# Lake McCarrons Management Plan



Capitol Region Watershed District Saint Paul, MN

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Prepared by: Barr Engineering Co.





# Lake McCarrons Management Plan

# April 2020

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#### Key Terms

**Algae:** Algae are microscopic plants that float in lake water. Algae become nuisances when they become abundant. A particular kind of algae – blue-green algae – are a particular nuisance because they form scums. All algae become more abundant as the level of phosphorus in the water increases. The abundance of algae is determined by measuring *chlorophyll* – a green pigment – in lake water.

**Alum:** Alum is a short-hand reference to the chemical aluminum sulfate. Alum, when applied to lakes, chemically binds with phosphorus to remove it from the water. The precipitate that forms, called a floc, settles to the lake bottom and forms a chemical barrier that retards phosphorus from being recycled back into the lake.

Anoxic: Devoid of dissolved oxygen.

**Best Management Practice:** One of many different structural or non–structural methods used to treat runoff, including such diverse measures as ponding, street sweeping, filtration through a rain garden and infiltration to a gravel trench.

**Chlorophyll:** Chlorophyll is a green plant pigment found in algae. Chlorophyll in lake water is used as a measurement for the presence of algae. It has been shown that chlorophyll concentration is correlated to the abundance of all algae.

**Clarity:** The transparency of lake water is easily observable. As the amount of algae increases, the water clarity decreases. Clarity is measured using a *Secchi disk*, an 8- inch white or black-and-white disk lowered over the side of a boat until it disappears.

**Eutrophic:** Eutrophic refers to a nutrient-enriched condition characterized by increased biological productivity. *Eutrophication* is the process by which lakes become eutrophic. Eutrophic lakes are generally considered to be impaired.

**Impairment:** Water bodies are listed as impaired if water quality standards are not met for designated uses including: aquatic life, aquatic recreation, and aquatic consumption.

**Iron-Enhanced Sand Filter:** Iron-enhanced sand filters are Best Management Practices (BMPs) that incorporate filtration media mixed with iron. The iron removes several dissolved constituents, including phosphate, from stormwater.

**P8:** P8 is a model that estimates pollution (like phosphorus) loads in stormwater. P8 stands for 'Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds.'

**Phosphorus:** Phosphorus is considered the limiting nutrient in lakes. This means it is the element (in the lake water) in shortest supply relative to the growth needs of algae. Phosphorus is measured from lake water collected at the middle of the lake.

**Protection:** This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

**Source (or pollutant source):** This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

**Stormwater:** Water that is generated by rainfall or snowmelt which causes runoff and is often routed into drain systems for treatment or conveyance.

**Thermocline:** The thermocline is the area of greatest temperature change that separates the warmer surface waters from the cool bottom waters in a lake. The depth of a lake's thermocline varies, normally becoming shallower from spring to summer, then deeper from summer to autumn. At overturn, the thermocline disappears.

**Trophic State:** Trophic state is the degree of eutrophication, usually expressed on a continuum. Trophic state is commonly indicated by phosphorus concentration, algae abundances (as chlorophyll) or water clarity (Secchi disk), either singly or in combination.

**Water Quality:** Refers to the condition of water. Water quality may be described or defined in many ways, ranging from subjective descriptions to legal standards. Water quality includes many aspects. Normally, water quality of lakes refers to the degree of eutrophication or trophic state.

**Watershed/Subwatershed:** A lake's watershed is the land area around the lake that contributes surface runoff to the lake. Subwatersheds are small subdivisions of a watershed.

# Acronyms

AAG	Agency Advisory Group
BMP	Best management practice
BWSR	Board of Water and Soil Resources
CAC	Citizens Advisory Committee
Chl-a	Chlorophyll-a
CLP	Curly-leaf Pondweed
CRWD	Capitol Region Watershed District
DO	Dissolved oxygen
GIS	Geographic information system
IESF	iron-enhanced sand filter
lbs/yr	Pounds per year
Lidar	Light detection and ranging
LVMP	Lake Vegetation Management Plan
µg/L	micrograms per liter
MnDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
NCHF	North Central Hardwood Forest
NPDES	National Pollutant Discharge Elimination System
P8	Program for predicting polluting particle passage thru pits, puddles, and ponds
RCPR	Ramsey County Parks and Recreation
ТР	Total phosphorus
TSS	Total suspended solids

# **1 Executive Summary**

Lake McCarrons has a surface area of 74.5 acres and a maximum depth of 54 feet—small and deep by Metro area norms. Located in the southeast corner of Roseville, the Lake McCarrons watershed covers 1,050 acres and is primarily residential land use. Like many other urban lakes, Lake McCarrons has previously experienced water quality problems, as documented in the 2003 Lake McCarrons Management Plan [2003 Plan] (The Osgood Group and Barr Engineering Co., 2003).

A 2004 in-lake alum treatment and several watershed improvement projects implemented since 2003 have resulted in significant water quality improvement for Lake McCarrons. As a result, CRWD recognizes the need for an updated lake management plan that reflects current water quality issues and identifies goals, objectives and recommended actions for watershed and in-lake management to protect and maintain exceptional water quality in Lake McCarrons.

The last ten years of Lake McCarrons growing season (June through September) lake water quality data include an average TP concentration of 18  $\mu$ g/L, which is well below the MPCA's 40  $\mu$ g/L TP criteria and below the lake's diatom-inferred historical TP concentrations of 24 to 26  $\mu$ g/L, which are indicative of presettlement conditions. In addition, the last ten years of mean summer lake water quality data include average Chlorophyll-*a* (Chl-*a*) and Secchi disc transparency measurements for Lake McCarrons that are significantly better than MPCA's respective criteria. As a result, it is important to establish Total Phosphorus (TP) targets that will protect the water quality of the Lake McCarrons.

The Capitol Region Watershed District (CRWD) is responsible for updating this Lake McCarrons Management Plan (Plan) for review by the public and the CRWD Board of Managers. An important component of Plan development process was stakeholder engagement to establish goals and expectations for Lake McCarrons. As part of the process, two stakeholder advisory groups were consulted to ensure all interests and inputs were included in the development of the Plan—the Agency Advisory Group (AAG) and the Citizens Advisory Committee (CAC).

Management goals set a vision for Lake McCarrons, and associated objectives provide a mechanism to measure progress towards meeting those goals. The five overarching management goals for Lake McCarrons and its watershed include:

- **Goal 1:** Maintain phosphorus and chloride concentrations below target levels in Lake McCarrons and reduce the water quality impact of other pollutants.
- **Goal 2:** Maintain a healthy, balanced aquatic ecosystem in Lake McCarrons.
- **Goal 3:** Promote sustained community stewardship of Lake McCarrons and its watershed.
- **Goal 4:** Reduce the risk of flooding to habitable structures and significant infrastructure surrounding Lake McCarrons and Villa Park.
- **Goal 5**: Support the recreational use of Lake McCarrons by achieving water quality and vegetation conditions consistent with the Lake's intended uses, including swimming, boating and fishing.

This Plan takes a protective management approach for maintaining exceptional water quality in Lake McCarrons. Specific management actions are anticipated for implementation over the next ten-year period (2021-2030), which will be combined with regular monitoring to evaluate progress at achieving the desired goals and objectives. This approach will also allow enough time for the Lake to respond to in-lake and watershed management actions and achieve ecological balance.

# 2 Introduction

### 2.1 Overview and Purpose

Lake McCarrons is a small urban lake located in the southeast corner of Roseville. Park and beach visitors, as well as lake area residents and neighbors enjoy the pleasant setting surrounding Lake McCarrons. Like many other urban lakes, Lake McCarrons had previously experienced water quality problems. As documented in the 2003 Lake McCarrons Management Plan [2003 Plan] (The Osgood Group and Barr Engineering Co., 2003), phosphorus and chlorophyll-a levels routinely exceeded MPCA's impaired waters criteria during the 1990s.

The Villa Park Ponds and Wetland System was constructed in the mid-1980s for the purpose of improving the water quality of stormwater entering the lake. This highly visible project was touted as a model for urban stormwater management, but it was quickly discovered that the system requires more maintenance than anticipated. It has been confirmed that the Villa Park system alone—even at their optimal performance—will not protect the beneficial uses of Lake McCarrons. Internal phosphorus sources must also be managed to reduce algae growth in the lake. An in-lake alum treatment was completed in 2004 to control internal phosphorus load, but will require continued monitoring to ensure that the TP target is being met.

Invasive species are also of concern. Eurasian watermilfoil was discovered in 2000 and zebra mussels were discovered in 2019. There are questions regarding what management actions will be needed to maintain a healthy, balanced aquatic ecosystem and recreational use in Lake McCarrons.

There are concerns about flooding of habitable structures in low-lying watershed areas. Increased precipitation trends due to climate change have the potential to exacerbate this problem in the future.

The Capitol Region Watershed District (CRWD) is responsible for the development of this plan in recognition of the issues and concerns noted above. The District also has the motivation and resources to carry out meaningful planning and management actions in cooperation with other agencies and interest groups. The District assembled an Agency Advisory Group (AAG) and requested their assistance with developing this updated Lake McCarrons Management Plan (Plan) for review by the public and the CRWD Board of Managers.

Numerous individuals and agency staff invested their time in this effort, and made this Plan a model of cooperation. The results of their efforts will mean Lake McCarrons can maintain exceptional water quality and enhanced aesthetics for the public and land owners that enjoy the lake. The primary purpose of the updated Plan is to develop management strategies that will be used as a framework for CRWD, local partners, and community stakeholders to protect Lake McCarrons over time. CRWD's approach to management of Lake McCarrons is described below.

# 2.2 Lake McCarrons Management Plan Framework

This Plan takes an adaptive management approach for maintaining exceptional water quality in Lake McCarrons. Specific management actions are anticipated for implementation over the next ten year period (2021-2030), which will be combined with regular monitoring to evaluate progress toward achieving the desired goals and objectives. This approach will also allow enough time for the lake to respond to in-lake and watershed management actions and achieve ecological balance.

The first step in the planning process was to complete the technical evaluations of Lake McCarrons' longterm chemical, biological and physical data to determine the primary factors affecting water quality under current conditions. A P8 watershed model (Walker and Walker, 2017) was developed and calibrated to include the most recent subwatershed delineations, changes in land use conditions, and the numerous structural Best Management Practices (BMPs) that have been constructed. P8 is a model used to simulate pollutant loading from urban watersheds that also estimates pollutant removal from stormwater treatment structures (e.g. stormwater ponds). Other technical studies were analyzed and an in-lake water quality model was developed and calibrated to document the latest scientific understanding of water quality issues in Lake McCarrons and its watershed (Section 3).

The second step in this Plan process was to set goals for Lake McCarrons. In addition to having a technical understanding of the Lake's issues and water quality concerns, a successful lake management plan requires an understanding of the regulatory requirements and the priorities of the community. To learn about the community's concerns, CRWD held discussions with stakeholders to identify additional issues facing Lake McCarrons from their perspective. This input was taken into consideration along with the regulatory requirements to develop management goals and objectives for the Plan (Section 4). Management actions are actual projects, programs, events, or organized efforts that will work toward achieving the goals and objectives of this Plan. The third step in the process sought to define these actions and describe how they would effectively achieve the goals and objectives for the lake.

Once actions have been evaluated and defined, the next step in the process is implementation of those actions (Section 5). This Plan lays out two major categories of management actions—projects and capital improvements. The details of how each action will be implemented will be further detailed in specific plans or feasibility study reports that contain more prescriptive detail about what what needs to occur. The management actions will primarily be carried out over the next ten years (2021-2030) to ensure goals and objectives are met.

# 3 Lake and Watershed Characterization

Available background information and data was consulted to understand the lake and watershed conditions of the Lake McCarrons watershed. This section examines current available lake water quality and watershed data and the role this data plays in model calibration, setting TP targets, and other implications for lake and watershed management.

The most relevant background information comes from the 2003 Lake McCarrons Management Plan [2003 Plan] (The Osgood Group and Barr Engineering Co., 2003). This study also drew from recent data sources including all available water quality monitoring data, fish and plant surveys, along with updated and calibrated watershed and in-lake water quality modeling.

### 3.1 Lake Water Quality Primer

The physical, chemical, and biological characteristics of lakes are extremely variable. Lakes vary physically in terms of light levels, temperature, and water currents. Lakes vary chemically in terms of nutrients, major ions, and contaminants; and vary biologically in terms of biomass structure and function. For the majority of Minnesota lakes, phosphorus is the limiting nutrient for algae growth, and an increase in phosphorus results in an increase in chlorophyll-*a* (Chl-*a*) concentrations and a decrease in water clarity which inhibits lake use. Eutrophic (or nutrient-rich) lakes can be restored by reducing phosphorus concentrations. This section is intended to provide a general background on the dynamics of nutrient availability and assimilation by introducing the basic concepts necessary to understand how lake systems function.

#### 3.1.1 Density Stratification

In lakes of the upper Midwest, the water near a lake's bottom will usually be at 39°F just prior to ice-melt in the spring (Water on the Web, 2004). As the surface water warms to 39°F, the density of the water increases causing the surface water to sink and mix with the waters below. Spring turnover occurs when the temperature (and density) of the surface water equals that of the bottom water and continues until the water temperature of the entire lake reaches approximately 39°F. The surface waters continue to absorb heat, causing the water temperatures to rise above 39°F, resulting in the density of the water to decrease and become less dense than the cooler water below. For a while, winds may still mix shallower lakes from bottom to top, but eventually the upper water of deeper lakes become too warm and too buoyant to completely mix with denser deeper water. The relatively large differences in density at higher temperatures are very effective at preventing mixing.

As summer progresses, the temperature (and density) differences between upper and lower water layers become more distinct (Water on the Web, 2004). Deep lakes generally become physically stratified by temperature into three identifiable layers, known as the epilimnion, metalimnion, and hypolimnion. The epilimnion is the upper, warm layer, and is typically well mixed within itself. Below the epilimnion is the metalimnion or thermocline region, a layer of water in which the temperature declines rapidly with depth. The hypolimnion is the bottom layer of colder water, isolated from the epilimnion by the metalimnion. The density change at the metalimnion acts as a physical barrier that prevents mixing of the upper and lower layers for several months during the summer. The depth of mixing depends in part on the exposure

of the lake to wind (its fetch), but is most closely related to the lake's size. Smaller to moderately-sized lakes (50 to 1,000 acres) typically stratify and become well-mixed to a depth of 10–23 feet in northern temperate climates.

As the weather cools during autumn, the epilimnion cools too, reducing the density difference between it and the hypolimnion (Water on the Web, 2004). As time passes, winds mix the lake to greater depths, and the thermocline gradually deepens. When surface and bottom waters approach the same temperature and density, autumn winds can mix the entire lake; the lake "turns over" again in fall. As the atmosphere cools, the surface water continues to cool until it freezes. A less distinct density stratification than that seen in summer develops under the ice during winter. This pattern (spring turnover — summer stratification — fall turnover — winter stratification) is typical for temperate lakes. Deeper lakes with this pattern of two mixing periods are referred to as dimictic, while shallower lakes with several mixing periods are referred to as polymictic. Dimictic lakes, like Lake McCarrons, as well as polymictic lakes, are common in Minnesota.

#### 3.1.2 Dissolved Oxygen

Biological activity peaks during the spring and summer when photosynthetic activity is increased by high solar radiation (Water on the Web, 2004). Furthermore, during the summer most lakes in temperate climates are stratified. The combination of thermal stratification and biological activity causes characteristic patterns in water chemistry. During summer stratification, the conditions in each layer diverge. The dissolved oxygen (DO) concentration in the epilimnion remains high throughout the summer because of photosynthesis and diffusion from the atmosphere. However, oxygen conditions in the hypolimnion vary with trophic status. In eutrophic (more productive) lakes, hypolimnetic DO declines during the summer because it is cut-off from all sources of oxygen, while organisms continue to respire and consume oxygen. The bottom layer of the lake and even the entire hypolimnion may eventually become anoxic, or totally devoid of oxygen.

As microorganisms continue to decompose material in the hypolimnion and bottom sediments, they consume oxygen, and DO in the water is depleted (Water on the Web, 2004). With ice cover, no oxygen can diffuse into the lake water, and, if snow covers the ice, it becomes too dark for photosynthesis to produce oxygen. This condition can cause high fish mortality during the winter, known as "winter kill." Low DO in the water overlying the sediments can exacerbate water quality deterioration; because when the DO level drops below 1 mg  $O_2/L$ , chemical processes at the sediment-water interface can cause a release of phosphorus from the sediments into the water. When a lake mixes in the spring, this new phosphorus and ammonium that has built up in the bottom water fuels increased algal growth.

#### 3.1.3 Nutrients

Aquatic organisms influence (and are influenced by) the chemistry of the surrounding environment. For example, phytoplankton extract nutrients from the water and zooplankton feed on phytoplankton. Nutrients are redistributed from the upper waters to the lake bottom as the dead plankton gradually settles to lower depths and decompose (Water on the Web, 2004).

Essential nutrients such as the bioavailable forms of phosphorus and nitrogen typically increase in the spring from snowmelt runoff and from the mixing of accumulated nutrients from the bottom during spring turnover and decrease during summer stratification as nutrients are taken up by algae. Nutrients are eventually transported to the bottom water when algae die and settle out (Water on the Web, 2004). Any "new" input of nutrients into the surface water may trigger a "bloom" of algae. Such inputs may be from upstream tributaries after rainstorms, from die-offs of aquatic plants, or from pulses of urban stormwater. In the absence of rain or snowmelt, an injection of nutrients may occur simply from high winds that mix a portion of the nutrient-enriched upper waters of the hypolimnion into the epilimnion.

A typical lake has distinct zones of biological communities linked to the physical structure of the lake. The littoral zone is the area near shore where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. Plants in the littoral zone also provide habitat for fish and other organisms.

Although an in-depth microscopic enumeration of the dozens of species of algae present in a water column is preferred, measuring the concentration of chlorophyll-*a* in lake water is easier and provides an estimate of algal biomass that is used by MPCA in evaluating the trophic state of all lakes. Chlorophyll-*a* is the green pigment that is responsible for a plant's ability to use sunlight energy to fix carbon dioxide into carbohydrates. Both chlorophyll-*a* and Secchi depth (a measure of water transparency) are long-accepted methods for estimating the amount of algae in lakes and the associated effect on water transparency. Like all other plants, algae require phosphorus to grow and reproduce. Phosphorus enters the water in two ways:

- **Externally**—from surface runoff entering the water or from groundwater. Humans can have profound influences on lake chemistry. Excessive landscape disturbance causes higher rates of leaching and erosion by removing vegetative cover, exposing soil, and increasing water runoff velocity, which in turn, may exacerbate downstream erosion from ravine and bluff sources. Lawn fertilizers, pet waste, leaf litter, grass clippings, wastewater and urban stormwater inputs all add nutrients such as nitrogen and phosphorus to watershed runoff. Dry deposition (typically associated with wind erosion), and atmospheric deposition from direct precipitation on the lake surface both contribute additional nutrients.
- **Internally**—from the sediments on the bottom of the lake. Phosphorus already in the lake naturally settles to the bottom and is periodically re-released from the sediments back into the water under certain conditions.

Even when external sources of phosphorus have been reduced or eliminated through best management practices, the internal recycling of phosphorus can still support explosive algal growth. Internal phosphorus loading is a large problem in lakes with developed watersheds because of historic inputs of phosphorus from urban storm water runoff. Phosphorus in runoff has concentrated in the sediments of urban lakes as successive years of algal blooms have died and settled to the lake bottoms. This phosphorus is recycled from the lake sediments into the overlying waters, primarily during summer

periods, when it contributes to the growth of nuisance algal blooms. Figure 3-1 is a simple graphic explaining the relationship between phosphorus, algae, and Dissolved Oxygen (Water on the Web, 2004).



Figure 3-1 Relationship between Phosphorus, Algae, and Dissolved Oxygen

### 3.1.4 The Food Chain

The biological communities within lakes may be organized conceptually into food chains and food webs to help us understand how the ecosystem functions. A broad base of primary producers (algae) supports overlying levels of herbivores (zooplankton), planktivores and much smaller numbers of carnivores (predators). These individual trophic levels may be idealized as a food chain, but in fact many organisms shift levels throughout their life cycle. For example, a larval fish may initially eat fine particulate material that includes algae before switching to graze on larger zooplankton and ultimately feeding on "forage fish" or young game fish when it reaches maturity. Figure 3-2 illustrates the lake zones and relationship between the various trophic levels in the food chain of most waterbodies (Water on the Web, 2004).



#### Figure 3-2 Graphic Illustrating Lake Trophic Level Relationships

#### 3.1.5 Trophic Status

Since the early part of the 20th century, lakes have been classified according to their trophic state. "Trophic" means nutrition or growth. A eutrophic ("well-nourished") lake has high nutrients and high plant growth. An oligotrophic lake has low nutrient concentrations and low plant growth. A mesotrophic lake falls somewhere between eutrophic and oligotrophic lakes. While lakes may be sorted into a few trophic classes, each lake has a unique constellation of attributes that contribute to its trophic status. The three main factors that regulate the trophic state of a lake include the rate of nutrient supply, climate, and the morphometry (or shape) of the lake basin.

This study is intended to identify nutrient sources, magnitudes, and resulting in-lake water quality for Lake McCarrons, comparing them to previously established standards, goals or reference conditions. Where these goals and reference conditions are not met, this Plan establishes target water-quality-improvement management actions that will protect and improve water quality conditions in the lake.

# 3.2 Lake McCarrons Characterization

#### 3.2.1 Historical and Current Morphometry

Figure 3-3 shows the lake bathymetry (depth) data collected by Ramsey County Soil & Water Conservation Division staff as a part of a vegetation survey on May 20, 2019. The Lake McCarrons water surface elevation on May 20, 2019 was 841.03 feet MSL. The bathymetric data from the recent survey is very similar to depths documented by previous reports, including the data resulting from MnDNR bathymetry. Lake McCarrons has a surface area of 74.5 acres and a maximum depth of 54 feet—small and deep by Metro area norms. The computed lake volume is 1,846 acre-feet, which corresponds with an average depth of 25 feet.

The lake typically has a distinct thermocline at 14 to 16 feet, which separates an upper, mixing layer of water from a cold, stagnant layer during the summer months. In fact, the lake is so strongly stratified that it does not always turn over in the fall (The Osgood Group and Barr Engineering Co., 2003). Based on measurements that are typically collected between May and October in most years, Lake McCarrons is generally mixing at depths between 25 and 30 feet in the spring and fall. Following the alum treatment, approximately 3 years of November monitoring data indicated lake mixing that exceeded a depth of 35 feet. There is no indication, from the available monitoring data, that the epilimnetic phosphorus concentration increases at the time of spring mixing.



#### 3.2.2 Water Quality in Lake McCarrons

This section provides an updated analysis of the water quality monitoring data compiled by CRWD to revisit the 2003 Plan water quality goals and objectives. This analysis includes evaluation of lake water quality monitoring data to determine whether the following 2003 Plan-specific objectives are met:

- Manage phosphorus so summer average lake concentration is 33 µg/L or less
- Keep winter dissolved oxygen concentrations above 3 mg/L in the top 4 feet of the lake during the winter

In addition, chloride concentrations in the lake were evaluated to determine if a chloride-specific objective should be included (since the MPCA standard for chloride was developed after the 2003 Plan was completed). The state standard for chloride is defined as not exceeding 230 mg/L chronic state standard for chloride in lakes more than once every three years.

#### 3.2.2.1 Phosphorus

The 2003 Plan set a Chl-*a* goal of 10  $\mu$ g/L based on an observation that, at higher concentrations, algae bloom frequencies and their resulting nuisance increased to a level commonly perceived to be 'impaired' for swimming (MPCA, 1997). Based on Lake McCarron's historical relationship between summer average total phosphorus (TP) and chlorophyll-*a* (Chl-*a*) when the 2003 Plan was written, it was determined that a TP goal of 33  $\mu$ g/L would likely ensure that the Chl-*a* goal of 10  $\mu$ g/L would be met on a consistent basis (see Figure 3-4). When recent monitoring data is included in the relationship between TP and Chl-*a*, the TP concentration associated with the 10  $\mu$ g/L threshold is even higher (40  $\mu$ g/L TP), which is the state standard for TP in deep lakes in the North Central Hardwood Forest ecoregion. However, diatom-inferred TP concentrations published by Heiskary and Swain (2002) indicate that Lake McCarrons' TP concentrations were likely in the range of 24 to 26  $\mu$ g/L prior to European settlement. This confirms that the 33  $\mu$ g/L TP goal is attainable in Lake McCarrons when internal and external TP loadings are controlled, and is still considered to be an appropriate goal for the lake.

Based on the historical relationship between summer average Secchi disc transparency and Chl-*a*, Figure 3-5 shows that the current Chl-*a* goal of 10  $\mu$ g/L should result in approximately 2.1 meters (7 feet) of Secchi disc transparency (noted by the red lines). This transparency is also higher than the deep lake standard in Lake McCarrons' ecoregion (1.4 meters).

Lake McCarron's water quality has improved significantly since the 2003 Plan due to an alum treatment in 2004. Since then, the average summer epilimnetic TP has varied between 12 and 25  $\mu$ g/L with no significant trends (Figure 3-6). Since 2004, the average summer Chl-*a* has routinely been below 5  $\mu$ g/L with no significant trends (Figure 3-7). Since the 2004 alum treatment, Figure 3-8 shows that Secchi disc transparency has varied between 2.5 and 5 meters, which represents an increase to a mesotrophic level or 'fully-supporting' conditions for swimming (MPCA, 1997).



Figure 3-4 Lake McCarrons Summer Average Chl-a Versus TP Relationship (1988-2018)



Figure 3-5 Lake McCarrons Summer Average Secchi Disc Transparency vs. Chl-a Relationship (1988-2018)



Figure 3-6 Lake McCarrons Historical Summer Average Total Phosphorus (1988-2018)



Figure 3-7 Lake McCarrons Historical Summer Average Chl-a (1988-2018)



Figure 3-8 Lake McCarrons Historical Summer Average Transparency (1988-2018)

#### 3.2.2.2 Dissolved Oxygen

A review of the winter lake water quality monitoring indicates that there were only five years over the last fourteen years (2005 through 2018) with dissolved oxygen (DO) data—none of the DO concentrations in the top four feet of Lake McCarrons dropped below 8.8 mg/L during that time. As a result, it does not appear that winterkill is a serious concern for the lake and this objective does not warrant inclusion in the 2020 Plan.

#### 3.2.2.3 Chloride

The 2003 Plan did not set goals/objectives for chloride levels, but Lake McCarrons has narrowly missed the impaired waters list for chloride, with three individual sample exceedances of the 230 mg/L standard spread over time frames greater than three years. If the increasing trend in average water column measurements, shown on Figure 3-9 continues, it is likely that the lake will become impaired within the next ten years. The chloride standard necessitates that the surface, bottom and mid-depth portions of the



lake do not exceed an average chloride concentration of 230 mg/L more than once every three years. As a result, the applicable chloride standards are included as a goal in this Plan.

Figure 3-9 Lake McCarrons Chloride Concentration Trendline (Average Water Column Measurements, 1988-2018)

#### 3.2.3 Lake Bottom Sediments

The MPCA and the Science Museum of MN previously analyzed sediment cores from Lake McCarrons to evaluate long-term changes or trends in certain water quality indicators (Heiskary and Swain, 2002). Their evaluation indicated that Lake McCarrons probably had much better water quality in pre-settlement times compared to the 1970s and 1990s. Specifically, their data indicate that the lake's phosphorus concentration has doubled sometime between the years 1800 and 1970. Their data also show higher and increasing level of chlorides. The phosphorus increase noted for Lake McCarrons is not unusual for Metro lakes, however, the chloride concentrations in Lake McCarrons are relatively high.

Barr (2003) analyzed Lake McCarrons' sediment to determine areal and depth distribution of mobile phosphorus and conducted laboratory dose tests with surficial sediment core subsamples to determine appropriate alum application dosages for the 2004 alum treatment.

Wenck (2016a) evaluated the internal sediment phosphorus loading in Lake McCarrons. The study quantified rates of phosphorus release from intact sediment cores under aerobic and anaerobic

conditions and examined spatial and vertical variations in the sediment's biologically-available phosphorus fractions.

CRWD (2019a) published an evaluation of the distribution of alum in Lake McCarrons, alum thickness, and the characteristics of overlying sediment deposition. The study indicates that there may be an unequal distribution of alum in Lake McCarrons. Potential reasons for the unequal distribution of alum and its decreasing efficacy were discussed, including:

- Wind direction, wind speed and/or lake currents could have affected the settling of alum particles
- Five days with precipitation in the seven days that followed the alum treatment that included a 0.88" rainfall event
- The lake's bathymetry can also play a role in the settling of suspended particles, where the lake bottom slope directs particles to low lying areas
- An average of 4.9 centimeters of sediment has buried the alum in the last thirteen years, which is approaching the six centimeter depth that was assumed to contribute mobile phosphorus in the lead up to the alum treatment.

### 3.2.4 Aquatic Vegetation and Invasive Species

The 2003 Plan noted that Eurasian watermilfoil had recently infested the lake and stated that 'we do not yet know to what extent it will be problematic in Lake McCarrons.' In addition, there was an incomplete baseline to evaluate prior conditions. Curly-leaf Pondweed (CLP) was also present as early as 1996 in aquatic plant surveys, and has been consistently observed in the lake in all annual surveys completed since 2013. CLP is of concern because its mid-summer dieback releases phosphorus into the water column at a time when algae are able to take it up.

A lake vegetation management plan (LVMP) is a document the Minnesota Department of Natural Resources (MnDNR) develops with public input to address aquatic plant issues on a lake. The LVMP is intended to balance riparian property owner's interest in the use of shoreland and access to the lake with preservation of aquatic plants, which is important to the lake's ecological health. MnDNR (2012) previously developed a LVMP for Lake McCarrons to prescribe the permitted aquatic plant management actions (mechanical and/or herbicides) for a five-year period, including controls for invasive plants and restoration of lake shore habitat.

On August 22, 2019 the MnDNR confirmed that zebra mussels were found in Lake McCarrons. Ramsey County staff conducted a targeted search and confirmed a lakewide zebra mussel presence.

The Lake McCarrons Aquatic Invasive Species (AIS) Plan (Wenck, 2018) was created to define the process and criteria by which AIS will be managed on Lake McCarrons. The LVMP will need to be updated for Lake McCarrons to define AIS threshold criteria that take seasonality and other factors into account. Section 4 discusses the management plan goals, objectives and recommended implementation plan actions that were developed for CRWD in the context of legacy (established), newly discovered and yet-to-bediscovered (or threatening) invasive species in the lake.

#### 3.2.5 Fisheries

The most recent fisheries survey was conducted in June 2019. The MnDNR assessments evaluate the fishes' numbers and weight compared to norms for similar lakes. According to MnDNR's report, Lake McCarrons has a variety of fish habitats. The status of the fishery (as of June 2019) is described as follows:

Northern Pike have been the primary management species in the lake. The lake has a history of experiencing partial winterkills that tend to reduce the number of small bluegills back to levels of abundance that the lake can support. Net catches were slightly better than what was seen in previous years, with gill net catches of Northern Pike above average and trap net catches of Bluegill also above average in abundance. Northern Pike averaged 22 inches and Bluegills ranged from 2.7 to 8.1 inches in length with an average length of 5.2 inches. The largest Black Crappie captured was 11.4 inches in length. Yellow Perch were captured in low abundance for lakes similar to McCarron. Largemouth Bass are present in the lake however none were captured in the gill or trap nets in 2019. Largemouth Bass were sampled by night electrofishing with thirty-six Largemouth Bass and two Smallmouth Bass being sampled by electrofishing (36.6 bass/hr on time), which was conducted around the entire shoreline of McCarrons Lake. The Largemouth Bass population size structure on McCarrons Lake is good with some quality size fish present. The Smallmouth Bass present in the lake are most likely the result of illegal transport and stocking by overzealous anglers. Anglers are reminded that the practice of non-permitted fish stocking is prohibited by state law.

The previous fisheries survey was conducted in August 2016, which followed MnDNR standard trap and gill net survey methods (Wenck, 2016b). There were 11 species collected from McCarrons Lake in 2016 with 212 individual fish collected. The most numerous fish collected in 2016 were black crappie (71), bluegill (63) and northern pike (55). The 2016 fish community appeared to be balanced with the presence of a large top predator community to provide "top-down" influence on the overall fish community, little to no evidence of a stunted panfish population, and limited benthic species (i.e. bullheads). The presence of large top predator species can be very important in fisheries management as trophic dynamics can contribute to water quality. There were more species collected in 2016 as compared to the 2014 survey. There was also a notable decrease in bluegill individuals and increase in northern pike in 2016 as compared to 2014, which supported the idea that the northern pike population is assisting in controlling the bluegill population within the lake.

# 3.3 Lake McCarrons and its Watershed

#### 3.3.1 Watershed Boundaries

Lake McCarrons' watershed refers to the area that collects and contributes stormwater runoff to the lake. As lands around a lake become urbanized, water runoff systems are altered in ways that increase the amount of runoff, the amount of pollution carried in the runoff, and the land area contributing runoff. In addition, the increase in hard surface usually results in preventing infiltration that would recharge groundwater.

The watershed boundary was determined using GIS mapping and takes into consideration the local topography and drainage networks surrounding Lake McCarrons. Seven major subwatersheds within the

Lake McCarrons watershed were also defined (Figure 3-10), including two small landlocked areas. A subwatershed is a localized drainage area within a greater watershed that drains to the lake. The Lake McCarrons subwatershed delineations were determined using GIS and are based on: (1) topography, (2) storm sewer discharge points (outfalls) to Lake McCarrons, (3) the subsurface storm sewer network extending upstream of the discharge point, and (4) storm sewer discharge monitoring locations (shown on Figure 3-10). The storm sewer networks in the McCarrons watershed are complex and incorporate several types of Best Management Practices (BMPs), as shown on Figure 3-11.

#### 3.3.2 Watershed Pollutant Sources and Pathways

Stormwater runoff carries excess pollutants like nutrients and sediment from the watershed to the lake, making the watershed a pollutant "source". The characteristics of the watershed have significant influence on the amount of runoff and what pollutants are being delivered to the lake. Figure 3-12 illustrates watershed processes and pollutant pathways typical to the Lake McCarrons watershed, including:

- A. **Pollutant Sources**: Includes trash, leaves, grass clippings, soil, animal waste, fertilizers, automobile fluids, road salt, and other chemicals—anything present on the landscape that can be flushed into a storm drain by rain or snowmelt.
- B. **Runoff**: Occurs when rain or snowmelt flows off the landscape, picking up pollutants and other material on its path. In urban environments, impervious surfaces like roofs, driveways, parking lots, sidewalks, and roads prevent water from soaking into the ground as it naturally would, causing stormwater runoff to generate and flow into storm drains.
- C. Stormwater Flows to Lake: Sewers function as underground streams to collect and convey stormwater— they prevent localized flooding by moving runoff from the landscape downstream. Storm sewers flow into Lake McCarrons, and as a result transfer runoff carrying pollutants from the landscape directly to the lake.







#### Figure 3-12 Watershed Pollutant Sources and Pathways

Phosphorus is the primary pollutant of concern from the Lake McCarrons watershed. Phosphorus enters lakes from several sources: rainfall and wind, internal recycling, surface runoff, and groundwater seepage. The measurement of phosphorus in runoff has been the subject of several intensive studies and currently accounts for the majority of all phosphorus entering Lake McCarrons.

Water quality studies have measured phosphorus in runoff, but have not specifically identified the exact source of phosphorus. Typically, phosphorus occurs naturally as part of living matter. As this material cycles and decomposes, phosphorus is released in mineral form or as attached to particles.

#### 3.3.3 Watershed Characteristics

Understanding Lake McCarrons watershed characteristics is important for managing runoff to the lake. Each subwatershed has different water and pollutant contributions depending on their land use/ imperviousness, soil types, and past management actions.

#### 3.3.3.1 Hydrologic Factors

Currently, the primary land use in the Lake McCarrons watershed is residential. For the creation of this Plan, subwatersheds were hand-digitized to each modeled BMP and hydrologic inputs were generated using best-available soil and impervious data sources. Figure 3-13 shows watershed imperviousness based on a 2015 Ramsey County land use study. Figure 3-14 provides soils mapping based on 2019 SSURGO soil data. Where underlying soil data was not available, HSG Type B soils were assumed. The majority of identified soils demonstrate a moderate potential for infiltration.





#### 3.3.3.2 Historical Management Actions

While several monitoring, modeling and planning activities have been completed for Lake McCarrons and its watershed, this section is intended to summarize past lake and watershed management actions that have been implemented to directly improve lake water quality.

#### Historical In-Lake Management Actions

As discussed in Section 3.2.2.1, an in-lake alum treatment was completed on Lake McCarrons in 2004. The alum treatment resulted in the application of 492.3 tons of alum to the lake from October 21<sup>st</sup> through the 24<sup>th</sup>, 2004. This resulted in significant improvement in lake water quality in subsequent years as described in Section 3.2.2.1.

No other in-lake management actions have been completed to improve water quality in Lake McCarrons, but it is expected that future in-lake alum treatments will be warranted when the TP concentration target is no longer met, as described in Section 3.5.1.

#### Historical Watershed Management Actions

The Villa Park Wetland Treatment System is a series of ponds and wetlands constructed in the mid-1980s to treat runoff before it enters Lake McCarrons. Prior to construction of this system, runoff was routed directly through this area in a channel and no ponding or wetland contact occurred. The constructed ponds and wetlands of the Villa Park Wetland Treatment System are separated by weirs (small dams) that finally empty into a terminal wetland with an outlet that keeps water levels in the terminal wetland high to facilitate water detention within the wetland. The first pond in the series was dredged to an area of about 2.4 acres in 2013 and has three inlets. This pond empties into a series of five wetland cells, followed by the terminal wetland (see Figure 3-15). The terminal wetland also receives input from the 'ice rink pond'.

Several modifications to the Villa Park Wetland Treatment System and a 100-acre addition to the tributary area have occurred since its original construction. In addition, much of the baseflow runoff has become 'channelized'—some of the flow through the ponds may be short-circuiting and flowing directly to the outlet. These factors may have accounted for decreased phosphorus removal efficiencies measured in recent years. The Villa Park Wetland Treatment System was originally considered experimental because it involves the use of detention pond(s) and a constructed wetland in combination to treat stormwater. For this reason, intensive monitoring was conducted before and after the construction (and dredging) of the ponds. The 2003 Plan documented several problems with the treatment efficiency of the Villa Park Wetland Treatment System.

Since the adoption of the 2003 Plan, many structural BMP projects for reducing phosphorus loads from stormwater runoff have been constructed in the Lake McCarrons watershed by CRWD and other partners. Structural BMPs are engineered systems that are designed to capture and treat stormwater runoff on the landscape such as a rain garden, an underground infiltration system, or a stormwater pond. In the Lake McCarrons watershed, structural BMP projects that have been constructed through 2019 that cumulatively receive, and provide partial treatment of, nearly all watershed runoff before it enters the lake. Table 3-1

provides a summary of the 71 documented BMPs, by project type, that have been constructed in the Lake McCarrons watershed through 2019.



Figure 3-15 Villa Park Wetland Treatment System Features

#### Table 3-1 Structural BMPs Constructed in Lake McCarrons Watershed Through 2019

ВМР Туре	# BMP Projects (through Year 2019)
Permeable Pavement	1
Native Buffer Plantings	12
Underground Filtration	2
Rain Garden	20
Bioretention Basin	5
Underground Infiltration	3
Iron Enhanced Sand Filter	2
Reuse System	1
Stormwater Pond	25

There have been several notable, large-scale (regional) structural BMP projects constructed in the Lake McCarrons watershed since 2003 by CRWD and partners. Table 3-2 lists all regional BMP projects in the Lake McCarrons watershed.

In addition to structural BMPs, significant efforts have occurred over time to reduce Lake McCarrons watershed TP loads through non-structural projects or practices. Non-structural practices focus on source management, such as proper disposal of pet waste, leaf clean-up efforts, storm drain debris clearing, street sweeping, or education on best practices. Phosphorus reductions through non-structural practices have been achieved through participation and promotion from partners, including efforts from citizens.

#### 3.3.4 Stormwater Runoff Monitoring and Quality

To measure the volume and quality of stormwater entering Lake McCarrons from the surrounding watershed, CRWD has monitored several BMPs and subwatershed outlets. Area-velocity sensors and automated water quality sampler stations are installed near the inlet or outfall locations at each site. The stations continuously measure discharge and take flow-paced samples during storm events. Samples are analyzed for a suite of water quality parameters, including nutrients, metals, solids, and bacteria. From this data, total annual discharge volumes and pollutant loads can be calculated to better understand watershed phosphorus contributions to Lake McCarrons.

CRWD compiled historical monitoring data at seven locations within the Lake McCarrons watershed (Figure 3-10). Level, flow, total suspended solids (TSS) concentrations, total phosphorus (TP) concentrations, and runoff volumes were used to calibrate the existing conditions P8 model (see Section 3.3.5). Table 3-3 summarizes the monitoring data available at each monitoring location.

#### Table 3-2 Regional Structural BMPs Constructed in Lake McCarrons Watershed Since 2003

Project Name	Subwatershed Location	Year	Project Description	Agency(s)
Parkview Centerl School Detention and Filtration	P1002A	Future	Construction of an underground storage and stormwater filtration system east of Parkview Center School.	CRWD, Ramsey County, Roseville, Roseville Area Schools
Upper Villa Infiltration and Reuse	P1007UVI	2016	Capstone Project involving the installation of a large underground infiltration and reuse system for irrigation application at the Villa Park baseball field.	CRWD, Roseville
Villa Park Wetland System Dredging	WP1001, WP12- 003CP, WP13-011a, WP13-011b, WP13- 012, WP13-023, WP13-024	2014	Capstone Project involving Villa Park Wetland restoration and dredging for the goal of providing additional storage in each basin for improved phosphorus removal.	CRWD
William Street Pond Improvement Project	WP10-001CP	2011	Capstone Project involving the installation of a SAFL Baffle at the pond inlet, dredging of sediment from the pond, and an outlet retrofit to include two iron-enhanced sand filters.	CRWD, Roseville
TH36 and Rice Interchange	WP10-002, WP1000, WP1003, WP1007	2010	Reconstruction of the Hwy 36 and Rice Street interchange. Involved the creation of Albemarle Pond, Marion Pond, William Pond, and Rice Pond.	Ramsey County
Roselawn Infiltration Trench	INF15-008	2015	Construction of an underground infiltration trench with the reconstruction of Victoria Street.	Roseville
Stewardship Grant Residential Rain Gardens	Various	2010-2018	20 residential rain gardens installed through CRWD's Stewardship Grant program	CRWD, private residents
Lower Villa Park Rain Garden	WP1001	2014	Construction of a stormwater pond to treat stormwater from Lower Villa Park Reconstruction.	Roseville
Mueller Bies Surface Filtration Basin	DP14-015	2014	Construction of a stormwater pond to treat stormwater from the Mueller Bies Funeral Home Parking Lot Expansion.	Private
Farrington Wetland	WP15-030	2015	Construction of a stormwater wetland basin south of TH 36 for the purpose of stormwater treatment from the Farrington Estates development.	Roseville
Victoria Street Rain Garden	DP1006	2003	Construction of a stormwater pond with the reconstruction of the west frontage road of Victoria Street.	Roseville

#### Table 3-3 Available Monitoring Data at Lake McCarrons Watershed Monitoring Locations

Monitoring Location	TSS (mg/L)	TP (mg/L)	Volume (ac-ft)	Level (feet)	Discharge (cfs)
Upper Villa Inlet	Х	Х	Х	Х	Х
Villa Park Inlet	Х	Х	Х		Х
Villa Park Outlet	Х	Х	Х		Х
William Street Pond Inlet	Х	Х			
William Street Pond Outlet	Х	Х			
Lake McCarrons Outlet			Х		Х
Alameda Pond				Х	

#### 3.3.5 Watershed Modeling and Pollutant Loads

#### 3.3.5.1 P8 Modeling

Water quality modeling of stormwater runoff in the Lake McCarrons watershed was conducted using the P8 Urban Catchment Model (Program for Predicting Polluting Particle Passage thru Pits, Puddles, and Ponds). P8 is a model used for predicting the generation and transport of stormwater runoff and pollutants in urban watersheds. The model tracks the movement of particulate matter (fine sand, dust, soil particles, etc.) as it is carried by stormwater runoff traveling over land and impervious surfaces. Particle deposition within ponds is tracked to estimate the amount of pollutants (carried by the particles) that eventually reach a water body versus those that are trapped within BMPs

Barr created a water quality model of the entire Lake McCarrons watershed, to evaluate the water quality performance of existing and proposed ponds and wetlands within the watershed (see Figure 3-11). Appendix A provides details regarding development of hydrologic, hydraulic, and water quality inputs for the P8 modeling.

For some of the lake subwatersheds, existing best management practices (BMPs) and natural waterbodies provide phosphorus removal prior to runoff reaching the lake. To estimate the removal, P8 simulates phosphorus inflow loads to each BMP and compares them to the total phosphorus load generated from each subwatershed in the model. Watershed sources of erosion and pond/lake sediment phosphorus release were excluded from this determination because the P8 model does not explicitly simulate phosphorus contributions from these sources. Separate estimates of sediment phosphorus release were determined from the monitoring data and compared with the P8 model loadings tributary to Villa Park wetland (as detailed in Appendix A).

Barr calibrated the existing conditions P8 model to the Upper Villa Inlet and Villa Park Outlet because a complete record of TSS, TP, and discharge volume is available between 2016 and 2018 at these locations. The model was validated by comparing model results to the William Street Pond TSS and TP concentrations and Villa Park Inlet TSS and TP loads. Appendix A details the review of collected monitoring data, calibration of modeled runoff, TSS, and TP load to collected monitoring data, and review and assessment of calibrated model results.

From the P8 model calibration, updated TP load estimates were determined from the Lake McCarrons watershed for the October 2008 through October 2018 modeling period. Table 3-4 provides a summary of the Lake McCarrons model outputs for outflow TP loads for each subwatershed. The table includes subwatershed name (shown on Figure 3-10), subwatershed area and TP load (following completion of Parkview development). Table 3-4 also lists TP load reductions for each subwatershed, expressed as the percent TP load reduction to the lake.

Figure 3-10 and Figure 3-11 show that, besides the direct drainage areas surrounding Lake McCarrons, there are two main tributary areas that drain to the lake—the Villa Park Wetland and Williams Street Pond. The tributary drainage area to the Villa Park wetland outfall is 732 acres, while the drainage area tributary to the Williams Street Pond outfall is 154 acres. The combined drainage area of both outfalls represents
94 percent of the Lake McCarrons contributing watershed area. The 10-year average annual TP load estimated from the P8 modeling for the Villa Park wetland outfall and the Williams Street Pond is 202 and 20 pounds, respectively. The combined TP load from both drainage areas is 222 pounds per year, which translates to a 10-year average annual TP loading rate of 0.25 pounds per acre per year, based on the future conditions modeling for the October 2008 through October 2018 modeling period. This TP loading rate represents nearly a 60 percent TP load reduction, as a result of treatment practices, compared to untreated stormwater runoff within the Lake McCarrons watershed.

#### 3.3.5.2 BMP Evaluation

The available monitoring data, including previously published technical evaluations, were combined with the calibrated P8 modeling for the Lake McCarrons watershed to complete current BMP evaluations (see Appendix A). A summary of the BMP evaluation results follows:

- **Alameda Pond**—despite data indicating that the bottom of the pond has elevated phosphorus concentrations in the summer, 53% of the incoming TP load is removed each year, based on mass-balance monitoring (Taguchi et al., 2019).
- **William Street Pond**—despite data indicating that the bottom of the pond has elevated phosphorus concentrations in the summer, 56% of the incoming TP load is removed each year, based on mass-balance monitoring (Taguchi et al., 2019).
- **Upper Villa Stormwater Reuse Facility**—combination of monitoring and modeling data indicate that approximately 47% of the incoming TP load is removed each year.
- Villa Park Treatment System—inflow and outflow mass balance monitoring data collected before and after the 2013 dredging of the Villa Park wetland indicate that there does not appear to be a significant increase in the treatment efficiency for TP after the dredging (CRWD, 2019b; Janke and Finlay, 2015). In addition, the average effluent concentrations of ortho- and dissolved phosphorus exceed the respective influent concentrations for almost every month between April and October, indicating that sediment phosphorus release is a problem. Overall, the average effluent TP concentration leaving Villa Park Outlet (0.17 mg/L) is approximately the same as the flow-weighted influent TP concentration (0.17 mg/L).

Major Subwatershed	Subwatershed Area (Acres)	% of Total McCarrons Watershed Area	Average Annual TP Watershed Load (lbs)	Average Annual TP Load to Lake (lbs)	TP Reduction to Lake (%)
Direct to Lake McCarrons	53.9	6%	114.2	112.9	1.1%
William Street Pond	153.8	16%	123.3	19.9	84%
Villa Park Wetland System	732.3	78%	556.2	201.9	64%
Total Contributing	940		794	335	58%
Non-Contributing	44.9	5%	60.9	0.0	100%

Table 3-4	Model Subwatershed TP Loads to Lake McCarrons

# 3.4 In-Lake Water Quality Modeling

#### 3.4.1 Model Calibration

An in-lake (as opposed to watershed) water quality model was developed for Lake McCarrons and calibrated for the 2017 growing season to evaluate the water budget and primary sources of phosphorus loading during the summer period. This is consistent with the time period relevant to lake water quality goals/standards, which apply to the period of June through September. The P8 model output was incorporated into the lake modeling spreadsheet to account for the watershed runoff components of the water and phosphorus loadings to Lake McCarrons.

Figure 3-16 shows good agreement between modeled and measured lake levels for Lake McCarrons after adjustments were made to account for a net inflow of groundwater baseflow to the lake with slightly higher magnitudes following snowmelt runoff.



Figure 3-16 Agreement between Modeled and Measured Lake Levels in Lake McCarrons

After the water balance components of the spreadsheet model were calibrated to the observations, the whole-lake and surface water components of the phosphorus mass balance were developed. Adjustments were made to net phosphorus settling in the lake and internal loading phosphorus release rates until the modeled whole-lake and epilimnetic TP values represented an optimum agreement (based on the Nash-Sutcliffe statistic) with the respective whole-lake and epilimnetic TP measurements during the course of the 2017 simulation. The summer average epilimnetic TP concentration for 2017 was 19 µg/L. Figure 3-17 shows the relationship between modeled and measured TP in Lake McCarrons epilimnion.



Figure 3-17 Relationship between Modeled and Measured TP in Lake McCarrons

#### 3.4.2 Model Results

The results from the P8 model were used to estimate TP loading from watershed sources, such as municipal stormwater sources and other sources of runoff. Figure 3-18 presents a breakdown of phosphorus loads for Lake McCarrons for the 2017 summer (June through September) season. The loads are measured in pounds and as a percentage. The largest source of TP load is from watershed runoff, while the second largest source is internal phosphorus load. While the lake water quality goals are already met, the modeling enables an evaluation of the sensitivity to changes in the TP load, which indicates that a 5 percent reduction from the watershed would result in 1  $\mu$ g/L reduction in the average epilimnetic TP concentration in Lake McCarrons for 2017. This shows the relative importance of improving the treatment efficiency of the Villa Park wetland treatment system, which currently does not provide a net reduction in the TP load to Lake McCarrons (see Section 3.3.5.2).



Figure 3-18 Summer (June through September) 2017 Lake McCarrons Water Quality Modeling Phosphorus Sources and Loads (pounds, %)

### 3.5 Lake McCarrons Water Quality Standards and Regulations

Lake McCarrons is located in the North Central Hardwood Forest Ecoregion and subject to deep lake eutrophication standards, which require TP concentrations be less than 40 µg/L, chlorophyll-*a* concentrations be less than 14 µg/L, and Secchi depth be greater than 1.4 meters (4.6 feet). Impairment occurs when annual average TP and at least one of the following two variables – chlorophyll-*a* or Secchi depth -- do not meet state standards (MPCA, 2018). The last ten years of mean summer (June through September) lake water quality data, shown in Table 3-5, include an average TP concentration of 18 µg/L for Lake McCarrons, which is well below MPCA's TP criteria and the diatom-inferred TP concentrations published by Heiskary and Swain (2002). Table 3-5 also shows that the last ten years of mean summer lake water quality data include average Chl-*a* and Secchi transparency measurements for Lake McCarrons that are significantly better than MPCA's respective criteria. As a result, it will be important to protect the excellent water quality of the Lake McCarrons by establishing TP targets that will, at a minimum, maintain the existing watershed and in-lake conditions.

# Table 3-5Comparison of State Water Quality Standards to Lake McCarrons' Ten-Year<br/>Average Water Quality Observations

Water Quality Variable	Growing Season (June–September) Mean Water Quality Standards and Lake McCarrons Observations						
	TP (µg/L)	Chl- <i>a</i> (µg/L)	Secchi (meters)				
North Central Hardwood Forest (Minnesota Lake Standards for Phosphorus, Chl- <i>a</i> , and Transparency)	<40	<14	>1.4				
Diatom-inferred TP concentrations (Heiskary and Swain, 2002)	24-26						
Lake McCarrons' Ten-Year Average (2009-2018)	18	4	3.3				

As discussed in Section 3.2.2.1, managing TP so that the summer average lake concentration is 33  $\mu$ g/L or less should continue as the primary goal for Lake McCarrons' water quality, but the following secondary objectives are also recommended as they can be combined to support the primary TP goal:

- Epilimnetic TP is highly correlated to hypolimnetic TP in Lake McCarrons. Independent analyses confirmed that the summer average epilimnetic TP concentration could return to what it was before the alum treatment if the average summer hypolimnetic TP concentration exceeds 300 µg/L. As such, if the average summer hypolimnetic TP concentration consistently exceeds the 300 µg/L threshold, then another alum treatment is likely warranted for Lake McCarrons.
- Subwatershed TP loading targets (discussed below) should be developed to determine when enough BMP treatment has been implemented throughout the watershed.

#### 3.5.1 Internal TP Concentration Reduction Target

The average hypolimnetic TP concentration prior to the 2004 alum treatment was 441  $\mu$ g/L with an average surface water TP concentration of 39  $\mu$ g/L. Regression of the average summer epilimnetic (surface water) and hypolimnetic TP concentrations (shown on Figure 3-19) indicates that epilimnetic TP concentrations could begin to return to pre-alum treatment levels when the hypolimnetic TP concentration returns to approximately 300  $\mu$ g/L. At this hypolimnetic concentration, Figure 3-19 shows the average summer epilimnetic TP concentration is expected to correspond with the 33  $\mu$ g/L goal.



Figure 3-19 Lake McCarrons Summer (June through September) Epilimnetic vs Hypolimnetic TP Relationship (1988-2018)

Linear regression of the average summer hypolimnetic TP concentrations since the 2004 alum treatment (shown in red and extrapolated in Figure 3-20), indicates that it will likely be 2032 before the TP concentration returns to  $300 \mu g/L$ , which is when it is expected that internal phosphorus loading could be similar to what it was before the alum treatment. This would represent 27 years of alum treatment effectiveness. It should be noted that, while linear regression provided the best fit to the existing average summer hypolimnetic TP concentrations since the 2004 alum treatment, it is unclear whether this linear response (while not unexpected) would likely continue into the foreseeable future, as shown on Figure 3-20. Factors that could influence this relationship include significant changes to watershed TP loading, lake residence time, lake stratification and hypolimnetic oxygen demand.

It is recommended that, if the five-year average summer hypolimnetic TP concentration (based on at least ten samples) exceeds the 300  $\mu$ g/L threshold and the average summer epilimnetic TP concentration exceeds the 33  $\mu$ g/L goal for a single year, then another alum treatment is warranted for Lake McCarrons.



Figure 3-20 Lake McCarrons Historical Summer Average Hypolimnetic TP (1988-2018)

#### 3.5.2 External TP Load Target

As previously discussed, water quality in Lake McCarrons is currently better than the water quality implied in its 33 µg/L TP goal as well as the diatom-inferred TP concentrations published by Heiskary and Swain (2002). As a result, the external TP load target recommended in this Plan is intended to maintain or protect the current water quality of Lake McCarrons by maintaining a three-year moving average TP loading rate consistent with the existing subwatershed TP loading rate of 0.25 pounds per acre per year, derived from the 10-year annual average of the P8 modeling described in Section 3.3.5.

# 4 Issues, Goals and Recommended Actions

## 4.1 Identification of Issues of Concern

The 2003 Plan developed goals, objectives and recommended management actions based on input from stakeholder advisory groups that did not limit their attention to solely water quality concerns. The 2003 Plan considered any concern relative to the quality, condition, and aesthetic appeal of Lake McCarrons. Specifically, the 2003 Plan addressed the following topics: water quality improvement, nuisance aquatic plant control, fisheries, recreational use, winterkill, wetland system operation, and coordination among jurisdictions.

CRWD staff are familiar with the 2003 goals, objectives, and management actions that have been previously implemented or further developed, although several of the goals and objectives require commitments from outside agencies such as Ramsey County Parks, City of Roseville, and the Minnesota Department of Natural Resources (MnDNR). As a result, the Lake McCarrons Management Plan Agency Advisory Group (AAG) was convened on June 25, 2019 to identify issues and goals for incorporation into the 2020 Plan, as well as to discuss expectations and constraints for the Lake McCarrons planning process.

At the AAG meeting, primary water concerns in Lake McCarrons were focused on watershed and internal phosphorus loading, chlorides, aquatic plant management (both invasive and non-invasive species), shoreline erosion, carp, and bacteria (E. Coli, particularly from geese). Water quality concerns about the Villa Park wetlands were specifically noted. The group also acknowledged the lake's high level of recreational use and the importance of its popular beach. Another meeting was held on October 21, 2019 to obtain public feedback on the issues and goals for the 2020 Plan.

Given these issues, the AAG and public outlined the following management goal topics for consideration in the 2020 Plan:

- Measurable goals
- Establishment of water quality thresholds (both internal loading and watershed loading) for management action
- Chloride prevention plan
- AIS management strategy
- Aquatic vegetation management
- Flood management
- Outreach, including websites and physical outreach elements (signage, kiosks, environmental programs, public art, etc.) at Lake McCarrons, and engagement with Lake McCarrons neighborhood, lakeshore residents, schools, and other community members
- Maintenance of the lake outlet
- Management of rough fish (carp)

- Vegetated shorelines
- Swimmable, fishable lake that is accessible for recreation
- Definition of roles and responsibilities among stakeholders
- Goose control and bacteria concerns
- Frequency of street sweeping
- Climate change
- Maintain Villa Park system and sediment accumulation at lake outfalls
- Track ongoing achievement of goals/objectives and practice adaptive management

# 4.2 Goals, Measurable Objectives and Recommended Actions

Based on a review of the 2003 Lake McCarrons Management Plan, recent monitoring data, past CRWD implementation activities, and input from the Lake McCarrons Management Plan AAG and the CRWD CAC, the following goals, objectives, and management actions are recommended for inclusion in the 2020 Plan (goals are shown in bold and management actions are shown in italics, below each objective).

# Goal 1: Maintain phosphorus and chloride concentrations below target levels in Lake McCarrons and reduce the water quality impact of other pollutants.

- A. Maintain in-lake summer average TP epilimnetic concentration less than 33 µg/L.
  - 1. Continue bi-weekly in-lake water quality sampling.
- B. Maintain subwatershed TP loading rate at or below 0.25 pounds per acre per year.
  - 1. Manage the release of phosphorus from Villa Park Ponds.
  - 2. Identify and prioritize BMPs, where applicable (i.e., subwatersheds where the three-year moving average annual TP loading rate objective is exceeded).
- C. Maintain summer average hypolimnetic TP concentration below 300 µg/L.
  - 1. *Reevaluate need for another alum treatment annually by reviewing hypolimnetic phosphorus concentrations.*
  - 2. Evaluate phosphorus concentrations in lake sediment cores every five years.
  - 3. Alum application to inactivate sediment phosphorus when summer average hypolimnetic TP concentration exceeds 300 µg/L.
- D. Minimize the frequency of in-lake chloride concentrations exceeding 230 mg/L.
  - 1. Complete a chloride source assessment and prevention plan for the Lake McCarrons subwatershed.
  - 2. Promote best winter deicing practices to the community.
  - 3. Collaborate with agency partners to promote best deicing practices and support innovations in deicing methods.

- 4. Routinely monitor and analyze chloride concentrations in Lake McCarrons and at storm sewer outlets.
- E. Reduce other non-point source pollutants to the lake (e.g., trash, sediment, and bacteria).
  - 1. Coordinate efforts with Ramsey County and assign roles and responsibilities.
  - 2. Provide educational materials to residents to promote best practices.
  - 3. Conduct a shoreline assessment to identify extent and degree of shoreline erosion and the management actions that should be pursued to improve the McCarrons shoreline (Ramsey Soil and Water Conservation District with CRWD funding).
  - 4. Continue the goose control program (Ramsey County Parks).
  - 5. Coordinate with community groups to develop a plan for reducing trash from the watershed and improve trash management within the immediate vicinity of Lake McCarrons.

#### Goal 2: Maintain a healthy, balanced aquatic ecosystem in Lake McCarrons.

- A. Prevent the introduction of new aquatic invasive species (AIS) and mitigate the impacts of existing invasive populations.
  - 1. Implement the Lake McCarrons AIS Plan.
  - 2. Manage established AIS populations in accordance with Lake McCarrons AIS plan.
- B. Maintain or increase abundance and distribution of native submersed aquatic plants throughout the growing season.
  - 1. Update and implement lake vegetation management plan.
  - 2. Conduct aquatic vegetation surveys at a minimum frequency of twice per year.
- C. Create and maintain stable shoreline buffers around Lake McCarrons.
  - 1. Develop and implement a Lake McCarrons Shoreline Management Plan
  - 2. Conduct shoreline assessment to identify extent and degree of shoreline erosion in Lake McCarrons
  - 3. Based on the shoreline assessment, determine which management actions should be pursued to improve the McCarrons shoreline.
  - 4. Provide consultation and cost share grants with Ramsey County and homeowners to improve shoreline buffers.
  - 5. Use lake level, bathymetric information (Ramsey County), and current science regarding causes of shoreline erosion to guide management (CRWD, Roseville and Ramsey County Parks).
- D. Maintain a balanced fishery.
  - 1. Continue implementing the fisheries management plan for Lake McCarrons (MnDNR).
  - 2. Develop long-term targets for balanced fishery (in partnership with MnDNR).
  - 3. Complete fish surveys approximately every 5 years (MnDNR), or as needed (CRWD), to determine species abundance and diversity.

#### Goal 3: Promote sustained community stewardship of Lake McCarrons and its watershed.

- A. Target communication and education efforts toward Lake McCarrons community.
  - 1. Continue to provide educational materials and cost sharing for shoreline landscaping to lakeshore owners.
  - 2. Provide technical assistance to lakeshore owners (Ramsey County Conservation District).
  - 3. Provide educational opportunities to McCarrons area residents on non-structural practices.
  - 4. Provide funding for implementing non-structural practices in the McCarrons watershed.
  - 5. Develop educational resources about Lake McCarrons for school groups and community groups.
  - 6. Develop and install new educational signage around Lake McCarrons.
  - 7. Incorporate art and other media as an alternative communication method of Lake McCarron's water quality.
  - 8. Develop and encourage volunteer efforts to protect Lake McCarrons.

# Goal 4: Reduce the risk of flooding to habitable structures and significant infrastructure surrounding Lake McCarrons and Villa Park.

- A. Maintain the Lake McCarrons outlet.
  - 1. Assign roles and responsibilities between Ramsey County and CRWD.
  - 2. Evaluate whether a redesigned outlet would be more easily maintained/kept free of debris.
- B. Identify the potential for homes and infrastructure flooding along the shoreline of Lake McCarrons and Villa Park during extreme storm events (e.g. the 100-year and 500-year storm events).
  - 1. Complete hydrology and hydraulics watershed modeling and communicate results to Roseville and Ramsey County.
  - 2. Work with partners to reduce flood risk to habitable structures.

# Goal 5: Support the recreational use of Lake McCarrons by achieving water quality and vegetation conditions consistent with the Lake's intended uses, including swimming, boating, and fishing.

- A. Maintain a variety of boating opportunities on Lake McCarrons.
  - 1. Use lake level, bathymetric information (Ramsey County) and current science regarding causes of shoreline erosion to guide management (CRWD, Roseville and Ramsey County Parks).
- B. Maintain fishing opportunities in Lake McCarrons.
  - 1. Continue implementing the fisheries management plan for Lake McCarrons (MnDNR).
  - 2. See management actions in Goal 2.
  - 3. Enhance and maintain existing designated fishing areas.

- C. Maintain wildlife viewing areas around Lake McCarrons
- D. Maintain conditions suitable for swimming in Lake McCarrons.
  - 1. See objectives 1A and 1E.
  - 2. Expand areal extent of E. coli testing in Lake McCarrons (Ramsey County with CRWD funding).
  - 3. Communicate beach closures due to unsafe bacteria levels (Ramsey County Parks).

# **5** Implementation

This section details the recommended management actions that warrant inclusion in the Implementation Plan for Lake McCarrons, in response to the issues, goals, and objectives outlined in Section 4.

# 5.1 Watershed Hydrologic/Hydraulic Modeling

It is assumed that this project would be completed by a consultant and would perform watershed hydrologic and hydraulic modeling to assess flood risk of structures and infrastructure including flooding issues at the intersection of Cohansey Boulevard and Bossard Avenue.

# 5.2 Update Lake Vegetation Management Plan (LVMP)

A lake vegetation management plan (LVMP) is a document the Minnesota Department of Natural Resources (MnDNR) develops with public input to address aquatic plant issues on a lake. The LVMP is intended to balance riparian property owner's interest in the use of shoreland and access to the lake with preservation of aquatic plants, which is important to the lake's ecological health. It is recommended that CRWD work with the MnDNR and the public to update the LVMP for Lake McCarrons to prescribe the permitted aquatic plant management actions (mechanical and/or herbicides) for a five-year period, including controls for invasive plants and restoration of lake shore habitat. The first step in this process will involve utilizing a recent aquatic vegetation survey that should be submitted to the MnDNR to confirm that the survey information can be used as the control for future plant management actions, or if further data collection is necessary. More fieldwork should be done as needed. Documenting the invasive species should be done as a part of this process.

It is assumed that this project would be completed by a consultant and could also involve the use of a task force of interested stakeholders that could work over the 2020-2021 timeframe. The LVMP should also define thresholds of AIS that necessitate active management and define goals under which aquatic plants will provide beneficial ecological and biological functions on Lake McCarrons.

# 5.3 Balanced Fishery Targets

It is assumed that this project would be completed by a consultant that would develop targets for a balanced fishery that provides angling opportunities, ensures a diversity of gamefish, and provides ecological and water quality benefits in Lake McCarrons. CRWD and the MnDNR will continue to implement the MnDNR's fisheries management plan for Lake McCarrons.

# 5.4 Shoreline Management Plan

The shoreline management plan is intended to identify the extent and degree of shoreline erosion in Lake McCarrons and guide management decisions intended to minimize erosion. The plan will incorporate upto-date information on lake level, bathymetric information and the current science regarding causes and effects of shoreline erosion. This project will be completed by a consultant that will conduct a shoreline inventory to determine the amount of shoreline suitable for landscaping and stabilization as well as the shoreline subject to erosion.

# 5.5 In-Lake Alum Treatment of Lake McCarrons

The application of aluminum has two expected mechanisms: (1) aluminum binds with iron-bound phosphorus in the sediment, thereby forming Al-P, and (2) a residual amount of unbound aluminum remains in the sediment and is available to bind phosphorus that is released from the decay of organic phosphorus. For most lake systems alum dosing is designed to provide some amount of "excess" aluminum to bind phosphorus released from decayed Org-P. However, the aluminum added to the sediment will age over time and be less effective at capturing more phosphorus. If pH and alkalinity conditions show a significant potential to lower pH below 6.0 during treatment, the treatment plan could be altered to replace a portion of the alum with sodium aluminate in order to buffer the pH or the alum dose can be applied over two or more phases of applications.

It is assumed that, initially, CRWD staff would reevaluate the need for another alum treatment annually by reviewing hypolimnetic phosphorus concentrations. After it is confirmed that the internal TP concentration target is exceeded, a project would be completed by a consultant to evaluate phosphorus concentrations in lake sediment cores and determine the alum dose (and suggested phasing) needed for another alum treatment.

Based on findings of the sediment core analysis and alum dosing evaluation, an implementation project would be initiated to apply alum to inactivate mobile sediment phosphorus and mitigate internal phosphorus loading. The recommended alum dose assumed for this implementation item was estimated based on the volume applied during the 2004 alum treatment. The total estimated costs (including engineering and treatment oversight) for the application of alum to the lake is shown in Table 5-1. Typically, in-lake alum treatments are effective for 15 to 20 years, but as previously discussed, it is expected that the effective life of the alum treatment in Lake McCarrons will be 27 years (same as previously estimated for the 2004 alum treatment).

# 5.6 Villa Park Performance Improvements

As noted in Section 3.3.5.2, the BMP evaluation monitoring confirmed that the Villa Park wetland system experiences sediment phosphorus release during the growing season that compromises the treatment potential. It is assumed that, initially, a project would be completed by a consultant to evaluate the performance of the Villa Park wetland system and investigate options for improving its functionality.

Based on findings of Villa Park performance improvement evaluation, an implementation project would be initiated to implement recommended measures to improve the functionality of the wetland system. For planning purposes, it is assumed that the improvement project would involve an alum application to inactivate mobile sediment phosphorus and mitigate internal phosphorus loading from the Villa Park wetland system. The order of magnitude cost estimated for this implementation item was estimated based on a similar option considered in the Villa Park Wetland Management Plan (Wenck, 2010). The total estimated costs (including engineering and treatment oversight) for the application of alum to the wetland is shown in Table 5-1. Typically, pond alum treatments would not be expected to experience an effective lifespan of more than 10 years, depending on the total incoming TP load, but the watershed configuration for this BMP option includes a significant level of upstream treatment to extend the alum treatment effectiveness.

# 5.7 Chloride Source Assessment and Prevention Plan

The chloride source assessment and prevention plan is intended to evaluate the sources and magnitudes of chloride loading in the Lake McCarrons watershed and assess the potential for reducing deicer applications from each source area. This project will be completed by a consultant that will inventory the potential sources of chloride, estimate the existing source loadings and potential for reducing deicer application rates within the Lake McCarrons watershed.

# 5.8 Future BMP Feasibility Studies and CIP Opportunities

It is assumed that future feasibility studies would be completed by a consultant that would explore the effectiveness of potential BMPs, including feasibility of existing practices and/or new innovative treatments, to reduce external/watershed TP loads and help achieve water quality goals outlined in the Plan. Based on the outcomes of BMP feasibility studies and/or redevelopments, future capital improvement projects (CIPs) will be implemented as opportunities arise. For example, it is expected that future CIP opportunities could include Victoria B Wetland enhancement and Alameda Pond improvements.

# 5.9 Implementation Plan Summary

Table 5-1 summarizes the estimated costs, timeline, and description of the actions recommended for the implementation plan.

The District prioritizes programs, projects, and activities to promote efficient use of finite staff and financial resources. Each activity included in Table 5-1 has been assigned one of the following three priority levels:

**Critical** – critical activities are necessary to perform the core functions and statutory duties of the District, as required by law, rule, or statute

**Important** – important activities are those that are led by the District in support of its goals and objectives, but are not required by law, rule, or statute, do not rise to the level of "critical".

**Beneficial** – beneficial activities are those that are aligned with District goals and objectives but are likely to be deferred to a future date, performed only if an opportunity arises, or be led by District partners, with the District supporting the activity through limited funding, technical assistance, and/or other cooperative efforts.

This classification system is qualitative and intended to serve as a guide for annual work planning and budgeting. Classification of an activity as critical, important, or beneficial does not, by itself, determine implementation of an activity relative to other activities or its planned schedule in Table 5-1. The annual work plan may accelerate, delay, delegate, or abandon activities relative to the 10-year implementation

plan. For example, activities led by partners may be implemented earlier or later than planned due to changing partner priorities, funding, and schedules.

## Table 5-1 Lake McCarrons Implementation Plan

			PRIORITY LEVEL (Critical, Important, Beneficial)			PARTNERS												
PLAN REFERENCE	PROGRAM/PROJECT TITLE	PROGRAM/PROJECT DESCRIPTION		Lead Agency	Cities	County	State/ Regional Agencies	Total Cost	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lake McCarrons Su	ibwatershed Projects																	
4.B.1., 4.B.2.	Watershed Hydraulic/Hydrologic Modeling	Perform watershed hydrologic and hydraulic modeling to assess flood risk of structures and infrastructure including flooding issue @ intersection of Cohansey Boulevard and Bossard Avenue	Critical	CRWD	х	х		\$ 30,000		\$ 30,000								
2.A.1., 2.A.2, 2.B.1., 2.B.2.	Lake vegetation management plan and AIS response plan	The AIS response plan will define the process and criteria by which AIS will be managed on Lake McCarrons. In addition, the lake vegetation management plan will define thresholds of AIS that necessitate active management and define goals under which aquatic plants will provide beneficial ecological and biological functions on Lake McCarrons.	Critical	CRWD	x	х	х	\$ 20,000	\$ 20,000									
2.D.1., 2.D.2, 2.D.3., 5.B.1., 5.B.2., 5.B.3.	Balanced fishery targets	Develop targets for a balanced fishery that provides angling opportunities, ensures a diversity of gamefish, and provides ecological and water quality benefits in Lake McCarrons. CRWD and the DNR will continue to implement the DNR's fisheries management plan for Lake McCarrons. (Draft LMP-Issues and Goals Memo)	Critical	MnDNR	x	х	x	\$ 15,000		\$ 15,000								
1.E.3., 2.C.1., 2.C.2., 2.C.3., 2.C.4, 2.C.5., 3.A.1., 3.A.2., 5.A.1.	Shoreline management plan	Identify the extent and degree of shoreline erosion in Lake McCarrons and guide management decisions intended to minimize erosion. The plan will incorporate up-to-date information on lake level, bathymetric information and the current science regarding causes and effects of shoreline erosion. This project will be completed by a consultant that will conduct a shoreline inventory to determine the amount of shoreline suitable for landscaping and stabilization as well as the shoreline subject to erosion. Ramsey County Conservation District may provide (future) technical assistance to lakeshore owners.	Critical	CRWD	x	x		\$ 15,000			\$ 15,000							
1.C.1., 1.C.2, 1.C.3.	Alum treatment evaluation	Reevaluate the need for another alum treatment annually by reviewing hypolimnetic phosphorus concentrations. Evaluate phosphorus fractions in lake sediment core subsamples every five years for historical comparison and internal load potential.	Critical	CRWD	x	х	x	\$ 15,000						\$ 15,000				
1.B.2., 1.E.1., 1.E.2., 1.E.4., 1.E.5., 5.D.1.	Future BMP feasibility studies TBD	The feasibility study should explore the effectiveness of potential BMPs to reduce external/watershed loads and help achieve water quality goals outlined in the Lake McCarrons Management Plan. The feasibility of existing practices and/or new innovative treatments should also be considered. Ramsey County Parks will take lead on continuing goose control program.	Important	CRWD	x	х		\$ 40,000					\$ 20,000	\$ 20,000				
1.B.1.	Evaluate Villa Park Performance Improvements	Evaluate the performance of the Villa Park wetland system and investigate options for improving its functionality	Important	CRWD	x			\$ 40,000	\$ 40,000									
1.D.1., 1.D.2, 1.D.3., 1.D.4.	Chloride Source Assessment and Prevention Plan	Evaluate the sources and magnitudes of chloride loading in the Lake McCarrons watershed and assess the potential for reducing deicer applications from each source area	Important	CRWD	x	х	x	\$ 50,000		\$ 25,000	\$ 25,000							
1.A.1., 5.D.2., 5.D.3.	Any other items from McCarrons LMP - Monitoring/Research	Complete monitoring and research of BMPs, Water Quality, Biological parameters of importance to inform the management decisions for successful implementation of the Lake McCarrons Management Plan.	Important	CRWD and Ramsey County	x	х	х	\$ -										
3.A.3., 3.A.5., 3.A.6., 3.A.7., 3.A.8.	Any other items from McCarrons LMP - Communications/Engagement	Implement strategic communications and engagement of the public to support and advocate for the successful implementation of the Lake McCarrons Management Plan.	Important	CRWD	х	х	х	\$-										
3.A.4., 4.A.1., 5.C.	Any other items from McCarrons LMP - Partnerships	Facilitate and nurture strong public, private and agency partnerships to successfully implement the Lake McCarrons Management Plan.	Important	CRWD	х	х	х	\$-										
								\$ 225,000	\$ 60,000	\$ 70,000	\$ 40,000	\$-	\$ 20,000	\$ 35,000	\$-	\$-	\$-	\$-
Lake McCarrons Su	bwatershed Capital Improvements																	
1.C.1., 1.C.2, 1.C.3.	Alum treatment	Based on findings of alum evaluation, apply alum to inactivate mobile sediment phosphorus and mitigate internal phosphorus loading.	Critical	CRWD			x	\$ 500,000										\$ 500,000
1.B.1.	Implement Villa Park Performance Improvements	Based on findings of Villa Park performance improvement evaluation, implement measures to improve the functionality of the wetland system	Important	CRWD	x			\$ 500,000		\$ 500,000								
1.B.2., 4.A.2.	Future CIPs as opportunities arise and/or from McCarrons LMP	TBD based on future opportunities	Important	CRWD	х	х	x	\$ 150,000								\$ 150,000		
								\$ 1,150,000	\$-	\$ 500,000	\$-	\$-	\$-	\$ -	\$ -	\$ 150,000	\$ -	\$ 500,000

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# Appendix A

BMP Evaluation and Watershed Model Calibration Technical Memo



# Technical Memorandum

To:Bob Fossum and Joe Sellner, Capitol Region Watershed DistrictFrom:Greg Wilson, Heather Hlavaty & Lulu Fang, Barr Engineering CompanySubject:Lake McCarrons Management Plan: Task 4 and 5 BMP Evaluation and Watershed<br/>Model CalibrationDate:November 8, 2019Project:Lake McCarrons Management Plan

As part of Tasks 4 and 5, Barr has developed an existing conditions water quality/quantity P8 model to evaluate the treatment performance of the existing BMPs in the Lake McCarrons watershed, including, but not limited to, the following BMPs:

- Villa Park Wetland System
- William Street Pond/IESF
- Boulevard RWGs
- Upper Villa Stormwater Reuse Facility
- Available plans for Parkview schools reuse system
- Nonstructural BMPs, where applicable

# 1.0 Summary of Data

As part of Tasks 1 through 3, Barr reviewed the background data, GIS and watershed modeling data provided by the District in the spring of 2019. On March 6, 2019, a data review memo was sent to the District summarizing the data provided by the District on February 2019. In response to the Summary of Existing Data/Follow-up Requests Memo, the District provided the following additional information:

- 1. TH 36 and Rice Interchange (May 6, 2019):
  - a. 10-002 Permit As-built report
  - b. 28-405 TH36 Rice As-built Storm Sewer Plans
  - c. NW Pond as-built
  - d. Proposed Conditions HydroCAD model and results
  - e. SW Pond west basin as-built
  - f. SW Pond east basin as-built
- 2. Upper Villa (May 6, 2019):
  - a. As-built Plans
- 3. Villa Park Dredging (May 6, 2019):

- a. Post-dredging as-built plans
- b. Villa Park Cross Sections (8 pages)
- 4. William Street Pond (May 6, 2019):
  - a. As-built drawing and details
- 5. Updated BMP Summary Spreadsheet (May 6, 2019)
- 6. "P8\_BMPs\_forCRWD\_06.05.shp" Shapefile with response to missing data (June 5, 2019)
- 7. Permits (June 5, 2019):
  - a. 15-030 Farrington Estates Grading Plan
  - b. 14-015 Mueller Bies as-built and HydroCAD output
  - c. 14-012 Villa Park grading plan
  - d. 16-017G Krook Magnuson Rain Garden plans and project summary
- 8. Alameda Pond Level Monitoring Data (July 25, 2019)
- 9. Upper Villa Cistern Volume and Depth Monitoring Data (July 31, 2019)

As-built and GIS stormsewer data was requested from the City of Roseville. The following information was provided:

- 1. GIS stormsewer database (February 11, 2019)
- 2. Rice Street and TH36 CAD stormsewer (May 19, 2019)
- 3. As-built plans (May 14, 2019)
- 4. Additional as-built plans (June 5, 2019)

As-built and GIS stormsewer data was requested from MnDOT for the study area. The following information was provided:

1. GIS stormsewer database (May 24, 2019)

#### 2.0 BMP Evaluation

Performance of BMPs within the Lake McCarrons watershed was evaluated by one of two methods: 1) comparing existing monitoring data between the inlet and outlet of the BMPs, or 2) using the calibrated P8 model to simulate pollutant loading upstream and downstream of the BMP. The BMPs with available monitoring data provided by the District are listed below:

- Villa Park Wetland System
- William Street Pond/IESF
- Upper Villa Stormwater Reuse Facility

The monitoring data provided for these BMPs was also used to calibrate the water quality/quantity P8 model, discussed in Section 3.0 and 4.0 of this memo. Barr developed the P8 model to evaluate the treatment performance of the remaining BMPs in the Lake McCarrons watershed where monitoring data

was not provided. Sections 3.0 and 4.0 describe the methods used to develop and calibrate the model. Results of the BMP evaluation are provided in Section 5.0.

# 3.0 Water quality model development

Barr created a water quality model spanning 1,060 acres within, and immediately tributary, to Lake McCarrons, to evaluate the water quality performance of ponds and wetlands within the watershed (see Figure 1). Using the water quality modeling program P8, the model was developed using data provided by MnDOT, the CRWD, and the City of Roseville. The following subsections outline development of P8 hydrologic, hydraulic, and water quality inputs.

#### 3.1 Outlet Hydraulics

Hydraulic inputs required for P8 modeling for all ponds, wetlands, and other BMPs within the watershed were developed from five sources: (1) available as-builts and record drawings; (2) HydroCAD models provided by the District; (3) the GIS stormsewer data provided by the City of Roseville and MnDOT; (4) the summary of BMP performance spreadsheet provided by the District; and (5) monitoring data provided by the District.

Where monitoring data or other survey information was available, the device was made into a General Device and the outlet rating curve was adjusted to match the observed data. The outlets for Alameda Pond, the Villa Park Sedimentation Pond, the Villa Park Outlet, and the Upper Villa Reuse System were revised to match the hydraulics of the complex system and to simulate results similar to the monitoring data. The rating curves were initially created by developing small XP-SWMM models of the outlet with a simple user-defined inflow at varied flowrates placed at the BMP. Revisions in the P8 general device rating curves were made to match monitoring data where it exists.

### 3.2 Storage and Bathymetry

Stage-storage data was redeveloped for all storage areas using 2011 Ramsey County LiDAR data. Bathymetry data in the provided HydroCAD models was used where it was available. Bathymetric contours from available record drawings were used to define bathymetric storage whenever available, as well. Where bathymetric storage data (i.e., storage below the pond/wetland normal water level) was not available, bathymetric storage was estimated using National Wetland Inventory (NWI) water area classifications and uniform depth assumptions. The Particle Removal Scale Factor (PRSF) modifies settling velocities and decay rates to account for device-specific characteristics. A PRSF less than 1.0 can be assumed to account for poor hydraulic design (outlet next to inlet, promoting short-circuiting of inflows, shallow basins). The default PRSF of 1.0 was decreased to 0.3 for all basins less than 2 feet deep and 0.6 for all basins between 2 and 3 feet deep. For ponds greater than 3 feet deep, the default PRSF of 1.0 was used.



#### 3.3 Hydrologic and Water Quality Inputs

Subwatersheds were hand digitized to each modeled BMP. P8 hydrologic inputs were generated for all subwatersheds using best-available soil and land use data sources (2019 SSURGO soil data, Physical Features database developed by Ramsey County in 2015, imperviousness analysis by Tim Anderson, Barr Engineering on January 2017, and NWI open water data). Where underlying soil data was not available, HSG Type B soils were assumed. Figure 2 is the result of the imperviousness analysis conducted by Tim Anderson at Barr Engineering based on the 2015 Ramsey County land use study. Figure 3 is a soils map based on 2019 SSURGO soil data. Typical NURP50 particle assumptions were used to define water quality component and input particle parameters in P8, except for the default particle filtration efficiencies, which were modified based on BMP type and/or data supporting the BMP evaluations.

#### 3.3.1 Rain gardens

The summary of BMPs spreadsheet provided by the District includes the location and treatment potential of rain gardens within the Lake McCarrons subwatershed. Where rain gardens exist, but no plans are available, the treatment provided by the BMP was incorporated into the hydrology inputs of the subwatershed by modifying the impervious runoff coefficient. This method was used to model 17 rain gardens. The subwatershed impervious runoff coefficient was adjusted by assuming the contained rain garden treated 100% of the "Impervious\_Surface\_Treated" field in the District Summery of BMPs spreadsheet. For example, if the rain garden treated 0.5 acres (10%) within a subwatershed with 5 acres of impervious surface, the impervious runoff coefficient was changed from 1.0 to 0.9.

#### 3.3.2 William Street Pond Filtration

The default P8 filtration efficiency is 90% for P0% and 100% for particle fractions P10% through P80%, in order to reflect the removal which would be expected through infiltration into the ground. However, in order to simulate pollutant removal via filtration (pollutants not removed being conveyed downstream), the removal efficiencies can be adjusted to reflect the typical phosphorus filtration efficiency of filtration or iron-enhanced sand filtration systems reported in the Minnesota Pollution Control Agency's (MPCA) Minimal Impact Design Standards (MIDS) calculator. For modeling and design purposes, the MPCA recommends the following filtration efficiencies.

#### Table 1 Recommended filtration efficiency

	Filtr	ation Efficiency (% remo	oval)
Filtration Type	Dissolved (P0%)	Particulate (P10%)	Particulate (P30% thru P80%)
Sand filters and Biofiltration <sup>1</sup>	0%	25%	100%
Iron-Enhanced Sand Filter <sup>2</sup>	60%	25%	100%

<sup>1</sup> <u>https://stormwater.pca.state.mn.us/index.php?title=Calculating\_credits\_for\_sand\_filter</u>

<sup>2</sup> <u>https://stormwater.pca.state.mn.us/index.php?title=Calculating\_credits\_for\_iron\_enhanced\_sand\_filter</u>





The filtration efficiency recommended for iron-enhanced sand filters was used as a starting point. Because monitoring data was provided at the inlet and outlet of the William Street Pond iron-enhanced filtration BMPs, the particle filtration efficiency of the P8 model can be adjusted to reflect the observed data. Optimization of the filtration efficiency values after model calibration is discussed in Section 4.2.2.

# 4.0 Model Calibration

#### 4.1 Monitoring Data

The District provided monitoring data at seven locations within the Lake McCarrons watershed (Figure 4). Level, flow, total suspended solids (TSS) concentrations, total phosphorus (TP) concentrations, and runoff volumes were used to calibrate the existing conditions P8 model. Figure 5 shows the downstream monitoring location for each subwatershed used to calibrate the model.

Table 2 summarizes the relevant monitoring data available at each monitoring location.

Monitoring Location	TSS (mg/L)	TP (mg/L)	Volume (ac-ft)	Level (feet)	Discharge (cfs)
Upper Villa Inlet	Х	Х	Х	Х	Х
Villa Park Inlet	Х	Х	Х		Х
Villa Park Outlet	Х	Х	Х		Х
William Street Pond Inlet	Х	Х			
William Street Pond Outlet	Х	Х			
Lake McCarrons Outlet			Х		Х
Alameda Pond				Х	

 Table 2
 Available monitoring data at each monitoring location

Barr calibrated the existing conditions P8 model to the Upper Villa Inlet and Villa Park Outlet because a complete record of TSS, TP, and discharge volume is available between 2016 and 2018 at these locations. Monitoring data provided at the Villa Park Inlet was not used to calibrate the model because flows over the spillway calculated using Manning's equation resulted in a larger measure of uncertainty than at the other two monitoring sites. The model was validated by comparing model results to the William Street Pond TSS and TP concentrations and Villa Park Inlet TSS and TP loads. The following subsection outlines the review of collected monitoring data, calibration of modeled runoff, TSS, and TP load to collected monitoring data, and review and assessment of calibrated model results.





#### 4.1.1 Precipitation Data

Rainfall data collected at the Villa Park gauge was provided by the District and used to generate hourly rainfall input files for P8 for the calibration period (2016 through 2018). A summary of total precipitation collected at the Villa Park gauge and University of Minnesota – St. Paul campus is provided in Table 3 below.

Year	Villa Park Gauge	UMN St. Paul
2016	23.5	26.0
2017	34.4	30.7
2018	20.9	23.3

Table 3	Total Annual Precir	nitation at Villa	Park and Univer	rsity of Minnesota	- St Paul
Table 3	Total Annual Liech	mation at vina	Tark and onlye	isity of Millinesota	- 51. 1 aui

Daily precipitation values were also plotted against the monitored continuous flow data at the Villa Park and Upper Villa Inlets as shown in Figure 6, Figure 7, and Figure 8. The plots below suggest that the University of Minnesota – St. Paul precipitation data may be more accurate during events where the Villa Park gauge may be over or underestimating rainfall. These instances are outlined in yellow below. In the highlighted locations, either the Villa Park gauge readings are lower or higher than expected given the peak flow through the Villa Park and Upper Villa inlets. Because of these discrepancies, and the differences in total precipitation depths for each year, the model was analyzed using the University of Minnesota – St. Paul precipitation data.



Figure 6 2016 Comparison of Precipitation Data and Monitored Flow



Figure 7 2017 Comparison of Precipitation Data and Monitored Flow



Figure 8 2018 Comparison of Precipitation Data and Monitored Flow

#### 4.1.2 Outliers

Barr removed pollutant load outlier events prior to calibration. Using methodology developed during calibration of the I-35W N Tunnel watershed P8 model (Barr, 2017), "outliers" were defined as loading events that produced pollutant loads greater than two (2) times the standard deviation from the average of events during the calibration period.

#### 4.2 Calibration

Barr calibrated the P8 model to event runoff and pollutant loading collected at the Upper Villa Inlet and Villa Park Outlet monitoring stations. The model was first calibrated to the most upstream monitoring location, the Upper Villa Inlet. The calibration process is discussed in the following subsections, and is summarized, below:

- 1) Calibrate event-based total runoff volume to monitored total volume at the Upper Villa Inlet monitoring station;
- Calibrate to continuous flow data at the Upper Villa Reuse Bypass. The bypass continuous flow data was provided between June and October 2017. This data was used to update the rating curve for the reuse system.
- 3) Calibrate modeled pollutant load (TSS and TP) to pollutant load observed at the Upper Villa Inlet monitoring station. Barr extracted a series of events for the TSS and TP load analysis. Because the P8 model is calibrated to interval water volume and pollutant loading, loading interval start and

end dates were rounded to the nearest hour to allow for more accurate comparison to the P8 model, which calculates loading hourly.

- 4) Calibrate modeled TP and DP fraction and filtration efficiency at the William Street Pond ironenhanced sand filters.
- 5) Validate water runoff volume at the Villa Park Outlet.
- 6) Validate modeled pollutant load (TSS and TP) to pollutant load observed at the Villa Park Outlet monitoring station using the same method described for the Upper Villa Inlet.

#### 4.2.1 Water Load Calibration

Because sediment and associated pollutant transport in P8 is a function of surface runoff, it is not possible to calibrate pollutant loads without first calibrating water loading. As discussed above, the model was first calibrated to the Upper Villa Inlet. A summary of the event-based monitored and modeled water loads on days with more than 0.25 inches of precipitation for that event are shown in Table 4 and Figure 9. Figure 10 is a 1-to-1 comparison plot of monitored vs. modeled total event volumes in acre-feet.

#### Table 4 Water Load Results at Upper Villa Inlet (pre-calibration)

Year	Monitored Total Volume (ac-ft)	Modeled Total Volume (ac-ft)	Percent Difference
2016	63	80	23%
2017	38	72	62%
2018	99	59	-51%
		Total Average Percent Difference	5%

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Figure 9 Event volume comparison for the 2016-2018 calibration years (pre-calibration).


Figure 10 1-to-1 event volume comparison at Upper Villa Inlet (pre-calibration)

The figures above show that event volumes produced in P8 are typically higher than observed event totals for small magnitude events and lower than observed for larger magnitude events during years 2016 and 2017. In year 2018, modeled event totals are typically smaller than observed for both large and small magnitude events; however, the overall average water load is 5% greater in the model than observed.

There are many P8 model parameters which can be used to adjust modeled TSS and TP loading the water volume. Barr focused on the adjustment of one parameter to calibrate the water loading:

• Depression Storage – adjusting impervious and pervious depression storage influences smaller magnitude events.

Because the model over predicts volume for smaller events, the impervious depression storage was increased from 0.02 inches to 0.06 inches. This change produced the following results (Table 5). Figure 11 shows the results of the 1-to-1 calibration changes.

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## Table 5Water Load Results at Upper Villa Inlet (calibrated)

Year	Monitored Total Volume (ac-ft)	Modeled Total Volume (ac-ft)	Percent Difference
2016	63	77	19%
2017	38	68	57%
2018	99	54	-58%
		Total Average Percent Difference	0%



Figure 11 1-to-1 event volume comparison at Upper Villa Inlet (calibrated)

The calibration changes were then validated at the Villa Park Outlet. To simulate the baseflow through the Villa Park system observed from the monitoring data, the watersheds just upstream of the Villa Park Inlet were modeled with percolation to the sedimentation pond upstream of the Villa Park Inlet gauge. The pre-calibration results are shown in Table 6. The calibrated results are in Table 7. Figure 12 shows the results of the 1-to-1 calibration changes at the Villa Park Outlet. After calibrating the water load, the total volume during summer months between 2016 and 2018 is the same at the Upper Villa Inlet and over predicted by 1% at the Villa Park Outlet. With these changes, the water load is considered calibrated.

Table 6	Water Load Results at Villa Park Outlet (pre-calibration)
	mater Load Roballo at Fina Fank Outlot (pro bandratori)

Year	Monitored Total Volume (ac-ft)	Modeled Total Volume (ac-ft)	Percent Difference
2016	274	283	3%
2017	253	387	42%
2018	154	158	3%
		Total Average Percent Difference	20%

 Table 7
 Water Load Results at Villa Park Outlet (calibrated)

Year	Monitored Total Volume (ac-ft)	Modeled Total Volume (ac-ft)	Percent Difference
2016	274	250	-9%
2017	253	299	17%
2018	154	137	-12%
		Total Average Percent Difference	1%



Figure 12 1-to-1 event volume comparison at Villa Park Outlet (calibrated)

## 4.2.2 Pollutant Load Calibration

To calibrate the TSS and TP load, specific events where the District retrieved composite samples were compared to the calibrated water load model results. Start and end dates and times from the composite samples were applied to the model to determine the total TSS and TP load at the monitoring location. The monitoring data was compared to the model with calibrated water load. Review of the results in Figure 13 and Figure 14 shows that, for TSS, the model tends to over-predict event loading for smaller loading events (associated with smaller, less-intense storm events where loading is driven by runoff and wash-off from impervious surfaces), and tends to under-predict for larger loading events (associated with larger, more-intense storm events) leading to a total TSS load 21% lower than monitored data. For TP, the model tends to under predict total event loading for all magnitude events by an average of 19%.



Figure 13 TSS event load comparison at Upper Villa Inlet (calibrated water load)



Figure 14 TP event load comparison at Upper Villa Inlet (calibrated water load)

There are many P8 model parameters which can be used to adjust modeled TSS and TP loading. These parameters include:

- Accumulation Rate buildup of particles on impervious surfaces (default translates to a median event mean concentration (EMC) of 100 mg/L TSS).
- Decay Rate removal via non-runoff processes.
- Washoff Coefficient used to compute particle washoff.
- Washoff Exponent used to compute particle washoff.
- Pervious and impervious runoff concentration TSS and TP concentration associated with generated runoff.
- Pervious runoff exponent relates runoff concentration to runoff intensity.
- Water quality component scale factors multiplier factors used to adjust pollutant loading generated by P8 (e.g., a TSS scale factor of 0.9 will reduce TSS loading by 10%).

Although all of these factors can be used to adjust pollutant loading, because composite event sampling of runoff at the monitoring locations includes loading from both pervious and impervious surfaces and

does not summarize how event concentration changes throughout the course of an event, there is insufficient justification to manipulate many of these model parameters.

For this reason, Barr focused on the adjustment of the water quality component scale factors to calibrate the TSS and TP event loading.

Barr performed multiple iterations adjusting these factors to understand the impact on the model event loading for both TSS and TP. To address over-prediction of TSS and under-prediction of TP loading at the UV Inlet, Barr adjusted the overall nutrient scale factors. In order to match the dissolved and total phosphorus influent loads, the mg/kg TP particle fractions were adjusted as shown in Table 8 below.

Particle Fraction	TSS (mg/kg)	TP (mg/kg)
P0%	0	53000
P10%	1000	11000
P30%	1500000	6500
P50%	1500000	3500
P80%	1500000	0

 Table 8
 Calibrated water quality component mg/kg scale factors

As discussed in Section 3.3.2, the default iron-enhanced filtration efficiency was revisited after the model was calibrated to water and nutrient load. To match the observed data at William Street Pond, the filtration efficiencies for P0% was decreased from 60% to 58%, the P10% was decreased from 25% to 5%, and the P30% through P80% were decreased from 100% to 80%.

The impact of the calibration adjustments on the final calibrated event loading are shown in Figures 15 and 16. The calibration updates reduced the total error in event-based pollutant loads at the Upper Villa Inlet from -21%, to 3.8% for TSS and from -19%, to 0.7% for TP. Typically, total loading error within 10% is considered reasonable for water quality model calibration (Barr, 2017).



Figure 15 TSS event load comparison at Upper Villa Inlet (fully calibrated)



## Figure 16 TP event load comparison at Upper Villa Inlet (fully calibrated)

The model was also validated at the William Street Pond iron-enhanced sand filters (IESF) where discrete TP and DP concentration samples were collected in 2016, 2017, and 2018. The average monitored concentration from the pond was compared to the average TP and DP concentrations generated from the calibrated P8 model on the day of collection. As mentioned above, the filtration efficiency was adjusted to match the effluent TSS and TP concentrations downstream of the IESFs. Figure 17 and Figure 18 compare the event-based average concentration of TP and DP leaving the pond through the IES filters. The calibrated model slightly under predicts the average concentration of TP by 2.5% and under predicts the average DP concentration by 1.8%. Since these values are within 10%, the calibration is considered complete.

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Figure 17 TP event concentration at William Street Pond Outlet (fully calibrated)



## Figure 18 DP event concentration at William Street Pond Outlet (fully calibrated)

The calibration changes for TSS and TP loading were validated at the Villa Park Outlet, as well. The calibrated model under predicts total TSS load at the Villa Park Outlet by 9.7%, which is within the accepted range of 10%. The Villa Park wetland system experiences phosphorus release during most of the growing season, resulting in nearly 0% TP reduction from the Villa Park Inlet to the Villa Park Outlet. The monitoring results are further discussed in Section 5.1. Section 5.4.1 describes the changes made to the model at the Villa Park wetland system in order to simulate the phosphorus release occurring in the

wetland. The results presented above confirm that the model has been successfully calibrated and can be used to evaluate existing BMPs within the Lake McCarrons watershed.

## 5.0 BMP Performance Evaluation

Using results from the calibrated P8 models, and the monitoring data provided by the District, BMP performance was evaluated. Performance of BMPs within the Lake McCarrons watershed was conducted by one of two methods: 1) comparing existing monitoring data between the inlet and outlet of the BMPs, or 2) using the calibrated P8 model to simulate pollutant loading upstream and/or downstream of the BMP, where necessary. The BMPs with available monitoring data provided by the District are listed below:

- Villa Park Wetland System
- William Street Pond/IESF
- Upper Villa Stormwater Reuse Facility

## 5.1 Villa Park Wetland System

Baseflow and storm monitored data from 2007 through 2018 at the Villa Park Inlet and Outlet was provided by the District. Several of the wetland cells were dredged in 2013. To evaluate the impact of the dredging on the system performance, the baseflow and storm nutrient data was analyzed before and after the project (data during and after 2014 was considered post-dredging). Total phosphorus, orthophosphorus, and dissolved phosphorus at the wetland inlet, just downstream of the Sedimentation Pond and downstream of the outlet beneath North McCarrons Boulevard are summarized in the figures and tables below. Table 9, Table 10 and Table 11 show the average treatment for all baseflow and storm samples. The wetland system releases greater concentrations of phosphorous to Lake McCarrons than what enters from the Villa Park Inlet. This may be exacerbated by an additional 118 acres of drainage area to the wetland system downstream of the Villa Park Inlet.

		Baseflow		Storm			
	Influent TP Conc. (mg/L)	Effluent TP Conc. (mg/L)	TP Removal Efficiency (%)	Influent TP Conc. (mg/L)	Effluent TP Conc. (mg/L)	TP Removal Efficiency (%)	
Average	0.265	0.282	-89%	0.222	0.245	-30%	
Median	0.167	0.198	-25%	0.181	0.203	-10%	
Min	0.010	0.062	-	0.056	0.072	-	
Max	1.780	2.240	-	1.480	0.926	-	
St. Dev.	0.284	0.266	-	0.165	0.147	-	

## Table 9 Total phosphorus treatment performance at Villa Park Wetland System

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		Baseflow		Storm			
	Influent Ortho-P Conc. (mg/L)	Effluent Ortho-P Conc. (mg/L)	Ortho-P Removal Efficiency (%)	Influent Ortho-P Conc. (mg/L)	Effluent Ortho-P Conc. (mg/L)	Ortho-P Removal Efficiency (%)	
Average	0.039	0.053	-153%	0.034	0.057	-274%	
Median	0.022	0.033	-51%	0.026	0.049	-88%	
Min	0.003	0.010	-	0.003	0.011	-	
Max	0.270	0.380	-	0.220	0.160	-	
St. Dev.	0.045	0.060	-	0.030	0.034	-	

#### Table 10 Ortho-P treatment performance at Villa Park Wetland System

#### Table 11 Dissolved phosphorus treatment performance at Villa Park Wetland System

		Baseflow		Storm			
	Influent DP Conc. (mg/L)	Effluent DP Conc. (mg/L)	DP Removal Efficiency (%)	Influent DP Conc. (mg/L)	Effluent DP Conc. (mg/L)	DP Removal Efficiency (%)	
Average	0.043	0.082	-94%	0.059	0.088	-68%	
Median	0.032	0.069	-48%	0.055	0.073	-1%	
Min	0.010	0.052	-	0.010	0.050	-	
Max	0.156	0.160	-	0.260	0.246	-	
St. Dev.	0.036	0.035	-	0.048	0.044	-	

As shown in Table 12, the treatment provided by the wetland system after the 2013 dredging project does not appear to provide significant benefit to the phosphorus treatment efficiency. However, Table 13 shows that the average effluent concentration does decrease which can be explained by the general downward trend in influent phosphorus concentration since 2007. This trend is shown in Figure 19, Figure 20, and Figure 21 below.

Table 12	Treatment	performance	at Villa	Park	Wetland S	System	pre- and	post-dredai	ing

	Base	flow	Storm		
	2007 to 2014	2014 to 2018	2007 to 2014	2014 to 2018	
TP Removal Efficiency (%)	-89%	-53%	-30%	-53%	
Ortho-P Removal Efficiency (%)	-153%	-156%	-274%	-156%	
DP Removal Efficiency (%)	-94%	-92%	-68%	-92%	

#### Table 13 Effluent Phosphorus (mg/L) at Villa Park Wetland System pre- and post-dredging

	Base	flow	Storm		
	2007 to 2014	2014 to 2018	2007 to 2014	2014 to 2018	
Effluent TP	0.282	0.192	0.245	0.192	
Effluent Ortho-P	0.053	0.039	0.057	0.039	
Effluent DP	0.082	0.081	0.088	0.081	



Figure 19 Monitored Total Phosphorus Removal at the Villa Park Wetland System



Figure 20 Monitored Ortho-Phosphorus Removal at the Villa Park Wetland System



Figure 21 Monitored Dissolved Phosphorus Removal at the Villa Park Wetland System

The influent and effluent concentrations were also analyzed for seasonal variability. Figure 22 through Figure 24 show that there is no significant difference in the influent and effluent TP concentrations during base and storm flow conditions. In the case of ortho-phosphorus and dissolved phosphorus, the average effluent concentration exceeds the influent concentration for almost every month between April and October. These results show similar trends summarized in the report: *2015 Analysis of Nutrient Loading and Performance of the Villa Park Wetland, 2006-2012* (1).





Figure 22 Seasonal Variability in Monitored Total Phosphorus Removal at the Villa Park Wetland System





Figure 23 Seasonal Variability in Monitored Dissolved Phosphorus Removal at the Villa Park Wetland System





## Figure 24 Seasonal Variability in Monitored Ortho-Phosphorus Removal at the Villa Park Wetland System

The following figures show the seasonal variability between all years with monitoring data compared to the years after the 2013 dredging of the Villa Park system. As shown in Figure 25 through Figure 27, and explained previously, the effluent phosphorus concentrations are typically lower after 2013; however, with

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the possible exception of ORP, there does not appear to be a significant increase in the treatment efficiency after the dredging of the Villa Park Wetland.



Figure 25 Seasonal and Post-Dredging Variability in Monitored Total Phosphorus Removal at the Villa Park Wetland System

Month





Figure 26 Seasonal and Post-Dredging Variability in Monitored Dissolved Phosphorus Removal at the Villa Park Wetland System





# Figure 27 Seasonal and Post-Dredging Variability in Monitored Ortho-Phosphorus Removal at the Villa Park Wetland System

In 2016, the Villa Park Reuse system was installed to reduce influent TP loading to the Villa Park Wetland System. Also confirmed in the CRWD 2019 *Villa Park Wetland System Performance Analysis*, the influent TP concentration at the Villa Park outlet has a generally decreasing trend since the 2013 dredging (2). Additional years of monitoring data would be needed to distinguish the impact of the Upper Villa Reuse system on the influent phosphorus loading to the Villa Park Wetland (see Figures 28 through 30).





Figure 28 Flow-Weighted Annual Average TP at the Villa Park Wetland System





Figure 29 Flow-Weighted Annual Average ORP at the Villa Park Wetland System





Figure 30 Flow-Weighted Annual Average DP at the Villa Park Wetland System

## 5.2 William Street Pond/IESF

Monitored data from 2013 through 2018 at the William Street Pond was used to evaluate performance of the iron enhanced sand filtration system associated with the pond outlet. Total phosphorus, orthophosphorus, and dissolved phosphorus sample concentrations at the pond inlet and downstream of the north and south iron-enhanced sand filters were summarized. Table 14, Table 15 and Table 16 show the respective total phosphorus, dissolved phosphorus, and ortho-phosphate treatment efficiencies of both iron-enhanced sand filters. As shown in the tables, the north and south filters have removed an average of 57.9% and 45.8% total phosphorus, 47.5% and 35.9% ortho-P, and 61.1% and 34.8% dissolved phosphorus, respectively, over the last 6 years. These results are similar to the results from the May 2017 *William Street Pond Iron-Enhanced Sand Filter Performance Report* which analyzed monitoring data from 2013 through 2016. As indicated in the report, and further confirmed below, the north IESF outperforms the south IESF for treatment of all forms phosphorus.

	Influent TP Conc. (mg/L)	N. Filter Effluent TP Conc. (mg/L)	S. Filter Effluent TP Conc. (mg/L)	N. Filter TP Removal Efficiency (%)	S. Filter TP Removal Efficiency (%)
Average	0.274	0.091	0.116	57.9	45.8
Median	0.229	0.090	0.116	59.0	49.8
Min	0.101	0.032	0.037	-	-
Max	0.900	0.234	0.236	-	-
St. Dev.	0.159	0.039	0.048	-	-

Table 14	Total phosphorus treatment performance at William Street Pond
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## Table 15 Ortho-P treatment performance at William Street Pond

	Influent Ortho-P Conc. (mg/L)	N. Filter Effluent Ortho-P Conc. (mg/L)	S. Filter Effluent Ortho-P Conc. (mg/L)	N. Filter Ortho- P Removal Efficiency (%)	S. Filter Ortho-P Removal Efficiency (%)
Average	0.031	0.005	0.012	47.5	35.9
Median	0.020	0.003	0.006	80.6	62.6
Min	0.003	0.003	0.003	-	-
Max	0.122	0.022	0.056	-	-
St. Dev.	0.029	0.004	0.013	-	-

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	Influent DP Conc. (mg/L)	N. Filter Effluent DP Conc. (mg/L)	S. Filter Effluent DP Conc. (mg/L)	N. Filter DP Removal Efficiency (%)	S. Filter DP Removal Efficiency (%)
Average	0.060	0.017	0.026	61.1	34.8
Median	0.046	0.010	0.010	73.4	66.6
Min	0.010	0.010	0.010	-	-
Max	0.187	0.122	0.129	-	-
St. Dev.	0.041	0.018	0.026	_	-

#### Table 16Dissolved phosphorus treatment performance at William Street Pond

Figure 31, Figure 32, and Figure 33 below show the combined average influent and effluent concentrations of TP, ortho-P, and dissolved P, respectively, for specific events over the course of the last 6 years. Figure 31 would indicate that since 2013, the influent total phosphorus concentration from the pond has a generally decreasing trend over time. The effluent concentration leaving the filters appears to be slightly higher in 2017 and 2018. Figure 32 and Figure 33 do not show similar trends in dissolved phosphorus and ortho-phosphate treatment.



Figure 31 Monitored Total Phosphorus Removal at the William Street Pond BMP



Figure 32 Monitored Ortho-P Removal at the William Street Pond BMP



Figure 33 Monitored Dissolved Phosphorus Removal at the William Street Pond BMP

## 5.3 Upper Villa Stormwater Reuse Facility

Influent TP, ortho-phosphate, and dissolved phosphorus monitoring data was collected upstream of the Villa Park Reuse System. However, no monitoring data was collected downstream of the system to quantify treatment efficiency of the system. Therefore, the calibrated P8 model was used to estimate the dissolved and total phosphorus reduction associated with the system (see Section 5.5).

## 5.4 Results Verification

## 5.4.1 Villa Park Outlet

Monitoring results were verified against historical reports and monitoring data. In the case of the Villa Park Wetland, phosphorus release occurs during the majority of the sampled events. Flow-weighted mean concentrations for a composite TP sample collected at the Villa Park Inlet and the Villa Park Outlet for the same storm event were compared to the P8 model for the same storms. These events and corresponding monitored and modeled flow-weighted mean TP concentrations are provided in Table 17. Red values are

instances where phosphorus release is occurs. The summarized events below suggest that the average effluent TP concentration leaving the Villa Park Outlet (0.17 mg/L) is approximately the same as the influent concentration (0.17 mg/L). In order to simulate this essentially 0% particle settling in the model, the particle removal scale factor through the Villa Park wetland system was changed from 1.0 to 0.2. With the particle scale removal factor reduced to 0.2, the average effluent modeled TP concentration leaving the Villa Park wetland (0.18 mg/L) is approximately 5% larger than the monitored effluent average concentration (0.17 mg/L).

	Monitored Data				Modeled Data				
Composite Sample Start Date	VP Inlet Obs. TP (mg/L)	VP Outlet Obs. TP (mg/L)	Percent TP Conc. Reduction	Obs. Flow Volume (ac-ft)	VP Inlet P8 TP (mg/L)	VP Outlet P8 TP (mg/L)	Percent TP Conc. Reduction	P8 Flow Volume (ac-ft)	
8/16/2016	0.20	0.21	-2%	4.80	0.19	0.14	23%	9.02	
9/21/2016	0.17	0.17	2%	10.67	0.18	0.20	-13%	10.46	
10/6/2016	0.19	0.20	-8%	9.58	0.23	0.19	16%	8.10	
4/15/2017	0.22	0.11	49%	2.47	0.26	0.16	37%	2.89	
6/11/2017	0.13	0.23	-74%	2.10	0.64	0.14	78%	3.75	
6/28/2017	0.11	0.13	-23%	1.09	0.40	0.21	46%	3.13	
8/9/2017	0.14	0.14	-1%	0.85	0.20	0.20	-1%	3.17	
8/13/2017	0.13	0.15	-17%	3.73	0.26	0.19	27%	7.62	
8/16/2017	0.20	0.14	34%	6.50	0.25	0.16	35%	9.08	
8/26/2017	0.13	0.15	-10%	6.14	0.20	0.16	21%	11.52	
9/25/2017	0.30	0.20	32%	1.72	0.37	0.12	68%	1.22	
6/16/2018	0.13	0.18	-38%	7.14	0.42	0.20	53%	6.50	
6/26/2018	0.13	0.17	-32%	5.42	0.34	0.19	45%	8.30	
8/24/2018	0.19	0.19	-3%	5.42	0.38	0.22	43%	7.57	

## Table 17 Total Phosphorus concentration comparison at the Villa Park Wetland System

## 5.4.2 Alameda Pond

The treatment from Alameda Pond (P8 device ID: WP14-004) and the William Street Pond (P8 device ID: WP10-001CP) were compared to the monitoring data summarized in the *Objective 3: Phosphorus Release from Stormwater Ponds* technical memo published in 2018 (3). The model was run during the timeframe that monitoring data was collected (July 2017 through May 2018). The model was run using precipitation data from the Villa Park rain gauge. Table 18 is a summary comparing the model to the technical memo.

#### Table 18 Total Phosphorus Load comparison at Alameda Pond

	Memo <sup>1</sup>	Model
TP Inflow (lbs.)	36.1	42.7
TP Outflow (lbs.)	16.9	11.1
Percent TP Removal	53%	74%

1 – The technical memo reports values in kilograms. These were converted to pounds to match the model output.

## 5.4.3 William Street Pond

The treatment provided by the William Street Pond was also compared to the results of the technical memo. As shown in Table 19, the model matches closely to the monitoring data.

Table 19 Total Phosphorus Load comparison at William Street Pond

	Memo <sup>1</sup>	Model <sup>2, 3</sup>
TP Inflow (lbs.)	10.6	11.6
TP Outflow (lbs.)	4.7	4.6
Percent TP Removal	56%	60%

1 – The technical memo reports values in kilograms. These were converted to pounds to match the model output.

2 - TP Inflow is calculated from the 13 total outflow + 08 sediment + decay terms.

3 – TP Outflow is calculated from the 03 infiltrate + 12 total outflow terms.

## 5.5 Mapping of Evaluated BMPs

After the model was calibrated, the future Parkview Center School underground detention and filtration system was added to the model (P8 Device ID: UGS1002). The figures shown below include the treatment provided by this proposed BMP.

Barr calculated average annual TSS and TP pollutant yield generated by device drainage areas for the study area based on a 10-year modeling period (October 2008 through October 2018). Total device drainage area yield is an estimate of the pollutant load generated by device drainage areas (devicesheds) throughout the modeling period with no consideration of pollutant removal by BMPs. Mapping of total yield can help to identify where pollutant loads are being generated in the watershed by highlighting areas where the areal yield rates are highest.

Effective yield reflects the yield rate after pollutant removal by the various BMPs throughout the watershed are considered. The intent is to present the loading that actually makes it into the receiving

waterbody from that location. For example, if a modeled BMP device removes half of the pollutant load it receives, then the effective yield rate tributary to that device would be half of the total yield rate. In the case of two or more BMPs occurring in series, effective yield accounts for reduction at the BMP and all downstream BMPs (i.e., the cumulative pollutant reduction). Cumulative pollutant reduction (%) is calculated based on the assumption that all pollutant outflow from a given BMP or device is further reduced by the percent pollutant reduction calculated at each downstream device. For example, if loading from an area is first treated by a BMP that removes 50% of the loading it receives and then treated by a second, downstream BMP that removes 30% of the loading it receives, the cumulative reduction (%) from that location is 65% [100% - (100% - 50%) x (100% - 30%) = 65%]. Effective yield is then calculated by applying the cumulative reduction (%) to the raw subwatershed yield [(Watershed Yield, lbs/acre/year) x (100% - Cumulative Reduction, %) = Effective Yield (lbs/acre/year)]. Because effective yield mapping indicates where yield is highest after considering the impact of existing water quality features, such mapping can be used to prioritize subwatersheds for future BMP implementation.

No load reduction occurs in P8 pipe devices. If the pipes are located upstream of a BMP that provides treatment, cumulative pollutant reduction (%) and effective yield will be calculated as described, above. For portions of the watershed where there is no downstream BMP (i.e., no downstream treatment), the effective yield is equal to the raw subwatershed yield.

Effective TP yield and TSS yield (lbs/ac/yr) are shown in Figure 34 and Figure 35, respectively. Pollutant reduction (%) of TP and TSS by BMPs within each device drainage area are shown in Figure 36 and Figure 37, respectively. Figure 34 through Figure 37 also show areas that were considered non-contributing, meaning they do not contribute runoff to the downstream storm sewer system during the entire 10-year period.








To:Bob Fossum and Joe Sellner, Capitol Region Watershed DistrictFrom:Greg Wilson, Heather Hlavaty & Lulu Fang, Barr Engineering CompanySubject:Lake McCarrons Management Plan: Task 4 and 5 BMP Evaluation and Watershed Model CalibrationDate:November 8, 2019Page:53

# 6.0 Description of Electronic Deliverables

Submitted along with this technical memorandum are copies of electronic data related to the Lake McCarrons watershed modeling update and calibration project. These files include digital copies of the report, model input data, and output files.

### 6.1 Model Report

The Model Report folder contains the final technical memorandum (i.e., this document) in Microsoft Word and PDF formats.

#### 6.2 Model Input Files

- Hydraulics
  - Storage: This folder contains the storage curves created from bathymetry data where provided. The folder also contains the 2011 DNR LiDAR storage curves for each subwatershed where bathymetry data was not provided.
  - $\circ$   $\;$  XP-SWMM: Models used to define the rating curves for complex outlets.
  - McCarrons\_P8Hydraulics.xlsx: spreadsheet documenting the P8 device data and assumptions used to develop the model hydraulics.
- Hydrology
  - Rainfall Data: precipitation files used for the P8 model
  - Uncalibrated: Includes the spreadsheet used to model the treatment from the rain gardens discussed in Section 3.3.1 and the spreadsheet to develop the uncalibrated model hydrology inputs.
  - o Calibrated: Includes the calibrated watershed import spreadsheet for the P8 model.

## 6.3 Model Output Files

- Calibration Results
  - Includes the spreadsheets used to summarize the results of calibration at the Upper Villa Inlet, Villa Park Outlet, and William Street Pond Inlet.
- AvgAnnual
  - Includes the spreadsheet used to summarize the calibrated 10-year average subwatershed and device TP and TSS treatment results.
- Calibrated\_Model\_Results.xlsx
  - Tabulation of model results shown on Figure 34 through Figure 37.
  - Table with summary of BMP P8 ID, BMP name, watershed TSS and TP percent reductions, and effective TSS and TP percent reductions.

#### 6.4 GIS Data

• Task5\_Model\_Data.gdb

 Geodatabase containing the calibrated subwatershed results and P8 devices used in the model and to generate Figure 34 through Figure 37.

# 7.0 References

1. **Benjamin D. Janke, Jacques C. Finlay.** *Analysis of Nutrient Loading and Performance of the Villa Park Wetland, 2006 - 2012.* Saint Paul, MN : Department of Ecology, Evolution, and Behavior, University of Minnesota, 2015.

2. **District, Capitol Region Watershed.** *Villa Park Wetland System Performance Analysis.* Saint Paul, MN : Capitol Region Watershed District, 2019.

3. Vinicius Taguchi, Tyler Olsen, Ben Janke, Heinz G. Stefan, Jacques Finlay, John S.Gulliver. Stormwater Research Summary Banner Objective 3 - Phosphorus Release from Stormwater Ponds. 2018.