METROPOLITAN COUNCIL

## Request for Scope of Work and Fee Estimate – Surface Water Quality Study (Study No. 7A)

**Project name:** White Bear Lake Area Comprehensive Plan **Date:** January 24, 2025
**Sublegislation:** Projects designed to increase groundwater recharge
**Study focus area:** Surface water quality study for White Bear Lake augmentation from chain of lakes

### Project Overview and Objectives

The Minnesota legislature provided funding for the Metropolitan Council (Met Council) to form a work group to develop a comprehensive plan to ensure communities in the White Bear Lake area have access to sufficient drinking water to allow for municipal growth while ensuring the sustainability of surface and groundwater resources to supply the needs of future generations. The completed plan must be submitted to the Minnesota Legislature by June 30, 2027. Met Council has established a work group consisting of the following members:

- Commissioners or designees from the DNR, MDH, and MPCA
- Representatives from Metropolitan Area Water Supply Advisory Committee (MAWSAC) and Saint Paul Regional Water Services (SPRWS).
- The communities of Stillwater, Mahtomedi, Hugo, Lake Elmo, Lino Lakes, North St. Paul, Oakdale, Vadnais Heights, Shoreview, Woodbury, New Brighton, White Bear Lake, White Bear Township, and North Oaks.

The consulting firms of Barr Engineering, Kimley-Horn, and Short Elliott Henderson (SEH) received master contracts for Water Supply Studies and Technical Analyses for White Bear Lake Area Comprehensive Plan (Contract Number 24P056). The consulting firm Hazen and Sawyer received a master contract for the Financial Analyses for White Bear Lake Area Comprehensive Plan (Contract Number 24P055).

The Comprehensive Plan shall evaluate the following water conservation methods as stated in the legislation:

1. Converting water supplies that are groundwater dependent to total or partial supplies from surface water
2. Reuse water, including water discharged from contaminated wells
3. Projects designed to increase groundwater recharge
4. Other methods for reducing groundwater use

For Category No. 3 projects designed to increase groundwater recharge, the work group identified and ranked the following potential solutions to further evaluate for this area of the legislation. The scope of work for this project includes studying and modeling surface water quality from the source (Mississippi River), in the chain of lakes, and in White Bear Lake, as it relates to potential solution No. 1 for lake augmentation. The results of this study will be used to further evaluate the infrastructure and treatment costs for lake augmentation as part of a separate study (Study No. 7B).

1. Lake augmentation by pumping treated surface water from the chain of lakes into White Bear Lake
2. Treat wastewater from local Met Council interceptors and inject the treated wastewater into the aquifer to raise groundwater elevations
3. Stormwater collection and infiltration to raise groundwater elevations

### Previous Met Council Surface Water Quality Analysis

Met Council Environmental Services (ES) water resources staff conducted previous water quality analysis work for the chain of lakes and White Bear in 2015-2016 and determined the following with respect to water quality data that existed at that time (see attached report for additional information).

- While multiple organizations have monitored Sucker, East Vadnais, and White Bear Lakes over time, the most recent and complete datasets have been collected by Ramsey County (White Bear Lake) and SPRWS for Sucker and East Vadnais Lakes.
- Ramsey County, SPRWS, and ES (for Mississippi River at Anoka, upstream from the SPRWS Fridley water intake) collected data using different monitoring programs with different end goals, leading to data collected at different depths, at different time intervals, with different equipment, for non-uniform chemical parameters determined by different laboratories. Concentrations for low level data, particularly phosphorus, were reported inconsistently by the three laboratories, with the SPRWS and Ramsey County labs having different reporting limits for phosphorus (0.02 mg/L vs. 0.01 mg/L, respectively). These factors make it difficult to conduct an accurate comparison of water quality in the river and lakes.
- Total phosphorus is the sole water quality parameter with sufficient data to allow comparison between the Mississippi River, and Sucker, East Vadnais, and White Bear Lakes. Different reporting limits for low level samples in the SPRWS, Ramsey County, and ES labs likely skewed reported average values. Comparison of average total phosphorus for May through September during 2005-2010 (which is when data were available for White Bear Lake) indicates phosphorus concentrations of 0.104 mg/L in the Mississippi River at Anoka, 0.015 mg/L in White Bear Lake and 0.039 mg/L and 0.035 mg/L in Sucker and East Vadnais Lakes, respectively, with the Mississippi River, Sucker and East Vadnais having more variability, with higher periodic concentrations.
- Comparison of total phosphorus for 2011-2015 indicates an average concentration of 0.121 mg/L in the Mississippi River at Anoka; 0.019 mg/L in White Bear Lake and 0.026 mg/L in East Vadnais. Data was not available for Sucker Lake during this time.
- The relatively low concentration of phosphorus in White Bear Lake means input of additional phosphorus to the lake may cause a disproportionately large decrease in water transparency, as predicted by statistical relationships developed by the MPCA and others.
- Temperature and dissolved oxygen profile plots indicate that thermal stratification at the West monitoring site in White Bear Lake has been intermittent, with short periods of near-sediment anoxia. Discharge of augmentation water could potentially disrupt stratification and cause delivery of near-sediment phosphorus to the lake surface.
- Effective operation of the East Vadnais hypolimnetic oxygenation system is essential to reduce and control phosphorus concentration in the lake. Disruption or discontinuance of the oxygenation system would likely result in elevated phosphorus concentrations in the lake.
- Besides phosphorus, other chemical and biological parameters are crucial to consider for protecting White Bear Lake, including differences between Sucker and East Vadnais Lakes and White Bear Lake in alkalinity, hardness, pH, sulfide, metals concentrations, bacteria abundance, chloride concentration, pesticide concentrations, PFAS, trace chemicals of emerging concern (like pharmaceuticals, estrogen disrupters, microplastics, etc.), and others. Insufficient data is available to compare the lakes for these parameters.
- Sufficient data are not available to identify, size, and provide costs for any necessary treatment to remove contaminants other than phosphorus.
- Lack of sufficient data for phosphorus, alkalinity, hardness, trace contaminants, and other parameters may hinder preparation of permits and verification of compliance with relevant state water quality standards and nondegradation requirements.

ES identified the following data gaps and potential risks in 2015-2016 in addition to other data gaps that may exist since then.

- Insufficient total phosphorus data to estimate potential changes to trophic level and water transparency in White Bear Lake with augmentation from Sucker or East Vadnais Lakes
- Lack of long-term monitoring showing effectiveness of East Vadnais hypolimnetic oxygenation system and lack of emergency operation plan for augmentation system if hypolimnetic oxygenation is disabled
- Insufficient data to assess potential threats to human and aquatic life from White Bear Lake augmentation

- Insufficient data to prepare necessary permits and meet regulatory requirements
- Insufficient data to identify, size, and estimate cost of treatment of augmentation water

**Scope of Work**

The consultant shall develop a calibrated surface water model to simulate flow patterns, water levels, and water quality; assess existing and future water quality conditions under various scenarios; provide decision support for water resource management strategies related to lake treatment and augmentation; and generate detailed documentation for model development and application. The consultant shall complete the following tasks to analyze and model the surface water quality upon mixing surface waters from the Mississippi River via the SPRWS pump station and the chain of lakes (Charley Lake, Pleasant Lake, Sucker Lake, and East Vadnais Lake) with White Bear Lake surface water. The final study report shall be submitted to ES by January 30, 2026, after all additional water sampling data is obtained by others in the spring, summer, and early fall of 2025.

**1. Project management**

a) Provide project management throughout the duration of the project. Project manager shall serve as the primary contact person with ES staff and attend all meetings, manage team and work, set schedules, and present study results to work group.

**2. Project team**

a) Project team, at a minimum, shall include the project manager, a senior hydrodynamic and surface water quality modeler, a water quality specialist, a GIS specialist, a data analyst, and a technical writer.

**3. Data collection and review**

a) Collect background information and past studies
b) Collect and create GIS data to support report figures and maps of study areas.
c) Collect existing surface water quality data for Mississippi River, chain of lakes, and White Bear Lake from ES, Ramsey County Public Works, SPRWS, Vadnais Lake Area Water Management Organization (VLAWMO), and other sources.
d) Review bathymetric surveys of water bodies from the DNR, United States Geological Survey (USGS), VLAWMO, and other sources
e) Review shoreline and riverbank characteristics, sediment composition, and distribution, physical structures, and tributary locations and characteristics.
f) Review hydrologic data including stream flow measurements, water level recordings, precipitation records, evaporation data, and weather data (temperature, wind, solar radiation).
g) Review all existing water quality data including temperature profiles, dissolved oxygen, nutrients, suspended solids, pH and conductivity, metals, toxic chemicals, and other constituents of concern.

**4. Projected Community Water Demands Review**

a) The consultant shall review and use the projected average day and maximum day demands for current conditions, year 2050, and ultimate development that have been prepared by ES for each of the fourteen (14) White Bear Lake Area work group communities and customers of SPRWS as they relate to potential future flow rates through the chain of lakes and White Bear Lake.

**5. Surface Water Quality Goals**

a) Review existing water quality data and additional water quality data to be obtained for the Mississippi River, chain of lakes, and White Bear Lake, and provide recommendations for additional sampling as needed. Additional water samples that could be obtained and analyzed by others could include, but are not limited to, phosphorus, nitrogen compounds, PFAS, alkalinity, hardness, pH, dissolved oxygen, temperature, sulfide, chloride, metals, dissolved solids, bacterial abundance, trace chemicals, invasive species, and emerging contaminants (pharmaceuticals, estrogen disruptors, etc.). Water sampling shall be conducted by others, and all water sampling and laboratory analysis costs shall be paid for separately from this project.

b) Identify and recommend acceptable water quality goals for the chain of lakes and White Bear Lake for both ecosystems and lake recreation to ES staff and other organizations.
c) Attend and conduct a meeting with ES, DNR, SPRWS, MDH, MPCA, Ramsey County Public Works, the VLAWMO, and others to discuss recommended water quality goals, additional water sampling needed, and objectives for study and modeling.

**6. Additional Surface Water Quality Review**

a) Review additional water quality data to be obtained by others for the Mississippi River, the chain of lakes (Charley Lake, Pleasant Lake, Sucker Lake, East Vadnais Lake, and White Bear Lake. To facilitate accurate statistical comparison of water quality between the water bodies, each will be sampled synoptically using the same type of equipment and all samples analyzed using one laboratory. Parameters to be sampled will include those that will help: 1) Identify level of treatment required for augmentation water prior to discharge to White Bear Lake, 2) Identify those parameters which may present risks to human health, aquatic recreation and aquatic life (including fisheries, aquatic plants, aquatic macroinvertebrates, and other aquatic life) in White Bear Lake, and 3) Quantify those parameters necessary to negotiate permits for augmentation with appropriate regulatory authorities and to verify compliance with state water quality standards and nondegradation requirements.

**7. Surface Water Quality Modeling and Analysis**

a) Prepare a computerized 3D surface water quality model with AEM3D from HydroNumerics or equal with hydrodynamic, water quality, and sediment transfer modules. Model shall be calibrated with hydrodynamic calibration, water quality calibration, sensitivity analysis, model validation using independent data states, and statistical analysis of model performance. Demonstrate proposed modeling software with ES staff prior to development of model. Present proposed model setup including grid development and refinement, boundary conditions, initial condition definition, parameter estimation, integration of physical features, and set-up of water quality components.
b) Complete a mass balance analysis as the first step to help better direct the model development.
c) Simulate and analyze water quality from the mixing of Mississippi River and the chain of lakes surface water as a whole with White Bear Lake surface water, and determine the long-term water quality results for multiple scenarios including their impacts and expected water quality and clarity for the chain of lakes (Charley Lake, Pleasant Lake, Sucker Lake, and East Vadnais Lake) and White Bear Lake for the current community water demands, projected 2050 community water demands, and the ultimate development community water demands from the White Bear Lake Area communities and customers that are served by SPRWS. The water quality parameters to be modeled and resulting concentrations and water clarity determined for all scenarios through modeling shall include, but not be limited to, trophic state, phosphorus, nitrogen compounds, alkalinity, hardness, pH, dissolved oxygen, temperature, sulfide, chloride, pesticide, PFAS, metals, dissolved solids, bacteria abundance, trace chemicals, emerging contaminants (pharmaceuticals, estrogen disruptors, microplastics, etc.).
d) After modeling is completed in Part c., model and complete a sensitivity analysis with higher, fictitious concentrations of the contaminants and water quality parameters that are modeled with actual water quality data to predict if higher concentrations could have minimal or significant impacts on the water bodies if such concentrations are experienced in the future.
e) In addition to determining concentration differences as a screening tool to identify potential impacts, model and determine the lake responses and eutrophication impacts with mass balances for high-risk constituents to determine the magnitude of their impacts for each scenario. Input data and toxic parameters will be established by ES staff and possibly other organizations.
f) Conduct a risk assessment for toxics, pesticides, organics, and other toxic substances using Mississippi River data and estimate parameter concentrations in each of the lakes using a mass balance approach for each of the scenarios. This also includes any injection for lake management such as ferric chloride that is injected by SPRWS.
g) Provide an overall mitigation plan to prevent, treat, and address contaminants of concern in the chain of lakes prior to augmenting and pumping the surface water to White Bear Lake. Infrastructure improvements for distribution and treatment as they relate to lake augmentation, including their estimated capital and operation and maintenance (O&M) costs, will be evaluated by others as part of a separate study.

**8. Watershed Modeling and Analysis**

a) Provide watershed modeling analysis for all watersheds that contribute stormwater runoff to the chain of lakes and White Bear Lake to determine runoff volume and pollutant loading to each of the lakes and include these results in the surface water quality modeling analysis.

**9. Report preparation and review**

a) Full report including model description, model scenarios and results, risk assessments, mitigation, plan, recommendations, and conclusion. Provide electronic Word copy of report with text, detailed graphs, figures, and maps that illustrate water quality modeling results for each of the lakes for all scenarios.
b) Attend one draft report review meeting with ES staff and address edits and other changes needed.
c) Submit final study report including an electronic copy of the model and all associated files.

**10. Public outreach**

a) Prepare meeting materials
b) Provide up to two presentations to the White Bear Area Comprehensive Plan Work Group

**<u>Requested Information from Consultant</u>**

The consultant shall provide the following information. All work and recommendation shall follow and comply with Minnesota rules governing waters of the state - Minnesota Rules, chapter 7050; the Federal Safe Drinking Water Act - US Code, Title 42, Chapter 6A, Subchapter XII); the National Primary Drinking Water Regulations and Implementation - Title 40, Code of Federal Regulations, Part 141 and Part 142; and Recommended Standards for Water Works (Ten States Standards) - Great Lakes - Upper Mississippi River Board (GLUMRB).

1. Detailed scope of work
2. Project manager and team
3. Estimated fee spreadsheet with scope of work/task breakdown, estimated hours for each task, staff names assigned to each task and their current hourly billing rates, and estimated fees.
4. Project schedule

METROPOLITAN COUNCIL

# MEMORANDUM

**TO:** Sam Paske, Assistant General Manager, Environmental Quality Assurance (EQA) – Metropolitan Council Environmental Services (MCES)

**FROM:** Karen Jensen and Erik Herberg, Water Resources Assessment Unit – MCES

**DATE:** January 4, 2016

**SUBJECT:** Comparison of water quality between White Bear Lake and potential surface water augmentation sources (Sucker and East Vadnais Lakes) and identification of data gaps and potential risks

## Executive Summary

This memo was assembled by Metropolitan Council Environmental Services (MCES) staff as part of the *Concept Cost Report for Augmentation of White Bear Lake with Surface Water,* prepared by the Minnesota Department of Natural Resources (DNR) with cooperation from MCES in response to legislative request ("Sucker Lake Chain of Lakes to White Bear Lake Augmentation"; SF 5: 2nd Engrossment – 89th Legislature, 2015 Special Session (2015-2015), Posted on 06/17/2015; HF 4: House for the 89th Legislature, 2015 1st Special Session (2015-1015).

The purpose of this memo is to assemble and compare available water quality data for White Bear Lake to that of potential surface water augmentation sources (Sucker Lake and East Vadnais Lake); to identify potential risks to White Bear Lake water quality, aquatic life, and aquatic recreation; to identify potential data gaps for permit preparation and regulatory review; to identify potential data gaps for sizing and estimating costs for any necessary treatment; and to recommend potential actions to reduce risk.

MCES has determined that

- While multiple organizations have monitored Sucker, East Vadnais, and White Bear Lakes over time, the most recent and complete datasets have been collected by Ramsey County (White Bear Lake) and Saint Paul Regional Water Services; SPRWS; Sucker and East Vadnais Lakes).
- Ramsey County, SPRWS, and MCES (for Mississippi River at Anoka, upstream from the SPRWS Fridley water intake) collected data using different monitoring programs with different end goals, leading to data collected at different depths, at different time intervals, with different equipment, for non-uniform chemical parameters determined by different laboratories. Concentrations for low level data, particularly phosphorus, were reported inconsistently by the three laboratories, with the SPRWS and Ramsey County labs having different reporting limits for phosphorus (0.02 mg/L vs. 0.01 mg/L, respectively). These factors make it difficult to conduct an accurate comparison of water quality in the river and lakes.
- Total phosphorus is the sole water quality parameter with sufficient data to allow comparison between the Mississippi River, and Sucker, East Vadnais, and White Bear Lakes. Different reporting limits for low level samples in the SPRWS, Ramsey County, and MCES labs likely

skewed reported average values. Comparison of average total phosphorus for May through September during 2005-2010 (which is when data were available for White Bear Lake) indicates phosphorus concentrations of 0.104 mg/L in the Mississippi River at Anoka, 0.015 mg/L in White Bear Lake and 0.039 mg/L and 0.035 mg/L in Sucker and East Vadnais Lakes, respectively, with the Mississippi River, Sucker and East Vadnais having more variable, with higher periodic concentrations.

- Comparison of total phosphorus for 2011-2015 indicates an average concentration of 0.121 mg/L in the Mississippi River at Anoka; 0.019 mg/L in White Bear Lake and 0.026 mg/L in East Vadnais. Data were not available for Sucker Lake during this time.
- The relatively low concentration of phosphorus in White Bear Lake means input of additional phosphorus to the lake may cause a disproportionately large decrease in water transparency, as predicted by statistical relationships developed by the MPCA and others.
- Temperature and dissolved oxygen profile plots indicate that thermal stratification at the West monitoring site in White Bear Lake has been intermittent, with short periods of near-sediment anoxia. Discharge of augmentation water could potentially disrupt stratification and cause delivery of near-sediment phosphorus to the lake surface.
- Effective operation of the East Vadnais hypolimnetic oxygenation system is essential to reduce and control phosphorus concentration in the lake. Disruption or discontinuance of the oxygenation system would like result in elevated phosphorus concentrations in the lake.
- Besides phosphorus, other chemical and biological parameters are crucial to consider for protecting White Bear Lake, including differences between Sucker and East Vadnais Lakes and White Bear Lake in alkalinity, hardness, pH, sulfide, metals concentrations, bacteria abundance, chloride concentration, pesticide concentrations, trace chemicals of emerging concern (like pharmaceuticals, estrogen disrupters, etc.), and others. Insufficient data are available to compare the lakes for these parameters.
- Sufficient data are not available to identify, size, and cost any necessary treatment to remove contaminants other than phosphorus.
- Lack of sufficient data for phosphorus, alkalinity, hardness, trace contaminants, and other parameters may hinder preparation of permits and verification of compliance with relevant state water quality standards and nondegradation requirements.

In specific, MCES identifies the following data gaps and potential risks

- Insufficient total phosphorus data to estimate potential changes to trophic level and water transparency in White Bear Lake with augmentation from Sucker or East Vadnais Lakes
- Lack of long-term monitoring showing effectiveness of East Vadnais hypolimnetic oxygenation (HO) system and lack of emergency operation plan for augmentation system if HO is disabled
- Insufficient data to assess potential threats to human and aquatic life from White Bear Lake augmentation
- Insufficient data to prepare necessary permits and meet regulatory requirements
- Insufficient data to identify, size, and estimate cost of treatment of augmentation water

Based on these conclusions, MCES recommends

- Identification of acceptable water quality goals for White Bear Lake, given potential detrimental effects from augmentation

- Collection of uniform, comparable data for the Mississippi River, Sucker Lake, East Vadnais Lake, and White Bear Lake, and potentially Centerville Lake, including sampling at depth. To facilitate accurate statistical comparison of water quality between the water bodies, each should be sampled synoptically using the same type equipment and all samples analyzed using one laboratory. Parameters sampled should include those that will help
    - Identify level of treatment required for augmentation water prior to discharge to White Bear Lake
    - Identify those parameters which may present risks to human health, aquatic recreation and aquatic life (including fisheries, aquatic plants, aquatic macroinvertebrates, and other aquatic life) in White Bear Lake
    - Quantify those parameters necessary to negotiate permits for augmentation with appropriate regulatory authorities and to verify compliance with state water quality standards and nondegradation requirements.
- Inclusion in augmentation system planning an acknowledgment that a long term monitoring plan should be implemented for the purpose of assessing White Bear Lake during augmentation, in order to evaluate short term and long term effects on lake water quality.
- Creation of a lake computer simulation model for White Bear Lake to assess potential alterations in water quality and biological activity from proposed augmentation program.

## Technical Memo Body

## Purpose of Memo

This memo was assembled by Metropolitan Council Environmental Services (MCES) staff as part of the *Concept Cost Report for Augmentation of White Bear Lake with Surface Water,* prepared by the Minnesota Department of Natural Resources with cooperation from MCES in response to legislative request ("Sucker Lake Chain of Lakes to White Bear Lake Augmentation"; SF 5: 2$^{nd}$ Engrossment – 89$^{th}$ Legislature, 2015 Special Session (2015-2015), Posted on 06/17/2015; HF 4: House for the 89$^{th}$ Legislature, 2015 1$^{st}$ Special Session (2015-1015). The purpose of this memo is to

- Assemble available water quality data for Sucker Lake, East Vadnais Lake, and White Bear Lake, as well as other sources waters (i.e. Mississippi River, Pleasant Lake, etc.), where possible.
- Compare water quality
- Identify potential water quality issues potential risks to aquatic life, human health, and aquatic recreation; and data gaps for regulatory authority review and permit preparation
- Identify potential water quality issues and data gaps for designing, sizing, and estimating cost for potential treatment of source water before discharge to White Bear Lake
- Assemble conclusions
- Recommend future actions, if any

MCES did not attempt to identify any changes in White Bear Lake water quality over. MCES did not attempt to correlate water quality in Sucker and East Vadnais Lakes with annual variation in Saint Paul Regional Water Services (SPRWS) operations or to volume of discharge to the lakes from SPRWS source waters.

## Data Sources and Existing Monitoring Programs

The water quality data presented in this memo originate from three agencies: Metropolitan Council Environmental Services (MCES), St. Paul Regional Water Services (SPRWS) and Ramsey County. The three agencies collect data using three separate monitoring programs, with disparate goals for the data and associated water quality assessments. To summarize,

- MCES collects water quality data from multiple stations within the region's three major rivers – the Mississippi, the Minnesota, and the St. Croix – in order to assess water quality impacts from wastewater treatment plant (WWTP) effluent discharge and to assess region-wide river water quality. Samples are regularly collected throughout the year and parameters include nutrients (phosphorus and nitrogen), sediment, chlorophyll, chloride, biological and chemical oxygen demand, alkalinity, hardness, bacteria, and metals, and occasionally miscellaneous parameters such as pesticides, PCBs, and contaminants of emerging concern.

  Temperature, pH, and dissolved oxygen data from the Mississippi River at Anoka was downloaded from Metropolitan Council's database via the EIMS website (*http://es.metc.state.mn.us/eims/*). Data for the remaining parameters for the Mississippi River at Anoka were obtained from MCES data management staff.

- SPRWS collects water quality data from multiple stations in water bodies used to transport and supply source water to the SPRWS water treatment plant (McCarron's WTP). SPRWS removes river water from the Mississippi at an intake located at the City of Fridley, adds a coagulant, and then pumps it through two pipes to Charley Lake. The coagulant allows formation of particles which then settle out in Charley Lake, removing various constituents, such as phosphorus and suspended sediment, from the river water. From Charley Lake the water flows by gravity to Pleasant Lake to Sucker Lake to East Vadnais Lake and then to McCarron's WTP. Additional source water may be discharged to Pleasant Lake from the Rice Creek/Centerville Chain of Lakes and from Otter and Bald Eagle Lakes. Well water from Prairie du Chien/Jordan Aquifer wells may be added downstream of East Vadnais Lake.

A one-year snapshot of the source waters entering the McCarrons's WTP is provided by the water use allocations reported to the Minnesota Department of Natural Resources (DNR) by SPRWS for 2014:

- Mississippi River water = 8,098 MGY (52%)
- East Vadnais Lake = 13,223 MGY (33% after subtracting Mississippi River volume)
- Centerville Lake = 0 MGY (0%)
- Prairie du Chien/Jordan Aquifer wells = 2,277 MGY (15%)
- Total = 15,500 MGY (assumes 100% of Mississippi River water flows to East Vadnais)

Since 1984, SPRWS has installed multiple practices to the Mississippi intake, to Pleasant Lake, and to Vadnais Lake with the goal of reducing taste and odor issues in drinking water produced by the McCarron's Water Treatment Plant (WTP). A timeline of installed practices includes (Austin et al., 2015):

- 1984 — No treatment on any lake
- November 1986 — Hypolimnetic aeration (HA) installed at East Vadnais Lake
- April 1987 — Ferric chloride feed at Mississippi River intake
- 1988 — Ferric feed piloted on East Vadnais Lake
- 1990 — HA replaced in East Vadnais Lake
- August 1994 — HA installed on Pleasant Lake
- 2007 — Pleasant Lake aeration system ceased
- 2009 — CH2M begins reservoir work
- Summer 2011 — Aeration systems removed from Pleasant and East Vadnais Lakes
- Fall 2011 — Hypolimnetic Oxygenation (HO) installed in East Vadnais Lake
- Fall 2013 — HO system installed in Pleasant Lake

Surface water samples from Sucker and East Vadnais Lakes were primarily collected by SPRWS during spring, summer, and fall (when lakes are more biologically active), except for the McCarron's WTP inlet, which was sampled year round. The SPRWS lake monitoring program focuses on the water quality parameters which provide pertinent data on potential drinking water taste and odor issues and potential human health metrics, in order to help optimize the efficiency of water treatment processes from the Mississippi River to the McCarron's WTP inlet. The SPRWS's end goal is to produce drinking water that meets and exceeds the Safe Drinking Water Act.

Water quality data for the water bodies along the SPRWS supply line (i.e. Mississippi River at Fridley, Pleasant Lake, Sucker Lake, East Vadnais Lake, and raw water entering McCarron's WTP) were provided by SPRWS staff.

- Ramsey County collects data from four monitoring stations within White Bear Lake, typically between May and September. The primary purpose of the county monitoring program is to assess the lake's trophic status – i.e. level of biological production – with a particular focus on those parameters indicative of level of human satisfaction with recreating (swimming, boating, and fishing) on the lake. Parameters assessed include Secchi disk depth (lake transparency), phosphorus concentration, chlorophyll a, (a surrogate for algal production), dissolved oxygen and temperature.

  White Bear Lake data were supplied to MCES by Ramsey County staff.

## Descriptions of Study Lakes

Sucker Lake is small (68 acres) and relatively shallow (24 feet maximum depth), East Vadnais larger and deeper (394 acres; greater than 50 feet maximum depth); while White Bear Lake has a surface area of greater than 2,400 acres and maximum depth greater than 83 feet at the East monitoring station (Table 1). Note that the West lobe of White Bear Lake, which is the proposed location for augmentation water discharge, is relatively shallow (approximately 22 feet). All three lakes have been listed in the MPCA's 303(d) (Impaired Water List; MPCA, 2014) as impaired for aquatic consumption due to mercury in fish tissue.

**Table 1: Comparison of lake morphologies, beneficial uses, and impairments in Sucker, East Vadnais, and White Bear Lakes**

| Lake | ID | Area (acres) | Maximum Depth (feet) | MPCA Beneficial Use Classification[4] | Impairments[5] |
|---|---|---|---|---|---|
| Sucker Lake | 62002800 | 68[1] | 24[1] | 1C, 2Bd, 3C | Aquatic Consumption (Hg in fish tissue) |
| East Vadnais | 62003801 | 394[2] | 53 (North)[2]<br>58 (South)[2] | 1C, 2Bd, 3C | Aquatic Consumption (Hg in fish tissue) |
| White Bear Lake | 82016700 | 2,416[3] | 83 (East)[3]<br>28 (North)[3]<br>35 (Center)[3]<br>22 (West)[3] | 2B, 3C | Aquatic Consumption (Hg in fish tissue) |

[1] According to Minnesota Department of Natural Resources (DNR) bathymetric maps dated 3/12/1980 (http://files.dnr.state.mn.us/lakefind/data/lakemaps/c2758010.pdf). Water level unknown.
[2] According to Minnesota Department of Natural Resources (DNR) bathymetric maps dated 7/30/1981 (http://files.dnr.state.mn.us/lakefind/data/lakemaps/b0486010.pdf). Water level unknown.
[3] According to Minnesota Department of Natural Resources (DNR) bathymetric maps dated 8/3/1978 (http://files.dnr.state.mn.us/lakefind/data/lakemaps/b0469011.pdf). Water level unknown.
[4] MPCA beneficial use classifications. 1C = drinking water; 2Bd = cool and warm water fisheries, drinking water; 3C = Industrial uses and cooling; 2B = cool and warm water fisheries
[5] MPCA 303(d) list, 2014. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/impaired-waters-list.html

East Vadnais and Sucker Lakes have more complicated contributing watersheds than that in White Bear Lake, which receives runoff from a directly-contributing watershed of 2,300 acres during normal precipitation years (7.744 acres during unusually wet years) (Table 2). East Vadnais and Sucker Lakes are identified as a single hydrologic system by the Vadnais Lakes Area Water Management Organization (VLAWMO). Both receive runoff from the landscape directly surrounding the lakes (2,192 acres) and from upstream waterbodies like Pleasant Lake and Lambert Creek (12,897 ac). The Mississippi River at the SPRWS Fridley intake location has a watershed area of greater than 12,000,000 ac, with associated water quality affected by agricultural drainage, wastewater treatment plant discharge, urban runoff, and gully and river bank erosion, among other sources.

**Table 2: Comparison of watershed areas of Sucker, East Vadnais, and White Bear Lakes**

| Waterbody | Lake ID | Direct Contributing Watershed Area (acres) | Upstream Watershed Area (acres) | SPRWS Source Watershed Area (Mississippi River at Fridley) (acres) | Total Area (Contributing, Upstream, and SPRWS) (acres) |
|---|---|---|---|---|---|
| East Vadnais/Sucker Lakes | 62003801<br><br>62002800 | 2,192 [1] | 12,897 [2] | 12,380,000 [3] | 12,392,897 |
| White Bear Lake | 82016700 | 2,300 – normal years [4]<br><br>7,744 – wet years [4,5] | 0 | 0 | 2,300<br><br>(7,744 wet years) |

[1] Vadnais Lake Area Watershed Management Organization (VLAWMO) Watershed Management Plan dated December, 2007. Accessed 12/16/2015. (http://www.vlawmo.org/files/6113/9343/9936/07_Chapter_2.pdf)

[2] Calculated as the sum of the upstream areas of Lambert Creek (5,140 acres), Tamarack/Wilkinson (4,391 acres), and Pleasant/Charley/Deep (3,366 acres), as reported in Vadnais Lake Area Watershed Management Organization (VLAWMO) Watershed Management Plan dated December, 2007. Accessed 12/16/2015. (http://www.vlawmo.org/files/6113/9343/9936/07_Chapter_2.pdf)

[3] Calculated using the drainage area delineation tool of USGS StreamStats with NAD 1983 Latitude 45.1033 and Longitude -93.2779 (approximate location of SPRWS intake pipe in the Mississippi River at Fridley).

4 Contributing watershed area in typical years. In extremely wet years, an additional 5,250 acres can contribute to the lake. Reported in Appendix 1 of White Bear Lake Conservation District (WBLCD) Lake Management Plan 4/27/99. Accessed 12/16/2015. (http://www.wblcd.org/wl/index.php/appendix-i#Drainage).

[5] 2010 Rice Creek Watershed District (RCWD) Watershed Management Plan, amended November 2014. Accessed 12/16/2015. (http://www.ricecreek.org/vertical/Sites/%7BF68A5205-A996-4208-96B5-2C7263C03AA9%7D/uploads/2010-RCWD-Watershed_Management_Plan-amended_11-12-14%281%29.pdf)

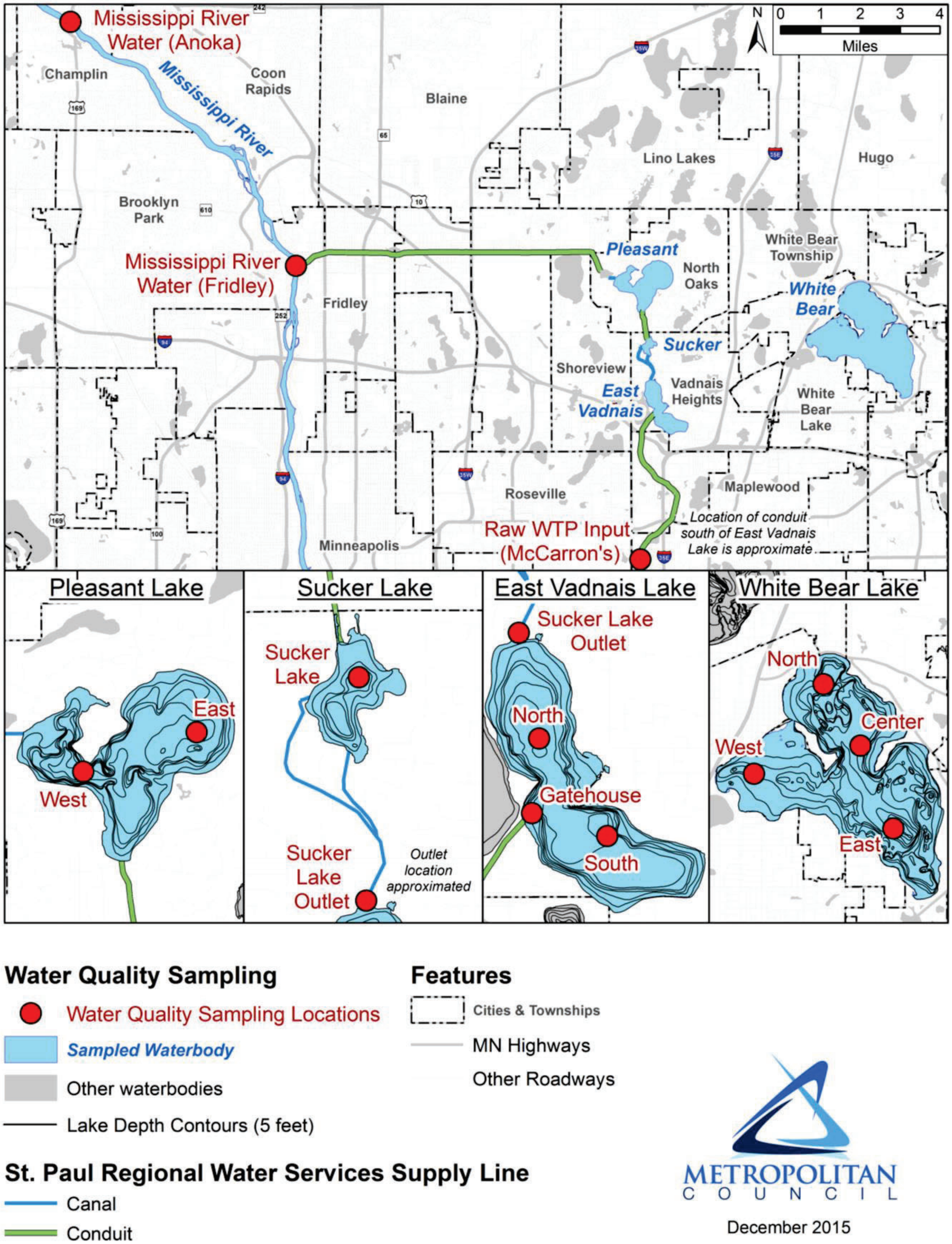
## Available Data and Sampling Locations

While the *Concept Cost Report for Augmentation of White Bear Lake with Surface Water* was specifically designed to look at the potential for surface water augmentation from Sucker Lake and from East Vadnais Lake, MCES staff compiled all available surface water quality data from 2005 to 2015 for 13 sampling sites on five water bodies – Mississippi River (at Anoka and Fridley), Pleasant Lake (East and West), Sucker Lake (Lake and Outlet), East Vadnais Lake (North, South, and Gatehouse), and White Bear Lake (North, East, West, and Central). For completeness, MCES also compiled data on the raw water entering McCarron's WTP from East Vadnais Lake. At some sites, water quality data are available before 2005, but is not included in this analysis. The locations of each sampling site are shown in Figure 1. A summary of the sampling at each site is presented below:

- **Mississippi River at Anoka** – sampled year-round since 1976 by MCES from the middle of the river, one meter below the surface.
- **Mississippi River at Fridley** – sampled year round by SPRWS from the intake pumping station (depth of the intake pipe in the Mississippi River was not provided).
- **Pleasant Lake (East and West)** – collected April to September by SPRWS, most often around 3 and 13 meters below the surface of the lake. Temperature and dissolved oxygen (DO) were measured at 1 meter increments from lake surface to lake bottom during multiple years.
- **Sucker Lake** – sampled April to October by SPRWS, most often at 3 and 5 meters deep. Monitoring ended in Sucker Lake at the end of 2009. Temperature and dissolved oxygen (DO) were measured at 1 meter increments from lake surface to lake bottom for multiple years, with 2008 as the last complete year of data.
- **Sucker Lake Outlet** – sampled by SPRWS during April to November at 3 meters below the surface of the end of the canal which drains into East Vadnais Lake. The exact location of the sampling station was not provided. Monitoring ended at the site after 2010.
- **East Vadnais (North and South)** – collected April to September by SPRWS, most often around 3 and 13 meters below the surface of the lake. Temperature and dissolved oxygen (DO) were measured at 1 meter increments from lake surface to lake bottom for multiple years.
- **East Vadnais (Gatehouse)** – sampled year-round by SPRWS near the intake pipe to McCarron's treatment plant, ranging from 7 – 15 meters below the surface, although exact depths were not provided.
- **Raw WTP Input (McCarron's Potable Water Treatment Plant (WTP))** - sampled year-round by SPRWS from the terminal chamber of the pipe bringing water from East Vadnais Lake to McCarron's WTP.
- **White Bear Lake** – four monitoring sites sampled May to September by Ramsey County, most often at or near the lake surface. Temperature and dissolved oxygen (DO) were measured at 1 meter increments from lake surface to lake bottom at all four sites for multiple years. At the East and Central sites, Total Phosphorus, turbidity, chloride, chlorophyll a, nitrate/nitrite, and ammonia were often monitored at additional depths.

Between 2005 and 2015, there are several periods of time where sampling was not performed regularly for parameters at several of the sites. These gaps in the datasets are summarized in the footnotes of Table 5 and Table 6.

**Figure 1. Water Quality Sampling Locations**



## Water Quality Comparison

Comparison of water quality between the various water bodies for many typical water quality parameters was not possible due to disparate and incomplete datasets for the river and each lake. Each of the three monitoring agencies (MCES, SPRWS, and Ramsey County) collected samples at dissimilar depths, different frequencies, and different seasons of the year, for different chemical and biological parameters, with different equipment, using different environmental testing laboratories, ultimately to meet different goals.

White Bear Lake was only sampled in the months of May through September, so datasets for all lakes were limited to those months. Sucker Lake and Sucker Lake Outlet were only sampled until 2009 and 2010, respectively, so MCES separated the datasets into two time frames: 2005 – 2010 and 2011 – 2015. The 2005 - 2010 allowed more direct comparison of Sucker, East Vadnais, and White Bear Lake.The 2011 - 2015 period presents the most recent available data for East Vadnais and White Bear Lakes, but excludes direct comparison with Sucker Lake, since no data were collected during that time. MCES used that data collected closest to the surface of the waterbodies, which is the most common practice in limnological comparisons.

MCES, Ramsey County and SPRWS have in-house laboratories. Variations in equipment and methods between laboratories resulted in variation in detection limits and reporting limits, particularly of total phosphorus (Table 3). Both SPRWS and Ramsey County use their respective reporting limits (which are determined by laboratory precision and accuracy, which are influenced by laboratory equipment, processes, analytical methods, and analysts) as minimal reported values for total phosphorus concentrations. MCES processed data as needed. For example, if multiple measurements of a parameter occurred on the same day at the same depth (for example, duplicate samples), those results were averaged to produce one value.

**Table 3. Summary of laboratory certification, phosphorus detection limits, and phosphorus reporting limits, for MCES, Ramsey County, and SPRWS labs**

| Agency | Laboratory Name | Certification | Total Phosphorus Detection Limit (mg/L) | Total Phosphorus Reporting Limit (mg/L) |
|---|---|---|---|---|
| MCES | MCES Analytical Services | MN Dept. of Health - ID 027-123-172 | 0.02 | 0.05 |
| Ramsey County | Ramsey County Lake Management | MPCA - ID MNL0002 | 0.004 | 0.01 |
| SPRWS | SPRWS – Water Quality Unit Laboratory | MN Dept. of Health - ID 027-123-106 | 0.009 | 0.02 |

Table 4 identifies a minimal slate of water quality parameters typically used by regulatory agencies to assess suitability of lake quality for human recreation and aquatic life. Additional parameters may be required by regulatory agencies before negotiating necessary permits for discharge of augmentation water to White Bear Lake. Table 4 also provides a summary of the calculated averages for those parameters for the Mississippi River at Anoka, and Sucker, East Vadnais, and White Bear Lakes for the months of May to September for 2005 – 2010 and 2011 –, while averages, medians, maximums, minimums, and counts of parameters at the original monitoring sites are detailed in Table 4 (for period 2005 – 2010) and Table 5 (for period 2011 – 2015).

**Table 4. Summary of averages for various water quality parameters in Sucker, East Vadnais, and White Bear Lakes for May to September in 2005-2010 and 2011-2015**

| | 2005 – 2010 (May – Sept) | | | | | 2011-2015 (May – Sept) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sites** | Mississippi River (Anoka) | Sucker Lake | Sucker Lake Outlet | East Vadnais Lake [a] | White Bear Lake [b] | Mississippi River (Anoka) | Sucker Lake | Sucker Lake Outlet | East Vadnais Lake [a] | White Bear Lake [b] |
| **Data Source** | MCES | SPRWS | SPRWS | SPRWS | Ramsey County | MCES | SPRWS | SPRWS | SPRWS | Ramsey County |
| **Sample Depth (meters)** | 1 | 3 | 3 | 3 | 0 - 0.5 | 1 | 3 | 3 | 3 | 0 - 0.5 |
| *Alkalinity, Total (mg/L as CaCO3)* | 174 | - | - | - | # | 168 | - | - | - | - |
| *Ammonia (mg-N/L)* | 0.04 | 0.256 * | 0.075 * | # | 0.055 | 0.03 | - | - | - | 0.024 |
| *Chloride (mg/L)* | 17.2 | - | - | - | 37.8 | 14.8 | - | - | - | 39.0 |
| *Chlorophyll a, corrected (ug/L)* | 39.3 | - | - | - | 4.62 | 19.5 | - | - | - | 4.91 |
| *Chlorophyll a, uncorrected (ug/L)* | 42.6 | 19.93 * | 14.97 | - | - | 22.4 | - | - | 12.73 | - |
| *Coliform, Total (CFU Count/100 mL)* [c] | - | - | 1224 | - | - | - | - | - | - | - |
| *Dissolved Oxygen (mg/L)* | 8.78 | - | # | # | 9.43 | 8.20 | - | - | - | 9.16 |
| *E. coli (MPN Count/100 mL)* [c] | 44 | - | 1 * | - | - | 71 | - | - | - | - |
| *Hardness, Total (mg/L as CaCO3)* | 208 | - | - | - | # | 198 | - | - | - | - |
| *Nitrate/Nitrite (mg-N/L)* | 0.89 | 0.146 * | 0.096 * | # | 0.012 | 0.90 | - | - | # | 0.016 |
| *Nitrogen, Total (mg-N/L)* [d] | 1.87 | # | # | - | 0.77 | 1.94 | - | - | 0.681 | 0.81 |
| *pH* [e] | 8.27 | - | - | - | 7.99 | 8.05 | - | - | # | 8.30 |
| *Phosphorus, Total (mg-P/L)* | 0.104 | 0.039 * | 0.056 * | 0.034 | 0.015 | 0.121 | - | - | 0.026 | 0.019 |
| *Secchi (m)* | - | # | - | # | 3.8 | - | - | - | - | 3.2 |
| *Temperature (°C)* | 21.3 | # | - | # | 20.80 | 20.7 | - | - | - | 21.03 |
| *Turbidity (NTU)* | # | - | - | - | 1.7 | - | - | - | # | 1.8 |
| *Turbidity (NTRU)* | 11 * | - | - | - | - | 12 | | | | |

Table Notes:

- Pound (#) = at least one sample was taken, but overall sampling was too infrequent (less than half of the time interval) to calculate a comparable average
- Dash (-) = not sampled
- Asterisk (*) = data gaps exist, meaning sampling was not performed regularly over the period of interest. See full tables in Appendix 1 for more information
- Data was used at the depth were samples were taken most frequently. Additional data is available at some sites at other depths.
- Basic data cleaning was performed which involved removing censored values (errors), converting units, and averaging replicate samples (i.e. samples which occurred on the same day at the same depth)

[a] East Vadnais averages were calculated using data from both the North and South sites
[b] White Bear Lake averages were calculated using data from all four sites (North, Center, East, West)
[c] Bacteria is reported as counts which can be exceptionally skewed, so the averages are calculated as Geometric Means
[d] For the Mississippi River at Anoka and White Beal Lake sites, Total Nitrogen was calculated as the sum of Nitrate/Nitrite and Total Kjeldahl Nitrogen
[e] pH is a log scale, so averages are calculated by converting values to hydrogen ion concentration [H+], averaging [H+], then converting back to pH

As shown in Table 4, there are no sites for which averages could be calculated for all parameters and likewise there are no parameters for which averages could be calculated at all sites. The most complete comparable dataset available is for total phosphorus. Comparison of average phosphorus concentrations for period 2005-2010 indicates phosphorus concentrations in Mississippi River were higher (0.104 mg/L) than those in the lakes; while concentrations in the SPRWS lakes (0.039 mg/L in

Sucker Lake and 0.034 mg/L in East Vadnais Lake) were higher than those in White Bear Lake (0.015 mg/L). For period 2011-2015, phosphorus concentrations were again higher in the Mississippi River (0.121 mg/L) than the lakes. No data were available for Sucker Lake for that period, but phosphorus in East Vadnais Lake (0.026 mg/L) appeared to remain higher than that in White Bear Lake (0.019 mg/L), despite the presence of the hypolimnetic oxygenation system.

Comparison graphs of total phosphorus for 2005 – 2015 (Figure 2) indicate the phosphorus concentrations in White Bear Lake remain fairly stable over time, while there is greater variability observed in the Mississippi River at Anoka and in Sucker and East Vadnais Lakes. The Mississippi River is the primary source water for the SPRWS system. River water enters the system at the Fridley intake, and flows to Charley and Pleasant Lakes before discharge to Sucker and East Vadnais Lakes. Phosphorus, as well as many other constituents, in the Mississippi is influenced by multiple factors, including precipitation and snowmelt, urban stormwater and agricultural runoff, discharge of wastewater effluent, and ditch, gully, and river bank erosion. Phosphorus, as well as many other chemical constituents in Sucker and East Vadnais Lakes are influenced by constituent concentration and volume of Mississippi River water delivered to the lakes, the constituent concentration and volume of water pumped from the Rice Creek Chain of Lakes and Otter and Bald Eagle Lakes, volume and constituent concentration of stormwater runoff from the lakes' direct watersheds, as well as by frequent modifications to aeration systems and alterations to coagulant application and dose.

**Figure 2. Annual average concentration of total phosphorus in the Mississippi River, Sucker, East Vadnais, and White Bear Lakes using data from May – September during 2005 – 2015**

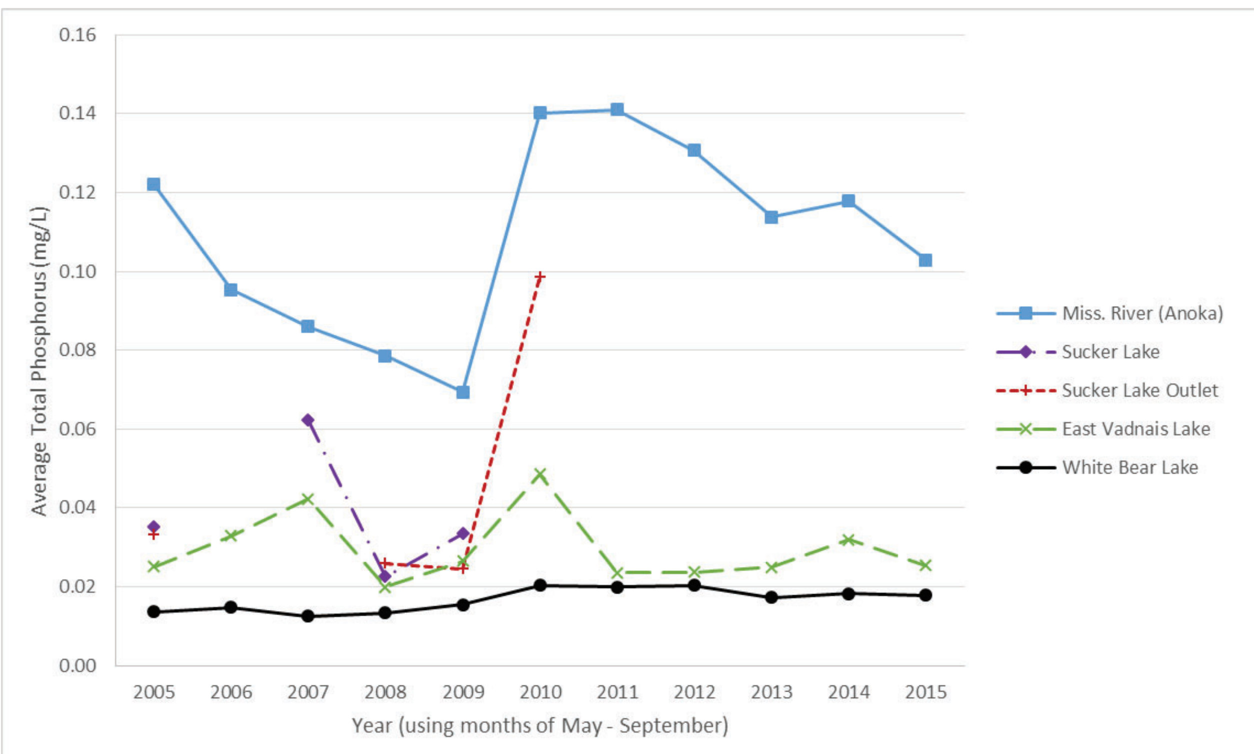
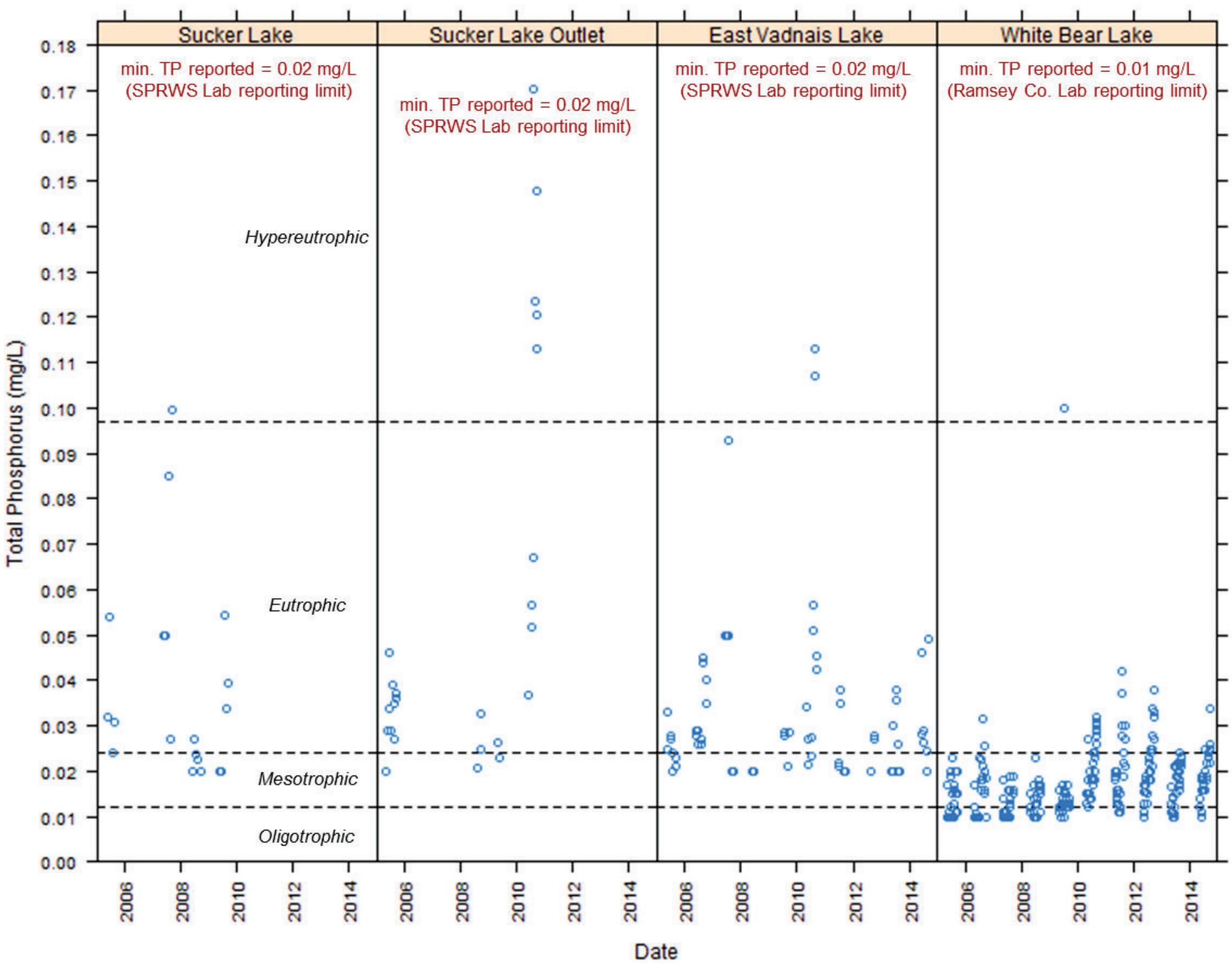



Figure 3 shows individual total phosphorus concentrations, including associated trophic status, for May through September during 2005-2015 in the Mississippi River and the monitoring stations within Sucker, East Vadnais, and White Bear Lakes. Trophic status was determined according to Carlson's Trophic State Index (Carlson,1977; MPCA, 2005) by using phosphorus as the sole parameters, since the chlorophyll dataset was not nearly as complete. Trophic status in lakes is generally classified as oligotrophic (very clear water with low phosphorus and few algae), mesotrophic (moderately clear water with relatively low phosphorus and algae), eutrophic (highly biologically active with elevated phosphorus, algae blooms, and low water clarity), or hypereutrophic (extremely biologically active with various high phosphorus, noxious and potentially toxic algae blooms, and very low water clarity).. The phosphorus concentrations at each White Bear Lake sampling site are generally around the borderline oligotrophic-mesotrophic to mesotrophic, with a few values trending toward eutrophic. In comparison, Sucker and East Vadnais Lake had much more variable phosphorus concentrations over time, which frequently reached eutrophic, and at times hypereutrophic, levels.

**Figure 3. Individual total phosphorus concentrations in Sucker, East Vadnais, and White Bear Lakes compared with Carlson's Trophic State Index (May to September, 2005 – 2015)**




Deep lakes thermally stratify annually during the open water season in the Twin Cities metropolitan area. Thermal stratification forms a water density gradient that eventually becomes strong enough which prevents the mixing of warmer surface waters with the deeper and more dense colder waters. Since the denser lower waters (called the hypolimnion) do not mix with the oxygenated surface waters, oxygen decreases over time. The hypolimnion of these lakes eventually become oxygen depleted (anoxic) after stratification occurs. The hypolimnion experiences differences in its chemistry compared to the surface waters because of the anoxic conditions.Anoxic conditions drive changes to sediment chemistry, resulting in chemical conversion and release of multiple chemicals, including phosphorus, iron, sulfide, and mercury. This chemical process has been manipulated over time in East Vadnais Lake due to the installation and alteration of hypolimnetic aeration and oxygenation systems, as well as intermittent application of ferric chloride.

Data were collected at uniform depth intervals during May through September for temperature and dissolved oxygen in all three lakes, although the last year with complete data for Sucker Lake was 2008. Depth profile plots for 2008 for Sucker Lake, East Vadnais Lake (South monitoring station, which is nearest proposed augmentation withdrawal site) and White Bear Lake (West monitoring station, which is nearest proposed augmentation discharge site) (Figure 4) indicate the formation of thermal stratification and resulting anoxia in both Sucker and East Vadnais Lakes, despite the presence of hypolimnetic aeration in East Vadnais at the time. White Bear Lake does not strongly stratify at the West monitoring site due to shallow depths; the temperature profiles indicate weak stratification with mid-summer mixing. This is reflected in the dissolved oxygen profiles, which indicate cycles of near-sediment anoxic and oxygenated conditions due to intermittent mixing. Similar plots for the most recent complete year of data (2014; Figure 5) indicate the influence of the hypolimnetic oxygenation system in East Vadnais; while the lake appears to have thermally stratified, near-sediment oxygen levels remain high. As in 2008, the 2014 profiles for White Bear Lake indicate weak thermal stratification and intermittent anoxia near the sediment.

Multiple corollary effects on lake water quality likely result from thermal stratification patterns, resulting near-sediment anoxia (in Sucker and East Vadnais Lakes), and manipulation of near-sediment oxygen levels using hypolimnetic aeration, hypoliminetic oxygenation, and application of ferric chloride (in East Vadnais Lake). SPRWS has focused data collection on total phosphorus due to assess potential effects on drinking water taste and odor. However multiple chemical parameters may be created, transported, and/or affected by thermal stratification cycles and near-sediment oxygen conditions, including sulfide, sulfate, iron, mercury, pH, alkalinity, and others. Withdrawal and transport of low oxygen water from either Sucker or East Vadnais Lakes for White Bear Lake augmentation could result in equipment corrosion, odor issues, and potential transport of high concentration pollutants to White Bear Lake. No data, beyond that for phosphorus, are available to assess level of chemical transformation and transport from either East Vadnais or Sucker Lakes to White Bear Lake.

**Figure 4. Interpolated Depth Profiles of Dissolved Oxygen and Temperature in Sucker Lake, East Vadnais Lake (South), and White Bear Lake (West) in May to September, 2008**

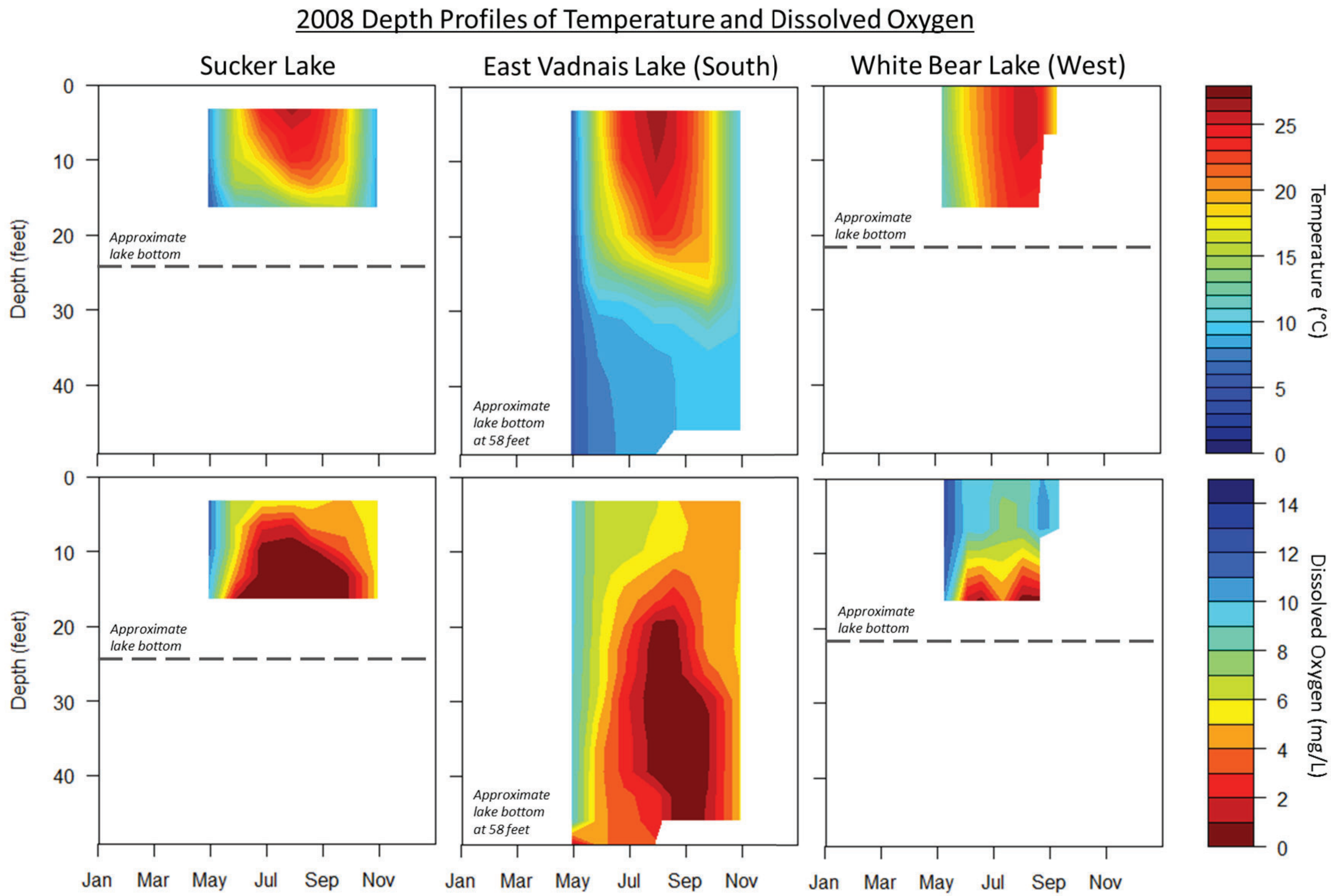
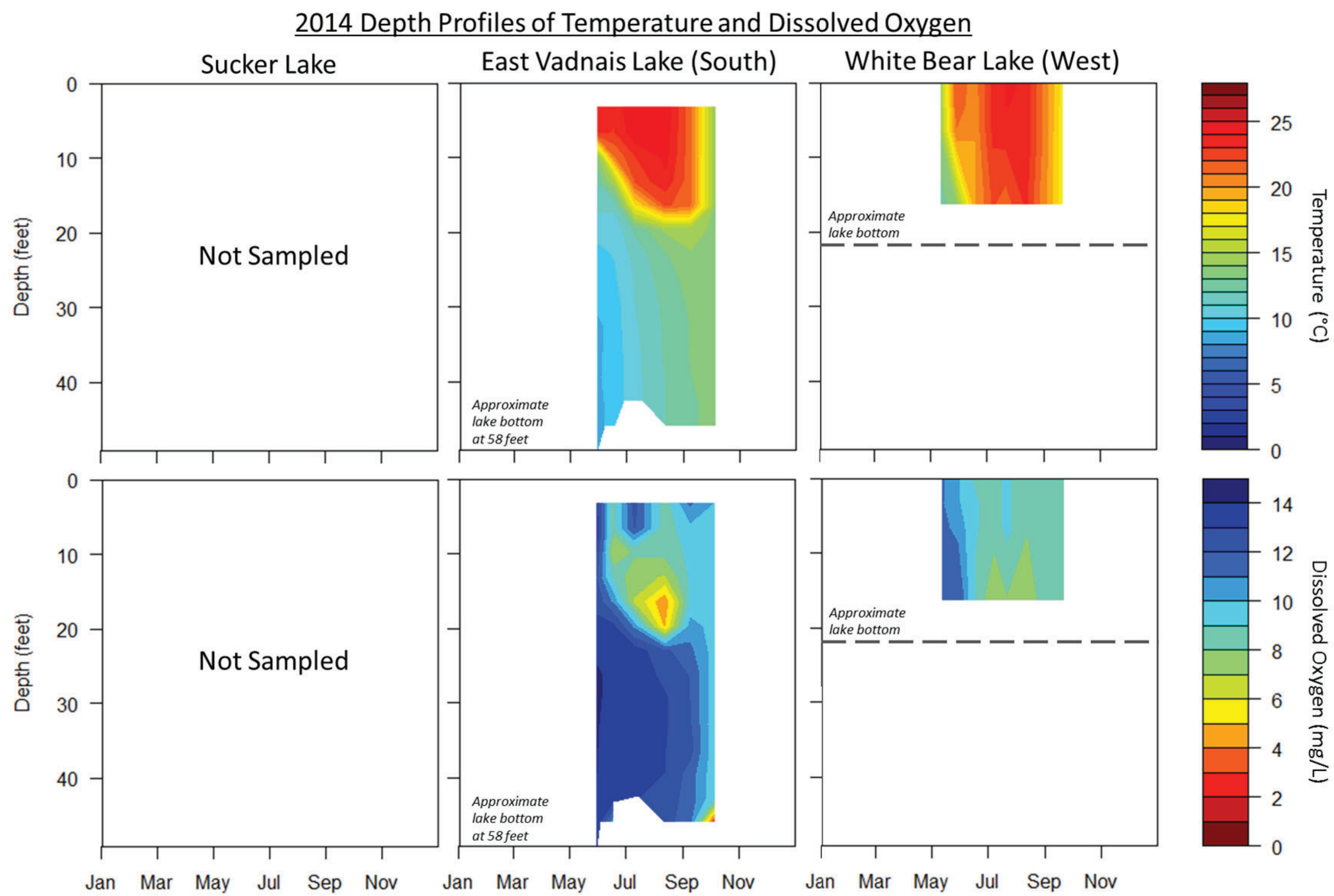


**Figure 5. Interpolated Depth Profiles of Dissolved Oxygen and Temperature in Sucker Lake, East Vadnais Lake (South), and White Bear Lake (West) in May to September, 2014**



## Identification of Data Gaps and Potential Risks

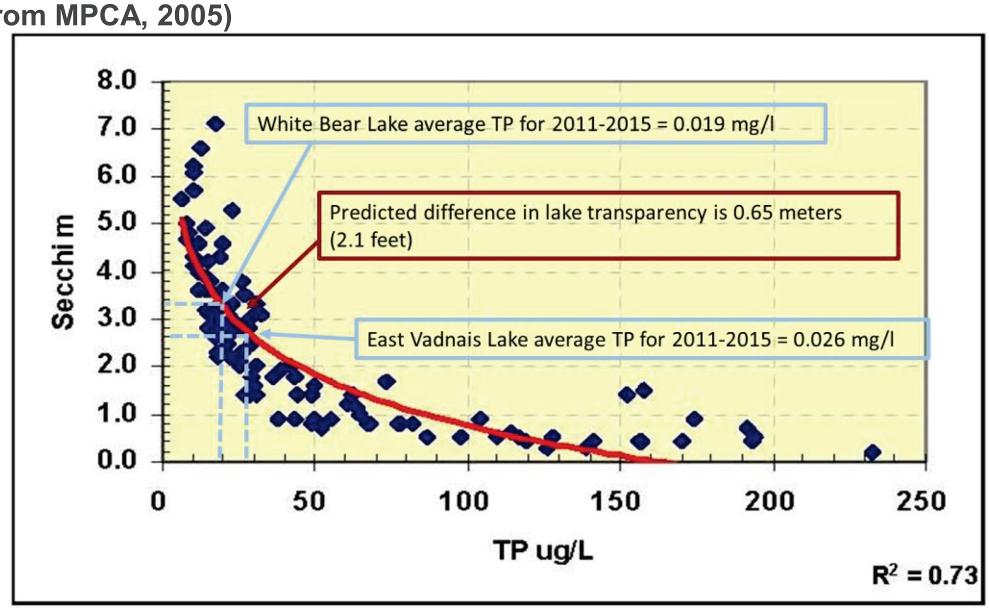
MCES has identified the following issues and data gaps as presenting potential risk to water quality, to accurate sizing and costing of necessary treatment, and to adequately address potential regulatory permit requirements:

1. **Lack of comparable total phosphorus data to estimate potential changes to trophic level and water transparency in White Bear Lake with augmentation from Sucker or East Vadnais Lakes**

   Total phosphorus concentrations have been reported for White Bear Lake and Sucker and East Vadnais Lakes, although differences in laboratory reporting limits for low level samples reduces the accuracy of any comparisons. Comparison of averages for 2005 – 2010 indicate phosphorus levels in Sucker and East Vadnais (0.039 and 0.035) higher than that in White Bear Lake (0.015 mg/L), while averages for 2011 – 2015 indicate phosphorus levels in East Vadnais (0.026 mg/L) and White Bear (0.019 mg/L) closer in value. White Bear Lake is mesotrophic and at times trending toward eutrophic. Lakes with relatively low phosphorus levels, like White Bear Lake, are particularly sensitive to additional inputs of phosphorus; elevated phosphorus results in more abundant algal growth, resulting in decreased lake transparency. The Minnesota Pollution Control Agency (MPCA, 2005) and others have documented the relationship between elevated phosphorus and declining water transparency (Figure 7), with low phosphorus lakes more susceptible to greater relative reductions in transparency. Collection of data from all three lakes, on same dates, using same laboratory, with emphasis on using low-level phosphorus methods, would allow accurate comparison between lakes and allow assessment of potential changes in White Bear Lake concentration and water transparency.

   Minnesota Statutes (M.S.) Chapter 7050 lists nondegradation (7050.0185) policy and specific water quality standards pertinent to White Bear Lake (7050.0220, 7050.0222, 7050.0223), including narrative eutrophication standards (7050.0222 subp.4a). It is beyond the scope of this memo to address potential permitting or treatment requirements, but both the nondegradation policy and eutrophication standards indicate maintenance of the existing concentration of phosphorus in White Bear Lake.

**Figure 7. Relationship between total phosphorus and transparency in Minnesota reference lakes (excerpted from MPCA, 2005)**



2. **Insufficient data demonstrating effectiveness of East Vadnais hypolimnetic oxygenation (HO) system and lack of emergency operation plan for augmentation system if HO is disabled**

   SPRWS has historically implemented hypolimnetic aeration in Pleasant and East Vadnais Lakes to control phosphorus concentrations, and has applied coagulants (primarily ferric chloride) to control near-sediment phosphorus release. Most recently, the SPRWS has installed hypolimnetic oxygenation in both Pleasant and East Vadnais Lakes (approximately 2011). SPRWS has collected four years of phosphorus data since installation of the hypolimnetic aeration, which indicates the phosphorus concentration in East Vadnais Lake has been at times higher, and is more variable, than that in White Bear Lake. In addition, installation and operation of the hypolimnetic aeration system and application of ferric chloride is necessary to control phosphorus concentrations in East Vadnais Lake. Discontinued operation of these controls would likely result in elevated phosphorus in East Vadnais. Identification of actions necessary to protect White Bear Lake quality if HO system is disabled need to be identified.

3. **Insufficient data to assess potential threats to human and aquatic life from White Bear Lake augmentation**

   MCES identified a slate of additional parameters typically used to assess suitability of water bodies for sustaining human recreation and aquatic life and which may be required for regulatory permit preparation and for sizing and costing necessary treatment of augmentation water. Parameters included alkalinity, hardness, pH, bacteria (fecal coliform and E. coli), chloride, chlorophyll a, nitrogen (including nitrate, ammonia, and total nitrogen), transparency, and turbidity. No comparable data are available for three lakes for these parameters.

   Discharge of Mississippi River water to the SPRWS system may influence the concentration of additional parameters in East Vadnais and Sucker Lakes, many not measured (for example, pesticides, estrogen compounds, pharmaceuticals, personal care products, and other trace contaminants). Mississippi River water quality is influenced by numerous pollutant sources, including runoff from agricultural and urban areas, discharge from wastewater treatment plants, and gully, ravine, and riverbank erosion, draining from approximately 19,300 square miles (12,380,000 acres). In addition, potential spills or illicit discharges to the river upstream of the Fridley SPRWS water intake potentially could impact the quality of water ultimately discharged to White Bear Lake.

4. **Insufficient data to prepare necessary permits and meet regulatory requirements**

   *Feasibility Assessment of Approached to Water Sustainability in the Northeast Metro* (MCES, 2014) identified a slate of potential permits required for construction of augmentation system. Of those, the following likely have requirements for presentation of comparative water quality data or proof or removal through treatment: Vadnais Lakes Area Water Management Organization (VLAWMO), Rice Creek Watershed District (RCWD), Minnesota Pollution Control Agency (MPCA) National Pollutant Discharge Elimination System (NPDES) and Stormwater Pollution Prevention Program (SWPPP) permits/requirements, and potentially Environmental Assessment Worksheet (EAW) and/or Environmental Impact Study (EIS) through Minnesota Environmental Quality Board (EQB).

5. **Insufficient data to identify, size, and cost of treatment of augmentation water and identify correct elevations for withdrawal and discharge pipes**

   Data necessary to properly identify, size, and cost treatment to remove pollutants that may detrimentally affect White Bear Lake (like phosphorus, metals, trace contaminants, and others) are not available. In addition, discharge pipe into West lob of White Bear Lake has potential to disrupt thermal stratification in the relatively shallow water, causing delivery of sediment phosphorus to lake surface. Some temperature and dissolved oxygen data are available at depth increments in the West lobe, but data may not have been collected frequently enough to assess potential of disrupting stratification.

## Conclusions

MCES has determined that

- While multiple organizations have monitored Sucker, East Vadnais, and White Bear Lakes over time, the most recent and complete datasets have been collected by Ramsey County (White Bear Lake) and SPRWS (Sucker and East Vadnais Lakes). Data on the Mississippi River (the primary SPRWS source water delivered to Sucker and East Vadnais Lakes) were collected by SPRWS and MCES.
- Ramsey County, SPRWS, and MCES collected data using different monitoring programs with different end goals, leading to data collected at different depths, at different time intervals, with different equipment, for non-uniform chemical parameters determined by different laboratories. Concentrations for low level data, particularly phosphorus, were reported inconsistently by the three laboratories, with the SPRWS and Ramsey County labs using different reporting limits for phosphorus (0.02 mg/L vs. 0.01 mg/L). These factors make it difficult to conduct an accurate comparison between the datasets.
- Total phosphorus is the one dataset complete enough to allow comparison between the Mississippi River, and Sucker, East Vadnais, and White Bear Lakes, although different reporting limits in the SPRWS and Ramsey County labs likely skew reported average values. Comparison of total phosphorus for May through September during 2005-2010 (which is when data were available for White Bear Lake) indicates phosphorus concentrations 0.015 mg/L of in White Bear Lake and 0.039 and 0.035 in Sucker and East Vadnais Lakes, respectively, with Sucker and East Vadnais more variable, with higher periodic concentrations. This variability may be caused by a combination of stormwater inputs from the surrounding Sucker Lake and East Vadnais Lake watershed areas, inflow of SPRWS source water from the Mississippi River and/or Centerville Lake/Rice Creek Chain of Lakes, and alterations in operation of the aeration systems in Pleasant Lake and East Vadnais Lake.
- Comparison of total phosphorus for 2011-2015 indicates an average concentration of 0.019 mg/L in White Bear Lake and 0.026 mg/L in East Vadnais. Data were not available for Sucker Lake.
- Comparison of total phosphorus for May through September during 2005-2015, using Carlson's Trophic State Index, indicates that White Bear Lake water trophic status has ranged from oligotrophic (clear water with low algal abundance) to mesotrophic/eutrophic (higher phosphorus with lower clarity and greater algal abundance). Sucker and East Vadnais Lakes have ranged from mesotrophic to hypereutrophic (low clarity, high phosphorus, noxious algal blooms).

- Input of additional phosphorus to White Bear Lake may cause a disproportionately large decrease in water transparency, as predicted by relationships developed by the MPCA and others.
- Temperature and dissolved oxygen profile plots indicate that thermal stratification in Sucker Lake results in near-sediment anoxia; that thermal stratification at the West monitoring site in White Bear Lake is intermittent, with short periods of near-sediment anoxia; and that while East Vadnais Lake thermally stratifies, hypolimnetic oxygenation appears to have disrupted near-sediment anoxia.
- That said, minimal information is available to assess potential of stratification disruption in the West lob of White Bear Lake due to discharge of augmentation water and subsequent delivery of near-sediment high phosphorus water to the lake surface.
- Effective operation of the East Vadnais hypolimnetic oxygenation system is essential to reduce and control phosphorus concentration in the lake. Disruption or discontinuance of the oxygenation system would like result in elevated phosphorus concentrations in the lake.
- Besides phosphorus, other chemical and biological parameters are crucial to consider for protecting White Bear Lake, including differences between Sucker and East Vadnais Lakes and White Bear Lake in alkalinity, hardness, pH, sulfide, metals concentrations, bacteria abundance, chloride concentration, pesticide concentrations, trace chemicals of emerging concern (like pharmaceuticals, estrogen disrupters, etc.), and others. Insufficient data are available to compare the lakes for these parameters.
- Necessary data are not available to identify, size, and estimate cost for any necessary treatment.
- Lack of data for phosphorus, alkalinity, hardness, trace contaminants, and other parameters may hinder preparation of permits and to verify compliance with relevant state water quality standards and nondegradation requirements.

## Recommendations

Based on the results of the water quality comparison, MCES recommends

- Identification of ultimate water quality goal for White Bear Lake, given potential effects from augmentation
- Collection of uniform, comparable data for the Mississippi River, Sucker Lake, East Vadnais Lake, and White Bear Lake, and potentially Centerville Lake, including sampling at depth. To facilitate accurate statistical comparison of water quality between the water bodies, each should be sampled synoptically using the same type equipment and all samples analyzed using one laboratory. Parameters sampled should include those that will help
  - Identify level of treatment required of augmentation water prior to discharge to White Bear Lake
  - Identify those parameters which may present risks to human health and risks to aquatic life (includes fisheries, aquatic plants, aquatic macroinvertebrates, and other aquatic life) in White Bear Lake
  - Quantify those parameters necessary to negotiate permits for augmentation with appropriate regulatory authorities and to verify compliance with state water quality standards and nondegradation requirements.
- Include in the concept planning for the augmentation system an acknowledgment that a long term monitoring plan should be implemented for the purposes of monitoring White Bear Lake

during implementation of the augmentation system, in order to evaluate the short term and long term effects that augmentation will have on White Bear Lake.

- Creation of a lake computer simulation model for White Bear Lake to assess potential alterations in water quality and biological activity from proposed augmentation program.

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## Table 5. Summary of water quality for various sampling stations during May to September, 2005-2010

Water Quality Statistics 2005 - 2010 (May - September) – Page 1

| Sites | | *Mississippi River Water (Anoka)* | *Mississippi River Water (Fridley)* | *Pleasant Lake (West)* | *Pleasant Lake (East)* | *Sucker Lake* | *Sucker Lake Outlet* | *East Vadnais Lake (North)* | *East Vadnais Lake (South)* | *East Vadnais Lake (Gatehouse)* | *Raw WTP Water (McCarron's)* | *White Bear Lake (North)* | *White Bear Lake (Central)* | *White Bear Lake (East)* | *White Bear Lake (West)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data Source** | | MCES | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | Ramsey County | Ramsey County | Ramsey County | Ramsey County |
| **Sample Depth (meters)** | | 1 | Taken from a pipe | 3 | 3 | 3 | 3 | 3 | 3 | At pipe inlet (7 - 15) | Taken from a pipe | 0 - 0.5 | 0 - 0.5 | 0 - 0.5 | 0 - 0.5 |
| *Alkalinity, Total (mg/L as CaCO3)* | Mean | 174 [e] | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Median | 171 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Max | 224 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Min | 128 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Count | 43 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| *Ammonia (mg-N/L)* | Mean | 0.04 | 0.08 * | # | # | 0.256 * † | 0.075 * | # | # | 0.045 * | 0.068 * | # | 0.058 * † | 0.056 † | # |
| | Median | 0.02 | 0.01 | # | # | 0.137 | 0.072 | # | # | 0.033 | 0.035 | # | 0.043 | 0.050 | # |
| | Max | 1.31 | 1.48 | # | # | 1.150 | 0.248 | # | # | 0.130 | 0.529 | # | 0.401 | 0.302 | # |
| | Min | 0.02 | 0.00 | # | # | 0.010 | 0.003 | # | # | 0.000 | 0.006 | # | 0.009 | 0.009 | # |
| | Count | 121 | 39 | # | # | 18 | 27 | # | # | 28 | 39 | # | 35 | 44 | # |
| *Chloride (mg/L)* | Mean | 17.2 [e] | - | - | - | - | - | - | - | - | - | 37.1 | 37.5 * † | 38.6 * † | 37.8 |
| | Median | 18.0 | - | - | - | - | - | - | - | - | - | 38.0 | 39.0 | 40.0 | 39.8 |
| | Max | 24.0 | - | - | - | - | - | - | - | - | - | 45.0 | 43.5 | 46.5 | 44.0 |
| | Min | 8.0 | - | - | - | - | - | - | - | - | - | 30.0 | 30.0 | 30.0 | 30.0 |
| | Count | 55 | - | - | - | - | - | - | - | - | - | 39 | 37 | 36 | 40 |
| *Chlorophyll a, corrected (ug/L)* | Mean | 39.3 | - | - | - | - | - | - | - | - | - | 4.77 | 5.04 † | 5.02 † | 3.65 |
| | Median | 37.0 | - | - | - | - | - | - | - | - | - | 3.41 | 3.53 | 3.84 | 2.90 |
| | Max | 100.0 | - | - | - | - | - | - | - | - | - | 14.90 | 14.70 | 17.44 | 13.64 |
| | Min | 13.0 | - | - | - | - | - | - | - | - | - | 1.18 | 1.02 | 1.10 | 0.63 |
| | Count | 77 | - | - | - | - | - | - | - | - | - | 43 | 45 | 45 | 45 |
| *Chlorophyll a, uncorrected (ug/L)* | Mean | 42.6 | 30.3 * | - | - | 19.93 * | 14.97 | - | - | - | - | - | - | - | - |
| | Median | 40.0 | 27.6 | - | - | 17.88 | 14.78 | - | - | - | - | - | - | - | - |
| | Max | 95.0 | 74.2 | - | - | 55.76 | 42.51 | - | - | - | - | - | - | - | - |
| | Min | 16.0 | 4.1 | - | - | 3.75 | 2.06 | - | - | - | - | - | - | - | - |
| | Count | 77 | 30 | - | - | 21 | 86 | - | - | - | - | - | - | - | - |
| *Coliform, Total (CFU /100 mL) [a]* | Mean | - | 9411 | - | - | - | 1224 | - | - | - | 339 | - | - | - | - |
| | Median | - | 9200 | - | - | - | 1300 | - | - | - | 560 | - | - | - | - |
| | Max | - | 99999 | - | - | - | 99999 | - | - | - | 99999 | - | - | - | - |
| | Min | - | 448 | - | - | - | 0 | - | - | - | 0 | - | - | - | - |
| | Count | - | 27 | - | - | - | 111 | - | - | - | 103 | - | - | - | - |
| *Dissolved Oxygen (mg/L)* | Mean | 8.78 | - | # | # | - | # | # | # | - | - | 9.43 † | 9.48 † | 9.37 † | 9.46 † |
| | Median | 8.65 | - | # | # | - | # | # | # | - | - | 9.33 | 9.29 | 9.36 | 9.51 |
| | Max | 12.42 | - | # | # | - | # | # | # | - | - | 12.16 | 13.43 | 12.68 | 12.57 |
| | Min | 6.50 | - | # | # | - | # | # | # | - | - | 7.78 | 7.60 | 7.35 | 7.24 |
| | Count | 118 | - | # | # | - | # | # | # | - | - | 44 | 45 | 45 | 45 |

## Water Quality Statistics 2005 - 2010 (May - September) – Page 2

| | | *Mississippi River Water (Anoka)* | *Mississippi River Water (Fridley)* | *Pleasant Lake (West)* | *Pleasant Lake (East)* | *Sucker Lake* | *Sucker Lake Outlet* | *East Vadnais Lake (North)* | *East Vadnais Lake (South)* | *East Vadnais Lake (Gatehouse)* | *Raw WTP Water (McCarron's)* | *White Bear Lake (North)* | *White Bear Lake (Central)* | *White Bear Lake (East)* | *White Bear Lake (West)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *E. coli (MPN/100 mL)* [a] | Mean | 44 | # | - | - | - | 1 * | - | - | 2 * | 0 * | - | - | - | - |
| | Median | 37 | # | - | - | - | 0 | - | - | 1 | 0 | - | - | - | - |
| | Max | 2420 | # | - | - | - | 82 | - | - | 155 | 10 | - | - | - | - |
| | Min | 3 | # | - | - | - | 0 | - | - | 0 | 0 | - | - | - | - |
| | Count | 112 | # | - | - | - | 51 | - | - | 58 | 47 | - | - | - | - |
| *Hardness, Total (mg/L as CaCO3)* | Mean | 208 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Median | 200 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Max | 300 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Min | 176 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| | Count | 12 | - | - | - | - | - | - | - | - | - | # | # | - | # |
| *Nitrate/Nitrite (mg-N/L)* | Mean | 0.89 | 0.381 * | # | # | 0.146 * † | 0.096 * | # | # | 0.082 * | 0.171 * | # | 0.012 * † | 0.012 † | # |
| | Median | 0.49 | 0.312 | # | # | 0.079 | 0.058 | # | # | 0.029 | 0.094 | # | 0.010 | 0.010 | # |
| | Max | 3.20 | 1.483 | # | # | 0.677 | 0.309 | # | # | 0.387 | 1.036 | # | 0.044 | 0.040 | # |
| | Min | 0.08 | 0.004 | # | # | 0.002 | 0.007 | # | # | 0.000 | 0.002 | # | 0.009 | 0.009 | # |
| | Count | 74 | 40 | # | # | 18 | 25 | # | # | 28 | 38 | # | 35 | 44 | # |
| *Nitrogen, Total (mg-N/L)* [b] | Mean | 1.87 | # | - | - | # | # | - | - | # | 0.760 * | # | 0.794 * † | 0.824 † | # |
| | Median | 1.46 | # | - | - | # | # | - | - | # | 0.742 | # | 0.778 | 0.750 | # |
| | Max | 4.40 | # | - | - | # | # | - | - | # | 1.437 | # | 1.212 | 1.410 | # |
| | Min | 0.81 | # | - | - | # | # | - | - | # | 0.356 | # | 0.334 | 0.386 | # |
| | Count | 73 | # | - | - | # | # | - | - | # | 26 | # | 34 | 42 | # |
| *pH* [c] | Mean | 8.27 | - | - | - | - | - | - | - | - | - | 8.18 † | 8.16 † | 7.69 † | 8.16 † |
| | Median | 8.31 | - | - | - | - | - | - | - | - | - | 8.32 | 8.28 | 8.16 | 8.39 |
| | Max | 8.71 | - | - | - | - | - | - | - | - | - | 8.88 | 8.86 | 8.81 | 9.06 |
| | Min | 7.84 | - | - | - | - | - | - | - | - | - | 7.65 | 7.52 | 6.65 | 7.36 |
| | Count | 121 | - | - | - | - | - | - | - | - | - | 44 | 45 | 45 | 45 |
| *Phosphorus, Total (mg-P/L)* [d] | Mean | 0.104 | 0.075 * | # | # | 0.039 * † | 0.056 * | 0.035 † | 0.034 † | 0.034 * | 0.032 * | 0.014 | 0.013 † | 0.019 † | 0.014 |
| | Median | 0.099 | 0.063 | # | # | 0.031 | 0.036 | 0.028 | 0.027 | 0.026 | 0.022 | 0.013 | 0.012 | 0.016 | 0.012 |
| | Max | 0.274 | 0.272 | # | # | 0.100 | 0.170 | 0.113 | 0.107 | 0.177 | 0.096 | 0.031 | 0.030 | 0.100 | 0.031 |
| | Min | 0.050 | 0.020 | # | # | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.010 | 0.010 | 0.010 | 0.010 |
| | Count | 75 | 40 | # | # | 19 | 24 | 29 | 27 | 44 | 39 | 44 | 44 | 45 | 45 |
| *Secchi (m)* | Mean | - | - | # | # | # | - | # | # | - | - | 3.7 | 4.0 | 4.1 | 3.5 |
| | Median | - | - | # | # | # | - | # | # | - | - | 3.7 | 3.9 | 3.7 | 3.2 |
| | Max | - | - | # | # | # | - | # | # | - | - | 6.0 | 7.8 | 7.8 | 5.4 |
| | Min | - | - | # | # | # | - | # | # | - | - | 1.9 | 2.1 | 2.1 | 2.0 |
| | Count | - | - | # | # | # | - | # | # | - | - | 42 | 44 | 45 | 45 |
| *Temperature (°C)* | Mean | 21.3 | - | # | # | # | - | # | # | - | - | 20.84 † | 20.75 † | 20.64 † | 20.96 † |
| | Median | 22.4 | - | # | # | # | - | # | # | - | - | 22.01 | 22.08 | 21.61 | 22.26 |
| | Max | 30.0 | - | # | # | # | - | # | # | - | - | 28.72 | 28.26 | 27.48 | 28.54 |
| | Min | 10.3 | - | # | # | # | - | # | # | - | - | 10.23 | 10.28 | 11.58 | 11.19 |
| | Count | 122 | - | # | # | # | - | # | # | - | - | 44 | 45 | 45 | 45 |

## Water Quality Statistics 2005 - 2010 (May - September) – Page 3

| | | *Mississippi River Water (Anoka)* | *Mississippi River Water (Fridley)* | *Pleasant Lake (West)* | *Pleasant Lake (East)* | *Sucker Lake* | *Sucker Lake Outlet* | *East Vadnais Lake (North)* | *East Vadnais Lake (South)* | *East Vadnais Lake (Gatehouse)* | *Raw WTP Water (McCarron's)* | *White Bear Lake (North)* | *White Bear Lake (Central)* | *White Bear Lake (East)* | *White Bear Lake (West)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Turbidity (NTU)* | Mean | - | - | - | - | - | - | - | - | - | - | 1.8 | 1.7 † | 1.7 † | 1.6 |
| | Median | - | - | - | - | - | - | - | - | - | - | 1.5 | 1.4 | 1.5 | 1.5 |
| | Max | - | - | - | - | - | - | - | - | - | - | 4.6 | 4.2 | 3.8 | 3.2 |
| | Min | - | - | - | - | - | - | - | - | - | - | 0.1 | 0.7 | 0.5 | 0.7 |
| | Count | - | - | - | - | - | - | - | - | - | - | 44 | 44 | 45 | 45 |
| *Turbidity (NTRU)* | Mean | 11 * | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Median | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Max | 28 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Min | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Count | 101 | - | - | - | - | - | - | - | - | - | - | - | - | - |

General Table Notes:

- Pound (#) = at least one sample was taken, but overall was sampled too infrequently (less than 3 years) to calculate a comparable average
- Dash (-) = not sampled
- When values were flagged with "Non-Detects" or "Reporting Limit" and had a sign (e.g. <), the sign was removed and the value of the given limit was used
- Since White Bear Lake was only sampled in the months of May - September, all datasets were filtered to only include data from 2005 - 2010 for the months of May - September. Additional data is available at some sites outside of those criteria.
- Data was used at the depth where samples were taken most frequently. Additional data is available at some sites at other depths.
- Basic data cleaning was performed which involved pivoting the data, removing censored values (errors), converting units, and averaging replicate samples (i.e. samples which occurred on the same day at the same depth)

[a] Bacteria is reported as counts which can be exceptionally skewed, so the averages are calculated as Geometric Means
[b] For the Mississippi River at Anoka and White Beal Lake sites, Total Nitrogen was calculated as the sum of Nitrate/Nitrite and Total Kjeldahl Nitrogen
[c] pH is a log scale, so averages are calculated by converting values to hydrogen ion concentration [H+], averaging [H+], then converting back to pH
[d] For consistency and accuracy between datasets from the different agencies, Total Phosphorus values which were below the Reporting Limit of each laboratory (MCES – 0.05 mg/L, SPRWS – 0.02 mg/L, Ramsey County – 0.01 mg/L) were censored and the value of the respective Reporting Limit was used
[e] Chloride and alkalinity samples at the Mississippi River at Anoka were sometimes filtered, sometimes not. This should not affect results since both parameters are dissolved.
* There are gaps in the data:

- Mississippi River Water (Anoka)
  - Turbidity (NTRU) – 2005
- Mississippi River Water (Fridley)
  - Total Phosphorus, Ammonia, and Nitrate/Nitrite - 2006 to mid-2007
  - Chlorophyll a (uncorrected) - 2005 and 2010
- Sucker Lake
  - Monitoring of all parameters stopped after 2009
  - Total Phosphorus, Ammonia, and Nitrate/Nitrite – 2006
- Sucker Lake Outlet
  - E. coli – 2005
  - Total Phosphorus, Ammonia, and Nitrate/Nitrite - 2006, 2007, half of 2008 and 2009
- Vadnais Lake (Gatehouse)
  - E. coli – 2005
  - Ammonia and Nitrate/Nitrite - 2007-2009
  - Total Phosphorus - 2007-2008, 2010
- Raw WTP Water (McCarron's)
  - Total Phosphorus, Ammonia, Nitrate/Nitrite, and Total Nitrogen - 2006 to mid-2007
  - E. coli - 2005 to mid-2006
- White Bear Lake (Central)

## Water Quality Statistics 2005 - 2010 (May - September) – Page 4

- White Bear Lake (East)
  - Chloride - 2005

† Additional data is available at other depths:

- Sucker Lake
  - Total Phosphorus, Ammonia, and Nitrate/Nitrite - at 5 meters
- Vadnais (North)
  - Total Phosphorus – at 6 meters and occasionally at 10 and 13 meters
- Vadnais (South)
  - Total Phosphorus - at 6 meters and occasionally at 10 and 13 meters
- White Bear Lake (North)
  - Dissolved Oxygen, Temperature, and pH - down to 6 meters at 1-2 meter intervals
- White Bear Lake (Central)
  - Dissolved Oxygen, Temperature, and pH - down to 8-12 meters at 1 meter intervals
  - Total Phosphorus, Turbidity (NTU), and Chloride - down to 8-12 meters at irregular 3-5 meter intervals
  - Chlorophyll a (corrected), Nitrate/Nitrite, Ammonia, and Total Nitrogen - at 2 meters
- White Bear Lake (East)
  - Dissolved Oxygen, Temperature, and pH - down to 16-20 meters at 1 meter intervals
  - Total Phosphorus, Turbidity (NTU), and Chloride - down to 14-18 meters at irregular 3-5 meter intervals
  - Chlorophyll a (corrected), Nitrate/Nitrite, Ammonia, and Total Nitrogen - at 2 meters
- White Bear Lake (West)
  - Dissolved Oxygen, Temperature, and pH - down to 3-5 meters at 1-2 meter intervals

Table prepared and completed in December, 2015 by Metropolitan Council Environmental Services staff

**Table 6. Summary of water quality for various sampling stations during May to September, 2011-2015**

Water Quality Statistics 2011 - 2015 (May - September) – Page 1

| Sites | | *Mississippi River Water (Anoka)* | *Mississippi River Water (Fridley)* | *Pleasant Lake (West)* | *Pleasant Lake (East)* | *Sucker Lake* | *Sucker Lake Outlet* | *East Vadnais Lake (North)* | *East Vadnais Lake (South)* | *East Vadnais Lake (Gatehouse)* | *Raw WTP Water (McCarron's)* | *White Bear Lake (North)* | *White Bear Lake (Central)* | *White Bear Lake (East)* | *White Bear Lake (West)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data Source** | | MCES | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | SPRWS | Ramsey County | Ramsey County | Ramsey County | Ramsey County |
| **Sample Depth (meters)** | | 1 | Taken from a pipe | 3 | 3 | 3 | 3 | 3 | 3 | At pipe inlet (7 - 15) | Taken from a pipe | 0 - 0.5 | 0 - 0.5 | 0 - 0.5 | 0 - 0.5 |
| *Alkalinity , Total (mg/L as CaCO3)* | Mean | 168 | 140 * | - | - | - | - | - | - | - | 144 * | - | - | - | - |
| | Median | 169 | 142 | - | - | - | - | - | - | - | 142 | - | - | - | - |
| | Max | 225 | 176 | - | - | - | - | - | - | - | 238 | - | - | - | - |
| | Min | 107 | 91 | - | - | - | - | - | - | - | 118 | - | - | - | - |
| | Count | 50 | 40 | - | - | - | - | - | - | - | 85 | - | - | - | - |
| *Ammonia (mg-N/L)* | Mean | 0.03 | 0.04 * | - | - | - | - | - | - | 0.251 * | 0.043 * | - | 0.024 | 0.025 | - |
| | Median | 0.02 | 0.00 | - | - | - | - | - | - | 0.000 | 0.000 | - | 0.020 | 0.020 | - |
| | Max | 0.16 | 0.73 | - | - | - | - | - | - | 5.380 | 0.320 | - | 0.057 | 0.065 | - |
| | Min | 0.02 | 0.00 | - | - | - | - | - | - | 0.000 | 0.000 | - | 0.020 | 0.020 | - |
| | Count | 108 | 34 | - | - | - | - | - | - | 34 | 34 | - | 37 | 39 | - |
| *Chloride (mg/L)* | Mean | 14.8 [e] | 18.8 * | - | - | - | - | - | - | - | 33.2 * | # | # | 39.2 | # |
| | Median | 15.0 | 18.0 | - | - | - | - | - | - | - | 33.5 | # | # | 40.0 | # |
| | Max | 23.0 | 31.0 | - | - | - | - | - | - | - | 42.0 | # | # | 52.0 | # |
| | Min | 7.0 | 12.0 | - | - | - | - | - | - | - | 24.0 | # | # | 24.5 | # |
| | Count | 107 | 40 | - | - | - | - | - | - | - | 40 | # | # | 39 | # |
| *Chlorophyll a, corrected (ug/L)* | Mean | 19.5 | - | - | - | - | - | - | - | - | - | 5.32 | 5.00 | 5.40 | 3.87 |
| | Median | 18.0 | - | - | - | - | - | - | - | - | - | 4.68 | 4.12 | 5.00 | 3.41 |
| | Max | 56.0 | - | - | - | - | - | - | - | - | - | 14.95 | 13.41 | 13.14 | 10.29 |
| | Min | 2.9 | - | - | - | - | - | - | - | - | - | 1.15 | 0.73 | 0.87 | 1.12 |
| | Count | 105 | - | - | - | - | - | - | - | - | - | 39 | 39 | 39 | 37 |
| *Chlorophyll a, uncorrected (ug/L)* | Mean | 22.4 | 12.9 * | 19.0 * † | 13.5 * † | - | - | 12.2 * | 13.4 * | - | - | - | - | - | - |
| | Median | 21.0 | 12.0 | 12.2 | 13.0 | - | - | 13.0 | 14.7 | - | - | - | - | - | - |
| | Max | 63.0 | 26.0 | 124.1 | 30.8 | - | - | 20.6 | 25.8 | - | - | - | - | - | - |
| | Min | 2.1 | 3.0 | 1.4 | 3.7 | - | - | 1.5 | 3.1 | - | - | - | - | - | - |
| | Count | 105 | 23 | 15 | 15 | - | - | 14 | 12 | - | - | - | - | - | - |
| *Coliform, Total (CFU /100 mL)* [a] | Mean | - | # | - | - | - | - | - | - | - | 193 * | - | - | - | - |
| | Median | - | # | - | - | - | - | - | - | - | 166 | - | - | - | - |
| | Max | - | # | - | - | - | - | - | - | - | 2420 | - | - | - | - |
| | Min | - | # | - | - | - | - | - | - | - | 10 | - | - | - | - |
| | Count | - | # | - | - | - | - | - | - | - | 29 | - | - | - | - |
| *Dissolved Oxygen (mg/L)* | Mean | 8.20 | 10.11 * | - | - | - | - | - | - | - | 9.62 * | 9.26 † | 9.19 | 9.06 | 9.14 |
| | Median | 8.05 | 9.90 | - | - | - | - | - | - | - | 9.70 | 9.29 | 9.13 | 8.78 | 9.14 |
| | Max | 11.36 | 13.40 | - | - | - | - | - | - | - | 12.10 | 12.22 | 12.29 | 12.52 | 11.63 |
| | Min | 5.97 | 7.60 | - | - | - | - | - | - | - | 4.80 | 7.84 | 7.40 | 5.85 | 7.22 |
| | Count | 106 | 39 | - | - | - | - | - | - | - | 39 | 39 | 39 | 40 | 37 |

## Water Quality Statistics 2011 - 2015 (May - September) – Page 2

| | | *Mississippi River Water (Anoka)* | *Mississippi River Water (Fridley)* | *Pleasant Lake (West)* | *Pleasant Lake (East)* | *Sucker Lake* | *Sucker Lake Outlet* | *East Vadnais Lake (North)* | *East Vadnais Lake (South)* | *East Vadnais Lake (Gatehouse)* | *Raw WTP Water (McCarron's)* | *White Bear Lake (North)* | *White Bear Lake (Central)* | *White Bear Lake (East)* | *White Bear Lake (West)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *E. coli (MPN/100 mL)* [a] | Mean | 71 | 51 * | - | - | - | - | - | - | 2 * | 1 * | - | - | - | - |
| | Median | 55 | 46 | - | - | - | - | - | - | 1 | 1 | - | - | - | - |
| | Max | 1986 | 548 | - | - | - | - | - | - | 299 | 488 | - | - | - | - |
| | Min | 6 | 1 | - | - | - | - | - | - | 0 | 0 | - | - | - | - |
| | Count | 108 | 33 | - | - | - | - | - | - | 38 | 38 | - | - | - | - |
| *Hardness, Total (mg/L as CaCO3)* | Mean | 198 | 156 * | - | - | - | - | - | - | - | 163 * | - | - | - | - |
| | Median | 192 | 158 | - | - | - | - | - | - | - | 157 | - | - | - | - |
| | Max | 268 | 196 | - | - | - | - | - | - | - | 263 | - | - | - | - |
| | Min | 164 | 106 | - | - | - | - | - | - | - | 131 | - | - | - | - |
| | Count | 13 | 40 | - | - | - | - | - | - | - | 77 | - | - | - | - |
| *Nitrate/Nitrite (mg-N/L)* | Mean | 0.90 | 0.381 * | # | # | - | - | # | # | 0.180 * | 0.256 * | - | 0.015 | 0.017 | - |
| | Median | 0.63 | 0.383 | # | # | - | - | # | # | 0.202 | 0.202 | - | 0.010 | 0.010 | - |
| | Max | 3.26 | 0.753 | # | # | - | - | # | # | 0.464 | 0.496 | - | 0.074 | 0.065 | - |
| | Min | 0.14 | 0.004 | # | # | - | - | # | # | 0.001 | 0.178 | - | 0.010 | 0.010 | - |
| | Count | 107 | 39 | # | # | - | - | # | # | 39 | 39 | - | 37 | 39 | - |
| *Nitrogen, Total (mg-N/L)* [b] | Mean | 1.94 | 1.24 * | 0.81 * † | 0.72 * † | - | - | 0.67 * † | 0.69 * † | 0.76 * | 0.82 * | - | 0.79 | 0.84 | - |
| | Median | 1.71 | 1.05 | 0.78 | 0.73 | - | - | 0.65 | 0.68 | 0.74 | 0.73 | - | 0.74 | 0.86 | - |
| | Max | 4.76 | 6.24 | 1.25 | 0.89 | - | - | 0.90 | 0.82 | 2.99 | 2.34 | - | 1.41 | 1.39 | - |
| | Min | 0.96 | 0.53 | 0.46 | 0.49 | - | - | 0.38 | 0.40 | 0.10 | 0.12 | - | 0.15 | 0.11 | - |
| | Count | 107 | 37 | 12 | 12 | - | - | 13 | 12 | 37 | 37 | - | 37 | 38 | - |
| *pH* [c] | Mean | 8.05 | 8.13 * | # | # | - | - | # | # | - | 7.93 * | 8.39 † | 8.41 | 8.11 | 8.40 |
| | Median | 8.09 | 8.21 | # | # | - | - | # | # | - | 7.96 | 8.41 | 8.42 | 8.35 | 8.45 |
| | Max | 8.58 | 8.70 | # | # | - | - | # | # | - | 10.91 | 9.07 | 9.16 | 9.70 | 9.23 |
| | Min | 7.61 | 7.83 | # | # | - | - | # | # | - | 7.56 | 7.98 | 7.98 | 7.31 | 7.97 |
| | Count | 109 | 32 | # | # | - | - | # | # | - | 120 | 38 | 38 | 39 | 36 |
| *Phosphorus, Total (mg-P/L)* [d] | Mean | 0.121 | 0.072 * | 0.035 * † | 0.031 * † | - | - | 0.026 † | 0.025 † | 0.032 * | 0.029 * | 0.018 | 0.018 | 0.018 | 0.020 |
| | Median | 0.111 | 0.063 | 0.028 | 0.026 | - | - | 0.024 | 0.020 | 0.025 | 0.025 | 0.018 | 0.017 | 0.018 | 0.019 |
| | Max | 0.275 | 0.229 | 0.075 | 0.065 | - | - | 0.049 | 0.046 | 0.250 | 0.058 | 0.034 | 0.038 | 0.037 | 0.042 |
| | Min | 0.050 | 0.020 | 0.020 | 0.020 | - | - | 0.020 | 0.020 | 0.020 | 0.020 | 0.010 | 0.010 | 0.010 | 0.013 |
| | Count | 107 | 39 | 16 | 16 | - | - | 20 | 19 | 39 | 38 | 38 | 39 | 39 | 37 |
| *Secchi (m)* | Mean | - | - | - | - | - | - | - | - | - | - | 3.2 | 3.4 | 3.4 | 2.8 |
| | Median | - | - | - | - | - | - | - | - | - | - | 3.0 | 3.2 | 3.1 | 2.9 |
| | Max | - | - | - | - | - | - | - | - | - | - | 6.0 | 6.3 | 7.2 | 3.8 |
| | Min | - | - | - | - | - | - | - | - | - | - | 1.8 | 1.8 | 1.8 | 1.7 |
| | Count | - | - | - | - | - | - | - | - | - | - | 36 | 39 | 38 | 31 |
| *Temperature (°C)* | Mean | 20.7 | - | - | - | - | - | - | - | - | 19.22 * | 20.94 † | 20.87 | 20.76 | 21.60 |
| | Median | 21.8 | - | - | - | - | - | - | - | - | 21.00 | 21.89 | 21.97 | 21.51 | 22.88 |
| | Max | 27.8 | - | - | - | - | - | - | - | - | 26.00 | 29.53 | 28.37 | 28.88 | 29.57 |
| | Min | 7.8 | - | - | - | - | - | - | - | - | 0.00 | 7.66 | 7.56 | 7.58 | 10.77 |
| | Count | 109 | - | - | - | - | - | - | - | - | 97 | 39 | 39 | 40 | 37 |

## Water Quality Statistics 2011 - 2015 (May - September) – Page 3

| | | Mississippi River Water (Anoka) | Mississippi River Water (Fridley) | Pleasant Lake (West) | Pleasant Lake (East) | Sucker Lake | Sucker Lake Outlet | East Vadnais Lake (North) | East Vadnais Lake (South) | East Vadnais Lake (Gatehouse) | Raw WTP Water (McCarron's) | White Bear Lake (North) | White Bear Lake (Central) | White Bear Lake (East) | White Bear Lake (West) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Turbidity (NTU)* | Mean | - | 8.4 * | # | # | - | - | # | # | - | 0.7 * | 2.0 | 1.8 | 2.0 | 1.6 |
| | Median | - | 5.9 | # | # | - | - | # | # | - | 0.4 | 1.3 | 1.3 | 1.8 | 1.6 |
| | Max | - | 28.3 | # | # | - | - | # | # | - | 6.8 | 6.0 | 9.8 | 5.1 | 3.3 |
| | Min | - | 1.8 | # | # | - | - | # | # | - | 0.2 | 0.7 | 0.6 | 0.5 | 0.8 |
| | Count | - | 41 | # | # | - | - | # | # | - | 92 | 37 | 38 | 38 | 36 |
| *Turbidity (NTRU)* | Mean | 12 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Median | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Max | 65 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Min | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Count | 108 | - | - | - | - | - | - | - | - | - | - | - | - | - |

General Table Notes:

- Pound (#) = at least one sample was taken, but overall was sampled too infrequently (less than 2.5 years) to calculate a comparable average
- Dash (-) = not sampled
- When values were flagged with "Non-Detects" or "Reporting Limit" and had a sign (e.g. <), the sign was removed and the value of the given limit was used
- Since White Bear Lake was only sampled in the months of May - September, all datasets were filtered to only include data from 2011 - 2015 for the months of May - September. Additional data is available at some sites outside of those criteria.
- Data was used at the depth where samples were taken most frequently. Additional data is available at some sites at other depths.
- Basic data cleaning was performed which involved pivoting the data, removing censored values (errors), converting units, and averaging replicate samples (i.e. samples which occurred on the same day at the same depth)

[a] Bacteria is reported as counts which can be exceptionally skewed, so the averages are calculated as Geometric Means

[b] For the Mississippi River at Anoka and White Beal Lake sites, Total Nitrogen was calculated as the sum of Nitrate/Nitrite and Total Kjeldahl Nitrogen

[c] pH is a log scale, so averages are calculated by converting values to hydrogen ion concentration [H+], averaging [H+], then converting back to pH

[d] For consistency and accuracy between datasets from the different agencies, Total Phosphorus values which were below the Reporting Limit of each laboratory (MCES – 0.05 mg/L, SPRWS – 0.02 mg/L, Ramsey County – 0.01 mg/L) were censored and the value of the respective Reporting Limit was used

[e] Chloride samples at the Mississippi River at Anoka were sometimes filtered, sometimes not. This should not affect results since Chloride is dissolved in water.

* There are gaps in the data:

- Mississippi River Water (Fridley)
  - All parameters – 2011
  - E. coli and Chlorophyll a (uncorrected) - also 2012
- Pleasant Lake (West)
  - All parameters - 2011 to mid-2012
- Pleasant Lake (East)
  - All parameters - 2011 to mid-2012
- East Vadnais Lake (North)
  - Chlorophyll a (uncorrected) and Total Nitrogen - 2011 to mid-2012
- East Vadnais Lake (South)
  - Chlorophyll a (uncorrected) and Total Nitrogen - 2011 to mid-2012
- East Vadnais Lake (Gatehouse)
  - All parameters – 2011
- Raw WTP Water (McCarron's)
  - All parameters – 2011
  - E. coli and Total Coliform - also 2012

† Additional data is available at other depths:

- Pleasant Lake (West)
  - Total Nitrogen and Total Phosphorus - at 13 meters
- Pleasant Lake (East)
  - Total Nitrogen and Total Phosphorus - at 13 meters

## Water Quality Statistics 2011 - 2015 (May - September) – Page 4

- East Vadnais Lake (North)
    - Total Nitrogen and Total Phosphorus - at 13 meters
- East Vadnais Lake (South)
    - Total Nitrogen and Total Phosphorus - at 13 meters
- White Bear Lake (North)
    - Dissolved Oxygen, Temperature, and pH - down to 6-7 meters at 1-3 meter intervals
- White Bear Lake (Central)
    - Dissolved Oxygen, Temperature, and pH - down to 8-10 meters at 1 meter intervals
    - Total Phosphorus, Turbidity (NTU), and Chloride - down to 8-10 meters at irregular 2-3 meter intervals
    - Chlorophyll a (corrected), Nitrate/Nitrite, and Ammonia - at 2 meters
- White Bear Lake (East)
    - Dissolved Oxygen, Temperature, and pH down to 20 - 22 meters at 1-2 meter intervals
    - Total Phosphorus, Turbidity (NTU), and Chloride - down to 20-22 meters at irregular 2-4 meter intervals
    - Nitrate/Nitrite, Ammonia, and Chlorophyll a (corrected) - at 2 meters
- White Bear Lake (West)
    - Dissolved Oxygen, Temperature, and pH - down to 3-5 meters at 1-2 meter intervals

Table prepared and completed in December, 2015 by Metropolitan Council Environmental Services staff