LAKE COUNTY, IL

2016 LAKE CARINA SUMMARY REPORT

LAKE COUNTY HEALTH DEPARTMENT

ECOLOGICAL SERVICES

Lake Carina, 2016

Lake Carina is a 22.7 acre borrow pit lake located entirely within the Lake Carina Forest Preserve along Milwaukee Avenue (IL Hwy 21) south of the intersection with the I-94 toll-way. Lake Carina was constructed as a borrow pit when the highway was developed in 1957. In 2007, development of the forest preserve began with the installation of a parking area, walking trail, and fishing pier.

In 2016, the Lake County Health Department– Ecological Services (LCHD-ES) monitored Lake Carina as part of routine water quality sampling. Two water samples were collected once a month from May through September. Due to Lake Carina's long fetch (longest diagonal distance on a lake) relative to its size, a strong stratification could not be established because of wind action. Lake Carina did weakly stratify in June. Water chemistry can be significantly different between the epilmnion (warm upper layer) and hypolmnion (cool bottom layer) within the lake. Due to Lake Carina's maximum depth and potential for stratification, two water samples were collected at the deepest point in the lake (Appendix A); three feet below the surface and 3 feet above the bottom. Samples were analyzed for nutrients, solid concentrations and other physical parameters. Additionally, an aquatic plant survey was conducted in July (2016) and a shoreline assessment. This report summarizes the water quality sampling results, aquatic plant survey, and shoreline survey conducted on Lake Carina by the LCHD-ES for 2016.

ECOLOGICAL SERVICES WATER QUALITY SPECIALISTS

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LAKE FACTS

MAJOR WATERSHED:

DES PLAINES RIVER

SUB-WATERSHED:

UPPER DES PLAINES

SURFACE AREA:

22.7 ACRES

SHORELINE LENGTH:

0.9 MILES

MAXIMUM DEPTH:

21.0 FEET

AVERAGE DEPTH:

13.68 FEET

LAKE VOLUME:

318.92 ACRE-FEET

WATERSHED AREA:

45.8 ACRES

LAKE TYPE:

BORROW PIT

CURRENT USES:

FISHING, WALKING TRAIL, AESTHETICS

ACCESS:

PUBLIC ACCESS VIA LAKE CARINA FOREST PRESERVE

LAKE CARINA SUMMARY

Following is a summary of the water quality sampling, shoreline survey and aquatic macrophyte survey from the 2016 monitoring season on Lake Carina. Lake Carina is an unusual lake in the county in terms of its trophic status. It is a low nutrient lake and classified as oligotrophic, one of the few in Lake County. The complete data sets can be found in Appendix A & B of this report, and discussed in further detail in the following sections. Included in the Appendix is an "Understanding Your Lake Data" guide that will help with additional questions about water chemistry results.

- Average water clarity as measured by Secchi depth in 2016 was 16.96 ft., which is a 28.4% increase since 2007 (13.21 ft.), and is above the Lake County median Secchi depth of 2.98 ft.
- Water clarity is influenced by the amount of particles in the water column; this is measured by total suspended solids. The average epiliminion TSS concentrations on Lake Carina was <1.4 mg/L in 2016, which is below the Lake County median of 8.2 mg/L and a decrease since 2007.
- Nutrient availability indicated that Lake Carina was phosphorus limited with an average TN:TP ratio of 45:1.
- In 2016, the average total epilimnion phosphorus concentration was 0.011 mg/L. This is below the Illinois Environmental Protection Agency (IEPA) water quality standard of 0.050 mg/L.
- There was a slight increase in Total Phosphorus since 2007. In 2007, all months were below detectable limit and in 2016 all months except September were below the detectable limit for phosphorus.
- Trophic State index (TSIp) value for Lake Carina is 38.7, meaning Lake Carina is oligotrophic—one of the few oligotrophic lakes within Lake County.
- A dissolved oxygen (DO) concentration of 5.0 mg/L is considered adequate to support fisheries and fish can suffer oxygen stress when DO drops below these levels. DO concentrations did not drop below 5 mg/L in the entire lake for all months sampled.
- Dissolved oxygen concentrations did not reach anoxic conditions (<1 mg/L) during the sampling period.
- The aquatic macrophyte survey showed that 88.8% of all sampling sites had plant coverage on Lake Carina.
- In 2016, a total of 7 plant species and 1 macro-algae (Chara) were present in Lake Carina.
- The most dominant aquatic plants in Lake Carina were Chara (a macro-algae), followed by Spiny Naiad.
- Aquatic invasive plant species were present including Curlyleaf Pondweed and Brittle Naiad. While Curlyleaf Pondweed was not observed during our sampling in August, it was noted in May and early season sampling.
- 21% of Lake Carina's shoreline was experiencing some degree of erosion.
- Based on the 2016 shoreline condition survey only 2% of Lake Carina's lakeshore buffer

Lake Carina is in the Upper Des Plaines River Watershed.

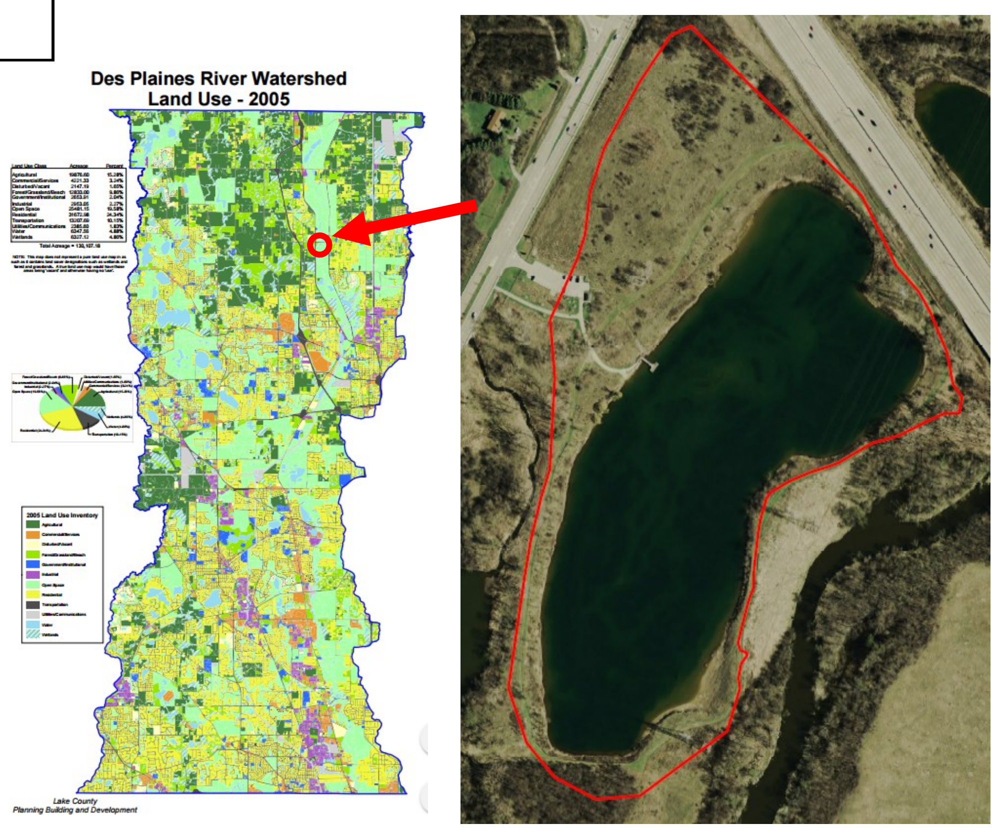
LAKES SAMPLED
Ames Pit
Bresen Lake
Lake Carina
Des Plaines Lake
Duck Lake
Fischer Lake
Fish Lake
Independence Grove
Lochanora Lake
Sterling Lake
Summerhill Lake
Wooster Lake

Watershed & Landuse

A watershed is an area of land where all surface water from rain, melting snow and ice, converge at a lower elevation, usually a lake, river, or other body of water. The source of a lake's water supply is very important in determining its water quality and choosing management practices to protect the lake. Lake Carina's watershed is small, at 45.8 acres and is encompassed within the Lake County Forest Preserve District (Figure 1). The watershed to lake ratio is important in understanding how nutrients enter the lake. Ames lake has a small watershed to lake ratio (2:1), however, once pollutants enter the lake they are retained there for up to 36 years! Therefore it becomes important to properly manage the lands in a way that minimizes pollutants such as phosphorus, nitrogen, and chlorides from entering the lake.

Lake Carina is part of the Des Plaines River Watershed. The Upper Des Plaines River watershed originates in Wisconsin in Racine and Kenosha counties and then flows south. The Upper Des Plaines River Watershed is approximately 307,000 acres or 480 square miles. 346 square miles are within the Illinois border. Lake County Stormwater Management Commission is developing a watershed-based plan for the entire Des Plaines River Watershed in Lake County as part of an IL EPA grant from its Section 319 Voluntary Nonpoint Source Pollution Reduction Program. The Des Plaines River is identified as an impaired waterbody by IL EPA and the watershed plan will address nonpoint source pollution, providing priority action items and projects to improve water quality. For more information or to become involved with stakeholder input as the watershed plan is being developed, please visit: https://www.lakecountyil.gov/2387/Des-Plaines-River-Watershed-Plan.

Figure 1: Lake Carina Watershed Delineation



Everyone lives in a watershed! A watershed is an area of land where surface water from rain and melting snow meet at a point, such as a lake or stream.

As a watershed is developed, the amount of impervious surface increases resulting in a greater influx of runoff entering our waters due to reduced infiltration of rainwater into the ground.

WATERSHED & LANDUSE (CONT.)

Land use plays a significant role on water quality of a lake. Based on aerial landuse data, the dominant landuse in the Lake Carina watershed are: Water (Lake Carina itself) at 55% of the watershed followed by Public Open Space (36%) (Figure 2, Table 1). As areas become more developed, that typically means an increase in impervious surfaces, reducing the amount of open space for infiltrating and storing precipitation. Each land use contributes a varied amount of runoff, mostly based on the amount of impervious surfaces within that landuse category. Impervious surfaces (parking lots, roads, buildings, compacted soil) impact water quality in lakes by increasing pollutant loads and water temperature. During storm events, pollutants such as excess nutrients (nitrogen and phosphorus), metals, oil and grease, and bacteria are easily transferred from impervious surfaces to storm drains, rivers, wetlands, and lakes.

Lake Carina receives the majority of it's runoff from the Public Open Space at 68% of the runoff coming from this category. It's important to note that landuses with high impervious surfaces, such as the Utility and Wastewater landuse category, can contribute a high percentage of runoff even if they are a small fraction of the overall landuse. For instance, in the Lake Carina watershed, the "Utilities" landuse only accounts for 8% of the total watershed but contributes 31% of the runoff. Lakes that receive a significant amount of stormwater runoff can have variable water quality that is heavily influenced by human activity. It's also important to note that while other landuses may contribute a smaller percentage of runoff, they can still deliver high concentrations of total suspended solids and total phosphorus (Appendix B).

Figure 2: Landuse in the Lake Carina Watershed

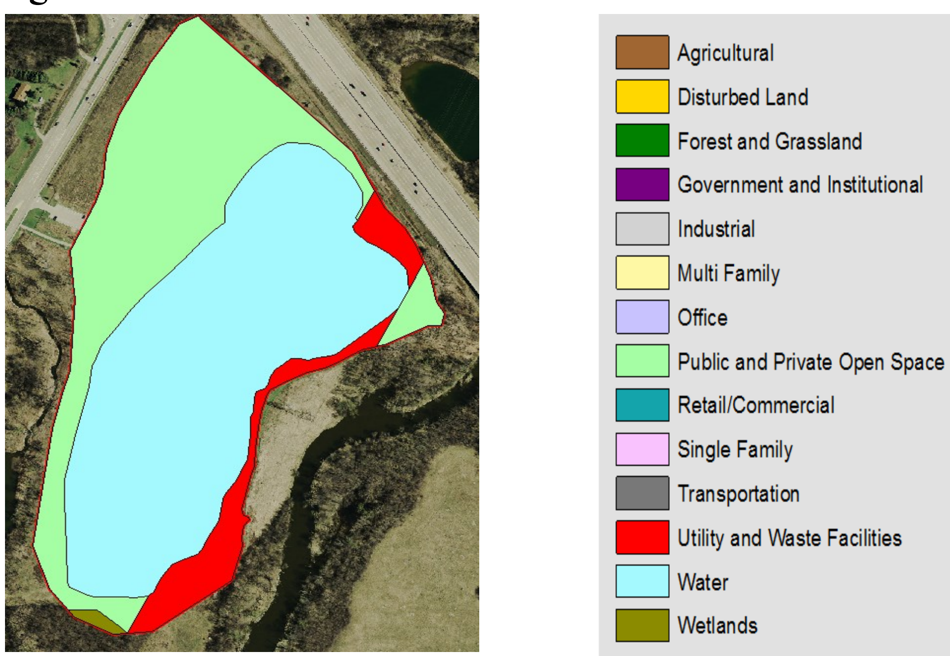


Table 1: Runoff Percentages by Landuse in the Lake Carina Watershed

Land Use	Acreage	% of Total	% Total of Estimated Runoff
Public and Private Open Space	14.65	35.83%	68.28%
Utility and Waste Facilities	3.37	8.24%	31.42%
Water	22.68	55.47%	0.00%
Wetlands	0.19	0.47%	0.30%
TOTAL	**40.89**	**100%**	100.00%

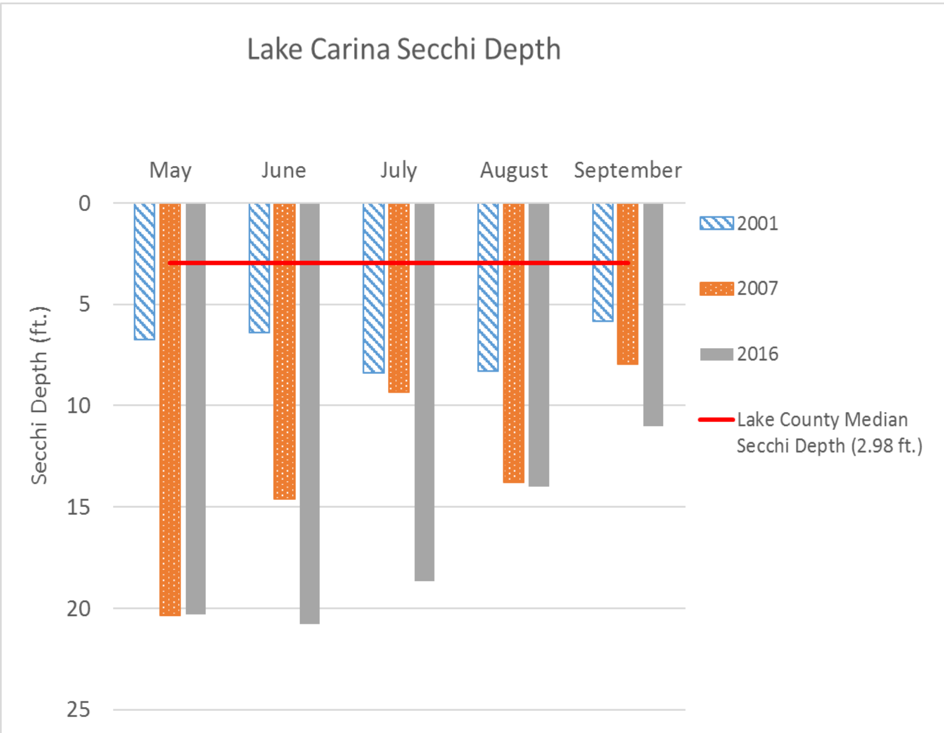
WATER CLARITY

Water clarity, or water transparency, is an indicator of water quality related to chemical and physical properties. Water clarity is typically measured with a Secchi disk and indicates the amount of light penetration into a body of water. It can also provide an indirect measurement of the amount of suspended material in the water. A number of factors can interfere with light penetration and reduce water clarity. This includes: algae, water color, re-suspended bottom sediments, eroded soil and invasive species. Boat propellers can also impact water clarity by redistributing loose bottom sediment and creating more turbid waters. Secchi disk depth is primarily used as an indicator of algal abundance and general lake productivity. Although it is only an indicator, Secchi disk depth is the simplest and one of the most effective tools for estimating a lake's productivity.

The 2016 average water clarity in Lake Carina, based on Secchi depth, was 16.96 ft. This is a 28.4% increase since the 2007 water quality sampling, which had a Secchi depth of 13.21 ft. Compared to other lakes in Lake County, Lake Carina is well above the median Lake County Secchi depth of 2.98 ft. Lake Carina is considered a borrow pit and these types of lakes typically have higher water clarity and lower nutrient levels then other lakes in the county. As seen in Figure 3, Secchi depth on Lake Carina has increased since the lake had started being sampled by LCHD in 2001 meaning overall water clarity is improving. Lake Carina had exceptionally clear water clarity, with secchi disk readings reaching the bottom in May.

Lake Carina Secchi depth was 16.96 ft., which is above the Lake County median Secchi depth of 2.98 ft.

Figure 3: Lake Carina Secchi depth by Year



WHAT YOU CAN DO TO IMPROVE WATER QUALITY ON AMES PIT?

- Do not throw leaves, grass clippings, pet waste, and other organic debris into the street or driveway. Runoff carries these through storm sewers, directly into Ames Pit Lake.
- If fishing in Lake Carina, please dispose of your trash properly.
- Build a rain garden to filter run-off from roofs, driveways, and streets. This allows the phosphorus to be bound to the soil so it does not reach surface waters.

VOLUNTEER LAKE MONITORING PROGRAM (VLMP)

The VLMP was established in 1981 by the Illinois Environmental Protection Agency (IEPA) to be able to collect information on Illinois inland lakes, and to provide an educational program for citizens. The volunteers are primarily lakeshore residents, lake owners/managers, members of environmental groups, and citizens with interest in a particular lake.

The VLMP relies on volunteers to gather information on their chosen lake. The primary measurement by volunteers is Secchi depth (water clarity). Water clarity can provide an indication of the general water quality of the lake. Other observations such as water color, suspended algae and sediment, aquatic plants and odor are also recorded. The sampling season is May through October with measurements taken twice a month.

Lake Carina has not participated in the VLMP program. Participating provides annual data that helps document water quality impacts and support lake management decisions. **LCHD recommends that the Lake County Forest Preserve consider participating in VLMP Program or encourage volunteers of the LCFPD to participate.** This will provide valuable data for the lake as it provides annual data and can help look at long term trends.

LAKE MONITORING VOLUNTEER PROGRAM ILLINOIS

For more information visit:

www.epa.state.il.us/water/vlmp/index.html

FOR MORE INFORMATION ON THE VLMP PROGRAM

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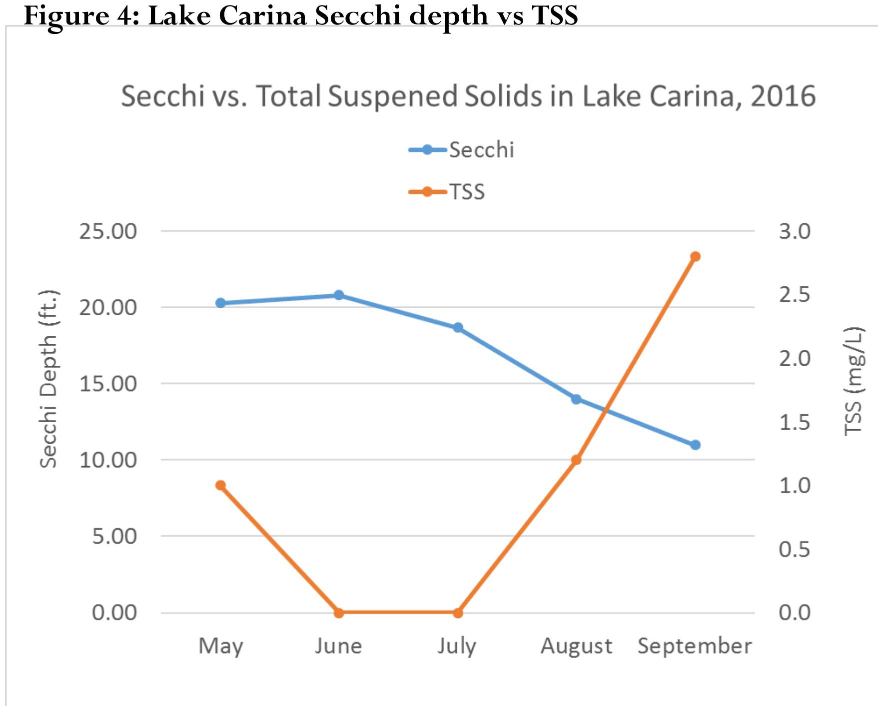
TOTAL SUSPENDED SOLIDS

Another measure of water clarity is turbidity and total suspended solids. Suspended particles dissipate light, which affects the depth at which plants can grow. The total suspended solid (TSS) parameter represents the concentration of all organic and inorganic materials suspended in the lake's water column, which includes both sediment and algal cells. Typical inorganic components of TSS are referred to as non-volatile suspended solids (NVSS). NVSS originate from weathering and erosion of rocks and soils in the lake's watershed and re-suspension of lake sediments. The organic portion of TSS are called volatile suspended solids (TVS). TVS is mostly composed of algae and other organic matter such as decaying plant and animal matter. Secchi depth and TSS are inversely related as shown in Figure 4.

Figure 4: Lake Carina Secchi depth vs TSS

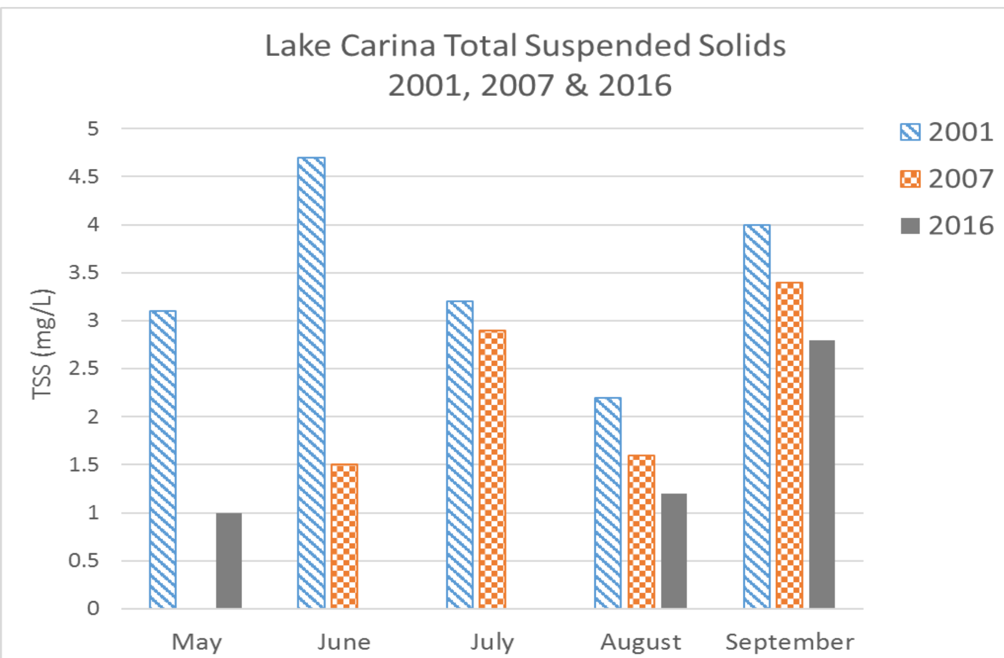


TOTAL SUSPENDED SOLIDS

2016 TSS concentrations in the epilimnion of Lake Carina averaged 1.4 mg/L. The 2016 concentration is a decrease in TSS since the 2007 sampling and is below the Lake County median of 7.8 mg/L (Figure 5). TSS ranged from non detectable to it's highest concentration of 2.8 mg/L, which occurred in September. High TSS values correlated with decrease in water clarity (Secchi disk depth) and can be detrimental to many aspects of lake ecosystem including the plant and fish communities (Figure 4, pg. 6). Algae blooms were noted in August and September in Lake Carina and these are the month's with the highest TSS concentrations throughout the monitoring season. The hypolimnetic TSS concentration averaged 1.7 mg/L which is also a decrease since the 2007 sampling concentration of 2.5 mg/L.

A lake can have a TSS impairment which is based on if the median surface NVSS is greater or equal to 12 mg/L for the monitoring season. Based on the 2016 sampling data, median surface NVSS was <1.0 mg/L, thus there is no TSS impairment.

Figure 5: Total Suspended Solid Concentrations in Lake Carina



DATE	DEPTH (ft.)	TSS (mg/L)	TS (mg/L)	TVS (mg/L)
5/17/16	3	1.0	792	131
6/14/2016	3	<1.0	796	154
7/12/2016	3	<1.0	784	129
8/16/2016	3	1.2	823	156
9/13/2016	3	2.8	791	121
Average		*1.4[k]*	*797*	*138*

TSS

Total Suspended Solids

TSS are particles of algae or sediment suspended in the water column.

TVS

Total Volatile Solids

TVS represents the fraction of total solids that are organic in nature, such as algae cells.

NVSS

Non-Volatile Suspended Solids

NVSS represents the non-organic clay and sediments that are suspended in the water column.

TDS

Total Dissolved Solids

TDS are the amount of dissolved substance such as salts or minerals in the water after evaporation.

NUTRIENTS: PHOSPHORUS

Organisms take nutrients in from their environment. In a lake, the primary nutrients needed for aquatic plant and algal growth are phosphorus (P) and nitrogen (N). Phosphorus occurs in dissolved organic and inorganic forms or attached to sediment particles. Phosphates, the inorganic form, are preferred for plant growth but other forms can be used. Phosphorus builds up in the sediments of a lake. The source of phosphorus to a lake can be external, internal, or both. Phosphorus originates from a variety of external sources, many of which are related to human activities including: human and animal waste, soil erosion, detergents, sewage treatment plants, septic systems, and runoff from lawns. Internal sources of phosphorus originate within the lake and are typically linked to the lake sediment. When phosphorus is bound to sediments it is generally not available for use by algae, however, various chemical and biological processes can allow phosphorus to be released from the sediment and be available in the water column. Carp spawning and feeding activity can release phosphorus by stirring up the bottom sediment and can add phosphorus through their fecal matter. Sediment resuspension and subsequent phosphorus release can occur through wind/wave action or heavy boat traffic. Lakes that experience anoxic conditions also contribute to the release of P from the bottom sediments. Lake Carina did not have anoxic conditions occur throughout the monitoring season.

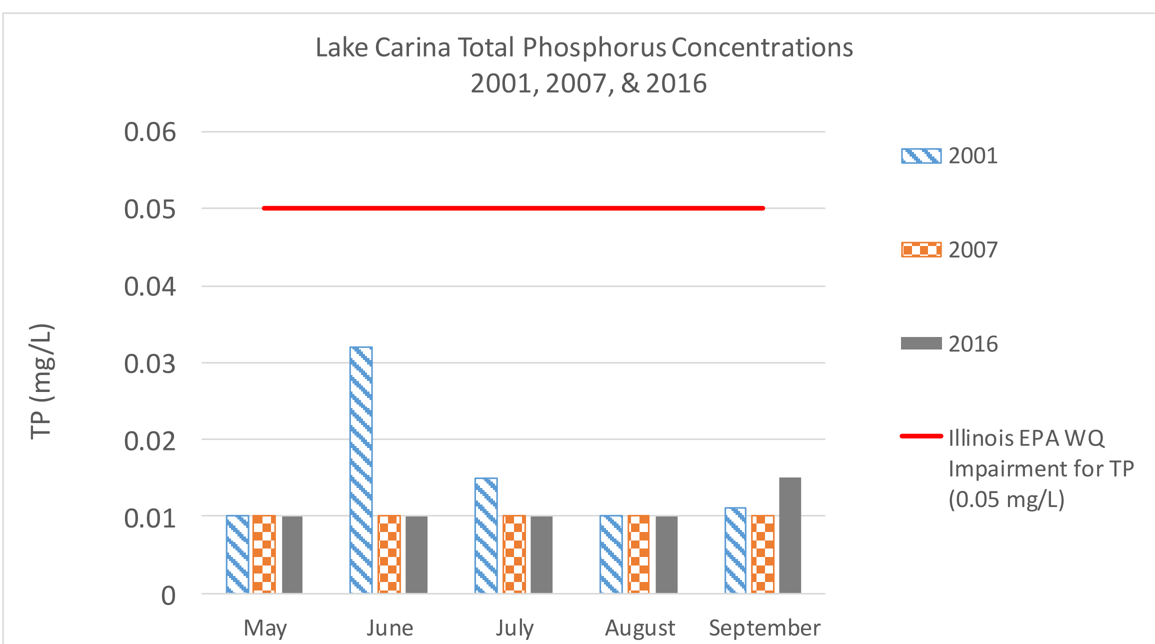
Overall, Lake Carina has relatively low TP concentrations due to its origin as a borrow pit. It has minimal build up of bottom sediment, which reduces the amount of nutrients built up in sediments available to be resuspended. It also has a relatively small watershed. The average total phosphorus concentrations in the epilimnion of Lake Carina were below the detection limit for all months except for September; when it was slightly above the detection limit at 0.015 mg/L. This is well below the Lake County Median TP concentration of 0.067 mg/L and below the IEPA water quality standard of 0.050 mg/L. TP concentrations have remained fairly stable since the 2001 and 2007 monitoring by LCHD (Figure 6), which is expected for a borrow pit and small watershed lake. The low levels of phosphorus along with a healthy plant community keep algae growth to a minimum.

WHAT HAS BEEN DONE TO REDUCE PHOSPHORUS LEVELS IN ILLINOIS?

July 2010—*The state of Illinois passed a law to reduce the amount of phosphorus content in dishwashing and laundry detergent*

July 2010: *The state of Illinois passed another law restricting the use of lawn fertilizers containing phosphorus by commercial applicators.*

Figure 6: Phosphorus Concentrations in Lake Carina monitored by LCHD

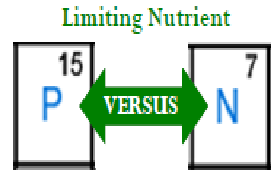


NUTRIENTS: NITROGEN

Nitrogen, in the forms of nitrate (NO_3^-), nitrite (NO_2^-), or ammonium (NH_4^+) is a nutrient needed for plant and algal growth. Nitrogen enters the ecosystem in a several chemical forms and a lake's nitrogen source can vary widely. Sources of nitrogen include septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, and sanitary landfills, and atmospheric deposition. All inorganic forms of nitrogen (NO3-, NO2-, and NH4+) can be used by aquatic plants and algae. If these inorganic forms exceed 0.3 mg/L, there is sufficient nitrogen to support summer algae blooms. If the surface median total nitrogen as N (TKN + NO2/NO3-N) exceeds 3.6 mg/L for the monitoring season, there is a nitrogen impairment for the water body.

Nitrogen concentrations (NO3-N and NH3-N) in the epilimnion of Lake Carina were below detectable concentrations for the entire monitoring season. There were no nitrogen impairments for Ames Pit. Total Kjeldahl nitrogen (TKN), an organically (algae) associated form of nitrogen, in Lake Carina averaged 0.397 mg/L, which is significantly lower than the Lake County median of 1.170 mg/L. Total Kjeldahl nitrogen is a measure of organic nitrogen, and is typically bound up in algal and plant cells.

Typically lakes are either phosphorus or nitrogen limited. This means that one of the nutrients is in short supply and any addition of that nutrient to the lake will result in an increase of plant and/or algal growth. Most lakes in Lake County are phosphorus limited. To compare the availability of nitrogen and phosphorus, a ratio of total nitrogen to total phosphorus (TN:TP) is used. Ratios less than 10:1 suggest the lake is limited by nitrogen, while ratios greater than 20:1 are limited by phosphorus. Lake Carina has a TN:TP ratio of 45:1, meaning the lake is phosphorus limited and additions of phosphorus into the lake system can contribute to algae issues. In 2007, the TN:TP ratio was 55:1.



TN:TP Ratio

<10:1 = nitrogen limited

>20:1= phosphorus limited

TN:TP Ratio on Lake Carina:

45:1

Lake Carina is Phosphorus Limited

WAYS TO REDUCE NUTRIENTS IN YOUR LAKE

Waterfowl management (ducks and geese)

- Do not feed or encourage others to feed waterfowl
- Use good landscaping practices to discourage waterfowl. Landscapes with taller plants and shrubbery can discourage geese.

Fertilizer use:

- If you apply fertilizers to lawns and gardens, have your soil tested to determine how much fertilizer to apply.
- Check the weather before applying fertilizer—avoid applying before heavy rainfalls.
- Sweep up any fertilizer which is spilled on impervious surfaces such as walks and driveways.
- Do not spread fertilizer within 75 feet of surface waters or wetlands

Pet Waste Disposal

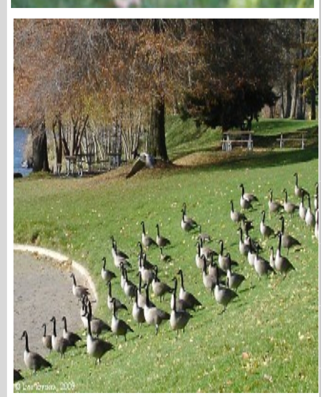
- Regularly scoop up and dispose of pest waste.

Landscaping Practices

- Consider native vegetation as a quality alternative to lawns. Native vegetation provides a more diverse plant community, and can filter out nutrients and also provides habitat for important pollinators.
- Plant a buffer strip of native plants (at least 20 feet) between the lake's edge and your property.

Keep fall leaves out of the storm drains

- Never rake leaves into or near storm drains, ditches, creeks, or on lakeshore.



TROPHIC STATE INDEX

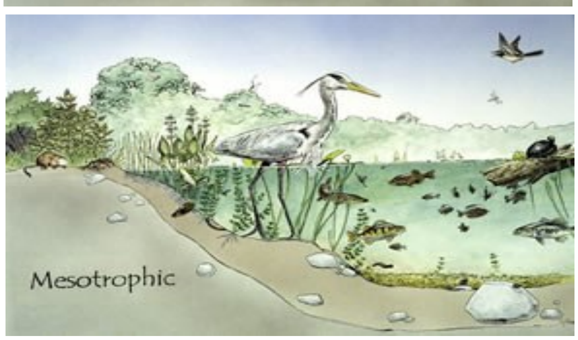
Trophic state describes the overall productivity of a lake and refers to the amount of nutrient enrichment within a lake system. This has implications for the biological, chemical and physical conditions of the lake. Lakes are classified into four main categories of trophic states that reflect nutrient levels and productivity. The four categories are: oligotrophic, mesotrophic, eutrophic, and hypereutrophic. These range from nutrient poor and least productive (oligotrophic) to most nutrient rich and most productive (eutrophic). Eutrophication is a natural process where lakes become increasingly enriched with nutrients. Lakes start out with clear water and few aquatic plants and over time become more enriched with nutrients and vegetation until the lake becomes a wetland. This process takes thousands of years. However, human activities that supply lakes with additional phosphorus and nitrogen (such as fertilizer, household products, waste by-products, etc.) are accelerating the eutrophication process.

The categorization of a lake into a certain trophic state should not be viewed as a "good to bad" categorization, as most lake residents rate their lake based on desired usage. For example, a fisherman would consider a plant-dominated, clear lake to be desirable, while a water-skier might prefer a turbid lake devoid of plants. Most lakes in Lake County are eutrophic or hypereutrophic. This is primarily as a result of cultural eutrophication. However, due to the fertile soil in this area, many lakes (especially man-made) may have started out under eutrophic conditions and will never attain even mesotrophic conditions, regardless of management options. This is not an excuse to allow a lake to continue to deteriorate, but may serve as a reality check for lake owners attempting to create unrealistic conditions in their lakes.

The Trophic State Index (TSI) value is based on phosphorus (TSIp) and Secchi (TSIsd) and are calculated from the monitoring data. A lake's response to additional phosphorus is an accelerated rate of eutrophication. In 2016, Lake Carina had a TSIp value of 38.7 which categorizes it as oligotrophic. Most borrow pits have lower nutrient enrichment and tend to be mesotrophic or oligotrophic. Based on the TSIp, Lake Carina is ranked 2nd out of 175 lakes studied by the LCHD-ES from 2000 –2016 (Appendix B).

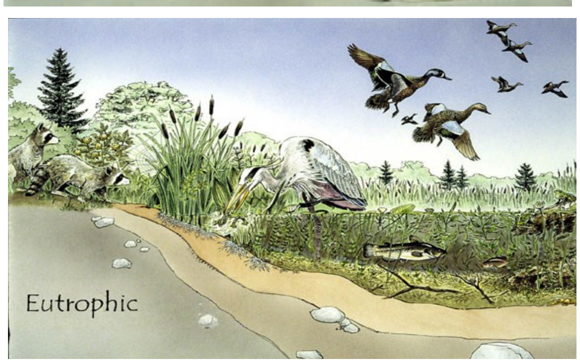
OLIGOTROPHIC

Lakes have low nutrients and are generally deep and free of weeds or large algae blooms. They do not support large fish populations.



MESOTROPHIC

Lakes have medium nutrients and intermediate level of productivity. Mesotrophic lakes typically have clear water with beds of submerged aquatic plants. Mesotrophic lakes can have a diverse fish population.



EUTROPHIC

Lakes are high in nutrients, and are usually weedy or subject to frequent algae blooms. Eutrophic lakes often support large fish populations but are also susceptible to oxygen depletion. Increased sedimentation also is typical of eutrophic lakes

LAKE COUNTY AVERAGE
TSIP = 66.1

LAKE CARINA
TSIP = 38.7

TROPHIC STATE:
OLIGOTROPHIC

RANK= 2/175

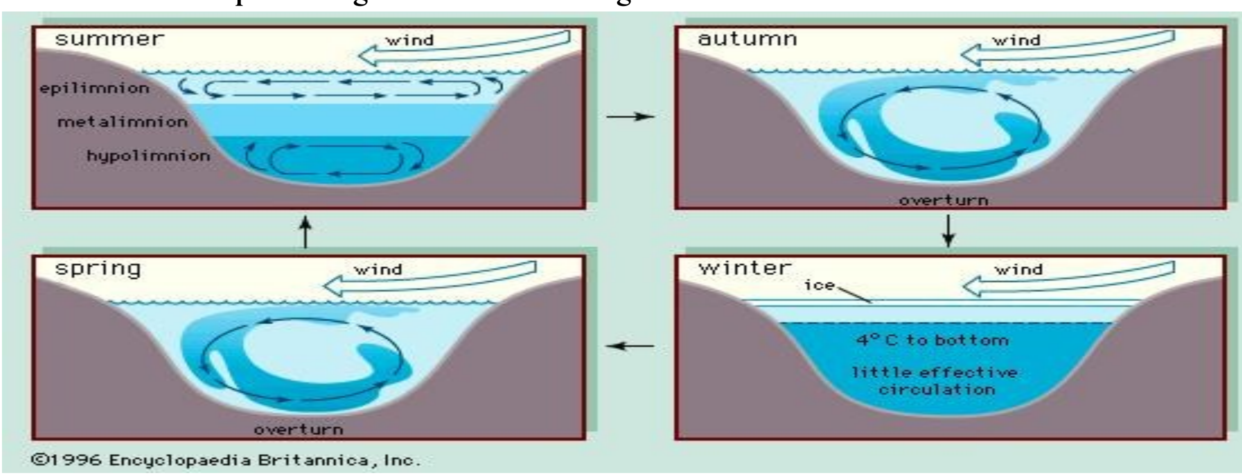
STRATIFICATION

A lake's water quality and ability to support fish are affected by the extent to which the water mixes. The depth, size, and shape of a lake are the most important factors influencing mixing, but climate, lakeshore topography, inflow from streams and vegetation also play a role. Variations in density caused by different temperatures can prevent warm and cold water from mixing, called stratification.

For example: when lake ice melts in early spring, the temperature and density of lake water will be similar from top to bottom. Since it is uniform throughout the water column, the lake can mix completely recharging the bottom water with oxygen and bringing nutrients up to the surface. Some lakes in summer experience stratification where the lake is dividing into three zones: epilimnion (warm surface layer), thermocline (transition zone between warm and cold water) and hypoliminion (cold bottom water). Stratification traps nutrients released from bottom sediments in the hypoliminion and prevents mixing (Figure 7).

Monthly depth profiles of water temperature, dissolved oxygen, conductivity, and pH every foot from the lake surface to the lake bottom on Lake Carina. The relative thermal resistance to mixing (RTRM) value can be calculated from this data and indicates if a lake stratifies, how great the stratification is, and at what depth the thermocline occurs. Values greater than 20 RTRM indicate stratification. Lake Carina only displayed a weak stratification in June (Figure 8), meaning the water chemistry and water column within Lake Carina was fairly well mixed throughout the entire season. Lake Carina's long fetch (longest diagonal distance on a lake), wind prevents a strong stratification to occur.

Figure 7: Schematic representing seasonal lake mixing and stratification



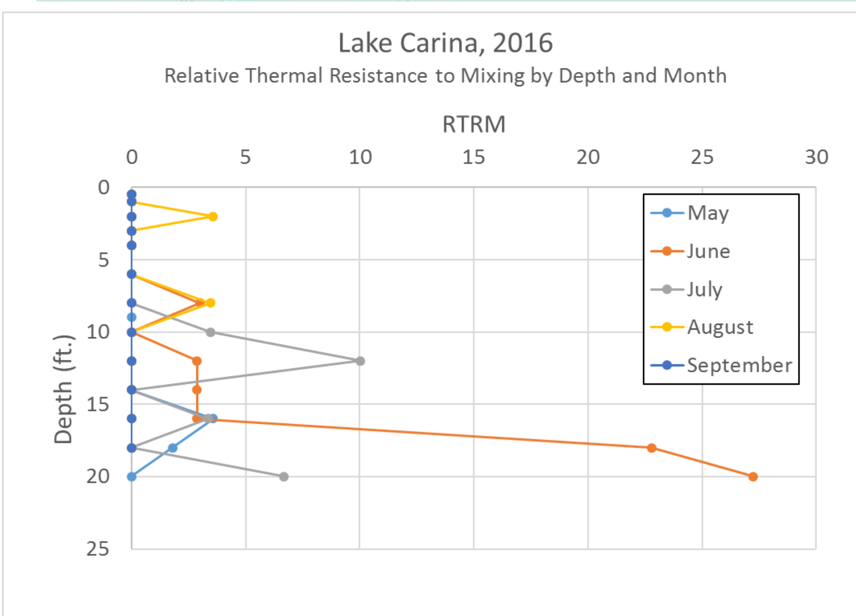


Figure 8: RTRM based on depth profile data in Lake Carina for 2016. Values greater than 20 RTRM indicate stratification.

DISSOLVED OXYGEN

A dissolved oxygen (DO) concentration of 5.0 mg/L is considered adequate to support a fishery since fish can suffer oxygen stress below this concentration. Dissolved oxygen (DO) concentrations in the water column of Lake Carina were adequate (>5.0 mg/L). Since Lake Carina did not stratify, water chemistry remained fairly constant throughout the water column as seen in the dissolved oxygen depth profile (Figure 9).

Anoxic conditions, where DO concentrations are <1 mg/L, did not occur in Lake Carina. Typically in deeper, thermally stratified lakes, oxygen production is greatest in the epiliminion, where sunlight drives photosynthesis, and oxygen consumption is greatest near the bottom of a lake, where organic matter accumulates and decomposes. The oxygen difference between the top and bottom water layers can be dramatic, with plenty of oxygen near the surface, but practically none near the bottom. This is important because the absence of oxygen (anoxia) near the lake bottom can have adverse effects in eutrophic lakes resulting in the chemical release of phosphorus from lake sediment and the production of hydrogen sulfide (rotten egg smell) and other gases in the bottom waters (Figure 10). Low oxygen conditions in the upper water of a lake can also be problematic since all aquatic organisms need oxygen to live. Lake Carina did not have any dissolved oxygen problems throughout the season.

Figure 9: The dissolved oxygen depth profile on Lake Carina shows that DO concentrations remain above 5 mg/L throughout the monitoring season.

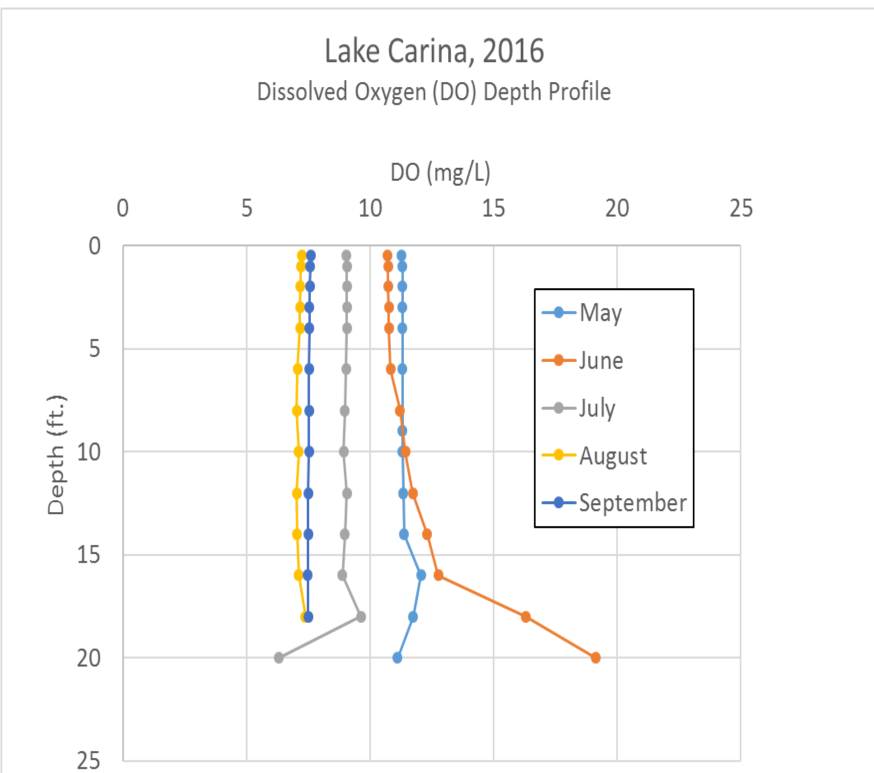
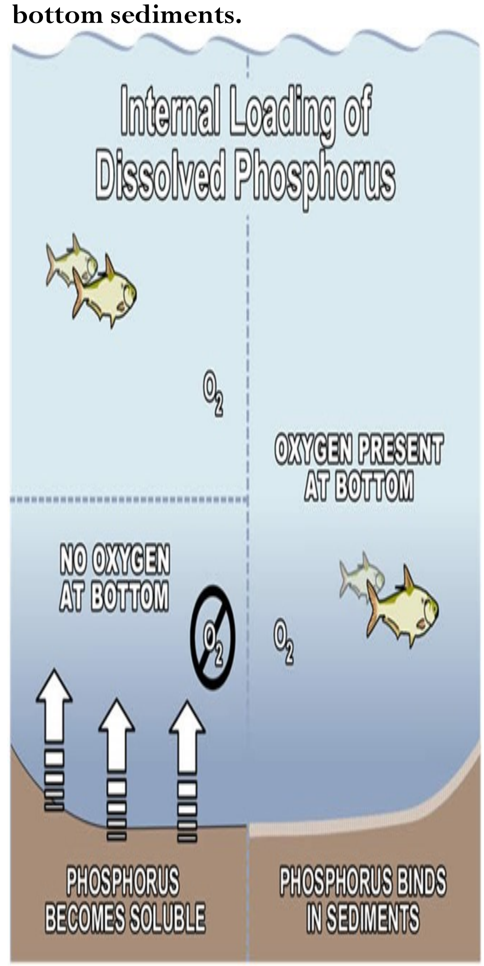


Figure 10: Schematic of how oxygen near the bottom of the lake and can impact phosphorus release from bottom sediments.



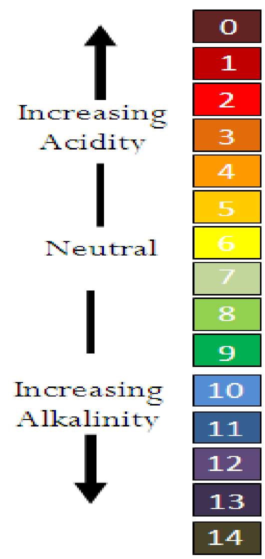
ALKALINITY AND PH

Alkalinity is the buffering capacity of a water body. It measures the ability of water bodies to neutralize acids and bases to maintain a stable pH. In a lake, alkalinity acts to buffer lakes from the effects of acid rain. Alkalinity comes from rocks, soils, salts, and certain plant activities. If a lakes watershed contains large quantities of calcium carbonate (CaCO3, limestone), the surface waters tend to be more alkaline; while granite bedrock does not have high amounts of CaCO3 and therefore lacks alkaline materials to buffer acidic inputs.

pH is a measure of the hydrogen ion concentration of water. As the hydrogen ions are removed, pH increases. A well buffered lake also means that daily fluctuations of CO2 concentrations result in only minor changes in pH throughout the day. Aquatic organisms benefit from stable pH. Each organism has an ideal pH threshold, but most aquatic organisms prefer pH of 6.5—8.0. pH values <6.5 or >9.0 cause a water quality impairment.

In 2016, the average alkalinity (CaCO3) concentration in Lake Carina was 133 mg/L which is below the Lake County median alkalinity concentration of 162 mg/L. The USEPA considers lakes with CaCO3 concentrations greater than 20 mg/L to not be sensitive to acidification.

Ames Pit average pH in 2016 was 8.44 for the entire season, which is above the Lake County median of 8.32. It remains within an adequate pH value for most aquatic organisms and there were no pH impairments for Lake Carina.

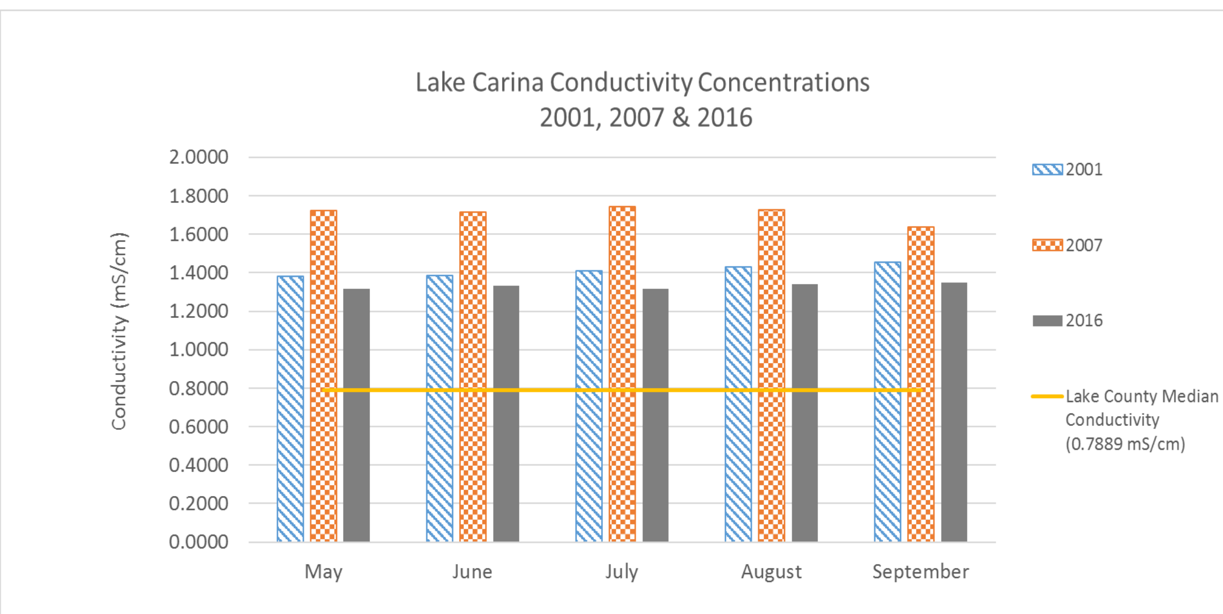


The pH scale ranges from 0 to 14. A pH of 7 is considered neutral. Substances with a pH of less than 7 are acidic, and greater than 7 are basic.

CONDUCTIVITY

Another parameter measured during the 2016 monitoring season is conductivity. Conductivity is the measure of different chemical ions in solution. As the concentration of these ions increases, conductivity increases. The conductivity of a lake is dependent on the lake and watershed geology, size of the watershed flowing into the lake, land use, evaporation, and bacterial activity. Conductivity in urban areas has been shown to be highly correlated with chloride ions found in road salt mixes. In 2016, Lake Carina's average conductivity concentration was 1.3312 mS/cm. This just under double the Lake County median conductivity concentration of 0.7889 mS/cm. This value is a decrease since the 2007 and 2001 concentrations (Figure 11).

Figure 11: Conductivity Concentrations in Lake Carina

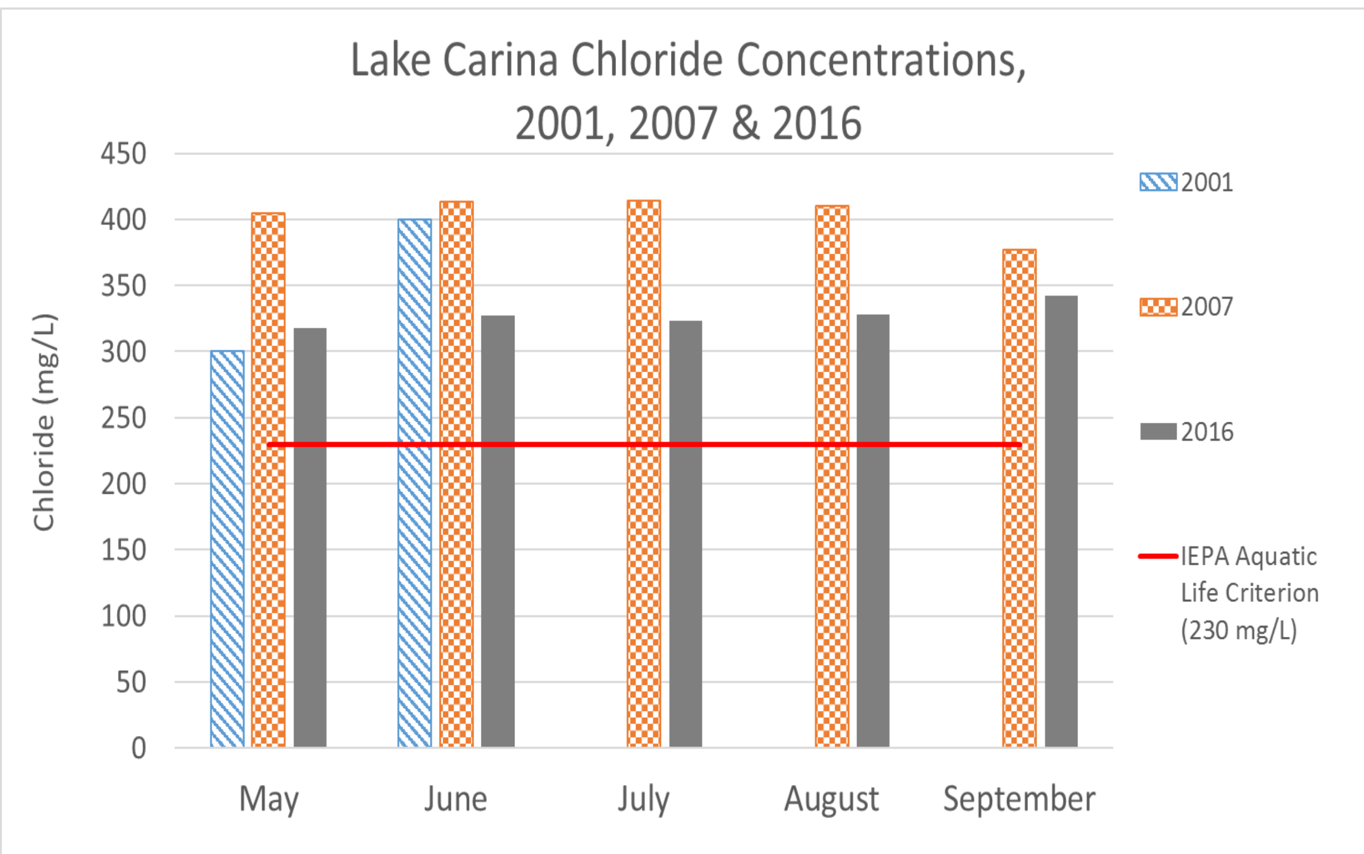


CHLORIDES

One of the most common dissolved solids is road salt used in winter road deicing. Most road salt is sodium chloride, calcium chloride, potassium chloride, magnesium chloride or ferrocynaide salts. Lake Carina's chloride concentration averaged 328 mg/L which is above the Lake County median of 127 mg/L (Figure 12). The United States Environmental Protection agency has determined that chloride concentrations higher than 230 mg/L can disrupt aquatic systems. Chloride ions do not break down and accumulate within a watershed. High chloride concentrations may make it difficult for many of our native plant species to survive while many of our invasive species such as Eurasian Watermilfoil, Cattail, and Common Reed are tolerant to high chloride levels. Chloride concentrations did decreases since the 2007 and 2001 sampling but still remain above the 230 mg/L recommendation by IL EPA.

The LCHD-ES and Lake County Stormwater Management Commission (LCSMC) have been holding annual trainings targeting deicing maintenance personnel for both public and private entities to hopefully reduce the amount of chloride being introduced into our environment while maintaining safe passageways. Almost all deicing products contain chloride so it is important to read an follow product labels for proper application. For instance, at 10F Fahrenheit, rock salt is not at all effective in melting ice and will blow away before it melts anything. Additionally calling your local township office to ask them if they are taking actions to minimize deicers on their properties or supporting changes in their deicing policy to minimize salt usage is encouraged. Unfortunately, Lake Carina is located directly off a major road which can contribute to the high chloride levels.

Figure 12: Lake Carina Chloride Concentrations



CHLORIDES & DE-ICING FACTS

ICE FACTS

- Deicers melt snow and ice. They provide no traction on top of snow and ice.
- Anti-icing prevents the bond from forming between pavement and ice.
- De-icing works best if you plow/shovel before applying material.
- Pick the right material for the pavement temperatures.
- Sand only works on top of snow as traction. It provides no melting.
- Anti-icing chemicals must be applied prior to snow fall.
- NaCl (Road Salt) does not work on cold days, less than 15° F.
- NaCl is more effective at warmer temperatures—when it is warmer out, you do not need to put as much road salt down to melt ice efficiently.

THE CRITICAL VALUE FOR CHLORIDES IN AQUATIC SYSTEMS IS 230 MG/L.

230 mg/L = 1 teaspoon of salt added to 5 gallons of water.

LAKE LEVELS AND PRECIPITATION

Lakes with stable water levels potentially have less shoreline erosion problems. . The lake level in Lake Carina was measured off of the inside post of the fishing pier. The lake level decreased from May through September by 25.08 inches (2.0 ft.). The most significant water level fluctuation occurred between July and August where the lake level decreased by 17.04 inches (1.42 ft.).

In order to accurately monitor water levels it is recommended that a staff gauge be installed and levels measured and recorded frequently (daily or weekly). The data provides lake managers a much better idea of lake level fluctuations relative to rainfall events and can aid in future decisions regarding lake level. A staff gauge is a great tool for measuring water level in lakes, rivers, reservoirs. The data collected can be compiled to help understand the natural fluctuations of the lake. Lakes with fluctuating water levels potentially have poorer water quality and have more shoreline erosion problems.

EXAMPLE OF A PERMANENT STAFF GAUGE

Rainfall information is also important for understanding lake water quality, as large rainstorm events can carry in pollutants, sediments, and affect water quality. Lake County Stormwater Management Commission has a number of rain gauges throughout the County. Based on the Libertyville rain gauge stations, below are rainfall totals for the monitoring season.

Level (in)	Seasonal Change (in)	Monthly Change (in)	Precipitation (in)
12.1			4.6
12.0	-0.12	-0.12	3.13
19.0	6.84	6.96	4.26
36.0	23.88	17.04	2.89
37.2	25.08	1.2	1.94

HARMFUL ALGAL BLOOMS

Algae are important to freshwater ecosystems and most species of algae are not harmful. Algae can grow quickly in water and is often associated with increased concentrations of nutrients such as nitrogen and phosphorus. Harmful algal blooms (HABs), also known as Blue-green algae or cyanobacteria, are a type of algae that can bloom and produce toxins. They are called harmful algal blooms because exposure to these blooms can result in adverse health effects to human and animals. Certain environmental conditions such as elevated levels of nutrients, warmer temperatures, still water, and plentiful sunlight can promote the growth of cyanbacteria to higher densities. However, their presence does not mean that toxins are present. It is still unclear what triggers HABs to produce the toxins. HABs tend to occur in late summer and early fall. Due to the potential presence of toxins, the IEPA and the LCHD have initiated a program to collect HABs from beaches and test for presence of microcystin, a common toxin produced by HABs.

In 2016, the US EPA has issued a draft of *Human Health Recreational Ambient Water Quality Criteria (AWQC) and/or Swimming Advisories for Microcystins and Cylindrospermospin.* This will be the first time the EPA is issuing recommendation concentrations of microcystins and cylindrospermopsin, two types of toxins associated with harmful algal blooms. Different cyanotoxins have different health effects associated with exposure. For example, microcystins are primarily associated with liver toxicity, while kidney toxicity is a key health effect for cylindrospermopsin. Other toxins have been shown to affect the skin, gastrointestinal, or nervous systems.

In 2016, there was a small blue green algae bloom noted on Lake Carina during the August sampling date. The sample was brought back to the lab and looked at under the microscope where it was noted to anabaena species. While Lake Carina does not have a public swimming beach, many users fish from the shorelines and dogs were often cited playing in the water. It is recommended to report any potential blue-green algae blooms by calling the Lake County Health Department. Blue-green algae blooms can be toxic to pets who drink from the water as well as to human health. Also, providing lake users within the LCFP facilities information about appearance of blue-green algae would be beneficial for reporting purposes.

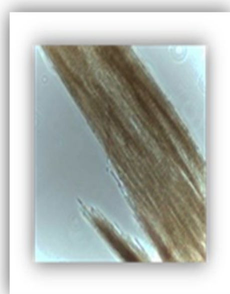
For more information or to report a blue-green algae bloom, contact the Lake County Health Department Environmental Services (847) 377-8030.

For More Information On Blue-green algae:
www.epa.state.il.us/water/surface-water/blue-green-algae.html

To report blue-green algae bloom:
Lake County Health Department
847-377-8030

Anabaena Sp.

Microcystis Sp.



Aphanizomenon Sp.

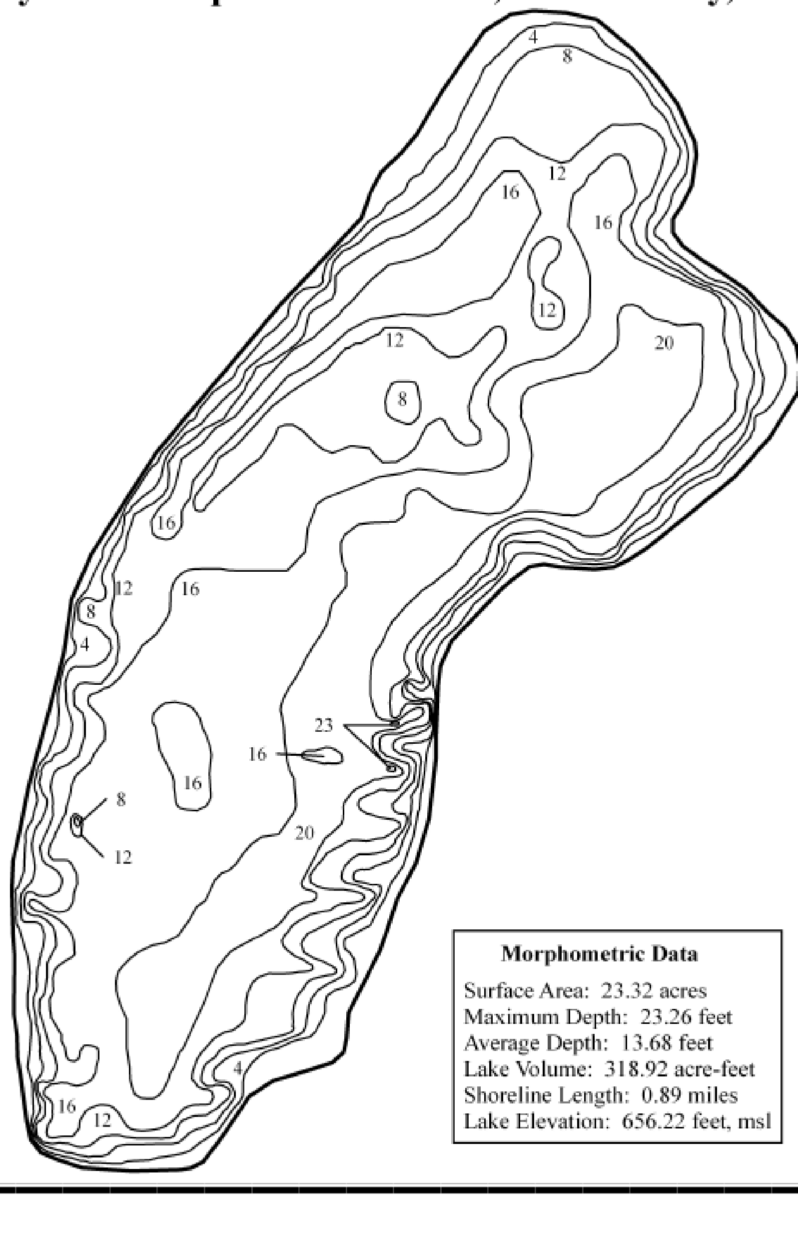
BATHYMETRIC MAPS

Bathymetric maps are also known as depth contour maps and display the shape and depth of a lake. They are valuable tools for lake managers because they provide information about the surface area and volume of the lake at certain depths. This information can then be used to determine the volume of lake that goes anoxic, how much of the lake bottom can be inhabited by plants, and is essential in the application of whole-lake herbicide treatments, harvesting activities and alum treatments of your lake. Other common uses for the map include sedimentation control, fish stocking, and habitat management.

The LCHD-ES collects field data for bathymetrics using a Lowrance HDS-5 Gen2; Lowrance cites accuracy measures of approximately 5m however actual acrruacy is typically better than this conservative estimate and has been discovered to be sub-meter (CIBiobase,2013). Once collected, the data was analyzed and imported into ArcGiS 10.2 for further analysis. In ArcGIS 10.2, the contours and volumes were generated from the triangular irregular network (TIN).

Lake Carina had a bathymetric survey conducted in 2008 by LCHD (Figure 13) The maximum depth was 23.26 ft. and average depth was 13.68 ft. Lake volume was 318.92 acre-feet. LCHD recommends updating bathymetric map every 10 years. For a complete list of the morphometric table for Lake Carina, refer to Appendix B.

Figure 13: Bathymetric Map of Lake Carina, Lake County, IL



Morphometric Data
Surface Area: 23.32 acres
Maximum Depth: 23.26 feet
Average Depth: 13.68 feet
Lake Volume: 318.92 acre-feet
Shoreline Length: 0.89 miles
Lake Elevation: 656.22 feet, msl

Bathymetric maps provide lake managers with an accurate lake volume that can be used for herbicide application and help anglers find potential fishing spots.

SHORELINE EROSION

Erosion is a natural process along lake shorelines primarily caused by wind and wave action resulting in the loss of material from the shoreline. Disturbed shorelines caused by human activity such as clearing of vegetation and beach rocks and increasing runoff will accelerate erosion. Eroded materials cause turbidity, sedimentation, nutrients, and pollutants to enter a lake. Excess nutrients are the primary cause of algal blooms and increased aquatic plant growth. Once in the lake, sediments, nutrients and pollutants are harder and more expensive to remove.

A shoreline erosion assessment was conducted on Lake Carina in 2016 (Figure 14). Lake Carina was divided into reaches, and the shoreline evaluated for none, slight, moderate and severe erosion based on exposed soil and tree/plant roots, failing infrastructure and undercut banks. Based on the 2016 data, 22% of Lake Carina's shoreline has some degree of erosion; with 17% being slight erosion, 3% being moderate erosion, and 2 % being severe. Erosion on Lake Carina is likely caused by the unstable soil type and unrestricted foot traffic. The most significant eroded areas tend to be near unrestricted foot traffic, particularly in the south-east portion of the lake. Erosion has decreased since the 2007 sampling, likely a result of increase of emergent plants established around the lake shoreline.

If these shorelines are repaired by the installation of a buffer strip with native plants, there are multiple benefits. First, the erosion is repaired and the new native plants can stabilize the shoreline to prevent future erosion. The addition of native plants adds habitat for wildlife and can also help filter pollutants and nutrients from the near shore areas. Natives shorelines also help lakes that have problems with geese and gulls, as it is not desirable habitat for them. . To see the complete dataset of shoreline erosion broken down by reach, refer to the shoreline condition assessment tables in Appendix B.

Figure 14: Shoreline Erosion Condition in Lake Carina

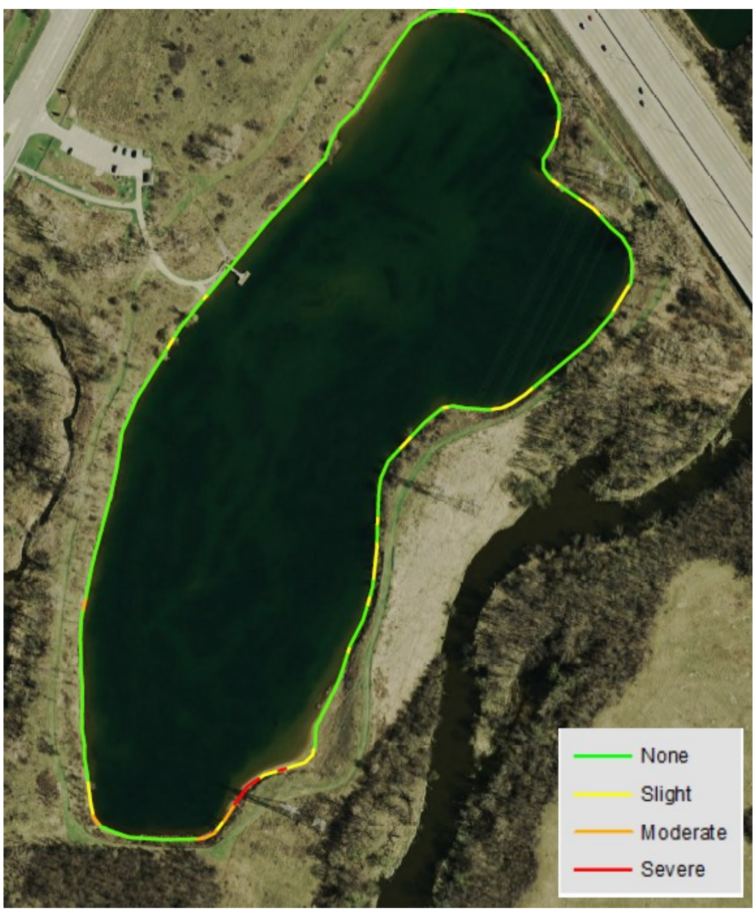
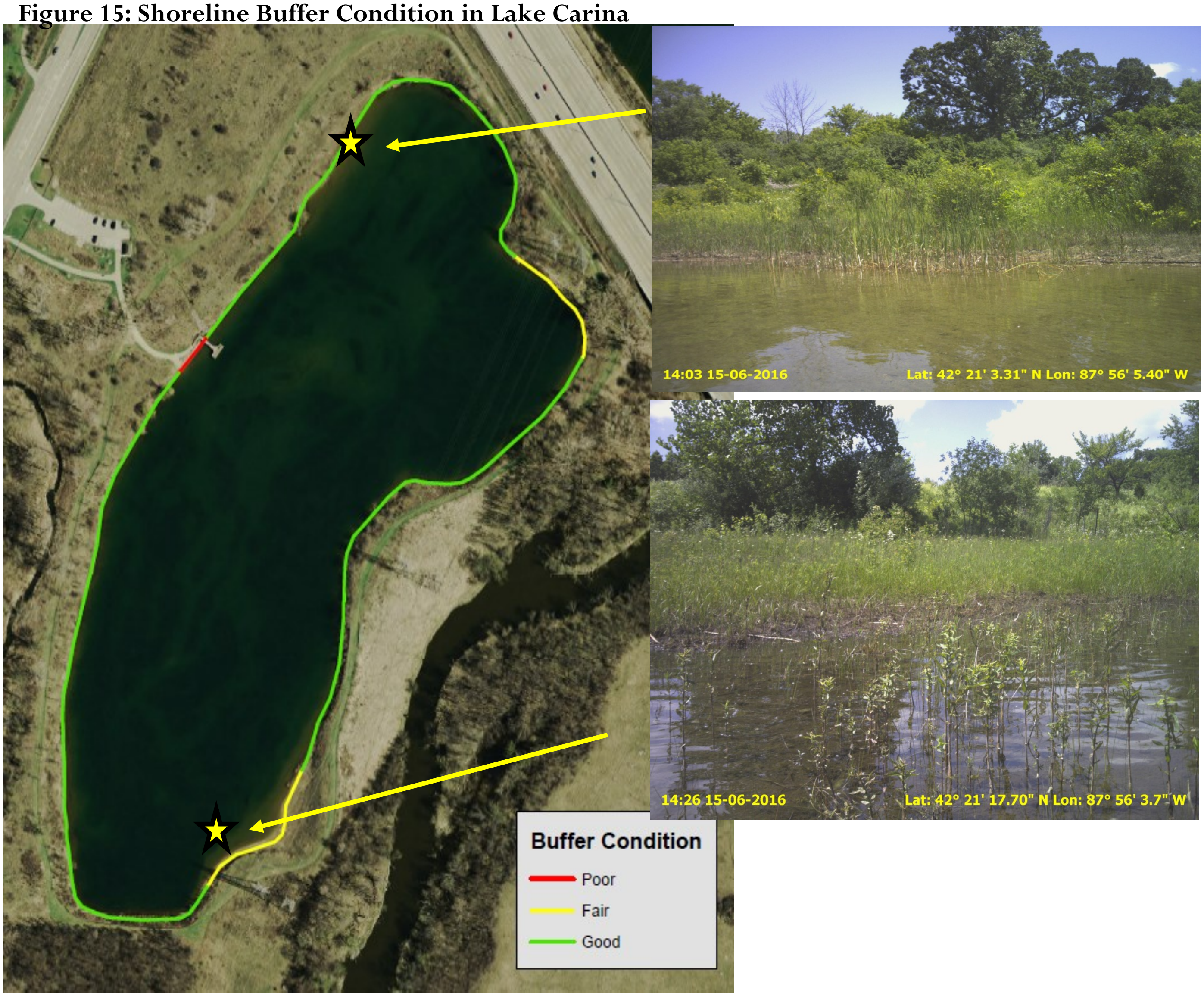


Table 2:

SHORELAND BUFFERS

A shoreland buffer helps stabilize the sediment near the lakes edge which prevents soil erosion. The buffer will also filter out pollutants and unwanted nutrients from entering the lake. Buffer strips should be at least 25 feet wide and can include native wildflowers, native grasses, and native wetland plants. Wider buffers may be needed for areas with a greater slope or additional runoff issues. Areas that are already severely or moderately eroding, a buffer strip of native plants may need to be bolstered for additional stability. Many LCFPD lakes have re-established buffers or do not mow to lakes edge to allow native grasses to grow. A shoreland buffer condition of Lake Carina was assessed by looking at the land within 25 feet of the lake's edge on aerial images in ArcGIS. Shoreland buffer's were classified into three categories; poor, fair or good based on the amount of unmowed grasses, forbs, tree trunks and shrubs, and impervious surfaces within that 25 foot range. In 2016, Lake Carina had 2% of the shoreline with poor buffer, 14% with fair, and 84% with good buffer (Figure 15). For a complete list of buffer condition by reach, refer to Appendix B.

Figure 15: Shoreline Buffer Condition in Lake Carina



Poor		Fair		Good		Total
Linear ft.	% Reach	Linear ft.	% Reach	Linear ft.	% Reach	ft.
96.5	2%	636.3	14%	3959.0	84%	4691.9

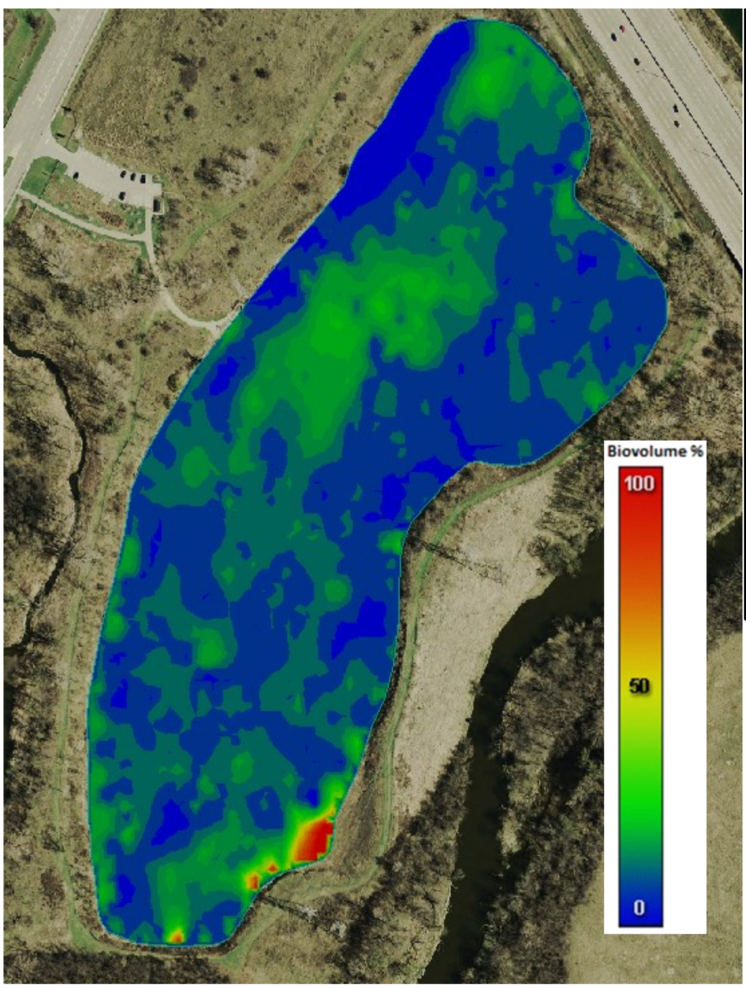
Aquatic plants

Aquatic plants are a critical component in a lakes ecosystem as they compete against algae for nutrients, improve water quality and provide fish habitat. **Their presence is natural and normal in lakes.** An aquatic macrophyte survey was conducted on Lake Carina in late July 2016. Sampling sites were based on a grid system created by mapping software, with each site located 30 meters apart for a total of 103 sites. At each site, overall plant abundance was ranked and plant species were identified and ranked. In addition to the plant rake survey, the lake was mapped using Sonar and CIBiobase as more accurate measure for overall aquatic plant biovolume. Based on the aquatic plant rake survey, plants occurred at 91 of the 103 sites (88% total lake coverage) with plants found at depths up to 19.2 feet . In the beginning of the season, plants were found all the way at the deepest point in the lake. Out of the sample points that did have plants the majority had 10-40% plant coverage; and mostly on the lower end. So while plant coverage was widespread, density was low.

There were a total of 7 aquatic plant species and one macro-algae were found in Lake Carina. Chara, a macro-algae, was by far the most dominant plant species occurring a 89% of the sampling sites. The next most abundant plant was Spiny Naiad at 15% of the sampling sites. The number of plant species (diversity) is the same as 2007 sampling . In 2007, Chara was still the most abundant plant observed. Chara's abundance has increased substantially as it was found at 50% of the sampling sites in 2007 and 89% of the sampling sites in 2016. There has been some change in plant species for instance, Vallisneria was found in 2007 but not 2016. Brittle Naiad (invasive) was found at one location in 2016 but not observed previously. Othewise, the aquatic plant community is fairly similar to the 2007 survey.

Figure 16 shows overall plant rake density on Lake Carina. For a complete list of aquatic plant species and density found in Lake Carina, refer to the aquatic plant table found in Appendix B.

Figure 16: Overall plant biovolume for Lake Carina, July 2016



Rake Density (coverage)	# of Sites	% of Sites
No Plants	12	11.7
>0-10%	28	27.2
10-40%	32	31.1
40-60%	21	20.4
60-90%	2	1.9
>90%	8	7.8
Total Sites with Plants	91	88.3
Total # Sites	103	100.0

AQUATIC PLANTS (CONTINUED)

Two exotic aquatic plants species were observed in Lake Carina in the 2016 aquatic vegetation survey; Curlyleaf Pondweed (CLP) and Brittle Naiad. CLP was not found during the aquatic plant survey in July, however it was observed in the lake during the early season. In fact, Curlyleaf Pondweed was pulled up from the bottom of the lake at the sampling site during the June sampling date. It should also be noted that while Curlyleaf Pondweed was not found during the macrophyte survey, this is influenced by the time of season that LCHD conducts the plant survey. Most plants are in full capacity in middle to late of summer which is most plant surveys are conducted in July and August. Unlike many other plants, Curlyleaf Pondweed has an earlier lifecycle. It typically peaks in May and June and can be completely gone from a lake by the time the late summer plant survey is conducted. For an accurate survey of Curlyleaf Pondweed, an early season aquatic plant survey would need to be conducted.

Brittle Naiad was also found in Lake Carina, although only found at 1 sample site. Brittle Naiad is native to Europe and Asia and has been introduced to the United States. Brittle Naiad can form dense mats that outcompete native species and can interfere with recreational activities such as boating, swimming, and fishing. It is currently not a problem in Lake Carina but should be observed in the future to see if Brittle Naiad expands.

The diversity and extent of plant populations can be influenced by a variety of factors. Water clarity and depth are the major limiting factors in determining the maximum depth at which aquatic plants will grow. When the light level in the water column falls below 1% of surface light level, plants can no longer grow. 1% surface light level is roughly at 2 times the average Secchi depth or can be measured with a photosynthetically active radiation (PAR) sensor. For Lake Carina, the 1% light level based on average Secchi values was approximately 30 ft feet. This is deeper than max depth of the lake and plants were found at the deepest location early in the season and. For a complete list of aquatic plants in Lake Carina, refer to the aquatic plant table in Appendix B.

AQUATIC PLANTS: WHERE DO THEY GROW?

Littoral Zone– the area that aquatic plants grow in a lake.

Algae– have no true roots, stems, or leaves and range in size from tiny, one- celled organisms to large, multicelled plant-like organisms.

Submerged Plants– have stems and leaves that grow entirely underwater, although some may also have floating leaves.

Floating-leaf Plants– are often rooted in the lake bottom, but their leaves and flowers lay flat on the water surface.

Emergent Plants– are rooted in the lake bottom, but their leaves and stems extend out of the water.

Invasive plant species found in Lake Carina, 2016

Curyleaf Pondweed

Curyleaf Pondweed

Brittle Naiad

Aquatic plants —dominant plants

Aquatic plants provide many water quality benefits and play an important role in the lakes ecosystem by providing habitat for fish and shelter for aquatic organism. Plants provide oxygen, reduce nutrients such as phosphorus to prevent algae blooms, and help stabilize sediment. A native plant community tends to be diverse and usually does not impede lake activities such as boating, swimming and fishing. The most dominant plants found in Lake Carina in 2016 were Chara and Spiny Naiad. Chara is a macro-algae and has cylindrical whorled branches. The branches are usually covered in a calcium carbonate giving them a gritty feel and it is commonly referred to as skunkweed for its odor. It's also found in alkaline (hard) waters and can provide habitats for many micro and macro invertebrates. Chara was found at 89.3% of the sample sites as shown in Figure 17. Spiny Naiad is a submerged aquatic plant. It is readily eaten by waterfowl and seeds of the plant have been shown to germinate after digestion, meaning plans can easily be spread by waterfowl. Seeds are considered to be long-lived in the seedbank, which means short times of drawdown or low water are unlikely to be effective at removing this plant. Spiny Naiad was found at 15.% of the sampling sites.

Figure 17: *Chara* abundance in Lake Carina, 2016

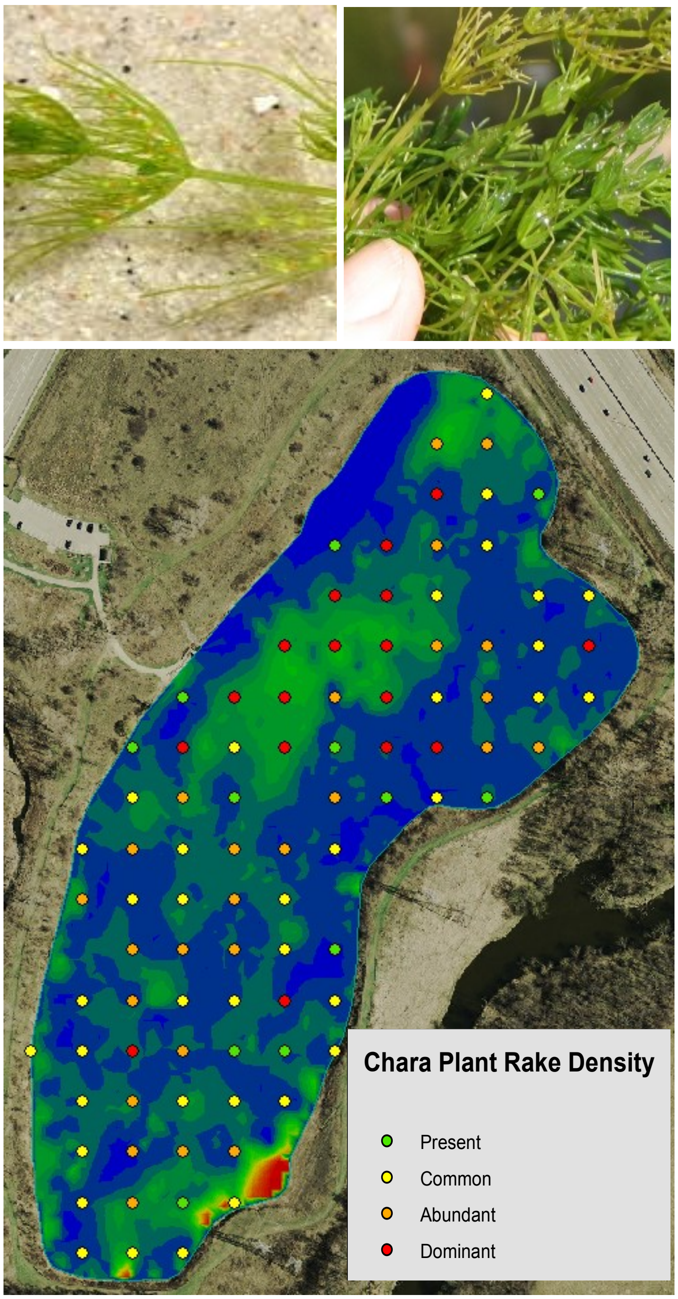
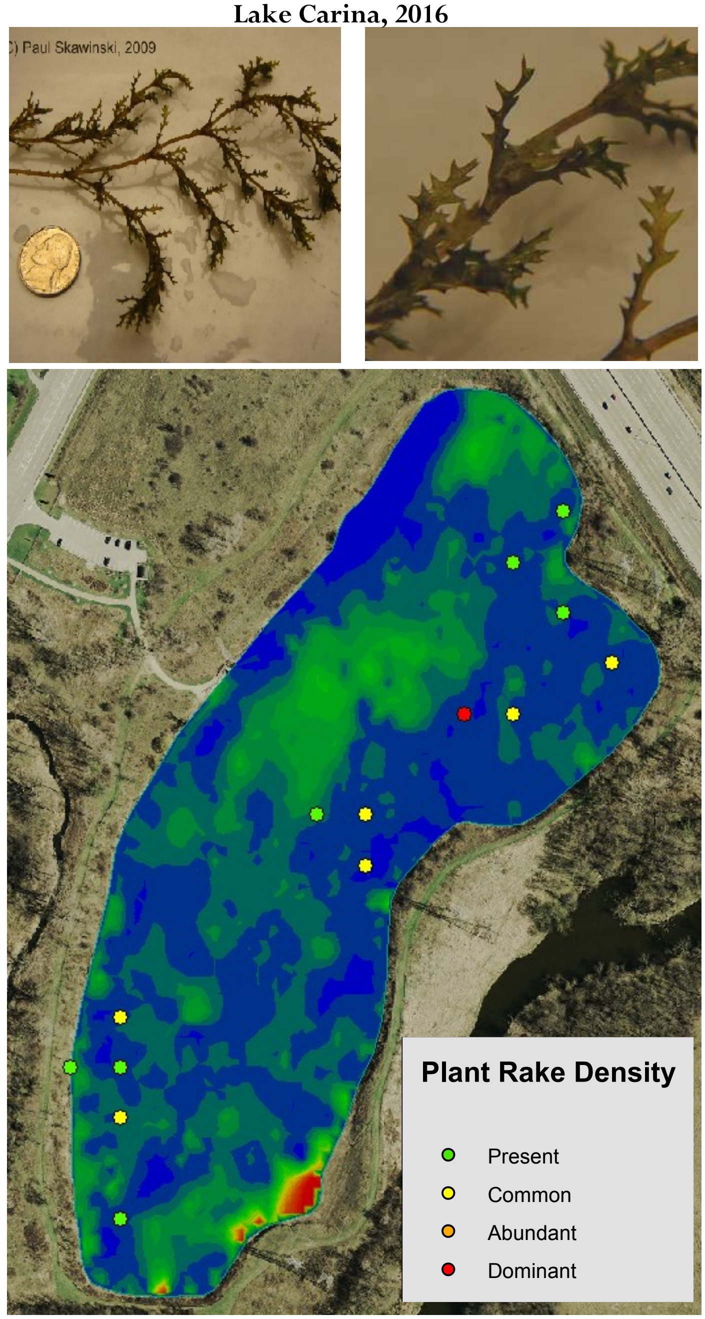


Figure 18: Spiny Naiad (*Najas minor*) abundance in Lake Carina, 2016



Aquatic plants and fish

Fish depend on aquatic plants to provide habitat and forage for food and most freshwater fish rely on aquatic plants at some point during their life stage. The plant composition and density can play an important role in the nesting, growth, and foraging success of these fish (Table 6). While many fish require some aquatic vegetation for growth, excessive amounts of aquatic vegetation can negatively impact growth by reducing foraging success. The parameters of an ideal fish habitat change base on the size and species of fish, the type of lake, structures present in the lake and many other factors. A survey of fish populations was last conducted by the IDNR in 2007 on Lake Carina. At that time, twelve different fish species were detected during a day of electro-fishing (Table 5). Bluegill made up 39% of the catch and most of the individuals were less than 3 inches. Black Crappie (26%) was the next most abundant species and ranges in size from 2.4 inches to 8.0 inches. A total of 30 Largemouth Bass were collected, however, the average size was only 5 inches. It was speculated that larger fish were present, just not collected.

Table 5. Fish Species in Lake Carina (2007 IDNR Survey)
Black Crappie
Bluegill
Sunfish
Largemouth Bass
Johnny Dater
Warmouth
Yellow Perch
Northern Pike
Common Carp
Bullhead Minnow
Blackstripe Topminnow

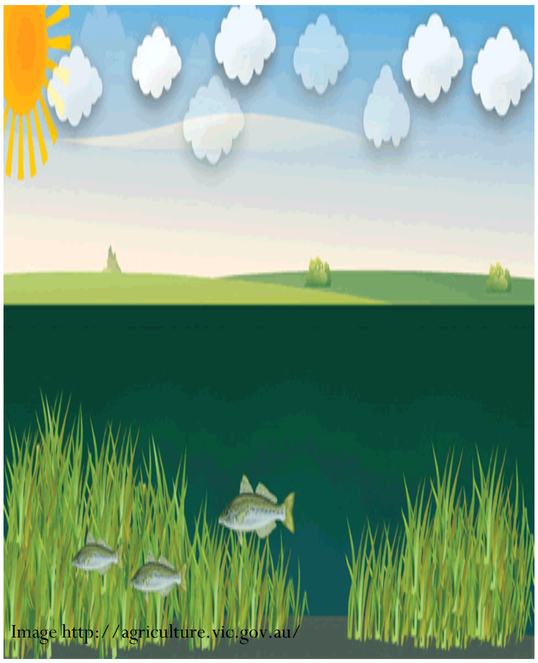


Image http://agriculture.vic.gov.au/

LAKE CARINA FISHING REGULATIONS

In addition to Illinois fishing regulations, Lake Carina has some lake specific regulations.

- Fishing is only allowed during the hours the preserve is open (6:30 a.m.—sunset)
- All anglers over 16 years of age must have a valid Illinois fishing license.
- Fish caught in other waters cannot be released into Lake Carina.
- Fishing is allowed from shore (no boats, float tubes, wading or swimming), and no ice fishing.

Table 6. Common fish and their plant affinity during various life stages and their

		Life Stage				Relationship	
Fish	**Plant Affinity**	**Larvae**	**Juvenile**	**Adult**	**Spawn**	**Forage**	**Predator avoidance**
Bluegill sunfish	High	X	X	X	X	X	X
Common carp	High	X	X	X	X	X	X
Largemouth bass	High	X	X	X	X	X	X
Musky	High	X	X	X	X	X	X
Northern Pike	High	X	X	X	X	X	X
Black crappie	Moderate		X	X	X	X	X
Smallmouth bass	Moderate		X	X		X	X
Yellow perch	Moderate	X	X			X	X
White crappie	Low		X			X	
Salmon, trout	Low		X				X
Shad	Low	X					
Walleye	Low			X		X	

Table adapted from Gettys, Lynn, William T. Haller and Marc Bellaud. "Biology and Control of Aquatic Plants: A Best Management Practices Handbook". 2009

FLORISTIC QUALITY INDEX

Floristic quality index (FQI) is an assessment tool designed to evaluate how close the flora of an area is compared to one of undisturbed conditions. It can be used to: 1) identify natural areas, 2) compare the quality of different sites or different locations within a single site 3) monitor long-term floristic trends and 4) monitor habitat restoration efforts. Each aquatic plant in a lake is assigned a number between 1 and 10 (10 indicating the plant species most sensitive to disturbance). This is done for every floating and submerged plant species found in the lake. The FQI is calculated by multiplying the average of these numbers by the square root of the number of these plant species found in the lake. A high FQI number indicates that a large number of sensitive, high quality plant species are present in the lake. Non-native species were also included in the FQI calculations for Lake County lakes. The median FQI for Lake County lakes from 2000-2016 is 13.9. Lake Carina had an FQI value of 9.5 ranking it 121 out of 171 lakes in Lake County (Appendix A). The FQI has decreased since the 2007 sampling when the FQI value was 12. 1, mostly the result of an additional aquatic invasive species found. LCHD recommends the LCFPD to develop an Aquatic Plant Management Plan (APMP) should take into consideration maintaining the high level native plants.

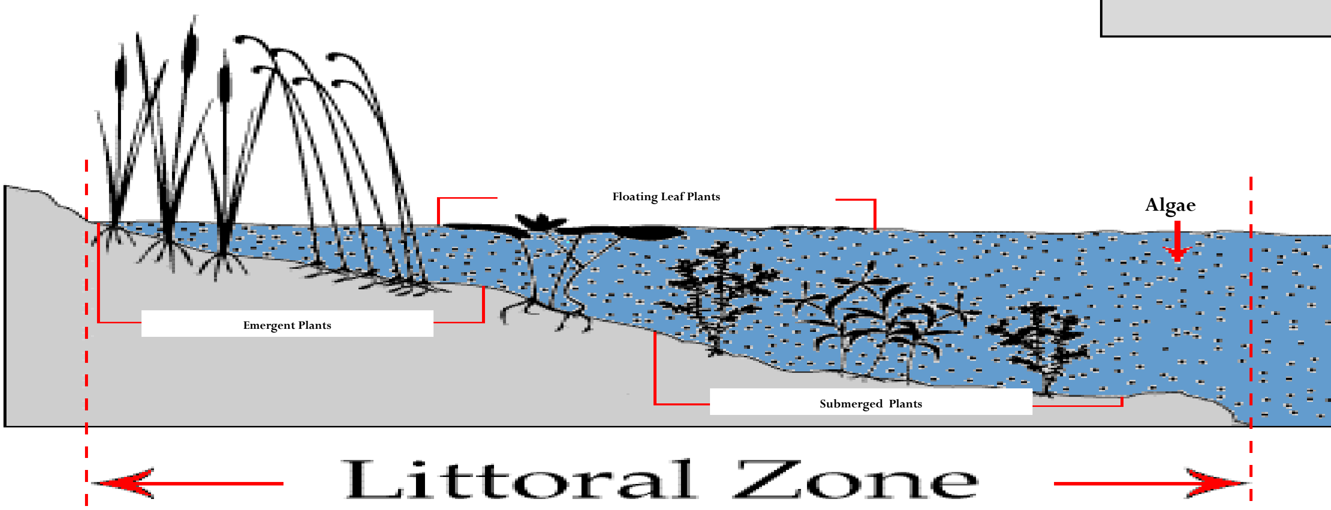
LAKE COUNTY AVERAGE FQI = 13.9

LAKE CARINA FQI = 9.5

RANK = 121/171

AQUATIC PLANTS SPECIES OBSERVED = 7

NATIVE PLANT SPECIES: 5



Source: Minnesota Department of Natural Resources

In many lakes, macrophytes contribute to the aesthetically pleasing appearance of the setting and are enjoyable in their own right. But even more important, they are an essential element in the life systems of most lakes.

- Macrophyte leaves and stems provide a habitat or home for small attached plants and animals. Some are microscopic in size and some are larger. These attached organisms are valuable as food for animals higher in the food chain, such as fish and birds.
- Many types of small organisms live in the sediment. There are insects that spend the immature stages of life in the sediments, leaving when they become adults. Decomposing plant life provides part of the food supply for these sediment-dwelling organisms and the emerging insects, in turn, are food for fish.
- The submerged portions of macrophytes provide shelter and cover for small or young fish from larger fish that would feed on them.
- Types of plants that extend above the water can provide cover for waterfowl and their young, and many plants can serve directly as food for certain types of waterfowl.
- Aquatic plants provide many water quality benefits such as sediment stabilization and competition with algae for available nutrients.

AQUATIC PLANT MANAGEMENT OPTIONS

Two sided rake for manual harvesting

Aquatic plants are essential for maintaining a balanced, healthy lake, but sometimes plants can create a nuisance for recreation, lake aesthetics, and invasive plant species can outcompete native plant species. Aquatic plant management is both controlling undesirable species while encouraging desirable species in important habitat areas. For Lake Carina and most of the Lake County Forest Preserve District lakes there has been little intervention in plant management, meaning plants are intentionally not controlled or manipulated but allowed to grow as environmental conditions dictate. This is generally a good strategy for low nutrient likes (oligotrophic and mesotrophic, such as Lake Carina, where rooted plants and algae are not naturally abundant and do not create recreational conflict. If a significant decrease in the diversity of native aquatic plant species occurs in the future in Lake Carina and/or aquatic invasive species continue to increase, aquatic plant management techniques may be used to manage the lake. The main types of plant control include: mechanical harvesting, manual harvesting, and herbicides. Mechanical harvesting involves the use of specially designed machines that cut and remove plant material from a lake. Harvesting only reduces the height of aquatic plants in the water column. Manual or hand harvesting is the most environmentally friendly is best for small scale operations. The most common control tool in aquatic plant management is the use of herbicides registered by the U.S. environmental Protection Agency. Below is a table that briefly summarizes some pros and cons of the different aquatic plant management techniques. This is not a comprehensive list and should only be used as a guide to understanding different management options available.

Management	Pros	Cons
Mechanical	Cost competitive with chemical controls	Undesirable plants may fragment, spread and col-
	Removes nutrients from the lake but may be minimal compared with input	Desirable plants such as pondweeds may be suppressed
	Removes organic material from the lake	Limited operation in shallow water and around
	May provide some selective control	Machine breakdowns can disrupt operations
		Drifting plant fragments may accumulate at
Hand Harvesting	Low Cost	Lab intensive
	Excellent control in small areas	Not suitable for large areas
	Low environmental impact	
Herbicides	Costs are reasonable in many situations	Involves the introduction of pesticides into shared
	Range of products and combinations available	Potential for misuse
	Some products are highly selective for nuisance	May contribute to the buildup of organic material
	Can provide complete control of plants for swimming beaches	Algal blooms are possible following large herbicide treatments
		Fish kills may occur with misuse of certain products
		Large treatments may encourage shifts in plant
		Water use restrictions may be need to be
		Does not address the cause of cultural eutrophication

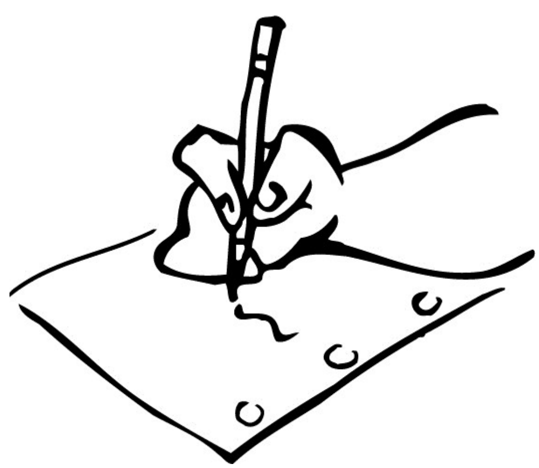
LAKE MANAGEMENT PLANS

It is recommended that a long term Lake Management Plans be developed to effectively manage lake issues. The Lake County Forest Preserve District can have a separate lake management plan for all lakes within their jurisdiction. All stakeholders should participate in the development of the plan and include homeowners, recreational users, lake management associations, park districts, townships or any other entity involved in managing Lake Carina. Lake Management plans should educate the public about specific lake issues, provide a concise assessment of the problem, outline methods and techniques that will be employed to control the problems and clearly define the goals of the program. Mechanisms for monitoring and evaluation should be developed as well and information gathered during these efforts should be used to implement management efforts (Biology and Control of Aquatic Plants, Gettys et al., 2009).

What are the steps in creating a Lake Management Plan?

1. **Getting Started**: Identify lake stakeholders and communication pathways
2. **Setting Goals:** Getting the effort organized, identifying problems to be addressed, and agreeing on the goals
3. **Problem Assessment & Analysis**: collecting baseline information to define the past and existing conditions. Synthesize the information, quantifying and comparing the current conditions to desired conditions, researching opportunities and constraints and setting direction to achieve goals.
4. **Alternatives:** List all possible management alternatives and evaluate their strengths, weakness, and general feasibility.
5. **Recommendations:** Prioritize management options, setting objectives and drafting the plan
6. **Project Management:** Management of assets, detailed records of expenses and time
7. **Implementation:** adopting the plan, lining up funding, and scheduling activities for taking action to achieve goals.
8. **Monitor & Modify:** Develop a mechanism for tracking activities and adjusting the plan as it evolves.

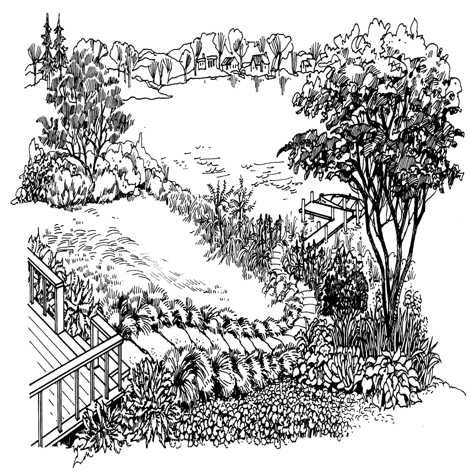
Follow these steps when getting started with writing Lake Management Plans. While each step is necessary, the level of effort and detail for each step will vary depending on the project's goals, size of the lake, and number of stakeholders.



LAKE RECOMMENDATIONS

In general, Lake Carina is a low nutrient lake, in part in due to its borrow pit origin and small watershed. Overall the lake has good water quality. To maintain the overall quality of Lake Carina and prevent any decline the ES (Ecological Services) has the following recommendations:

- LCHD encourages LCFPD to participate in the Volunteer Lake Monitoring Program to give yearly data for Lake Carina and other Lake County Forest Preserve Lakes. Participating in this program can provide useful data to observe changes in the lakes water clarity overtime. Contact the LCHD-ES at 847-377-8009 to get involved in the VLMP program.
- Consider shoreline restoration in areas where there is visible erosion issues. Re-planting native plants and emergent plants can minimize the amount of erosion occurring along the shoreline.
- Chloride, while declining since LCHD has begun monitoring this lake in 2001, remains above the Aquatic Life Criterion of 230 mg/L. It is recommended to practice best management practices for salt and de-icing of roads, sidewalks, and driveways in the watershed. Consider the benefit of attending one of Lake County Health Departments De-Icing workshops held annually in October to learn about these best management practices.



- Develop a Lake Management Plan that incorporates aquatic plant management. It is recommended that the LCFPD have a separate document as part of their strategic plan related to lakes and lake management that can include their rules and regulations on how they manage the lakes.
- Install a sign to educate on ways to reduce the spread of Aquatic Invasive Species. Since Lake Carina is mostly visited by fishermen, it would be useful to place a sign near the lake access discussing AIS species and ways to prevent them.
- It is recommended to update fisheries survey to assess fish population and in Lake Carina, the last survey was completed in 2007.
- Bathymetric maps should be updated every ~10 years. The most recent bathymetric map for Lake Carina is 2008.
- Become familiar with the appearance of harmful algal blooms and report any blooms to the LCHD-ES by calling 847-837-8030. Also, educate lake users about the appearance of harmful algal blooms so that blooms can be reported to the Lake County Health Department.

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Lake County Health Department and Community Health Center

ECOLOGICAL SERVICES

Senior Biologist: Mike Adam

madam@lakecountyil.gov

Population Health Services
500 W. Winchester Road
Libertyville, Illinois 60048-1331

Phone: 847-377-8030
Fax: 847-984-5622

For more information visit us at:

http://www.lakecountyil.gov/Health/want/BeachLakeInfo.htm

Protecting the quality of our lakes is an increasing concern of Lake County residents. Each lake is a valuable resource that must be properly managed if it is to be enjoyed by future generations. To assist with this endeavor, Population Health Environmental Services provides technical expertise essential to the management and protection of Lake County surface waters.

Environmental Service's goal is to monitor the quality of the county's surface water in order to:

- Maintain or improve water quality and alleviate nuisance conditions
- Promote healthy and safe lake conditions
- Protect and improve ecological diversity

Services provided are either of a technical or educational nature and are provided by a professional staff of scientists to government agencies (county, township and municipal), lake property owners' associations and private individuals on all bodies of water within Lake County.

Appendix A:
Figures

Lake Carina Sampling Point, 2016

LakeCounty
Health Department and
Community Health Center

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0 100 200 300 400
Feet

Ecological Services
Product Number COS16
Revised 05/2016

Lake Carina Watershed Boundary

LakeCounty
Health Department and
Community Health Center

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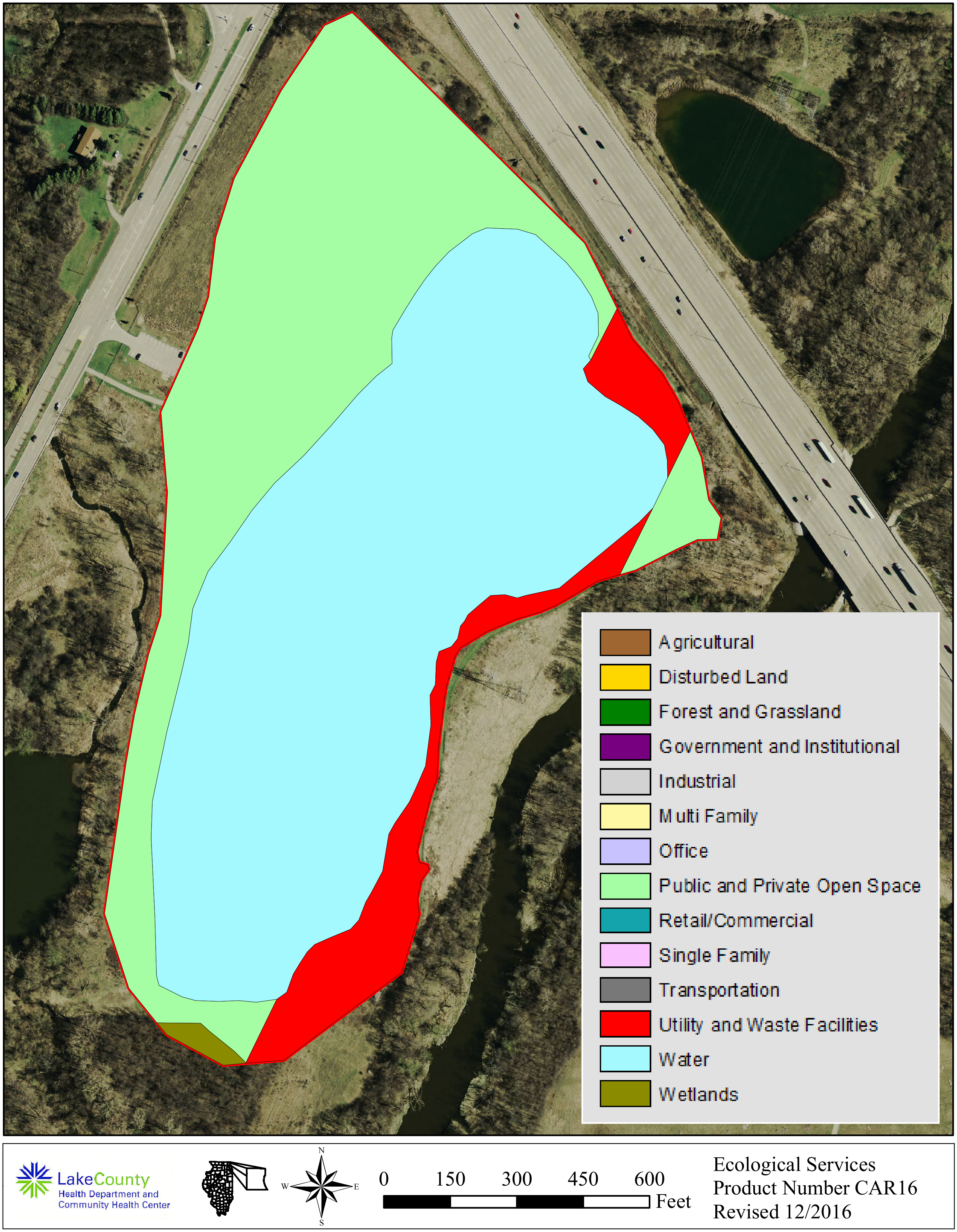
Feet

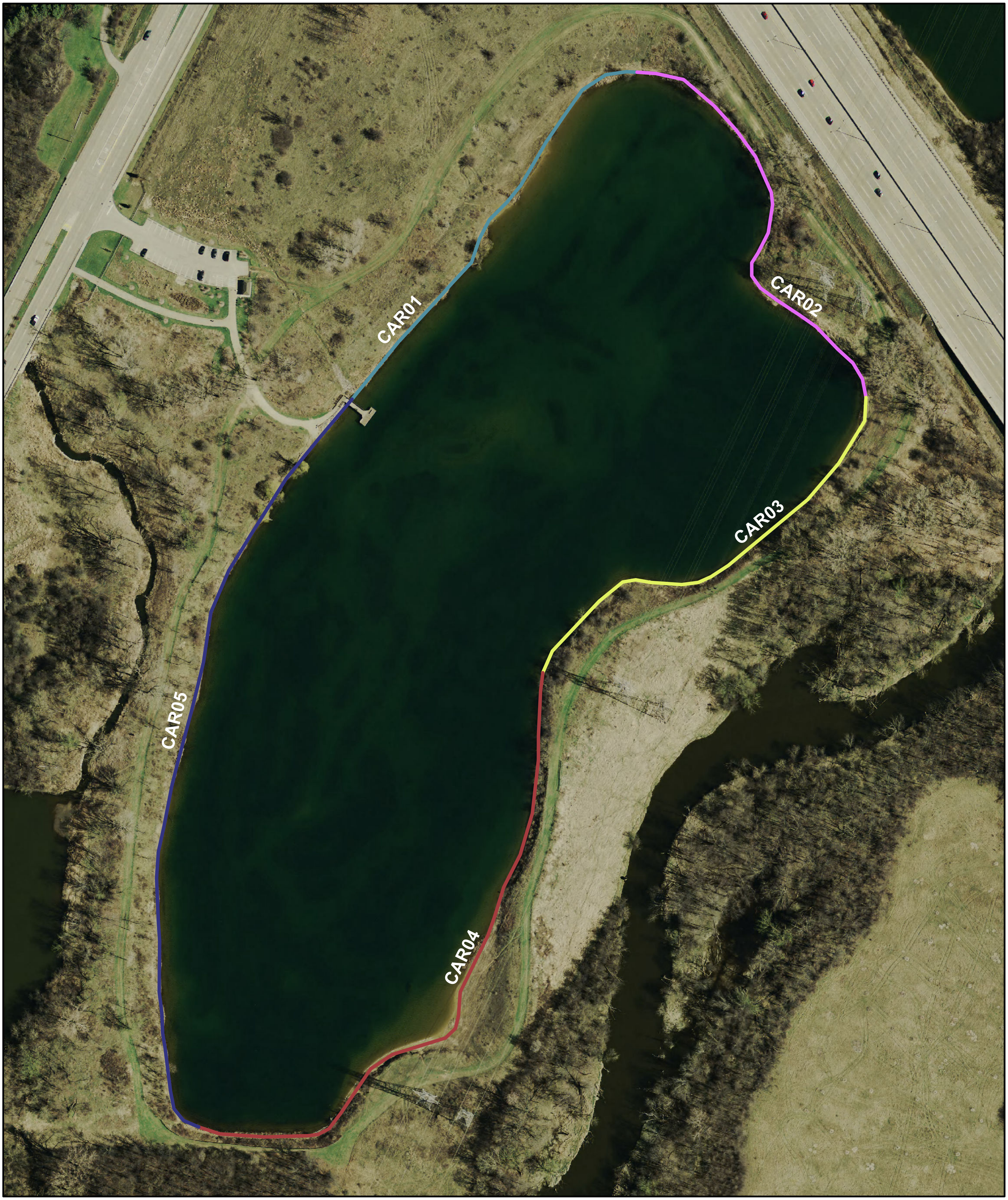
Ecological Services
Product Number CAR16
Revised 12/2016

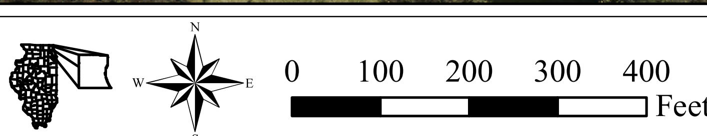
Lake Carina Watershed Boundary



Ecological Services
Product Number CAR16
Revised 12/2016

Lake Carina Shoreline Reaches, 2016

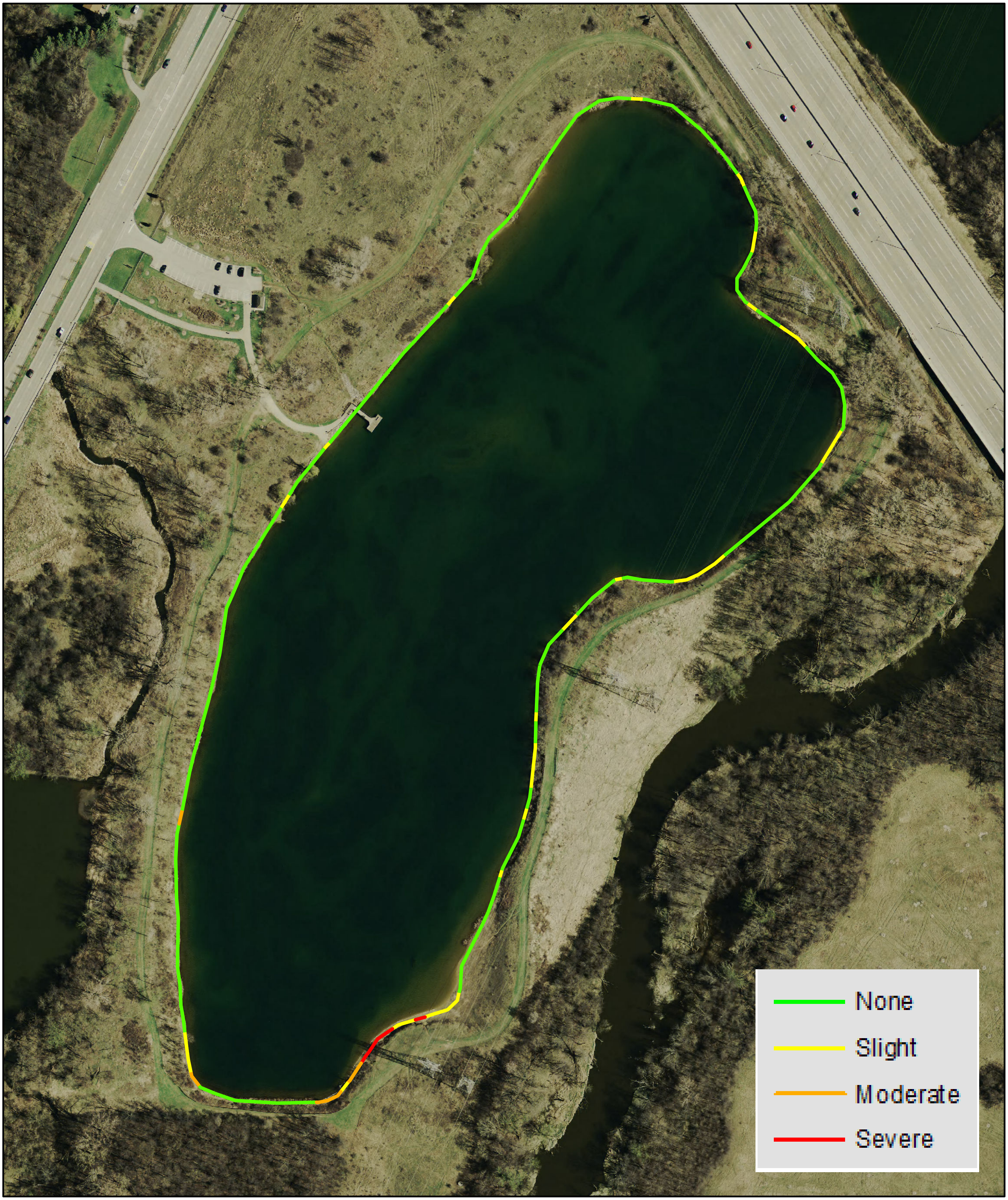




LakeCounty
Health Department and
Community Health Center

Ecological Services
Product Number CAR16
Revised 06/2016

Lake Carina Shoreline Erosion 2016



LakeCounty
Health Department and
Community Health Center

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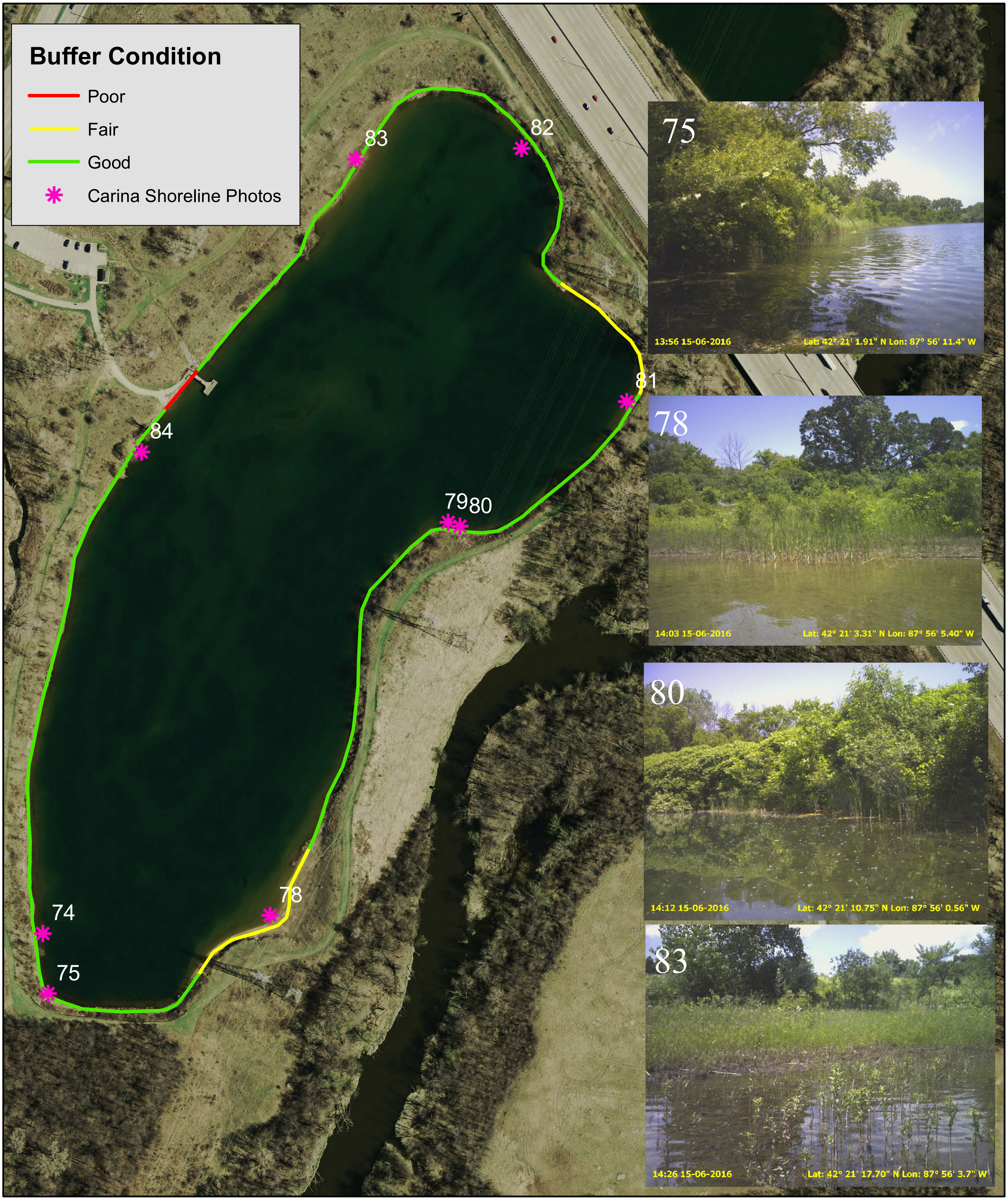
Ecological Services
Product Number CAR16
Revised 11/2016

Lake Carina Lakeshore Buffer 2016



LakeCounty Health Department and Community Health Center

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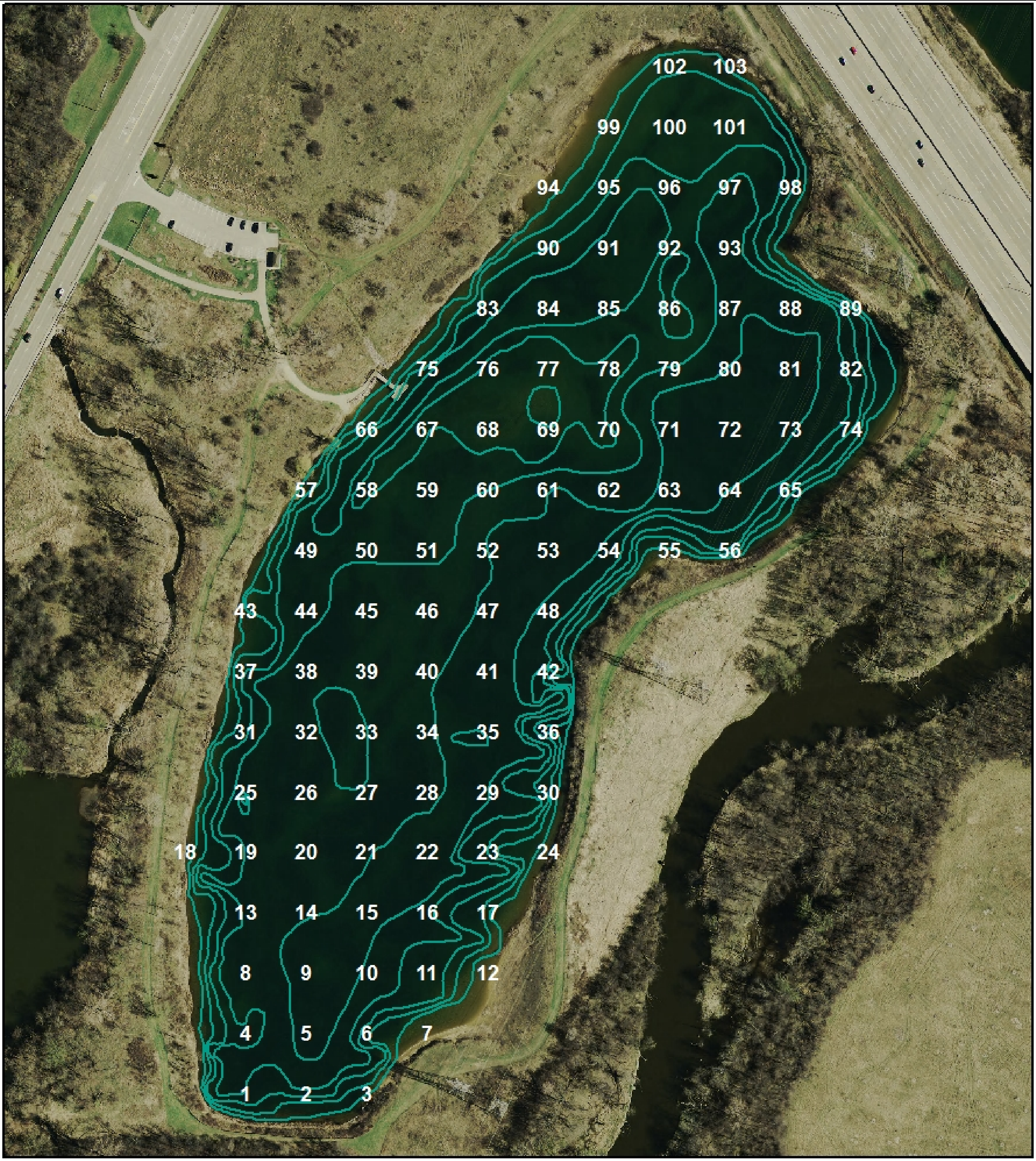
Ecological Services
Product Number CAR16
Revised 11/2016

Carina Plant Grid 2016



LakeCounty
Health Department and Community Health Center

N W E S

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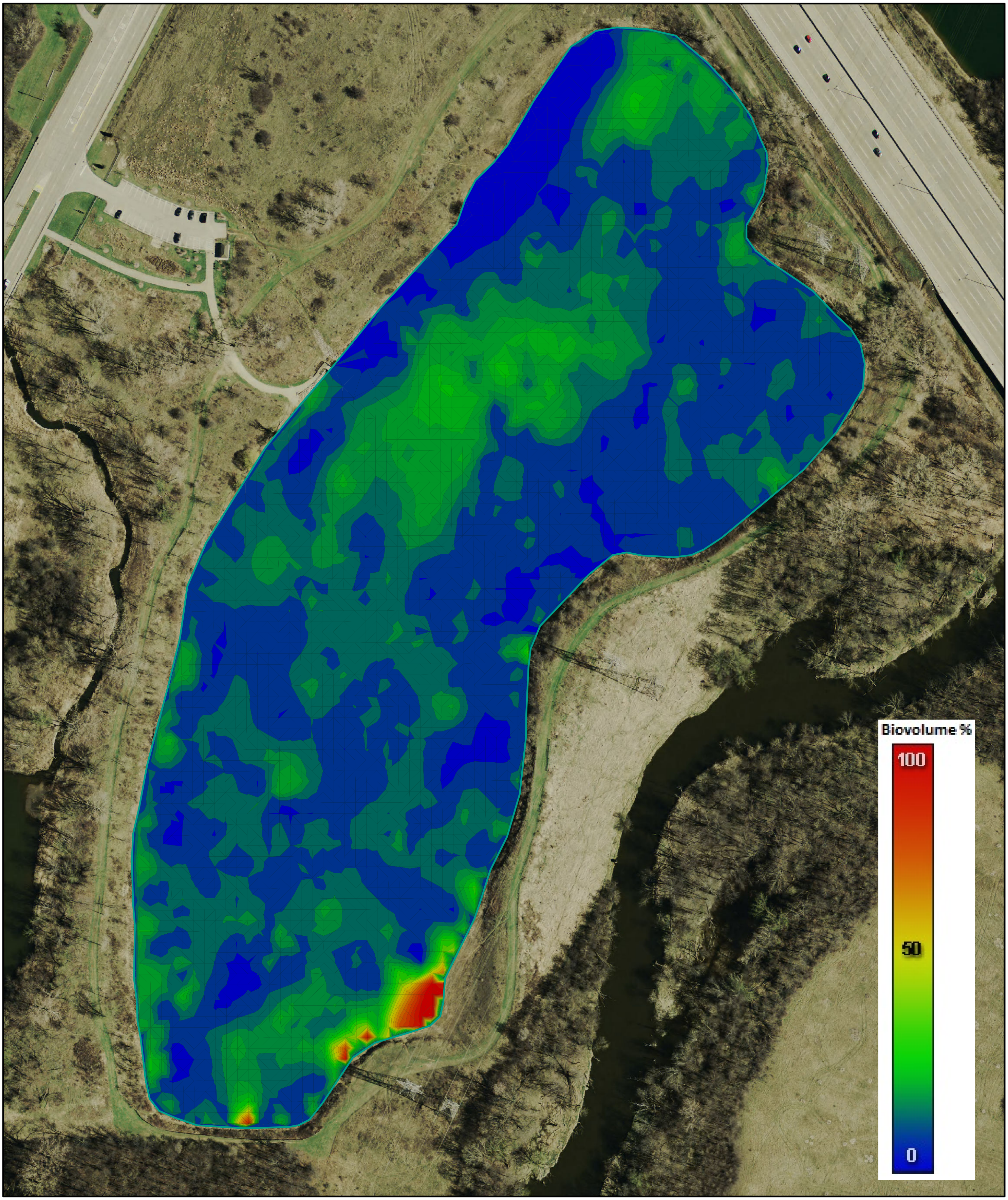
Ecological Services
Product Number COS.16
Revised 105/2016

Lake Carina Plant Biovolume, August 2016



LakeCounty
Health Department and
Community Health Center

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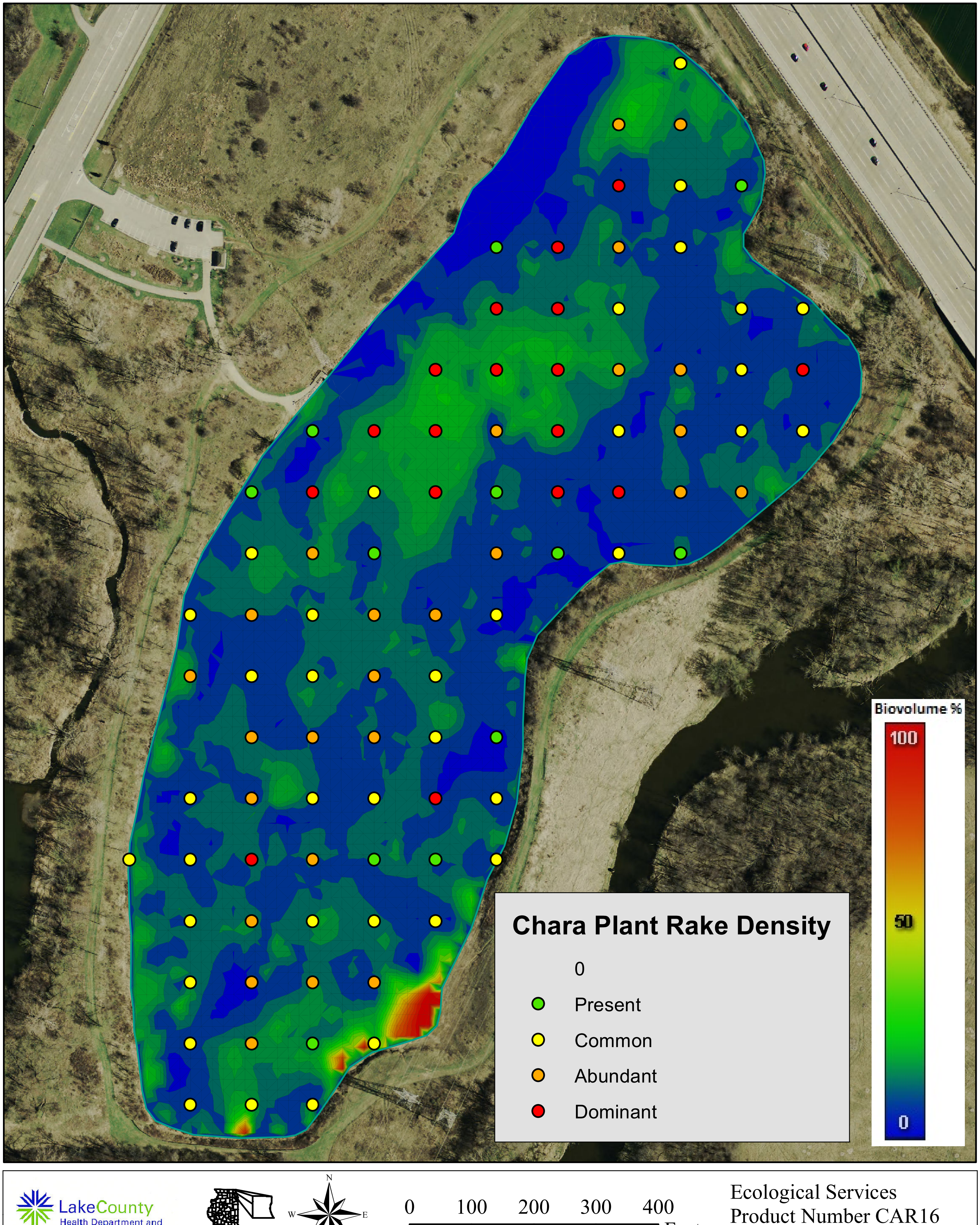
Ecological Services
Product Number CAR16
Revised 12/2016

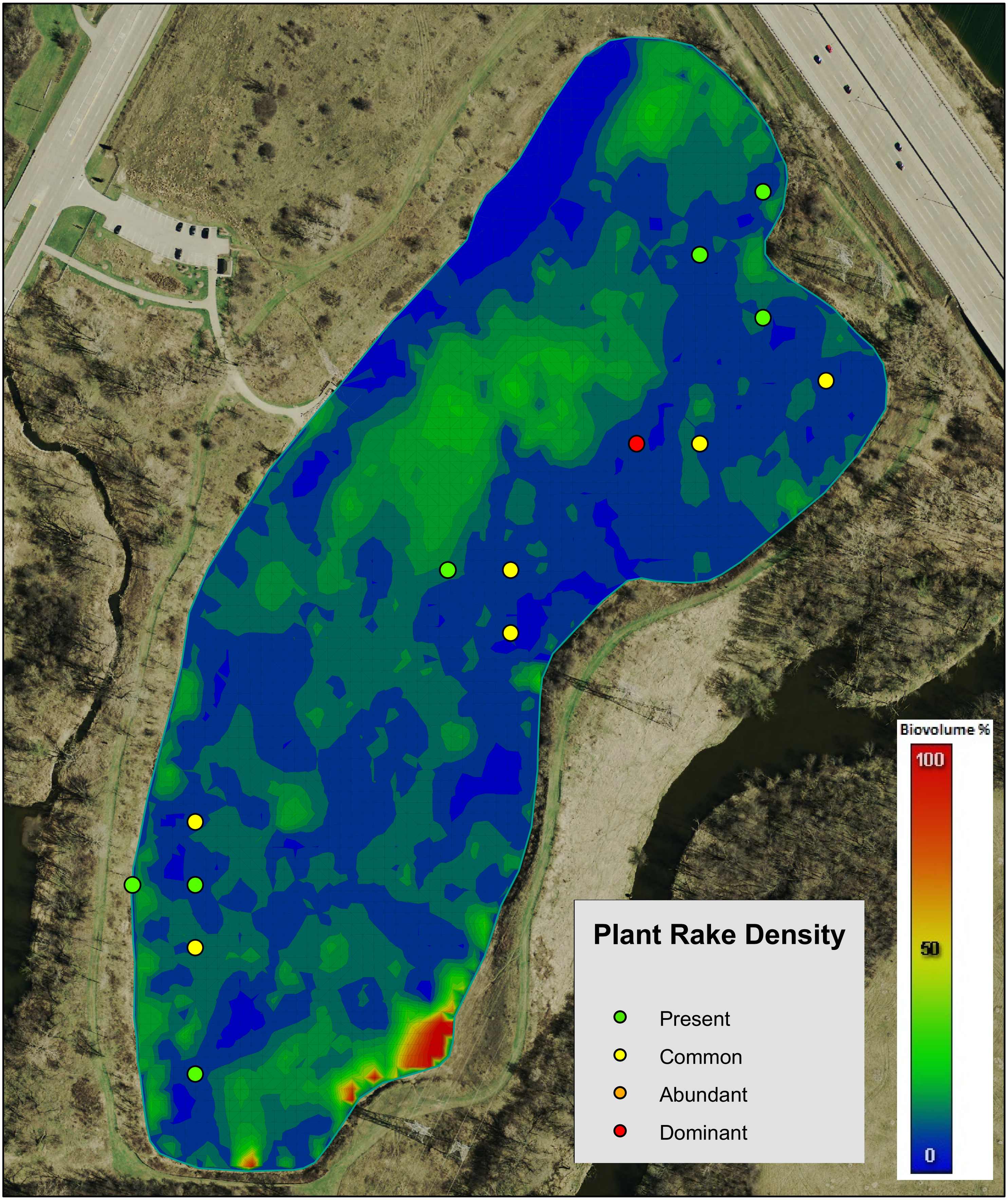
Lake Carina Chara Rake Density and Overall Biovolume, July 2016

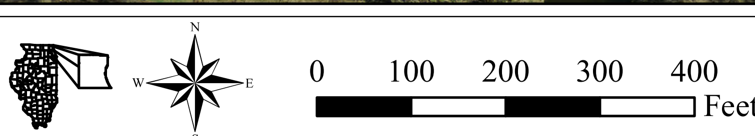


LakeCounty
Health Department and
Community Health Center

Ecological Services
Product Number CAR16
Revised 12/2016

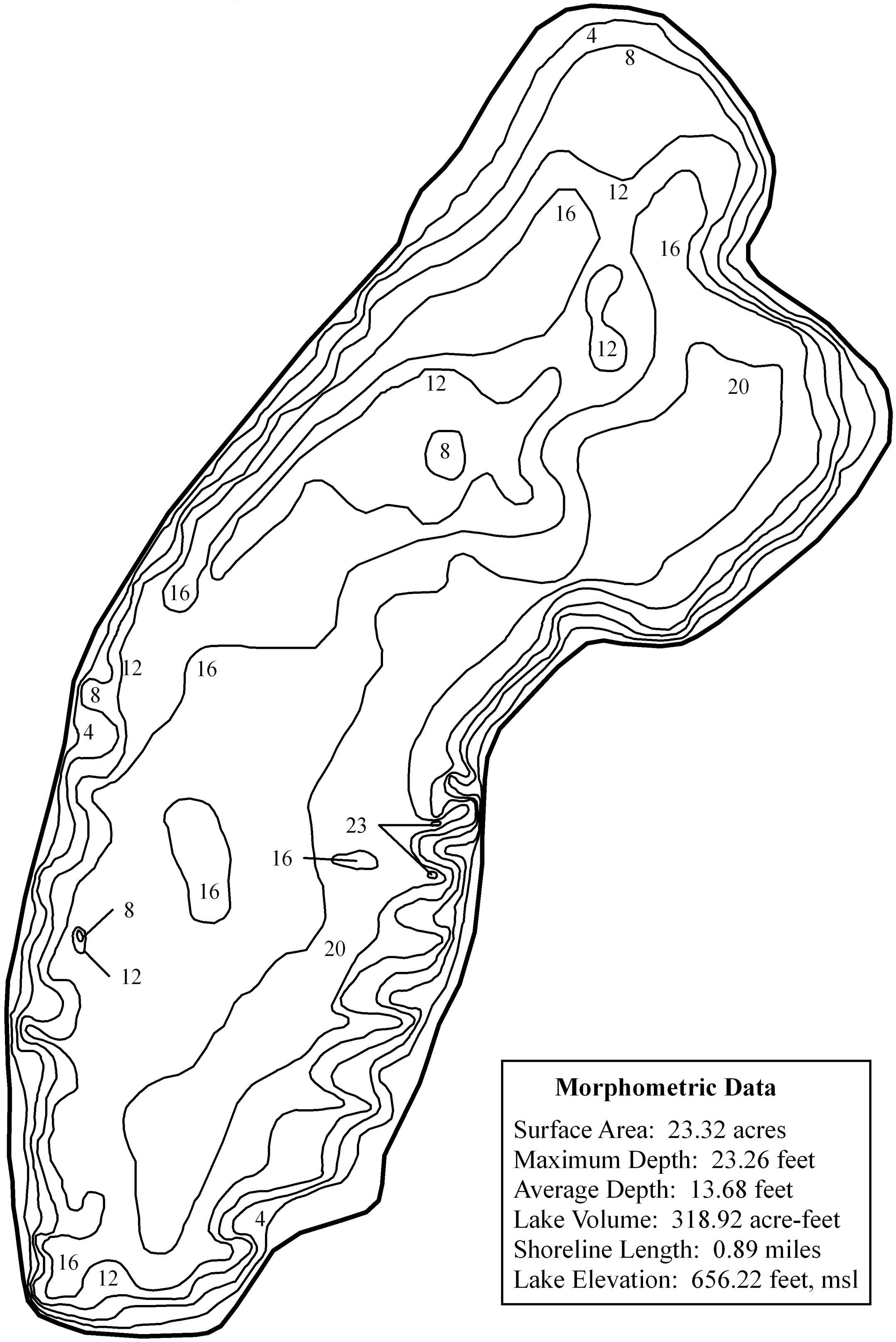
Lake Carina Spiny Naiad Rake Density and Overall Biovolume, July 2016





Ecological Services
Product Number CAR16
Revised 12/2016

Bathymetric Map of Lake Carina, Lake County, IL



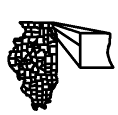
Morphometric Data

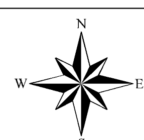
Surface Area: 23.32 acres
Maximum Depth: 23.26 feet
Average Depth: 13.68 feet
Lake Volume: 318.92 acre-feet
Shoreline Length: 0.89 miles
Lake Elevation: 656.22 feet, msl

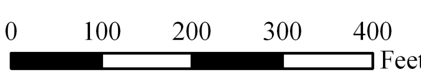
Survey Data Collected June 25, 2008

This map is intended for water quality reference only, not intended for navigational, swimming, or diving purposes.

LakeCounty
Health Department and
Community Health Center







Lakes Management Unit
Product Number COS.BM08
Revised 12/2008

Appendix B:

Tables

Lake Carina Water Quality Summary Table
(2001, 2007, and 2016)

2016	Epilimnion															
DATE	DEPTH	ALK	TKN	NH_3-N	NO2+NO3[*]	TP	SRP	TDS*	Cl^-	TSS	TS	TVS	SECCHI	COND	pH	DO
17-May	3	140	0.324	<0.1	<0.05	<0.01	<0.005	710	318	1.0	792	131	20.30	1.3176	8.43	11.30
14-Jun	3	130	0.365	<0.1	<0.05	<0.01	<0.005	717	327	<1.0	796	154	20.80	1.3320	8.54	10.76
12-Jul	3	125	0.341	<0.1	<0.05	<0.01	<0.005	709	323	<1.0	784	129	18.68	1.3163	8.51	9.05
16-Aug	3	132	0.41	<0.1	<0.05	<0.01	<0.005	722	328	1.2	823	156	14.00	1.3421	8.39	7.16
13-Sep	3	136	0.544	<0.1	<0.05	0.015	<0.005	725	342	2.8	791	121	11.00	1.3480	8.35	7.55
	Average	133	0.397	<0.1[k]	<0.05[k]	.011[k]	<0.005[k]	717	328	1.4[k]	797	138	16.96	1.3312	8.44	9.16

2007	Epilimnion															
DATE	DEPTH	ALK	TKN	NH_3-N	NO2+NO3[*]	TP	SRP	TDS	Cl^-	TSS	TS	TVS	SECCHI	COND	pH	DO
9-May	3	160	<0.5	<0.1	<0.05	<0.01	<0.005	NA	405	<1.0	959	139	20.34	1.7210	8.22	9.26
13-Jun	3	141	<0.5	<0.1	<0.05	<0.01	<0.005	NA	413	1.5	1000	189	14.60	1.7150	8.44	9.25
11-Jul	3	138	<0.5	<0.1	<0.05	<0.01	<0.005	NA	414	2.9	1000	190	9.35	1.7440	8.30	7.75
8-Aug	3	134	<0.5	<0.1	<0.05	<0.01	<0.005	NA	410	1.6	933	140	13.78	1.7260	8.29	7.31
12-Sep	3	152	<0.5	<0.1	<0.05	<0.01	<0.005	NA	377	3.4	897	125	7.97	1.6360	8.05	6.57
	Average	145	<0.5[k]	<0.1[k]	<0.05[k]	<0.01[k]	<0.005[k]	NA	404	2.4	958	157	13.21	1.7084	8.26	8.03

2001	Epilimnion															
DATE	DEPTH	ALK	TKN	NH_3-N	NO_3-N	TP	SRP	TDS	Cl^-	TSS	TS	TVS	SECCHI	COND	pH	DO
1-May	3	181	<0.5	<0.1	0.052	<0.01	<0.005	766	NA	3.1	809	193	6.76	1.3820	8.05	9.78
5-Jun	3	170	<0.5	<0.1	<0.05	0.032	<0.005	820	NA	4.7	822	181	6.40	1.3850	8.00	8.39
10-Jul	3	153	<0.5	<0.1	<0.05	0.015	<0.005	744	NA	3.2	852	194	8.37	1.4090	8.04	7.79
7-Aug	3	148	<0.5	<0.1	<0.05	<0.01	<0.005	794	300	2.2	886	203	8.30	1.4300	7.94	7.05
5-Sep	3	160	0.54	<0.1	<0.05	0.011	<0.005	788	400	4.0	802	111	5.84	1.4550	7.95	6.98
	Average	162	0.54[k]	<0.1[k]	0.052[k]	0.019[k]	<0.005[k]	782	350	3.4	834	176	7.13	1.4122	8.00	8.00

Glossary

ALK = Alkalinity, mg/L $CaCO_3$
TKN = Total Kjeldahl nitrogen, mg/L
NH_3-N = Ammonia nitrogen, mg/L
NO_3-N = Nitrate nitrogen, mg/L
NO2+NO3 = Nitrite and Nitrate nitrogen, mg/L
TP = Total phosphorus, mg/L
SRP = Soluble reactive phosphorus, mg/L
TDS* = Total dissolved solids, mg/L (calculated value)
Cl^- = Chloride ions, mg/L
TSS = Total suspended solids, mg/L
TS = Total solids, mg/L
TVS = Total volatile solids, mg/L
SECCHI = Secchi disk depth, ft.
COND = Conductivity, milliSiemens/cm
DO = Dissolved oxygen, mg/L

Note: "k" denotes that the actual value is known to be less than the value presented.
NA = Not Applicable
* = Prior to 2006 only Nitrate was analyzed

Lake Carina Water Quality Summary Table
(2001, 2007, and 2016)

2016 **Hypoliminion**

DATE	DEPTH	ALK	TKN	NH_3-N	NO2+NO3*	TP	SRP	TDS*	Cl^-	TSS	TS	TVS	SECCHI	COND	pH	DO
17-May	17	139	0.308	<0.100	<0.05	0.012	<0.005	709	322	<1.0	782	123	NA	1.3157	8.46	11.90
14-Jun	17	129	0.377	0.133	<0.05	0.01	<0.005	712	324	<1.0	796	151	NA	1.3216	8.61	14.51
12-Jul	17	127	0.347	<0.100	<0.05	0.015	<0.005	708	319	1.3	814	163	NA	1.3141	8.49	8.88
16-Aug	16	133	0.397	<0.100	<0.05	<0.01	<0.005	722	329	2.6	823	147	NA	1.3413	8.39	7.11
13-Sep	15	136	0.529	<0.100	<0.05	<0.01	<0.005	725	333	2.7	807	147	NA	1.3470	8.37	7.48
	Average	133	0.392	0.107[k]	<0.05[k]	0.011[k]	<0.005[k]	715	325	1.7[k]	804	146	NA	1.3279	8.46	9.98

2007 **Hypolimnion**

DATE	DEPTH	ALK	TKN	NH_3-N	NO2+NO3*	TP	SRP	TDS	Cl^-	TSS	TS	TVS	SECCHI	COND	pH	DO
9-May	18	160	<0.5	<0.1	<0.05	<0.01	<0.005	NA	404	1.6	953	138	NA	1.7060	8.07	10.26
13-Jun	16	150	<0.5	<0.1	<0.05	<0.01	<0.005	NA	413	3.3	1030	206	NA	1.7490	8.04	7.42
11-Jul	16	141	<0.5	<0.1	<0.05	0.01	<0.005	NA	412	5.2	990	179	NA	1.7490	8.20	7.39
8-Aug	16	140	<0.5	<0.1	<0.05	<0.01	<0.005	NA	420	3.9	990	192	NA	1.7750	7.94	4.81
12-Sep	17	153	<0.5	<0.1	<0.05	<0.01	<0.005	NA	382	3.5	896	134	NA	1.6350	8.06	6.54
	Average	149	<0.5[k]	<0.1[k]	<0.05	<0.01[k]	<0.005[k]	NA	406	3.5	972	170	NA	1.7228	8.06	7.28

2001 **Hypolimnion**

DATE	DEPTH	ALK	TKN	NH_3-N	NO_3-N	TP	SRP	TDS	Cl^-	TSS	TS	TVS	SECCHI	COND	pH	DO
1-May	19	183	<0.5	<0.1	0.059	0.015	<0.005	749	NA	5.5	807	188	NA	1.4300	7.51	8.27
5-Jun	18	170	<0.5	<0.1	<0.05	0.014	<0.005	816	NA	5.2	829	164	NA	1.3860	7.98	8.05
10-Jul	16	176	0.53	<0.1	<0.05	0.032	<0.005	772	NA	15.5	885	188	NA	1.4900	7.09	0.93
7-Aug	16	191	0.51	<0.1	<0.05	0.024	0.007	830	300	6.9	951	246	NA	1.5170	7.08	0.30
5-Sep	16	160	0.55	<0.1	<0.05	0.010	0.006	812	400	4.1	802	94	NA	1.4580	7.81	5.70
	Average	176	0.53[k]	<0.1[k]	0.059[k]	0.019	0.007[k]	796	350	7.4	855	176	NA	1.4560	7.49	4.65

Glossary

ALK = Alkalinity, mg/L $CaCO_3$
TKN = Total Kjeldahl nitrogen, mg/L
NH_3-N = Ammonia nitrogen, mg/L
NO_3-N = Nitrate nitrogen, mg/L
NO2+NO3 = Nitrite and Nitrate nitrogen, mg/L
TP = Total phosphorus, mg/L
SRP = Soluble reactive phosphorus, mg/L
TDS* = Total dissolved solids, mg/L (calculated value)
Cl^- = Chloride ions, mg/L
TSS = Total suspended solids, mg/L
TS = Total solids, mg/L
TVS = Total volatile solids, mg/L
SECCHI = Secchi disk depth, ft.
COND = Conductivity, milliSiemens/cm
DO = Dissolved oxygen, mg/L

Note: "k" denotes that the actual value is known to be less than the value presented.
NA = Not Applicable
* = Prior to 2006 only Nitrate was analyzed

Lake Carina 2016 Multiparameter Data

Date	Text Depth	Dep25	Temp	DO	DO%	SpCond	pH	BGA-PC
MMDDYY	feet	feet	øC	mg/l	Sat	mS/cm	Units	RGU
5/17/2016	0.48216	0.50	14.87	11.3	112.0000	1.3156	8.40	0.09
5/17/2016	1.07912	1.00	14.86	11.3	112.1000	1.3157	8.41	0.09
5/17/2016	1.76136	2.00	14.87	11.3	112.3000	1.3175	8.43	0.04
5/17/2016	2.81424	3.00	14.86	11.3	112.2000	1.3176	8.43	0.06
5/17/2016	3.4932	4.00	14.86	11.3	112.2000	1.3175	8.43	0.07
5/17/2016	5.31688	6.00	14.85	11.3	112.1000	1.3173	8.43	0.07
5/17/2016	7.49152	9.00	14.85	11.3	112.1000	1.3172	8.43	0.07
5/17/2016	9.34144	10.00	14.84	11.3	112.1000	1.3174	8.43	0.07
5/17/2016	11.43408	12.00	14.83	11.3	112.4000	1.3172	8.44	0.08
5/17/2016	13.42504	14.00	14.82	11.4	112.9000	1.3169	8.44	0.06
5/17/2016	15.50456	16.00	14.66	12.1	119.2000	1.3154	8.47	0.07
5/17/2016	17.55456	18.00	14.58	11.7	115.9000	1.3160	8.45	0.07
5/17/2016	19.76856	20.00	14.53	11.1	109.3000	1.3159	8.39	0.08

Date	Text Depth	Dep25	Temp	DO	DO%	SpCond	pH	BGA-PC
MMDDYY	feet	feet	øC	mg/l	Sat	mS/cm	Units	RGU
6/14/2016	0.6	0.50	23.11	10.7	125.3000	1.3329	8.54	-0.04
6/14/2016	1.0	1.00	23.12	10.7	125.8000	1.3332	8.54	-0.01
6/14/2016	2.1	2.00	23.12	10.7	125.9000	1.3332	8.54	-0.03
6/14/2016	3.1	3.00	23.12	10.8	126.2000	1.3332	8.54	-0.05
6/14/2016	4.2	4.00	23.12	10.8	126.1000	1.3331	8.54	-0.04
6/14/2016	5.9	6.00	23.11	10.8	126.9000	1.3328	8.54	0
6/14/2016	8.1	8.00	23.05	11.2	131.3000	1.3315	8.54	-0.02
6/14/2016	10.0	10.00	23.02	11.4	133.7000	1.3301	8.55	-0.04
6/14/2016	12.1	12.00	22.96	11.7	137.2000	1.3288	8.56	-0.01
6/14/2016	14.2	14.00	22.88	12.3	143.6000	1.3274	8.57	0.01
6/14/2016	16.0	16.00	22.73	12.8	148.5000	1.3258	8.57	0
6/14/2016	18.0	18.00	21.98	16.3	186.8000	1.3174	8.65	-0.02
6/14/2016	19.3	20.00	20.92	19.1	215.0000	1.3031	8.71	0.02

Date	Text Depth	Dep25	Temp	DO	DO%	SpCond	pH	BGA-PC
MMDDYY	feet	feet	øC	mg/l	Sat	mS/cm	Units	RGU
7/12/2016	0.2	0.50	27.19	9.0	114.3000	1.3166	8.48	-0.05
7/12/2016	0.6	1.00	27.18	9.1	114.3000	1.3167	8.50	-0.02
7/12/2016	1.8	2.00	27.15	9.1	114.4000	1.3165	8.50	-0.04
7/12/2016	2.7	3.00	27.14	9.1	114.2000	1.3163	8.51	-0.03
7/12/2016	3.7	4.00	27.15	9.1	114.4000	1.3166	8.51	-0.06
7/12/2016	5.8	6.00	27.13	9.0	114.0000	1.3165	8.51	-0.05
7/12/2016	7.7	8.00	27.10	9.0	113.3000	1.3165	8.51	-0.07
7/12/2016	9.6	10.00	27.02	8.9	112.6000	1.3159	8.51	-0.06
7/12/2016	11.6	12.00	26.76	9.1	113.5000	1.3148	8.50	-0.05
7/12/2016	13.3	14.00	26.71	9.0	112.4000	1.3150	8.49	-0.05
7/12/2016	15.7	16.00	26.65	8.9	111.1000	1.3148	8.47	-0.03
7/12/2016	17.7	18.00	26.60	9.6	120.4000	1.3133	8.52	0.3
7/12/2016	19.1	20.00	26.40	6.3	78.3000	1.3088	8.14	0.37

Lake Carina 2016 Multiparameter Data

Date	Text Depth	Dep25	Temp	DO	DO%	SpCond	pH	BGA-PC
MMDDYY	feet	feet	øC	mg/l	Sat	mS/cm	Units	RGU
8/16/2016	0.7624672	0.5	28.102	7.23	92.9	1.3418	8.34	-0.05
8/16/2016	1.0971129	1	28.102	7.19	92.4	1.342	8.37	-0.05
8/16/2016	2.1765092	2	28.099	7.18	92.3	1.342	8.38	-0.06
8/16/2016	3.2001313	3	28.072	7.16	92	1.3421	8.39	-0.03
8/16/2016	4.089239	4	28.054	7.16	91.9	1.3419	8.39	-0.05
8/16/2016	6.0511813	6	28.004	7.06	90.5	1.342	8.39	-0.04
8/16/2016	7.9671918	8	27.984	7.03	90.2	1.3419	8.38	-0.05
8/16/2016	10.040683	10	27.963	7.11	91.1	1.3419	8.39	-0.06
8/16/2016	12.012468	12	27.955	7.03	90.1	1.342	8.39	-0.05
8/16/2016	14.167979	14	27.941	7.05	90.2	1.3418	8.39	-0.09
8/16/2016	16.126641	16	27.921	7.11	91	1.3413	8.39	-0.11
8/16/2016	17.934384	18	27.916	7.38	94.4	1.341	8.42	-0.03

Date	Text Depth	Dep25	Temp	DO	DO%	SpCond	pH	BGA-PC
MMDDYY	feet	feet	øC	mg/l	Sat	mS/cm	Units	RGU
9/13/2016	0.8333334	0.5	24.555	7.6	91.5	1.3477	8.29	-0.04
9/13/2016	1.0137796	1	24.538	7.58	91.3	1.3475	8.33	-0.03
9/13/2016	1.5813649	2	24.557	7.56	91.1	1.3479	8.35	0
9/13/2016	2.7329397	3	24.558	7.55	91	1.348	8.35	0.02
9/13/2016	3.5564306	4	24.567	7.55	90.9	1.3481	8.36	-0.03
9/13/2016	5.5052495	6	24.569	7.53	90.8	1.3482	8.37	0.02
9/13/2016	7.5196853	8	24.568	7.53	90.7	1.3482	8.37	-0.02
9/13/2016	9.5439636	10	24.569	7.52	90.6	1.3482	8.37	-0.01
9/13/2016	11.505906	12	24.566	7.5	90.4	1.3481	8.37	-0.02
9/13/2016	13.559712	14	24.562	7.49	90.2	1.348	8.37	-0.01
9/13/2016	15.511812	16	24.551	7.48	90.1	1.3477	8.37	0.01
9/13/2016	17.506562	18	24.528	7.5	90.3	1.347	8.37	0

Lake Carina Landuse Data

Land Use	Acreage	% of Total
Public and Private Open Space	14.65	35.83%
Utility and Waste Facilities	3.37	8.24%
Water	22.68	55.47%
Wetlands	0.19	0.47%
TOTAL	**40.89**	**100%**

Land Use	Acreage	Runoff Coeff.	Estimated Runoff, acft.	% Total of Estimated Runoff
Public and Private Open Space	14.65	0.15	6.04	68.28%
Utility and Waste Facilities	3.37	0.30	2.78	31.42%
Water	22.68	0.00	0.00	0.00%
Wetlands	0.19	0.05	0.03	0.30%
TOTAL	**40.89**		**8.85**	100.00%

Lake volume	**318.92**	**acre-feet**
Retention Time (years)= lake volume/runoff	**36.04**	**years**
	13152.89	**days**

NOTE: Runoff calculations do not include the acreage of the lake itself, which is part of the total watershed area

Table 1: Lake Carina Shoreline Erosion Condition 2016

Reach	No Erosion		Slight Erosion		Moderate Erosion		Severe Erosion		Total	Lateral Recession Rate
	ft.	%	ft.	%	ft.	%	ft.	%	ft	ft/yr
CAR01	725.5	97%	19.1	3%	0.0	0%	0	0%	744.6	0.01
CAR02	586.4	79%	159.7	21%	0.0	0%	0	0%	746.1	0.01
CAR03	550.0	72%	215.9	28%	0.0	0%	0	0%	765.9	0.01
CAR04	656.2	59%	271.3	24%	89.7	8%	100.8	9%	1117.9	0.06
CAR05	1154.1	88%	111.1	8%	52.3	4%	0	0%	1317.4	0.01
Total	3672.1	78%	777.0	17%	141.9	3%	100.8	2%	4691.9	

Table 2: Lake Carina Lakeshore Buffer Condition 2016

Reach	Poor		Fair		Good		Total
	ft.	%	ft.	%	ft.	%	ft
CAR01	0.0	0%	0.0	0%	744.6	100%	744.6
CAR02	0.0	0%	231.2	31%	514.8	69%	746.1
CAR03	0.0	0%	51.9	7%	714.0	93%	765.9
CAR04	0.0	0%	353.1	32%	764.8	68%	1117.9
CAR05	96.5	7%	0.0	0%	1220.9	93%	1317.4
Total	96.5	2%	636.3	14%	3959.0	84%	4691.9

Lake Carina
2016 Aquatic Macrophyte Survey

Aquatic Plants found at 91 sampling sites in Lake Carina in July 2016
The maximum depth that plants were found was 19.2 ft.

Plant Density	American Pondweed	Chara	Sago Pondweed	Slender Naiad	Small Leaf Pondweed	Spiny Naiad	Brittle Naiad
Absent	94	11	100	96	98	87	102
Present	5	12	2	6	4	9	1
Common	4	37	1	1	1	6	0
Abundant	0	26	0	0	0	1	0
Dominant	0	17	0	0	0	0	0
% Plant Occurence	8.7	89.3	2.9	6.8	4.9	15.5	1.0
Total Sites	103	103	103	103	103	103	103

Distribution of Rake Density across all sampling sites

Rake Density (coverage)	# of Sites	% of Sites
No Plants	12	11.7
>0-10%	28	27.2
10-40%	32	31.1
40-60%	21	20.4
60-90%	2	1.9
>90%	8	7.8
Total Sites with Plants	91	88.3
Total # Sites	103	100.0

Morphometric Features of Lake Carina ~

Data From the June 2008 Bathymetric Survey, LCHD Lakes Management Unit

Contour (Feet)	Area Enclosed (Acres)	Percent of Total Acres	Volume (Acre-feet)	Depth Zone (Feet)	Area (Acres)	Percent (Depth Zone to Total Acres)	Percent (Acre-feet to Total Volume)
0	23.32	100.0%	23.07	0 - 1	0.50	2.1%	7.2%
1	22.82	97.9%	22.57	1 - 2	0.50	2.2%	7.1%
2	22.32	95.7%	22.06	2 - 3	0.51	2.2%	6.9%
3	21.81	93.5%	21.57	3 - 4	0.48	2.1%	6.8%
4	21.33	91.5%	21.10	4 - 5	0.45	1.9%	6.6%
5	20.88	89.5%	20.66	5 - 6	0.44	1.9%	6.5%
6	20.44	87.6%	20.19	6 - 7	0.48	2.1%	6.3%
7	19.96	85.6%	19.70	7 - 8	0.51	2.2%	6.2%
8	19.45	83.4%	19.12	8 - 9	0.65	2.8%	6.0%
9	18.80	80.6%	18.43	9 - 10	0.74	3.2%	5.8%
10	18.07	77.5%	17.64	10 - 11	0.85	3.6%	5.5%
11	17.21	73.8%	16.69	11 - 12	1.04	4.5%	5.2%
12	16.17	69.4%	15.56	12 - 13	1.22	5.2%	4.9%
13	14.95	64.1%	14.15	13 - 14	1.59	6.8%	4.4%
14	13.36	57.3%	12.39	14 - 15	1.91	8.2%	3.9%
15	11.45	49.1%	10.61	15 - 16	1.67	7.1%	3.3%
16	9.78	42.0%	8.85	16 - 17	1.84	7.9%	2.8%
17	7.94	34.1%	6.87	17 - 18	2.11	9.0%	2.2%
18	5.84	25.0%	4.80	18 - 19	2.01	8.6%	1.5%
19	3.83	16.4%	2.23	19 - 20	2.88	12.3%	0.7%
20	0.95	4.1%	0.54	20 - 21	0.74	3.2%	0.2%
21	0.21	0.9%	0.11	21 - 22	0.18	0.8%	0.03%
22	0.03	0.1%	0.01	22 - 23	0.03	0.1%	0.004%
23	0.0003	0.0%	0.01	23+	0.0003	0.001%	0.002%
			318.92		23.32	100%	100%

Maximum Depth of Lake: 23.26 Feet
Average Depth of Lake: 13.68 Feet
Volume of Lake: 318.92 Acre-Feet

Area of Lake: 23.32 Acres
Shoreline Length: 0.89 Miles
Water elevation at 656.22 feet above mean sea level

LakeCounty
Health Department and
Community Health Center

Lake County average Floristic Quality Index (FQI) ranking 2000-2016.

RANK	LAKE NAME	FQI (w/A)	FQI (native)
1	Cedar Lake	37.4	38.9
2	East Loon Lake	34.7	36.1
3	Cranberry Lake	29.7	29.7
4	Deep Lake	29.7	31.2
5	Round Lake Marsh North	29.1	29.9
6	West Loon Lake	27.1	29.5
7	Sullivan Lake	26.9	28.5
8	Bangs Lake	26.2	27.8
9	Little Silver Lake	25.2	26.7
10	Third Lake	25.1	22.5
11	Fourth Lake	24.7	27.1
12	Indpendence Grove	24.4	26.8
13	Sun Lake	24.3	26.1
14	Redwing Slough	24.0	25.8
15	Schreiber Lake	23.9	24.8
16	Lakewood Marsh	23.8	24.7
17	Sterling Lake	23.6	25.4
18	Deer Lake	23.5	24.4
19	Round Lake	23.5	25.9
20	Pistakee Lake	23.5	25.2
21	Lake Marie	23.5	25.2
22	Lake of the Hollow	23.0	24.8
23	Nippersink Lake (Fox Chain)	22.4	23.2
24	Countryside Glen Lake	21.9	22.8
25	Grass Lake	21.5	22.2
26	Davis Lake	21.4	21.4
27	Timber Lake (North)	20.9	23.4
28	Lake Catherine	20.8	21.8
29	Cross Lake	20.7	18.7
30	ADID 203	20.5	20.5
31	Broberg Marsh	20.5	21.4
32	McGreal Lake	20.2	22.1
33	Fox Lake	20.2	21.2
34	Honey Lake	20.0	20.0
35	Lake Barrington	19.9	21.8
36	Lake Kathryn	19.6	20.7
37	Druce Lake	19.1	21.8
38	Turner Lake	18.6	21.2
39	Salem Lake	18.5	20.2
40	Duck Lake	18.3	19.2
41	Wooster Lake	18.0	20.1
42	Lake Helen	18.0	18.0
43	Old Oak Lake	18.0	19.1
44	Lake Minear	18.0	20.1
45	Potomac Lake	17.8	17.8
46	Lake Zurich	17.7	18.9
47	Redhead Lake	17.7	18.7
48	Long Lake	17.7	15.8
49	Hendrick Lake	17.7	17.7
50	Rollins Savannah 2	17.7	17.7
51	Grandwood Park Lake	17.2	19.0
52	Seven Acre Lake	17.0	15.5
53	Lake Miltmore	16.8	18.7
54	Petite Lake	16.8	18.7
55	Channel Lake	16.8	18.7
56	McDonald Lake 1	16.7	17.7
57	Highland Lake	16.7	18.9
58	Almond Marsh	16.3	17.3

Lake County average Floristic Quality Index (FQI) ranking 2000-2016.

RANK	LAKE NAME	FQI (w/A)	FQI (native)
59	Owens Lake	16.3	17.3
60	Windward Lake	16.3	17.6
61	Butler Lake	16.1	18.1
62	Grays Lake	16.1	16.1
63	White Lake	16.0	17.0
64	Dunns Lake	15.9	17.0
65	Dog Bone Lake	15.7	15.7
66	Osprey Lake	15.5	17.3
67	Heron Pond	15.1	15.1
68	Ames Pit	15.1	17.6
69	North Churchill Lake	15.0	15.0
70	Hastings Lake	15.0	17.0
71	Forest Lake	14.8	15.9
72	Dog Training Pond	14.7	15.9
73	Summerhill Estates Lake	14.5	15.5
74	Grand Ave Marsh	14.3	16.3
75	Nippersink Lake	14.3	16.3
76	Taylor Lake	14.3	16.3
77	Manning's Slough	14.1	16.3
78	Tower Lake	14.0	14.0
79	Dugdale Lake	14.0	15.1
80	Eagle Lake (S1)	14.0	15.1
81	Crooked Lake	14.0	16.0
82	Spring Lake	14.0	15.2
83	Lake Matthews	13.9	15.5
84	Longview Meadow Lake	13.9	13.9
85	Fischer Lake	13.6	14.7
86	Bishop Lake	13.4	15.0
87	Mary Lee Lake	13.1	15.1
88	Old School Lake	13.1	15.1
89	Lake Tranquility (S1)	12.6	12.6
90	Buffalo Creek Reservoir 1	12.5	11.4
91	Buffalo Creek Reservoir 2	12.5	11.4
92	McDonald Lake 2	12.5	12.5
93	Rollins Savannah 1	12.5	12.5
94	Stone Quarry Lake	12.5	12.5
95	Kemper Lake 1	12.2	13.4
96	Pond-A-Rudy	12.1	12.1
97	Stockholm Lake	12.1	13.5
98	Lake Leo	12.1	14.3
99	Lambs Farm Lake	12.1	14.3
100	Bresen Lake	12.0	13.9
101	Grassy Lake	12.0	12.0
102	Flint Lake Oulet	11.8	13.0
103	Albert Lake	11.5	10.3
104	Rivershire Pond 2	11.5	13.3
105	Hook Lake	11.3	13.4
106	Briarcrest Pond	11.2	12.5
107	Lake Naomi	11.2	12.5
108	Pulaski Pond	11.2	12.5
109	Lake Napa Suwe	11.0	11.0
110	Redwing Marsh	11.0	11.0
111	West Meadow Lake	11.0	11.0
112	Nielsen Pond	10.7	12.0
113	Lake Holloway	10.6	10.6
114	Sylvan Lake	10.6	10.6
115	Echo Lake	10.4	10.4
116	Gages Lake	10.2	12.5

Lake County average Floristic Quality Index (FQI) ranking 2000-2016.

RANK	LAKE NAME	FQI (w/A)	FQI (native)
117	College Trail Lake	10.0	10.0
118	Valley Lake	9.9	9.9
119	Werhane Lake	9.8	12.0
120	Fish Lake	9.6	10.6
121	Lake Carina	9.5	12.5
122	Columbus Park Lake	9.2	9.2
123	Lake Lakeland Estates	9.2	9.2
124	Waterford Lake	9.2	9.2
125	Bluff Lake	9.1	11.0
126	Lake Fairfield	9.0	10.4
127	Des Plaines Lake	8.6	9.9
128	Antioch Lake	8.5	8.5
129	Loch Lomond	8.5	8.5
130	Lake Fairview	8.5	6.9
131	Timber Lake (South)	8.5	6.9
132	East Meadow Lake	8.5	8.5
133	South Churchill Lake	8.5	8.5
134	Kemper Lake 2	8.5	9.8
135	Lake Christa	8.5	9.8
136	Lake Farmington	8.5	9.8
137	Lucy Lake	8.5	9.8
138	Lake Louise	8.4	8.4
139	Bittersweet Golf Course #13	8.1	8.1
140	Lake Linden	8.0	8.0
141	Sand Lake	8.0	10.4
142	Countryside Lake	7.7	11.5
143	Fairfield Marsh	7.5	8.7
144	Lake Eleanor	7.5	8.7
145	Banana Pond	7.5	9.2
146	Slocum Lake	7.1	5.8
147	Lucky Lake	7.0	7.0
148	North Tower Lake	7.0	7.0
149	Lake Forest Pond	6.9	8.5
150	Ozaukee Lake	6.7	8.7
151	Leisure Lake	6.4	9.0
152	Peterson Pond	6.0	8.5
153	Little Bear Lake	5.8	7.5
154	Deer Lake Meadow Lake	5.2	6.4
155	ADID 127	5.0	5.0
156	Island Lake	5.0	5.0
157	Liberty Lake	5.0	5.0
158	Oak Hills Lake	5.0	5.0
159	Slough Lake	5.0	5.0
160	International Mining and Chemical Lake	5.0	7.1
161	Lochanora Lake	5.0	5.0
162	Diamond Lake	3.7	5.5
163	Lake Charles	3.7	5.5
164	Big Bear Lake	3.5	5.0
165	Sand Pond (IDNR)	3.5	5.0
166	Harvey Lake	3.3	5.0
167	Half Day Pit	2.9	5.0
168	Hidden Lake	0.0	0.0
169	St. Mary's Lake	0.0	0.0
170	Willow Lake	0.0	0.0
171	Woodland Lake	0.0	0.0
	Mean	**13.9**	**14.9**
	Median	**13.4**	**14.7**

Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
1	Sterling Lake	0.0110	38.73
2	Lake Carina	0.0110	38.73
3	Indpendence Grove	0.0130	41.14
4	Cedar Lake	0.0130	41.14
5	Druce Lake	0.0140	42.21
6	Windward Lake	0.0160	44.13
7	Lake Minear	0.0164	44.49
8	Sand Pond (IDNR)	0.0165	44.57
9	West Loon	0.0170	45.00
10	Pulaski Pond	0.0180	45.83
11	Ames Pit	0.0190	46.61
12	Banana Pond	0.0200	47.35
13	Gages Lake	0.0200	47.35
14	Lake Kathryn	0.0200	47.35
15	Highland Lake	0.0202	47.49
16	Lake Miltmore	0.0210	48.05
17	Timber Lake (North)	0.0210	48.05
18	Lake Zurich	0.0210	48.05
19	Cross Lake	0.0216	48.46
20	Dog Training Pond	0.0220	48.72
21	Sun Lake	0.0220	48.72
22	Deep Lake	0.0230	49.36
23	Lake of the Hollow	0.0230	49.36
24	Round Lake	0.0230	49.36
25	Stone Quarry Lake	0.0230	49.36
26	Bangs Lake	0.0260	51.13
27	Lake Leo	0.0260	51.13
28	Lake Barrington	0.0270	51.68
29	Cranberry Lake	0.0270	51.68
30	Dugdale Lake	0.0270	51.68
31	Peterson Pond	0.0270	51.68
32	Little Silver Lake	0.0280	52.20
33	Wooster Lake	0.0290	52.71
34	Lambs Farm Lake	0.0310	53.67
35	Old School Lake	0.0310	53.67
36	Grays Lake	0.0310	53.67
37	Harvey Lake	0.0320	54.13
38	Butler Lake	0.0324	54.31
39	Hendrick Lake	0.0340	55.00
40	Fourth Lake	0.0360	55.82
41	Sullivan Lake	0.0370	56.22
42	Sand Lake	0.0380	56.60
43	Third Lake	0.0384	56.77
44	Diamond Lake	0.0390	56.98
45	East Loon	0.0400	57.34
46	Schreiber Lake	0.0400	57.34
47	Waterford Lake	0.0400	57.34
48	Hook Lake	0.0410	57.70
49	Lake Tranquility (S1)	0.0412	57.77
50	Nielsen Pond	0.0450	59.04
51	Seven Acre Lake	0.0460	59.36

Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
52	Turner Lake	0.0460	59.36
53	Willow Lake	0.0460	59.36
54	East Meadow Lake	0.0480	59.97
55	Lucky Lake	0.0480	59.97
56	Old Oak Lake	0.0490	60.27
57	College Trail Lake	0.0500	60.56
58	Summerhill Estates Lake	0.0514	60.96
59	Hastings Lake	0.0520	61.13
60	West Meadow Lake	0.0530	61.40
61	Lucy Lake	0.0550	61.94
62	Lake Linden	0.0570	62.45
63	Lake Christa	0.0580	62.70
64	Owens Lake	0.0580	62.70
65	Briarcrest Pond	0.0580	62.70
66	Honey Lake	0.0586	62.85
67	Redhead Lake	0.0608	63.38
68	St. Mary's Lake	0.0608	63.38
69	Duck Lake	0.0610	63.43
70	Lake Lakeland Estates	0.0620	63.66
71	Lake Naomi	0.0620	63.66
72	Lake Catherine	0.0620	63.66
73	Liberty Lake	0.0630	63.89
74	North Tower Lake	0.0630	63.89
75	Werhane Lake	0.0630	63.89
76	Countryside Glen Lake	0.0640	64.12
77	Davis Lake	0.0650	64.34
78	Leisure Lake	0.0650	64.34
79	Channel Lake	0.0680	65.00
80	Buffalo Creek Reservoir 1	0.0680	65.00
81	Mary Lee Lake	0.0680	65.00
82	Little Bear Lake	0.0680	65.00
83	Crooked Lake	0.0710	65.62
84	Timber Lake (South)	0.0720	65.82
85	Lake Helen	0.0720	65.82
86	Grandwood Park Lake	0.0720	65.82
87	ADID 203	0.0730	66.02
88	Fish Lake	0.0730	66.02
89	Broberg Marsh	0.0780	66.97
90	Echo Lake	0.0790	67.16
91	Countryside Lake	0.0800	67.34
92	Lake Nippersink	0.0800	67.34
93	Woodland Lake	0.0800	67.34
94	Redwing Slough	0.0822	67.73
95	Tower Lake	0.0830	67.87
96	Antioch Lake	0.0850	68.21
97	Potomac Lake	0.0850	68.21
98	White Lake	0.0862	68.42
99	Grand Ave Marsh	0.0870	68.55
100	North Churchill Lake	0.0870	68.55
101	McDonald Lake 1	0.0880	68.71
102	Pistakee Lake	0.0880	68.71

Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
103	Lake Fairview	0.0890	68.88
104	Rivershire Pond 2	0.0900	69.04
105	South Churchill Lake	0.0900	69.04
106	McGreal Lake	0.0910	69.20
107	Lake Charles	0.0930	69.51
108	Deer Lake	0.0940	69.66
109	Eagle Lake (S1)	0.0950	69.82
110	International Mine and Chemical Lake	0.0950	69.82
111	Valley Lake	0.0950	69.82
112	Buffalo Creek Reservoir 2	0.0960	69.97
113	Big Bear Lake	0.0960	69.97
114	Fox Lake	0.1000	70.56
115	Nippersink Lake - LCFP	0.1000	70.56
116	Sylvan Lake	0.1000	70.56
117	Petite Lake	0.1020	70.84
118	Longview Meadow Lake	0.1020	70.84
119	Lake Marie	0.1030	70.98
120	Dunn's Lake	0.1070	71.53
121	Lake Forest Pond	0.1070	71.53
122	Long Lake	0.1070	71.53
123	Grass Lake	0.1090	71.80
124	Des Plaines Lake	0.1090	71.80
125	Spring Lake	0.1100	71.93
126	Kemper 2	0.1100	71.93
127	Bittersweet Golf Course #13	0.1100	71.93
128	Osprey Lake	0.1110	72.06
129	Bluff Lake	0.1120	72.19
130	Middlefork Savannah Outlet 1	0.1120	72.19
131	Lochanora Lake	0.1120	72.19
132	Round Lake Marsh North	0.1130	72.32
133	Deer Lake Meadow Lake	0.1160	72.70
134	Lake Matthews	0.1180	72.94
135	Taylor Lake	0.1180	72.94
136	Island Lake	0.1210	73.31
137	Columbus Park Lake	0.1230	73.54
138	Lake Holloway	0.1320	74.56
139	Fischer Lake	0.1380	75.20
140	Slocum Lake	0.1500	76.40
141	Lakewood Marsh	0.1510	76.50
142	Pond-A-Rudy	0.1510	76.50
143	Forest Lake	0.1540	76.78
144	Bresen Lake	0.1580	77.15
145	Middlefork Savannah Outlet 2	0.1590	77.24
146	Grassy Lake	0.1610	77.42
147	Salem Lake	0.1650	77.78
148	Half Day Pit	0.1690	78.12
149	Lake Louise	0.1810	79.11
150	Lake Eleanor	0.1810	79.11
151	Lake Farmington	0.1850	79.43
152	ADID 127	0.1890	79.74

Lake County average TSI phosphorus (TSIp) ranking 2000-2016.

RANK	LAKE NAME	TP AVE	TSIp
153	Lake Napa Suwe	0.1940	80.11
154	Loch Lomond	0.1960	80.26
155	Patski Pond	0.1970	80.33
156	Dog Bone Lake	0.1990	80.48
157	Redwing Marsh	0.2070	81.05
158	Stockholm Lake	0.2082	81.13
159	Bishop Lake	0.2160	81.66
160	Ozaukee Lake	0.2200	81.93
161	Kemper 1	0.2220	82.06
162	Hidden Lake	0.2240	82.19
163	McDonald Lake 2	0.2250	82.25
164	Oak Hills Lake	0.2790	85.35
165	Heron Pond	0.2990	86.35
166	Rollins Savannah 1	0.3070	86.73
167	Fairfield Marsh	0.3260	87.60
168	ADID 182	0.3280	87.69
169	Manning's Slough	0.3820	89.88
170	Slough Lake	0.3860	90.03
171	Rasmussen Lake	0.4860	93.36
172	Albert Lake, Site II, outflow	0.4950	93.62
173	Flint Lake Outlet	0.5000	93.76
174	Rollins Savannah 2	0.5870	96.08
175	Almond Marsh	1.9510	113.40
	Average	***0.1113***	***65.8***

Appendix C:
Methods for Field Data Collection and Laboratory Analyses

Water Sampling and Laboratory Analyses

Two water samples were collected once a month from May through September. Sample locations were at the deepest point in the lake (see sample site map), three feet below the surface, and 3 feet above the bottom. Samples were collected with a horizontal Van Dorn water sampler. Approximately three liters of water were collected for each sample for all lab analyses. After collection, all samples were placed in a cooler with ice until delivered to the Lake County Health Department lab, where they were refrigerated. Analytical methods for the parameters are listed in Table A1. Except nitrate nitrogen, all methods are from the Eighteenth Edition of Standard Methods, (eds. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1992). Methodology for nitrate nitrogen was taken from the 14th edition of Standard Methods. Dissolved oxygen, temperature, conductivity and pH were measured at the deep hole with a Hydrolab DataSonde® 4a. Photosynthetic Active Radiation (PAR) was recorded using a LI-COR® 192 Spherical Sensor attached to the Hydrolab DataSonde® 4a. Readings were taken at the surface and then every two feet until reaching the bottom.

Plant Sampling

In order to randomly sample each lake, mapping software (ArcMap 9.3) overlaid a grid pattern onto an aerial photo of Lake County and placed points 60 or 30 meters apart, depending on lake size. Plants were sampled using a garden rake fitted with hardware cloth. The hardware cloth surrounded the rake tines and is tapered two feet up the handle. A rope was tied to the end of the handle for retrieval. At designated sampling sites, the rake was tossed into the water, and using the attached rope, was dragged across the bottom, toward the boat. After pulling the rake into the boat, plant coverage was assessed for overall abundance. Then plants were individually identified and placed in categories based on coverage. Plants that were not found on the rake but were seen in the immediate vicinity of the boat at the time of sampling were also recorded. Plants difficult to identify in the field were placed in plastic bags and identified with plant keys after returning to the office. The depth of each sampling location was measured either by a hand-held depth meter, or by pushing the rake straight down and measuring the depth along the rope or rake handle. One-foot increments were marked along the rope and rake handle to aid in depth estimation.

Plankton Sampling

Plankton were sampled at the same location as water quality samples. Using the Hydrolab DataSonde® 4a or YSI 6600 Sonde® 1% light level depth (depth where the water light is 1% of the surface irradiance) was determined. A plankton net/tow, with 63μm mesh, was then lowered to the pre-determined 1% light level depth and retrieved vertically. On the way up the water column, plankton were collected within a small cup on the bottom of the tow. The collected sample was then emptied into a pre-labeled brown plastic bottle. The net was rinsed with deionized water into the bottle in order to ensure all the plankton were collected. The sample was then transferred to a graduated cylinder to measure the amount of milliliters (mL) that the sample was. The sample was then returned to the bottle and preserved with Lugol's iodine solution (5 drops/mL). The sample bottle was then closed and stored in a cooler until returning to the lab, where it was transferred to the refrigerator until enumeration. Enumeration was performed within three months, but ideally within one month, under a microscope. Prior to sub-sample being removed for enumeration, the sample bottle was inverted several times to ensure proper homogenization. An automated pipette was used to retrieve 1 mL of sample, which was then placed in a Sedgewick Rafter slide. This is a microscope slide on which a rectangular chamber has been constructed, measuring 50 mm x 20 mm in area and 1 mm deep. The slide was then placed under the microscope and counted at a 20X magnification (phytoplankton) or 10X magnification (zooplankton). For phytoplankton, twenty fields of view were randomly counted with all species within each field counted. Due to their larger size, zooplankton were counted throughout the entire slide. Through calculations, it was determined how many of each species were in 1 mL of lake water.

Phytoplankton (algae) are free-floating and microscopic and are distinguished from plants because they lack roots, stems and leaves. There are four distinct groups of phytoplankton found in Lake County lakes: blue-greens, greens, diatoms, and dinoflagellates/chrysophytes. Blue-greens are also known as cyanobacteria because they are the only group of bacteria that obtain their energy from photosynthesis like plants. Some of these species can be toxic. Green algae are the closest ancestors of land plants and are the most common group. Diatoms are unique because they are encased in a cell wall made of silica that can be very ornate. Dinoflagellates and chrysophytes are almost always flagellated (able to move by flagella, a whip-like tail) and some can both photosynthesize and consume bacteria for food.

Zooplankton are made up of rotifers and two crustacean groups; the cladocerans and the copepods (broken down further into calanoids and cyclopoids). Rotifers are smaller and most have a crown of cilia (hair-like structure) used for movement and drawing in suspended particles to eat. Crustaceans have jointed appendages and are enclosed in an exoskeleton. Cladocerans, such as the "water flea" Daphnia species, are filter-feeding like rotifers, while the copepod group contains both filter-feeders (calanoids and cyclopoids) and raptorial species (cyclopoids).

Shoreline Assessment

Shoreline Assessment Protocol

Each lake was divided into reaches in ArcGIS based on nearshore landuse. For each reach, a shoreline assessment worksheet was filled out in the field focusing on shoreline conditions (land use, slope, erosion, buffer, etc) that describe the overall reach segment of the lake.

A GPS Trimble unit was used to collect the degree of shoreline erosion along the entire length of the lake. The degree of shoreline erosion was categorically defined as none, slight, moderate, or severe. Below are brief descriptions of each category.

Table 1: Degree of Shoreline Erosion

Category	Description
None	Includes man-made erosion control such as rip-rap and sea wall.
Slight	Minimal or no observable erosion; generally considered stable; no erosion control practices will be recommended with the possible exception of small problem areas noted within an area otherwise designated as "slight". Beaches have been included as "slight" erosion.
Moderate	Recession is characterized by past or recently eroded banks; area may exhibit some exposed roots, fallen vegetation or minor slumping of soil material; erosion control practices may be recommended although the section is not deemed to warrant immediate remedial action.
Severe	Recession is characterized by eroding of exposed soil on nearly vertical banks, exposed roots, fallen vegetation or extensive slumping of bank material, undercutting, washouts or fence posts exhibiting realignment; erosion control practices are recommended and immediate remedial action may be warranted.

Lateral recession rates were calculated on a per reach basis based on the IL EPA stream methodology, defining lateral recession into four main categories (slight, moderate, severe, and very severe). Descriptions of each category are defined in the Table 2.

Table 2: Lateral Recession Rate Categories

Lateral Recession Rate	Description	Description
0.01 – 0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetation overhanging. No exposed tree roots.
0.06 – 0.2	Moderate	Bank mostly bare with some rills and vegetation overhanging.
0.3 – 0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

Shoreline Buffer Condition

Lakeshore buffer condition was assessed using a qualitative methodology that considered an area up to 25 feet inland from the shoreline for each reach. The assessment was done by viewing high resolution 2014 aerial images in ArcGIS. A 25 foot buffer was chosen based on research that indicates a 25-foot vegetated buffer is the minimum effective width for in-lake habitat maintenance (a 15 foot buffer is the minimum effective width for bank stability). Criteria used for category assignment are shown in table below.

Table 3: Shoreline Buffer Condition Categories

Category	Criteria	Percentage
Good	Unmowed grasses & forbs + tree trunks + shrubs *and* impervious surfaces	≥70% ≤5%
Fair	Unmowed grasses & forbs + tree trunks + shrubs *and* Impervious surface	≥50% and <70% ≤10%
Poor	Unmowed grasses & forbs +tree trunks + shrubs *and* Impervious surface	<50% ≥50%

Wildlife Assessment

Species of wildlife were noted during visits to each lake. When possible, wildlife was identified to species by sight or sound. However, due to time constraints, collection of quantitative information was not possible. Thus, all data should be considered anecdotal.
Some of the species on the list may have only been seen once, or were spotted during their migration through the area.

Table A1. Analytical methods used for water quality parameters.

Parameter	***Method***
Temperature	Hydrolab DataSonde® 4a or YSI 6600 Sonde®
Dissolved oxygen	Hydrolab DataSonde ®4a or YSI 6600 Sonde®
Nitrate and Nitrite nitrogen	USEPA 353.2 rev. 2.0 EPA-600/R-93/100 Detection Limit = 0.05 mg/L
Ammonia nitrogen	SM 18th ed. Electrode method, #4500 NH_3-F Detection Limit = 0.1 mg/L
Total Kjeldahl nitrogen	SM 18th ed, 4500-N_{org} C Semi-Micro Kjeldahl, plus 4500 NH_3-F Detection Limit = 0.5 mg/L
pH	Hydrolab DataSonde® 4a, or YSI 6600 Sonde® Electrometric method
Total solids	SM 18th ed, Method #2540B
Total suspended solids	SM 18th ed, Method #2540D Detection Limit = 0.5 mg/L
Chloride	SM 18th ed, Method #4500C1-D
Total volatile solids	SM 18th ed, Method #2540E, from total solids
Alkalinity	SM 18th ed, Method #2320B, patentiometric titration curve method
Conductivity	Hydrolab DataSonde® 4a or YSI 6600 Sonde®
Total phosphorus	SM 18th ed, Methods #4500-P B 5 and #4500-P E Detection Limit = 0.01 mg/L
Soluble reactive phosphorus	SM 18th ed, Methods #4500-P B 1 and #4500-P E Detection Limit = 0.005 mg/L
Clarity	Secchi disk
Color	Illinois EPA Volunteer Lake Monitoring Color Chart
Photosynthetic Active Radiation (PAR)	Hydrolab DataSonde® 4a or YSI 6600 Sonde®, LI-COR® 192 Spherical Sensor

Appendix D:
Interpreting Your Lake's Water Quality Data

Lakes possess a unique set of physical and chemical characteristics that will change over time. These in-lake water quality characteristics, or parameters, are used to describe and measure the quality of lakes, and they relate to one another in very distinct ways. As a result, it is virtually impossible to change any one component in or around a lake without affecting several other components, and it is important to understand how these components are linked.

The following pages will discuss the different water quality parameters measured by Lake County Health Department staff, how these parameters relate to each other, and why the measurement of each parameter is important. The median values (the middle number of the data set, where half of the numbers have greater values, and half have lesser values) of data collected from Lake County lakes from 2000-2010 will be used in the following discussion.

Temperature and Dissolved Oxygen:

Water temperature fluctuations will occur in response to changes in air temperatures, and can have dramatic impacts on several parameters in the lake. In the spring and fall, lakes tend to have uniform, well-mixed conditions throughout the water column (surface to the lake bottom). However, during the summer, deeper lakes will separate into distinct water layers. As surface water temperatures increase with increasing air temperatures, a large density difference will form between the heated surface water and colder bottom water. Once this difference is large enough, these two water layers will separate and generally will not mix again until the fall. At this time the lake is thermally stratified. The warm upper water layer is called the ***epilimnion***, while the cold bottom water layer is called the ***hypolimnion***. In some shallow lakes, stratification and destratification can occur several times during the summer. If this occurs the lake is described as polymictic. Thermal stratification also occurs to a lesser extent during the winter, when warmer bottom water becomes separated from ice-forming water at the surface until mixing occurs during spring ice-out.

Monthly temperature profiles were established on each lake by measuring water temperature every foot (lakes $\leq$ 15 feet deep) or every two feet (lakes > 15 feet deep) from the lake surface to the lake bottom. These profiles are important in understanding the distribution of chemical/biological characteristics and because increasing water temperature and the establishment of thermal stratification have a direct impact on dissolved oxygen (DO) concentrations in the water column. If a lake is shallow and easily mixed by wind, the DO concentration is usually consistent throughout the water column. However, shallow lakes are typically dominated by either plants or algae, and increasing water temperatures during the summer speeds up the rates of photosynthesis and decomposition in surface waters. Many of the plants or algae die at the end of the growing season. Their decomposition results in heavy oxygen consumption and can lead to an oxygen crash. In deeper, thermally stratified lakes, oxygen production is greatest in the top portion of the lake, where sunlight drives photosynthesis, and oxygen consumption is greatest near the bottom of a lake, where sunken organic matter accumulates and decomposes. The oxygen difference between the top and bottom water layers can be dramatic, with plenty of oxygen near the surface, but practically none near the bottom. The oxygen profiles measured during the water quality study can illustrate if this is occurring. This is important because the absence of oxygen (anoxia) near the lake bottom can have adverse effects in eutrophic lakes resulting in the chemical release of phosphorus from lake sediment and the production of hydrogen sulfide (rotten egg smell) and other gases in the bottom waters. Low oxygen conditions in the upper water of a lake can also be problematic since all aquatic organisms need oxygen to live. Some oxygen may be present in the water, but at too low a concentration to sustain aquatic life. Oxygen is needed by all plants, virtually all algae and for many chemical reactions that are important in lake functioning. Most adult sport-fish such as largemouth bass and bluegill require at least 3 mg/L of DO in the water to survive. However, their offspring require at least 5 mg/L DO as they are more sensitive to DO stress. When DO concentrations drop below 3 mg/L, rough fish such as carp and green sunfish are favored and over time will become the dominant fish species.

External pollution in the form of oxygen-demanding organic matter (i.e., sewage, lawn clippings, soil from shoreline erosion, and agricultural runoff) or nutrients that stimulate the growth of excessive organic matter (i.e., algae and plants) can reduce average DO concentrations in the lake by increasing oxygen consumption. This can have a detrimental impact on the fish community, which may be squeezed into a very small volume of water as a result of high temperatures in the epilimnion and low DO levels in the hypolimnion.

Nutrients:

Phosphorus:

For most Lake County lakes, phosphorus is the nutrient that limits plant and algae growth. This means that any addition of phosphorus to a lake will typically result in algae blooms or high plant densities during the summer. The source of phosphorus to a lake can be external or internal (or both). External sources of phosphorus enter a lake through point (i.e., storm pipes and wastewater discharge) and non-point runoff (i.e., overland water flow). This runoff can pick up large amounts of phosphorus from agricultural fields, septic systems or impervious surfaces before it empties into the lake.

Internal sources of phosphorus originate within the lake and are typically linked to the lake sediment. In lakes with high oxygen levels (oxic), phosphorus can be released from the sediment through plants or sediment resuspension. Plants take up sediment-bound phosphorus through their roots, releasing it in small amounts to the water column throughout their life cycles, and in large amounts once they die and begin to decompose. Sediment resuspension can occur through biological or mechanical means. Bottom-feeding fish, such as common carp and black bullhead can release phosphorus by stirring up bottom sediment during feeding activities and can add phosphorus to a lake through their fecal matter. Sediment resuspension, and subsequent phosphorus release, can also occur via wind/wave action or through the use of artificial aerators, especially in shallow lakes. In lakes that thermally stratify, internal phosphorus release can occur from the sediment through chemical means. Once oxygen is depleted (anoxia) in the hypolimnion, chemical reactions occur in which phosphorus bound to iron complexes in the sediment becomes soluble and is released into the water column. This phosphorus is trapped in the hypolimnion and is unavailable to algae until fall turnover, and can cause algae blooms once it moves into the sunlit surface water at that time. Accordingly, many of the lakes in Lake County are plagued by dense algae blooms and excessive, exotic plant coverage, which negatively affect DO levels, fish communities and water clarity.

Lakes with an average phosphorus concentration greater than 0.05 mg/L are considered nutrient rich. The median near surface total phosphorus (TP) concentration in Lake County lakes from 2000-2010 was 0.065 mg/L and ranged from a non-detectable minimum of <0.010 mg/L on seven lakes to a maximum of 3.880 mg/L on Albert Lake. The median anoxic TP concentration in Lake County lakes from 2000-2010 was 0.174 mg/L and ranged from a minimum of 0.012 mg/L in Independence Grove Lake to a maximum of 3.800 mg/L in Taylor Lake.

The analysis of phosphorus also included soluble reactive phosphorus (SRP), a dissolved form of phosphorus that is readily available for plant and algae growth. SRP is not discussed in great detail in most of the water quality reports because SRP concentrations vary throughout the season depending on how plants and algae absorb and release it. It gives an indication of how much phosphorus is available for uptake, but, because it does not take all forms of phosphorus into account, it does not indicate how much phosphorus is truly present in the water column. TP is considered a better indicator of a lake's nutrient status because its concentrations remain more stable than soluble reactive phosphorus. However, elevated SRP levels are a strong indicator of nutrient problems in a lake.

Nitrogen:

Nitrogen is also an important nutrient for plant and algae growth. Sources of nitrogen to a lake vary widely, ranging from fertilizer and animal wastes, to human waste from sewage treatment plants or failing septic systems, to groundwater, air and rainfall. As a result, it is very difficult to control or reduce nitrogen inputs to a lake. Different forms of nitrogen are present in a lake under different oxic conditions. NH_4^+ (ammonium) is released from decomposing organic material under anoxic conditions and accumulates in the hypolimnion of thermally stratified lakes. If NH_4^+ comes into contact with oxygen, it is immediately converted to NO_2 (nitrite) which is then oxidized to NO_3^- (nitrate). Therefore, in a thermally stratified lake, levels of NH_4^+ would only be elevated in the hypolimnion and levels of NO_3^- would only be elevated in the epilimnion. Both NH_4^+ and NO_3^- can be used as a nitrogen source by aquatic plants and algae. Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen plus ammonium. Adding the concentrations of TKN and nitrate together gives an indication of the amount of total nitrogen present in the water column. If inorganic nitrogen (NO_3^-, NO_2^-, NH_4^+) concentrations exceed 0.3 mg/L in spring, sufficient nitrogen is available to support summer algae blooms. However, low nitrogen levels do not guarantee limited algae growth the way low phosphorus levels do. Nitrogen gas in the air can dissolve in lake water and blue-green algae can "fix" atmospheric nitrogen, converting it into a usable form. Since other types of algae do not have the ability to do this, nuisance blue-green algae blooms are typically associated with lakes that are nitrogen limited (i.e., have low nitrogen levels).

The ratio of TKN plus nitrate nitrogen to total phosphorus (TN:TP) can indicate whether plant/algae growth in a lake is limited by nitrogen or phosphorus. Ratios of less than 10:1

suggest a system limited by nitrogen, while lakes with ratios greater than 20:1 are limited by phosphorus. It is important to know if a lake is limited by nitrogen or phosphorus because any addition of the limiting nutrient to the lake will, likely, result in algae blooms or an increase in plant density.

Solids:

Although several forms of solids (total solids, total suspended solids, total volatile solids, total dissolved solids) were measured each month by the Lakes Management Staff, total suspended solids (TSS) and total volatile solids (TVS) have the most impact on other variables and on the lake as a whole. TSS are particles of algae or sediment suspended in the water column. High TSS concentrations can result from algae blooms, sediment resuspension, and/or the inflow of turbid water, and are typically associated with low water clarity and high phosphorus concentrations in many lakes in Lake County. Low water clarity and high phosphorus concentrations, in turn, exacerbate the high TSS problem by leading to reduced plant density (which stabilize lake sediment) and increased occurrence of algae blooms. The median TSS value in epilimnetic waters in Lake County was 8.1 mg/L, ranging from below the 0.1 mg/L detection limit to 165 mg/L in Fairfield Marsh.

TVS represents the fraction of total solids that are organic in nature, such as algae cells, tiny pieces of plant material, and/or tiny animals (zooplankton) in the water column. High TVS values indicate that a large portion of the suspended solids may be made up of algae cells. This is important in determining possible sources of phosphorus to a lake. If much of the suspended material in the water column is determined to be resuspended sediment that is releasing phosphorus, this problem would be addressed differently than if the suspended material was made up of algae cells that were releasing phosphorus. The median TVS value was 123.0 mg/L, ranging from 34.0 mg/L in Pulaski Pond to 298.0 mg/L in Fairfield Marsh.

Total dissolved solids (TDS) are the amount of dissolved substances, such as salts or minerals, remaining in water after evaporation. These dissolved solids are discussed in further detail in the *Alkalinity* and *Conductivity* sections of this document. TDS concentrations were measured in Lake County lakes prior to 2004. This practice was discontinued due to the strong correlation of TDS to conductivity and chloride concentrations. Since 2004, chloride concentrations data are collected..

Water Clarity:

Water clarity (transparency) is not a chemical property of lake water, but is often an indicator of a lake's overall water quality. It is affected by a lake's water color, which is a reflection of the amount of total suspended solids and dissolved organic chemicals. Thus, transparency is a measure of particle concentration and is measured with a Secchi disk. Generally, the lower the clarity or Secchi depth, the poorer the water quality. A decrease in Secchi depth during the summer occurs as the result of an increase in suspended solids (algae or sediment) in the water column. Aquatic plants play an important role in the level of water clarity and can, in turn, be negatively affected by low clarity levels. Plants increase clarity by competing with algae for resources and by stabilizing sediments to prevent sediment resuspension. A lake with a healthy plant community will almost always have higher water clarity than a lake without plants. Additionally, if the plants in a lake are removed (through herbicide treatment or the stocking of grass carp), the lake will probably become dominated by algae and Secchi depth will decrease. This makes it very difficult for plants to become re-established due to the lack of available sunlight and the lake will, most likely, remain turbid. Turbidity will be accelerated if the lake is very shallow and/or common carp are present. Shallow lakes are more susceptible to sediment resuspension through wind/wave action and are more likely to experience clarity problems if plants are not present to stabilize bottom sediment.

Common Carp are prolific fish that feed on invertebrates in the sediment. Their feeding activities stir up bottom sediment and can dramatically decrease water clarity in shallow lakes. As mentioned above, lakes with low water clarity are, generally, considered to have poor water quality. This is because the causes and effects of low clarity negatively impact both plant and fish communities. Fish populations will suffer as water clarity decreases due to a lack of food and decreased ability to successfully hunt for prey. Bluegills are planktivorous fish and feed on invertebrates that inhabit aquatic plants. If low clarity results in the disappearance of plants, this food source will disappear too. Largemouth Bass and Northern Pike are piscivorous fish that feed on other fish and hunt by sight. As the water clarity decreases, these fish species find it more difficult to see and ambush prey and may decline in size as a result. This could eventually lead to an imbalance in the fish community. Phosphorus release from resuspended sediment could increase as water clarity and plant density decrease. This would then result in increased algae blooms, further reducing Secchi depth and aggravating all problems just discussed. The median Secchi depth for Lake County lakes is 2.95 feet. From 2000-2010, both Ozaukee Lake and McDonald Lake #2 had the lowest Secchi depths (0.25 feet) and West Loon Lake had the highest (23.50 feet). As an example of the difference in Secchi depth based on plant coverage, South Churchill Lake, which had no plant coverage and large numbers of Common Carp in 2003 had an average Secchi depth of 0.73 feet (over four times lower than the county average), while Deep Lake, which had a diverse plant community and few carp had an average 2003 Secchi depth of 12.48 feet (almost four times higher than the county average).

Another measure of clarity is the use of a light meter. The light meter measures the amount of light at the surface of the lake and the amount of light at each depth in the water column. The amount of attenuation and absorption (decreases) of light by the water column are major factors controlling temperature and potential photosynthesis. Light intensity at the lake surface varies seasonally and with cloud cover, and decreases with depth. The deeper into the water column light penetrates, the deeper potential plant growth. The maximum depth at which algae and plants can grow underwater is usually at the depth where the amount of light available is reduced to 0.5%-1% of the amount of light available at the lake surface. This is called the euphotic (sunlit) zone. A general rule of thumb in Lake County is that the 1% light level is about 1 to 3 times the Secchi disk depth.

Alkalinity, Conductivity, Chloride, pH:

Alkalinity:

Alkalinity is the measurement of the amount of acid necessary to neutralize carbonate ($CO_3^{=}$) and bicarbonate (HCO_3^-) ions in the water, and represents the buffering capacity of a body of water. The alkalinity of lake water depends on the types of minerals in the surrounding soils and in the bedrock. It also depends on how often the lake water comes in contact with these minerals. If a lake gets groundwater from aquifers containing limestone minerals such as calcium carbonate ($CaCO_3$) or dolomite ($CaMgCO_3$), alkalinity will be high. The median alkalinity in Lake County lakes (162 mg/L) is considered moderately hard according to the hardness classification scale of Brown, Skougstad and Fishman (1970). Because hard water (alkaline) lakes often have watersheds with fertile soils that add nutrients to the water, they usually produce more fish and aquatic plants than soft water lakes. Since the majority of Lake County lakes have a high alkalinity they are able to buffer the adverse effects of acid rain.

Conductivity and Chloride:

Conductivity is the inverse measure of the resistance of lake water to an electric flow. This means that the higher the conductivity, the more easily an electric current is able to flow through water. Since electric currents travel along ions in water, the more chemical ions or dissolved salts a body of water contains, the higher the conductivity will be. Accordingly, conductivity has been correlated to total dissolved solids and chloride ions. The amount of dissolved solids or conductivity of a lake is dependent on the lake and watershed geology, the size of the watershed flowing into the lake, the land uses within that watershed, and evaporation and bacterial activity. Many Lake County lakes have elevated conductivity levels in May, but not during any other month. This was because chloride, in the form of road salt, was washing into the lakes with spring rains, increasing conductivity. Most road salt is sodium chloride, calcium chloride, potassium chloride, magnesium chloride or ferrocyanide salts. Beginning in 2004, chloride concentrations are one of the parameters measured during the lake studies. Increased chloride concentrations may have a negative impact on aquatic organisms. Conductivity changes occur seasonally and with depth. For example, in stratified lakes the conductivity normally increases in the hypolimnion as bacterial decomposition converts organic materials to bicarbonate and carbonate ions depending on the pH of the water. These newly created ions increase the conductivity and total dissolved solids. Over the long term, conductivity is a good indicator of potential watershed or lake problems if an increasing trend is noted over a period of years. It is also important to know the conductivity of the water when fishery assessments are conducted, as electroshocking requires a high enough conductivity to properly stun the fish, but not too high as to cause injury or death.

Since 2004 measurements taken in Lake County lakes have exhibited a trend of increasing salinity measured by chloride concentrations. The median near surface chloride concentration of Lake County Lakes was 142 mg/L. In 2009, Schreiber Lake had the lowest chloride concentration recorded at 2.7 mg/L. The maximum average chloride measurement was at 2760 mg/L at IMC. It is important to note that salt water is denser than fresh water and so it accumulates in the hypolimnion or near the bottom of the lake, this can impact mixing of bottom waters into surface waters in lakes that experience turnover. This phenomenon could have far reaching impacts to an entire ecosystem within a lake. Further, in studies conducted in

Minnesota, chloride concentrations as low as 12 mg/L have been found to impact some species of algae.

pH:

pH is the measurement of hydrogen ion (H^+) activity in water. The pH of pure water is neutral at 7 and is considered acidic at levels below 7 and basic at levels above 7. Low pH levels of 4-5 are toxic to most aquatic life, while high pH levels (9-10) are not only toxic to aquatic life they may also result in the release of phosphorus from lake sediment. The presence of high plant densities can increase pH levels through photosynthesis, and lakes dominated by a large amount of plants or algae can experience large fluctuations in pH levels from day to night, depending on the rates of photosynthesis and respiration. Few, if any pH problems exist in Lake County lakes. Typically, the flooded gravel mines in the county are more acidic than the glacial lakes as they have less biological activity, but do not usually drop below pH levels of 7. The median near surface pH value of Lake County lakes was 8.37, with a minimum average of 7.07 in Bittersweet #13 Lake and a maximum of 10.40 in Summerhill Estates Lake.

Eutrophication and Trophic State Index:

The word *eutrophication* comes from a Greek word meaning "well nourished." This also describes the process in which a lake becomes enriched with nutrients. Over time, this is a lake's natural aging process, as it slowly fills in with eroded materials from the surrounding watershed and with decaying plants. If no human impacts disturb the watershed or the lake, natural eutrophication can take thousands of years. However, human activities on a lake or in the watershed accelerate this process by resulting in rapid soil erosion and heavy phosphorus inputs. This accelerated aging process on a lake is referred to as cultural eutrophication. The term trophic state refers to the amount of nutrient enrichment within a lake system. *Oligotrophic* lakes are usually deep and clear with low nutrient levels, little plant growth and a limited fishery. *Mesotrophic* lakes are more biologically productive than oligotrophic lakes and have moderate nutrient levels and more plant growth. A lake labeled as *eutrophic* is high in nutrients and can support high plant densities and large fish populations. Water clarity is typically poorer than oligotrophic or mesotrophic lakes and dissolved oxygen problems may be present. A *hypereutrophic* lake has excessive nutrients, resulting in nuisance plant or algae growth. These lakes are often pea-soup green, with poor water clarity. Low dissolved oxygen may also be a problem, with fish kills occurring in shallow, hypereutrophic lakes more often than less enriched lakes. As a result, rough fish (tolerant of low dissolved oxygen levels) dominate the fish community of many hypereutrophic lakes. The categorization of a lake into a certain trophic state should not be viewed as a "good to bad" categorization, as most lake residents rate their lake based on desired usage. For example, a fisherman would consider a plant-dominated, clear lake to be desirable, while a water-skier might prefer a turbid lake devoid of plants. Most lakes in Lake County are eutrophic or hypereutrophic. This is primarily as a result of cultural eutrophication. However, due to the fertile soil in this area, many lakes (especially man-made) may have started out under eutrophic conditions and will never attain even mesotrophic conditions, regardless of any amount of money put into the management options. This is not an excuse to allow a lake to continue to deteriorate, but may serve as a reality check for lake owners attempting to create unrealistic conditions in their lakes.

The Trophic State Index (TSI) is an index which attaches a score to a lake based on its average total phosphorus concentration, its average Secchi depth (water transparency) and/or its average chlorophyll *a* concentration (which represent algae biomass). It is based on the principle that as phosphorus levels increase, chlorophyll *a* concentrations increase and Secchi depth decreases. The higher the TSI score, the more nutrient-rich a lake is, and once a score is obtained, the lake can then be designated as oligotrophic, mesotrophic or eutrophic. Table 1 (below) illustrates the Trophic State Index using phosphorus concentration and Secchi depth.

Table 1. Trophic State Index (TSI).

Trophic State	TSI score	Total Phosphorus (mg/L)	Secchi Depth (feet)
Oligotrophic	<40	≤ 0.012	>13.12
Mesotrophic	≥40<50	>0.012 ≤ 0.024	≥6.56<13.12
Eutrophic	≥50<70	>0.024 ≤ 0.096	≥1.64<6.56
Hypereutrophic	≥70	>0.096	< 1.64