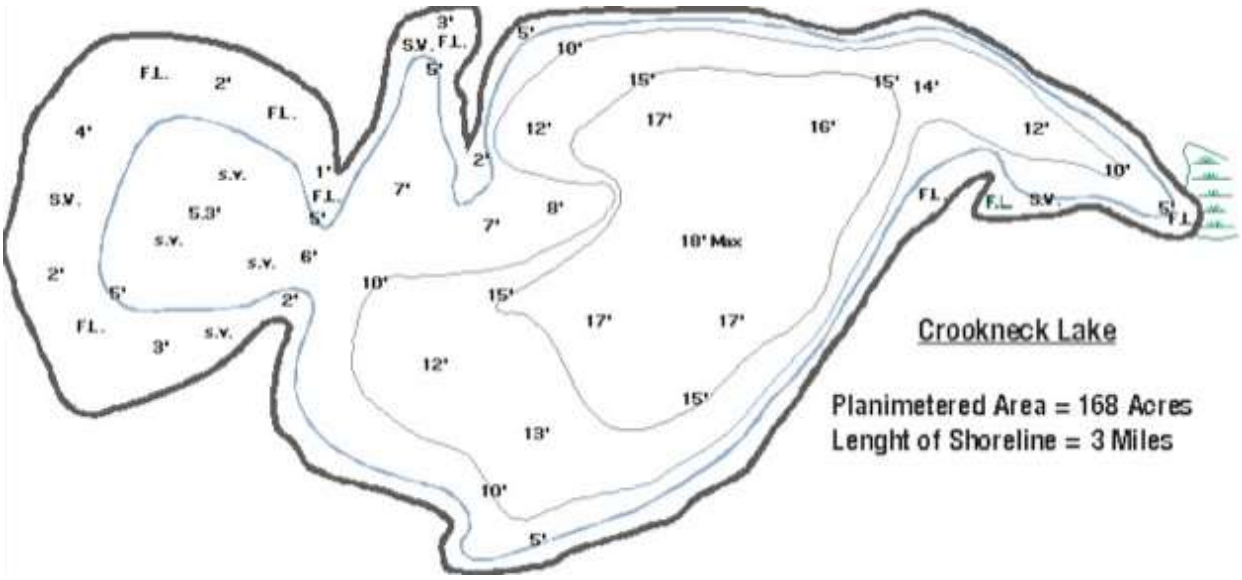
Crookneck Lake Management Plan



Crookneck Lake Improvement District

And

Lake Crookneck Improvement Association

2023

Executive Summary

The *Crookneck Lake Management Plan* serves as a guide for both the Crookneck Lake Improvement District (CLID) and the Lake Crookneck Improvement Association (LCIA) to continue a legacy of working together to enhance the health of the Crookneck Lake ecosystem. Although the organizations rely on separate governance models and funding streams, working in concert enhances overall outcomes as the CLID is limited to the powers outlined in its Establishment Order while the LCIA is limited to the vote of its members. The *Crookneck Lake Management Plan* details programs to monitor the health of the lake, identify threats, and develop corrective solutions to enhance the lake's ecosystem while maximizing the recreational use of the lake. The plan is written with a focus to serve as an educational aide "tutorial" for board members and a reference for raparian property owners. Futhermore it is recognized that both the CLID and LCIA lack the governance to mitigate the full range of potential, current or future, threats to the health of the lake's ecosystem. Key to the success of this plan is the recognition that "management of the quality of the lake begins with the users of the lake who have the ability to make the greatest impact by demonstrating self-compliance".

Over the last five years, the Minnesota Department of Natural Resources (DNR) and Pollution Control Agency (MPCA) has divided Minnesota lakes into groups with common characteristics. Working with the MPCA, the DNR launched a series of enhanced surveys to evaluate lakes reflecting changes over time. Score the Shore, Score Your Shore, plant, and fish surveys have been developed. For example, previous fishery surveys would list numbers and sizes of each species. The new Fish-based Index of Biological Integrity (Fish-based IBI or FIBI) survey includes this data plus information on whether the species present are tolerant or intolerant to changes in water clarity or habitat. An overall score is calculated defining the health of the lake. The fish-based IBI is one important component that is considered during the MPCA watershed assessment process. Specifically, it is the primary tool used to assess whether a lake fully supports "*aquatic life"*. Similarly the MPCA Lake Monitoring Program uses physical measurements of water quality such as water clarity, amount of chlorophyll-a and total phosphorus to assess whether the lake fully supports "*aquatic recreation"*. These measurements represent a snapshot in time of a lake's conditions whereas the biological community as measured by the Index of Biological Integrity reflects changes to the lake over several years or more.

Historically lake associations or property owners have responded to what can be described as a "focused" finding, i.e., rising water levels, excess or invasive weeds, shoreline damage, to name a few. Oftentimes these findings originated from governmental agencies, commercial vendors, or property owner observations and were thought of as a "trigger point" or a "call to action". Previous editions of the *Crookneck Lake 5-year Management Plan* detailed "studies, plans, or actions taken" which were predominantly focused on these specific issues. This plan incorporates the components of previous editions while reflecting the current philosophy of multi-year trend analysis by the MPCA and DNR. As such, the name of the plan will be the *Crookneck Lake Management Plan* and will serve as the legislative requirement for a 5-year management plan and as a Crookneck Lake Management Work Plan.

Index

Introduction

Crookneck Lake, previously known as Lake McDonald, is a public 168-acre lake in Morrison County, Minnesota, south of the town of Motley. The lake is a natural lake located in the North Central Hardwoods Forest ecoregion and lies within the Upper Mississippi River basin, part of the Long Prairie River Watershed. The lake occupies approximately 40% of a smaller watershed consisting of only 477 acres. Primary use of land adjacent to the shoreline is forested land and homesteads. Shoreline is heavily developed with less than 10 percent undeveloped. The lake is fed by groundwater and has one seasonal, limited surface inlet. The mean depth of the lake is approximately 9 feet with a maximum depth of 22 feet. Approximately 131 acres of the lake is less than 15 feet deep. This area is referred to as the "littoral zone". Midsummer water clarity is sufficient to allow submersed plant growth to a depth of approximately 9 feet. Crookneck Lake is a multi-use lake, primarily used for swimming, fishing, and boat recreation activities. It has an aesthetic value to residents providing a diverse habitat for wildlife. The lake supports a sport fishery consisting of northern pike, largemouth bass, and multiple species of panfish. Wildlife known to use the lake include muskrats, beavers, turtles, waterfowl, eagles, loons, and wading birds.

During 1980, the Lake Crookneck Improvement Association (LCIA) was established by a group of concerned riparian property owners and was subsequently chartered by the Minnesota Secretary of State. The LCIA served as a self-funded association relying on voluntary donations and annual membership dues to execute its mission to conserve the water quality and fishery, manage native and non-native aquatic species (predominantly management of excessive aquatic vegetation), and shoreline management of the lake while also providing a platform for building community relations. As the cost associated with aquatic vegetation management increased over the years, a more equitable method to share the burden between all riparian owners was sought. During July 2005, the Morrison County Commissioners established the Crookneck Lake Improvement District (CLID). The vision for the CLID was the conservation of the ecosystem of the lake long term. From 2005 through 2010, the LCIA undertook several projects to promote this vision. Since then, the LCIA has evolved towards promoting community relations programs.

Aquatic plant management was conducted in Crookneck Lake for many years without a written comprehensive lake management plan. As a result, satisfaction with the lake management approach and results were mixed. Because Aquatic Plant Management is both directly and indirectly related to Water Quality, Shoreline Development, and Fisheries, a comprehensive plan was published during 2004 titled *The* C*rookneck Lake Vegetative Management Plan*. During 2017, this plan was revised and titled the *Crookneck Lake 5-Year Management Plan*.

The *Crookneck Lake 5-Year Management Plan* served as a LCIA and CLID stakeholders report. Although the 2017 edition mirrored the original 2004 plan, significant revisions were incorporated. Since the establishment of the CLID during 2005, several initiatives were undertaken by the LCIA which contributed to the overall quality and management of Crookneck Lake. The 2017 plan:

1. Reviewed and consolidated CLID and LCIA historical lake data and provided a platform for future data collection related to the Crookneck Lake watershed.
2. Established goals to:

A. Make Improvements to the Water Quality of the Crookneck Lake Ecosystem.
B. Improve Habitat and Maintain Healthy Fish Populations.
C. Provide Solutions That Will Protect the Future of the Crookneck Lake Ecosystem.

D. Pursue Initiatives Which Protect Property Values of Riparian Owners.

Since the 2017 plan was published its usefulness has been limited. Although the goals and objectives remained over the five-year period and were reported on at the annual CLID meeting, historical documents were not available to members due to the loss of our original website. Currently, a new website is under design and being populated with historical records.

The previous editions of the Crookneck Lake management plans focused on water quality, shoreline conservation, aquatic invasive species management (primarily vegetation), and fisheries. Since the 2017 plan was published, the MN DNR has adopted several surveys rating lakes on an indexing model which allows for grading a lake while also providing for a comparison model to like sized lakes with similar characteristics. One notable survey, the "Score the Shore" survey (depicted below), describes the lake-wide lakeshore habitat, detects substantial lake-wide lakeshore habitat score changes over time, and compares lake-wide lakeshore habitat scores within and between watersheds and ecoregions to assess patterns and trends. Notably the *"Score the Shore Survey"* survey sites are selected randomly, systematically, at regular interval patterns, around the lake perimeter and are not associated with individual properties or lots. In addition, the survey does not assess structures that may occur in the Shoreland or Shoreline Zones. A separate but similar survey, *"Score Your Shore"* has been developed for riparian landowners to self-assess their developed lot.

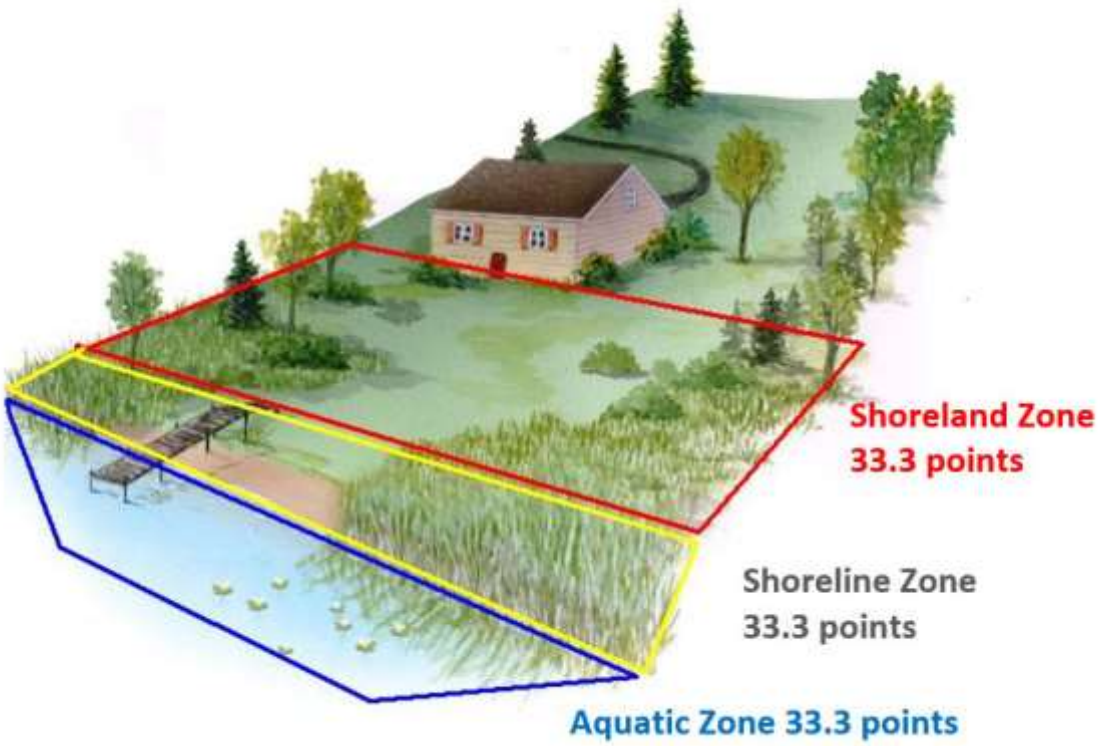
One drawback associated with the *"Score the Shore"* survey is the 10-year period between surveys associated with recent implementation and the ten-year survey cycle which does not allow for trend analysis, although a score is determined for comparison to the lake's assigned group. The complimentary *"Score Your Shore"* survey provides an immediate feedback tool for individual riparian owners to identify areas to focus on which would contribute to an overall improved lake score in the future.

The DNR has also developed other Index Based Integrity (IBI) surveys, to include fish-based and plant-based IBIs, to assess the health of a watershed. Used in conjunction with the legacy MPCA Lakes Monitoring Program, the lake's *aquatic life* and *aquatic recreational use* can be scored against a group of like characterized lakes.

Breaking it down to one basic concept, the health of a lake is directly linked to water clarity. Water clarity is derived from the water that enters the lake and what may come with it and what is in the lake, i.e., weeds and algae. This concept was one of the cornerstones for the development of the Score the Shore survey. As water interacts in each zone it may eventually impact the clarity of the lake's water.

The authors of the plan recognize the current limitations of the CLID and LCIA when it comes to management of the health of the lake. When governance charters for the CLID and LCIA were originally composed the focus was on water quality, aquatic invasive species management and community relations. As time has marched on and research has led to the development of new survey models, the future may shift towards management of stressors on the lake's ecosystem which result in a long-term outcome on the lake. Since a majority of these items fall outside of the CLIDs governance documents, a comprehensive education program may bridge the gap.

Figure 1. Score The Shore habitat zones



Goals of the Crookneck Lake Management Program

It is the objective of the Lake Crookneck Improvement Association (LCIA) and Crookneck Lake Improvement District (CLID) to develop, implement, monitor, and manage aquatic and land use strategies and techniques to improve the effects of cultural development on Crookneck Lake and its watershed. Monitoring and managing the lake's ecosystem is crucial to the success of the management plan. A basic knowledge of each program, water quality, shoreline development, aquatic plants and invasive species, and fisheries, is required. It is critical to recognize that elements identified under one goal may impact elements found in other goals just as one goal may impact another goal. Failure to address the entire spectrum can lead to unforeseen damage to the entire ecosystem of the watershed. It is recognized that community education and relations are the cornerstones to attaining support for programs central to attainment of these goals.

Both the LCIA and the CLID have collected data and/or chartered several studies over the years. Turning the data into useful information resulting into what may be referred to as a "Call for Action or a Trigger Point" is oftentimes difficult due to the timeliness of data trends and a multitude of variables which may impact one or more data points. In addition, corrective actions oftentimes may be out of the scope of the CLID or LCIA but within that of riparian property owners or government agencies. Furthermore, it is recognized that as the LCIA evolved into more of a social organization (4th July Boat Parade, Kids Fishing Contest, Concert on the Lake), a platform for educational programs has diminished over time.

In contrast to previous editions of this plan which developed goals focused on specific topics, i.e., Aquatic Invasive Species, Water Quality, etc. this edition will resemble the "Score the Shore" survey model with notable inclusions detailed within each goal. As such, a goal will be established for each of the Score the Shore habitat zones in addition to a goal for management of the CLID and LCIA.

Goal 1. Managing the Quality of the Shoreland Zone: *The Shoreland Zone is defined as the portion of land which is most likely to be developed and approximates the required minimum setback distance for shoreland structures. Since there are measures that can be taken to limit runoff or controlling the quality of water passing through this zone for the purposes of this plan the Shoreland Zone will extend beyond the normal setback to include any sources of water flowing to and through this expanded shoreland zone to the Shoreline Zone.* Mitigating projects focus on controlling either what or how much of a substance enters the lake or watershed. An effective shoreland management program may indicate the need for control of water levels, septic system compliance inspections, erosion control projects, or runoff diversion projects.

Objective 1. Surveillance/Diagnostic Studies: The CLID and LCIA have sponsored a multitude of studies to assess controlling what may be reaching the lake. Many of the historical studies were performed by the LCIA prior to the establishment of the CLID but serve as critical benchmarks for future endeavors. The use of overflight imagery, satellite imagery, or thermal imagery can provide information suggestive of external nutrient loading sites, run off or erosion sites, possible restoration sites and effects of high and low water conditions. Although thermal analysis overflight studies are no longer available, mastery of the Morrison County's Beacon site provides cursory information. Since the lake continues to show a turnover of ownership annually, results of previous findings are noteworthy topics for either future monitoring or educational programs.

Element 1. Lakeshore recreational fire pits (Runoff Management): Over the 3-years following the 2001 thermal overflight study, open fire pits were moved back from the shoreline with a vast majority being replaced by fire rings minimizing or eliminating a source of nutrient runoff into the lake. *If it is observed that fire pits are being placed near the shoreline, the subject of nutrient loading from ash will be included in CLID and LCIA Newsletters and/or meetings.*

Element 2. Scandia Valley Transfer Station (Groundwater Management): One of the findings of the thermal flyover was a large plum directly across from the transfer station. Several lake property owners raised a concern "is the transfer station a source of contaminants to the lake?" A cursory review found that prior to operating as a transfer station it operated primarily as a burn site. Residents reported it was the norm to drop off old batteries or open paint containers which would also be burned along with other household waste. Currently the Transfer Station only burns excess yard debris (leaves, branches). There was no knowledge or record of electrical transformer storage, a source of PCB, a qualifier for EPA clean-up funds. The soil around the transfer station is predominantly sand and most likely filters runoff. It was concluded that the sandy soil most likely would filter out any surface contaminants prior to reaching the groundwater table and traversing to the lake although the influence of fluctuations in the water table is unknown. The LCIA elected not to perform any environmental well testing in an arc between the transfer station and the lake due to cost and no evidence of PCB sources. Local laboratory sources for private well water testing was provided to association members. *In the future, if the subject of the quality of drinking water or possible contaminants from the Transfer Station comes up, particularly since we have a steady turnover of property ownership, the topic will be included in CLID and LCIA Newsletters and/or meetings to include sources for water testing.*

Element 3. Septic System Integrity - Compliance Inspection (Groundwater Management): In 2008, the LCIA managed a voluntary septic system (septic tank with drain field, holding tank,

or outhouse) compliance inspection based on current state and county statutes. The project was deemed a success with 71 of 78 compliant and those non-compliant being brought up to code. Several of the non-compliant systems were easily corrected and had the owners been aware of the issue would have done so sooner. *During odd numbered years review common code violations and publish them in CLID or LCIA Newsletters and/or as an educational topic at annual meetings.*

Objective 2. Run Off Management: Control of runoff water reaching the shoreline and filtering of the runoff water prior to reaching the shoreline is critical to the quality of the water entering the lake and impacting the health of the lake.

Element 1. Road Design/Management: Lake associations and/or districts can provide a wealth of information, "local knowledge", focused on mitigating runoff from reaching a lake. *Road projects in proximity to lakes trigger* e*arly engagement in the design process to ensure incorporation of mitigation concepts into project designs during their infancy rather than more costly design revisions or change orders which may result in less desirable outcomes.*

Element 2. Winter Road Salt Use: Road safety remains paramount during winter conditions. Winter road salt remains the primary source of changes in a lake's alkalinity, a long-term stressor on a lake, due to spring thaw runoff. The increase in the alkalinity of the lake is a cumulative effect of the exposure to road salt over many years. *Working with Scandia Valley Township annually to identify potential areas where road salt usage may be decreased would result over time in curbing an increase in the alkalinity of local lakes.*

Element 3. Rain Gardens: Rain Gardens are an effective way to control runoff from roadways and topsoil erosion from reaching the lake. Funding for rain gardens can be obtained from the Morrison County Soil and Water Conservation District (SWCD), although the funding comes with strict design and future years compliance standards. *Since the lake experiences a turnover of riparian ownership each year, periodically include the topic in Newsletters or annual meetings as an educational topic*.

Goal 2. Managing the Quality of the Shoreline Zone*: The Shoreline Zone is defined and scored as the portion of land between the Shoreland and Aquatic Zones which in previous plans was referred to as Managing Shoreline Development. It begins at the water's edge and extends landward to the bank. This zone may be narrow or broad, depending on the slope.* Often Managing Shoreline Development serves to identify immediate or long-term impacts development may have on the lake since this area is easily recognizable as the interface of land and water. Monitoring water levels in conjunction with mitigating the effects of varying levels is integral to mitigating shoreline erosion. Morrison County Soil and Water Conservation District (SWCD) shoreline surveys provide valuable shoreline assessments and erosion control or restoration recommendations.

Objective 1. Shoreline Habitat Preservation and Restoration: Crookneck Lake is a small, developed recreational lake. Over the past 20 years shoreline erosion control has been the primary concern of most riparian property owners. The natural shoreline has been replaced by rip-rap in significant areas of the shoreline. As the water continues to recede or establishes a new norm, there may be an increased focus on shoreline restoration projects by riparian owners.

Element 1. SWCD Reviews: The SWCD has a history of providing professional surveys and consultation services on shoreline management and restoration for Crookneck Lake. Both high and low water conditions have varying effects on the shoreline erosion and habitat. *Both receding and higher water levels trigger a need for a SWCD consultation survey. As the water increases or recedes erosion conditions may be enhanced, as well as a need for restoration projects to enhance the shoreline habitat as the water levels fluctuate.*

Objective 2. Mitigating and/or Managing the Effects of High Water or Low Water Lake Levels: The combination of high-water conditions combined with the effect of the force of waves causes vast areas of either shoreline erosion and/or structure damage. Rip-rap has been installed to reinforce shorelines. At the time the rip-rap was installed the perception was the water would not recede to previous norms. An unknown is now surfacing as the water recedes. Will an undercutting occur along the rip-rap water interface? Also, will habitat restoration be required.

Element 1. "No Wake Zone": The Morrison County Sheriff posted a "No Wake Zone Within 300 Feet of Shore" notice at the public access to the lake and has patrolled the lake on numerous occasions with what can be described as "moderate" compliance. Two issues compounded compliance with this posting, the relatively small size of the lake offering a limited zone for use of watercraft and the inability of the Sherriff to issue citations for noncompliance. Postings occurred on 5 July 2018 when the water level was 2.27 ft above the Ordinary High Water (OHW) level and on 10 June 20014 when the OHW was 1.57 ft above the OHW level. *During 2023 and beyond, monitor the lake level and request the Sheriff post a revised warning when the lake-level exceeds 1.75 ft above the OHW level or during times when shoreline erosion is reported, and Soil and Water Conservation District suggests a No-Wake Zone posting as a mitigating measure.*

Element 2. "Coir Log Shoreline Reinforcement/Restoration": Coir logs (shredded coconut shells) can be used as a shoreline interface with the lake to mitigate shoreline erosion. This is a preferred remedy in a shallow area as it provides a medium for plant growth leading to shoreline restoration with a goal of providing critical fishery habitat. Over the years, individuals who attempted to protect their shoreline from further erosion abandoned Coir logs for rip-rap as the water continued to rise resulting in the need to stack multiple levels of Coir logs which over time decomposed and failed. As the water recedes Coir logs remain a viable option for restoration of shallow shoreline banks. *As the water levels rise or recede Coir logs may be a preferred method for areas requiring a temporary buffer or shoreline restoration. Their use and vendor reference should be included in CLID and/or LCIA Newsletters along with shoreline restoration techniques.*

Element 3. "Rip-Rap" Shoreline Reinforcement: A majority of property owners have installed rip-rap as the water level rose which served as a long term erosion buffer. However, it lacks a medium for shoreline plant growth critical for fish habitat and the effect of wave undercutting is unknown should the lake continue to recede. As mentioned under **High Thrust/Propulsion Watercraft (see Goal 3, Objective 2, Element 5)** a few residents have reported that the waves produced by these boats have washed up over their rip-rap resulting in a concern of erosion from behind their rip-rap which may ultimately destabilize the rip-rap. *As the water level recedes or rises monitor the effect of wave erosion on rip-rap and the impact on the quality of water and if erosion occurs consult with shoreline vendors or SWCD prior to preparing education materials.*

Element 4. Impact of High-Water on Structures, Septic Systems and Wells: As record high-water levels were reached, several structures around Crookneck Lake were impacted. The impact on any septic systems is unknown, however Lake Shamineau reported septic system failures. Many of the structures impacted by high water are in areas within a close proximity to the ordinary high-water level. A few owners have raised and/or repaired structures damaged by water. As the lake has receded the risk to these properties has largely been mitigated. Several unknowns continue to exist. As the lake reached record levels, did it compromise the integrity of any septic systems on Crookneck Lake and what was the level of the water when this occurred? Also, at what levels are structures and/or wells impacted. Determining the answer to these questions may not be available with regard to specific properties. Sources may include Morrison County Planning and Zoning who may collect this data as part of their septic system permitting and inspection procedures or they may be able to utilize aerial data found in Beacon to produce maps, or the Morrison County assessor's office may include a basic assessment during their 5-year assessment cycle, or if the Score Your Shore Survey is deployed the item could be included for review. If the data is available, a general area threat assessment around Crookneck Lake based on lake-levels may be able to be developed and turned into a warning system. *In the future, as the water-level rises, a warning indicator for structures and/or septic systems within a zone around the lake could be posted on the website. (Note: This is an overall lake water-level warning condition indicator and is not intended to be property specific).*

Goal 3. Managing the Quality of the Aquatic Zone: *The Aquatic Zone is defined and scored as the lake that begins at the land-water interface and extends lakeward 50 feet. It includes shallow water where rooted aquatic plants may grow; this is also the zone of a lake that is most likely to be utilized and impacted by riparian residents. Since Crookneck Lake is a relatively shallow lake with approximately 70% being within the littoral zone, an area which supports the growth of aquatic plants, for purposes of this plan the Aquatic Zone will include the entire lake. Water Quality, Aquatic Plant and Invasive Species Management, and Fisheries will be included under this goal.*

Objective 1: Participate in the MPCA Lakes Monitoring Program: Managing Water Quality assesses the current and the long-term health of the lake by identifying threats to the lake early, while remediation is still feasible. Water clarity is key to a healthy ecosystem. As the management of the health of a lake has evolved over recent years across America and many of the concepts adopted by regulatory agencies (State and County) have evolved one concept remains, "managing the clarity of the water". Water quality packages include Secchi depth, pH, TEMP, Dissolved Oxygen, Conductivity, Total Dissolved Solids, Alkalinity, Total Phosphorus, Total Suspended Solids, Chlorophyll-A, and Nitrates. The MPCA Lakes Monitoring Program uses physical measurements of water quality such as water clarity, amount of chlorophyll-a and total phosphorus to assess whether the lake fully supports *aquatic recreation*. These measurements represent a snapshot in time whereas the biological community as measured by the index of biological integrity (IBI) surveys reflect changes to the lake over multiple years. In 2014, the lake was scored as being in an overall healthy "Mesotrophic" state and classified as a "full use recreational lake" where it has been since.

Element 1. Participate in the MPCA Lakes Monitoring Program. A decision was made during 2006 to monitor two sites for water quality and participate in the MPCA Lakes Monitoring Program. Samples are collected for Total Phosphorus and Chlorophyll-a analysis along with a Secchi depth reading. The Primary Site represents the main body of the lake. The

Secondary Site represents an area adjacent to where most of the spring thaw flows into the lake. *Continue to fund, sample, and monitor data for trends and/or shifts from two sites reporting findings to riparian owners with recommendations for enhancing the overall recreation use of the lake now and in the future.*

Element 2. Maintain the Lake's "Mesotrophic State" Classification: A long-term goal was established during 2014 to maintain the lake in the "Mesotrophic State" range. *Analyze data and consult with lake management professionals to identify threats to the lake and take mitigation measures to ensure continued classification in the Mesotrophic range maintaining the lake as a full use aquatic recreational lake.*

Objective 2: Implement an Aquatic Plant and Invasive Species Management Program That Conforms to Federal and State Regulations. Monitoring and managing aquatic plant populations is integral to managing the quality of the Aquatic Zone by determining the need or effects of management efforts, shoreline development, or identification of the introduction of exotic species for treatment. Management of aquatic invasive species (such as Curly-leaf pondweed, Eurasian watermilfoil, Purple Loosestrife, Zebra mussel, Starry Stonewort) and other non-native and native species whether known or unknown is a necessary component towards maintaining the lake as a viable natural resource in the County. Aquatic plants are important to the lake and play a crucial role in the oxygen gradient and uptake of nutrients, protection of the shoreline from wave activity while providing critical fish habitat and provide habitat for the fisheries across the lake. Excess aquatic plants present during periods of low-water level conditions result in significant impacts on the recreational use of the lake. The use of aquatic control techniques such as mechanical, chemical, and biological controls will be executed to achieve a healthy and balanced aquatic community which promotes a balanced fishery habitat.

Element 1: Manage the Curly-leaf pondweed Population: Prior to 2007, Curly-leaf pondweed dominated the Crookneck Lake submersed invasive plant community and caused most of the aquatic plant related problems across the lake. Curly-leaf pondweed grows throughout the winter months and is only a nuisance prior to the Fourth of July, at which time it completes its life cycle and drops out of the water column until the following year. The western end of the lake was covered by a solid mass of pondweed plants in 2005, with dense patches present in many other locations around the lake. *A long-term goal to survey and treat Curly-leaf pondweed annually to reduce the level of Curly-leaf pondweed population to less than 5 acres was established in 2006.*

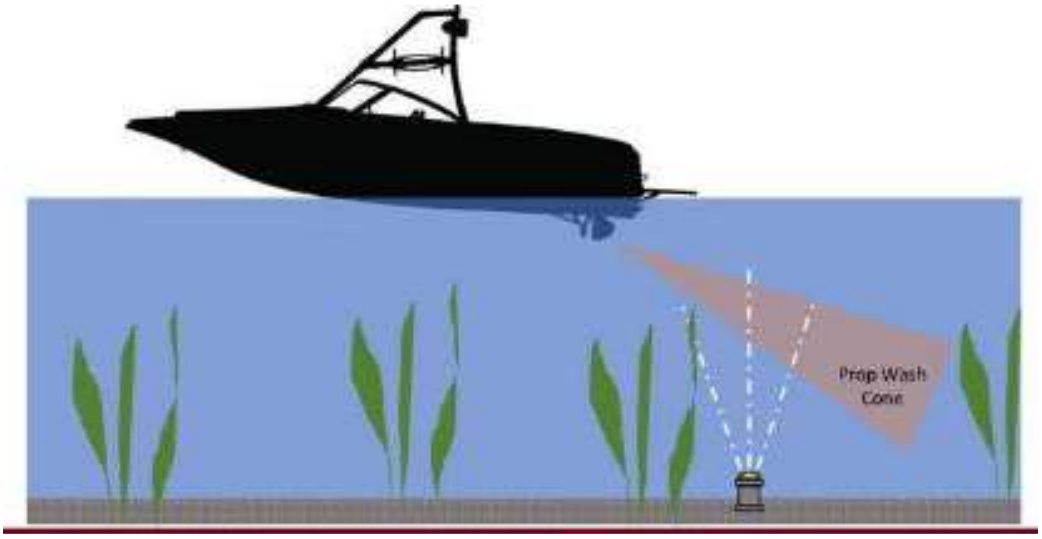
Element 2: Manage the Eurasian watermilfoil (EWM) Population: During 2018, Eurasian watermilfoil (EWM) was identified in an isolated location and subsequently aggressively treated by herbicide during 2019 and 2020. One plant located outside of this zone was physically removed during 2019. No additional EWM has been located during 2021 or 2022. *A long-term goal was established in 2019 to survey the lake annually, aggressively treat the current area to isolate or eliminate the EWM from it, and aggressively treat any other areas EWM is located across the lake.*

Element 3: Monitor for Evidence of an Outbreak of Zebra Mussels and Provide Prevention Education: Since the establishment of the CLID, invasive species across Minnesota has not been limited to vegetation. In the recent past, Fish Trap Lake followed by Crookneck Lake and Lake Alexander were identified as being infested with Zebra mussels. During 2017, Crookneck Lake joined a program managed by Morrison County testing for

immature Zebra mussels (veliger stage) and Spiny Water Flee. Results through 2022 have been negative for both. An adult pair of Zebra mussels were confirmed on the Crookneck Lake access dock after it was removed from the lake during October 2018. Since that time no additional adult Zebra mussels have been identified in the lake. Based on the original observation, Crookneck Lake was posted on the MN DNR Infested Waters database. Educational brochures were prepared for distribution at the public lake access as well as a designation being placed on the access informational lake map. *A long-term goal was established in 2017 to monitor for the presence of Zebra mussels and Spiny Water Flee and provide educational materials at the lake access designed to prevent the transport of Zebra mussels or other invasive species from Crookneck Lake to other waters.*

Element 4: Monitor the Lake for the Presence of New Invasive Species: The threat of a new invasive species remains moderately high since numerous visitors frequent the lake and multiple larger surrounding lakes throughout the year. *A long-term goal was established to contract for annual surveys of the lake for the early detection of new invasive species, to work with surveyors to assess the threat based on local lake surveys and formulate preventive measures.*

Element 5: Monitor the Impact of High Thrust/Propulsion Watercraft on Small, Shallow Lakes: The extent of the impact these watercrafts have on the lake is currently under study (see figure below). Overall impact on disturbance of the thermocline resulting in mixing of decaying sediment, water turbidity (clarity), up-rooting of aquatic vegetation, and wave erosion along shorelines remain areas of concern with respect to use of these watercraft on a lake of limited size and depth such as Crookneck Lake. Preliminary observations indicate an increase in the quantity of floating vegetation, increased lakebed disturbance, and larger sized waves reaching shorelines have occurred following their use. *A short-term goal was established in 2021 to monitor studies being performed by the Saint Anthony Falls Research Laboratory and continue to observe impacts on Crookneck Lake. If it is determined the waves produced may be detrimental to Crookneck Lake a measure such as the one undertaken by Lake Minnetonka or a more restrictive action to mitigate the impact of the waves produced by these watercrafts will be investigated further.*



Saint Anthony Falls Study

Objective 3. Monitoring and Managing Fisheries: Although monitoring and managing fisheries per se is not a function of either the CLID or LCIA it is a critical indicator of the overall health of the lake and as such results of the MN DNR surveys are closely monitored. Fish populations within the lake provide an important indicator of how management procedures are affecting the lake. Monitoring and managing fisheries are a cornerstone for future years of a healthy population of a multitude of aquatic species. Populations could be reduced or increased based upon monitoring. Stocking of fish or removal of fish may be conducted to achieve healthy populations. Historical surveys consisted of gill nets and/or electrofishing along shorelines with fish being sorted by species and sized. These surveys have evolved into a revised surveying model referred to as a Fish-based Index of Biological Integrity (FIBI).

The FIBI was developed by the MN DNR by sampling a wide range of lakes, ranging from high-quality lakes to those with significantly degraded water quality and/or shoreline habitat. A statistical analysis found a relationship between communities of fish, water quality, and physical hibitat characteristics. Further statistical analysis led to expectations for fish communities based on water depth and shoreline characteristics. The FIBI includes multiple measurements of the fish communities. When added together, the score reflects the lake's *biological health*. Each IBI score is generated using eight to fifteen calculated measurements, depending on the lake type. These measurements are known to correspond with varying levels of human-caused stressors from activities such as land use alteration within a lake's watershed and physical habitat alteration along the lake's shoreline. The fish-based IBI is one important component that is considered during the MPCA watershed assessment process. Specifically, the fish-based IBI is a primary tool used to assess whether a lake fully supports *aquatic life*. Similarly the MPCA Lake Monitoring Program uses physical measurements of water quality such as water clarity, amount of chorohyll-a and total phosphorus to assess whether the lake fully supports *aquatic recreation*.

Goal 1. Monitor Fishery Surveys and Develop a Baseline Fish-Based IBI for Crookneck Lake. Fish-based IBI (FIBI) scores are used by DNR staff to place lakes into one of six assessment categories: exceptional, fully supporting, vulnerable, not supporting (impaired), inconclusive information and insufficient information. The FIBI uses fish community data to measure the lake's health, and types of fish species present can help identify any stressors that may be negatively affecting the lake environment. *A goal was set to attain an mid-range or better "fully supporting" assessment score for our group of lakes and develop programs to mitigate any stressors identified.*

Element 1. Utilize the Fish-based IBI To Develop Protocols to Enhance Status of Crookneck Lake: Since the FIBI is a new surveying protocol for the MN DNR, a repeat survey was necessary to attain a baseline score for Crookneck Lake. The intitial 2021 survey scored the lake as "exceptional", an outlyer for the Group 4 lakes. As such, the survey was repeated during 2022 with the final report due during 2023, although preliminary results indicate a rating of "fully supporting" and consistent with findings of lakes in Group 4. *Continue to monitor FIBI surveys and consult with both the MN DNR and SWCD to identify stressors to the lake which may be adversely impacting the FIBI survey. Develop programs to address stressors identified and provide educational information to raparian property owners.*

Goal 4. Monitoring the Management of the Lake Crookneck Improvement Association (LCIA) and Crookneck Lake Improvement District (CLID): *Critical review of the CLID and LCIA Board of Directors management ensures the continued viability of each organization.* The use of internal audits to ensure compliance with Minnesota statutes, the LCIA Constitution

and Bylaws, and the Order Establishing the CLID by the Morrison County Commissioners are critical, as well as budgetary forecasting to ensure the continued financial viability of each organization.

Objective 1. Manage the CLID as directed by its Establishment Order and state mandates and manage the LCIA as directed by its Constitution and Bylaws, and state mandates.

Element 1. The MN Secretary of State requires various reports and subscriptions annually. *Perform timely reporting (i.e., financial) and renewal of subscriptions (i.e., insurance) ensures continuous compliance and good standing. Report annually to Board of Director's on time filings.*

Element 2. Manage the CLID and LCIA in a transparent manner. *Hold annual meetings open to all constituents or members. Publish and post minutes and financial reports on website. Hold elections for board of directors following established protocols.*

Element 3. Perform Internal and External Process Reviews: *Periodically complete reviews of processes and financial documents to provide a measure of transparency to constituents and members. Document findings at annual meetings or Board of Director meetings.*

Element 4. Maintain a website for the CLID and LCIA: Both the CLID and LCIA produce documents annually which require storage for future reference. *A website accessible to all riparian owners shall be developed, maintained, and updated with documents in a timely manner, by a webmaster.*

Objective 2. Gain a mastery of the new IBI based lake surveys, the Score the Shoreland survey, and the Score the Shoreline surveys: Since many of the new surveys utilized by the MPCA and DNR do not fall within the governance of either the CLID or the LCIA, the two groups will need to work in harmony to enhance the quality of Crookneck Lake.

Element 1. Gain a mastery of these new survey programs. As the rollout of the new surveys continues, interpretation of results will be the centerpiece for future lake management. *Once a basic knowledge of the new surveys is attained, the subject should be included in either CLID or LCIA annual meetings.*

Element 2. Deploy the Score Your Shore Survey: Introduce the Score Your Shore Survey at both CLID and LCIA meetings to determine if there is an interest in deploying the program across Crookneck Lake. If such a program is desired solicit a group of volunteers to manage the program. *Train a group of riparian owners to survey each property around the lake providing a report to property owners with specific findings.*

Element 3. Develop programs to improve results attained on the new lake surveys. Once the results of the new surveys are published a detailed review to identify any potential stressors to be addressed or recommendations for improvement will be performed. *Prepare educational materials to share at CLID and/or CLID meetings detailing survey findings and any suggested corrective actions to mitigate stressors identified.*

Implementation

The *Crookneck Lake Management Plan* is intended to be a "living" document. The appendixes serve as a historical review of data from both Lake Crookneck Improvement Association (LCIA) and Crookneck Lake Improvement District (CLID) files and as a tutorial for board members and riparian property owners. It is not the intent of this plan that every element within a goal would require annual action. Supporting documentation will be posted and stored on the Crookneck Lake.com website.

Plan Duration and Review

It may be necessary to make minor adjustments to this plan at any time. As new goals or elements are adopted or existing ones modified or discontinued, revisions will be made within the plan and a revised plan posted on our website. This may be done by mutual agreement. At a minimum both parties agree to review the plan and its effectiveness in reaching its goals every five years. The next review will be performed during spring 2028 and documented in the CLID and LCIA Annual Meeting minutes that year.

Stakeholder Input to the Plan

Draft copies of this plan were distributed to Lake Crookneck Improvement Association and Crookneck Lake Improvement District boards to provide an opportunity for comment and suggested edits to the plan.

Approval

Board of Director's from both the Lake Crookneck Improvement Association and Crookneck Lake Improvement District reviewed and approved this edition of the *Crookneck Lake Management Plan* during March 2023.

Implementation Date: April 1, 2023

Appendix A. Tutorial on Water Quality and the MPCA Lakes Monitoring Program

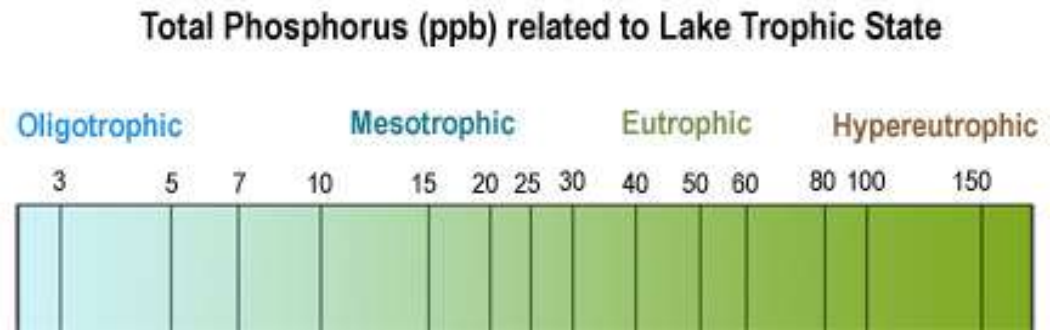
Water Quality is a critical component to a healthy, viable ecosystem. Oftentimes when "water quality" is addressed the immediate focus falls on the management of the quality of the lake water within the shoreline. Since the predominant water source of Crookneck Lake is groundwater with a minor, seasonal source being a surface inlet, managing water quality reflects not only the quality of the lake proper but also the groundwater sources.

Water quality is directly related to water clarity. Too much or too little clarity may have an adverse effect on the quality of the water. Managing the following programs are a few examples of methods available to improve the lake's clarity: use of aeration, chemical treatments and/or mechanical harvesting of weeds, introduction of native aquatic plants, aquatic plant management, shoreline development, and fisheries applications. Managing programs which lower the concentrations of nutrients or contaminants from entering the groundwater or the runoff reaching the lake, in conjunction with programs to control the overall biomass within the lake or from disrupting the lakebed sediment, will improve clarity while enhancing the overall water quality of the lake.

Water clarity is directly linked to the health of the lake. The MPCA and the MN DNR utilize measurements of total phosphorus, chlorophyll-a, and water transparency (Secchi depth) to determine trends over multiple years and calculate a Trophic State index for each component. An average is assigned, compared to other lakes within a comparison grouping, and assigned an overall *aquatic recreational use grade*.

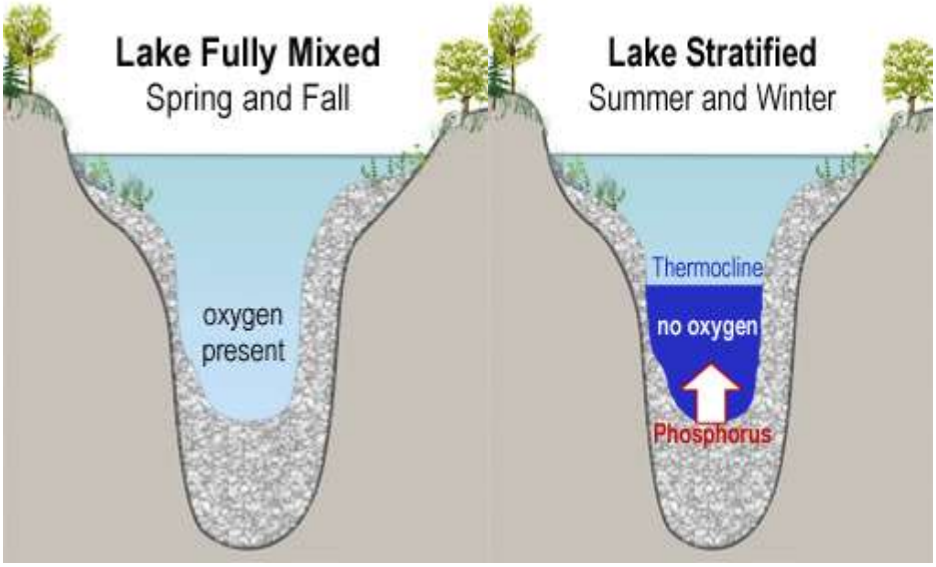
Total Phosphorus: Phosphorus is a nutrient important to plant growth. In most lakes, phosphorus is the limiting nutrient, which means that everything that plants and algae need to grow is available in excess (sunlight, warmth, water, nitrogen, etc.) except phosphorus. Hence, the more phosphorus the more plants and algae in the lake. Major sources of phosphorus include human and animal waste, soil erosion, detergents, septic systems and runoff from farms or fertilized lawns.

Phosphorus is usually measured in two ways in lakes, ortho-phosphate (soluble reactive phosphorus) and total phosphorus. Total phosphorus is the preferred way to measure phosphorus in lakes because it is more stable and includes both ortho-phosphate and the phosphorus in plant and animal fragments suspended in the lake water. Total phosphorus annual mean values are both predictive of the lake's water quality and the lake's trophic state as shown below.



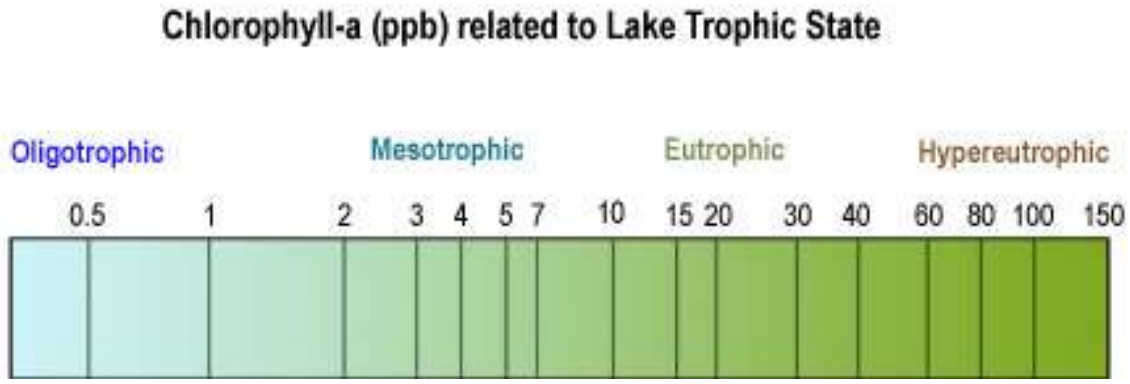
Phosphorus can also enter lakes from sediment at the bottom of the lake. When the bottom of the lake is deficient in oxygen (anoxic), usually in the late summer and late winter, chemical processes at the sediment/water interface cause phosphorus to be released from the sediments. This phenomenon is called internal loading because the phosphorus is coming from within the lake (from the sediment). When the lake mixes again, this increased phosphorus fuels algae growth. Mixing occurs during the Spring and Fall and is evidenced by cloudy, sediment laden water. A question has been raised recently could a similar phenomenon, although limited in scope, be triggered by the use of high thrust/propulsion watercraft (see discussion under Appendix B).

If phosphorus inputs are decreased or eliminated, less plants and algae grow and the water quality can improve.



Chlorophyll-a: Chlorophyll-a is a pigment that makes plants and algae green and allows photosynthesis to occur. During photosynthesis, plants use the sun's energy to convert carbon dioxide and water into oxygen and cellular material.

Chlorophyll-a is tested in lakes to determine the quantity of algae. Algae is important in lakes because it adds oxygen to the water as a by-product of photosynthesis. If there are too many algae it can produce a foul odor and be unpleasant for swimming. Chlorophyll-a concentration can tell you a lot about the lake's water quality and trophic state as shown below. By comparing annual mean chlorophyll-a values you can see if the concentration of algae in the lake per year is increasing, decreasing, or staying the same.



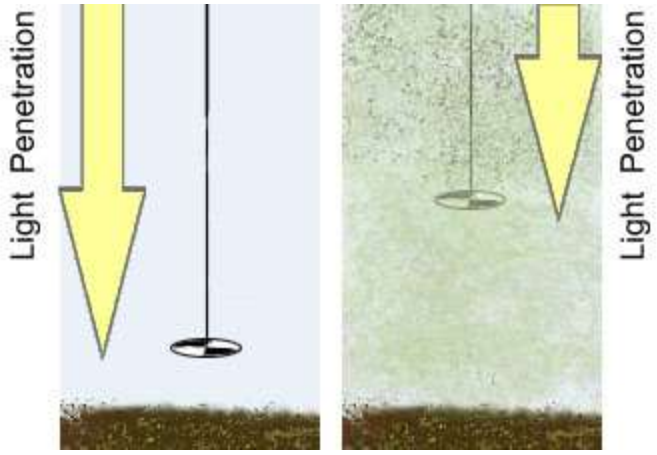
The amount of algae growth in a lake depends on many factors, including water transparency, water temperature, predation by zooplankton, and the availability of nutrients (especially phosphorus and nitrogen). There are natural seasonal variations in algae concentrations. In the spring, the water is transparent, and there are many nutrients available due to the spring turnover; however, the water is not very warm, which limits algae growth. As the water warms throughout the summer, algae grow to higher concentrations. When there is heavy rain more nutrients get washed into the lake, fueling an algae bloom. As the algae concentration increases the water transparency decreases. This means that less light can penetrate through the water, so the algae are only at the very top of the lake where there is enough light for photosynthesis. In late summer, the algae community is dominated by cyanobacteria (blue-green algae). Cyanobacteria can become very thick and have a foul odor as it decays.

When algae die, they sink to the bottom of the lake and get decomposed by microbes and invertebrates. This decomposition process uses up oxygen. In eutrophic lakes where there is a lot of algae, there needs to be a lot of decomposition and all the oxygen at the bottom of the lake gets used up. When this happens, the fish move up to the shallower areas of the lake where there is still oxygen available.

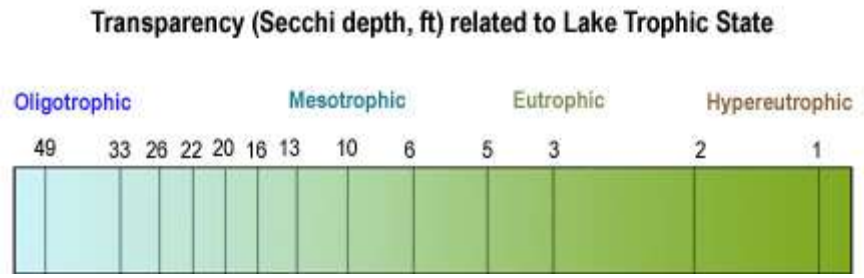
Transparency Measured as Secchi Depth: Transparency is how easily light can pass through a substance. For lakes this means how far does sunlight penetrate the water. As mentioned above, plants and algae need sunlight to grow, so their growth is limited to areas where the sunlight penetrates. The area around the lake that is shallow enough for plants to receive sunlight is referred to as the littoral zone.

Water transparency depends on the number of particles in the water. Particles can be algae or sediment from erosion, the more particles the less transparency.

Water transparency is measured with a Secchi disk. The depth that the Secchi disk can no longer be seen through the water is the Secchi depth. When the water transparency is low, the Secchi depth is low.



Since water transparency is directly related to Total Phosphorus and Chlorophyll-a conclusions about the trophic state of the lake can be drawn from measuring the Secchi depth.



Trophic State Index: As indicated above, Phosphorus, Chlorophyll-a, and Secchi depth are related. When phosphorus increases, algae increase. As algae increase, transparency decreases with a resultant decrease in Secchi depth.

The numeric value from these three measurements have different units and ranges and as such cannot be compared to each other or averaged. Through mathematical equations each result can be converted into what is referred to as a trophic state index (TSI).

The overall trophic state index (TSI) of the lake is the average of the TSI for the phosphorus, the TSI for the chlorophyll-a, and the TSI for the Secchi depth. It can be thought of as the lake condition considering phosphorus, chlorophyll-a and Secchi depth.

Trophic States are defined as divisions of a continuum in phosphorus and algae concentrations. The TSI ranges from 0-100 with scores on the lower end having sparse algae, low phosphorus, and high transparency (oligotrophic), to green lakes, with very high nutrient levels (hypertrophic). TSI is not necessarily interchangeable with desired water quality. Water quality is subjective and depends on the intended use of the water body. Below is a summary explanation of trophic states and a list of characteristics.

TSI	Chl-a (ug/L)	SD (ft)	TP (ug/L)	Attributes	Fisheries & Recreation
<30	<0.95	>26.2	<6	**Oligotrophy:** Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water.	Trout fisheries dominate
30-40	0.95-2.6	13.1-26.2	6-12	Bottom of shallower lakes may become anoxic (no oxygen).	Trout fisheries in deep lakes only. Walleye, Tullibee present.
40-50	2.6-7.3	6.6-13.1	12-24	**Mesotrophy:** Water moderately clear most of the summer. May be "greener" in late summer.	No oxygen at the bottom of the lake results in loss of trout. Walleye may predominate.
50-60	7.3-20	3.3-6.6	24-48	**Eutrophy:** Algae and aquatic plant problems possible. "Green" water most of the year.	Warm-water fisheries only. Bass may dominate.
60-70	20-56	1.6-3.3	48-96	Blue-green algae dominate, algal scums and aquatic plant problems.	Dense algae and aquatic plants. Low water clarity may discourage swimming and boating.
70-80	56-155	0.8-1.6	96-192	**Hypereutrophy:** (light limited productivity). Dense algae and macrophytes.	Water is not suitable for recreation.
>80	>155	<0.8	192-384	Algal scums, few aquatic plants	Rough fish (carp) dominate; summer fish kills possible

Lakes Monitoring Program: During 1989, a group of concerned citizens joined the Lake Monitoring Program by taking Secchi disk readings of Crookneck Lake. The first comprehensive lake water quality assessment was done in 1992. Water samples were sampled for determination of alkalinity, color (Platinum-cobalt Units), total phosphorus, and chlorophyll-a. In 2001, the Lake Crookneck Improvement Association (LCIA) began monitoring water quality with AW Research Laboratories for Total Phosphorus, Chlorophyll-a, and Secchi depth, components of the MPCA Lakes Monitoring Program, for the purpose of obtaining the trophic status of the lake. From 2006–2014 and since 2018 testing has been performed by RMB Environmental Laboratories. In 2014, the lake was scored as being in an overall healthy "Mesotrophic" state and classified as a "full use recreational lake" where it has been since.

The Trophic State Index (TSI) for Crookneck Lake is "Mesotrophic" with overall conditions suitable for swimming and wading, with good clarity and low algae levels throughout the open water season, classified by the MPCA as a "Full Use Recreational Lake

Summary data from RMB Laboratory Database for a period spanning 2006-2022 (no sampling during 2015-2018) for Primary Site 202.

Parameters	13-Year average of all summer samples	Parameter TSI	Expected TSI range of Lakes in same ecoregion	Number of Samples
Transparency (ft)	8.9	46.2	38 - 47	75
Chlorophyll-a (parts per billion)	6.5	47.4	44 - 53	72
Total Phosphorus (parts per billion)	24.2	49.4	42 - 52	76

Source: RMB Environmental Labs: Assessments (rmbel.info) **"Select Morrison County…Crookneck Lake…Individual Lake Data Summary table format…select site 202…year range.**

Summary data from RMB Laboratory Database for a period spanning 2006-2022 (no sampling during 2015-2018) for Secondary Site 203.

Parameters	13-Year average of all summer samples	Parameter TSI	Expected TSI range of Lakes in same ecoregion	Number of Samples
Transparency (ft)	8.9	46.2	38 - 47	55
Chlorophyll-a (parts per billion)	6.5	47.4	44 - 53	30
Total Phosphorus (parts per billion)	24.2	49.4	42 - 52	62

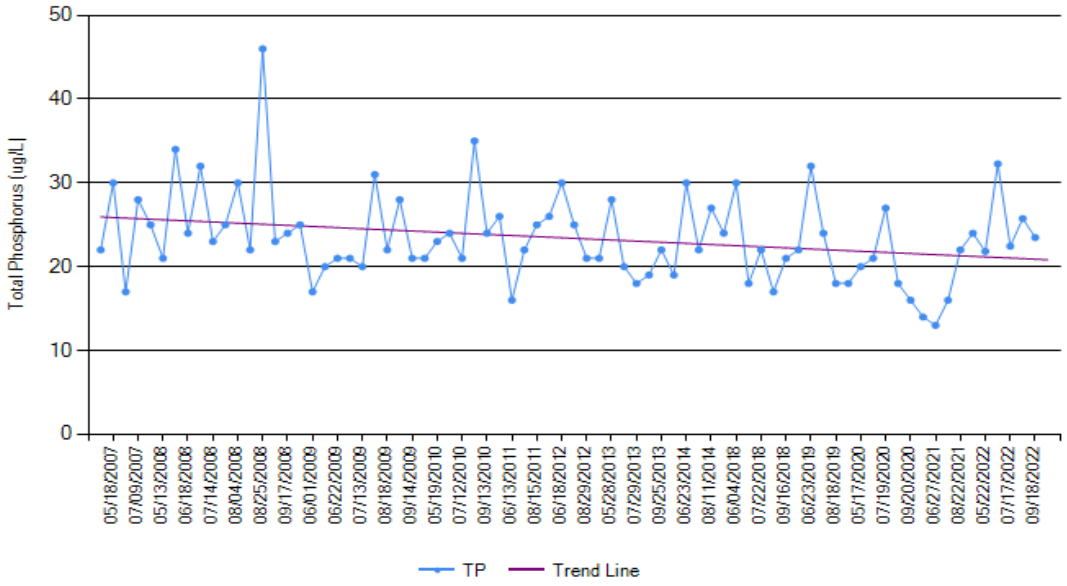
Notable is the same TSI results for each component for each site, although the number of samples vary.

Below are graphic displays of Total Phosphorus, Chlorophyll-a, and Secchi depth over time, also available on the RMB site. Source: **RMB Environmental Labs:** Assessments (rmbel.info) **"Select Morrison County…Crookneck Lake…Trend Analysis Report…select analyte…select site …year range.**

Trend Analysis Report

County	Lake	Site	Data Evaluated	Dates Evaluated
Morrison	Crookneck (ID # 49-0133-00)	202		9/26/2006 - 9/18/2022

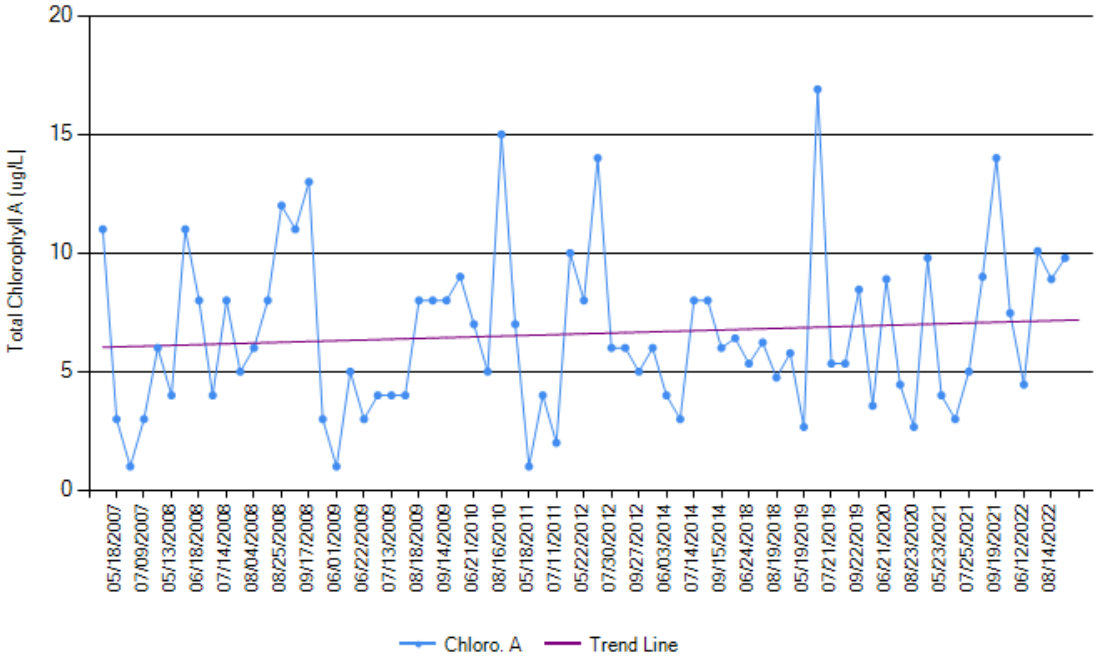
Total phosphorus is decreasing, which indicates improving water quality (95% confidence).



Trend Analysis Report

County	Lake	Site	Data Evaluated	Dates Evaluated
Morrison	Crookneck (ID # 49-0133-00)	202		9/26/2006 - 9/18/2022

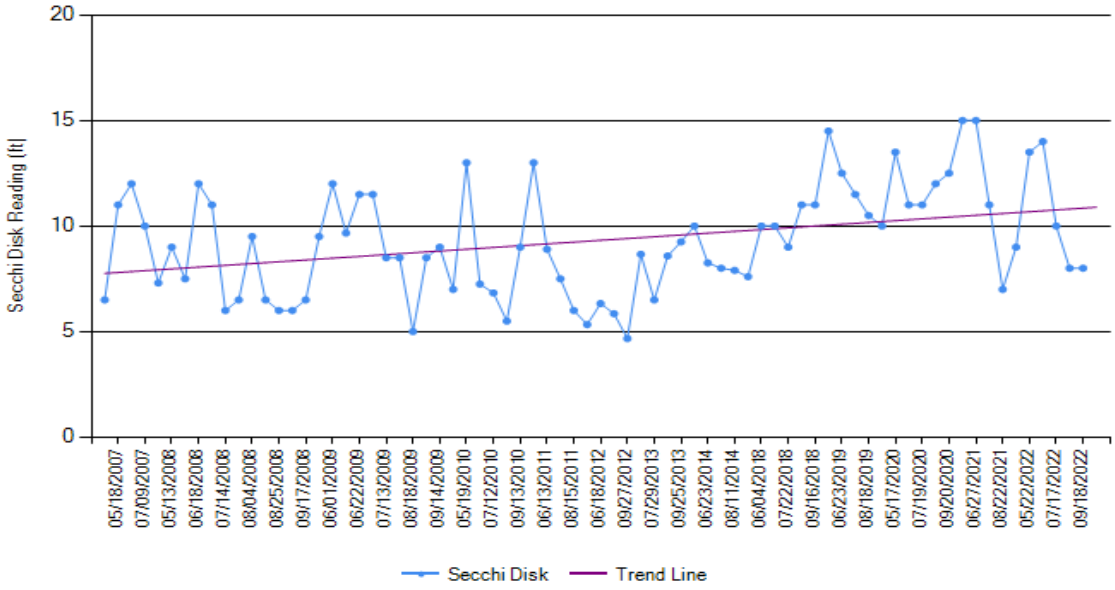
No Significant Trend Exists



Trend Analysis Report

County	Lake	Site	Data Evaluated	Dates Evaluated
Morrison	Crookneck (ID # 49-0133-00)	202		9/26/2006 - 9/18/2022

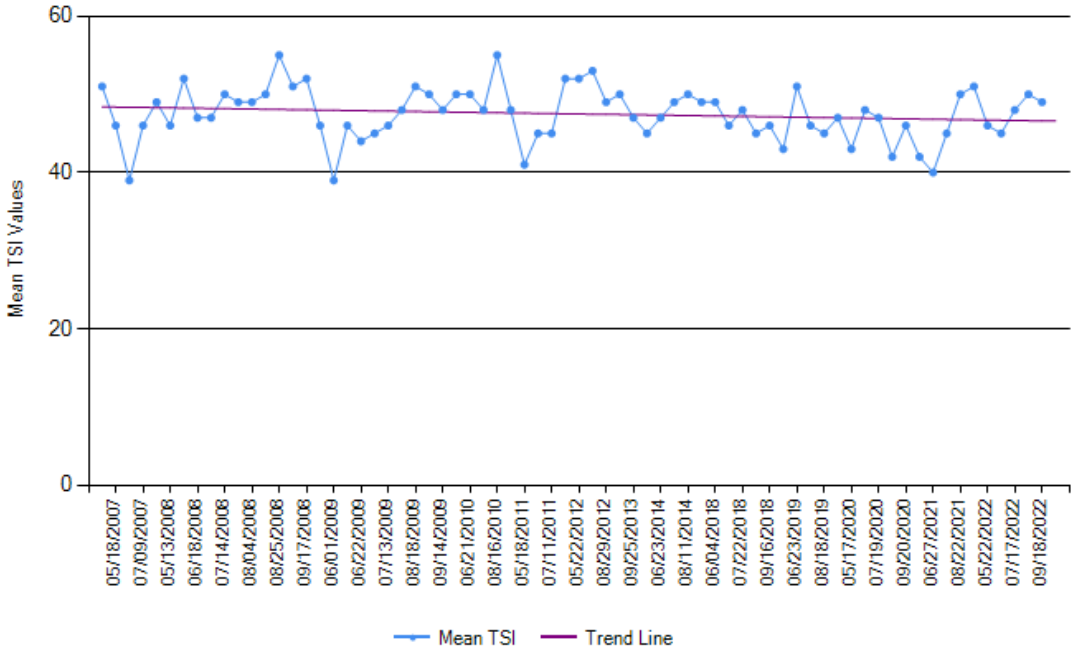
Secchi depth is increasing, which indicates improving water quality (99% confidence).



Trend Analysis Report

County	Lake	Site	Data Evaluated	Dates Evaluated
Morrison	Crookneck (ID # 49-0133-00)	202	Mean TSI	9/26/2006 - 9/18/2022

Mean TSI is decreasing, which indicates improving water quality (80% confidence).



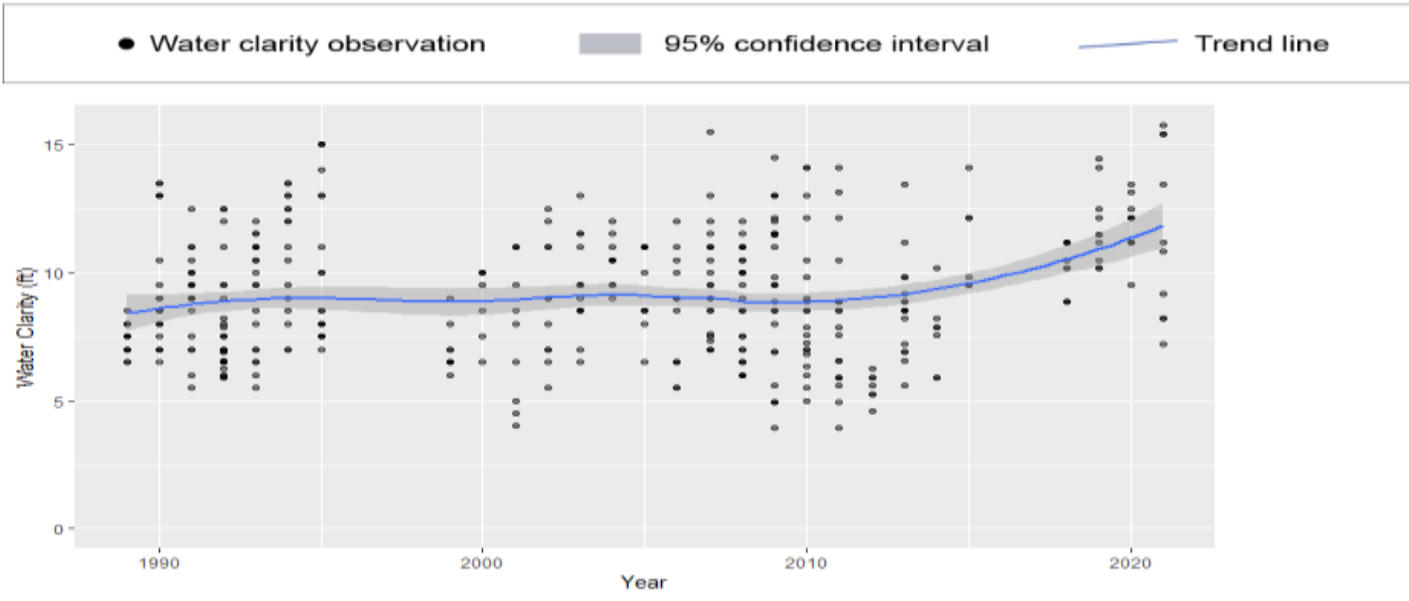
Mean TSI Seasonal Trends

County	MN ID#	Lake	Site	Data Evaluated	Date Range	Data Source
Morrison	49-0133-00	Crookneck	202	tsiavg_vc	9/26/2006 - 8/14/2022	RMB

The MN DNR has also performed statistical analysis on Crookneck Lake utilizing data from the MPCA Lakes Monitoring Program.

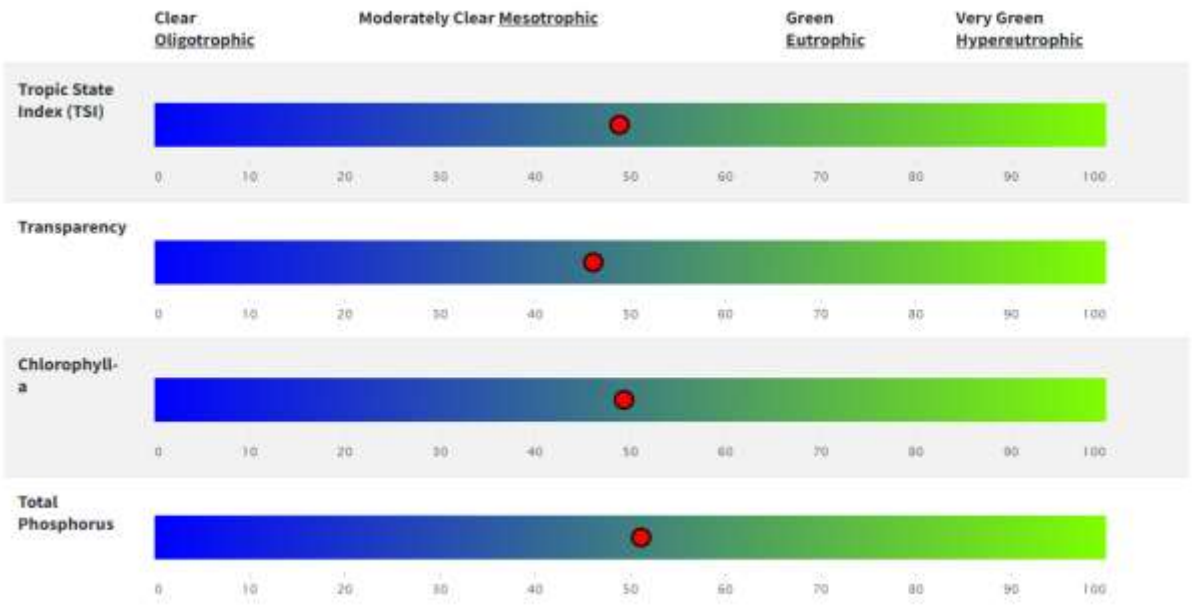
Water transparency trend analysis is an excellent indicator of water quality. The figure below depicts the water clarity of Crookneck Lake over time. The trend analysis was performed with a Seasonal Mann Kendall test. This statistical test detects changes in water clarity over time by comparing months across years (example – Mays are compared to Mays, Junes to Junes, etc.). The trend line indicates the direction of detected changes in water clarity. The gray area around the trend line represents the range where the actual clarity will fall with 95% certainty. Source: Search Results | Minnesota DNR (state.mn.us)…Crookneck…Water Quality…Transparency Trends.

For the years 1989 to 2021 there is no identifiable water clarity trend. For the most recent year of the analysis, median water clarity was 5.02 feet lower than the watershed median. Authors note: Two of the three larger lakes in the watershed are infested with Zebra mussels.



Crookneck Lake Lakes Program Water Quality Summary: As mentioned above, the MPCA and DNR utilize Trophic State Index (TSI) findings to assign *Recreational Suitability Measures.*

The **TSI** is a number that summarizes a lake's overall nutrient richness. Nutrient richness ranges from clear lakes, low in nutrients (oligotrophic), to green lakes, with very high nutrient levels (hypereutrophic). The chart below shows the overall TSI rating for Crookneck Lake (top bar), followed by TSI ratings for the individual parameters that contribute to nutrient richness. The TSI calculations are based on data collected between June and September 2008 to 2017. Overall Trophic State Index for this lake: **49.**



Source: Search Results | Minnesota DNR (state.mn.us)…Crookneck…Water Quality…Water Quality Summary.

Appendix B. Tutorial on Management of Aquatic Vegetation and Invasive Species

The need to manage aquatic vegetation arises when plant cover and/or biomass become sufficiently high to disrupt the natural balance of a lake. Excessive growth of aquatic plants interferes with nearly all forms of recreation and causes adverse biological problems. Dense plant growth at the water surface impedes exchange of gases between the air and water, thereby contributing to nighttime dissolved oxygen depletion and large daily pH fluctuations. These conditions are detrimental to fish and other aquatic life and are compounded during low water level times. Production of desirable sport fish (e.g., largemouth bass) is maximal at intermediate levels of plant cover and biomass. Excessive plant cover makes it difficult for larger fish to capture smaller food fish, which can lead to reduced production of larger piscivorous fish and to stunted populations of small forage fish.

Exotic aquatic plants (e.g., plants that do not naturally occur in this area or lake) are often the cause of severe problems when they invade lakes. For example, Eurasian watermilfoil *(Myriophyllum spicatum* L.) and Curly-leaf pondweed *(Potamogeton crispus* L.) expand rapidly to replace native vegetation and form dense monospecific beds. Compared with most native aquatic plants, these exotic species concentrate their stems and leaves at the water surface, interfering with recreation to a much greater extent than comparable quantities of native plants. Highly developed lakes and those used intensively for recreation are more susceptible to invasion and degradation by opportunistic exotic plant species.

At moderate density levels aquatic plants provide important benefits to the lake, including oxygen production, invertebrate habitat, and cover for small fish. Thus, management of problem aquatic plant growth should be conducted in such a way as to preserve desirable aquatic vegetation. Management can preserve beneficial aquatic vegetation in several ways. Selective techniques control problem species with minimal effect on desirable ones. Limiting the application of control techniques to areas where they are needed can also preserve desirable vegetation. In general, some areas in every lake should be set aside for little or no management to preserve species that are sensitive (non-tolerant) even to selective controls.

The native plant species in Crookneck Lake also benefit the lake, performing such functions as stabilizing sediments and providing critical habitat for fish and other aquatic organisms. In general, native species cause substantially fewer problems than exotic plant species. However, when they become particularly dense and tall, they do cause problems, usually in isolated areas. These issues are compounded during periods of low water levels when surface carpeting may predominate in the west bay, and across extensive zones throughout the main lake. As the water level decreases, an increase in the disruption of submersed vegetation occurs resulting in islands of weeds floating on the surface or tangling in plants reaching the surface. This phenomenon is limited during periods of high water.

Native Aquatic Plant Surveys: Thirty-seven aquatic plants species were found in Crookneck Lake during the 2003 Vegetation Survey. Except for Curly-leaf pondweed, the remaining aquatic plants in the lake are native North American species. For the most part, a diverse community of native plants was present at levels beneficial to the lake ecosystem, and which caused relatively few problems. Naiads, bushy pondweed, water celery and coontail were common during 2003, presumably because of the mild winter. During cool summers these species typically grow as a carpet on the bottom, but do not approach the surface. During

warmer summers following mild winters, these species often grow to the surface and can attain densities approaching those achieved by Curly-leaf pondweed. Other native plants grew at low densities or were sufficiently low growing (stature) to cause few problems. Water lilies were found at several locations around the lake. Patches of broad leaf pondweed, flat stem pondweed, and variable pondweed were widespread, but overall, these species were only moderately abundant in 2003. The other species were relatively uncommon.

DNR aquatic vegetation point-intercept surveys were performed during May 2005 and June 2020 to assess the distribution of aquatic plants in Crookneck Lake. The primary purpose for this type of survey was to develop baseline knowledge of the current plant community in the lake, and over time compare plant variation (in plant presence and spatial location). Moreover, these surveys help the DNR and their partners to monitor native plant communities and evaluate possible responses to invasive aquatic plant management via herbicide control. It is important to note that distributions of aquatic plants may vary from year to year due to effects such as differences in weather and water depth, as well as the effects from management efforts. For example, the water level was 2.19 ft above the ordinary high water (OHW) level during the 2005 survey and 3.13 ft above the OHW level during the 2020 survey. Another example, prior to 2006 the primary method of nuisance weed control was mechanical harvesting. Since 2006, herbicide use has been the predominant control method.

During the 2020 DNR survey, plants were found in a range of water depth from 1 to 16 feet. Most plants were growing in a depth range between 4 and 10 feet. In the littoral zone, 90% of the surveyed points had submersed native vegetation. Curly-leaf pondweed (CLP) was the only invasive species and relatively sparse at 1%. This finding was consistent with the Spring Aquatic Invasive Survey which did not identify CLP for treatment; one of two years CLP was not treated since 2006. In addition to the point-intercept surveys conducted by the DNR Invasive Species Program in 2005 and 2020, RMB Laboratories conducted surveys in 2014, 1016, 2017, and 2018. Over the 15-year period from 2005 to 2020, the percent of submersed native taxa declined from 95% to 90% while the mean submersed native taxa per point intercept remained between 1.7 and 1.8.

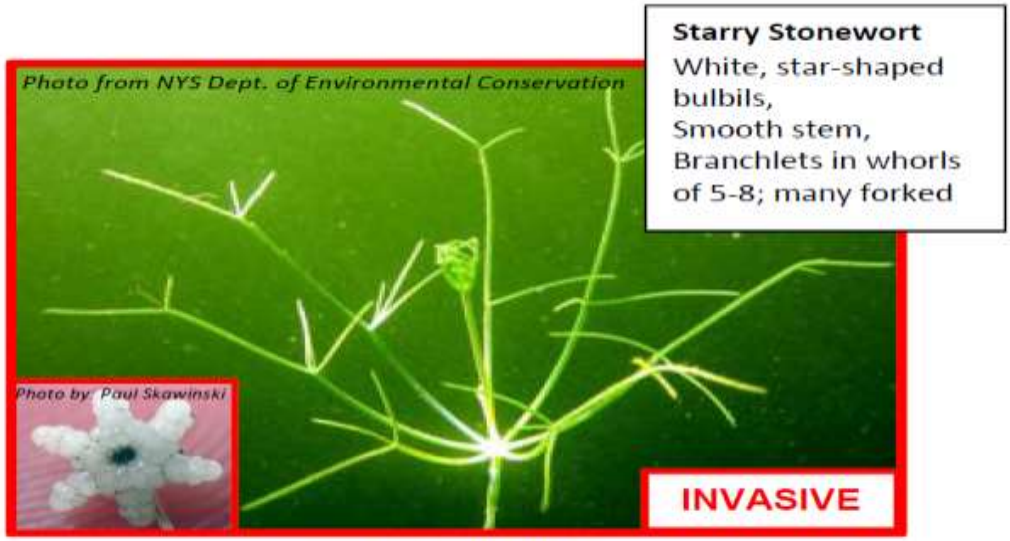
See Crookneck Lake …LID…Aquatic Invasive Species Management (surveys and reports) … and also Special Studies.

Aquatic Plant Management: Since 1981 many forms of aquatic plant management occurred on Crookneck Lake including the use of mechanical harvesting, herbicide and algaecide use. Individual homeowners have contracted with commercial applicators to control vegetation along shorelines for recreational access to the lake. No known biological controls have been used. From 1981 to 2005, aquatic plant management was performed using a commercial harvester and a small harvester owned by the lake association. The predominant vegetation harvested was *Coontail-Ceratophyllum echinatum.*

Aquatic Invasive Species of Interest: Below is a pictorial of the common aquatic invasive species found in Minnesota waterways within the Crookneck Lake region. The photos were extracted from RMB Vegetation Surveys of Crookneck Lake.

Eurasian Watermilfoil
(*Myriophyllum spicatum*)

Curly-leaf Pondweed
(*Potamogeton crispus*)



Starry Stonewort
(Nitellopsis obtuse)

Zebra mussel

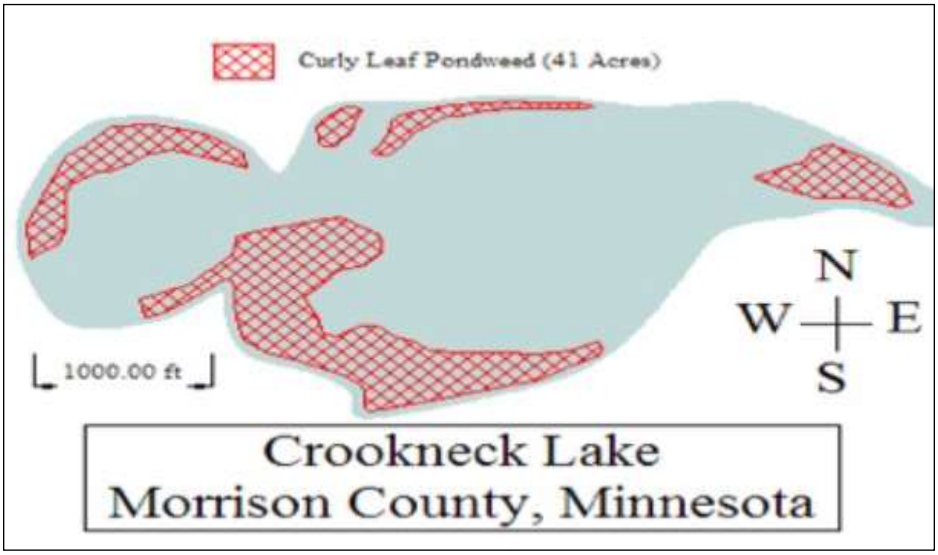
Management of the Curly-leaf pondweed Population: Prior to 2007, Curly-leaf pondweed dominated Crookneck Lake submersed invasive plant community and caused most of the aquatic plant related problems across the lake. Curly-leaf pondweed grows throughout the winter months and is only a nuisance prior to the Fourth of July, at which time it completes its life cycle and drops out of the water column until the following year. The western end of the lake was covered by a solid mass of pondweed plants in 2005, with dense patches present in many other locations around the lake.

Annual surveys are performed to identify the presence of invasive species and delineate treatment zones. Since 2006, Crookneck Lake has been treating Curly-leaf pondweed annually with herbicides. Under current DNR treatment protocols, on any given year a permit to treat up to 19.6 acres can be attained (15% of 131 littoral acres = 19.6 acres). An exception to the policy was granted during our early years of treating Curly-leaf to get the population under control.

The table below illustrates the number of acres treated annually for Curly-leaf pondweed. No treatment was done during 2009 and 2020 due to a low zonal density of Curly-leaf pondweed identified for treatment.

See Crookneck Lake …LID…Aquatic Invasive Species Management … CLP History of Acres Treated and Annual Survey Reports.

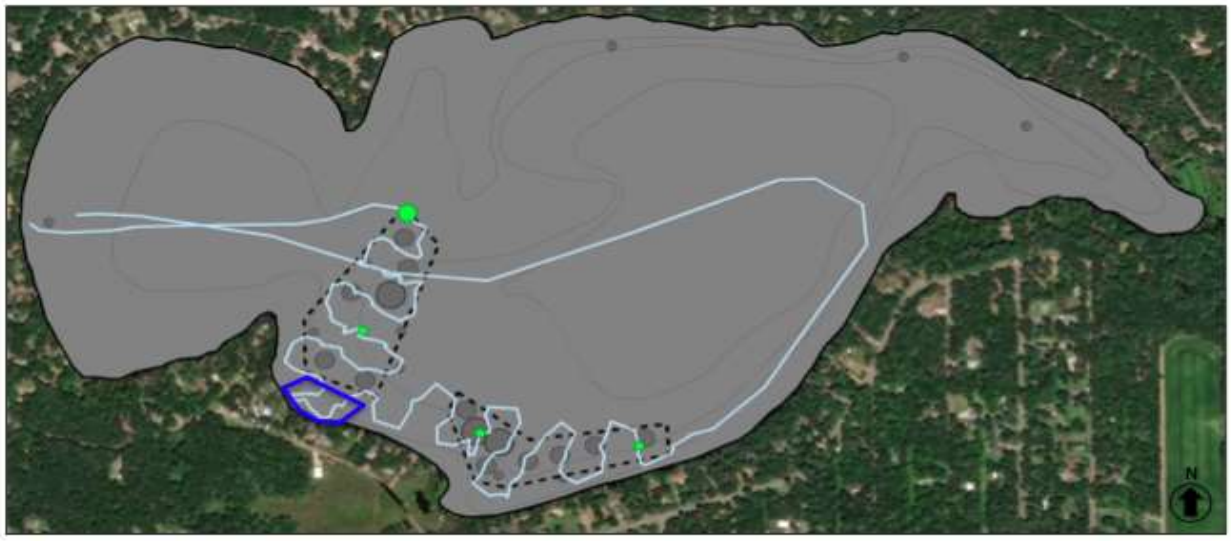
The Curly-leaf pondweed populated significant areas of the lake, predominantly shorelines, during the early years of treatment. Over the past ten years it has been predominantly located for treatment in what has been described as a horseshoe east and south of the west bay.



2005 CLP Initial Survey (1st yr. treated 2006)

See Crookneck Lake …LID…Aquatic Invasive Species Management … Annual Survey Reports.

Management of the Eurasian watermilfoil (EWM) Population: During 2018, Eurasian watermilfoil (EWM) was identified in an isolated location and subsequently treated by herbicide during 2019 and 2020. One plant was located along the east shoreline and physically removed during 2019. No additional EWM has been located during 2021 or 2022.



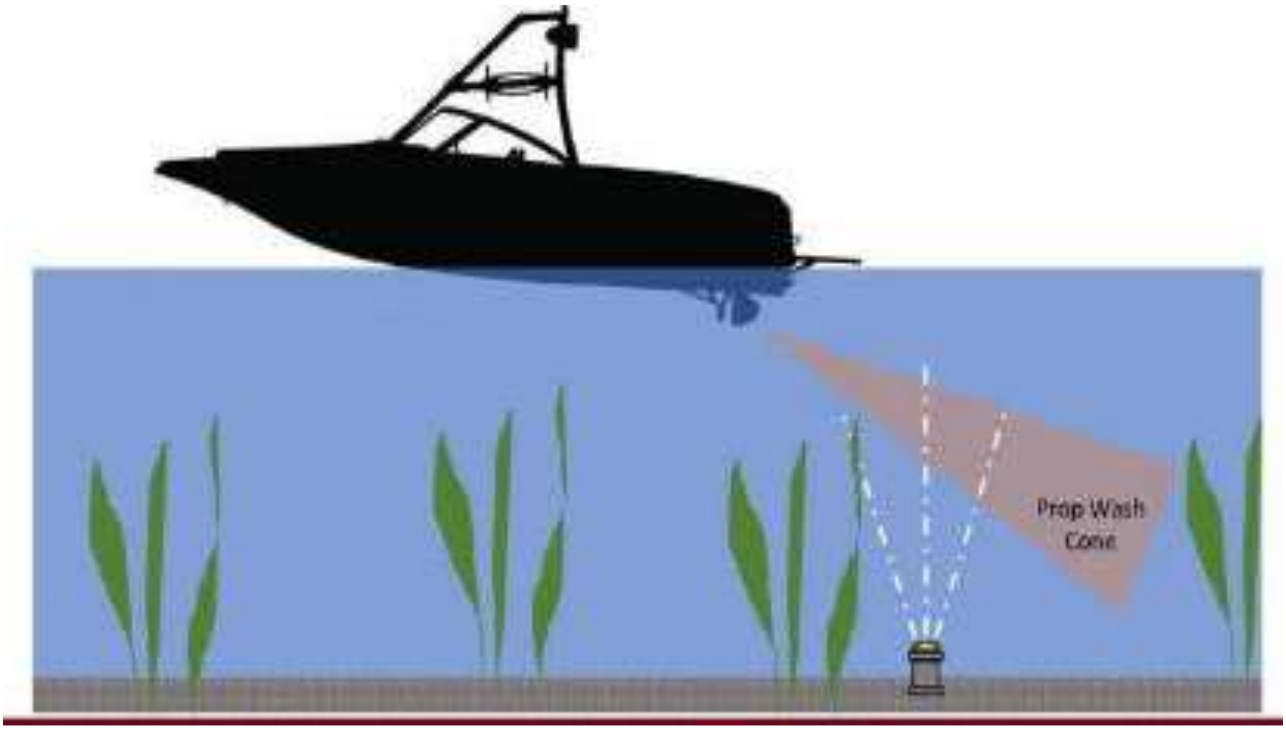
Location of 2018-2020 Eurasian watermilfoil delineated by the blue zone.

Monitoring for a further outbreak of Zebra mussels and Providing Prevention Education: Since the establishment of the CLID, invasive species across Minnesota has not been limited to vegetation. In the recent past, Fish Trap Lake followed by Crookneck Lake and Lake Alexander were identified as being infested with Zebra mussels. During 2017, Crookneck Lake joined a program managed by Morrison County testing for immature stage of Zebra mussels (veliger) and Spiny Water Flee. Results through 2022 have been negative for both. An adult pair of Zebra mussels were confirmed on the lake access dock after it was removed from the lake during October 2018. Since that time no additional adult Zebra mussels have been identified in the lake. Based on the original observation, Crookneck Lake was listed on the MN DNR Infested Waters

database. Educational brochures were prepared for distribution at the public lake access as well as notation on the lake access informational lake map and the Quad Lakes brochure.

Monitoring the lake for the presence of new invasive species: The threat of a new invasive species remains moderately high for Crookneck Lake since numerous visitors not only frequent the lake but also our three larger neighboring lakes. Working in concert with the Lake Improvement District's from each of these lakes as well as the County's AIS Program manager we have formed a collective for sharing information and best practices.

Monitoring the Impact of High Thrust/Propulsion Watercraft on Submersed Vegetation: The extent of the impact these watercrafts have on disruption of submersed aquatic vegetation, lakebed sediment, and shoreline erosion is unknown with precursory studies underway (see figure below). Overall impact on disturbance of the thermocline resulting in mixing of decaying sediment, water turbidity (clarity), up-rooting of aquatic vegetation, and wave erosion along shorelines remain areas of concern with respects to use of these watercraft on a lake of limited size and depth such as Crookneck Lake. Preliminary observations indicate an increase in the quantity of floating vegetation, increased lakebed disturbance, and larger sized waves reaching shorelines have occurred following their use on Crookneck Lake. Members of the CLID board continue to monitor studies being performed by the Saint Anthony Falls Research Laboratory, the progress of Lake Minnetonka towards regulating their usage, as well as monitoring their usage and impact on Crookneck Lake. It is unknown at this time if some form of use limitations for smaller, predominantly shallow lakes, such as Crookneck Lake, will be required in the future.



Saint Anthony Falls Study

Appendix C. Tutorial on Managing the Shoreland Zone: The Shoreland Zone is defined as the portion of land which is most likely to be developed and approximates the required minimum setback distance for shoreland structures. Since there are measures that can be taken to limit runoff or improve the quality of water reaching this zone for the purposes of this tutorial the Shoreland Zone will extend beyond the normal setback to include sources of water flowing to and through this zone to the Shoreline Zone (buffer between land and lake).

Shoreland habitat loss has been identified as the largest problem adversely affecting the health of lakes in the United States (US EPA 2010). Natural lake shores are unique transition zones between the land and the water and provide valuable ecological services that benefit wildlife and water quality. As people recreate and build on lakes critical areas for wildlife and fish, as well as important filtering and stabilization effects, are lost as lake shores change from "wild" naturally vegetated areas to "domesticated" sites of turf grass and hard surfaces with sparse or no vegetation. This is by no means a condemnation but more an acknowledgement that over time land use policies have brought us to where we are and perhaps there are some mitigating factors which can be taken to protect or enhance our investments in the future.

Mitigating projects focus on controlling either what or how much of a substance enters the watershed. An effective shoreland management program may indicate the need for control of water levels, septic system compliance inspections, erosion control projects, and runoff diversion projects. Projects across the state have included but are not limited to sewage mitigation, ranging from septic inspection to community sewage projects, and erosion control projects ranging from rain gardens to road designs, and lake-leveling projects, ranging from dams to pumping projects.

Surveillance/Diagnostic Studies: Both the Lake Crookneck Improvement Association (LCIA) and the Crookneck Lake Improvement District (CLID) have sponsored a multitude of studies. Many of the historical studies were performed by the LCIA prior to the establishment of the CLID but serve as critical benchmarks for future endeavors. In some cases, follow-up studies may not be available, for example the Thermal Over-Flight Analysis due to the service no longer being available; however, the recommendations remain viable today. Mastery of photo imagery provided on the Morrison County Beacon website may provide meaningful suggestive information in the future. The CLID, in concert with the LCIA, will continue to manage these programs in the future to promote the quality of the Crookneck Lake ecosystem.

Over-flight Analysis: The use of over flight imagery, satellite imagery, or thermal imagery can provide information suggestive of external nutrient loading sites, run off or erosion sites, possible restoration sites and effects of high and low water conditions. Two thermal analysis studies of Crookneck Lake were performed during 5/27/1989 and 6/22/2001. See Crookneck Lake …LCIA…Meeting Minutes and Documents … 2001 Environmental Assessment Overflight.

As a result of these studies several initiatives and/or reviews were accomplished:

Lakeshore recreational fire pits (Runoff Management): Over the 3-years following the 2001 thermal study, open fire pits were moved back from the shoreline with a vast majority being replaced by fire rings minimizing or eliminating a source of nutrient runoff into the lake.

Scandia Valley Transfer Station (Groundwater Management): Prior to 1985, the Scandia Valley Transfer Station functioned as what can be described as a "burn dump" operation. One of the findings of the thermal fly over was a large plum directly across from the transfer station. Several lake property owners raised a concern "could the transfer station be a source of contaminants to the lake?" The LCIA performed a cursory review and identified the following: Lake Lena, Crookneck Lake and Lake Shamineau share a common water table with the ordinary high water level decreasing from Lena to Crookneck to Shamineau. The ground water table has three veins which flow through the transfer station towards Crookneck. There are a few small collecting ponds on or adjacent to the station. The soil is predominantly sand and most likely filters runoff. Prior to operating as a transfer station, residents reported it was the norm to drop off old batteries or open paint containers. There was no knowledge or record of electrical transformer storage, a source of PCB, a qualifier for EPA clean-up funds. The LCIA elected not to perform environmental well testing in an arc between the transfer station and the lake due to cost and no evidence of PCB sources. Local laboratory sources for private well water testing was provided to association members. Currently the Transfer Station burns excess yard debris (leaves, branches). It was concluded that the sandy soil most likely would filter out any surface contaminants prior to reaching the groundwater table and traversing to the lake although the influence of fluctuations in the water table is unknown as well as to whether this may be a source of nutrients accounting for the aquatic bloom. The topic of ground water contamination periodically comes up.

Septic System Integrity - Compliance Inspection (Groundwater Management): In 2008, the LCIA applied for and received a grant from the Initiative Foundation of Little Falls to inspect septic systems (septic tank with drain field, holding tank, or outhouse) for compliance with current state and county statutes. Participation in the program was voluntary for all riparian landowners. The project was deemed a successful endeavor with 71 of 78 systems inspected being compliant and those out of compliance brought into compliance on a voluntary basis. In addition, all owners were provided with a guide on proper use and maintenance of septic systems. See Crookneck Lake …LID…Special Studies & Reports…2009 Septic Initiative Summary Report.

Run Off Management: Control of runoff water reaching the shoreline and filtering of the water prior to reaching the shoreline is critical to the health of the lake.

Road Design/Management: Lake associations and/or districts have a responsibility to engage in the design of road projects or major repairs from the outset to provide a wealth of information, "local knowledge", focused on mitigating runoff from reaching the lake. Early engagement in the process allows for incorporation of mitigation concepts into project designs during their infancy rather than more costly design revisions or change orders. One example Crookneck was involved in was the Pine View Blvd project.

Pine View Blvd Project: During the design phase of the Pine View Blvd repaving project Scandia Valley Township solicited input into measures which would protect the quality of the lake. Curbing, culverts, and the use of holding ponds were incorporated to mitigate the effect of runoff into the lake; particularly during the spring thaw which has a propensity to introduce sources of alkalinity into the lake.

Winter Road Salt Use: Road salt is the primary source of alkalinity for Scandia Valley Township lakes. The change in alkalinity is slow and takes years to demonstrate an influence. One teaspoon of salt is enough to permanently pollute five gallons of water. This contamination is irreversible, and it negatively impacts human health and the environment. Although salt is helpful for deicing, it should be used sparingly to decrease the negative impacts of chloride in our freshwater lakes (RMB December 2022 Newsletter). Consideration should be placed on an annual review of the usage of sand/salt during winter months by the Scandia Valley Township with a goal of diminishing a source for both sediment and alkalinity for the Scandia Valley lakes. Bottom line: transportation safety must remain paramount during winter driving conditions.

Rain Gardens: Rain Gardens are an effective way to control runoff from roadways prior to reaching the lake as well as topsoil erosion. Following an education campaign by the LCIA, one rain garden was designed and funded by the Morrison County Soil and Water Conservation District while other members of the LCIA incorporated the concepts into landscaping designs.

Appendix D. Tutorial on Managing the Shoreline Zone: The Shoreline Zone is an area of critical importance to the lake's water quality providing a buffer between the land and lake while oftentimes providing a critical fishery habitat. Over time, the definition of "where does shoreline begin" has been debated. For purposes of this document, the zone will vary in width as you traverse the lake but in general should be thought of as "a buffer zone". Included in this tutorial will be a review of lake-levels and mitigation of high-water levels.

Since 2000, Crookneck Lake's water level has trended up, reaching an all-time high in 2019. The increase has not been a year-over-year increase and the trend since 2020 has been down. The primary impact to most riparian property owners was destruction of the shoreline, although a few did experience damage to buildings. County agencies performed shoreline studies and provided mitigation recommendations as well as the board of directors for both the LCIA and CLID monitored and provided input to projects proposed and/or underway by Lake Shamineau organizations to lower their water level. As the levels increased, property owners acted across the board to stabilize their shorelines to maintain property values. Various mitigating measures have been implemented.

Soil and Water Conservation Studies: Two studies were performed during periods of high-water times by county officials.

2002 SWCD Study: During 2002, the Morrison County Soil and Water Conservation District performed a comprehensive analysis of the shoreline of Crookneck Lake focusing on shoreline erosion. At the time of the study, the water level was considered high. Based on the level of shoreline development, soil composition being predominately sand based, and the extent of erosion the recommended best preventative measure available at the time was installation of "rip-rap." See Crookneck Lake …LCIA…Meeting Minutes and Documents…2002 Shoreline Assessment.

2018 SWCD Study: During Sep 2018, the Morrison County Soil and Water Conservation District performed a comprehensive analysis of the shoreline of Crookneck Lake focusing on mitigation efforts residents have taken since the 2002 survey to manage the record setting high-water conditions. At the time of the study, a vast number of property owners have installed rip-rap with a few utilizing Coir (coconut) logs. These measures have been largely successful during the recent high-water times dating back to 2011 to control shoreline erosion. Recommendations were made to enhance the mitigation efforts made with a focus on future shoreline restoration ideas incorporating the planting of native vegetative plantings along the shoreline. See Crookneck Lake …LCIA Meeting Minutes and Documents…2018 Shoreline Assessment.

Mitigating and/or Managing the Effects of High Water: The combination of high-water conditions combined with the effect of the force of waves caused vast areas of either shoreline erosion and/or structure damage. Mitigation efforts included but are not limited to:

"No Wake Zone": The Morrison County Sherriff posted a "No Wake Zone Within 300 Feet of Shore" notice at the public access to the lake and has patrolled the lake on numerous occasions with what can be described as "moderate" compliance. The size of the lake and the inability of the Sherriff to issue citations for noncompliance had an impact on compliance. Postings occurred on 5 July 2018 when the water level was 2.27 ft above the Ordinary High Water (OHW) level and on 10 June 20014 when the OHW was 1.57 ft above the OHW level.

"Coir Log Reinforcement": A few individuals on the lake utilized Coir logs along the shoreline to buffer the shoreline interface with the lake to mitigate shoreline erosion. This is a preferred remedy as it provides a medium for plant growth reinforcement providing critical fish habitat. Over the years, this procedure was replaced by rip-rap as the varying water levels reached record levels and wave activity damaged the logs and prevented vegetative growth.

"Rip-Rap": A majority of property owners have installed rip-rap which serves as a long term erosion buffer, however it lacks a means for shoreline plant growth critical for fish habitat. As mentioned under *High Thrust/Propulsion Watercraft* (Appendix B) a few residents have reported that the waves produced by these boats have washed up over their rip-rap resulting in a concern of further erosion.

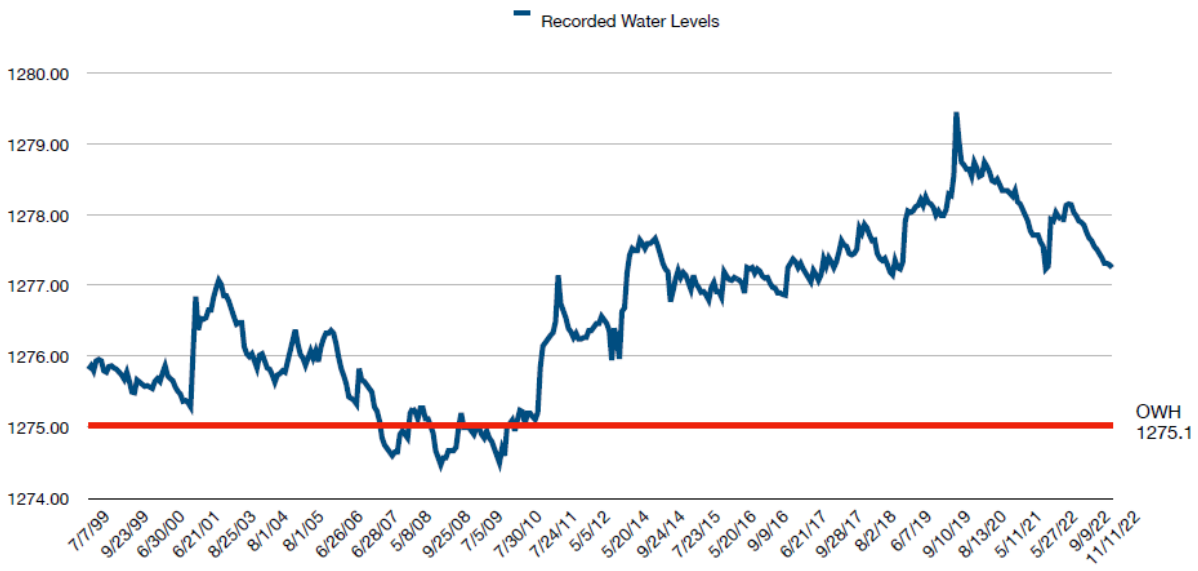
"Structure Fortification/Raising": A few owners have raised and/or repaired structures damaged by high water.

Managing Low or High-Water Levels (Impacts Shoreline Erosion, Water Quality, Weed Management, Fisheries, and Property Value): Crookneck Lake is a small, shallow lake located between three of the largest lakes in Morrison County: Alexander, Fish Trap, and Shamineau. The lake is landlocked and has a relatively small watershed of 510 acres resulting in widely fluctuating water levels. A steep hill runs along the north side of the lake and most of the landowners have built on top of the bluff, thus leaving the lakeshore more natural looking. Water clarity historically decreases during the summer months due to algae blooms. Sand is the most abundant shallow water substrate around the lake. The lake has a diverse population of aquatic plants growing up to a depth of 18 feet. Much of the shoreline is developed. Most anglers on the lake seek out Northern Pike, Largemouth Bass, Black Crappie, and Bluegill.

When it comes to lake management decisions it is a balancing act between what is best for the Crookneck Lake ecosystem while maintaining property values. The ability to attain many of the goals of this management plan can be directly linked to the proportion of biomass within the lake. As the water level goes down, the biomass within the water increases which leads to the detriment of the quality of the lake overall and vice versa during high water times.

Water-Levels: Over the years the lake has demonstrated ebbs and flows below and above its Ordinary High Water (OHW) level, which has led to lively debates depending on one's personal viewpoint. Since 2011, the lake has been at levels above the OHW level. Except for a few residents, owners have been able to mitigate the effects of the high water and protect their property value.

Water levels have been recorded for Crookneck Lake dating back to one reading in 1994, followed by multiple annual readings from 1999 to now. The graph below demonstrates that since 1999, the lake has been above its Ordinary High Water (OHW) level for a majority of years.



Source: DNR Lake Finder, Crookneck (49013300) | LakeFinder | Minnesota DNR (state.mn.us) …lake levels…download ASCII file or see Crookneck Lake …LID…Special Studies & Reports...2023 Crookneck Recorded Water Levels (graph of database) and also Lake Info (tool bar opening screen).

Lake Crookneck Lake is spring feed with one limited surface inlet. During low water times, some residents have suggested pursuing measures to open the inlet as well as close it during high water times. The inlet originates from what has become known as the South 203 Watershed over the last few years.

Lake-Level Management Projects: Since 2017, two major initiatives have been sponsored by Lake Shamineau to manage their water level. One group, the Lake Shamineau Emergency Task Force, has focused their efforts on managing the surface flow of water into the lake. The Lake Shamineau Lake Improvement District (LSLID) has focused their efforts on a project to pump water out of the lake.

South 203 Watershed Project: This watershed is located to the south of CR 203 (330) and north CR 3 (320) and beginning approximately at 30th Ave on the east extending to HWY 10 on the west with an outlet leading to the Fish Trap Creek via the "Blue Line Trench" which was developed during 1932 by the CPA (see map below). A lateral ditch from the Blue Line Trench just west of the Friendly Inn flows north to Crookneck Lake. Dating back to 1962, following the spring thaw, water has flowed from this watershed to Crookneck Lake into June providing a source of what is considered quality water. During the winter of 2020, a project was undertaken by Shamineau Lake to clear out the Blue Line Trench to promote the flow to the west and lower the watershed. Since 2020, no water has flowed into Crookneck Lake via the lateral ditch, a first dating back to 1962. During 2022, the South 203 Watershed reached the lowest level in modern history.

South 203 "Blue Line Trench" Project (February 2020)

Lake Shamineau Lake-Lowering Project: During 2017, the Lake Shamineau Lake Improvement District (LSLID) began a project to lower the water level. The LSLID met with the Crookneck Lake Improvement District (CLID) through fall of 2020. The CLID was focused on a review of the causes of increase runoff into the lakes and what mitigation efforts could be made, whereas the LSLID was solely focused on a pumping project. The LSLID requested a Letter of Support to which the CLID declined, and the lines of communication subsequently broke down. The CLID's primary concern was a lack of project definition, any recognition that the LSLID's pumping project may impact Crookneck Lake or that we share a common watershed (groundwater), a fact which has now been recognized by their project engineer. Data shared with the LSLID over the years included:

Analysis of lake-level data drawn from the MN DNR Lake Finder database that demonstrates the lake levels for Crookneck Lake and Lake Shamineau track remarkably close since 1999 (see Figure 1 below).

University of Minnesota "Historical Aerial Photographs" collection dating back to the late 1940s and 1950s, performed by a member of the Lake Shamineau Emergency Task Force (LSETF), suggests that there may have been a natural outlet of Crookneck Lake into Lake Shamineau via the wetlands located to northwest of Crookneck Lake prior to Pine View Blvd being established. The two lakes are within approximately 100 yards of each other in this area.

The 2019 Groundwater Atlas of Morrison County, geological review and our close proximity would all support the conclusion that Lake Shamineau and Crookneck Lake share a common groundwater table flowing through and under Crookneck Lake towards Lake Shamineau.

Review of Table 1 demonstrates that since 1999 Crookneck Lake has been above its Ordinary High Water (OHW) level 19 of 24 years with 4 of these years following a period of drought. On numerous occasions, the CLID has made it known that our position is that both lakes should not be lowered below six inches above their OHW levels by means of a non-natural method allowing for a buffer should the region experience a period of drought.

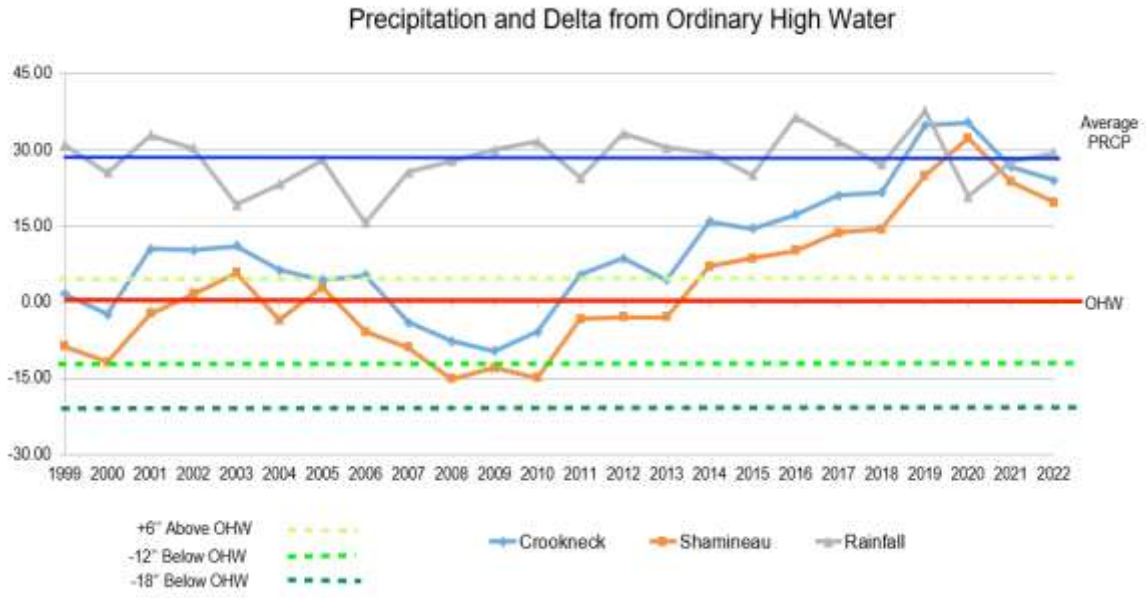
Table 1: Crookneck Lake and Lake Shamineau Data.

Year to Year Period	Year to Year Crookneck Lake	Year to Year Lake Shamineau	Year	Precipitation	Delta OHW Crookneck Lake	Delta OHW Shamineau Lake
1999 – 2000	-4.08	-3.12	**1999**	31.01	+1.62	-8.75
2000 – 2001	+7.98	+9.59	**2000**	25.54	-2.46	-11.87
2001 – 2002	-0.18	+3.84	**2001**	32.91	+10.44	-2.28
2002 – 2003	+0.72	+4.20	**2002**	30.37	+10.26	+1.56
2003 – 2004	-4.62	-9.30	**2003**	19.23	+10.98	+5.76
2004 – 2005	-1.98	+6.41	**2004**	23.19	+6.36	-3.54
2005 – 2006	+0.90	-8.69	**2005**	28.0	+4.38	+2.87
2006 – 2007	-9.35	-3.12	**2006**	15.62	+5.28	-5.82
2007 – 2008	-3.61	-6.24	**2007**	25.6	-4.07	-8.94
2008 – 2009	-1.92	+2.22*	**2008**	27.86	-7.68	-15.18
2009 – 2010	+3.78	-1.92*	**2009**	29.98	-9.6	-12.96*
2010 – 2011	+11.22	+11.52*	**2010**	31.6	-5.82	-14.88*
2011 – 2012	+3.24	+0.36	**2011**	24.43	+5.4	-3.36
2012 – 2013	-4.32	+0.06	**2012**	33.19	+8.64	-3.0
2013 – 2014	+11.52	+9.90	**2013**	30.04	+4.32	-2.94
2014 – 2015	-1.32	+1.68	**2014**	29.3	+15.84	+6.96
2015 – 2016	+2.70	+1.50	**2015**	24.99	+14.52	+8.64
2016 – 2017	+4.78	+3.48	**2016**	36.44	+17.22	+10.14
2017 – 2018	+0.06	+0.78	**2017**	31.6	+21.0	+13.62
2018 – 2019	+13.07	+10.56	**2018**	27.08	+21.6	+14.4
2019 – 2020	+0.73	+7.32	**2019**	28.48	+34.67	+24.96
2020 – 2021	-7.8	-8.58	**2020**	20.79	+34.4	+32.28
2021 – 2022	-2.6	-4.02	**2021**	27.77	+26.6	+23.7
			2022	31.4	+24.0	+19.68

Methodology for Data Analysis: Source: DNR Lake Finder, Crookneck (49013300) | LakeFinder | Minnesota DNR (state.mn.us) …lake levels…download ASCII file. To determine the annual delta from the Ordinary High Water (OHW) level the first recorded reading of the year (representing snowpack run off) and the last recording of the year (representing summer rainfall) are averaged and a positive or negative delta from the OHW is calculated. The "Year to Year" represents either a plus or negative delta over the 2-year period. NOTE: The "*" years are based on single data point readings; only one reading to determine the annual delta from the OHW.

Precipitation data represents the annual precipitation recorded at Brainerd, MN. Brainerd Weather in 2022 (extremeweatherwatch.com)

Figure 1: Precipitation and Delta from Ordinary High Water Level



Year	Crookneck	Shaminea	Rainfall
1999	1.62	-8.75	31.01
2000	-2.46	-11.87	25.54
2001	10.44	-2.28	32.91
2002	10.26	1.56	30.37
2003	10.98	5.76	19.23
2004	6.36	-3.54	23.19
2005	4.38	2.87	28
2006	5.28	-5.82	15.62
2007	-4.07	-8.94	25.6
2008	-7.68	-15.18	27.86
2009	-9.6	-12.96	29.98
2010	-5.82	-14.88	31.6
2011	5.4	-3.36	24.43
2012	8.64	-3	33.19
2013	4.32	-2.94	30.4
2014	15.84	6.96	29.3
2015	14.52	8.64	24.99
2016	17.22	10.14	36.44
2017	21	13.62	31.6
2018	21.6	14.4	27.08
2019	34.8	24.96	37.7
2020	35.4	32.3	20.79
2021	26.6	23.7	27.7
2022	24	19.68	29.45

Source: * Precipitation through 7 December 2022 Brainerd, MN. Brainerd Weather in 2022 (extremeweatherwatch.com)

Source: The DNR has measured the water level of Crookneck Lake since 1994. See Crookneck Lake …CLI…Special Studies & Reports...Crookneck Shamineau Water Level Data.

Appendix E. Tutorial on Future of Lake Surveys

The Minnesota Department of Natural resources (DNR) and pollution control Agency (MPCA) have implemented the use of indices of biological integrity (IBIs) to base assessment decisions regarding the health of an ecosystem and its aquatic life use.

Lake Index of Biological Integrity: An indicator of a lake's health is the community of fish, plants, and other aquatic life it sustains, sometimes referred to as the biological community. Certain species cannot survive without clean water and a healthy habitat while others are tolerant of degraded conditions. Species that fall into either of these groups are referred to as "indicators" of the health of the lake. An index of biological integrity (IBI) is a score that compares the types and numbers of fish, plants or other aquatic life observed in a lake to what is expected for a healthy lake. The biological communities present in a lake are the result of cumulative effects of natural and human-caused influences within the entire area of the land and water that flows into the lake. These communities change in predictable ways in response to factors such as degraded water quality or loss of shoreline habitat. DNR personnel assess the overall biological health of a lake based on measurements of these communities.

Fish-Based Index of Biological Integrity: Currently, the primary tool to assess the health of a lake is a fish-based IBI (FIBI). The FIBI was developed by the MN DNR by sampling a wide range of lakes, ranging from high-quality lakes to those with significantly degraded water quality or shoreline habitat. A statistical analysis found a relationship between communities of fish and water quality physical hibitat characteristics. Further statistical analysis led to four fish-based IBIs being developed to accuaretly evaluate different types of lakes and expectations for their associated fish communities. The four FIBIs were based on water depth (deep vs. shallow) and shoreline characteristics (round vs. complex shoreline).

The FIBI survey process is multi-faceted. Diverse methods sample fish in the lake with each method targeting different kinds of fish. Methods include gill netting, trap netting, seining and backpack electrofishing to sample the fish population. Once fish are collected, they are sorted by species, counted, weighed, measured and released back. The data is analyzed to calculate the IBI score. Each IBI score is generated using between eight and fifteen calculated measurements, depending on the type of lake. Examples include either raw counts or proportions of species that are classified as: native, intolerant, tolerant, vegetation-dewelling, small benthic-dwelling, insectivorous, carnivorous, omnovorus, or belonging to the cyprinid (i.e., minnows and shiners) family. These measurements are known to correspond with varying levels of human-caused stress from land use activities of the shoreland and alteration of the physical shoreline habitat.

Fish-based IBI (FIBI) scores are used by DNR staff to place lakes into one of six assessment categories: exceptional, fully supporting, vulnerable, not supporting (impaired), inconclusive information and insufficient information. The FIBI uses fish community data to measure the lake's health, and types of fish species present can help identify any stressors that may be negatively affecting the lake environment. In Minnesota lakes, certain fish species cannot survive without clean water and a healthy habitat, (e.g., Banded Killifish, Iowa Darter, and Rock Bass), while other species are tolerant of degraded conditions (e.g., Green Sunfish). A low FIBI score compared to others in the lake's peer group would lead to a need to further research the cause and identify stressors on the habitat resulting in the low FIBI score. DNR staff will study stressors impacting the biological communities found in impaired and vulnerable lakes.

The fish-based IBI is one important component that is considered during the MPCA watershed assessment process. Specifically, it is the primary tool used to assess whether a lake fully supports *aquatic life*. Similarly the MPCA Lakes Monitoring Program (see Appendix A) uses physical measurements of water quality such as water clarity, amount of chorohyll-a and total phosphorus to assess whether the lake fully supports *aquatic recreation*. These measurements represent a snapshot in time of lake conditions whereas the biological community as measured by the IBI reflects changes to the lake over several years or more. Taken together, these assessments provide important information to guide Clean Water Act planning and restoration.

Floristic Quality Assessment (FQA): Since the 1990s Minnesota has been studying and monitoring wetlands. To support the goal of "no-net-loss of wetland acres" in addition to including the quality and biological integrity of the wetland the MPCA developed a meandering survey methodology, a wetland monitoring and assessment approach using a FQA, a vegetation-based ecological condition assessment. Currently the focus of the FQAs is on wetlands but application to lake assessment may be in the future. Lake surveys are currently performed by the DNR and contract surveyors. Point-intercept surveys assess the overall populations of the lake's aquatic vegetation.

Stressors to Biological Communities: Lake's which are classified as impaired are currently investigated by Minnesota agencies to identify potential stressors. Should Crookneck Lake receive a rating as "vulnerable" or negative trends are noted, a thourough reveiw should be taken to identify any underlying stressors.

Numerous stressors are considered during these reviews, but most often the focus is on the shoreline habitat and water quality on the fish community. A number of stressors have been identified:

Eutrophication is the enrichment of a water body with nutrients.

Physical habitat alteration may refer to characteristics such as water depth, substrate size and type, aquatic and raprian vegetation cover, and bank structure.

Riparian lakeshore development adjacent to lakes is known to have negative effects on riparian and aquatic habitat and can alter spatial and distribution patterns and community compositions of fish and plants. Residential development that affects the lakeshore includes clearing of riparian vegetation for lawns and views, addition of sand blankets for swimming beaches or riprap for erosion control, and destruction of aquatic vegetation and placement of docks for recreation. The status of the current aquatic community in any lake is a reflection of the effects of the collective activities resulting from loss of raparian and aquatic habitat over several decades. For example, decreases in FIBI metrics characterizing vegetation-dwelling and other intolerant nearshore fish species have been observed as dock density, an indicator of residential development on lakes, exceeds ten docks per kilometer of shoreline.

Aquatic plant removal may be detrimental to certain populations of fish particularly along shorelines, whereas management of aquatic invasive species is critical to the floristic integrity of the lake.

Water level management has historically been undertaken in response to preceived problems that humans have with the quantity of water within a lake basin at a givin time. Alteration of water level regimes can reduce abundance and diversity of nearshore plants either because periods of low water no longer exists or because swings in water level become more extreme.

Sedimentation is the deposition of suspended solid materials. Sedimentation has the potential to change substrate charteristics within lakes, which may negatively affect richness and abundance of aquatic plants as well as vegetation and substrate-dependent fish species. Sources of sedimentation is shoreland runoff and disturbance of the lake's lakebed sediment.

Altered interspecific competion results from the introduction from non-native species, either plant or non-plant species.

Changes in water temperature, dissovled oxygen concentration, alkalinity (primary source is road salt), pesticides, and metals all may have a negative impact on certain species of fish.

Score the Shore Survey: The "Score the Shore Survey" depicted below describes the lake-wide lakeshore habitat, detects substantial lake-wide lakeshore habitat score changes over time, and compares lake-wide lakeshore habitat scores within and between watersheds and ecoregions to assess patterns and trends. Notably the *"Score the Shore Survey"* surveys sites are randomly selected in a random, systematic, and regular interval pattern around the lake perimeter. The sites are not associated with individual properties or lots and do not assess structures that may occur in the Shoreland or Shoreline Zones. A separate but similar survey, *"Score Your Shore"* has been developed for riparian landowners to self-assess their developed lot.

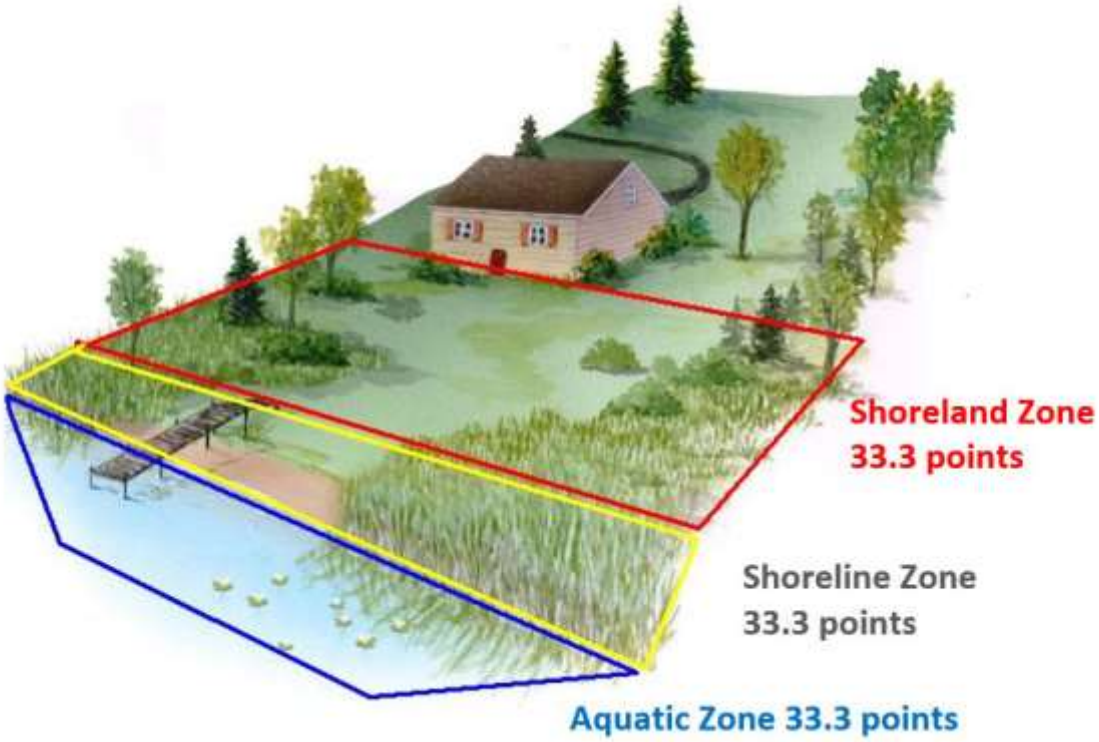
One drawback associated with the *"Score the Shore"* survey is the 10-year period between surveys associated with recent implementation and the ten-year survey cycle which does not allow for trend analysis, although a score is determined for comparison to the lake's assigned group. The complimentary *"Score Your Shore"* survey provides an immediate feedback tool for individual riparian owners to identify areas to focus on which would contribute to an overall improved Score the Shore score in the future.

Each site's zone (shoreland, shoreline, and aquatic) is awarded a score between 0-33. The three are totaled for the total score for the site. Site scores are then averaged to determine the lake's score. Higher scores are associated with greater amount of natural habitat, whereas lower scores are associated with a high amount of habitat that has been physically disturbed or altered by humans.

Interpreting the score is relatively straight forward. Scores fall into one of four groups: high, moderate, low, or very low. A high score correlates to lakes with a high percentage of unaltered habitat in each of the three zones, whereas a very low score correlates to lakes which are heavily altered by the removal of vegetation and related habitat and/or the addition of numerous unnatural structures such as docks. It is important to note that a very high score in one zone can overcome a low score in another zone and result in an overall average score necessitating a review of the individual zone scores for a complete assessment.

Breaking it down to one basic concept, the health of a lake is directly linked to water clarity. Water clarity is derived from the water that enters the lake and what may come with it and what is in the lake, i.e., weeds and algae. This concept was one of the bases for the development of the Score the Shore survey depicted below. As water interacts in each zone it may eventually impact the clarity of the lake's water.

Figure 1. Score The Shore habitat zones



Crookneck Lake Results: During the 2020s Crookneck Lake had its initial FIBI and Score the Shore surveys, and a periodic Aquatic Vegetation Management Report.

Fish-based IBI: On July 1 and 2, 2021 a targeted survey of nearshore fish species in Crookneck Lake was conducted. Backpack electrofish and seining was completed at ten sampling sites. Nearshore sampling captured 13 species of fish including three species that are intolerant of disturbance (i.e., Banded Killifish, Iowa Darter, and Rock Bass) and no species that are tolerant of disturbance. The nearshore data was combined with trap net and gill net data from the June 2021 survey to describe fish community and provide a Fish-based IBI (FIBI) score. Data from this survey indicates Crookneck Lake is healthy as indicated by an "exceptionally high" FIBI score of 65, well above the impairment threshold for aquatic life use determined for similar lakes. Since this was the first FIBI survey on Crookneck Lake and the results indicate an exceptionally high FIBI score the survey was repeated during 2022. Results are not available at this time. Source: Search Results | Minnesota DNR (state.mn.us)…Crookneck…Fishery Lake Survey…Targeted Survey (2021-07-01)

Score the Shore Survey: On June 28, 2022, the DNR performed its first survey on Crookneck Lake. The average lakewide habitat score was 70.9, indicating overall lakeshore habitat quality as "moderate" (66-84). Approximately 86 percent of the sites were developed with a mean score of 68.3 while undeveloped sites had a mean score of 87.1. Comparison statewide, Crookneck's 70.9 is below the statewide average of 74.4. See Crookneck Lake …LID…Special Studies & Reports...2022 Score the Shore Survey Report (draft).

Aquatic Vegetation Management Report: The survey occured on June 20, 2020. Plants were present throughout the lake to a depth of 15 feet. Within the littoral zone (zone in lake from 0-15 foot depth range), 90% of the point-intercepts had native submersed taxa. The average number of native submersed taxa per sample point was 1.8. In total, thirteen submersed taxa, one invasive taxa, and one floating-leaf taxa were observed. Source: Source: The DNR has measured the water level of Crookneck Lake since 1994. See Crookneck Lake …LID…Aquatic Invasive Species...2020 AIS DNR Vegetation Management Survey.

Appendix F: Tutorial on Management of the Crookneck Lake Improvement District (CLID) and Lake Crookneck Improvement District (LCIA)

Administration and accountability of this plan is the responsibility of both the Crookneck Lake Improvement District (CLID) and Lake Crookneck Improvement Association (LCIA) Board of Directors. Stewardship is the key to the success of these organizations. Governance of the CLID is derived from its Order of Establishment, whereas governance for the LCIA is derived from its Constitution and Bylaws. Each organization operates independent of the other. Both organizations hold an annual meeting where the business of the organization occurs, Treasurer Reports are presented, and elections held, although significant differences in protocols exist.

The CLID annual meeting arguably is more rigid in its requirements, e.g., meeting notice must be posted in Morrison County Record, meeting notice with ballot mailed to all riparian owners, closed ballot with a mail in provision, formal process for approving work plan and budget for the following year, etc., followed by the Board of Directors voting on a Levy to fund the CLID. During the month following the meeting, the Board of Directors meet with the Morrison County Board of Commissioners who approve the work plan, budget, and levy by motion. In comparison, the LCIA members attending the meeting transact all of the LCIA business at the meeting, i.e., nominate and vote on Board of Director vacancies, budget and annual dues, annual activities, etc.

The CLID Board of Directors in 2016 developed an internal audit process to ensure compliance with mandates and reported findings at the 2017 annual meeting. This process continues to be reported at annual CLID meetings. See Crookneck Lake …LID … Annual Meetings … Specific Annual Meeting and Annual Power Point Presentations.

During 2017, the CLID Treasurer developed and published a 10-yr review of the financial records of the CLID. This report is now updated and published annually. See Crookneck Lake … LID … Treasurer's Reports.

The LCIA annual business is accomplished at the LCIA Annual Business Meeting which includes its financial report. See Crookneck Lake … LCIA … Meeting Minutes.

The CLID and LCIA share a common website named Crookneck Lake.

Historical Review of Contract Support: Several vendors have been utilized in the management of Crookneck Lake over the years to survey for Aquatic Invasive Species (AIS), harvest vegetation by mechanical means or treat with herbicides, and perform water quality analysis.

During the early years of the LCIA management of nuisance weeds was predominantly accomplished by mechanical harvesting. The LCIA purchased a small harvester (Hockney) which members could use to cut weeds along their shoreline to gain access to the lake or clear an area for recreation. Annually the LCIA would contract with Lakeshore Restoration, Rogers, MN to cut a large path around the west bay allowing for access to the lake. During 2006, the CLID contracted with PLM, Brainerd, MN to both survey the lake for aquatic invasive species, predominantly Curly-leaf pondweed, and subsequently treat it with herbicides. In addition to these surveys, the MN DNR also performed vegetation surveys of the lake in addition to confirming the presence of Curly-leaf pondweed prior to treatment. During 2014, the DNR

questioned a potential conflict of interest in having PLM perform both the surveys and the treatments. As such, RMB Environmental Laboratories, Detroit Lakes, MN was selected to perform the surveys since they were already performing the water quality analysis on samples collected for the MPCA Lakes Monitoring Program. Prior to RMB performing the water quality studies, A&W Labs, Brainerd, MN performed the water analysis. PLM and Lakeshore Restoration submitted treatment bids with PLM being selected based on cost of bid, a treatment plan which factored in both depth of water and efficacy characteristics of the herbicide, as well as our current working relationship. The relationship with PLM has continued over the years as we have been able to work in concert with the DNR to gain approval to use cost-effective alternative herbicides on Crookneck Lake. We continued to contract with RMB to perform surveys through 2018. During the fall of 2018, a resident identified Eurasian watermilfoil (EWM) in the lake. After consulting with the DNR and PLM, Freshwater Scientific Services (FWSS) was contracted to perform AIS surveys. The FWSS ecologist is a recognized expert in EWM and has a rich knowledge of Crookneck Lake having performed his graduate degree research work on the lake. In addition, FWSS utilizes a continuous zig-zag pattern along the shoreline vs. point-intercept across the lake methodology for sampling sites. In summary, the vendors available to us include (bold depicts current contracts):

Freshwater Scientific Services: **AIS surveys, Zebra mussel dive survey** and (veliger stage) testing

Lakeshore Restoration: herbicide treatment

PLM: AIS surveys, **herbicide treatment**

RMB Environmental Labs: AIS surveys, **water quality studies**, **Zebra mussel (veliger stage) testing***

*** Morrison County funds and contracts for the Zebra mussel (veliger stage) testing**

Appendix G. Bibliography

Crookneck Lake: the CrookneckLake.com website contains years of historical data and governance documents for both the Crookneck Lake Improvement District (CLID) and Lake Crookneck Improvement Association (LCIA). See Crookneck Lake

MN Pollution Control Agency (MPCA): Minnesota Uses Floristic Quality Assessments to Enhance State Wetlands Monitoring Efforts. The survey is currently being used for wetlands and may be applied to lake management on some scale in the future. Minnesota Uses Floristic Quality Assessments to Enhance State Wetlands Monitoring Efforts | US EPA

RMB Environmental Labs: Assessments (rmbel.info) **"Select Morrison County…Crookneck Lake…multiple water quality reports can be reviewed to include "Summary" and "Trend Analysis". Within each report is a tab "Understanding This Report". A vast majority of the information found there is included in Appendix A."**

MNDNR Lake Finder: "Select Morrison County…Crookneck Lake…open Crookneck Lake…multiple reports or surveys can be downloaded to include Fisheries Lake Surveys, Water Levels, Water Quality, Aquatic Plant Surveys, and Water Clarity Reports. Search Results | Minnesota DNR (state.mn.us)

Score Your Shore Survey: This site provides a PDF guide for scoring your property as well as a power point presentation on the survey.
Score Your Shore: | a citizen shoreline description survey | Minnesota DNR (state.mn.us)

Lake Index of Biological Integrity Lake Index of Biological Integrity | Minnesota DNR (state.mn.us)

Stressors to Biological Communities in Minnesota's Lakes, Feb 2018 Stressors to Biological Communities in Minnesota's Lakes (state.mn.us)

Development of fish-based indices of biological integrity for Minnesota Lakes. Bacigalupi, Jacquelyn et.al. (PDF) Development of fish-based indices of biological integrity for Minnesota lakes (researchgate.net)

Brainerd Weather: precipitation data. Brainerd Weather in 2022 (extremeweatherwatch.com)