dissolved oxygen, E. coli, pH, biological oxygen demand, temperature, temperature change, phosphorus, nitrate, turbidity, total solids, chlorides, ammonia nitrogen, atrazine
6) E. Coli
7) Secchi depth, total phosphorus, chlorophyll a
8) Dissolved oxygen (% saturation), biological oxygen demand (5-day), nitrate, pH, orthophosphate, temperature change, turbidity, fecal or E. coli colonies

A summary of the sampled parameters follows:

Dissolved Oxygen

Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration, and as a waste product of photosynthesis. The oxygen is used by plants and animals for respiration and by the aerobic bacteria that consume oxygen during the process of decomposition. When organic matter such as animal waste or improperly treated wastewater enters a body of water, algae growth increases and the dissolved oxygen levels decrease as the plant material dies off and is decomposed through the action of the aerobic bacteria. Dissolved oxygen is essential for aquatic plants and animal life and is one of the best indicators of the health of an aquatic ecosystem. Dissolved oxygen can range from 0-18 mg/L, but most natural aquatic systems require 5-6 mg/L to support a diverse population. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/L, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills.

Nitrate

Nitrate (NO_3-) rich effluents discharged into water can degrade water quality by encouraging excessive growth of algae. As decomposition of plant and animal material occurs, dissolved oxygen levels decrease and nitrate levels increase. In addition, bacteria break down large protein molecules into ammonia which combines with oxygen to form nitrates and nitrites. Unpolluted waters usually have a nitrate level below 4 mg/L. In Indiana waters, nitrate-nitrogen levels typically range between 0.9 and 3.15 mg/L, although in areas where land use is predominately agricultural, nitrate concentrations exceeding 10 mg/L are common.

Nitrite

Nitrite (NO_2) is typically present in extremely low concentrations. Nitrite is rarely measurable in unpolluted natural waters with readings generally less than 1 mg/L. High concentrations may be indicative of septic or sewage.

Ammonia

Ammonia (NH_3) is the most reduced form of nitrogen and is found in water where dissolved oxygen is lacking. Ammonia is a product of the microbiological decay of animal and plant protein and can be reused directly to produce plant protein. The presence of ammonia in raw surface waters is generally an indication of domestic pollution. Ammonia is toxic to fish and aquatic organisms, even in very low concentrations. When levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Ammonia levels greater than approximately 0.1 mg/L usually indicate polluted waters. According to the Indiana Administrative Code, maximum (unionized) ammonia concentrations should range between 0 and 0.21 mg/l depending upon temperature and pH.

Ammonium

Ammonium (NH_4+) is dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonium as they decompose dead plant and animal matter. Ammonium is found where dissolved oxygen is lacking, often in the hypolimnia of eutrophic lakes. Ammonium is released from decomposing organic material under anoxic conditions and accumulates in the hypolimnion of thermally stratified lakes. If ammonium comes into contact with oxygen, it is immediately converted to nitrite (NO_2) which is then oxidized to nitrate (NO_3-). Both ammonium and nitrate can be used as a nitrogen source by aquatic plants and algae.

Total Kjeldahl Nitrogen

To determine total Kjeldahl nitrogen, the amount of organic nitrogen contained in water is measured. Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen plus ammonium. The organic nitrogen concentration is the total Kjeldahl nitrogen concentration minus the ammonia concentration. Organic nitrogen may be either dissolved or suspended particulate matter in water. High levels of organic nitrogen in water may indicate excessive production or organic pollution from the watershed. Animal and human waste, decaying organic matter, and live organic material like tiny algae cells can causes organic nitrogen enrichment of lake water.

Orthophosphate

Phosphorus is a nutrient that acts as a fertilizer for aquatic plants. This increased growth may cause an increase in the fish population and improve the overall water quality. However, when nutrient levels are high, excessive plant and algae growth creates water quality problems, using up large amounts of oxygen. This condition is known as eutrophication or over-fertilization of receiving waters. Phosphorus occurs in natural waters in the form of phosphates (PO_4), although over half of the phosphates in lakes, streams, and rivers come from human uses. In unproductive lakes, orthophosphate is between 0.005 and 0.007 mg/L. Flowing waters should have levels below 0.01 mg/L.

Total Phosphorus

Ideally, soluble reactive phosphorus concentrations should be 0.01 mg/L or less at spring turnover to prevent summer algae blooms. A concentration of total phosphorus below 0.02 mg/L should be maintained to prevent nuisance algal blooms. The range for total phosphorus in Indiana waters is quite broad (0.01-0.17 mg/l) with a state average of 0.09 mg/l. A level of 0.03 mg/l is generally thought to indicate eutrophication potential. The State of Indiana does not currently have a water quality standard for phosphorus.

Chloride

The chloride ion (Cl-) form has very different properties from chlorine gas (Cl2), which is used for disinfecting. The chloride ion (Cl-) in lake water is commonly considered an indicator of human activity. Agricultural chemicals, human and animal wastes, and road salt are the major sources of chloride in lake water. Seawater contains approximately 20g/L of chloride ions-1000 times that of fresh- water lakes. Public Drinking Water Standards require chloride levels not to exceed 250 mg/L. Chloride levels do not harm aquatic life until the concentration is very large, at least 1000 mg/l.

Atrazine

Atrazine is a triazine herbicide that is widely used in the U.S. to control broadleaf weeds in the production of corn and sorghum. Atrazine is generally applied to soil pre-planting or pre-emergence, but is sometimes also applied to the foliage post-emergence. Atrazine can enter surface waters through runoff, spray drift, discharge of contaminated groundwater to surface water, wet deposition (dissolution of atrazine vapor in rainfall and washout of particulate bound atrazine), dry deposition (dry settling of particulate bound atrazine), and sorption from the vapor phase. For human health protection, EPA has set a maximum contaminant level of 3 μg/L in drinking water. EPA also has set draft ambient aquatic life criteria at 350 μg/L for protection from acute effects and 12 μg/L for protection from chronic effects.

Fecal Coliform

Fecal coliform are bacteria found in the intestinal tracts of warm blooded animals. Its presence is an indication that the feces of warm blooded animals exist in the water. The presence of coliform indicates the potential for other harmful pathogenic organisms, making the water unsuitable for human recreation. In Indiana, the Administrative Code sets the maximum *E. coli* standard at 235 colonies/100 mL in any one sample within a 30-day period.

Temperature

Water temperature is a controlling factor in the rate of metabolic and reproductive activities for aquatic life. A rise in temperature can increase metabolic activity, provide conditions for the growth of disease-causing organisms, and lower the amount of dissolved oxygen. Water temperature is influenced by water flow, streamside vegetation, turbidity, ground water inputs, and water release from industrial activities. Removal of streamside vegetation and stream channeling along roads can raise the water temperature. The Indiana Administrative Code sets maximum temperature limits to protect aquatic life. For instance, temperatures during the month of May should not exceed 80°F (23.7°C) by more than 3°F (1.7°C). June temperatures should not exceed 90°F (32.2°C).

pH

The pH of water is a measure of the concentration of hydrogen ions. The pH is measured on a scale from 1 to 14, with 1 being most acidic, 7 neutral, and 14 most basic or alkaline. The pH of water influences many types of chemical reactions. A slight decrease in pH may greatly increase the toxicity of substances such as cyanides, sulfides, and most metals. The solubility of most metals is increased at a lower pH and, therefore, the metals are more available for biological processes. A slight increase in pH may greatly increase the toxicity of pollutants such as ammonia. A pH range of 6.5 to 8.2 is optimal for most organisms. Rapidly growing algae and vegetation remove carbon dioxide (CO_2) from the water during photosynthesis, which can result in a significant increase in pH. Most natural waters have pH values from 5.0 to 8.5.

Biological Oxygen Demand

Biochemical Oxygen Demand (BOD) is a measure of the quantity of dissolved oxygen used by bacteria as they break down organic wastes. High BOD levels indicate that large amounts of organic matter are present in the stream. In slow-moving and polluted waters, much of the available dissolved oxygen is consumed by bacteria, robbing other aquatic organisms of the dissolved oxygen needed to live. A BOD level of 1-2 mg/L is very good, 3-5 mg/L is moderately clean, 6-8 mg/L is somewhat polluted and 9 mg/L and higher is generally polluted.

Turbidity

Turbidity is the measurement of the relative clarity of water. Turbid water is cloudy and is caused by suspended and colloidal matter such as clay, silt, organic, and inorganic matter, and microscopic organisms (algae). Turbidity should not be confused with color, since darkly colored water can still be clear and not turbid. Turbid water may be the result of soil erosion, urban runoff, algal blooms, and bottom sediment disturbances that can be caused by boat traffic and abundant bottom feeding fish. A reading of 100 NTU or greater is excessive while 50 NTU is generally considered turbid.

Total Suspended Solids

Total suspended solids include all particles suspended in the water that can be trapped by a filter such as inorganic materials (those not derived from living things like soil and industrial waste), organic materials like detritus (dead plant or animal material), live organisms, and sewage. Large amounts of suspended solids can reduce lake clarity, reduce light availability, and cause an increase in water temperature because the particles can trap heat from the sun. Additionally, high solids measurements can indicate high levels of nutrients, bacteria, metals, and other chemicals since many of these pollutants are attached to sediment. Management practices that prevent soil loss and erosion can help to maintain low total suspended solid concentrations. Some of these practices are: erosion control during construction and development, streamside vegetated buffer maintenance, conservation tillage, storm water detention, and wetland restoration. Although neither the United States Environmental Protection Agency nor the State of Indiana currently have total suspended solid standards, generally, concentrations greater than 80 mg/l can cause deleterious effects to aquatic life. Overall, it is typical of clear water to have total suspended solids levels below 25 mg/L, an intermediate aquatic level to have between 25-100 mg/L and muddy water to have levels above 100 mg/L.

Secchi Depth

Secchi disk is a measurement of water clarity. Water clarity is affected by two main factors: algae and suspended sediments. Sediments may be introduced into the water by either runoff from the land or from sediments already on the bottom of the lake. Algae are a natural component of the food chain in lakes. Algae are microscopic plants, which grow like plants do; they need sufficient light and nutrients to survive. When there are too many nutrients in the lake, the algae multiply enough to cause a decrease in water clarity. Other factors that may affect the reading will be the color of the water, wind, waves, and sunlight.

Some lakes have a natural brown color. The color is not an indication of pollution or suspended sediments, but of tannic acids produced by decaying plants. Light does not penetrate as deeply in these darkened waters, so these brown lakes will generally have fewer algae than clear lakes.

Secchi disk transparency readings can give a rough estimate of the depth to which oxygen can support fish and other aquatic life. Generally the Secchi disk depth times 1.7 is the depth to which light can penetrate. For example, if the Secchi disk reading was 10 feet, then light can penetrate to a depth of approximately 17 feet. If light can penetrate this far, then there is enough light to support an algal population. The *photic zone* is defined as the vertical depth of a lake that has enough light to support plant growth. A secchi disk reading of 15 to 20 feet is excellent whereas a reading less than 2 feet is poor.

Chlorophyll *a*

Chlorophyll *a* is the photosynthetic pigment that causes the green color in algae and plants. The concentration of chlorophyll *a* present in the water is directly related to the amount of algae living in the water. Excessive concentrations of algae give lakes an undesirable "pea soup" appearance. Ryding and Rast (1989)[1] deal with characteristics of eutrophication in lakes and they give the following boundary values for mean and peak chlorophyll a values, as follows:

	Mean Range (µg/L)	Peak Range (µg/L)
Oligotrophic	0.8 - 3.4	2.6 - 7.6
Mesotrophic	3.0 - 7.4	8.9 - 29
Eutrophic	6.7 - 31	16.9 - 107

An analysis method was developed based upon the sampling locations and parameters from the available data. The developed methodology included:

- Analysis of the combination of data from the 70s and 80s for corresponding sampling locations
- Analysis of the 1995 Watershed Water Quality Sampling, both wet and dry weather testing
- Analysis of the 1995 Kosciusko County Health Department Wawasee Lake Study
- Analysis of the Kosciusko County Stream Monitoring Watershed Study
- Analysis of the E. coli data from the public water system testing sites
- Analysis of the data from the Indiana Clean Lakes Program
- Analysis of the Hoosier Riverwatch sampling data
- Comparison of the data sets

[1]Ryding, S. O. and W. Rast. 1989. *The control of eutrophication of lakes and reservoirs. Man and the Biosphere Series, Volume* 1, UNESCO, Parthenon Publication Group, Park Ridge, New Jersey. 314 pp.

III. RESULTS

A. 70s and 80s

Both studies from the 1970s and 1980s sampled similar locations across Lake Wawasee and Syracuse Lake. The studies were conducted to determine the degree and rate of eutrophication in the lakes. In the 1971, the samples were concentrated along the shore areas and in channels. The results indicated the following:

- the dissolved oxygen levels were high;
- nitrogen and phosphorus were subject to fluctuation but remained low;
- the channels were generally in worse condition than the shore areas; and
- the channels subject to human use or areas where the streams and channels merged with open water generally had high nitrogen and phosphorus levels and lower levels of dissolved oxygen.

On average, dissolved oxygen, nitrate, and total phosphorus levels for the 1971 study were 7.1, 1.3, and 0.04 mg/L, respectively. The study concluded that both lakes were not in immediate danger of excessive eutrophication. Refer to the figures in Appendix B for graphical representations of the collected data organized by parameter.

The study in 1982 collected samples from surface water 4 to 12 inches deep. The results indicated that:

- two sites fell below 5 mg/L for dissolved oxygen;
- pH was within range of most natural lakes;
- phosphorus was high but not unexpected for the time of year;
- 2 sites had ammonia levels approaching 1 mg/L indicating the possibility of intrusion of polluted effluent;
- nitrate was low which is not unusual for the time of year since the upper levels of the lake tend to decrease sharply; and
- 7 sites were above 100 col/100mL for fecal coliform indicating the lake is suspect of human recreational use.

On average, dissolved oxygen, nitrate, and total phosphorus levels in the 1982 study were 7.9, 0.07, and 0.13 mg/L, respectively. Overall, the study found that the chemical samples were in line for the lakes but the bacteria levels exceeded those for human health. Graphs of each parameter are included in Appendix B.

In comparing the two studies, fourteen sampling sites coincided with one another. The sampling results for the fourteen locations were combined to compare the corresponding parameters of dissolved oxygen, nitrate, total phosphorus, and fecal coliform. Four graphical representations, one for each parameter, are contained in Appendix B.

The analysis revealed that:

- Dissolved oxygen levels were consistently high with the exception of Cedar Point where the 1971 reading fell below 5 mg/L but rebounded in the 1980s to 9 mg/L.
- Nitrate levels were high in 1971 compared to 1982. However, the nitrate levels in 1971 and 1982 were below the 4 mg/L level indicating the waters were unpolluted.
- Total phosphorus was higher in 1982 than in 1971. The level of phosphorus in 1982 throughout the sampling sites indicated the potential for eutrophication. Within the 1982 study, it was noted that the levels were not unexpected for the time of year and were thought to be attributed to sediments, organic materials, or waste materials. In 1971, Marineland Gardens and Enchanted Hills indicated the potential for eutrophication.
- Fecal coliform levels varied throughout the sampling locations as well as between the two studies. The highest reported value was listed as being >200 col/100 mL. With the state standard being a maximum of 235 col/100 mL for a sample during a 30 day period, it is not known if the standard was exceeded. However, no one sampling site was listed as having a reading of >200 col/100 mL from both studies. Thus in most cases, the high fecal coliform level was not repetitive. The levels are of concern and noted as such in the 1982 study.

B. <u>1995 Watershed Water Quality Sampling – Wet and Dry Weather</u>

Direct measurements of non-point source pollution inputs to the lakes and streams of the watershed were performed to quantify the amount of pollutants being transported through the watershed. Samples were taken during both dry and wet weather conditions in the Spring and early Summer of 1995, before and after crop planting.

Six graphical representations, one for each parameter, are provided in Appendix C.

The study concluded that:

- Nutrients and suspended solids are generally higher during wet weather events.
- The Dillon Creek South Tributary usually has the highest nutrient and suspended solids concentrations.
- The TSS and phosphorus levels were low when compared to other agricultural waters. Although, the phosphorus levels exceed overall optimal levels while TSS fell below the overall optimal levels.
- Nitrogen levels are unusually high in Dillon Creek Middle and South tributaries when compared to other Indiana streams.

C. 1995 Kosciusko County Health Department Wawasee Lake Study

On July 11, 1995, the Kosciusko County Health Department and the WACF Ecology Committee sampled 31 sites throughout Lake Wawasee. The sites were sampled coinciding with the high recreation traffic from the July 4th holiday. The results, presented in Appendix D, indicated the parameters were generally within acceptable limits. Dissolved oxygen and ammonia were within acceptable ranges while orthophosphate was high at all sites. The main areas of concern were at Enchanted Hills and the Turkey Creek outlet where high nitrite levels were reported. Similarly, Turkey Creek had the highest fecal coliform reading of 150 col/100 mL. The level was within the state standard; however, it was noted that the mouth of Turkey Creek sampling site continues to have consistently high concentrations each time it is sampled.

D. Kosciusko County Stream Monitoring Watershed Study

Within the Kosciusko County Stream Monitoring Watershed Study, three sites at Lake Wawasee were sampled: Turkey Creek at Pickwick Road Bridge, Turkey Creek at the outflow to Lake Wawasee, and Dillon Creek at the outflow to Lake Wawasee. Between the three sites, samples were taken on seven different occasions from November 1996 through May 1998. The results, as presented in Appendix E, indicated that dissolved oxygen, pH, turbidity, and chlorides were within acceptable ranges; E. coli was of concern at the Dillon and Turkey Creek outflows, total phosphorus was high at all three sites, nitrate was high at the Dillon and Turkey Creek outflows, total solids was high at all three sites, ammonia was high at Turkey Creek outflow, and atrazine was detectable at each location tested for pesticides.

E. 1998 E. Coli Testing

WACF provided results for a total of seven data samples that were collected and analyzed for E. coli levels. Turner Technologies took the following samples on August 2, 1998 around 3:00PM:

1) a kitchen tap sample where the water originated from a private well at Pier 759
2) a community access point at the Lilly Property, East
3) a community access point at the Lilly Property, West
4) a community access point at the Lilly Property, Center
5) a community access point at Sandbar 3
6) a community access point at Sandbar 2
7) a community access point at Sandbar 1

All samples measured less than 10 col/100 mL except at the Lilly property, center location where the sample measured 30 col/100 mL. Based upon a satisfactory and unsatisfactory level, all seven samples had test results indicating the samples to be satisfactory. Overall, the public water system reports indicate that E. coli was not of concern

F. Indiana Clean Lakes Program

The Indiana Clean Lakes Program initiated a volunteer monitoring program in 1989 with goals of:

- Identifying long-term water quality trends in lakes
- Involving citizens in the active stewardship of their lakes
- Providing opportunities for citizens to learn more about lakes

Within the monitoring program, secchi depth, phosphorus, and chlorophyll a samples have been taken for Lake Wawasee. The gathered data for Lake Wawasee includes a summary from 1989 to 2003. Generally four to five samples were taken each year for total phosphorus and chlorophyll a while anywhere from 8 to 20 secchi disk reading were taken annually.

In reviewing the reported data, graphical representations, as shown in Appendix F, were formulated to interpret the secchi depth, total phosphorus, and chlorophyll a from 1989 to 2003. The data throughout the years was plotted and trendlines developed. Based upon the developed trendlines:

- Secchi depth, on average, developed a trend of approximately 11.5 feet
- Total phosphorus demonstrates a trend of increasing over the years, originating in 1989 around 7 μg/L (0.007 mg/L) to 17 μg/L (0.017 mg/L) in 2003.
- Chlorophyll a increased throughout the years from approximately 0.3 μg/L (0.0003 mg/L) in 1989 to 1.5 μg/L (0.0015 mg/L) in 2003

Even with total phosphorus and chlorophyll a demonstrating trends of increased levels, the readings are well below the recommended levels of 0.03 mg/L for total phosphorus and 3.4 μg/L for chlorophyll a. The phosphorus and chlorophyll a levels and a consistent secchi disk depth trend of 11.5 feet indicate the health of Lake Wawasee is in excellent condition.

G. Hoosier Riverwatch

Hoosier Riverwatch is a state-sponsored water quality monitoring initiative sponsored by the Indiana Department of Natural Resources, Division of Soil Conservation in cooperation with Purdue University Agronomy Department. The program was started in 1994 to increase public awareness of water quality issues and concerns by training volunteers to monitor stream water quality. Hoosier Riverwatch collaborates with agencies and volunteers to:

- Increase public involvement in water quality issues through hands-on training of volunteers in stream monitoring and cleanup activities.
- Educate local communities about the relationship between land use and water quality
- Provide water quality information to citizens and governmental agencies working to protect Indiana's rivers and streams.

WACF began monitoring the waters within the Lake Wawasee watershed in 2000. WACF monitors, Lake Wawasee, Syracuse Lake, Turkey Creek, Dillon Creek, Knapp Lake, and Harper Lake. WACF is using the standard chemical test procedures to arrive at a final Water Quality Index (WQI).

Hoosier Riverwatch trains volunteers to conduct eight chemical tests for dissolved oxygen, pH, biological oxygen demand (5-day), phosphates, E. coli, water temperature change, nitrates, and turbidity. Each individually measured parameter is ranked as either being poor, fair, good, or excellent. The individual measurements are then used to determine the overall WQI. The WQI ranges from 1 to 4; 1 is poor, 2 is fair, 3 is good, and 4 is excellent.

Data was analyzed from fourteen different locations, eight locations within the vicinity of Lake Wawasee, three surrounding Syracuse Lake, and three to the southeast of Lake Wawasee and Syracuse Lake. The results are presented in Appendix G.

Samples along Lake Wawasee were collected at the Dillon Creek outflow, Main Channel, South Shore outflow, Johnson Bay, Syracuse Dam, South Shore Golf Course storm pipe, and the Turkey Creek outflow. The results indicated the following for the Lake Wawasee sampling locations:

- Fecal coliform levels were occasionally high at Dillon Creek and Turkey Creek outflows
- Turbidity, at times, was high at the South Shore outflow
- Orthophosphate levels were within optimal ranges
- pH was questionable during one sample at the Turkey Creek outflow
- Nitrate was at adequate levels
- Biological oxygen demand was good
- Dissolved oxygen was at times questionable at the Main Channel, Johnson Bay, and the South Shore storm pipe

Overall, the WQI averaged 3.34 for the Lake Wawasee samples. The Main Channel and the Syracuse Lake Dam samples exemplified the best WQI. The storm pipe at the South Shore Condo had the lowest WQI of 2.8.

Syracuse Lake samples were taken at Syracuse Lake, Henry Ward Park and the Maxwelton Golf Course outflow. The results at Syracuse Lake are as follows:

- Fecal coliform levels at one sampling for the Maxwelton Golf Course outflow exceeded state standards
- Turbidity was at adequate levels for all samples
- Orthophosphate was excessive at one of the samples for the Maxwelton Golf Course outflow
- PH levels were good
- Nitrate levels were at adequate levels for all samples
- Biological oxygen demand at the Maxwelton Golf Course outflow was questionable for one sample
- Dissolved oxygen levels were, at times, poor at Syracuse Lake and the Maxwelton Golf Course outflow

Overall, the WQI average for Syracuse Lakes samples was 3.14. The Maxwelton Golf Course outflow had one questionable level on the August 15, 2002 sampling with a WQI of 2.4.

For the area to the southeast of Lake Wawasee and Syracuse Lake, samples were taken at Harper Lake, Knapp Lake, and Little Knapp Lake. The data indicated the following:

- Fecal coliform levels were excessive at Harper and Little Knapp Lakes
- Turbidity was poor at a sample at Little Knapp Lake
- Orthophosphate levels were good for all samples
- PH levels were good for all samples
- Nitrate levels were good for all samples
- Dissolved oxygen samples were generally poor for all three sampling locations

Overall, the WQI for the area to the southeast averaged 3.17. Harper Lake had the lowest WQI reading of 2.83.

Samples for all three areas, Lake Wawasee, Syracuse Lake, and the area to the southeast, indicated that the parameters of concern were the high levels of fecal coliform and turbidity and the low levels of dissolved oxygen. On the other hand, the Hoosier Riverwatch data indicated that nitrate is not a problem for the area. For the fourteen different sampling locations, the WQI average of 3.27 indicated the water quality to be good for the area.

H. Comparison of the Data Sets

In comparing the data from the eight provided sources, data was consistently provided for the Turkey Creek outflow and the Dillon Creek outflow. Dissolved oxygen, fecal coliform, orthophosphate, and total phosphorus were generally measured at these sites throughout the data sets. In comparing the parameters of the two sites, the two sites had similar results as displayed in Appendix H. The dissolved oxygen levels varied throughout the years but all readings were above the optimal level of 5-6 mg/L. Fecal coliform levels were generally high at both sites with the levels exceeding state standards within most recent years. Orthophosphate and total phosphorus levels were always excessive at the two sites.

It should be noted that graphical comparison of the eight data sets was difficult due to different sampling sites and different sampling parameters where a site and/or parameter might not have been measured during all studies. For instance, Rainey Court was sampled in 1971 and during the 1995 Kosciusko County Health Department Study. The two studies both sampled dissolved oxygen and E. coli/fecal coliform but in 1971 nitrate and total phosphorus were sampled while in 1995 nitrite, ammonia, and orthophosphate were sampled. Similarly, the Hoosier Riverwatch data measurements were generally reported as a range of values and not a specific value making it difficult to compare against other data sets.

The inconsistency among the data sets challenges the owner to organize graphical representations for the sites from the 1970s through current. To alleviate inconsistencies in the future, it is recommended that representative sampling sites and parameters become established. For instance, samples have already been concentrated at Odgen Island, Conklin Bay, Marineland Gardens, the Turkey Creek outflow, Turkey Creek at Indian Village, the Dillon Creek outflow, South Shore, Kanata Manayunk, and the Papakeechie outlet. Efforts should be made to continue sampling at such sites to develop trends. Also, parameters such as dissolved oxygen, nitrate, total phosphorus, orthophosphate, and fecal coliform should continue to be sampled.

IV. PROJECT CONCLUSIONS

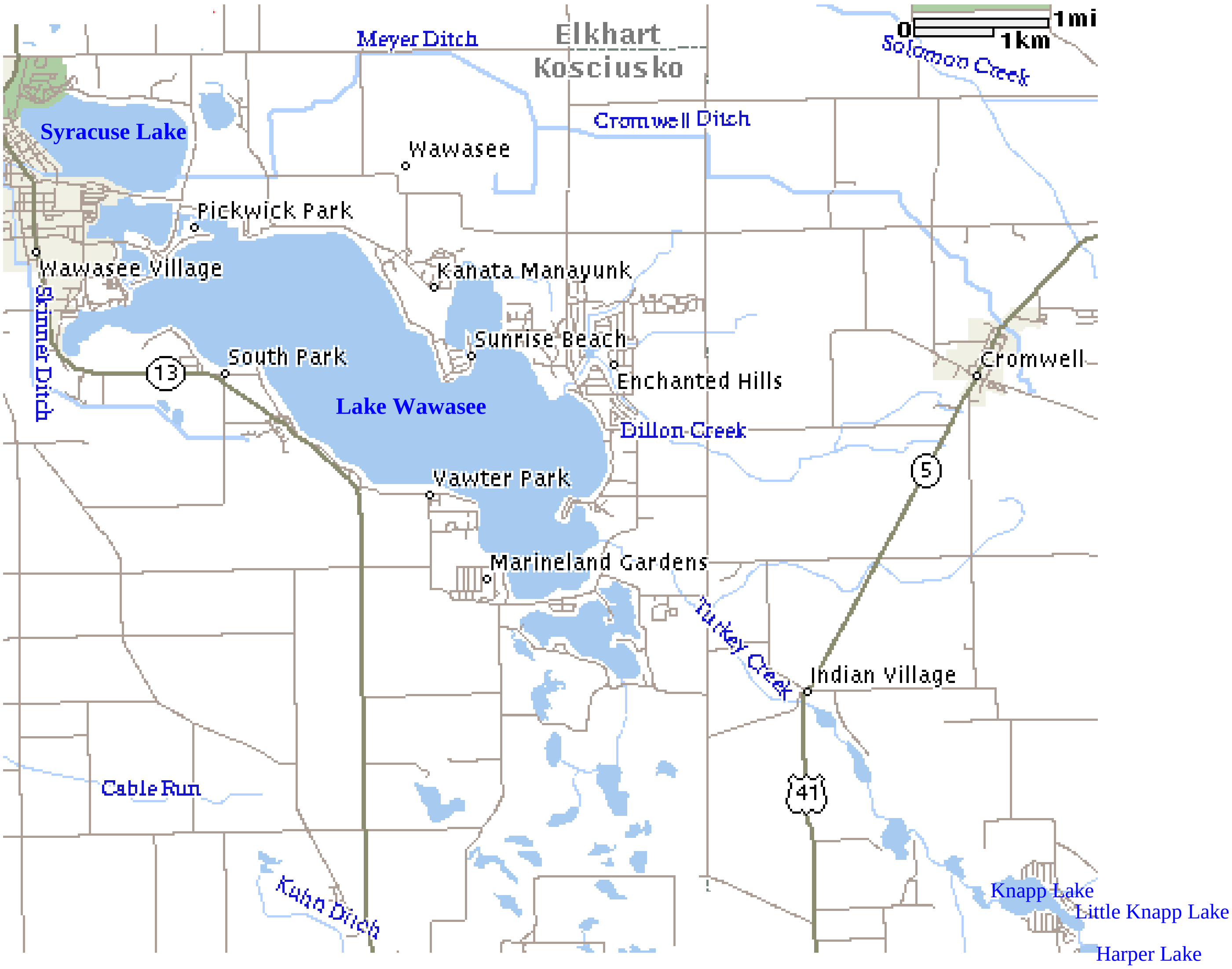
The overall project purpose is to provide a summary of the water quality within the Lake Wawasee watershed. Overall, the analysis indicated the watershed to be of good water quality.

The individual comparisons helped depict which parameters were of concern at a specific time. For instance, in 1971 nitrate was high. In 1982 phosphorus and fecal coliform were high. In the 1995 studies, phosphorus continued to be high as well as E. coli levels. In the 2000s, fecal coliform, turbidity, and dissolved oxygen were of concern. These individual comparisons helped to identify overall trends. Overall, the parameters tend to fluctuate over the years. The Indiana Clean Lakes Program perhaps best explains the overall trend throughout the years. The Indiana Clean Lakes Program data indicates that even though the individual samples fluctuate, the trend is for the overall water quality to be at adequate levels exemplifying good water quality.

APPENDIX A

Area Map


Maxwelton Golf Club
Lakeview Park
Boner Lake
Syracuse
Turkey Creek
Syracuse Lake
Wawasee
Wawasee
Pickwick Park
Wawasee Golf Club
Wawasee Village
Kale Island
Oakwood Park
Kanata Manayunk
Johnson Bay
Sand Point
Black Point
Sunrise Beach
Conklin Bay
South Park
Ogden Island
Enchanted Hills
Lake Wawasee
Cedar Point
Dillon Creek
South Shore Golf Club
Vawter Park
Morrison Island
Turkey Creek
Redmon Park
Marineland Gardens
Wawasee Public Fishing Area
Papakeechie Lake Dam
Wawasee State Fish Hatchery
Papakeechie Lake
Dewart Lake
Musquabuck Park
Quaker Haven Park
Defries Landing
Hammond Lake
Village Lake
Allen Lake
Tri-County State Fish And Game Area
Rothenberger Lake
13
5


Meyer Ditch
Elkhart
Kosciusko
0 1mi
1km
Solomon Creek
Syracuse Lake
Cromwell Ditch
Wawasee
Pickwick Park
Wawasee Village
Kanata Manayunk
Skinner Ditch
Sunrise Beach
13
South Park
Enchanted Hills
Cromwell
Lake Wawasee
Dillon Creek
5
Vawter Park
Marineland Gardens
Turkey Creek
Indian Village
41
Cable Run
Kuhn Ditch
Knapp Lake
Little Knapp Lake
Harper Lake

APPENDIX B

Analysis of the 1970s and 1980s Data

APPENDIX C

Analysis of the 1995 Watershed Water Quality Sampling

APPENDIX D

Analysis of the 1995 Kosciusko County Health Department Wawasee Lake Study

APPENDIX E

Analysis of the Kosciusko County Stream Monitoring Watershed Study

APPENDIX F

Analysis of the Indiana Clean Lakes Program Data

APPENDIX G

Analysis of the Hoosier Riverwatch Data

APPENDIX H

Comparison of the Data Sets