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2015 Water Quality Monitoring and Watershed Management Plan Implementation Status Report

Prepared for:

Clearwater River Watershed District

75 Elm St E
PO Box 481
Annandale, Minnesota
55389

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Prepared by:

WENCK Associates, Inc.
1800 Pioneer Creek Center
Maple Plain, MN 55359
Phone: 763-479-4200
Fax: 763-479-4242

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Acronyms

BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BWSR	MN Board of Water & Soil Resources
cfs	cubic feet per second
CFU/100 mL	colony forming units per 100 milliliters
Chlor-*a*	Chlorophyll-*a*
CRWD	Clearwater River Watershed District
District	Clearwater River Watershed District
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
lbs	Pounds
MDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
µg/L	micrograms per liter
mg/L	milligrams per liter
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest
Ortho-P	Ortho-Phosphorus
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
WMP	Watershed Management Plan

Executive Summary

This report was prepared by Wenck Associates, Inc. (Wenck) for the Clearwater River Watershed District (CRWD) to provide a progress report of Watershed Management Plan (WMP) Implementation activities in the District. The report summarizes 2015 hydrologic, hydraulic and water quality monitoring data and provides an analysis of progress towards goals in the context of the District's watershed management activities.

In 2015, the CRWD made progress towards goals established in the Watershed Management Plan by doing the following:

- Began construction on two projects to protect and improve water quality in the Cedar Lake sub-watershed. The Highway 55 Project located just upstream of Cedar Lake was completed in the summer of 2015. Construction on the Swartout Lake Project was substantially complete in January 2016 and will be finished in the spring. Both projects are funded through a Clean Water Fund grant via MN BWSR and property taxes on benefited property owners.
- Conducted ongoing monitoring of the Kingston Wetland Restoration Project constructed in 2013; this monitoring was planned for and funded through a Federal 319 grant and is required by the DNR permit for the project. Monitoring continued to show the project has improved dissolved oxygen (DO) concentrations so that the river now meets the State of Minnesota DO standard in most flow regimes. Data also shows a reduction in the export of soluble reactive phosphorus from Kingston Wetland to lakes downstream. Indices of biotic integrity also showed significant improvement. The sediment trap forebay was maintained in 2015. The final project report for the Section 319 grant was competed summer 2015.
- Continued work for on-going projects:
    - Final construction and project closeout for the Phase II Kimball Stormwater Project was completed 2015.
    - Continued to enroll participants to conduct gridded soil testing and GPS aided fertilizer application for the Targeted Fertilizer Application Project in the upper watershed, which is funded in part by a federal Section 319 grant. The District engineer and Administrator also gave several presentations on the project to interested parties.
    - Continued targeted implementation of agricultural cost share BMPs in high priority locations that were identified through the TMDL study. This included a Clean Water Legacy grant to install alternate tile intakes.
- Continued to implement rough fish management (removal and migration barriers).
- Completed concept designs for the Watkins Area Stormwater Treatment Project.
- Implemented additional monitoring tasks to fill data gaps identified in the TMDL. Collection of these data assist in achieving grants, final design of capital improvement projects and improved targeting of BMPs.
- Continued Aquatic Invasive Species (AIS) work with lake associations as initiated by lake associations.
- Administrator Loewen actively participated in the Stearns County AIS Committee and was part of Wright County's AIS advisory group to its AIS Task Force.
- Collaboration with the Mississippi River (St. Cloud) Watershed WRAPS Implementation.

- Conducted various civic engagement activities, including focused outreach to district school via partnership with the Sauk River Watershed District

In 2016, the CRWD plans to continue progress towards Watershed Management Plan and TMDL goals by:

- Continuing to monitor water quality, hydrology and hydraulics to track water quality trends and the effectiveness of existing management strategies. These actions help to improve efficiencies of implementation projects.
- Conducting rough fish removal and migration management as necessary.
- Complete the Targeted Fertilizer Application Project and publish results.
- Continuing to monitor the Kingston Wetland Restoration Project.
- Completing construction on the Cedar Lake Watershed Protection & Improvement Project.
- Begin construction of the Watkins Area Stormwater Treatment Project.
- Continuing enrollment in the alternative tile intake project.
- Continuing update of upper watershed sediment & bacteria source inventory; begin implementing projects to address identified sources.
- Identifying additional projects and continuing to apply for grant dollars to fund other CRWD projects.
- Completing maintenance on existing projects as noted in annual project inspections.
- Continuing education and outreach efforts.
- Conducting the annual strategic planning session in March to evaluate WMP implementation, perform adaptive management and identify additional needs.
- Beginning discussions for update of the 10-year comprehensive plan.

Significant hydrologic, hydraulic and water quality findings in this report include the following:

1. Overall, annual precipitation and runoff was above normal at monitored locations for the year in 2015. Precipitation ranged from 37.61 inches in Annandale to 32.12 inches in Kimball. Runoff near the watershed outlet was below average at 5.9 inches (compared to 7.9 inches in an average year).
2. Phosphorus loads from the Clearwater River are stable to declining, but still above water quality target loads: 2,926 lbs. at the Grass Lake Dam and 7,438 lbs. upstream of Lake Betsy.
3. Lake water quality is stable to improving in all CRWD lakes based on long-term trends. Lake Betsy remains a bright spot in the watershed. Water quality in this lake (located in the high priority target watershed for implementation) has improved dramatically since implementation activities began in 2009.

1.0 Introduction

The Clearwater River Watershed District (CRWD) has conducted a stream, precipitation, and lake monitoring program since 1980 (Appendix A). Ongoing monitoring is critical to establish long term water quality and hydrologic trends. In 2009, the annual report in which these data were published was expanded to include tracking CRWD progress towards water quality goals in terms of program/ project implementation. This allows the CRWD to optimize costs and benefits of protection and restoration of natural resources within the District.

1.1 MONITORING & REPORT OBJECTIVES

The objectives of the Water Quality Monitoring and Watershed Management Plan Implementation Status program are:

1. Track progress towards water quality goals for impaired waters by:
    a) Measuring water quality trends in lakes and streams and pollutant loads
    b) Tracking programs and projects implemented
    c) Evaluating water quality in the context of programs/ projects implemented
2. Fill data gaps identified in the TMDLs
3. Continue to provide baseline water quality data and calibration data sets to refine TMDL load reductions
4. Track long-term trends in all CRWD waters monitored ensuring early detection of declining trends
5. Provide recommendations for ongoing programs, projects and watershed management strategies based on data

Data collected through the monitoring program has documented dramatic improvements in lake water quality since the early 1980s, as well as significant reductions in stream nutrient and sediment loads (Appendix B and C). These improvements are largely the result of the CRWD's 1980 Chain of Lakes Restoration Project and other more recent CRWD initiatives. However, some water bodies do not meet state water quality standards for designated uses (aquatic habitat or recreation for example).

1.2 TMDL'S

The CRWD, in partnership with the Minnesota Pollution Control Agency (MPCA), began a Total Maximum Daily Load (TMDL) study in 2003 to address the District's impaired waters. The TMDL process establishes the amount of a given pollutant that the water body can assimilate while still meeting its designated uses. The TMDL studies were finalized in 2008 and the required nutrient, bacteria and oxygen demand load reductions were quantified.

The status of TMDLs in the District is shown in Table 1-1. All are complete and were approved by the MPCA, EPA and the public via a public comment period.

Through the TMDL process, the CRWD identified a suite of implementation strategies in the watershed needed to meet water quality goals for impaired waters and to protect water quality of all CRWD waters. Through the study, the District also prioritized implementation areas to maximize cost/ benefit. These are documented in the Watershed Restoration and Protection Plan for the CRWD (TMDL Implementation Plan) which was approved by the MPCA in May of 2009.

Following the completion of the TMDLs, the CRWD undertook a revision of its Watershed Management Plan to reflect the recommendations in the TMDL and expand on them. The revised Watershed Management Plan was completed and approved by BWSR in 2011. TMDL reports can be found at the MPCA website at http://www.pca.state.mn.us/water/tmdl. The Watershed Management Plan is available at the CWRD web site www.crwd.org.

Another TMDL for the larger 8-digit hydrologic unit code (HUC) 07010203, which includes CRWD as well as the Elk River watershed (Figure 1-1) was completed in 2015. This process began in 2009 under the MPCA's new approach to TMDLs called the watershed approach. The watershed approach is a 10-year rotation for assessing waters of the state on the level of Minnesota's major watersheds (8-digit HUCs). It was led by the Elk River Watershed Association (ERWSA) and Sherburne County Soil and Water Conservation District. Data collected through this project has resulted in the identification of new impairments and TMDLs needed within the CRWD based on indices of biotic integrity. A Watershed Restoration & Protection Strategies Report was established as part of this approach and can be reviewed at the MPCA website listed above.

Table 1-1: Impaired Waters in CRWD

Water	Impairment and Impaired Use	TMDL Status	Listing Date
Clear Lake (47-0095)	Nutrients, aquatic life and recreation	EPA Approved.	2008
Lake Betsy (47-0042)			2008
Union Lake (86-0298)			2008
Scott Lake (86-0297)			2008
Lake Louisa (86-0282)			2004
Lake Marie (73-0014)			2008
The Clearwater River, Clear Lake to Lake Betsy	Dissolved oxygen and bacteria, aquatic life & recreation		2004
Lake Caroline (86-0281)	Nutrients, aquatic life and recreation	EPA Approved.	2010
Lake Augusta (86-0284)			2010
Swartout Lake (86-0208)			2010
Lake Albion (86-0212)			2010

Water	Impairment and Impaired Use	TMDL Status	Listing Date
Henshaw Lake (86-0213)			2010
The Clearwater River, Grass Lake to the Mississippi	Dissolved oxygen, aquatic life and recreation	This listing was under consideration at MPCA as data collected during the 2007 TMDL study did not support the presence of an impairment, however, data collected in 2011 have indicated an impairment may exist under some high flow conditions. This listing was addressed during the Mississippi St. Cloud Watershed TMDL. EPA Approved.	2008
Clearwater River (Scott Lake to Lake Louisa)	Aquatic Life (Aquatic macroinvertebrates, fish)		Listed in 2012.
Clearwater River (Clearwater Lake to Mississippi River)	Aquatic Life (Fish)		Listed in 2012.
Fairhaven Creek (Headwaters to Lake Louisa)	*E. coli* bacteria		Listed in 2012.

1.3 CURRENT PROJECTS

To meet lake water quality goals, nutrient loads must be managed from both watershed sources and internal nutrient cycling sources. Several of the watershed management strategies identified for lakes will also assist with meeting bacteria and dissolved oxygen goals for the Clearwater River. Projects and programs to achieve water quality goals were identified in the CRWD's Watershed Restoration and Protection Plan and are expanded upon in the CRWD's Watershed Management Plan which has been formally approved by BWSR.

The CRWD has also applied for grants since 2009 to fund several of the projects/ programs identified through the TMDL process and subsequent studies. Projects and their status are described in detail in Section 2 of this report.

1.4 CURRENT MONITORING

The 2015 CRWD monitoring plan is found in Appendix A, and summarized below. Figure 1-2 shows locations that were monitored in 2015. Figure 1-3 shows locations of impaired water bodies in the CRWD.

Figure 1-1: Geographic Coverage of 8-Digit HUC Watershed TMDL Completed in 2015

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Figure 1-2: 2015 Monitoring Locations

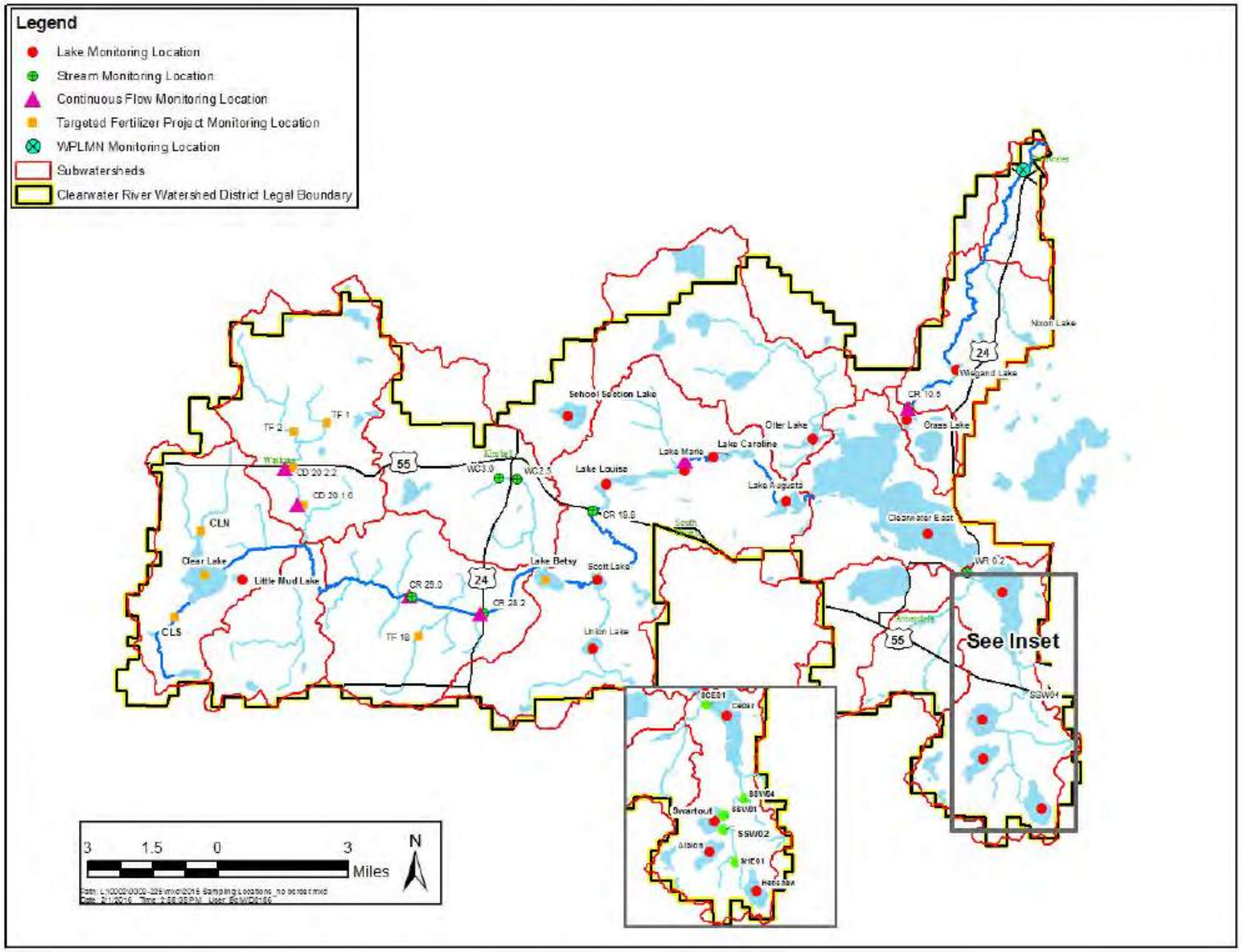
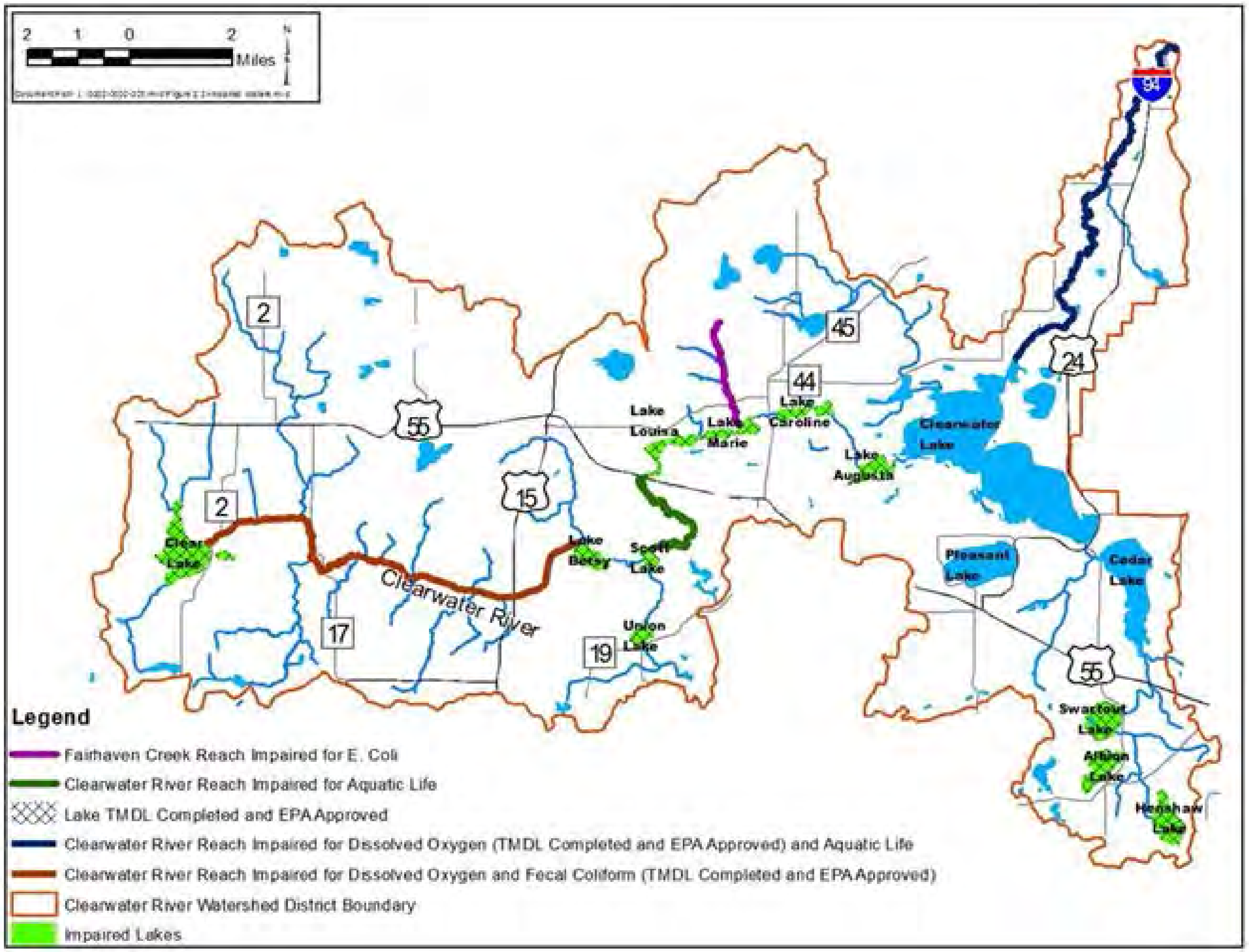


Figure 1-3: Impaired Water Bodies in CRWD



2.0 Progress Towards Water Quality Goals

The CRWD Plan identifies the upper watershed (upstream of Lake Betsy) as the highest priority for implementing both capital projects and programmatic BMPs. Because of the flow-through nature of the Clearwater Chain of Lakes, water quality in upper watershed lakes like Clear Lake and Lake Betsy is the primary driver of water quality in downstream lakes like Clearwater Lake. Nutrient loads from upper watershed lakes and their tributary watersheds drive impairments in lakes further downstream. Clear Lake, Lake Betsy, and the tributary watersheds are targeted for intensive BMPs to not only improve water quality in those lakes, but to also reduce the load to downstream water bodies. All lakes will eventually be targeted, but the greatest impact will be achieved for the lowest cost by initially focusing the efforts on improvements in the upstream end of the District and working downstream.

2.1 PROCESS

The CRWD Plan is specific in its focus: implement the identified projects and programs in high priority geographical areas. The District makes annual adjustments to further focus and refine management activities. The Board and staff review this report, and compare findings to the Watershed Management Plan then prioritize projects and programs. They typically select 1-3 projects and programs to focus on in the coming year. The annual planning is based on remaining programs and projects identified in the Plan, water quality monitoring findings as well as other opportunistic projects identified during the year. This on-going strategic planning keeps the CRWD focused and efficient.

2.2 SUMMARY

The following section summarizes year by year strategy as well as programs and projects undertaken since the plan was adopted:

2009

- Prioritized 6 projects from the overall TMDL Implementation Plan
    - City of Kimball Stormwater Retrofit
    - Lake Betsy Internal Load Management
    - Watkins treatment area
    - Targeted Fertilizer Application Project
    - Kingston Wetland Restoration
    - Clear Lake South Sand Filter/ Weir
- Applied for grants for each of prioritized projects, received grant for Kimball stormwater (Kimball Stormwater would eventually be broken into 2 phases, grant for Phase I was received in 2009)
- Implemented agricultural BMPs identified in the TMDL Implementation Plan in upper watershed
- Conducted additional monitoring, including collection of lake bottom samples and sediment phosphorus release analysis in Clear and Betsy Lakes
- Implement education program including watershed tours and outreach to lake associations, farmers and local government units.

2010

- Applied for received grant for Kingston Wetland Restoration and Targeted Fertilizer Application Project
- Applied for Watkins Area Restoration Grant and Lake Betsy Internal Load, grants not funded
- Applied for and received CCM funding for streambank restoration.
- Implemented BMPs identified in the TMDL Implementation Plan
- Conducted additional monitoring to fill in data gaps and continue to assess internal loading in District lakes
- Implement education program including watershed tours and outreach to lake associations, farmers and local government units.
- Implemented Fertilizer Field Trial Project

2011

- Constructed Kimball Stormwater Project (now known as Phase I)
- Applied for and secured a grant for Kimball Stormwater Phase II
- Implemented BMPs identified in the TMDL Implementation Plan
- Applied for and received CCM funding for streambank restoration.
- Conducted supplemental water quality and hydrologic monitoring in accordance with recommendations of the implementation plan throughout the District to track progress and focus implementation efforts.
- Implement education program including watershed tours and outreach to lake associations, farmers and local government units.
- Implemented Fertilizer Field Trial Project

2012

- Applied for and secured funding for 1 grant for two projects in the Cedar Lake Subwatershed:
  - Highway 55 project
  - Swartout Wetland Project
- Completed Clear Lake South Sand Filter/ Weir
- Implemented BMPs identified in the TMDL Implementation Plan
- Applied for and received CCM funding for streambank restoration.
- Conducted supplemental water quality and hydrologic monitoring in accordance with recommendations of the implementation plan throughout the District to monitor project performance and better focus implementation efforts.
- Implement education program including watershed tours and outreach to lake associations, farmers and local government units.
- Implemented Targeted Fertilizer Project

2013

- Advanced implementation for priority projects
  - Completed design of Kimball Phase II stormwater retrofit; worked to complete permitting
  - Further developed feasibility for Betsy Lake Internal Load Management
  - Feasibility study of Lake Augusta Internal Load management options
  - Lake Augusta AIS Project
- Applied for and received CCM funding for streambank restoration.

- Secured funding for 20 CCM crew hours for stream bank stabilization for 2014.
- Implemented BMPs identified in the TMDL Implementation Plan
- Conducted supplemental water quality and hydrologic monitoring in accordance with recommendations of the implementation plan throughout the District to monitor project performance and better focus implementation efforts.
- Implement education program including watershed tours and outreach to lake associations, farmers and local government units.
- Began Kingston Wetland Restoration Project
- Implemented Targeted Fertilizer Project

2014

- Advanced implementation for priority projects
  - Completed 90% of construction for Kimball Phase II stormwater retrofit
  - Conducted Feasibility Study Betsy Lake Internal Load Management
  - Completed design and permitting for two Cedar Lake projects, construction to begin early in 2015
  - Continued implementation of Targeted Fertilizer Application Program, early reports from Co-Ops indicate enrollment is approaching goals
- The Targeted Fertilizer Application Program was Awarded
  - Minnesota Association of Watershed District Program of the Year
  - Environmental Initiative Natural Resources Award
- Applied for both rounds of BWSR's Targeted Watershed Implementation Funding to complete the plan implementation, CRWD was not selected for either grant.
- Applied for a Clean Water Legacy (CWL) grant for the Watkins Project
- Applied for 319 funds for the Alternative Tile Intake Demonstration Program
- Measured and recorded positive results of the Kingston Wetland Restoration Project including reduced soluble phosphorus export from the wetland and improved dissolved oxygen concentrations downstream
- Conducted supplemental water quality and hydrologic monitoring in accordance with recommendations of the implementation plan throughout the District to monitor project performance and better focus implementation efforts.
- Implemented education program including watershed tours and outreach to lake associations, farmers and local government units.

2015

- Received a Clean Water Legacy Grant for the Watkins project and began design and permitting.
- Completed final project closeout for Kimball Phase II.
- Completed construction for the Highway 55 portion of the grant-funded Cedar Lake Watershed Protection and Improvement Project.
- Achieved substantial completion Swartout portion of the grant-funded Cedar Lake Watershed Protection and Improvement Project.
- Awarded 319 funds for the Alternative Tile Intake Demonstration Program and began program implementation.
- Continued to enroll landowners in the Targeted Fertilizer Application Program.
- Reported positive results of the Kingston Wetland Restoration Project in the final report and maintained sediment forebay.
- Continued to implement rough fish management (removal and migration barriers)

- Implemented agricultural best management practices via existing District cost-share and/or partnering with other entities (ex SWCDs).
- Conducted water quality and hydrologic monitoring in accordance with recommendations of the implementation plan throughout the District to monitor project performance and better focus implementation efforts.
- Continued Aquatic Invasive Species (AIS) work with lake associations as initiated by lake associations. Actively participated with county-level AIS activities.
- Implemented education program including school district outreach via partnership with Sauk River Watershed District, watershed tours and outreach to lake associations, farmers and local government units.

The CRWD has implemented several major projects to achieve water quality goals; status is shown in Table 2-1.

Table 2-1: Priority Implementation Projects

Project	Potential TP Reduction (lbs/yr)	Estimated Expense	Status
Projects Recently Completed			
Cedar Lake Restoration (06-01 Original)	1,500 lbs/yr	$295,000	Project completed, currently in project maintenance phase
City of Kimball Stormwater Management (Phase I)	244	$189,550	Secured grant funds and partner contribution from the City of Kimball. Construction of the project was substantially completed November 2010. Final grading, planting, and stabilization were completed in 2011. Follow up monitoring was conducted in 2012 and 2013.
Clear Lake Notched Weir	588	$75,000	Easement was secured for project in 2011. Permit applications were completed and submitted in December 2011. Project was constructed in 2012. Monitoring conducted in 2013.
City of Kimball Stormwater Reclamation and Reuse (Phase II)	118	$738,000	Secured grant funds in 2011. Completed design and permitting for project in 2013. Construction 90% complete in 2014. Construction was completed in 2015. Signage and education and outreach were installed in 2015.
Kingston Wetland Feasibility Study and Wetland Restoration	1,970	$739,000	A $404,300 grant was secured for this project. Stream monitoring and other data collection tasks began in Spring 2011. Data collection, modeling, and design were completed in 2012. The project was constructed in 2013 and monitoring was conducted to measure the success of the project. Results indicate improvement in indices of biotic integrity (IBI) and water quality throughout the reach and downstream. The project was completed in 2015.
Conservation Corps	TP load reduction	$65,275	Originally implemented in 2010 when work was Conducted along 2,800 linear feet of streambank.

Project	Potential TP Reduction (lbs/yr)	Estimated Expense	Status
Streambank Restoration	associated with sediment load reduction		CRWD secured a $28,875 grant for the project from Conservation Corps Minnesota. Additional grant funding was secured in 2011 and work on 6,700 linear feet of stream channel was completed between 2011 and 2013.
Projects In Progress			
Cedar Lake Watershed Protection and Improvement Projects (06-01-Modified)	1,280	$554,200	The project targets reductions to the largest watershed sources of nutrient to Cedar and Swartout Lakes by installing filters to remove soluble phosphorus currently exported from degraded wetlands and lakes. The target is to size filters to treat baseflow and the 1.25-inch event to provide the maximum cost/ benefit while preserving upstream hydrology. The projects target reductions from the largest watershed sources of nutrients to each lake providing 80% of the necessary watershed load reductions to Swartout Lake (800 lbs/yr), and 40% of the necessary watershed load reductions to Cedar Lake (480 lbs/ yr).
City of Kimball Stormwater Reclamation and Reuse (Phase II)	118	$738,000	Secured grant funds in 2011. Completed design and permitting for project in 2013. Construction 90% complete in 2014. Construction was completed in 2015. Signage and education and outreach were installed in 2015.
Kingston Wetland Feasibility Study and Wetland Restoration	1,970	$739,000	A $404,300 grant was secured for this project. Stream monitoring and other data collection tasks began in Spring 2011. Data collection, modeling, and design were completed in 2012. The project was constructed in 2013 and monitoring was conducted to measure the success of the project. Results indicate improvement in indices of biotic integrity (IBI) and water quality throughout the reach and downstream.

Project	Potential TP Reduction (lbs/yr)	Estimated Expense	Status
GPS Fertilizer Application	3,200	$871,000	Implemented field trial in 2010 on approximately 1,400 acres using District funds. Completed analysis of data gathered in 2010. Implemented on an additional 567 acres in 2011. Grant funding secured in 2011 to expand the program to 16,000 acres in a priority implementation area. The program achieved 70% uptake of the practice in the implementation area through 2015. Monitoring was conducted on tile outlets and tributary streams and ditches in the project area.
Expand Education Program	NA		Incorporated in grant funded scopes of work are efforts to expand the CRWD's Education/ Outreach programs. The CRWD currently has a strong relationship with Lake Associations and hosts educational events that primarily target adults. The education program was expanded to include social media outreach as well as school age children in the community.
Watkins Impoundment	796	$645,882	Land was acquired for this project. An initial grant application for $351,906 scored highly but was not selected in 2009 due to amount requested. Conducted additional feasibility work and completed another grant application which was not awarded. The District received grant award in 2015 and began design and permitting. Construction is planned for late 2016 or early 2017.
Potential Future Projects			
Lake Betsy Internal Load	1,300 – 6,500 lbs	$250,000-$600,000	Grant applications were most recently denied in 2014. A feasibility study was conducted in 2014 to support project development.
Clear Lake soluble P load from watershed	TBD	TBD	Watershed soluble phosphorus loads to Clear Lake are a priority and needed to meet lake water quality goals. Investigate opportunities to retrofit existing project to incorporate soluble P removal.
CD 20 Project	TBD	TBD	CD 20 is a major source of bacteria to the Clearwater River. Investigate sources and opportunities to mitigate loads.

2.3 STATUS / RESULTS

2.3.1 Cedar Lake Project 06-1

The Cedar Chain of Lakes Restoration Project #06-1 began in 2007 as a response to a petition by lakeshore residents to address the declining water quality and severe algae blooms in Cedar Lake. The goal of the project was to reduce the annual phosphorus load to Cedar Lake to 1,000 lbs. which translates into an in-lake summer average phosphorus concentration in Cedar Lake of 20 µg/L.

The District implemented several projects identified in the Engineer's Report (Wenck 2006) between 2007-2015. The District managed rough fish populations through winter seining and installation of five fish migration barriers to control access to rough fish spawning areas. CRWD constructed the Segner Pond treatment wetland and implemented watershed BMPs such as tile inlet buffers and buffer strips in the high priority areas.

Cedar Lake residents and the active Cedar Lake Conservation Club approached the CRWD in 2011 to request the District apply for additional grant funding to install more capital projects. The District secured a Clean Water Legacy Grant to construct two additional projects and the original project was modified to include the Highway 55 filtration project and a Swartout Wetland Restoration. These projects are discussed in the following sections. The District project (O6-01) included water quality monitoring to track progress towards water quality goals. The monitoring and results are described in the following sections.

2.3.1.1 Cedar Lake Project Monitoring

Cedar Lake, Swartout Lake and Albion Lake were monitored four times from June to September in 2015. Tributaries to the lakes were also monitored at five locations in 2015. Tributaries were monitored to track annual loading to the lakes, which assists in determining progress towards meeting loading goals in addition to tracking the health of the streams.

The District used Lowrance HDS sonar technology and ciBioBase to evaluate bathymetry, bottom (sediment) composition and evaluate vegetation location and biomass in Swartout and Albion Lakes in 2015. The District also conducted point intercept plant survey's to assess submergent vegetation for each lake.

Cedar Lake
Overall water quality appears to have stabilized or be slightly improving in Cedar Lake over the last 10 years (Appendix C). Episodic algal blooms, while decreasing, still occur in the lake, especially early in the growing season. The Cedar Lake Conservation Club continues to treat and monitor curly leaf pondweed and Eurasian watermilfoil within the lake.

Swartout Lake
Water quality is improving in Swartout (Appendix C) but remained above TMDL goals in 2015. Chlorophyll-*a* concentrations were slightly higher in 2015 compared to 2014. Overall, chlorophyll-*a* concentrations have improved and remained relatively stable over the past 10 years. This is likely the result of improved aquatic vegetation growth within the lake which has helped limit the amount of nutrients available for algae growth. Prior to 2010, the lake

had been very turbid due to the absence of rooted aquatic plants and large rough fish populations. Water clarity was good in 2015 as the summer average Secchi disk depth once again met the TMDL goal. Carp migration management efforts combined with an extensive fish kill in the winter of 2010 have likely had a major impact on the improved water clarity and plant growth noted in Swartout Lake. While a small number of carp have been observed in the lake since 2012, it appears that the population has stabilized and has not increased to the high levels observed prior to 2010.

A 2005 vegetation survey in the lake showed the population of rooted aquatic plants growing in the lake was effectively zero. Vegetation surveys conducted in 2010 through 2015 found submergent vegetation growing at approximately 25 to 65% of sample points across the lake. Figure 2-1 shows bathymetric contours and compares vegetation biovolume mapped during the 2014 and 2015 surveys.

The 2015 late summer vegetation inventory showed that submerged vegetation coverage and density increased from 2014 as shown in Figure 2-1. From 2010 to 2014, submergent vegetation was limited to shallow nearshore areas along the western and northern shorelines of the lake despite increased clarity throughout the lake. In 2015, submerged aquatic vegetation was observed around nearly the entire lake from the shoreline to areas with water depths to approximately 6 feet. Overall, submerged vegetation was observed at nearly 65% of sample points in 2015. Submerged aquatic vegetation density appears to be limited by bottom substrate and not just water clarity as areas with mucky bottom sediments are vegetated with dense stands of native species while other areas of the lake with similar depth with a sand/gravel substrate are more sparsely vegetated.

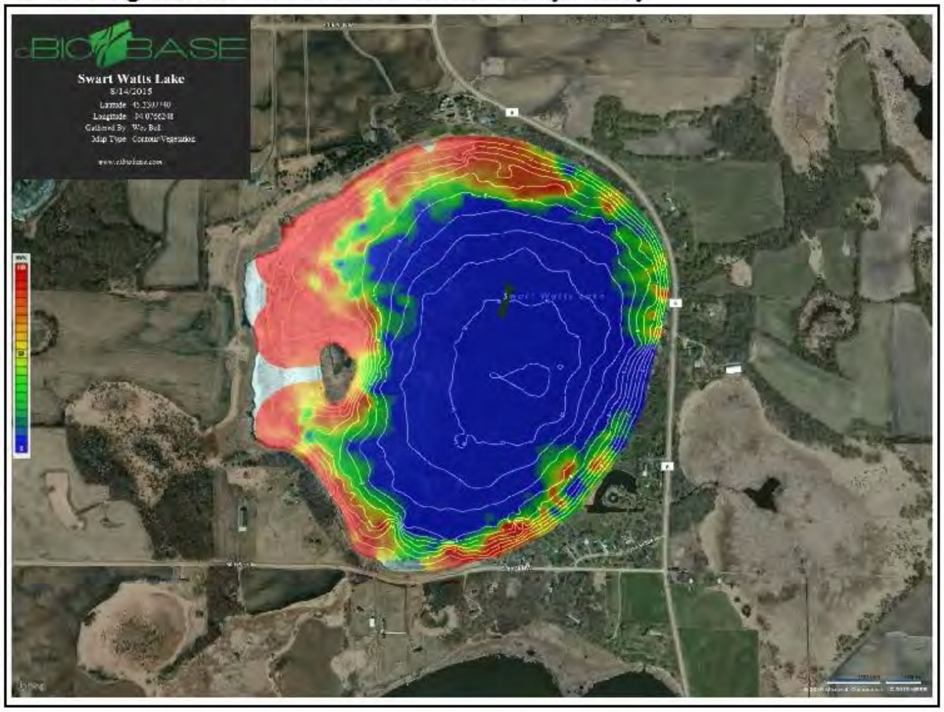
As in previous years, the submergent vegetation community was dominated by native species in 2015, with coontail and bushy pondweed being the most abundant species observed. The vegetation community appears to be transitioning from being dominated by sago pondweed and narrowleaf pondweed species to coontail and bushy pondweed. While each of these are native species, coontail is typically a more tolerant species. As shown in Figure 2-1, the vegetation biovolume was highest in 2015 in the western portion of the lake and near shore around the perimeter of the lake where dense stands of bushy pondweed and coontail were observed. While curly leaf pondweed was not observed at any of the survey points, a young plant was observed floating near the east end of the lake.

The current clear water condition of Swartout Lake represents the stable and healthy condition of a shallow lake. Clear water allows for abundant submergent vegetation growth, which stabilizes bottom sediments and provides food and cover for invertebrates, fish, and other aquatic animals.

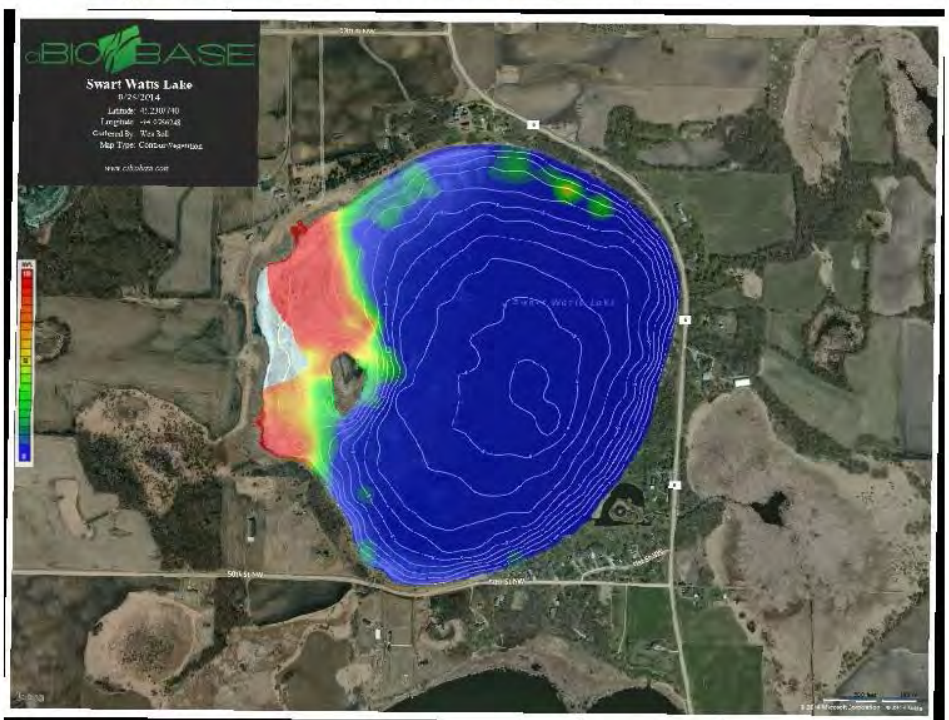
In conclusion, the water quality improvements that have been observed in Swartout Lake since recent fish management efforts and the 2010 fish kill demonstrate the impact rough fish have on the ecology and water quality of shallow lakes throughout the CRWD.

Figure 2-1: Swartout Lake 2015 Aquatic Vegetation and Water Depth

2015 Vegetation Biovolume and Bathymetry



2014 Vegetation Biovolume and Bathymetry



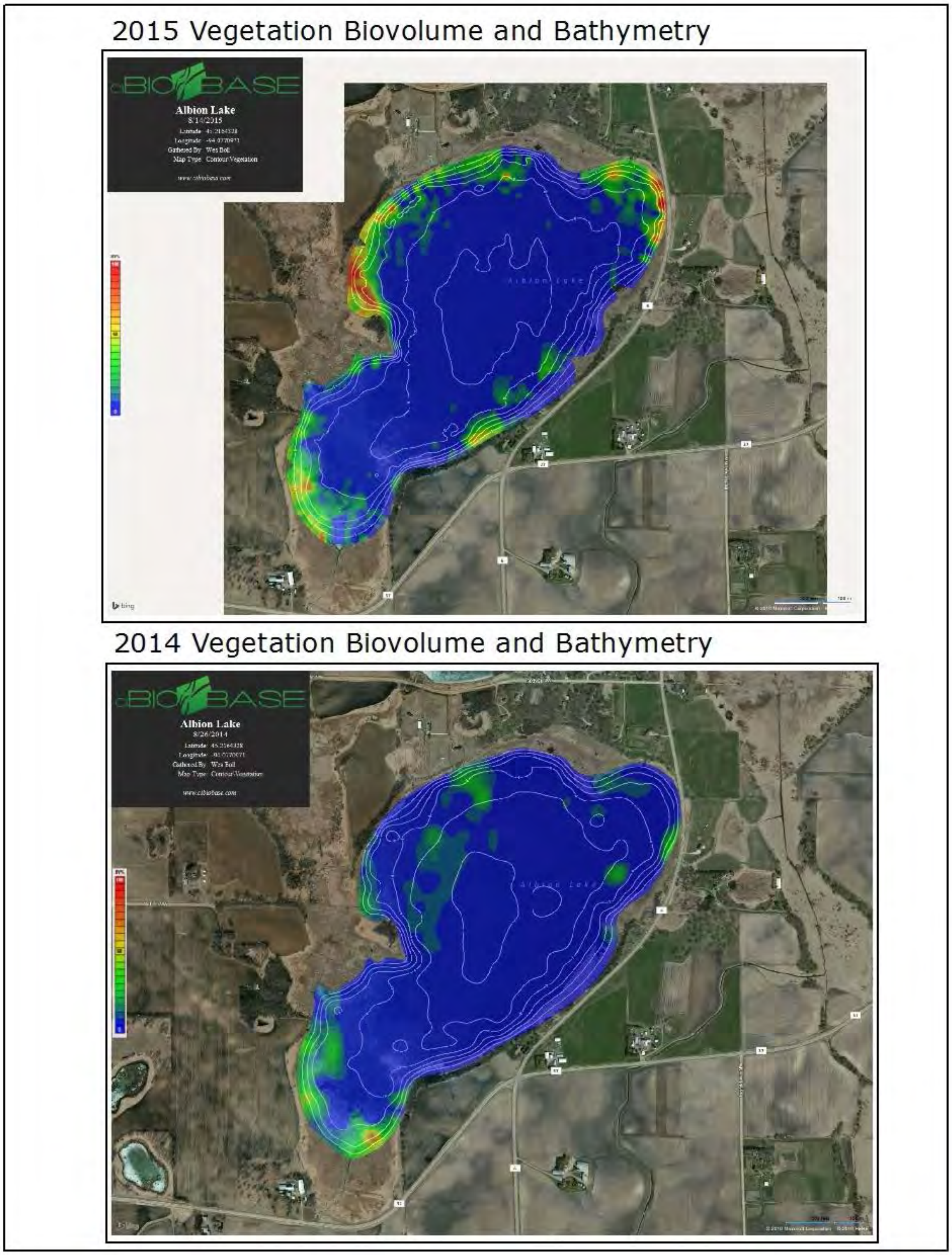
Albion Lake

As shown on the Albion Lake report card in Appendix C, summer average phosphorus and Chlorophyll-*a* concentrations were among the lowest ever observed in Albion Lake in 2014 and 2015, however they are still above TMDL goals. In spite of the reduction in phosphorus and chlorophyll-*a* concentrations, water clarity continued to be poor and has been since 2010.

A review of average summer phosphorus concentrations in 2015 demonstrates that total phosphorus throughout the summer was comprised almost entirely of particulate phosphorus with very little ortho-phosphorus. This is likely due to the rapid uptake of any available dissolved phosphorus by algae combined with re-suspension of bottom sediments in the lake from rough fish and wind.

An aquatic vegetation survey was conducted during late summer in 2015. Aquatic vegetation was observed at 38% of the survey points, similar to coverage in recent years. As shown in Figure 2-2, vegetation was limited to areas shallower than four feet near shore. Vegetation density and biovolume appeared to increase in 2015 as dense stands of vegetation were observed near shore around most of the lake. Sago pondweed was the only submerged vegetation species observed in with the exception of coontail being observed at one sample point. Floating turions and young curly leaf pondweed plants were also observed. A 2013 survey conducted early in the season found that curly leaf pondweed was very common in the lake. A fringe of emergent vegetation dominated by hardstem bulrush and cattail was also observed in portions of the lake.

Figure 2-2: Albion Lake 2014-2015 Aquatic Vegetation Biovolume and Water Depth



Henshaw Lake

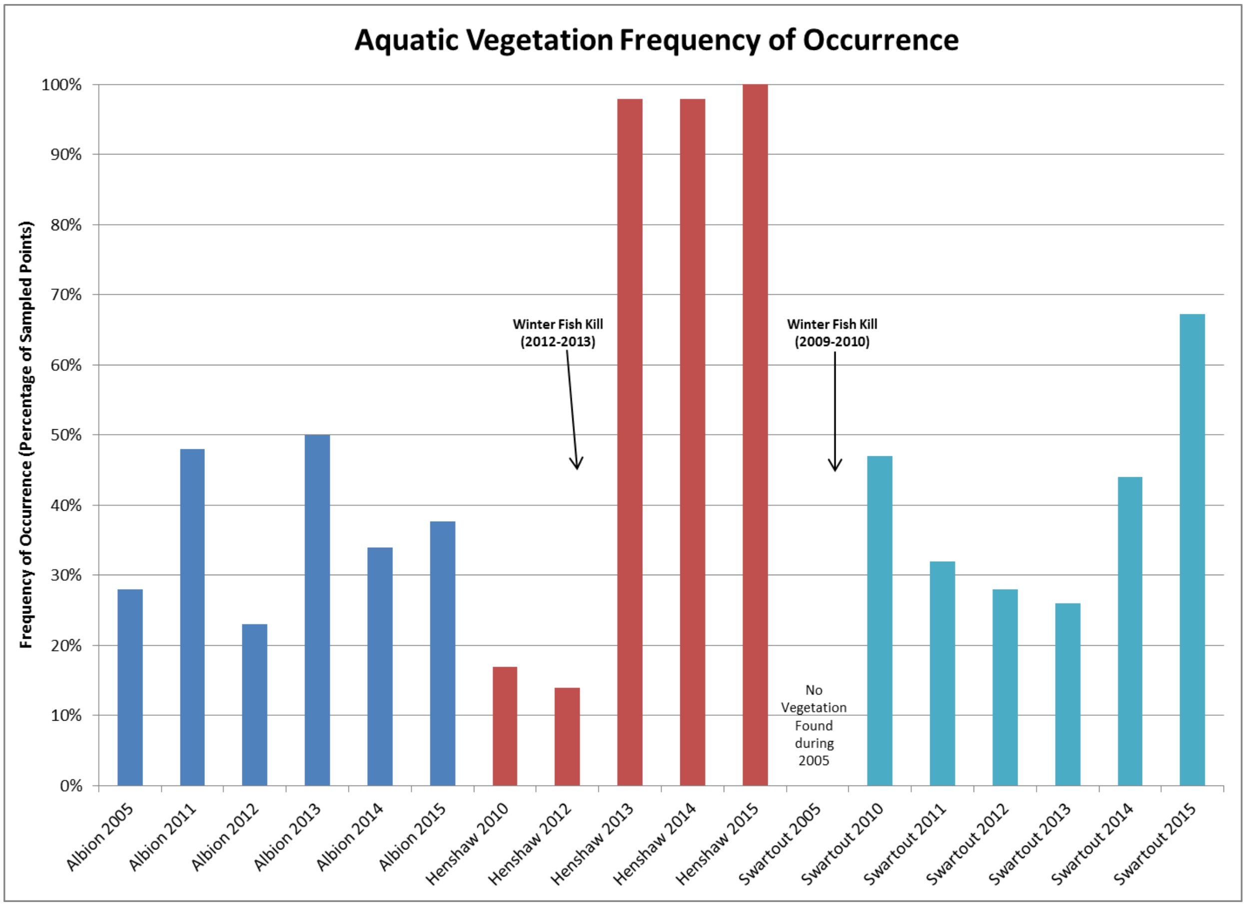
Water quality has improved in Henshaw Lake following an extensive fish kill during the winter of 2012-2013. As summarized on the Henshaw Lake report card in Appendix C, summer average phosphorus concentrations in 2015 were similar to recent years and far lower than concentrations observed prior to 2009. However, TP concentrations still remain above the TMDL goal for the lake. Chlorophyll-a measurements were not collected in 2015 due to heavy plant growth which made access to the lake monitoring station extremely difficult. Previous data shows chlorophyll-a concentrations met TMDL goals in 2013 and 2014. Though it was not directly measured in 2015, water clarity was good in Henshaw Lake as evident by the extensive growth of submerged vegetation.

The dramatic improvement in water quality following the 2012-2013 winterkill suggests that the rough fish population was likely the main driver of poor water quality in Henshaw Lake.

Due to the dense vegetation that prevented boating on the lake in 2015, a full vegetation survey was not conducted. A partial survey was conducted on the lake to determine the vegetation community species composition in early September. Vegetation coverage over the entire lake was near 100% again in 2015. For comparison, as demonstrated in Figure 2-3, aquatic vegetation surveys found vegetation at less than 20% of sampled points during surveys conducted in 2010 and 2012.The vegetation community appeared to have shifted in 2015 from being dominated by sago pondweed, to being dominated by northern water milfoil and coontail, as these 2 species were found growing in dense stands that reached the surface. Curly leaf pondweed has been observed to be abundant in the lake during previous year's surveys.

Aquatic vegetation coverage, density, and diversity remained improved in Henshaw in 2015 as the lack of rough fish in the lake allowed for increased water clarity and optimal conditions for submerged vegetation growth. The current state of the aquatic vegetation in Henshaw Lake is reflective of a healthy shallow lake in the clear water state and provides optimal habitat and food for fish, waterfowl, and other wildlife.

Figure 2-3: Aquatic Vegetation Frequency of Occurrence in Albion, Henshaw, and Swartout Lakes



Tributary Monitoring

Five tributary streams in the Cedar Lake subwatershed were monitored in 2015 to quantify nutrient loads to the lakes. Locations of the monitored tributary streams are shown on Figure 2-4. Annual runoff at each monitoring site from 2007 to 2015 is shown in Figure 2-5. The calculated phosphorus loads from 2007 to 2015 are shown in Figure 2-6. Mean TP concentrations for 2015 are shown in Table 2-2 along with ortho-P concentrations and TP loading rates for each monitoring location. Overall, runoff at Cedar Lake tributary monitoring stations were within range of those observed in past years. Mean TP concentrations were also similar to those observed in recent years. Phosphorus loads were similar to previous years and close to the watershed load goal for Cedar Lake (1,000 lbs/ year average). These results suggest export of soluble phosphorus from wetlands and lakes in the sub-watersheds upstream of Cedar Lake is a significant contributor to the phosphorus load to Cedar Lake.

Figure 2-4: Cedar Lake tributary monitoring locations and fish barriers.

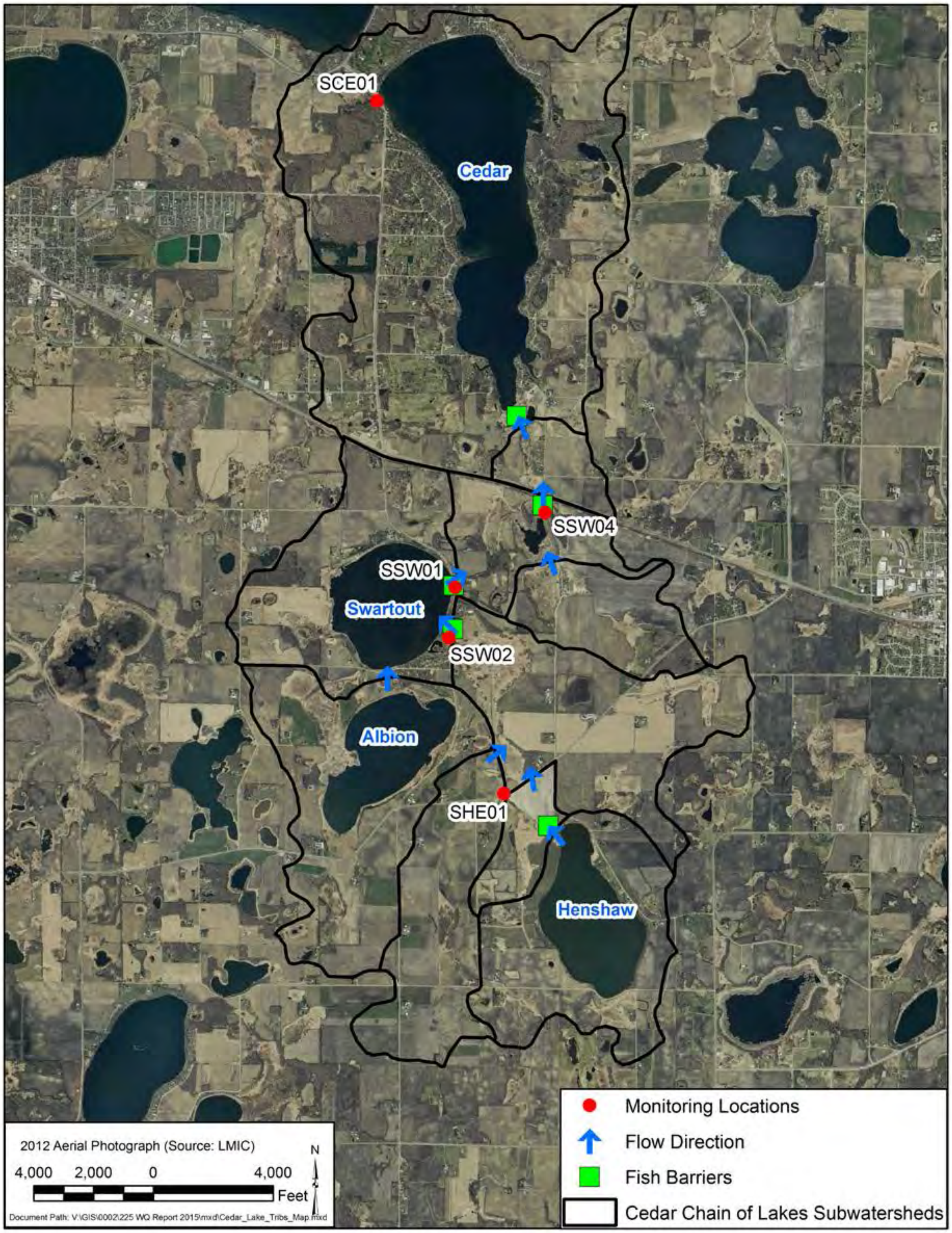


Figure 2-5. Cedar Lake tributary monitoring annual runoff depth (inches/year)

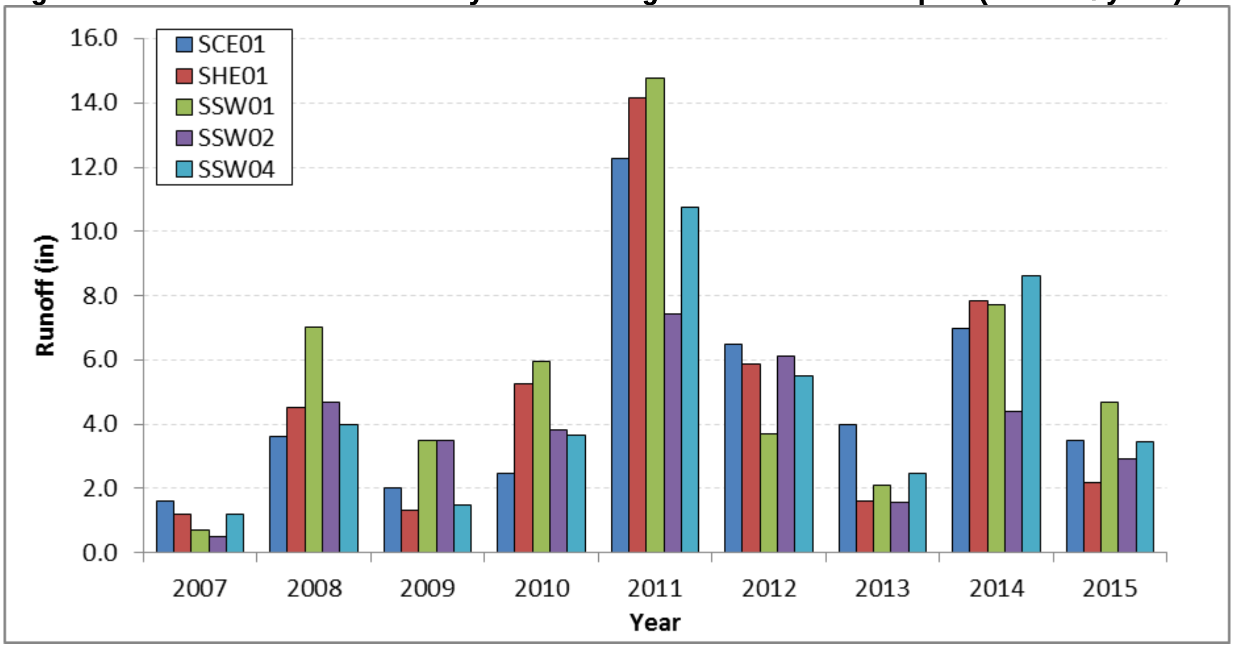


Figure 2-6. Cedar Lake tributary monitoring annual TP loads (lbs/year)

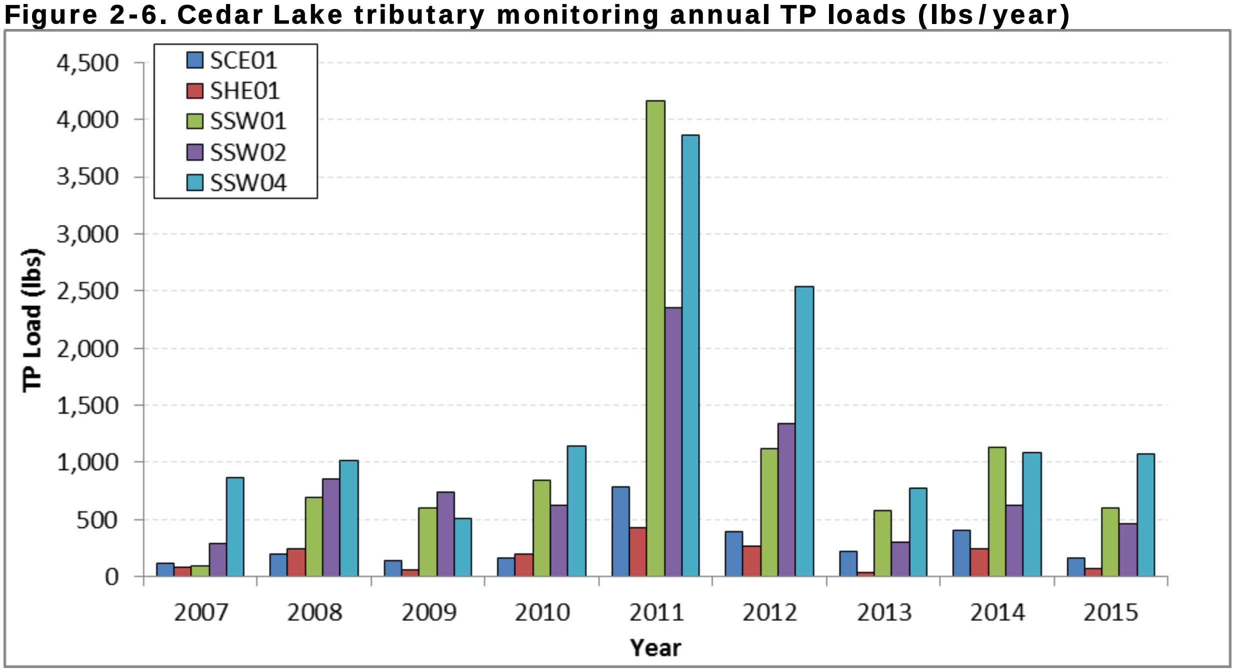


Table 2-2: 2015 phosphorus loading rates and TP and ortho-P concentrations

Site	Watershed Size [acres]	TP Loading rate [lbs/acre]	Mean TP Concentration [ug/L]	Mean Ortho-P Concentration [ug/L]	TP as Ortho-P [percent]
SHE01	1,082	0.06	121	23	19%
SCE01	8,930	0.02	23	10	43%
SSW04	5,532	0.19	248	90	36%
SSW02	2,690	0.17	260	101	39%
SSW01	4,768	0.13	118	17	14%

2.3.1.2 Cedar Lake Project- 2015 Work

The District sought and received a grant to design and construct two projects as part of the Cedar Lake Watershed Protection & Improvement Project; Project 06-10 was amended to include these projects. The highway 55 Project, located just north of highway 55 between Cedar Lake and its upstream watershed was constructed and online for the water year of 2015. It consists of a low flow diversion with a filter-berm. This project will be evaluated by monitoring the water quality trends in Cedar Lake.

The other project was a wetland restoration/ soluble phosphorus filter installed upstream of Swartout Lake. It targeted reducing the largest watershed load contributing nutrients to Swartout Lake. The project was constructed in the winter of 2015 and 2016 and will be completed in the spring of 2016. This project will be evaluated by monitoring the water quality trends in Swartout Lake as well as discrete monitoring.

2.3.1.3 Cedar Lake Project- Conclusions

The monitoring results for this project over the last several years continue show that projects and programs have effectively reduced in-lake concentrations and loads to the lakes. These results further support the water quality goals for Cedar Lake are appropriate. The monitoring results also highlight the relationship between Cedar Lake water quality and the fish and plant communities in the shallow upstream lakes: Swartout, Albion, and Henshaw. This project has demonstrated the importance of restoring the ecology and biological health of the entire system in order to manage shallow lakes to the clear-water state.

Ideally, shallow lake management plans incorporate water level management to promote vegetation growth, and more intensive fish community management strategies, such as lake drawdowns or the application of Rotenone to promote rough fish kills. Efforts to implement some of these strategies have been met with resistance on the part of land owners. To date, biological management strategies are limited to rough fish migration barriers and harvesting, and limited watershed BMPs.

While water quality is stable to improving throughout the Cedar Lake chain, additional load reductions are necessary to achieve in-lake water quality goals for Cedar, Swartout, Albion and Henshaw. Constructed began in 2015 on the Cedar Lake Restoration and Protection Project which includes two projects upstream of Cedar Lake to achieve additional load reductions.

2.3.2 Kingston Wetland Feasibility Study and Restoration

The Kingston Wetland Feasibility Study and Restoration Project was designed to restore main channel dissolved oxygen concentrations in the Clearwater River and reduce the seasonal export of soluble phosphorus to impaired lakes while maintaining particulate phosphorus sequestering capacity, and improve stream and wetland habitat and ecology.

The final project report was completed in 2015. Conclusions of the report are listed below:

- Reduced Sediment Oxygen Demand & Improved DO: The restored channel morphometry reduced sediment oxygen demand and supported higher in-stream DO over longer periods of time. The CRWD's watershed-based TMDL implementation plan identifies the need for a 60% reduction of the SOD in the wetland to meet state standards. This project targets that entire reduction. DO concentrations have improved; 69% of measurements downstream of the wetland violated state standards prior to restoration, post restoration violations occurred only 27 % of the time. The time-frames over which impairments occurred were also limited- pre project violations occurred across the flow spectrum, post project, violations are largely limited to very low flow conditions (Section 3).
- Improved Habitat: Indices of biotic integrity show improvement post project. This indicates improvements in habitat, which meets the second goal of the project (wetland and riverine habitat is restored to support a wider range of wildlife). Habitat in the main channel was improved post project: Hilsenhoff Biotic Index (HBI) improved from 8.26 pre project to 6.08 post-project. The best achievable HBI goal for rivers in this area is 5.8.
- Reduced Phosphorus Export Downstream: Large late summer spikes in soluble P downstream of the wetland suggested that the wetland was exporting P to impaired lakes downstream. The project targets a 1,970 lb/yr TP reduction to Lake Betsy by preventing soluble phosphorus export from the riparian wetland. Upstream and downstream P concentrations post project are almost identical which suggests that the project achieved its second goal of a 20% P reduction. The improvement of average summer surface phosphorus concentrations in Lake Betsy also support this finding; concentrations improved from the 269 ug/L (the assessment period for the TMDL) to 119 ug/L in 2014.
- Contributes to Phosphorus Reduction Goals Downstream: The riverine nature of the system means that meeting water quality goals in Lake Betsy is critical to meeting goals in five other downstream lakes.
- Broader Implications for DO-impaired Streams in Minnesota: The project provides a successful blueprint for other problem areas in the state in terms of channel morphometry and wetland restorations needed to address DO, nutrient and biotic impairments.

The District also conducted Project maintenance in 2015 by cleaning out the sedimentation basin at the upstream end of the project.

2.3.3 City of Kimball Stormwater (Phases I & II)

These restoration and protection projects targeted phosphorus and sediment removal to protect and improve Lake Betsy and Willow Creek. The project elements were designed to collecting, pretreat, infiltrate and reuse stormwater runoff from in and around the City of Kimball. Prior to the project, stormwater runoff from the City of Kimball drained untreated into Willow Creek, a trout stream. Willow Creek is tributary to Lake Betsy, which is impaired by excess nutrients. Estimated phosphorus reduction from Phase I was 244 lbs/yr; 1,175 lb per year phosphorus reduction is expected from Phase II.

While the Phase II project was substantially complete in 2014, the District achieved final project closeout in spring 2015. CRWD staff retained a private consultant to maintain native vegetation in the raingarden on site. Continued vegetation maintenance in the raingarden and basin is planned for 2015, including new plantings. A contractor was retained in 2015 to manage and maintain native vegetation for both Phase I and Phase II.

2.3.4 GPS Fertilizer Application

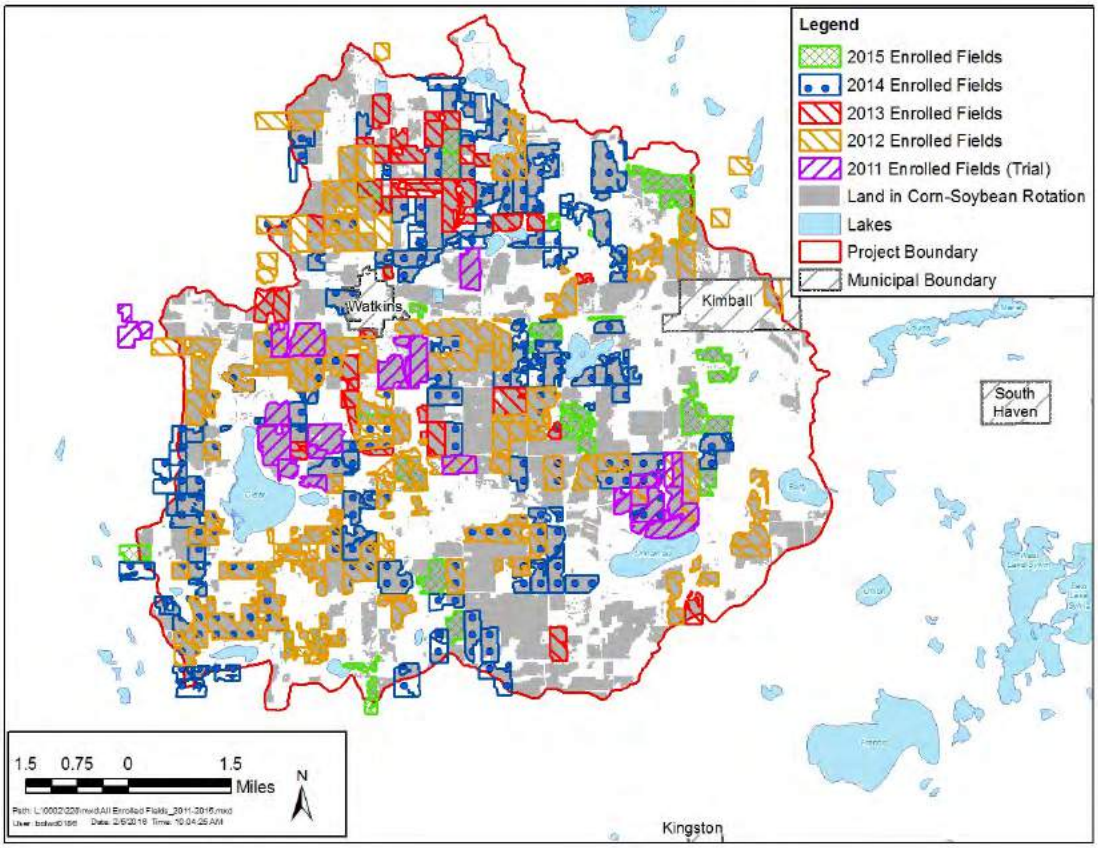
Using grant funds secured in 2011, this project has a goal of enrolling up to 16,000 acres in the target watershed in a gridded soil testing and GPS fertilizer application project. The project includes systematic soil tests to determine nutrient concentrations and the proper amount of fertilizer to be applied in each field. The fertilizer is applied using GPS to apply the correct amount of fertilizer in each grid of the fields based on the results of the soil tests. The goal of the program is a 10% reduction in fertilizer application rates on selected priority cropland in the District resulting in a potential 3,200 lb annual reduction of phosphorus load in the watershed tributary to Lake Betsy. It is estimated that the program could potentially translate into a 10% to 50% reduction in phosphorus runoff from the watershed.

Program enrollment is summarized in Table 2.8 and Figure 2.9 below. From 2012 through the end of 2015, 15,826 acres have been enrolled in the program, representing approximately 70% of cropland in corn and soybean rotation in the watershed tributary to Lake Betsy. All data will be summarized in an end of project report in 2016.

Table 2-3: Enrollment Summary

Year	Annual Enrollment (acres)	Total New Enrollment (acres)
2012	7,279	7,279
2013	1,713	1,713
2014	8,252	5,813
2015	1,693	1,021
	18,937	**15,826**

Figure 2-7: Enrolled Fields through 2015



2.3.5 Watkins Impoundment

The District secured a Clean Water Legacy grant for this project in 2014 and began design and permitting in 2015.

The proposed project is the construction of an impoundment and filtration system on a 20-acre CRWD-owned parcel of land northeast of the city to treat runoff discharged from the city's storm drainage system. Modeled load reduction is 815 lbs of phosphorus per year. Construction is planned for late 2016 or early 2017.

2.4 FUTURE PROJECTS & PROGRAMS

The District’s 2016 plans are not final until after the CRWD Board of Managers sets the course in early 2015, however, the following projects have been and continue to be priorities for the District and may be pursued in 2016.

- Lake Betsy Internal load management
- County Ditch 20 load reduction
- Clear Lake north soluble phosphorus reduction

3.1 PRECIPITATION

Total annual precipitation measured in 2015 was above normal at all four monitoring locations across the District. Precipitation was above normal in five months during 2015: May, July, August, October and November. However, some very large storm events during these months contributed to above average precipitation for the entire year. Table 3-1 summarizes 2015 precipitation levels and Appendix D contains summary charts for each station.

Table 3-1: Clearwater River Watershed District 2015 Precipitation Records and Normals (inches)

Month	2015 St. Cloud (Saint Cloud WSO Airport)	1981-2010 Normal (St. Cloud)	2015 Watkins (Meeker)	2015 Watkins1 (Meeker)	2015 Kimball (Meeker)	1981-2010 Normal (Litchfield)	2015 Annandale/ Corinna (Wright)	1981-2010 Normal (Cokato)
January	0.24	0.65	0.17	0.04	0.33	0.70	0.40	0.77
February	0.35	0.59	0.33	0.05	0.11	0.64	0.59	0.70
March	0.38	1.55	0.68	0.21	0.96	1.46	0.35	1.63
April	1.67	2.57	1.48	1.54	1.54	2.60	0.92	2.97
May	6.03	2.95	8.04	6.42	6.41	3.22	6.04	3.39
June	4.66	4.17	4.69	3.73	3.09	4.99	3.56	4.57
July	7.18	3.31	6.22	5.93	6.13	3.83	6.20	3.70
August	3.10	3.79	6.27	6.95	5.99	3.86	9.94	4.23
September	2.24	3.46	2.25	1.83	1.86	3.39	2.05	3.25
October	3.14	2.49	2.20	3.33	2.53	2.42	3.20	2.50
November	3.10	1.38	3.47	3.07	2.96	1.32	3.15	1.61
December	1.02	0.82	0.78	1.43	0.20	0.87	1.21	0.94
Total	**33.11**	**27.73**	**36.58**	**34.52**	**32.12**	**29.30**	**37.61**	**30.26**

V:\Technical\0002\225 2015 Water Quality Monitoring\Water Quality Data Analysis\[Stream Loads_2015.xlsx]LOAD_CALCS

Below Normal Precipitation

Above Normal Precipitation

3.2 RUNOFF AND DISCHARGE

The above-average precipitation in 2015 contributed to moderate runoff in 2015. Rainfall was above normal in August, September and October which helped prevent late summer/fall drought which has been common in recent years. Runoff over the upper watershed was 4.2 inches upstream of Lake Betsy at CR 28.2 and 5.9 inches at the outlet of Clearwater Lake (CR10.5), which is below the long-term average runoff at CR 10.5 of 7.9 inches and similar to other years with similar precipitation.

Average flows in the Clearwater River were below the long-term average at CR 28.2 and CR10.5; at 30 cfs and 123 cfs, respectively. Table 3-2 summarizes the runoff volumes and average flows for the monitoring stations. Table B-1 in Appendix B compares the long-term precipitation to runoff for the CRWD as recorded at CR 10.5. Figure B-1 in Appendix B compares historic annual runoff and precipitation in the CRWD. Total runoff over the District is shown in Table B-2 in Appendix B.

Table 3-2: 2015 Runoff Volume and Average Flow

Station	Tributary Sub-watershed Area [acres]	Runoff Volume [ac-ft]	Runoff Over Watershed [inches]	Average Flow [cfs]
CR 10.5	99,200	48,945	5.9	123
CR 28.2	33,977	11,861	4.2	30
WR0.2	16,992	2,426	1.7	6

Continuous Flow Monitoring Sites

In 2015, stream levels were monitored continuously at three sites on the Clearwater River to develop a continuous flow record at the sites, which allows for better quantification of seasonal runoff and annual phosphorus loads. Pressure transducers were also installed at the Fairhaven Dam, and along County Ditch 20 at River Miles 2.2 & 1.0 (CD20 2.2 & 1.0) Pressure transducers recorded the stream surface elevation at 15 minute intervals upstream of the Kingston Wetland at CR29.0 and downstream of the Kingston Wetland at CR28.2 while the Clearwater River was flowing from April to October. A pressure transducer was also installed at the Grass Lake Dam from April to October in 2015 (site locations shown on Figure 1-2).

Water elevations were converted to flow using unique stage-discharge relationships (rating curves). The rating curves for each monitoring station were developed using stage and flow measured in the field over several monitoring seasons. 2015 continuous flows near Kingston Wetland (CR29.0 and CR28.2) and CR10.5 are shown in Figures 3-1 and 3-2, respectively. The figures demonstrate three large storm peaks in May, late July and early August.

Comparing the flow upstream of Clearwater Chain of Lakes (Figure 3-1) to the flow downstream of the Clearwater Chain of Lakes (Figure 3-2) shows the dampening of the peak flows resulting from storage in the intervening lakes and wetlands. Specific travel times for runoff from a storm to move from the upstream end of the watershed downstream varies and depend on several factors including the size, location and duration of the storm, the starting elevations of the intervening lakes and wetlands, antecedent moisture conditions, and the time of year.

Figure 3-1: 2015 Clearwater River Continuous Flow at Kingston Wetland.

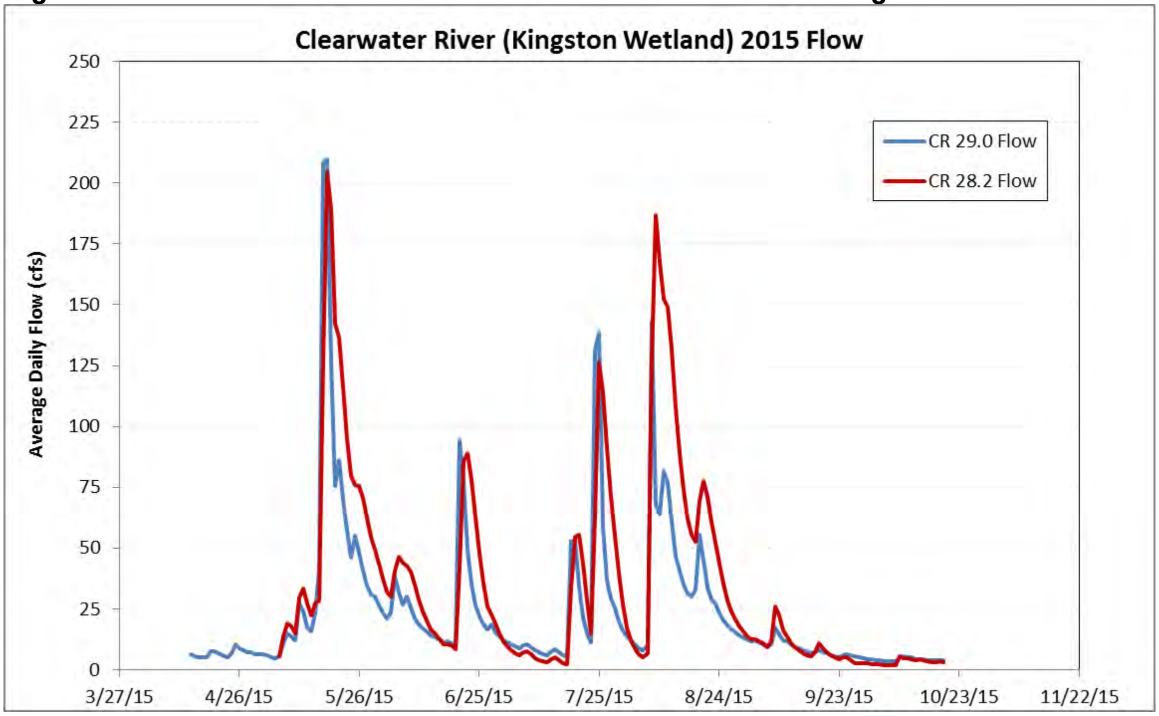
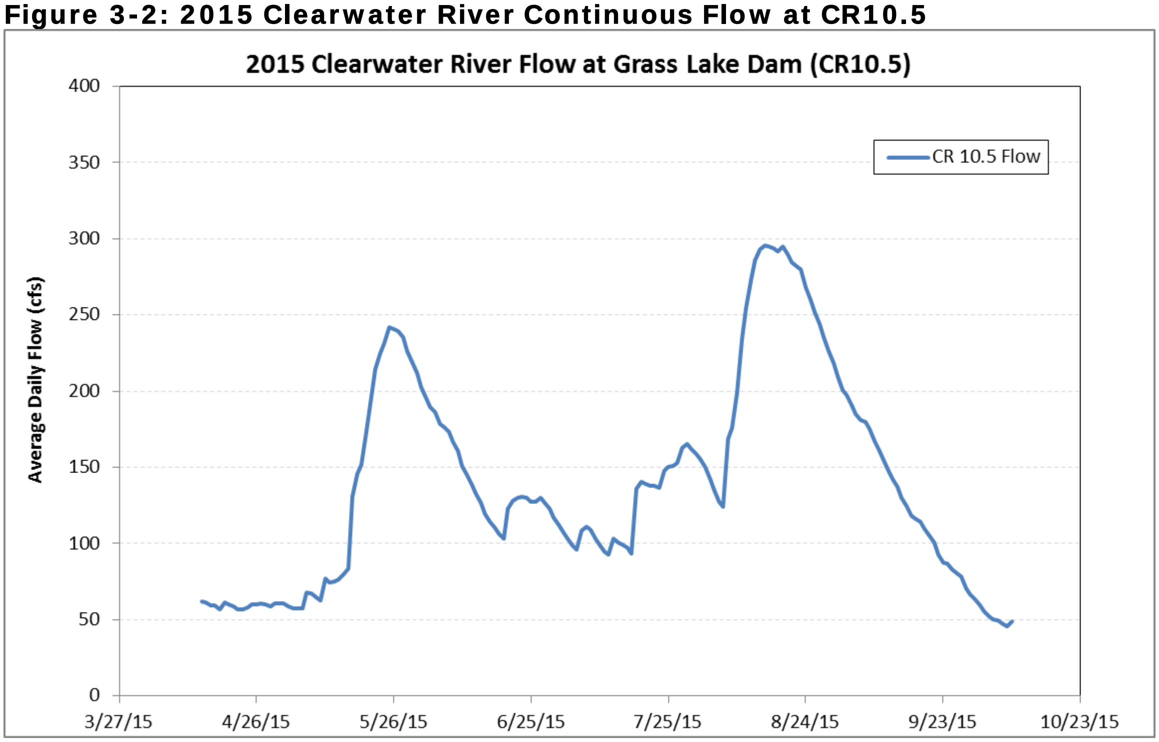


Figure 3-2: 2015 Clearwater River Continuous Flow at CR10.5

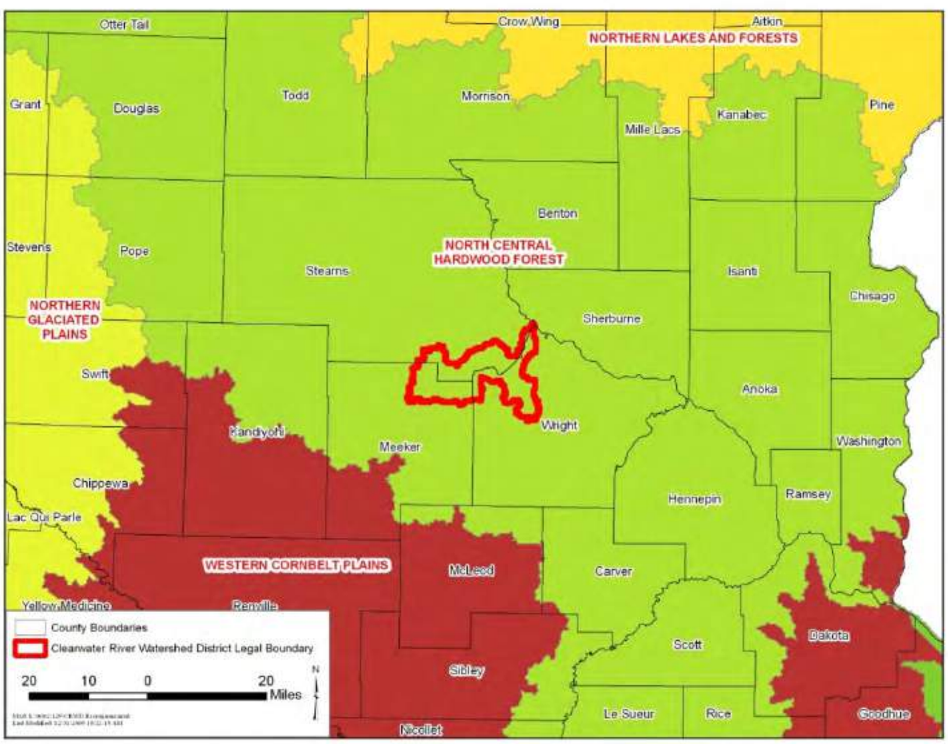


4.1 STREAM WATER QUALITY

Stream water quality was monitored at several locations in the CRWD. Two long-term stations on the Clearwater River and one long-term station on Warner Creek in 2015. Stream water quality was also monitored at additional stations (Figure 1.2). Water quality samples were collected monthly or bi-monthly while the streams were flowing from April to October. The water quality samples were analyzed for total phosphorus, ortho-phosphorus, and total suspended solids concentrations (nitrogen was also sampled for select stations). Field data collected during monitoring visits included water temperature, dissolved oxygen, water level, and flow.

Annual mean concentrations were calculated for comparison to typical concentration ranges and state water quality impairment standards, which are organized by ecoregion across the state. CRWD lies entirely in the North Central Hardwoods Forest NCHF Ecoregion but is close to the border with the Western Corn Belt Plains (WCBP) Ecoregion as demonstrated in Figure 4-1. The watershed tributary to station CR28.2 has characteristics similar to the nearby WCBP ecoregion. The new Central River Region Standard reflects this and is shown in Figure 4-2 for comparison with measured values.

Figure 4-1: Clearwater River Watershed District Ecoregions



4.1.1 Phosphorus Concentrations and Phosphorus Loads

Stream loads and mean phosphorus concentrations were calculated at each monitoring station on the Clearwater River, Warner Creek, Willow Creek, Clear Lake tributary streams, and County Ditch 20 in 2015 to track the health and integrity of the streams with respect to state standards and to monitor loads to the lakes which drive water quality. Tributary streams were also monitored in the Cedar Lake sub-watershed and were discussed in Section 2.0.

Mean phosphorus concentrations were also calculated for each as well as the newly adopted river eutrophication standards for TP (Figure 4-2). At the long-term monitoring stations, mean phosphorus concentrations at CR10.5, WC2.5, WC3.0, and WR0.2 were below the central river region eutrophication standard. Phosphorus concentrations measured at all other stations were well above the eutrophication standard. Figure 4-3 shows mean phosphorus concentration measured at the tile monitoring sites. Phosphorus at these sites was slightly lower than many of the stream sites, however most of the phosphorus is in dissolved form (ortho-P) which is more available for uptake by algae and aquatic plants.

Figure 4-2: Clearwater River Watershed District 2015 Mean Phosphorus Concentrations

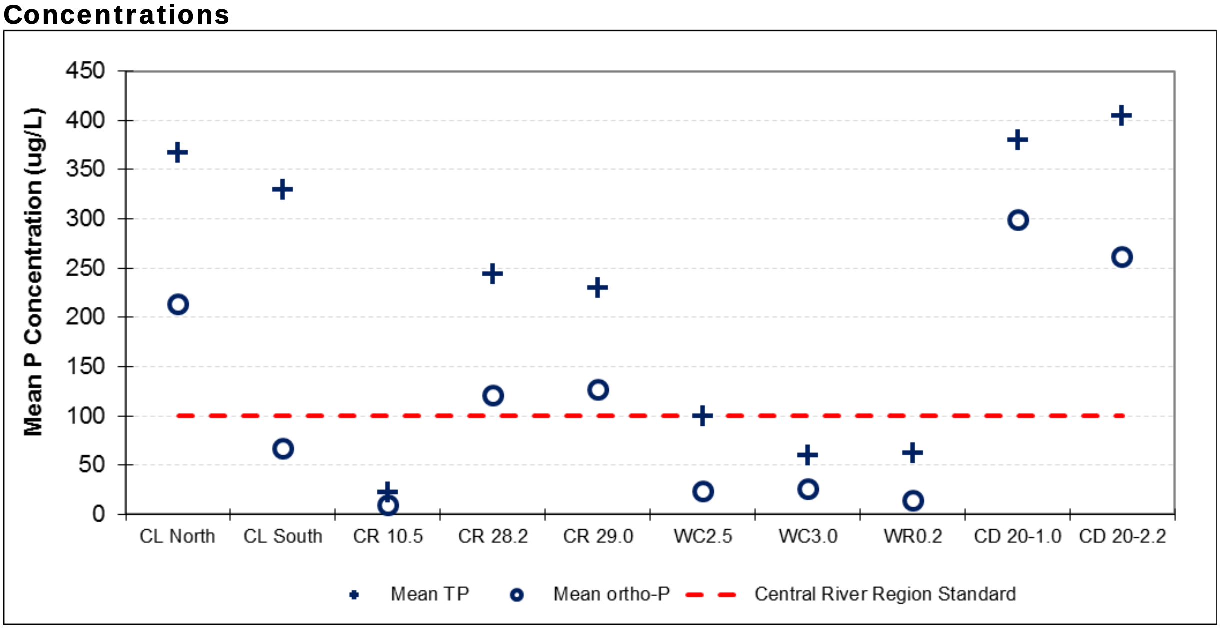
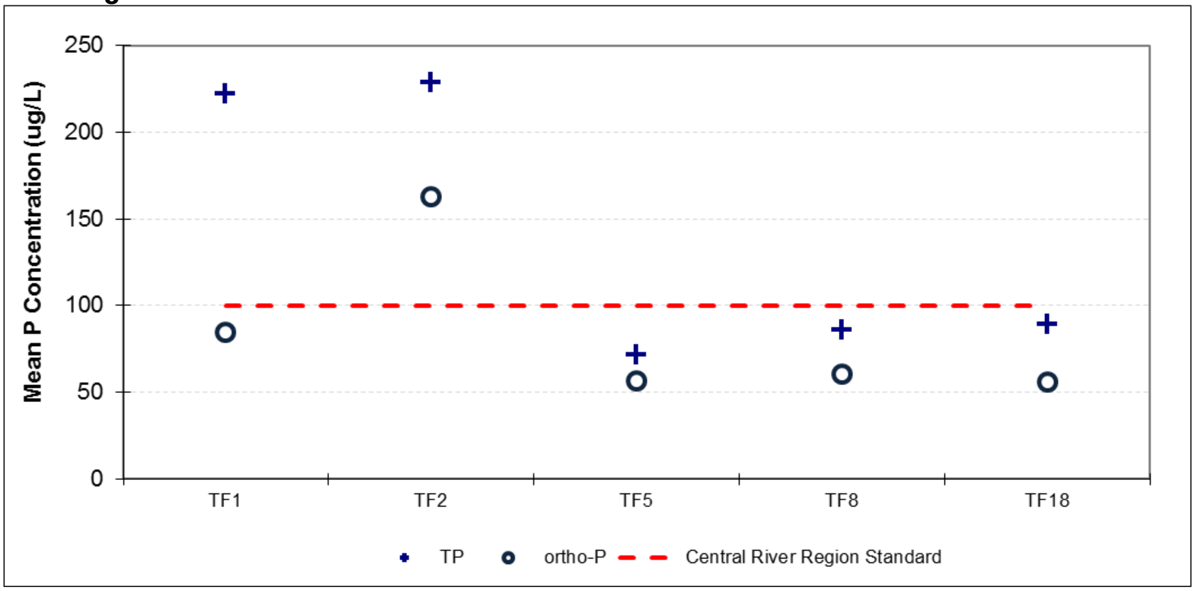


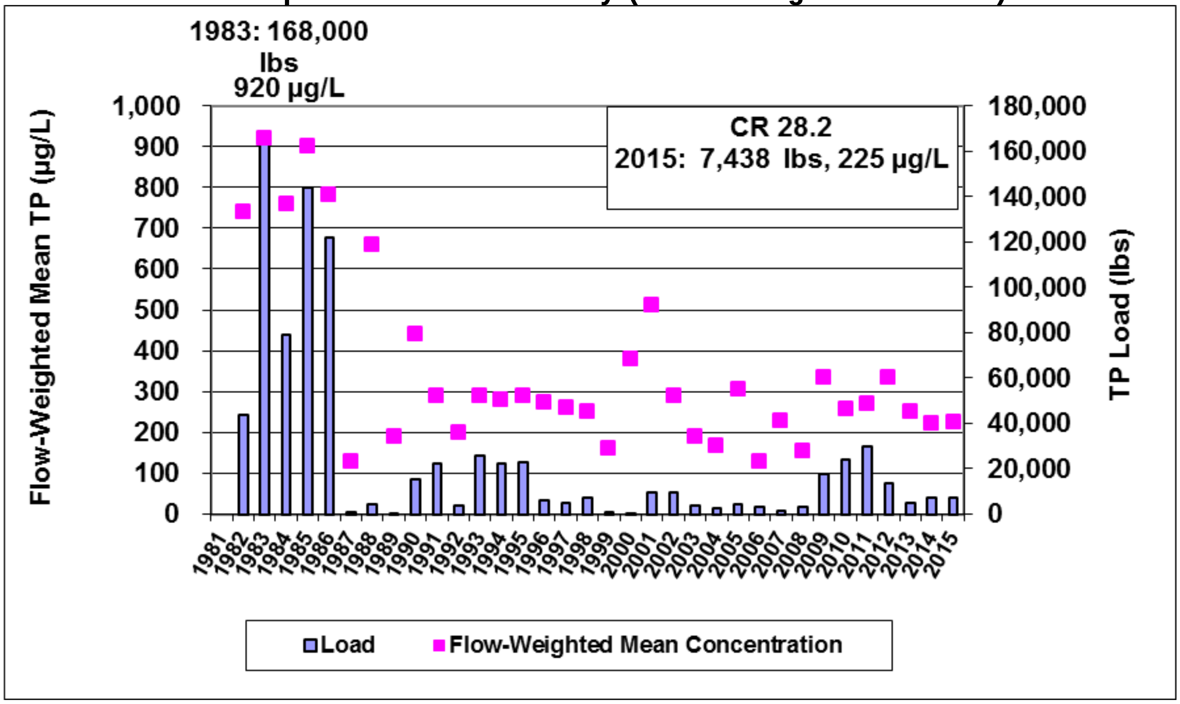
Figure 4-3. 2015 Mean Phosphorus Concentrations in Collection Points for Tile Drainage.



Baseline total phosphorus (TP) concentrations in the Clearwater River remain low as compared with conditions monitored in the early 1980s. Flow-weighted mean total phosphorus concentrations at CR 28.2, just upstream of Lake Betsy, ranged from 740 to 920 μg/L in the early 1980s. The 2015 concentration was 225 μg/L, which is similar to the range of concentrations observed in recent years and far lower than concentrations seen in the early 1980s.

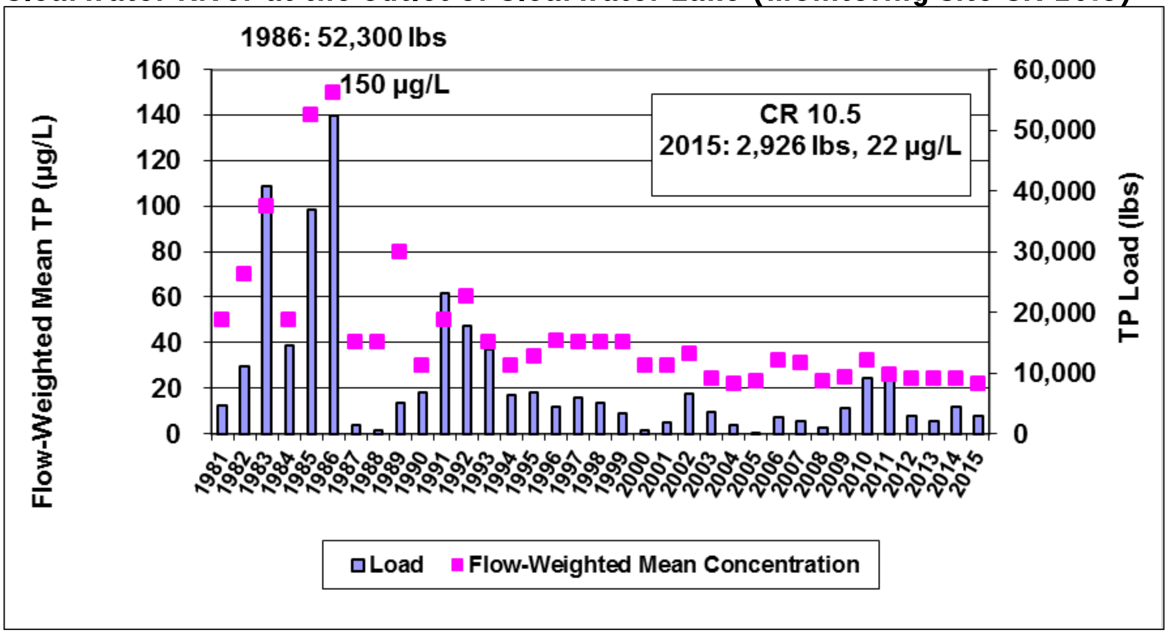
The TP load at CR28.2 was calculated using the continuous flow record data collected at CR28.2. TP load and concentration measured at CR28.2 in 2015 was almost identical to those measured in 2014. Phosphorus loads and concentrations at CR28.2 have remained fairly stable over the last 3-4 years and are well below the high TP loads observed in the early 1980s. However, TP concentrations are more than two times the central river eutrophication standard. Figure 4-3 shows the historical phosphorus load and flow-weighted mean concentration at CR 28.2.

Figure 4-4: Historical Total Phosphorus Loading and Mean Concentration in the Clearwater River upstream of Lake Betsy (monitoring site CR 28.2)



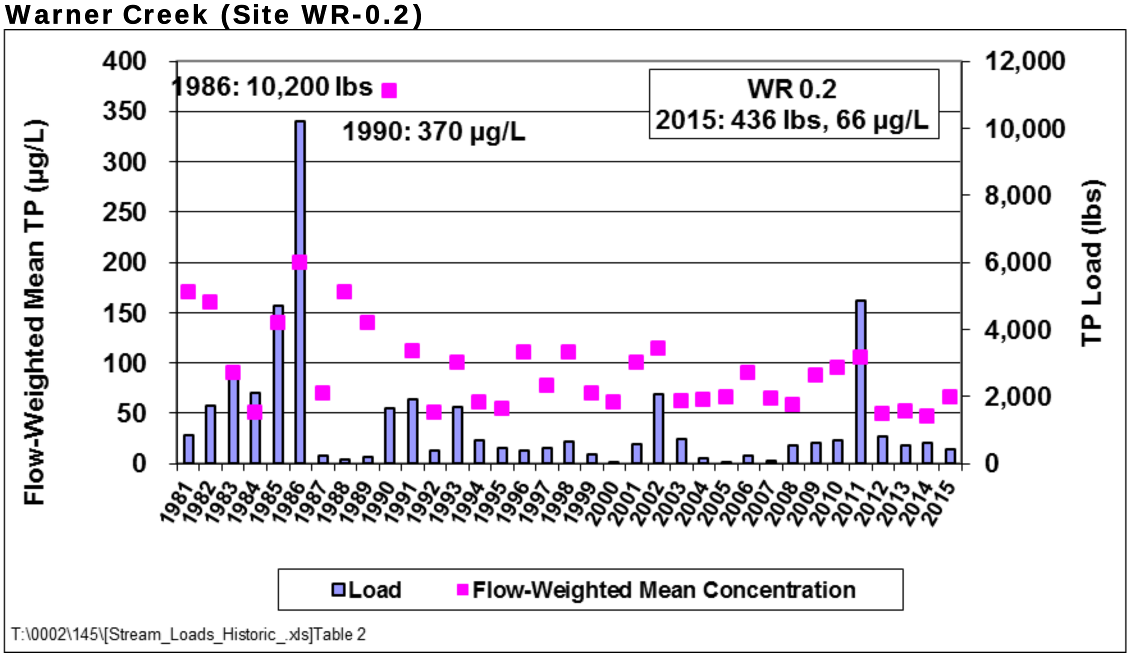
Flow-weighted mean TP concentrations and phosphorus loads at CR 10.5 were calculated using flows over the dam that were calculated using continuous level data collected upstream of the Grass Lake Dam. The estimated mean phosphorus concentration at CR 10.5 in 2015 was 22 µg/L, which is significantly lower than concentrations measured in the 1980s. Mean TP concentrations at this station appear to be exhibiting a stable and perhaps slightly decreasing trend, which is reflective of water quality conditions in Clearwater Lake. The 2015 total phosphorus load was 2,926 lbs. (Figure 4-4), which is slightly lower than loads observed in recent years and comparable to other years with similar runoff.

Figure 4-5: Historical Total Phosphorus Loading and Mean Concentration in the Clearwater River at the outlet of Clearwater Lake (monitoring site CR 10.5)



Phosphorus loads and mean phosphorus concentrations in Figure 4-5 compare historical total phosphorus loads and mean phosphorus concentrations in Warner Creek at monitoring station WR0.2. The flow-weighted mean TP concentration at Warner Creek in 2015 was 66 µg/L, which is slightly higher than 2014 but lower than concentrations observed at this site from 2008 to 2011. The total phosphorus load in 2015 was 436 lbs., which is similar to the 2014 load and loads observed since 2012.

Figure 4-6: Historical Total Phosphorus Loading and Mean Concentration at Warner Creek (Site WR-0.2)



Willow Creek has been monitored at two locations upstream and downstream of the City of Kimball since 2012 in order to monitor the effectiveness of projects constructed in the City. As shown in Table 4-1, concentrations decreased slightly from upstream to downstream, while loads increased slightly from upstream to downstream proportionately with the increase in flow. Phase II of the Kimball Stormwater Project was under construction in 2014, once complete it should further reduce hydraulic and nutrient loads to Willow Creek and downstream lakes.

Loads in 2015 downstream appear to be higher than upstream—a significant drainage area empties into the creek between WC 3.0 upstream and WC 2.5 downstream so increased loading is expected. Ideally we would have been able to compare pre project levels to post project levels and determine the shift in relative difference between upstream since the total loads don't tell the entire story. However, we are limited to looking at upstream to downstream concentrations. Besides the intervening drainage area and rainfalls larger than the BMP targeted return event, we also see three samples in which soluble phosphorus is low, but TSS is high downstream. This can indicate an actual increase in TSS, or represent issues specific to the stream morphometry at the sampling location downstream site which is shallow and difficult to sample without mobilizing sediment.

Table 4-1: Willow Creek Phosphorus Concentrations and Phosphorus Loads

Year	Runoff [inches]		Meant TP [µg/L]		TP Load [lbs]	
	WC2.5	WC3.0	WC2.5	WC3.0	WC2.5	WC3.0
2012	5.11	3.65	90	126	713	619
2013	2.89	2.59	101	119	452	415
2014	4.19	3.75	55	59	355	299
2015	3.04	3.10	145	61	686	254

Two tributaries to Clear Lake were also monitored in 2015 (Table 4-2). Monitoring will continue at these two locations in future years to track the progress of District projects implemented in the subwatershed tributary to Clear Lake.

Table 4-2: Clear Lake Tributaries Phosphorus Concentrations and Phosphorus Loads

Year	Runoff [inches]		Meant TP [µg/L]		TP Load [lbs]	
	CLN	CLS	CLN	CLS	CLN	CLS
2012	14.73	14.42	512	221	1,796	1,013
2013	4.01	2.04	495	190	475	123
2014	13.87	7.97	296	145	981	367
2015	14.23	7.75	351	258	1,194	636

As shown in Figure 4-7, County Ditch 20 was also monitored in 2015 at two locations upstream and downstream of the Watkins wetland. As shown in Table 4-3, total phosphorus concentrations were similar and high at both sites with slightly higher concentrations observed at downstream station CD 20-1.0. The phosphorus load was over twice as high at the downstream monitoring location. The proportion of total phosphorus comprised of soluble phosphorus was very high at both sites, indicating potential export of soluble phosphorus from wetlands in this sub-watershed as a significant source of phosphorus. A continuous flow gauge was installed at stations CD20-2.2 & 1.0. A comparison of continuous flows recorded at this site indicates that actual runoff may be over double what is indicated by grab sampling over 10 inches of runoff vs 4.2 inches. This highlights the importance of comparing appropriate records during monitoring, runoff from a continuous flow record is not the same as runoff from discrete flow measurements. Additional rating curve data is needed to validate that finding. Grab sample results are reported here.

Table 4-3: County Ditch 20 Phosphorus Concentrations and Phosphorus Loads

Year	Runoff [inches]		Meant TP [µg/L]		TP Load [lbs]	
	CD20-1.0	CD20-2.2	CD20-1.0	CD20-2.2	CD20-1.0	CD20-2.2
2013	2.10	1.15	376	341	1,477	633
2014	4.23	2.26	341	144	3,185	1,384
2015	4.21	2.94	357	370	2,809	1,766

Figure 4-7: County Ditch 20 Monitoring Locations

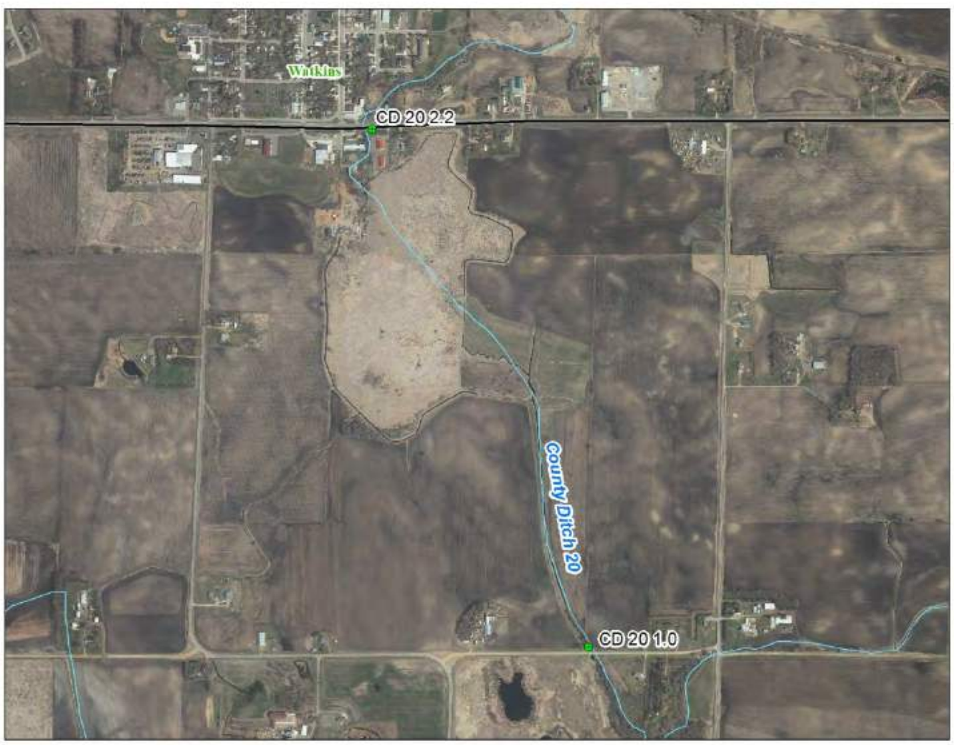


Table 4-4 shows areal phosphorus loading rates throughout the District in 2015. Phosphorus loading rates were lowest at sites in the lower watershed, 0.03 lbs/acre at CR 10.5 and WR0.2. Loading rates at upper watershed stations (CR28.2, CR29.0, CD20-1.0, CD20.-2.2, Clear Lake North and South) were generally higher with loading rates ranging from 0.20 to 1.13 lbs/acre.

It is notable that the loading rate at CR28.2 was less than the loading rate at CR29.0 upstream of the Kingston Wetland, demonstrating a decrease of phosphorus export from the Kingston Wetland Project. Loading rates for the upper most portion of the District likely are the truest measurement of watershed phosphorus export as loading data collected downstream reflects the sedimentation of phosphorus in District Lakes.

Ortho-phosphorus (OP) is measured in streams because it is the dissolved form of phosphorus which is more readily used by algae. Relative fractions of ortho-phosphorus to total phosphorus provide valuable insight into the sources of nutrients in the District and potential solutions. Table 4-4 shows the ratio of the flow-weighted means of OP to TP as a percentage at each monitoring site.

OP continues to make up a high percentage of TP in some monitoring stations in 2015. This is especially true of monitoring locations downstream of large wetland complexes, as anoxic conditions developed in these basins during periods of low flow and OP was released from wetland sediments. Specifically, this was observed at monitoring sites on County Ditch 20 and Clear Lake North. Results from tile monitoring conducted as part of the GPS Fertilizer Application Project demonstrate a high proportion of OP in water draining from subsurface tiles, which may be contributing to elevated fractions of OP at some monitoring sites.

Table 4-4: 2015 Phosphorus Loading Rates by Tributary Watershed

Site	Watershed Area [acres]	TP Load [lbs]	TP as ortho-P [percent]	Phosphorus Loading Rate [lbs/acre]
CR10.5	99,200	2,926	41%	0.03
WR0.2	16,992	436	28%	0.03
WC2.5	6,838	686	19%	0.10
WC3.0	5,926	254	34%	0.04
CD20-2.2	7,152	1,766	63%	0.25
CD20-1.0	8,247	2,809	82%	0.62
CR28.2	33,977	7,438	47%	0.22
CR29.0	27,695	5,442	51%	0.20
CLN	1,055	1,194	63%	1.13
CLS	1,404	636	24%	0.45

4.1.2 Total Suspended Solids

Samples were also analyzed for total suspended solids (TSS) in 2015. Mean concentrations of TSS are compared to the newly adopted 30 mg/L TSS standard for rivers and streams in the North Central Hardwood Forest (NCHF) Ecoregion.

Figure 4-8: 2015 Total Suspended Solids Mean Concentrations in the CRWD

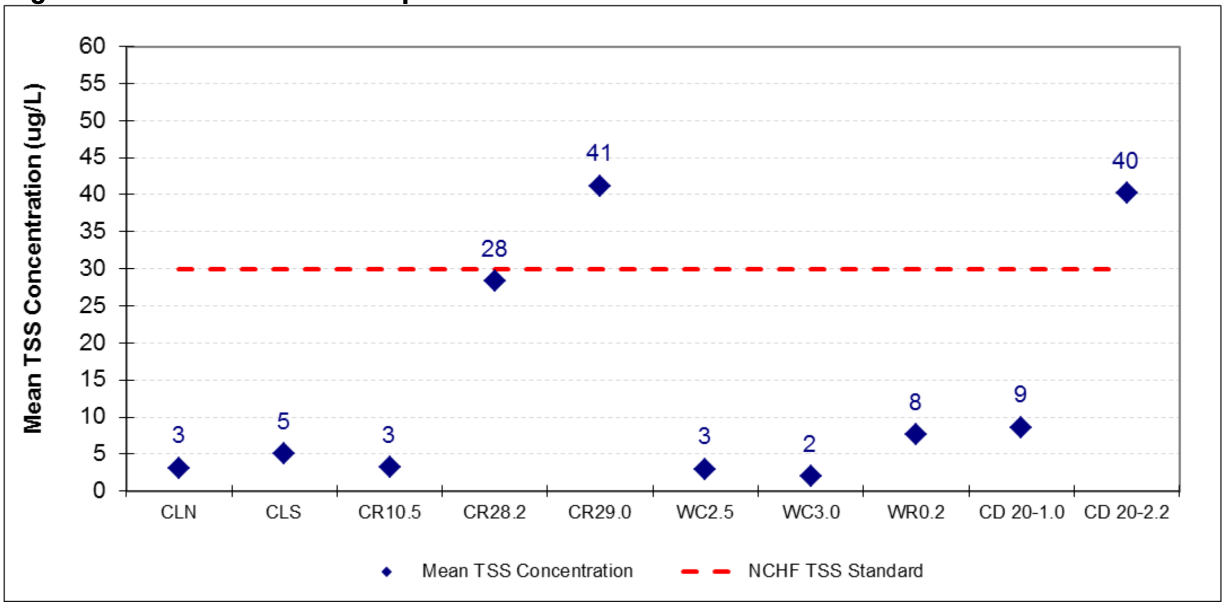
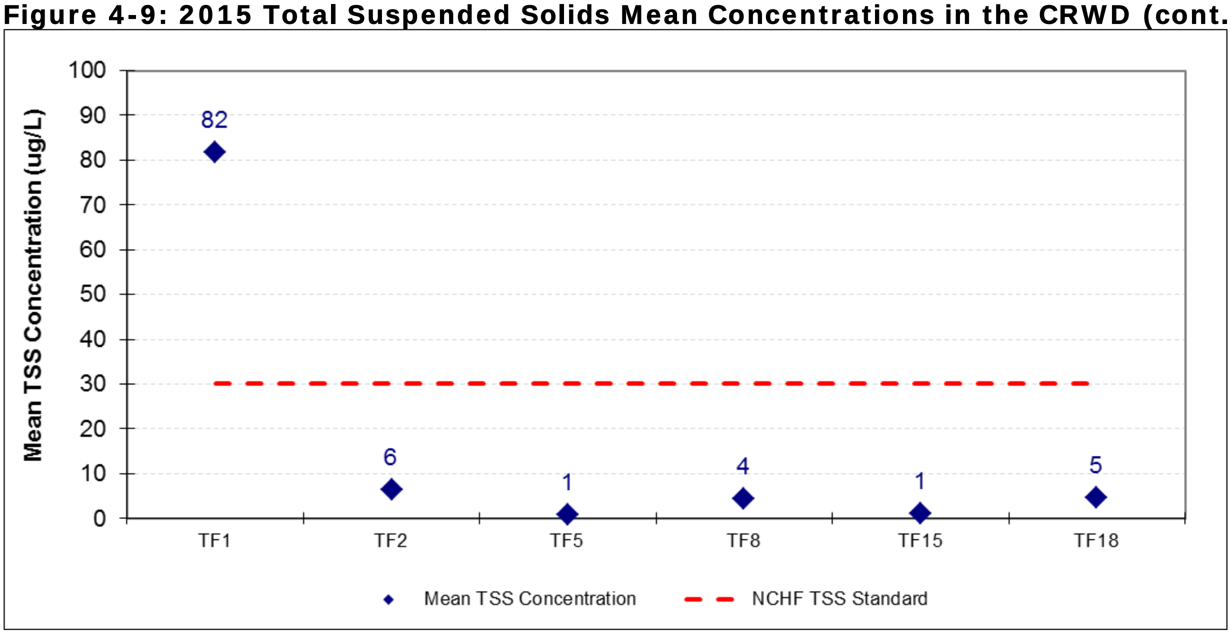


Figure 4-9: 2015 Total Suspended Solids Mean Concentrations in the CRWD (cont.)



4.1.3 Nitrogen Monitoring

CRWD expanded its stream monitoring in 2013 to include nitrogen (N) series monitoring at several stations in the upper watershed (see orange squares in Figure 1-2 for 2015 sites). Concern about N in surface water has grown in recent decades due to: 1) increasing studies showing toxic effects of nitrate on aquatic life, 2) increasing N concentrations and loads in the Mississippi River combined with nitrogen's role in causing a large oxygen-depleted zone in the Gulf of Mexico, and 3) the discovery that some Minnesota streams exceed the 10 mg/l standard established to protect potential drinking water sources. In 2013, the MPCA published the Nitrogen in Minnesota Surface Waters Report which discusses the sources, trends and potential ways to reduce nitrogen in Minnesota's surface waters. In 2014, the

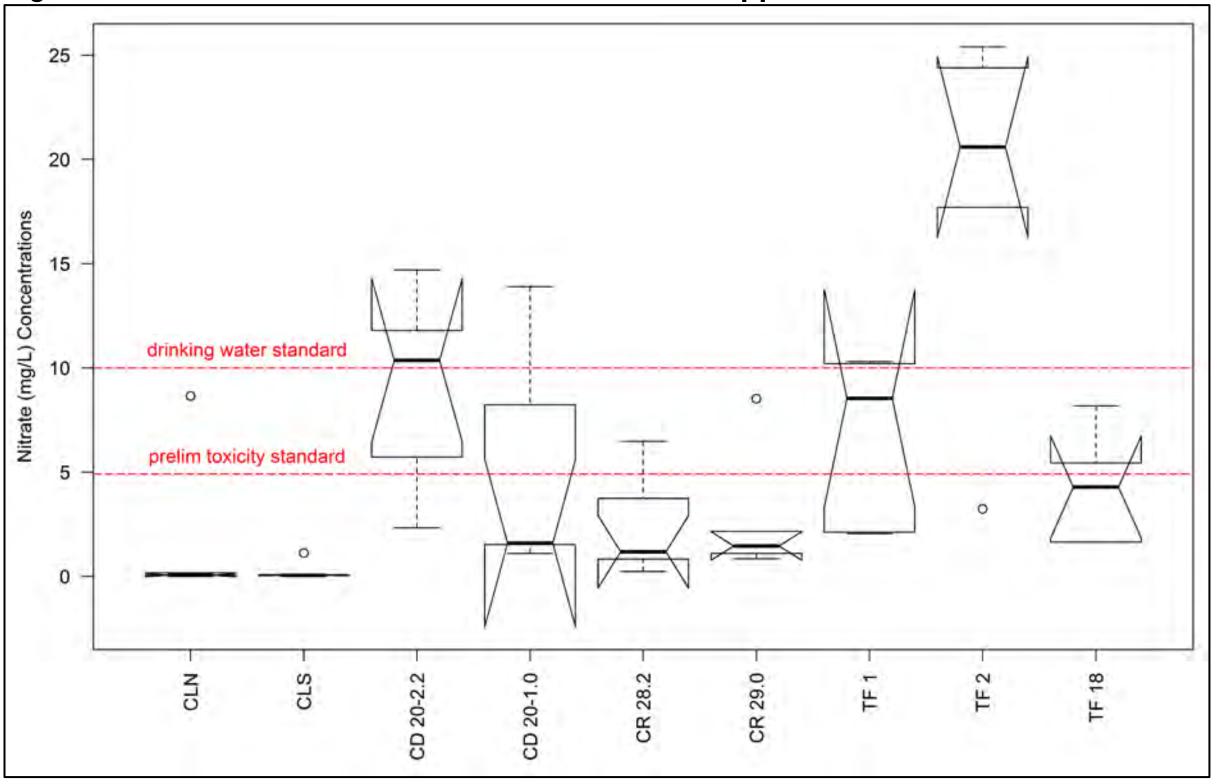
State of Minnesota released The Minnesota Nutrient Reduction Strategy Report which calls for a N reduction of 45% throughout the Mississippi River Basin. Additionally, the MPCA is currently in the process of developing nitrate water quality standards based on aquatic life toxicity for surface waters throughout the state. The CRWD recognizes these efforts and the increased awareness and concern of nitrogen loading to surface waters in the state of Minnesota.

Nitrogen enters water in numerous forms, including both inorganic and organic. The primary inorganic forms of N are ammonia, ammonium, nitrate, and nitrite. Organic-nitrogen (Organic-N) is found in proteins, amino acids, urea, living and dead organisms (i.e., algae and bacteria) and decaying plant material. Organic-N is usually determined from the laboratory method called total Kjeldahl nitrogen (TKN), which measures a combination of organic N and ammonia+ammonium. Since N can transform from one form to another, it is often considered in its totality as total nitrogen (TN). The relative amounts of the different forms of N in surface waters depends on many factors, including: proximity to point and nonpoint pollution sources; influence of groundwater baseflow discharge; abundance and type of wetlands; reservoirs and lakes in the pathway of flowing streams; as well as other natural and anthropogenic factors. Temperature, oxygen levels, and bio-chemical conditions each influence the dominant forms of N found in a given soil or water body.

Nitrate (NO_3) is very soluble in water and is negatively charged, and therefore moves readily with soil water through the soil profile, where it can reach subsurface tile lines or groundwater. Nitrate pollution of shallow groundwater is common among agriculturally dominated watersheds with coarse textured soils. Upon application to a field, nitrogen not utilized by plants can leach into the ground and moves into nearby lakes, streams, and wells or be carried by tile drainage directly into a stream. Minnesota rules have an existing nitrate standard for the protection of human health at 10 mg/l, which applies to surface waters designated for drinking water uses (class 2A and class 2Bd). Minnesota is currently in the process of developing nitrate standards for aquatic life toxicity. In 2010, the MPCA published a draft technical support document that proposed a nitrate standard of 4.9 mg/l to address aquatic life toxicity. However, because the EPA is currently carrying out supplemental aquatic life toxicity tests for nitrate, the MPCA put these proposed standards on hold.

Nitrate was monitored at 9 stations in the upper watershed in 2015. The nitrate monitoring data are presented as box plots in Figure 4-10. Not surprisingly, the results indicate the stream locations where tile drainage collects (TF1, TF2, and TF18) had high levels of nitrate that were consistently above the proposed toxicity standard, and occasionally exceeded the drinking water standard. Nitrate levels in County Ditch 20 were also high, particularly at CD20-2.2. County Ditch 20 is an agricultural watershed with significant tile drainage. Nitrate concentrations were consistently lower at CD20-1.0 compared to CD20-2.2 likely due to denitrification in the wetland south of Watkins (Figure 4-7). The mainstem (CR28.2 and CR29.0) and Clear Lake (CLN and CLS) monitoring stations displayed relatively low nitrate concentrations compared to the other sites in the upper watershed.

Figure 4-10. 2015 Nitrate concentrations in the upper Clearwater River watershed.



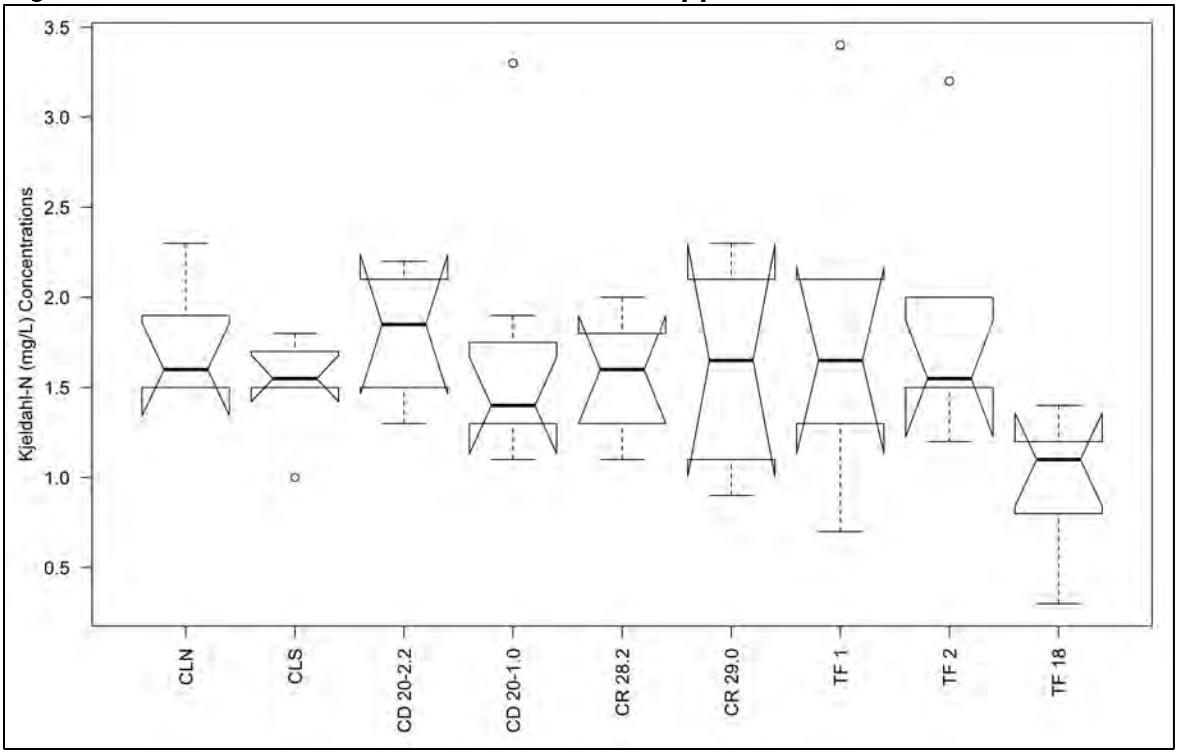
Note: horizontal lines above and below the box are maximum and minimum of the data. The upper and lower limit of the box is, by default, the 75th and 25th quantile. The thick line in the box represents the median of the data. The open circles are data points that fall out of the range and could be considered outliers.

TKN is the sum of ammonia+ammonium plus organically bound N. Ammonia (NH_3) is toxic to fish and other aquatic organisms. Ammonium (NH_4), the predominant form in the pH range of most natural waters, is less toxic to fish and aquatic life as compared to NH_3. Common sources of ammonia/ammonium include human and animal wastes, as well as certain fertilizers and industrial wastes. Ammonia and ammonium most commonly enter surface waters through overland runoff or direct discharges from wastewater sources.

The second component of TKN is organically bound N. The organic component can be determined by subtracting ammonia+ammonium from TKN. Common sources of organic nitrogen include plant and animal waste or decomposing organisms. Organic forms of nitrogen are typically unavailable for plant and animal growth and assimilation. Of the TKN components, ammonia+ammonium break down quickly in natural systems and are rapidly converted to nitrate by nitrifying bacteria, a process which consumes oxygen. Organic nitrogen can also be broken down and converted to nitrate, but it is usually a slower process. Because of its abundance in waste products and the potential for oxygen depletion (nitrification), WWTP effluent is often monitored for TKN.

TKN was measured at 9 stations in the upper watershed in 2015. Results show TKN levels were relatively low and consistent at all 9 stations in the upper watershed (Figure 4-10). TKN at the tile monitoring sites were similar to those measured at the Clear Lake, County Ditch 20, and Clearwater River mainstem sites. These results suggest nitrate is the dominant form of nitrogen in the upper portion of the watershed and TKN loading should not be viewed as a major concern.

Figure 4-11. 2015 TKN concentration in the upper Clearwater River watershed.



Note: horizontal lines above and below the box are maximum and minimum of the data. The upper and lower limit of the box is, by default, the 75th and 25th quantile. The thick line in the box represents the median of the data. The open circles are data points that fall out of the range and could be considered outliers.

4.1.4 Dissolved Oxygen

Dissolved oxygen (DO) was measured at each stream monitoring location as DO is essential to the survival of in-stream biota like fish and macroinvertebrates and is therefore an indicator of the presence of suitable habitat. DO is also measured to track progress towards achieving the DO TMDL for the Clearwater River and to ensure that other streams in the CRWD meet the MPCA's water quality standard for DO (5 mg/L or higher as a daily minimum).

Prior to the construction of the Kingston Wetland restoration project, data collected at CR28.2 demonstrated that low-flow DO violations occurred downstream of Kingston Wetland for most of the year and were driven primarily by wetland sediment oxygen demand (SOD). The Kingston Wetland restoration project rerouted low-to-mid flows of the Clearwater River through a restored meandering stream channel instead of through the Kingston Wetland in early 2013. The DO concentrations observed in summer 2013, 2014 and 2015 demonstrate that DO concentrations were only slightly lower downstream of the Kingston Wetland, and the period during which DO concentrations are in violation of the DO standard was reduced to extreme low flow conditions (flows less than 2 cfs) in late summer and early fall (Figure 4-12).

Figure 4-13 shows DO data collected at tributary stream monitoring sites in 2015. DO concentrations fell below the impairment standard at most tributaries monitored. In some cases, low DO is the result of oxygen demand in upstream wetlands. In others low summer flow and increased temperatures contributes to low DO.

Figure 4-12: 2015 Clearwater River Dissolved Oxygen Concentrations

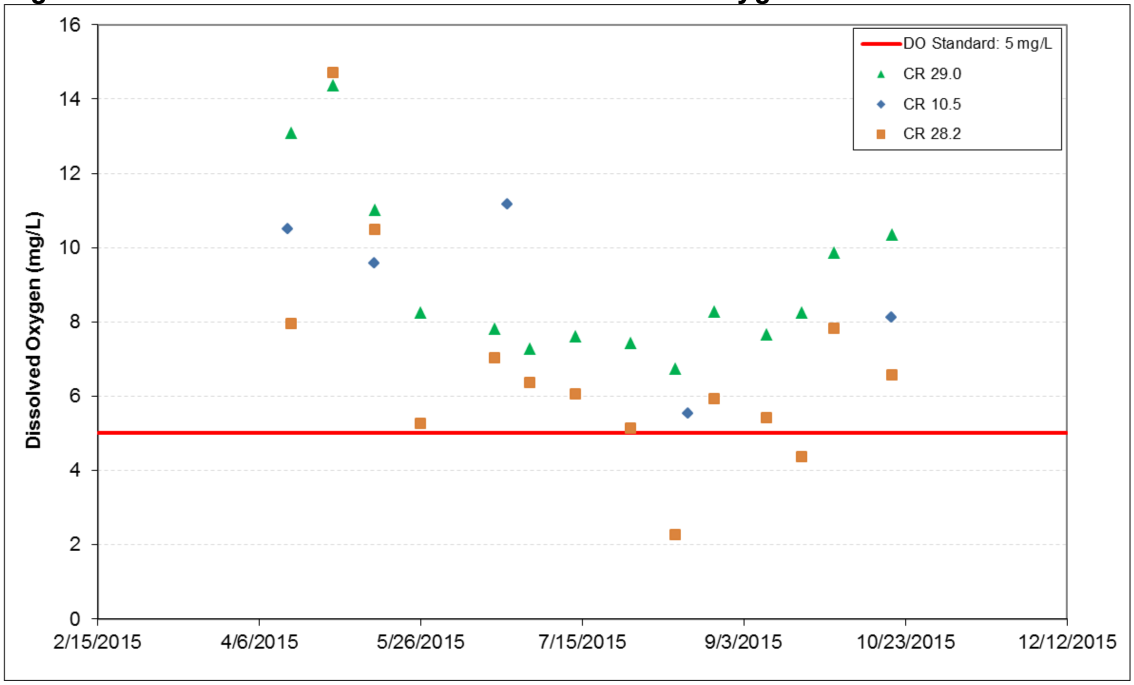
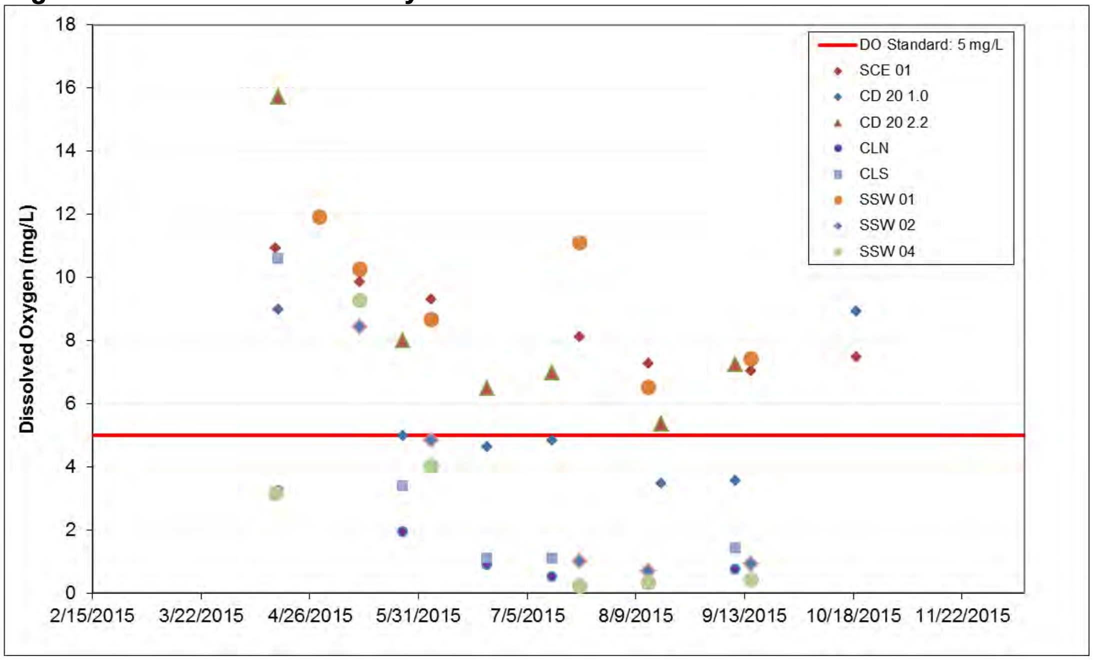


Figure 4-13: 2015 Tributary Stream DO Concentrations



Additional stream water quality data is found in Appendix B, including summaries of historical phosphorus loads, stream flows, and flow-weighted mean concentrations. Appendix F shows phosphorus concentrations at each site monitored in 2013.

4.1.5 *E. Coli* Bacteria

Bacteria is measured in the CRWD to track progress towards meeting the CRWDs bacteria TMDL in the Clearwater River between Clear Lake and Lake Betsy, to ensure that other areas within the District meet the state standards, and to track sources of non-point source pollution in the District.

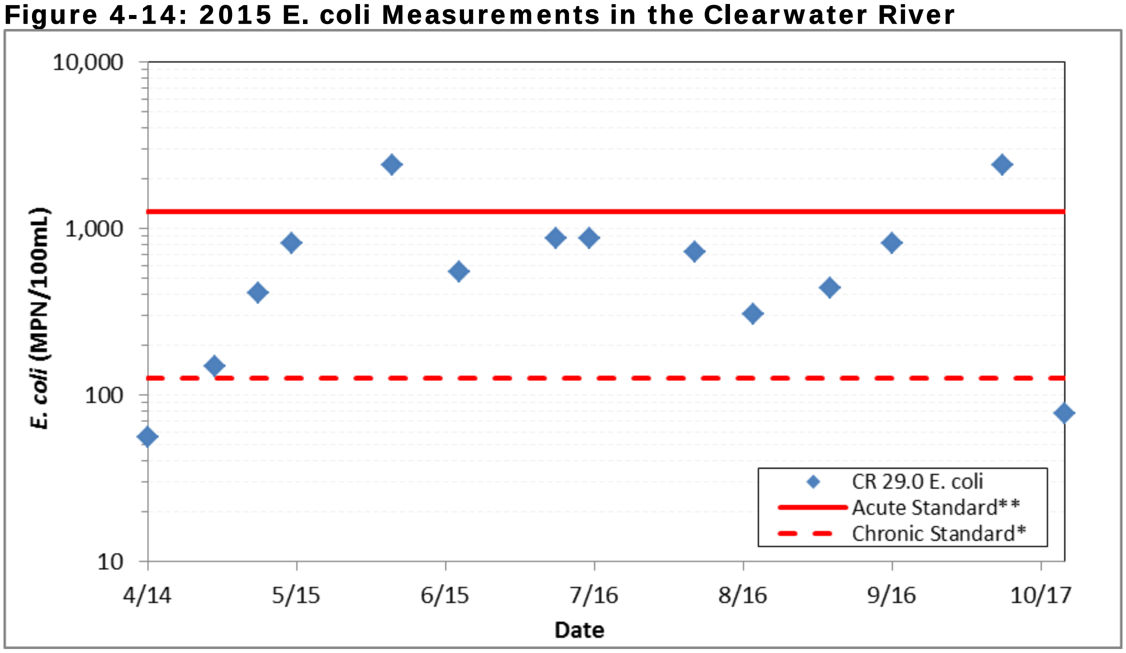
Measurements of most probable number (MPN) of colony forming units (CFU) per 100 mL of *E. coli* were taken at one location on the Clearwater River (CR29.0). Data collected at this site tracks TMDL implementation progress. Table 4-5 shows the monthly geometric means of *E. coli* at CR28.2.

Table 4-5: E. coli Monthly Geometric Means in the Clearwater River

Month	*E. Coli* Geometric Mean [MPN/100mL]	# of Measurements
April	91	2
May	579	2
June	547	2
July	866	2
August	473	2
September	596	2
October	432	2

Nearly all samples collected at CR29.0 from May through September exceeded the chronic standard in 2015 (Figure 4-14). Two of the samples exceeded the acute standard. Depending on the sources of bacteria in the watershed, this may indicate the need for additional projects to target and control bacteria concentrations. Such projects may include limiting and controlling livestock access to the River and tributaries.

Figure 4-14: 2015 E. coli Measurements in the Clearwater River



*Chronic Standard: Not to be exceeded by the monthly geometric mean
**Acute Standard: Maximum not to be exceeded by 10% of samples taken in a calendar month

4.2 LAKE WATER QUALITY

The CRWD measures lake water quality to track progress towards meeting state standards, track long-term trends and identify potential areas where water quality is declining. The CRWDs 21 lakes are sampled on a rotating basis identified in the District's monitoring plan.

CRWD sampled seventeen lakes in 2015. Parameters analyzed in 2015 included surface TP, ortho-phosphorus, Chlorophyll-a, and a field reading of Secchi depth. Surface samples characterize lake water quality. Samples for TP, ortho-phosphorus, and total iron were also collected near the lake bottom for selected lakes. Water temperature and DO profile data was also collected at each lake to better characterize lake stratification and periods of anoxia which helps determine the potential for internal loading from lake sediments.

4.2.1 2015 Monitoring Results

Summer average (June 1 to September 30) values were compared with the MCPA eutrophication standards for phosphorus, Chlorophyll-a, and Secchi disk depth, based on Ecoregion and lake type. The MPCA uses separate standards for shallow (less than 15 foot maximum depth or 80% of lake area less than 15 feet deep) and deep lakes (greater than 15 foot maximum depth). The appropriate standards for lakes monitored in the CRWD, which is in the North Central Hardwood Forest Ecoregion, are shown in Table 4-6. The MPCA standards are also used as the TMDL goals for summer average concentrations and Secchi depth in District lakes.

Table 4-6: MPCA Standards for Lakes in the North Central Hardwood Forest Ecoregion

Lake Category	TP [µg/L]	Chlorophyll-a [µg/L]	Secchi Depth [meters]
Shallow Lakes	60	20	1.0
Deep Lakes	40	14	1.4

Source: Minnesota Pollution Control Agency

Figures 4-15 and 4-16 compare the average total phosphorus concentrations in lakes sampled in 2015 to the TMDL goal.

Figure 4-15: 2015 Summer Average Total In-Lake Phosphorus Concentrations (Deep Lakes)

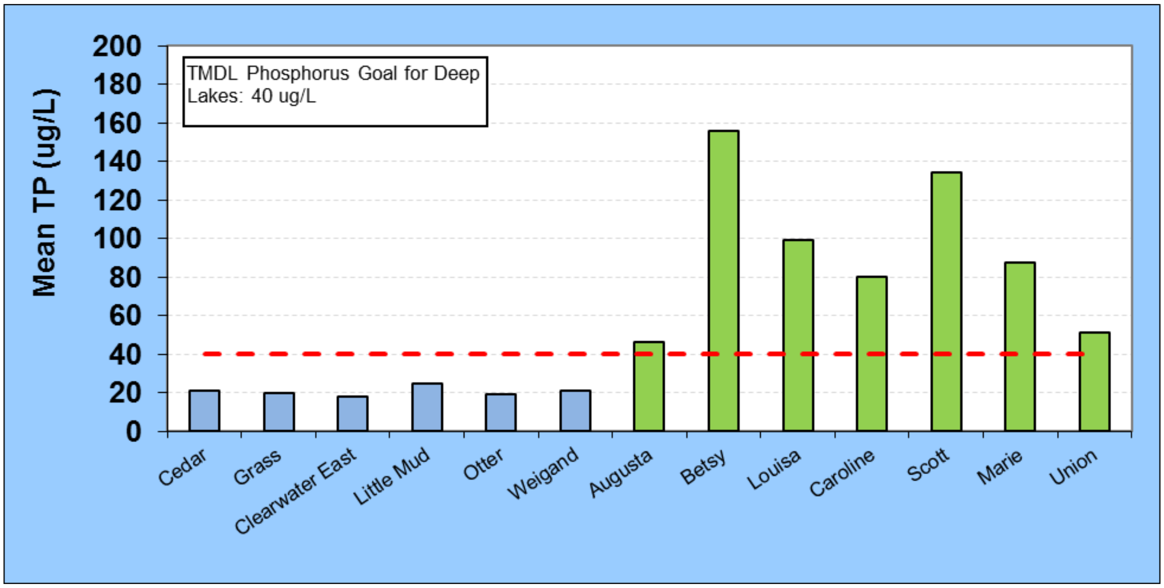
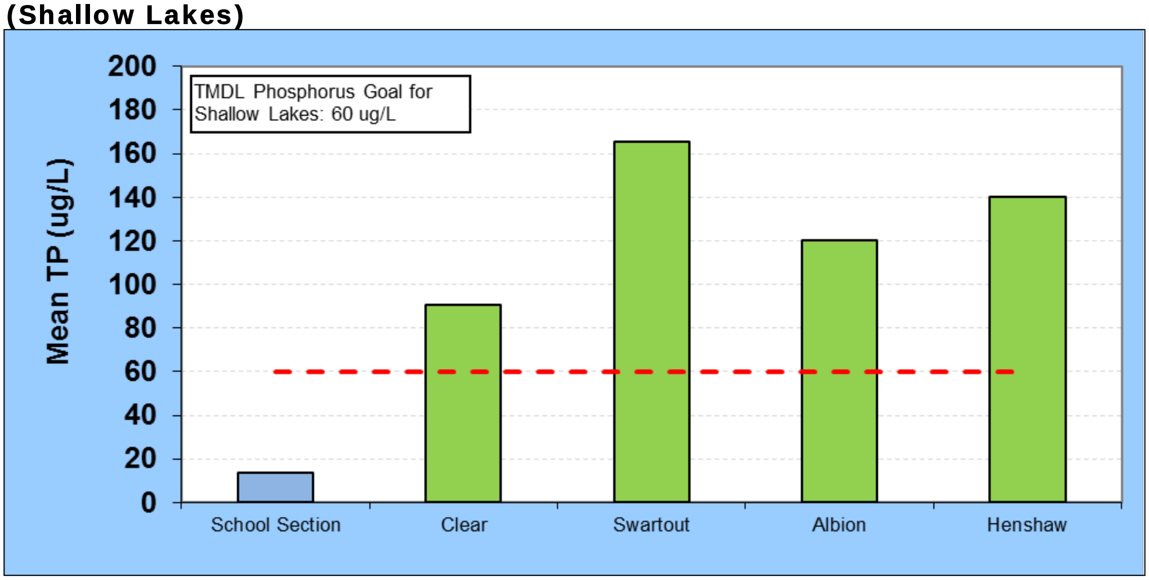


Figure 4-16: 2015 Summer Average Total In-Lake Phosphorus Concentrations (Shallow Lakes)



In general, phosphorus concentrations were slightly higher in approximately half of the lakes monitored in 2015 compared to recent years due to increased runoff and loading from the watershed. Based on the 2015 monitoring data for each lake Union, Caroline, Marie, Louisa, Augusta, Scott, Betsy, Clear, Albion, Henshaw, and Swartout were above state standards for TP. Although phosphorus concentrations did not meet TMDL goals in these lakes, concentrations did improve in Clear, Marie, Scott, and Swartout Lakes in 2015 compared to 2014.

Figures 4-17 and 4-18 compare the most recent summer average chlorophyll-a concentrations for fourteen CRWD lakes to the appropriate chlorophyll-a TMDL goal. In 2015, Caroline, Scott, Marie, Albion and Swartout Lakes were above the TMDL goal for chlorophyll-a. It is interesting to note that several of the lakes that did not meet TP standards in 2015 did meet chlorophyll-a standards. These lakes included Union, Betsy, Augusta, Louisa and Clear Lakes. This suggests something other than phosphorus may be limiting algae growth in these lakes. A recent trend of decreasing chlorophyll-a concentrations continued in 2015 in Caroline, Clear, Clearwater, Grass, Louisa and Scott Lakes.

Figure 4-17: 2015 Summer Average Chlorophyll-a Concentrations (Deep Lakes)

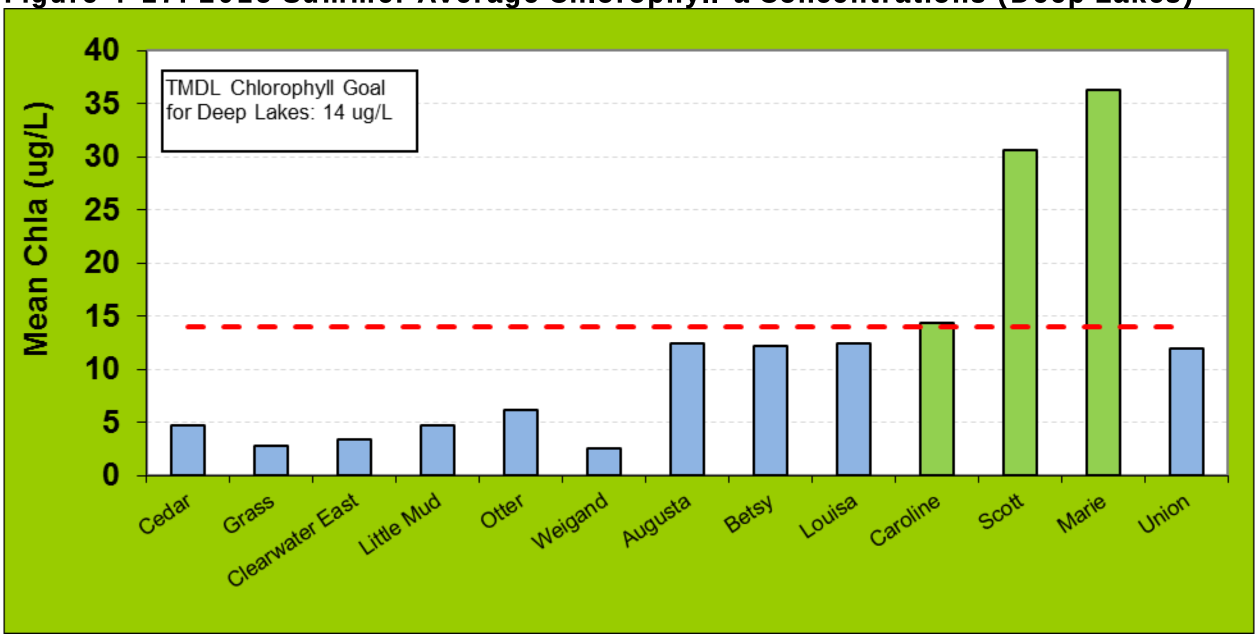
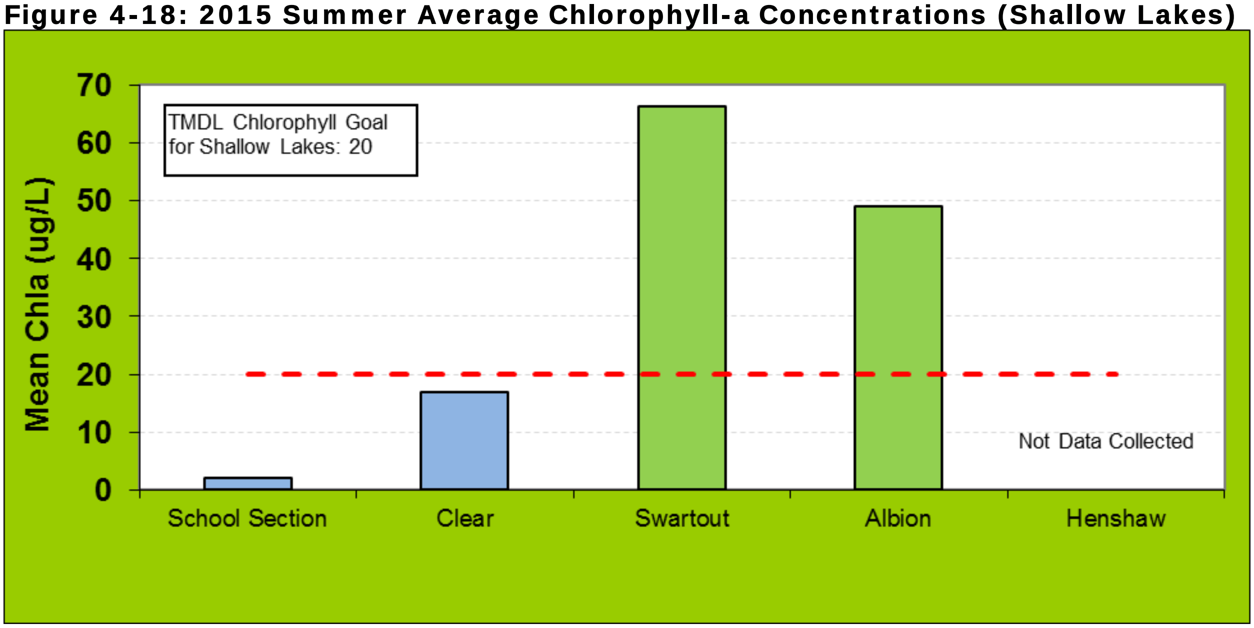


Figure 4-18: 2015 Summer Average Chlorophyll-a Concentrations (Shallow Lakes)



Figures 4-19 and 4-20 compare the 2015 Secchi disk depth for CRWD lakes to the appropriate state standards. In general, water clarity improved in many District lakes in 2015 likely due to the decreased algae growth as seen in the chlorophyll-a data. State standards were met for all lakes except Marie, Union, Swartout and Albion.

Figure 4-19: 2015 Summer Average In Lake Secchi Depth (Deep Lakes)

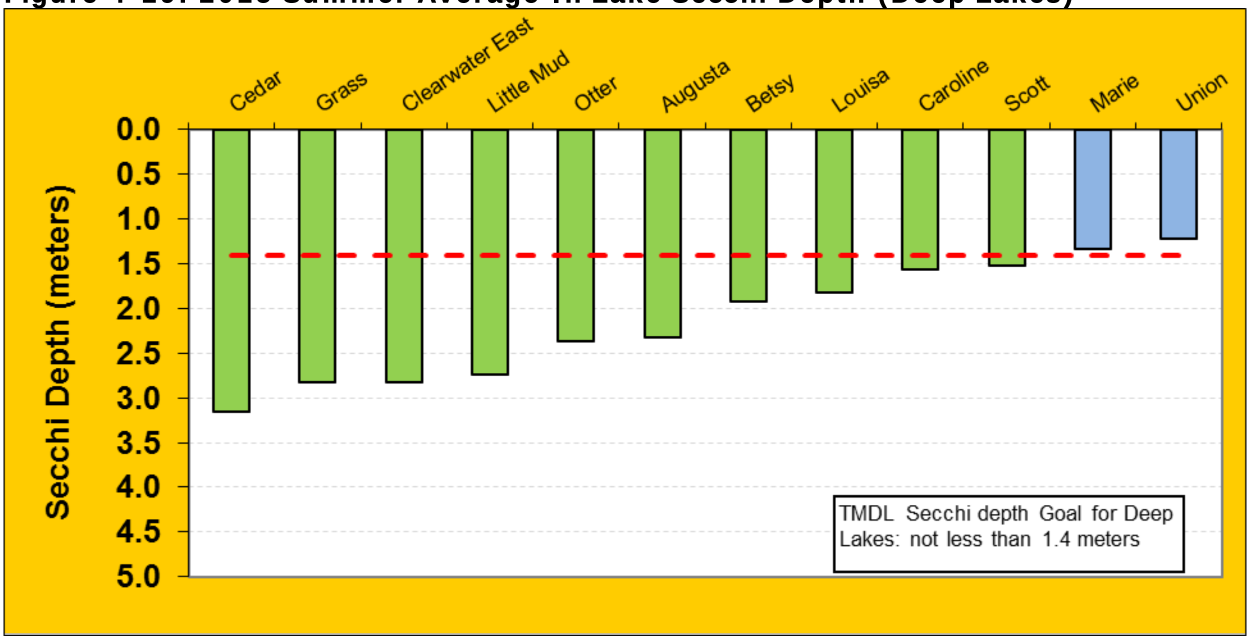
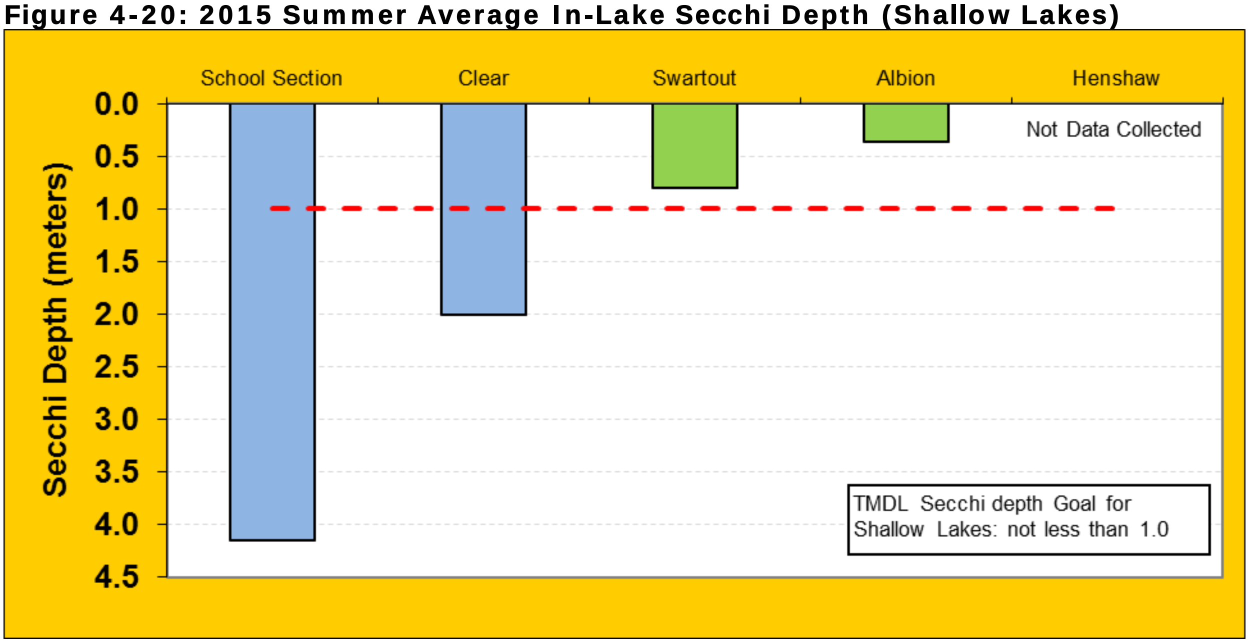


Figure 4-20: 2015 Summer Average In-Lake Secchi Depth (Shallow Lakes)



As demonstrated in Table 4-7, phosphorus and Chlorophyll-a concentrations were near the low end of historic ranges in most lakes in 2015. Phosphorus concentrations in Clearwater, Little Mud, School Section and Swartout Lake and Chlorophyll-a concentrations in Clearwater, Little Mud and School Section were the lowest ever observed in these lakes.

Secchi disk depths were near the midpoint of historic ranges in most lakes in 2015, with the best Secchi readings ever observed in Augusta, Cedar, Clear and School Section Lakes. Secchi depth was near the low end of the historic range in only Albion and Union Lakes 2015.

Table 4-7: 2015 Mean In-Lake Total Phosphorus, Chlorophyll-a, and Secchi Depth, and Historical Ranges

	TP [ug/l]		Chlorophyll-a [ug/L]		Secchi Depth [meters]	
Lake	**2015 Mean**	**Historical Range Mean**	**2015 Mean**	**Historical Range Mean**	**2015 Mean**	**Historical Range Mean**
Albion	121	104-296	49	37-204	0.4	0.3-1.2
Augusta	46	28-300	12	4-73	2.3	1.1-2.3
Betsy	158	120-700	14	4-170	2.1	0.5-2.4
Caroline	80	36-300	14	3-55	1.6	0.8-2.1
Cedar	21	19-58	5	3-20	3.2	1.1-3.2
Clear	98	80-307	20	17-153	1.8	0.3-1.8
Clearwater West	18	18-130	3	3-85	2.8	1.2-3.0
Grass	20	17-38	3	1-14	2.8	1.9-3.4
Henshaw	140	81-390	NA	7-278	NA	0.2-1.7
Little Mud	25	25-62	5	5-83	2.7	1.6-3.4
Louisa	100	33-440	12	4-101	1.8	0.6-2.1
Marie	88	69-360	36	4-153	1.3	0.4-2.3
Otter	19	13-34	6	1-8	2.4	1.9-3.0
School Section	14	14-50	2	2-14	4.2	1.0-4.2
Scott	134	82-660	31	3-223	1.5	0.5-1.9
Swartout	166	166-438	66	11-832	0.8	0.2-2.1
Union	45	25-88	12	7-39	1.2	1.0-2.6
Weigand	21	28-61	3	3-12	NA	1.4-3.7

Exceeds state standards

Table 4-8 summarizes phosphorus concentration trends in each lake. Again, phosphorus concentrations did not meet state standards in 11 lakes in 2015. Overall, based on the most recent monitoring data for all lakes within CRWD, water quality is generally good and remaining stable or improving. During years with high runoff, phosphorus concentrations in certain lakes approach concentrations observed in the Clearwater River. During dry years, internal loading contributes a larger portion of the phosphorus load to the lakes.

Table 4-8: Lake Trend and Impairment Summary

Lake	Last Monitored	Phosphorus Trend	Use
Albion*	2015	Recent Decreasing Trend	Impaired
Augusta*	2015	Stable Trend	Impaired
Bass	2013	Stable Trend	Full Use
Betsy*	2015	Recent Stable Trend	Impaired

Lake	Last Monitored	Phosphorus Trend	Use
Caroline*	2015	Recent Increasing Trend	Impaired
Cedar	2015	Stable Trend	Full Use
Clear*	2015	Recent Decreasing Trend	Impaired
Clearwater East	2013	Recent Stable Trend	Full Use
Clearwater West	2015	Recent Decreasing Trend	Full Use
Grass	2015	Decreasing Trend	Full Use
Henshaw*	2015	Recent Increasing Trend	Impaired
Little Mud	2015	Decreasing Trend	Full Use
Louisa*	2015	Recent Increasing Trend	Impaired
Marie*	2015	Recent Decreasing Trend	Impaired
Nixon	2013	Recent Stable Trend	Full Use
Otter	2015	Stable Trend	Full Use
Pleasant	2014	Stable Trend	Full Use
School Section	2015	Stable Trend	Full Use
Scott*	2015	Recent Inconsistent Trend	Impaired
Swartout*	2015	Recent Stable Trend	Impaired
Union*	2015	Recent Increasing Trend	Impaired
Wiegand	2015	Decreasing Trend	Full Use

*Exceeded TP standard in 2015

4.2.2 Additional Monitoring Efforts

Samples were collected near the bottom at Augusta, Betsy, Caroline, Clear, Louisa, Marie, Scott and Union Lakes in 2015 and analyzed for total phosphorus, ortho-phosphorus, and total iron. A summary of surface and bottom phosphorus concentrations, bottom iron concentrations, and a DO/temperature profile at each lake for each monitoring date is found in Appendix E. A summary of bottom phosphorus data collected at each lake since 2009 is found in Appendix H. A summary of current and historical lake data is also found on the lake report cards in Appendix C.

Analysis of these parameters in bottom samples is helpful in estimating internal nutrient cycling in lakes. In-lake nutrient cycling is an important component of the whole lake nutrient budget. Phosphorus builds up in lake-bottom sediments due to increases in phosphorus load export from the tributary watershed.

Lake profile data, in which temperature and dissolved oxygen were recorded at 1 meter increments in each lake helps to identify the period of stratification in lakes. This data also allows quantification of the period of anoxia, defined as dissolved oxygen levels less than 2 mg/L, in each lake. Internal loading can be a result of sediment anoxia, where weakly bound phosphorus is released into the water column in a form readily available for phytoplankton production.

Review of the lake profile data collected in 2015 demonstrates that most lakes that typically stratify were stratified in early June and remained stratified through September.

Table 4-9 provides a summary of conditions in CRWD lakes which can be used to determine the potential for in-lake nutrient cycling in each lake sampled in 2015. Generally, lakes which have high bottom phosphorus concentrations and periods of anoxia from stratification are susceptible to internal nutrient cycling. Lake stratification patterns identified in Table 4-9 vary between water bodies. Lake stratification can drive anoxia, which can drive internal loading in deeper lakes. Identifying the stratification and anoxic period can guide design of efforts to reduce internal loading.

Table 4-9: 2015 Summer Average Concentrations and Lake Stratification Patterns

Lake Name	Surface Summer Average TP (µg/L)	Surface Summer Average OP (µg/L)	Bottom Summer Average TP (µg/L)	Bottom Summer Average OP (µg/L)	Lake Stratification Pattern
Albion	121	11	Not Sampled		Mixed
Augusta	46	6	459	309	Strongly Stratifies
Betsy	158	72	790	537	Weakly Stratifies
Caroline	80	26	1613	1143	Strongly Stratifies
Cedar	21	9	Not Sampled		Strongly Stratifies
Clear	98	38	366	172	Polymictic
Clearwater West	Not Sampled		Not Sampled		Strongly Stratifies
Henshaw	Not Sampled		Not Sampled		Mixed
Louisa	100	38	1160	835	Strongly Stratifies
Marie	88	18	1166	869	Strongly Stratifies
Pleasant	Not Sampled		Not Sampled		Strongly Stratifies
Scott	134	57	314	194	Polymictic
Swartout	166	16	Not Sampled		Mixed
Union	51	7	1250	867	Strongly Stratifies

Mixed and Polymictic: In mixed water bodies, water temperature is fairly uniform from top to bottom in the lake. As a result, oxygen enriched water from near the surface is able to mix throughout the water column, and anoxia is typically not present. Polymictic lakes are lakes that develop a weak stratification and mix periodically throughout the growing season. As a result of the frequent mixing, anoxic conditions would likely occur infrequently.

Stratified: In stratified lakes a warm surface layer forms during summer months and the lake maintains a cooler lower layer in the lake and prevents mixing between the two layers. This does not allow oxygen enriched water to reach the bottom layer and anoxia can develop below the thermocline.

Lakes with high bottom phosphorus concentrations that experience anoxic conditions during periods when the lake is stratified have a high potential for internal loading. Lakes with the highest bottom concentrations of phosphorus in 2014 include Betsy, Caroline, Louisa, Marie, and Union. Based on the presence of high bottom phosphorus concentrations, lake stratification patterns, and associated periods of anoxia during a given year, these lakes have a high potential for internal loading. Shallow lakes such as Henshaw, Albion, Swartout, and Clear can load internally throughout the season based on disturbance of bottom sediments from wind and rough fish.

As shown in Appendix C and in Lake Phosphorus and Profile Data in Appendix E, the bottom phosphorus concentrations in most lakes generally increased throughout the summer in 2015 as anoxic conditions developed in these lakes in early summer. Bottom phosphorus concentrations typically decrease after mixing with the entire water column during fall turnover. This pattern of seasonal increase in bottom phosphorus concentrations is evident in most years as shown in Appendix H, which compares bottom phosphorus concentrations in District Lakes since 2009.

Lake report cards provide a more detailed summary of present and historic water quality for each lake and are included in Appendix C. Water quality lab reports are in Appendix E, and field notes are in Appendix F which are not published with the report, but are available at the CRWD office, and can be downloaded from the MPCA web site.

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OFFICE MEMORANDUM

TO: BOARD OF MANAGERS

FROM: REBECCA KLUCKHOHN, DISTRICT ENGINEER; OFFICE STAFF

DATE: 02/09/2015

SUBJECT: PROPOSED 2015 WATER QUALITY MONITORING PROGRAM

Introduction

The Clearwater River Watershed District has conducted an annual water quality monitoring program at selection locations throughout the watershed in 1981 in an effort to assess District progress towards water quality goals, track long-term water quality trends, and evaluate effectiveness of existing water quality improvement projects and programs. The proposed 2015 program is intended to continue this effort.

The water quality monitoring program is divided into five categories: lake monitoring, stream monitoring, 2015 WPLMN, data MAR (management, analysis, reporting), and supplemental monitoring. The 2015 proposed monitoring stations are shown on Figure 1. The 2015 proposed lake monitoring follows the long-term lake monitoring plan as shown in Table 1. The 2015 proposed stream monitoring follows the long-term stream monitoring plan as shown in Table 2. The proposed monitoring sites together with a proposed schedule and laboratory/field parameters are show in Table 3. The proposed budget for the three water quality monitoring categories is shown in Tables 4 and 5.

Lake Monitoring

It is recommended the District's 2015 lake monitoring include the lakes shown on Table 1. Grass, Clearwater East, Augusta, Caroline, Marie, Louisa, and Scott will be monitored June – September as part of ongoing operation and maintenance of the Clearwater River Chain of Lakes (1980) Restoration Project. Instead of monitoring from Wiegand Lake, samples and field parameters will be taken from 161st St E Bridge below Wiegand Lake (Nordell Bridge). Little Mud, Otter, School Section, and Union lakes will be monitored June – September as general fund tasks. Cedar, Albion, Swartout, and Henshaw lakes will be monitored from June - September as part of ongoing operation and maintenance of Project #06-1. Clear and Betsy lakes will be monitored from May to September as part of the Targeted Fertilizer Application Reduction Project. A nitrogen suite will be sampled from the surface water for these two lakes.

Cedar, Albion, Swartout, and Henshaw lakes will be monitored from June – September as part of ongoing operation and maintenance of Project #06-1. It is also recommended the District continue to conduct aquatic vegetation surveys in Albion, Swartout, and Henshaw lakes in 2015. The vegetation surveys should be conducted in late summer to track the overall vegetation coverage and species in each lake to compare to surveys conducted in previous years. The lakes would also be mapper using sonar equipment during the survey to provide aquatic vegetation biomass, lake contours, lake volume, and bottom hardness data.

Surface water samples and profiles of field parameters should be collected at all of the sampled lakes. Bottom samples should be collected in Betsy, Clear, Augusta, Scott, Louisa, Marie, Caroline, and Union lakes to track internal loading. The proposed stations and the parameters to be monitored are shown on Table 3.

Stream Monitoring

It is recommended the District's 2015 stream monitoring include the streams shown on Table 2. The Clearwater River will be monitored at least once a month at stations CR 10.5, CR 28.2, and CR 29.0 from March – October. CR 28.2 and CR 29.0 will be monitored twice per month as part of the Kingston Wetland Restoration Project. A nitrogen suite will be sampled once a month from CR 28.2 and CR 29.0. Warner Creek will be monitored at WR 0.2 once a month from March – October. Willow Creek will be monitored at WC 2.5 and WC 3.0 once a month from March – October to track the progress of projects implemented in the City of Kimball.

Tributary streams in the Cedar Lake subwatershed will be monitored from March – October at stations SSW01, SSW 02, SSW 04, SHE 01, and SCE 01. Continuous water level will be recorded at SSW 04. Additional monitoring stations will be established at the two components of the Cedar Lake Watershed Protection & Improvement Project, in order to quantify project effectiveness (tentatively titled stations OH 1, OH 2, and ES 1).

All stream stations will be monitored for water quality and flow. Water quality parameters are total phosphorus, ortho-phosphorus, and total suspended solids. Samples will be collected to be analyzed for E-coli at CR 29.0. Continuous water level will be recorded at CR 10.5, the Fair Haven Dam, CR 28.2, and CR 29.0.

As shown in Figure 1, several other stream locations in the upper watershed will be monitored as part of the Targeted Fertilizer Application Reduction Project in 2015. These include TF 1, TF 2, TF 18, CD 20 2.2, CD 20 1.0, CLN and CLS. In addition to the standard parameters, a nitrogen suite will be sampled as well from these locations.

Targeted Fertilizer Tile Monitoring

Three tile outlets are monitored as part of the Targeted Fertilizer Application Reduction Project. Field staff time for monitoring these tile outlets is estimated at 18 hours. Depletion of soil P from areas which were not fertilized as part of this project will be evaluated. These data may be available in the existing data set; if not, the District will contact the partnering cooperatives and provide instructions. This activity is required and funded through this project's grant.

2015 Watershed Pollution Load Monitoring Network (WPLMN)

The District has agreed to serve as a subcontractor to Sherburne SWCD for the monitoring of WPLMN's site on the Clearwater River in Clearwater, MN (see figure 1). The purpose of the WPLMN is to provide a state-wide monitoring network in order to obtain spatial and long-term pollutant load information from the state's rivers and streams. 160 hours of District staff time is estimated for this site's operation. Funding for this site's monitoring is covered by a grant with the MN Pollution Control Agency; as such, there will be no cost to the District for this work. As part of this monitoring activity, the District will be receiving some new monitoring equipment.

Data Management, Analysis and Report

The objectives of the Water Quality Monitoring and Watershed Management Plan Implementation Status program are:

1. Track progress towards water quality goals for impaired waters by:
    a. Measuring water quality trends in lakes and streams and pollutant loads
    b. Tracking programs and projects implemented
    c. Evaluating water quality in the context of programs/ projects implemented
2. Fill data gaps identified in the TMDLs
3. Continue to provide baseline water quality data and calibration data sets to refine TMDL load reductions
4. Track long-term trends in all CRWD waters monitored ensuring early detection of declining trends
5. Provide recommendations for ongoing programs, projects and watershed

The hydrologic, hydraulic and water quality monitoring data (field and laboratory) collected under this proposal will be maintained in the MPCA's online database and evaluated to determine CRWD's progress towards water quality goals. The District will publish results annually.

Supplemental Monitoring

In addition to the two categories listed above, it is recommended that supplemental monitoring efforts be considered in 2015. The proposed supplemental monitoring efforts would allow the District to track the success of individual projects or to investigate specific water quality concerns.

<u>Supplemental Monitoring Task 1: Watkins Monitoring</u>

BWSR recently awarded CRWD a grant to construct a water quality project in Watkins on land the District currently owns. Water quality and flow monitoring at sites upstream and downstream is recommended to support design. Upon signing of the contract, these efforts will be covered under grant activities. However, it will be important to collect early spring data; these data may be missed if the District waits until the contract is signed. The cost includes installation of one pressure transducer (or ISCO) to record level, flow gauging and water quality sampling for traditional parameters. The estimated cost for this task is $800 plus 10 hours of field staff time. Some Wenck Associates staff time will also be needed to assist with installation of the ISCO and training in its operation.

<u>Supplemental Monitoring Task 2: Additional lake mapping with sonar equipment</u>

This task involves District engineering and District staff mapping selected lakes with sonar equipment that allows for the quantification of aquatic vegetation biomass, lake contours, lake volume, and bottom hardness. This information, in combination with water quality data collected on the lakes, would assist the District in planning future potential projects or evaluating past projects on District lakes. The estimated cost for this task is $1,150.00 per lake for field data collection and processing of the data, and 8 hours of field staff time. Recommended lakes for this data collection and analysis in 2015 are Clear and Augusta.

Supplemental Monitoring Task 3: Additional Lake Betsy Monitoring – Internal Load

The results of the Lake Betsy Internal Load Management Study indicate that a whole –lake alum treatment may be a more cost effective alternative to Hypolimnetic Withdrawal. In order to provide better data for future internal load reduction work in Lake Betsy, the Board of Managers may want to consider an alum dosing study. This task involves collecting sediment from the lake bottom and conducting lab tests to determine optimum alum dosing and develop an estimate of probable cost. The lab costs for this are about $5,500 with an additional 4 hours of staff time.

Supplemental Monitoring Task 4: Sediment Cores

CRWD TMDL Studies indicated a need to more directly quantify internal loads in District Lakes. To date the CRWD have conducted lake core studies to measure release rates on Lake Betsy, Scott Lake, Clear Lake and Lake Augusta. In 2003, a different method was used to measure release rates in Lakes Louisa and Marie. The Board of managers may wish to evaluate internal loading in Lake Caroline in 2015. The estimated cost for this task is $2,500 plus 4 to 6 hours of field staff time and the cost of sample delivery and equipment rental.

Supplemental Monitoring Task 5: Sampling at CR 19.8

This task involves monitoring water quality and flow at the Clearwater River at site CR 19.8 (State Highway 55 river crossing) upstream of Lake Louisa. Monitoring would be performed once a month from March – October. Water quality parameters would be total phosphorus, ortho-phosphorus, and total suspended solids. Flow would be gauged when possible at this site. Water level readings at the Fair Haven Dam could also be used to measure flow at this station. The estimated cost for this task is $300.00, plus 6 hours of field staff time.

Supplemental Monitoring Task 6: Monitor inlet tributary above Lake Augusta

Wright County is planning to realign CO RD 136, located just west of Lake Augusta. Now would be a good opportunity to quantify pollutant loading from the tributary stream this road crossing just northwest of Lake Augusta to determine if a water quality improvement should be sought as part of the planned realignment. The estimate cost for this task is $300.00, plus 6 hours of field staff time.

Supplemental Monitoring Task 7: Contingency Monitoring

This task involves collecting up to 2 additional samples from routine monitoring stations CR 28.2, CR 10.5, and WR 0.2 during high runoff periods following significant precipitation events. Flows would also be monitored during these events. This task also includes collecting up to 4 additional samples in the watershed to document unique events observed by CRWD staff, such as runoff from feedlots or other discharges to water bodies that have previously gone unmonitored. The estimated cost for this task is $750.00 plus 7.5 hours of field staff time.

Table 1: Proposed Long-Term Water Quality Monitoring Plan for CRWD Lakes

LAKE STATIONS	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Clearwater Lake:										
Clearwater East		X		X		X		X		X
Clearwater West	X		X	X	X		X		X	
Main Stem Lakes:										
Augusta		X		X	X*	X	X	X	X	X
Louisa	TMDL*	X		X	X	X	X	X	X	X
Caroline	X		X	X	X	X	X	X	X	X
Scott	x		X	X	X*	X	X	X	X	X
Marie	x*		X	X	X	X	X	X	X	X
Betsy		X		X*	X	X	X	X	X	X
Other Lakes:										
Cedar	X		X^	X^	X^	X^	X	X	X	X
Pleasant		X	X(3)	X	X		X		X	
School Section		X		X		X		X		X
Nixon		X	X	X		X		X		
Otter		X		X			X			X
Bass	X		X+	X		X		X		
Clear			X	X*	X	X	X	X	X	X
Union			X	X	X	X	X	X	X	X
Henshaw		X	X^	X^	X^	X^	X	X	X	X
Little Mud	X			X			X			X
Wiegand				X			X#			X#
Swartout	X		X^	X^	X^	X^	X	X	X	X
Albion	X		X^	X^	X^	X^	X	X	X	X
Grass			X	X		X		X		X

LAKE STATIONS	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Number of Lakes Monitored W/ CRWD Funding	10	9	14	22	14	17	17	17	14	18

Notes: ^Part of Project #06-1; +Added to assess trends, *Lake bottom sediment cores collected and analyzed, # Monitored from Nordell Bridge

Table 2: Proposed Long-Term Water Quality Monitoring Plan for CRWD Streams

STREAM STATIONS	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cedar Lake Subwatershed[^]										
SCE 01			X	X	X	X	X	X	X	X
SHE 01			X	X	X	X	X	X	X	X
SSW 01			X	X	X	X	X	X	X	X
SSW 02			X	X	X	X	X	X	X	X
SSW 04			X	X	X	X	X	X	X	X
Clearwater River										
CR 10.5	X	X	X	X	X	X	X	X	X	X
CR 28.2	X	X	X	X	X	X[+*]	X[+*]	X[+*]	X[+*]	X[+*]
CR 29.0	X					X[+*]	X[+*]	X[+*]	X[+*]	X[+*]
Other Streams:										
CLN					X		X[*]	X[*]	X[*]	X[*]
CLS	X				X		X[*]	X[*]	X[*]	X[*]
CD 20 - 1.0	X			X				X[*]	X[*]	X[*]
CD 20 - 2.2	X							X[*]	X[*]	X[*]
WC 2.5							X	X	X	X
WC 3.0							X	X	X	X
WR 0.2	X	X	X	X	X	X	X	X	X	X
Number of Streams Monitored W/ CRWD Funding	7	3	8	9	10	9	13	15	15	15

Notes: [^]Part of Project #06-1; [+]Part of Kingston Wetland Project, [*]Part of Targeted Fertilizer Project

Table 3: Proposed 2015 CRWD Monitoring Plan Summary

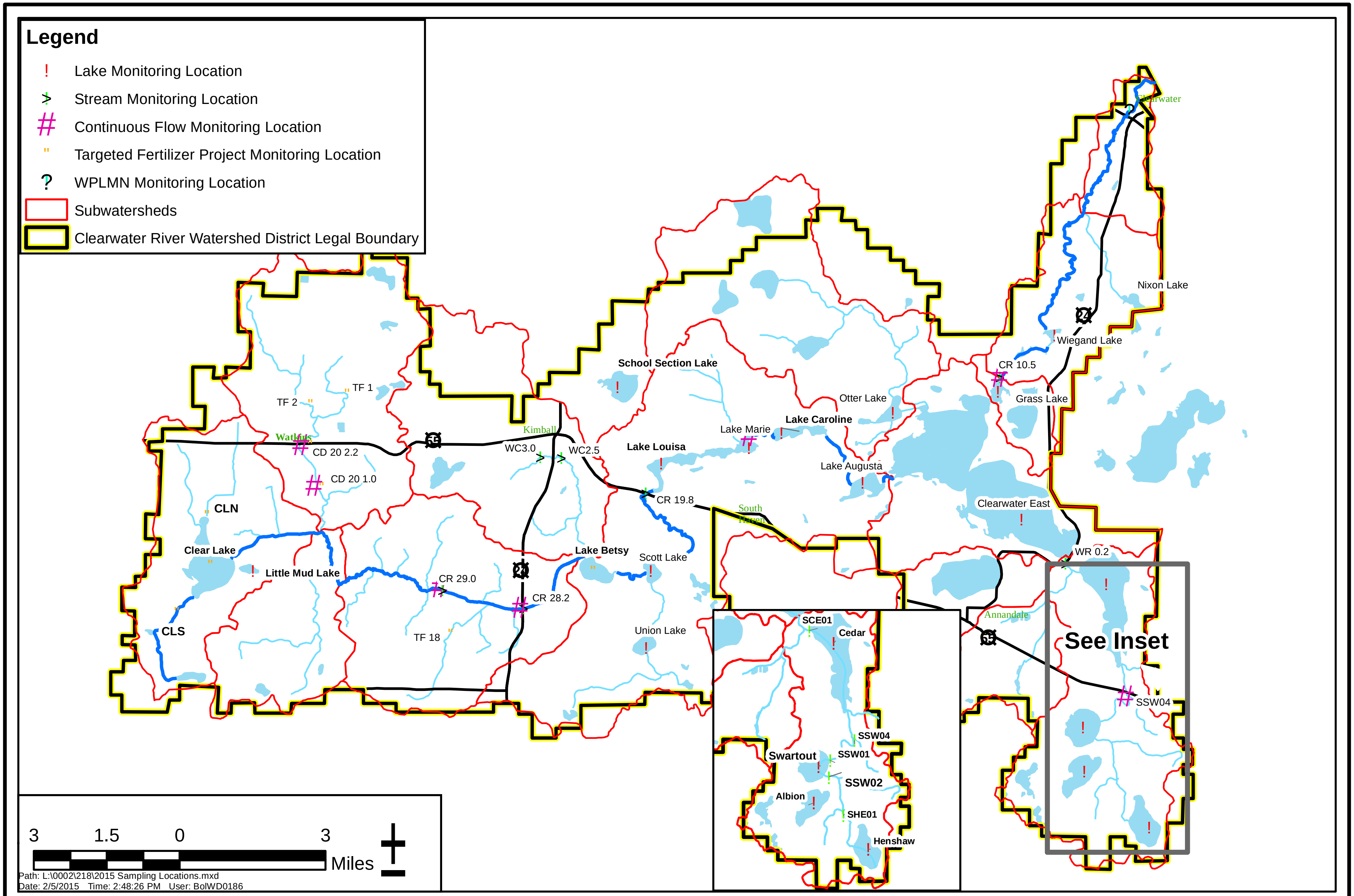
Category	2014 Schedule	Station	Parameters
Lakes:	June 3-7, July 8-12, August 5-9, September 2-6 Note: (Lake sampling to be completed by September 15)	*The CRWD will monitor Clearwater (East), Grass, Augusta, Louisa, Caroline, Scott, and Marie (monitored under the Chain of Lakes (1980) Project). *Little Mud, Otter, School Section, and Union (monitored under the general fund.) *Cedar, Albion, Swartout, and Hensaw Lakes (monitored under Project #06-1.) *Clear and Betsy (monitored under the Targeted Fertilizer Project.) *Wiegand lake (monitored from Nordell Bridge.)	*Field: Secchi depth, DO and temperature profiles. *Lab: surface samples for total phosphorus, ortho phosphorus, and chlorophyll-a. *Bottom samples for total phosphorus, ortho phosphorus, and total iron in Augusta, Louisa, Caroline, Scott, Marie, Union, Clear, and Betsy.
Streams:	Twice monthly March-October	CR 28.2 and CR29.0 (monitored under Kingston Wetland & Targeted Fertilizer Project)	Field: DO, temperature, conductivity, pH ; Lab: total phosphorus, ortho phosphorus, TSS; E-coli at CR 29.0
	Monthly March-October	CR 10.5 (monitored under the general fund)	Field: DO, temperature, conductivity, pH ; Lab: total phosphorus, ortho phosphorus, TSS
	Monthly March-October	Warner Creek at WR0.2 (general fund); Willow Creek at WC 2.5 and WC 3.0 (Chain of Lakes (1980) Project)	Field: DO, temperature, conductivity, pH ; Lab: total phosphorus, ortho phosphorus, TSS
	Monthly March-October	Clear Lake North, Clear Lake South, CD 20-1.0, CD20-2.2, TF 1, TF 2, TF 18 (monitored under Fertilizer Application Project)	Field: DO, temperature, conductivity, pH ; Lab: total phosphorus, ortho phosphorus, TSS
	Monthly while streams are flowing from March-October	SSW01, SSW02, SSW04, SCE01, and SHE01 (monitored under Project #06-1)	Field: DO, temperature, conductivity, pH ; Lab: total phosphorus, ortho phosphorus, TSS
	Continuous: March-October	CR 10.5 & Fair Haven Dam(general fund) CR 28.2 & CR 29.0 (Kingston Wetland) SSW 04 (Project #06-1) CD 20-2.2 (Targeted Fertilizer)	Place continuous water level recorders after ice-out, check throughout year, pull in October
Precipitation:	Daily	Corinna, Kimball, Watkins	

Table 4: Proposed 2015 Water Quality Monitoring Cost Sheet, per category and funding source

Funding Source	Estimated Field Staff Costs ($30/hr.)	Laboratory Costs	Other Costs	Total Costs
Lake Monitoring				
General [100]	$1,680.00	$491.00	$64.00	$2,235.00
Chain of Lakes [210]	$2,940.00	$1,936.00	$104.00	$4,980.00
Project #06-1 [215]	$1,680.00	$692.00	$112.00	$2,484.00
Veg. Surveys [215]	$270.00	$0.00	$1,500.00	$1,770.00
Targeted Fert. [247]	$1,050.00	$1,035.00	$164.00	$2,249.00
			TOTAL	$13,718.00
Stream Monitoring				
General [100]	$480.00	$1,991.20	$64.00	$2,535.20
Chain of Lakes [210]	$540.00	$826.80	$104.00	$1,470.80
Project #06-1 [215]	$960.00	$1,378.00	$112.00	$2,450.00
Kingston Wetland [246]	$480.00	$551.20	$64.00	$1,095.20
Targeted Fert. [247]	$1,680.00	$4,208.40	$164.00	$6,052.40
Tile Monitoring [247]	$540.00	$1,402.80	$20.00	$1,962.80
CLWP&I [215]	$337.50	$172.25	$20.00	$529.75
			TOTAL	$16,096.15
2015 WPLMN				
General [100]	Covered by MPCA grant			
Data Analysis & Reporting				
General [100]	$0.00	$0.00	$8,000.00	$8,000.00
Chain of Lakes [210]	$0.00	$0.00	$2,000.00	$2,000.00
Project #06-1 [215]	$0.00	$0.00	$2,000.00	$2,000.00
Kingston Wetland [246]	$0.00	$0.00	$2,000.00	$2,000.00
Targeted Fert. [247]	$0.00	$0.00	$2,000.00	$2,000.00
			TOTAL	$16,000.00
Supplemental Monitoring				
Supplemental #	**Funding Source**			**Total Cost**
1	Chain of Lakes [210]			$1,790.00
2	General [100]			$1,693.33
	Chain of Lakes [210]			$846.67
3	Chain of Lakes [210]			$6,172.00
4	Chain of Lakes [210]			$3,922.00
5	Chain of Lakes [210]			$480.00
6	General [100]			$480.00
7	General [100]			$585.00
	Chain of Lakes [210]			$390.00
			TOTAL	$16,359.00
Note: 2015 WPLMN is fully refundable through MPCA grant. As such, actual cost to CRWD will be $0.00 for this category.				

Table 5: Proposed 2015 Water Quality Monitoring Budget, per funding source

Funding Source	Proposal Amount	Amount Budgeted	Current Cash
Monitoring, No Supplemental Monitoring			
General [100]	$12,770.20	$33,150.00	$476,813.09
Chain of Lakes [210]	$8,450.80	$1,200.00	$216,825.34
Project #06-1 [215]	$9,213.75	$7,200.00	$278,261.79
Kingston Wetland [246]	$3,115.20	$7,450.00	$137,020.14
Targeted Fertilizer [247]	$12,264.20	$9,300.00	$225,856.02
TOTAL	$45,814.15	$58,300.00	
Only Supplemental Monitoring			
General [100]	$2,758.33	$33,150.00	$476,813.09
Chain of Lakes [210]	$13,600.67	$1,200.00	$216,825.34
Project #06-1 [215]	$0.00	$7,200.00	$278,261.79
Kingston Wetland [246]	$0.00	$7,450.00	$137,020.14
Targeted Fertilizer [247]	$0.00	$9,300.00	$225,856.02
TOTAL	$16,359.00	$58,300.00	
All Monitoring			
General [100]	$15,528.53	$33,150.00	$476,813.09
Chain of Lakes [210]	$22,051.47	$1,200.00	$216,825.34
Project #06-1 [215]	$9,213.75	$7,200.00	$278,261.79
Kingston Wetland [246]	$3,115.20	$7,450.00	$137,020.14
Targeted Fertilizer [247]	$12,264.20	$9,300.00	$225,856.02
TOTAL	$62,173.15	$58,300.00	
Note: Previous years proposed Water Quality Monitoring Program Totals are: 2014: $47,050.00 2013: $38,626.00 2012: $47,714.00 2011: $53,706.00			



CLEARWATER RIVER WATERSHED DISTRICT

Proposed 2015 Monitoring Locations

JAN 2015

Figure 1

APPENDIX B Table B-1
Historical Mean Flow and Phosphorus Loading

Clearwater River Watershed District

2015 Annual Report

Station Main Stem:	Year	Average Stream Flow (cu m/sec)	(cfs)	Flow-Weighted Average Total Phosphorus Concentration (mg/L)	Total Phosphorus Load (kg)	(lb)	µg/L
CR 28.2	1981 (1)	--	--	1.400	--	--	1,400
	1981						
(Actual River	1982 (1)	0.93	32.8	0.740	19,700	43,500	740
Mile 27.2)	1983	2.62	92.6	0.920	76,000	168,000	920
	1984	1.49	52.6	0.760	35,700	78,800	760
	1985	2.32	81.9	0.900	65,500	144,000	900
	1986	3.20	113	0.780	55,200	122,000	780
	1987	0.11	3.90	0.130	460	1,020	130
	1988	0.09	3.12	0.660	1,850	4,080	660
	1989	0.02	0.72	0.190	120	260	190
	1990	0.51	18.0	0.440	7,040	15,500	440
	1991	1.11	39.1	0.290	10,200	22,500	290
	1992	0.26	9.30	0.200	1,660	3,650	200
	1993	1.28	45.2	0.290	11,600	25,600	290
	1994	1.17	41.2	0.280	10,100	22,300	280
	1995	1.15	40.4	0.288	10,400	22,900	288
	1996	0.33	11.7	0.274	2,860	6,300	274
	1997	0.27	9.36	0.260	2,170	4,790	260
	1998	0.41	14.4	0.250	3,190	7,020	250
	1999	0.08	2.78	0.160	400	870	160
	2000	0.02	0.72	0.380	240	530	380
	2001 (4),(5)	0.27	9.46	0.510	4,309	9,500	510
	2002	0.47	16.50	0.291	4,290	9,460	291
	2003	0.28	9.92	0.190	1,710	3,770	190
	2004	0.48	17.04	0.166	1,248	2,751	166
	2005 (6)	1.11	39.28	0.306	1,862	4,105	306
	2006	0.31	11.10	0.130	1,328	2,928	130
	2007	0.14	5.02	0.228	767	1,692	228
	2008	0.64	22.53	0.155	1,333	2,938	155
	2009	1.15	40.60	0.333	7,982	17,597	333
	2010	1.55	54.60	0.258	10,866	23,955	258
	2011	2.62	92.66	0.269	13,593	29,967	269
	2012	1.01	35.72	0.335	6,096	13,440	335
	2013	0.55	19.38	0.252	2,261	4,984	252
	2014	1.04	36.83	0.222	3,358	7,404	222
	2015	0.84	29.75	0.225	3,374	**7438.00**	225
CR 10.5	1981 (1)	1.15	40.6	0.050	2,060	4,550	50
	1982 (1)	2.20	77.8	0.070	4,990	11,000	70
	1983	5.64	199	0.100	18,500	40,800	100
	1984	4.28	151	0.050	6,620	14,600	50
	1985	3.88	137	0.140	16,700	36,800	140
	1986	5.52	195	0.150	23,700	52,300	150
	1987	0.46	16.2	0.040	600	1,320	40
	1988	0.23	7.95	0.040	260	580	40
	1989	0.97	34.2	0.080	2,340	5,150	80
	1990	3.77	133	0.030	3,060	6,750	30
	1991	6.68	236	0.050	10,500	23,200	50
	1992	4.16	147	0.060	8,090	17,800	60
	1993	5.01	177	0.040	6,330	14,000	40
	1994	2.92	103	0.030	2,850	6,290	30
	1995	2.83	100	0.034	3,040	6,710	34
	1996	1.53	54.2	0.041	1,970	4,350	41
	1997	2.06	72.8	0.040	2,690	5,940	40
	1998	1.78	63.0	0.040	2,330	5,120	40
	1999	1.25	44.1	0.040	1,520	3,350	40
	2000	0.31	10.8	0.030	280	610	30
	2001 (4),(5)	0.90	31.7	0.030	850	1,873	30
	2002	2.46	87.0	0.035	2,950	6,500	35
	2003	2.11	74.6	0.024	1,590	3,500	24
	2004	1.66	58.8	0.022	639	1,409	22
	2005 (6)	3.05	107.6	0.023	59	130	23
	2006 (6)	1.76	62.2	0.032	1,263	2,785	32
	2007	0.97	34.1	0.031	933	2,057	31
	2008	1.27	44.8	0.023	452	997	23
	2009	3.99	141.0	0.025	1,949	4,297	25
	2010	6.16	217.5	0.032	4,150	9,149	32
	2011	9.20	325.1	0.026	4,645	10,240	26
	2012	2.59	91.37	0.024	1,365	3,009	24
	2013	2.16	76.50	0.024	959	2,115	24
	2014	4.57	161.31	0.024	2,000	4,409	24
	2015	3.47	122.77	0.022	1,327	2,926	22

APPENDIX B Table B-1
Historical Mean Flow and Phosphorus Loading

Clearwater River Watershed District

2015 Annual Report

Station Main Stem:	Year	Average Stream Flow (cu m/sec)	(cfs)	Flow-Weighted Average Total Phosphorus Concentration (mg/L)	Total Phosphorus Load (kg)	(lb)	µg/L
WR 0.2 (2)	1981 (1)	0.07	2.60	0.170	390	860	170
	1982 (1)	0.23	8.20	0.160	780	1,720	160
	1983	0.47	16.50	0.090	1,270	2,800	90
	1984	0.60	21.20	0.050	950	2,100	50
	1985	0.48	17.10	0.140	2,130	4,700	140
	1986	0.86	30.40	0.200	4,630	10,200	200
	1987	0.04	1.50	0.070	100	230	70
	1988	0.01	0.40	0.170	60	130	170
	1989	0.03	1.19	0.140	80	180	140
	1990	0.06	2.28	0.370	750	1,660	370
	1991	0.26	9.22	0.111	860	1,900	111
	1992	0.11	4.02	0.050	170	370	50
	1993	0.24	8.59	0.100	760	1,670	100
	1994	0.18	6.34	0.060	320	700	60
	1995	0.12	4.27	0.054	210	460	54
	1996	0.05	1.78	0.110	180	380	110
	1997	0.09	3.15	0.077	220	480	77
	1998	0.09	3.11	0.110	290	650	110
	1999	0.06	2.03	0.070	130	280	70
	2000 (3)	0.01	0.44	0.060	25	56	60
	2001 (4),(5)	0.08	2.88	0.100	257	567	100
	2002	0.26	9.17	0.114	930	2,060	114
	2003	0.16	5.79	0.062	320	710	62
	2004	0.07	2.6	0.063	78	172	63
	2005	0.58	20.6	0.066	22	48	66
	2006	0.06	2.1	0.090	102	224	90
	2007	0.03	0.9	0.064	34	76	64
	2008	0.31	11.1	0.058	246	542	58
	2009	0.15	5.3	0.087	273	602	87
	2010	0.16	5.6	0.095	311	685	95
	2011	1.12	39.47	0.105	2,202	4,854	105
	2012	0.48	17.08	0.049	371	818	49
	2013	0.49	17.37	0.052	240	529	52
	2014	0.38	13.47	0.046	278	613	46
	2015	0.17	6.09	0.066	198	436	66

NOTES:

Flow values are time-weighted averages unless otherwise noted.

Total phosphorus values are flow- and time-weighted averages unless otherwise noted.

(1) Values in 1981 and 1982 are arithmetic means
(2) Station WR 0.2 was designated Station WC 0.2 in 1981-1983
(3) Phosphorus values in 2000 are flow-weighted and adjusted per log-log regression on flow so as to correspond to annual mean flows.
(4) 2001 Flow and total phosphorus values are arithmetic averages.
(5) 2001 total phosphorus loads estimated from arithmetic averages of flow and total phosphorus values.
(6) Values in 2005 and 2006 were calculated using supplemental flow data from CSAH 40 near Clearwater

V:\Technical\0002\225 2015 Water Quality Monitoring\Water Quality Data Analysis\[Stream_Loads_Historic_15.xls]Table 2

Appendix B-TABLE B-2

YEARLY PRECIPITATION AND RUNOFF TOTALS

Clearwater River Watershed District

2015 Annual Report

Precipitation (inches of water)

YEAR	Watkins		Kingston		Maine Prairie		Corinna		Area-Weighted Precipitation Average		Runoff (inches)
1981	--		--		--		--		19.76	(1)	3.6
1982	--		--		--		--		24.58	(1)	6.8
1983	46.54		--		42.32		35.02		41.78		17.4
1984	32.23		30.13		32.37		36.07		32.95		13.3
1985	40.72		39.49		45.28		--		42.22		12.0
1986	40.02		35.63		39.68		33.40		37.26		16.0
1987	18.97		15.40		19.41		16.16		17.52		1.4
1988	16.57		18.98		15.96		15.01		16.48		0.7
1989	22.13		22.68		21.80		16.96		20.68		3.0
1990	40.35		39.18		41.36		32.18		37.94		11.7
1991	41.30		45.11		43.41		36.28		41.01		20.7
1992	23.06		18.41		20.47		24.35		22.01		12.9
1993	40.17		35.27	(2)	37.54	(2)	33.33		36.71		15.5
1994	34.77		--		30.13		30.26		31.98		9.0
1995	33.80		--		33.65		28.66		32.21		8.8
1996	31.31		--		24.32	(2)	26.13	(2)	27.59		4.8
1997	24.18		--		21.90		27.37		24.43		6.3
1998	30.03		--		29.39		27.43	(2)	29.05		5.5
1999	22.08		--		22.31	(2)	27.71		23.84		3.9
2000	23.83		--		20.56		19.91		21.22		1.0
2001	31.00		--		33.56		29.57		31.28		2.8
2002	37.50		--		40.27		44.72		40.57		7.6
2003	22.63		--		21.34		26.77	(2)	23.02		6.5
2004	33.58		--		33.58		31.67		33.10		2.8
2005	32.30	(2)	--		--		41.47		36.89		8.6
2006	20.95		--		--		23.38		22.17		4.2
2007	26.58		--		--		27.82		27.20		3.0
2008	26.19		--		--		25.00		25.58		2.0
2009	28.86		28.06*		--		27.65		28.26		7.6
2010	34.36		36.56*				32.94		33.65		13.1
2011	30.87		33.61*				30.61		30.74		18.8
2012	27.42		27.50				28.50		27.81		5.6
2013	28.30		24.35				28.87		27.17		3.9
2014	29.49		29.70				28.48		29.22		8.1
2015	35.55		32.12				37.61		35.09		6.0
								Mean	29.51		7.9
								Std. Dev.	7.6		5.4

NOTES:

Whole watershed runoff is based on time-weighted average flow at Grass Lake Dam (station CR 10.5), and total drainage area of 155 square miles.

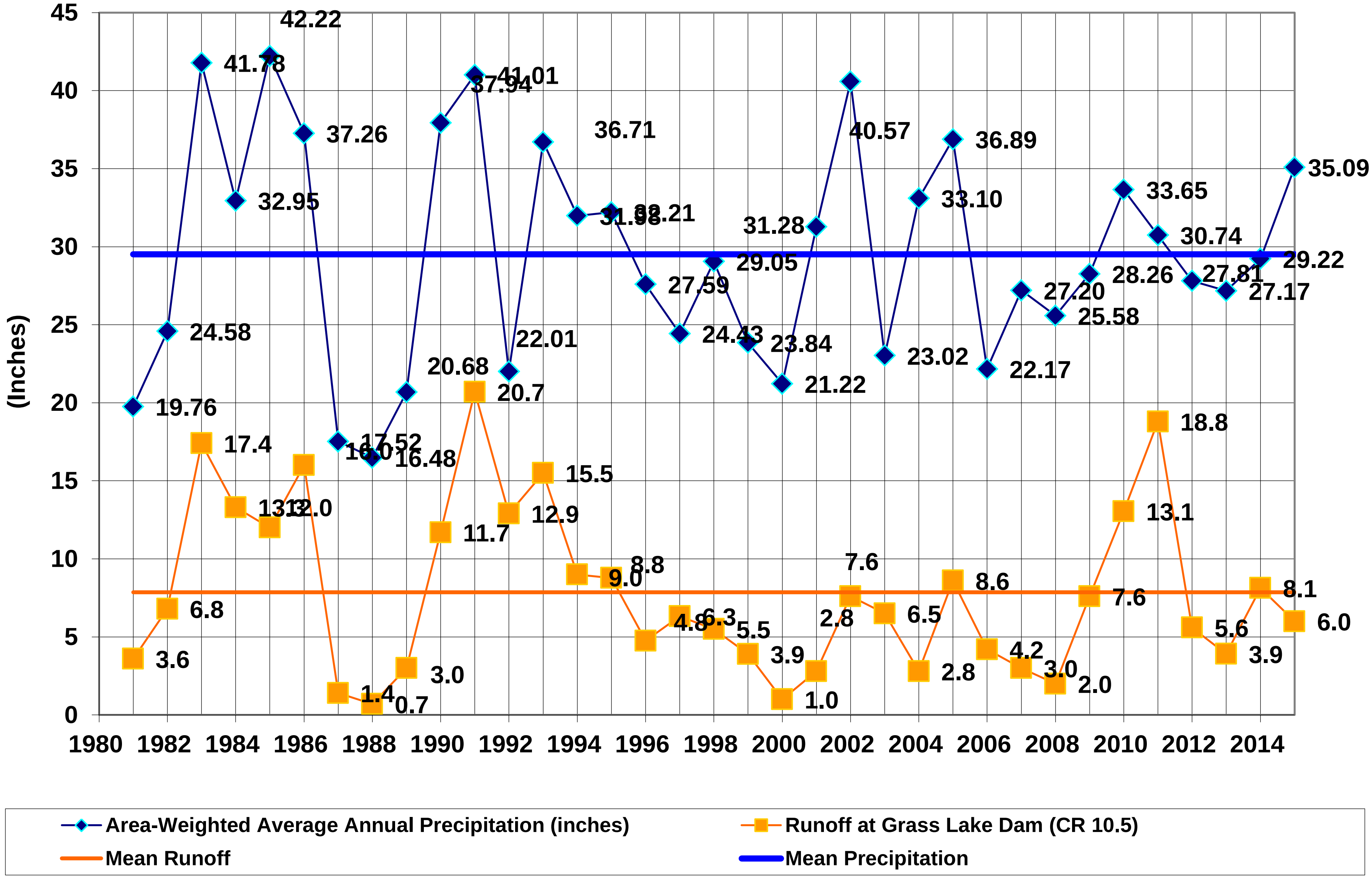
(1) Data for single gauge in east-central part of watershed (Camp Heritage on Lake Caroline).

(2) Average values of other stations in District were used to fill in missing data.

* Value from Kimball Station

V:\Technical\0002\225 2015 Water Quality Monitoring\Water Quality Data Analysis\[Stream_Loads_Historic_15.xls]Prec

Appendix B Figure B- 1
Clearwater River Watershed District
2015 Annual Report



V:\Technical\0002\225 2015 Water Quality Monitoring\Water Quality Data Analysis\Stream_Loads_Historic_15Precip_Runoff_Graph_07

ALBION LAKE

Clearwater River WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 251 acres

Residence Time: 1,752 days

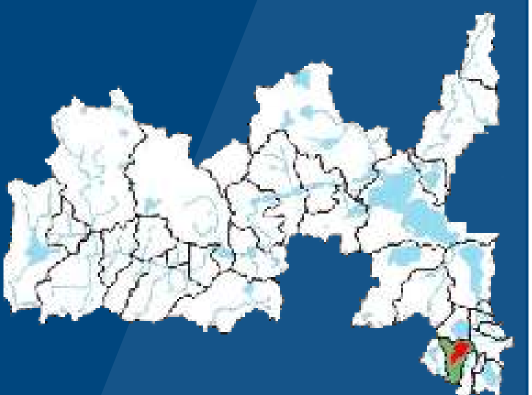
Surface Area: 251 acres

Subwatershed Area: 1,094 acres

Maximum Depth: 9 feet

Upstream Waters: None

Common Fish	Common carp, black bullhead
Dominant Vegetation	Sago pondweed
Invasive Species	Curly-leaf pondweed
Status	Impaired; TMDL Completed 2010



Secchi
2015: 0.4 m
Standard >1.0 m

Chl-a
2015: 49 ug/L
Standard <20 ug/L

Management Strategy
Restore:
By reducing internal load through ecosystem restoration

TP
2015: 121 ug/L
Standard <60 ug/L

Key Issues
- **Internal load**
- **Watershed load**
- **Rough fish**

STATUS
(Impaired)

TO DO LIST

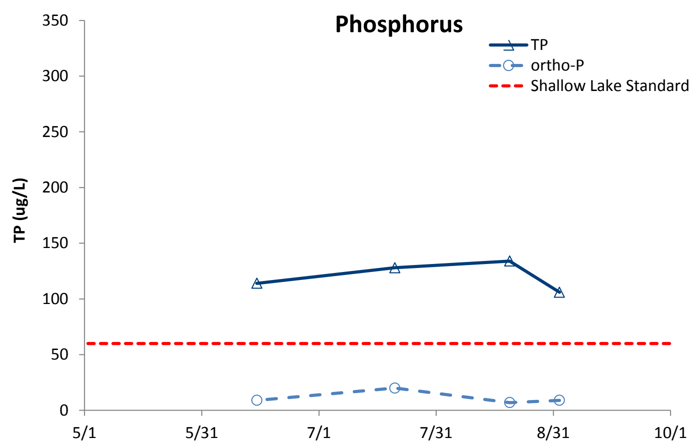
- Rough fish management
- Curly-leaf pondweed management

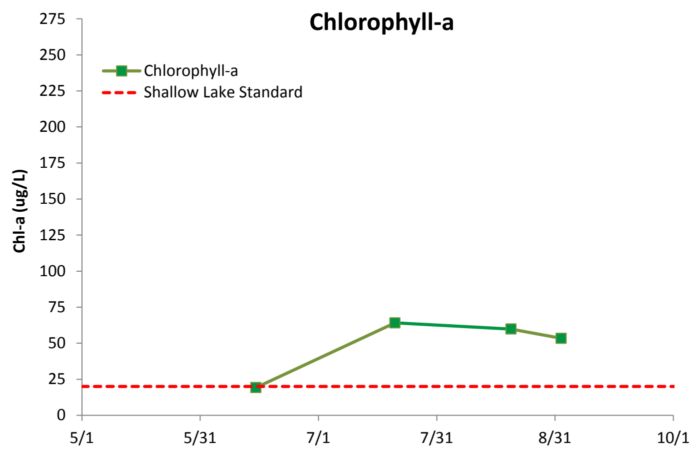
Prepared By: WENCK ASSOCIATES

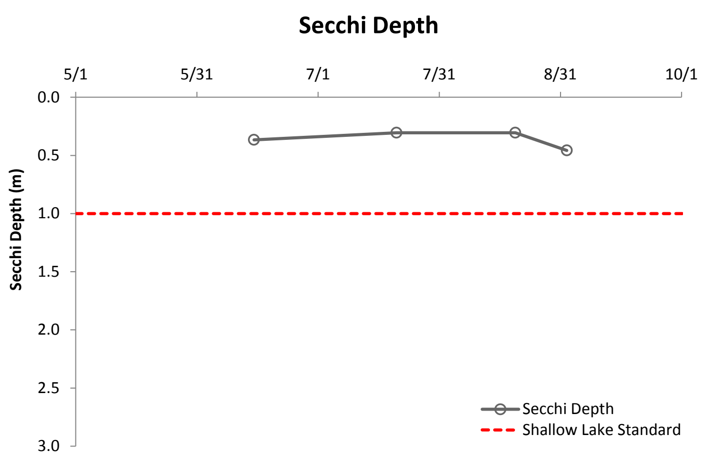
ALBION LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

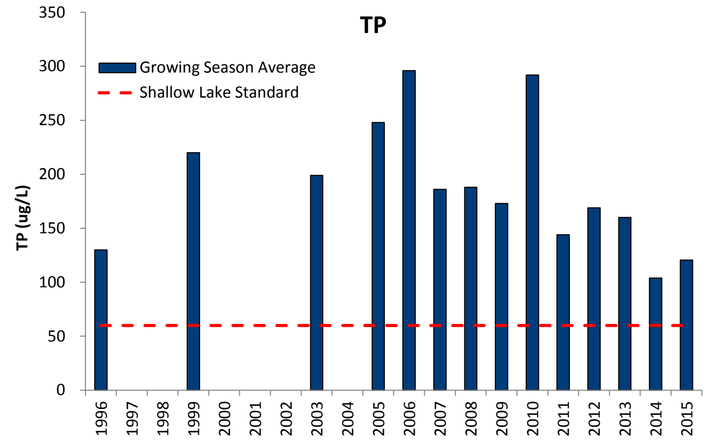
2015 Water Quality

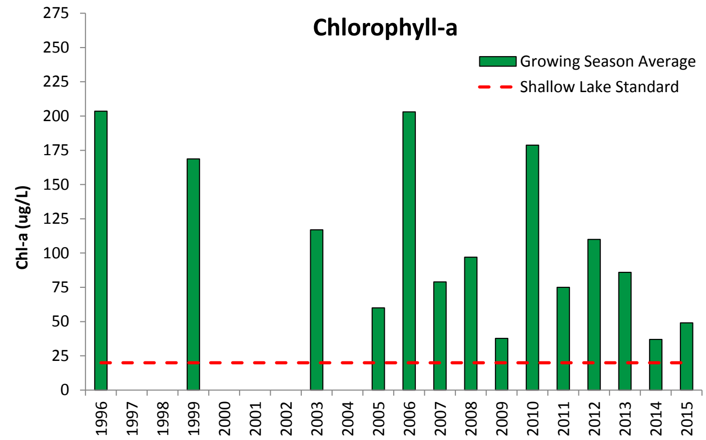


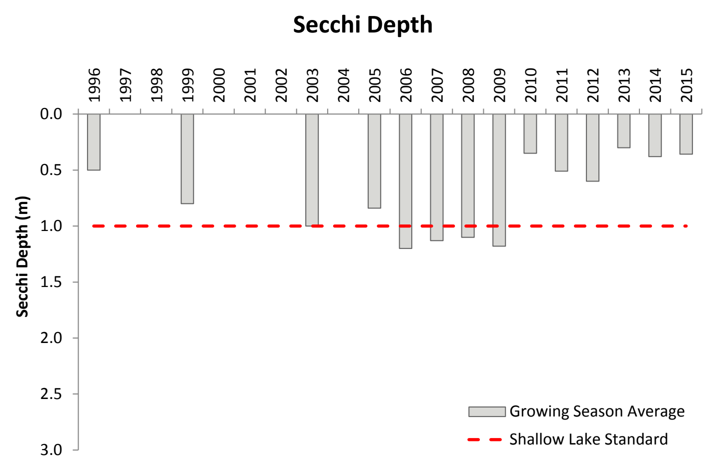




Historic Water Quality







Prepared By: WENCK ASSOCIATES

CEDAR LAKE

QUICK FACTS

Littoral Area: 315 acres

Surface Area: 790acres

Subwatershed Area: 9,715 acres

Maximum Depth: 108 feet

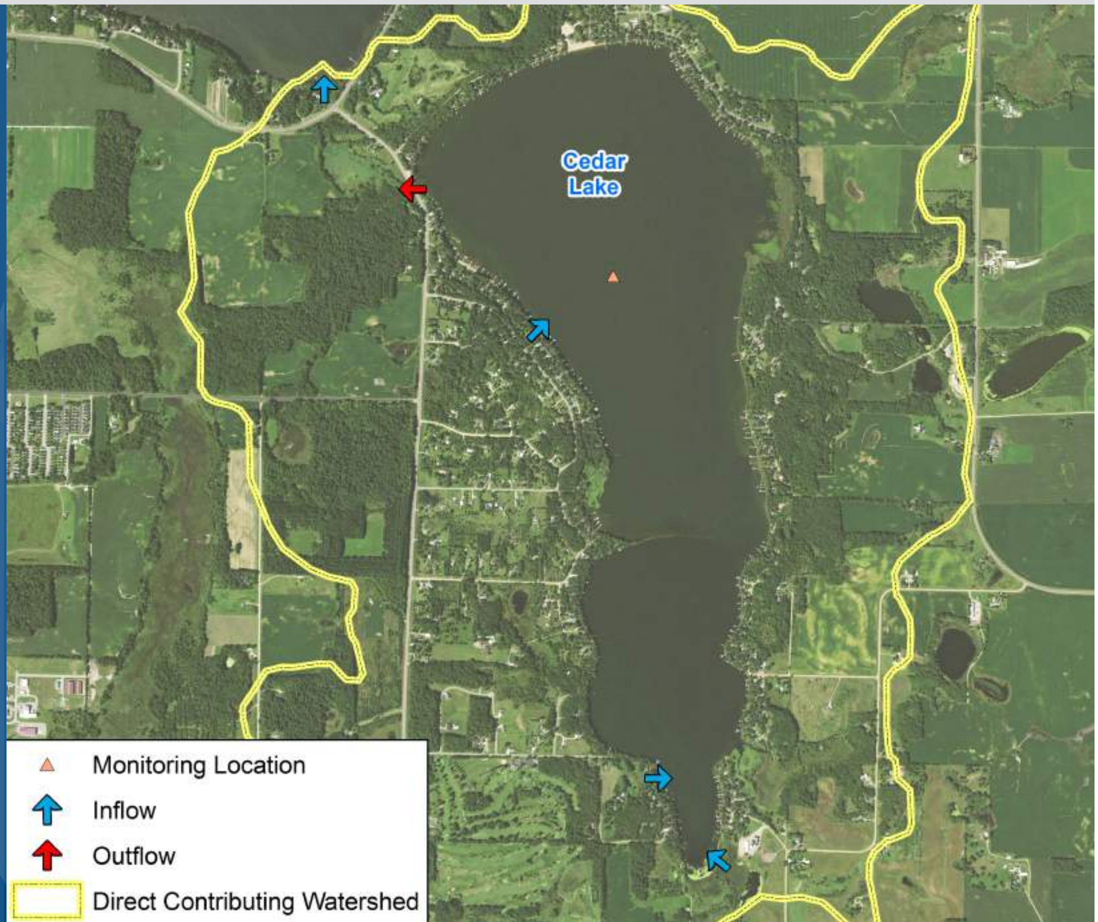
Upstream Waters: Swartout, Albion, Henshaw

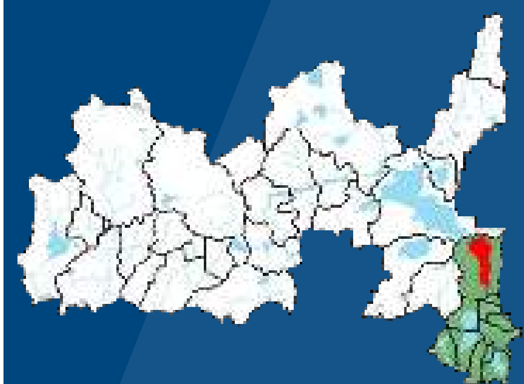
Common Fish: Bluegill, Northern Pike, Walleye, Largemouth Bass

Dominant Vegetation: Coontail, northern water milfoil, chara

Invasive Species: Eurasian water milfoil, curly-leaf pondweed

Status: Not Impaired





TO DO LIST

- Manage curly-leaf pondweed
- Rough fish management in upstream lakes
- Internal load management study
- Manage soluble P loads from watershed

Secchi
2015: 3.2 m
Standard >1.4 m

Chl-a
2015: 5 ug/L
Standard <14 ug/L

Management Strategy
Protect:
By managing watershed loads from upstream shallow lakes

TP
2015: 21 ug/L
Standard <40 ug/L

Key Issues
▲ Upstream lakes
▲ Watershed load

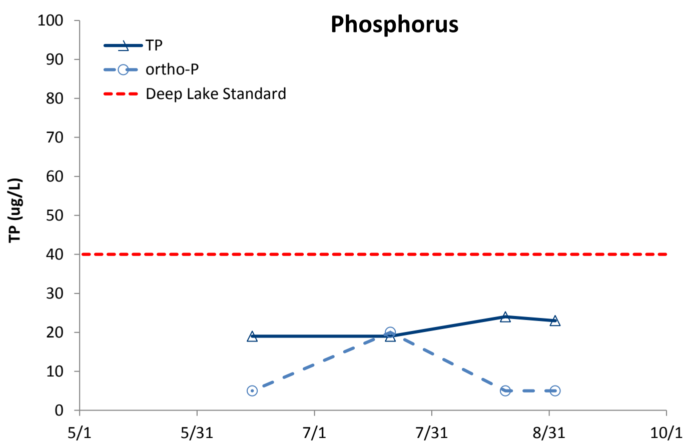
STATUS
(Meeting goals)

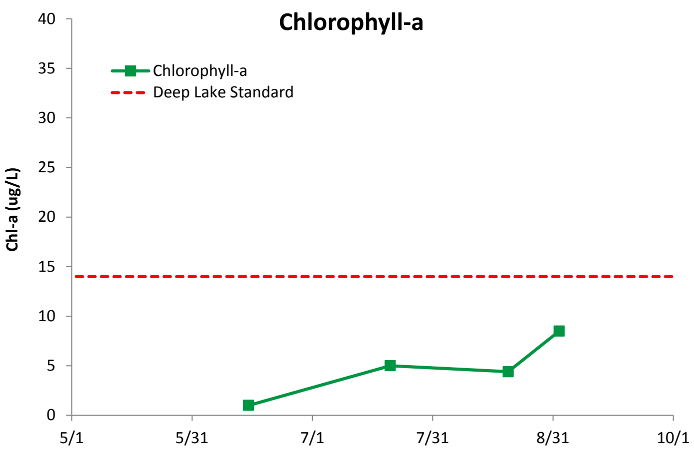
Prepared By: WENCK ASSOCIATES

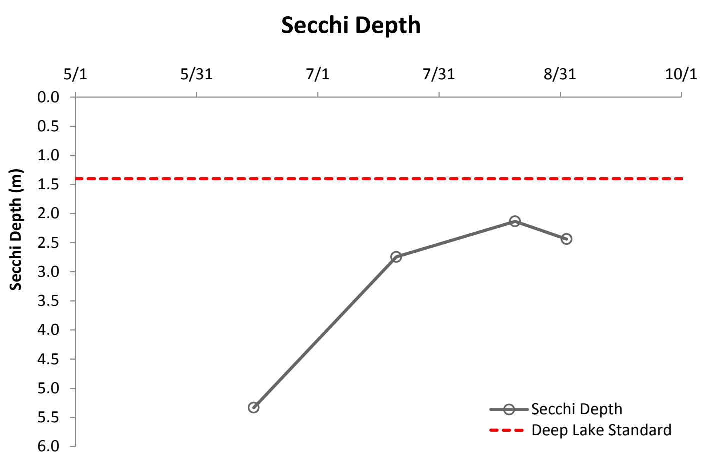
CEDAR LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

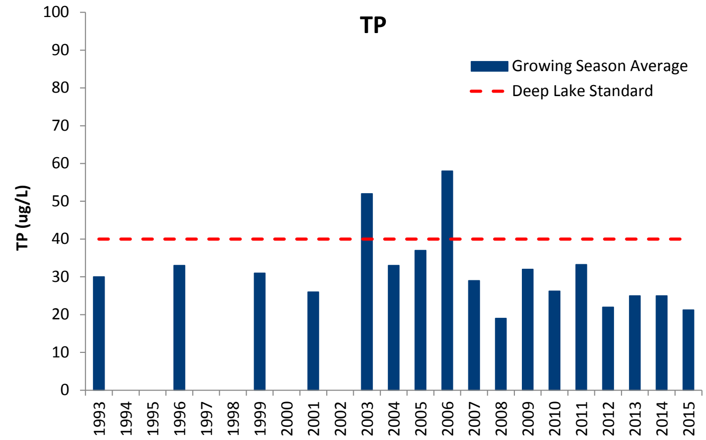
2015 Water Quality

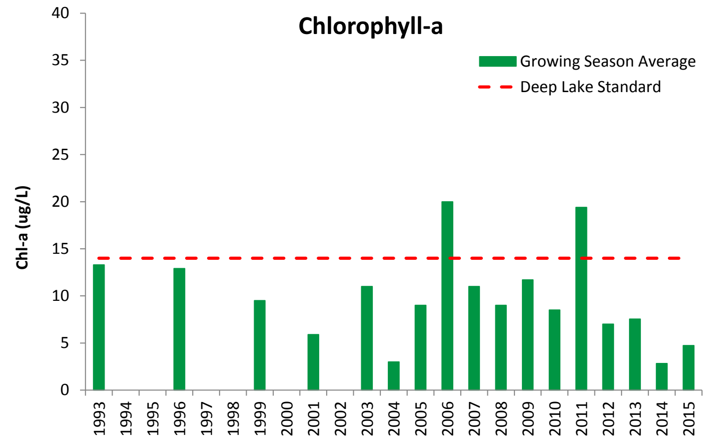


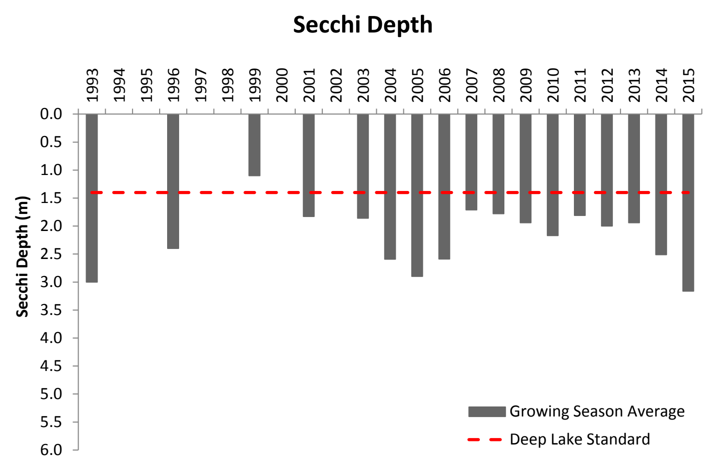




Historic Water Quality







Prepared By: WENCK ASSOCIATES

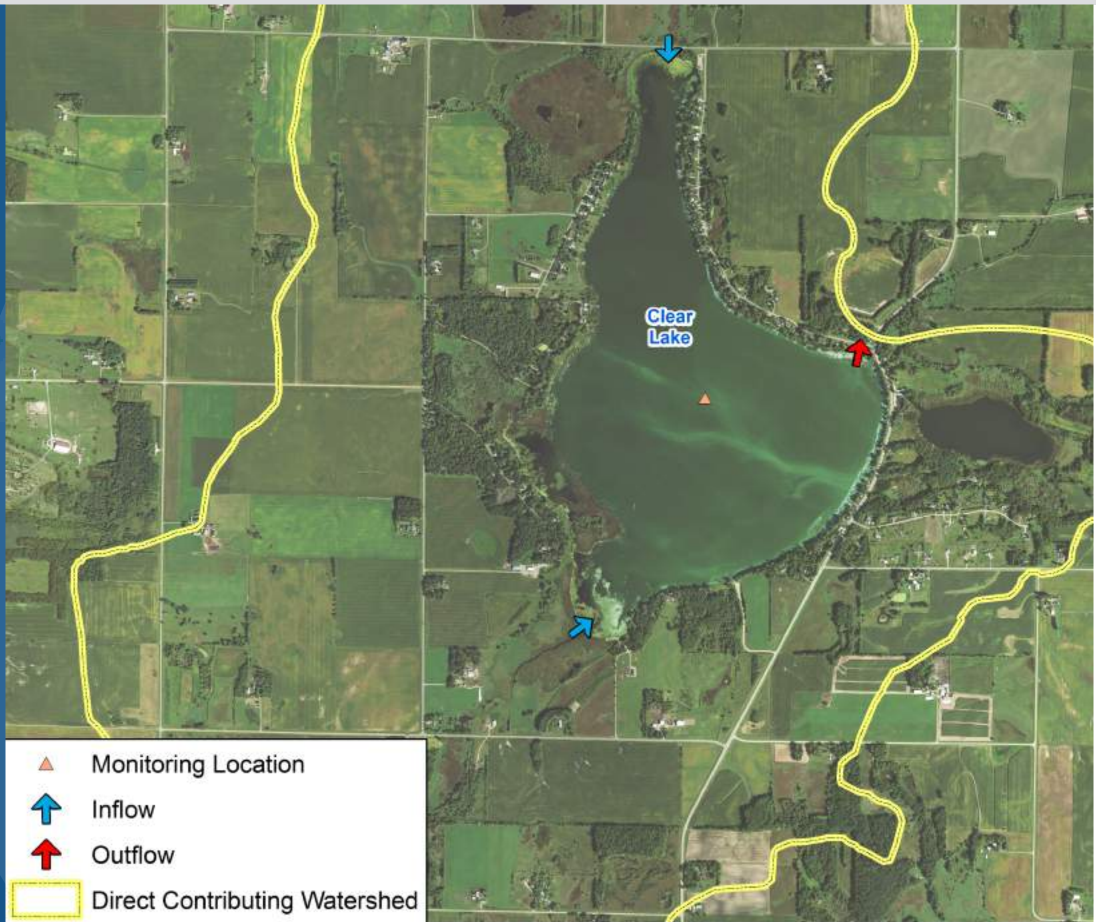
CLEAR LAKE

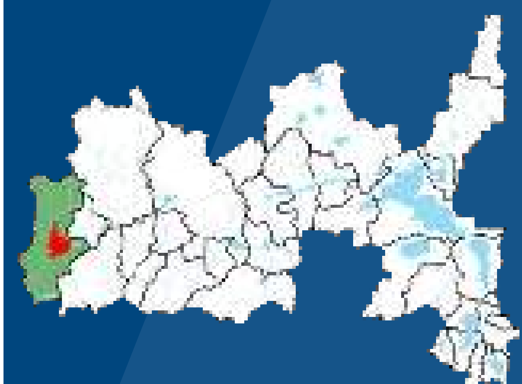
Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

- **Littoral Area**: 441 acres
- **Residence Time**: 686 days
- **Surface Area**: 529 acres
- **Subwatershed Area**: 6,801 acres
- **Maximum Depth**: 18 feet
- **Upstream Waters**: None

Common Fish	Northern Pike, Black Crappie, Walleye, Bluegill
Dominant Vegetation	No Recent Survey
Invasive Species	Eurasian water milfoil, Curly-leaf pondweed
Status	Impaired, TMDL completed in 2009





TO DO LIST

- Manage curly-leaf pondweed
- Manage rough fish
- Manage soluble P loads from watershed

Secchi
2015: 1.8 m
Standard >1.0 m

Chl-a
2015: 20 ug/L
Standard <20 ug/L

Management Strategy
Restore:
By reducing internal load through ecosystem restoration

TP
2015: 98 ug/L
Standard <60 ug/L

Key Issues
- **Internal load**
- **Watershed load**

STATUS
(Impaired)

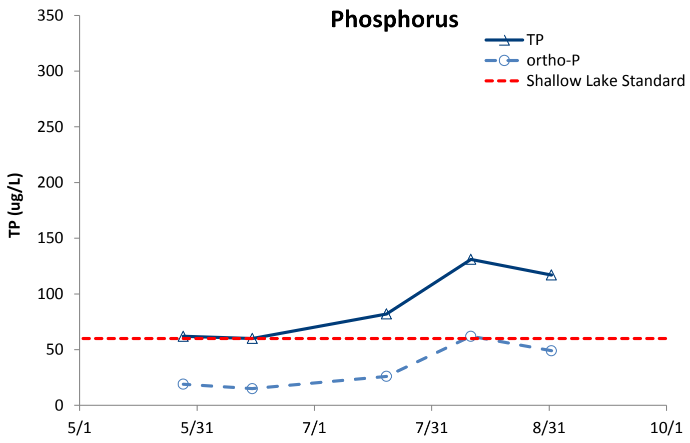
Prepared By: WENCK ASSOCIATES

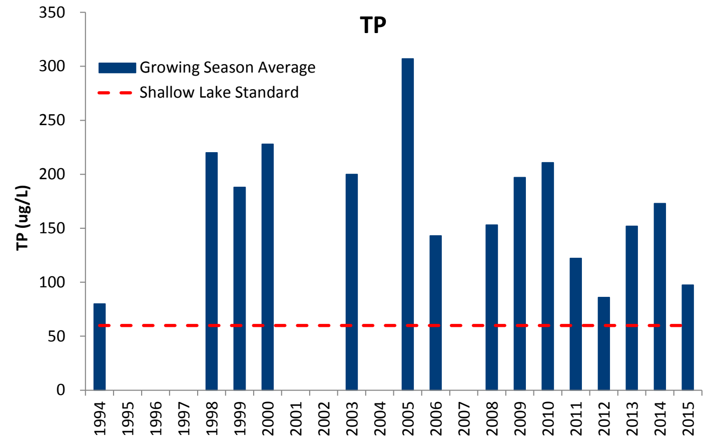
CLEAR LAKE

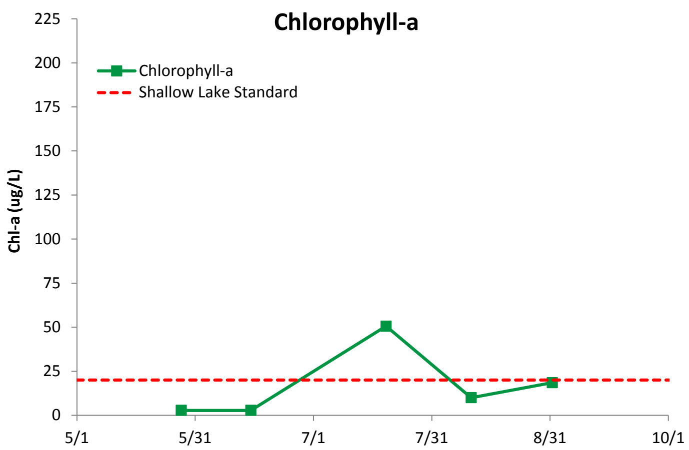
Clearwater River WATERSHED DISTRICT Promote | Protect | Preserve

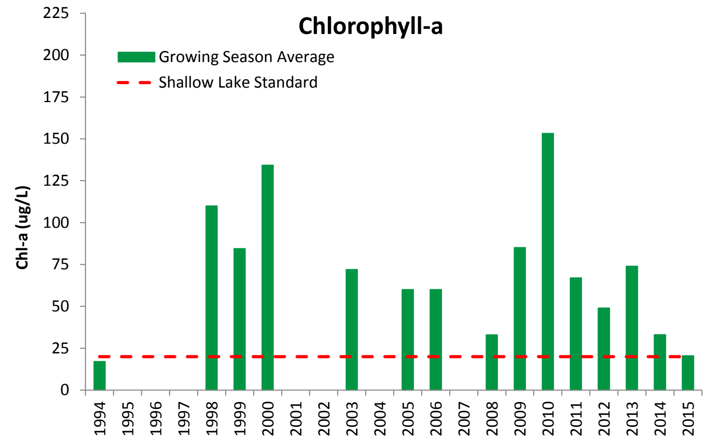
2015 Water Quality

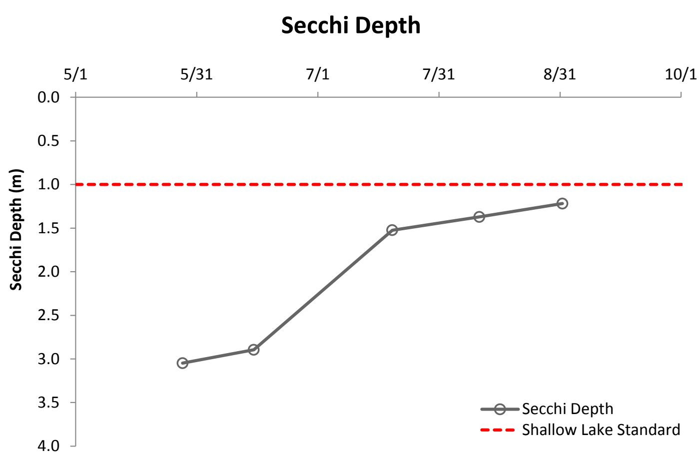
Historic Water Quality

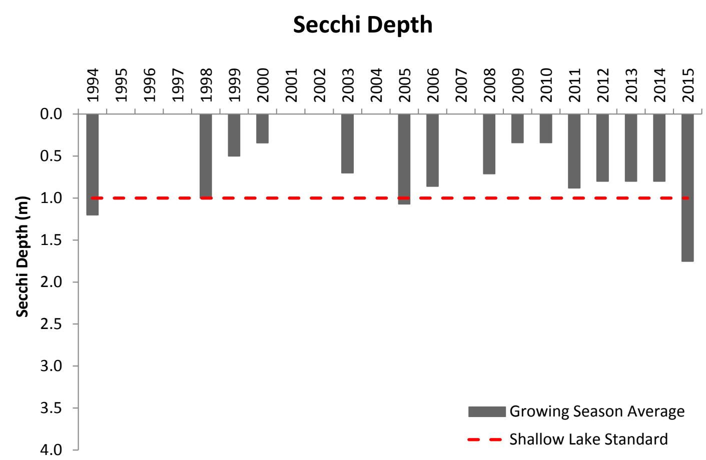












Prepared By: WENCK ASSOCIATES

CLEARWATER LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 1,596 acres

Surface Area: 3,158 acres

Subwatershed Area: 100,232 acres

Maximum Depth: 73 feet

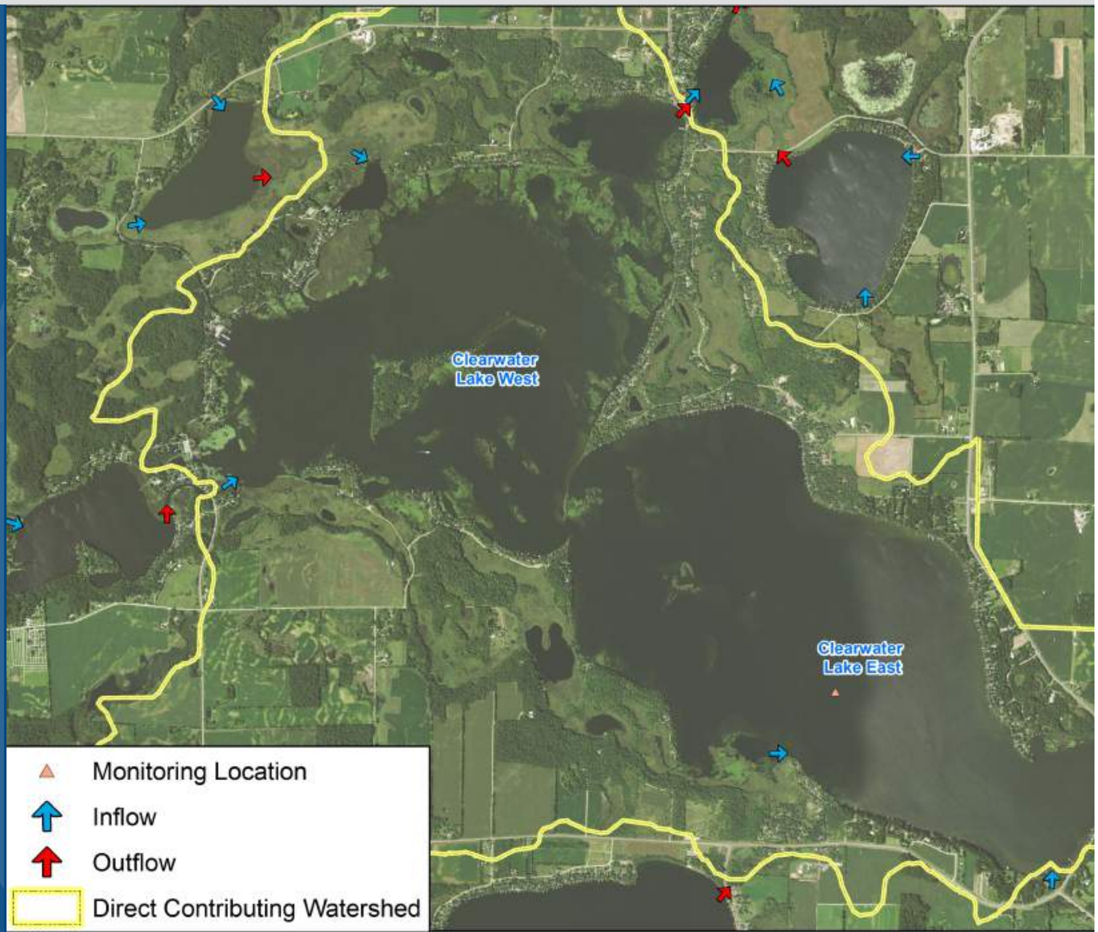
Upstream Waters: Clearwater River, Augusta, Cedar, Otter, and Pleasant Lake

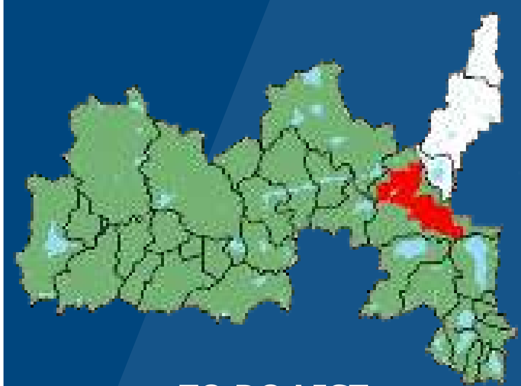
Common Fish: Bluegill, Northern Pike, Walleye, Largemouth Bass, Yellow Bullhead

Dominant Vegetation: No Recent Survey

Invasive Species: Eurasian water milfoil, curly-leaf pondweed, zebra mussels

Status: Not Impaired





TO DO LIST

- Protect
- Manage upstream loads
- AIS management

Secchi
2015: 2.8 m
Standard >1.4 m

Chl-a
2015: 3 ug/L
Standard <14 ug/L

Management Strategy
Protect:
Continue to implement upper watershed management

TP
2015: 18 ug/L
Standard <40 ug/L

Key Issues
- **Upstream lakes**
- **Watershed load**

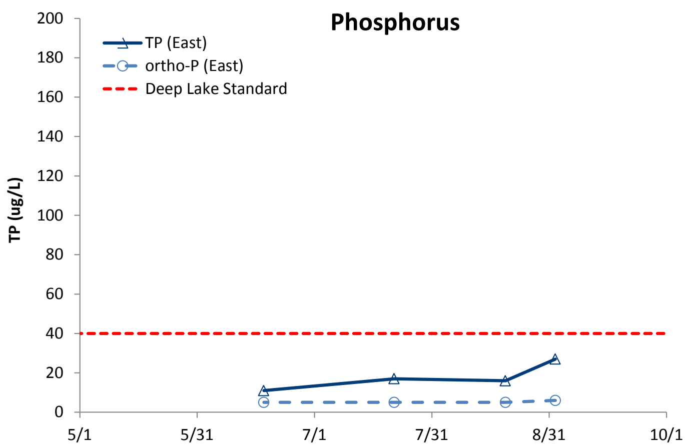
STATUS
(Meeting goals)

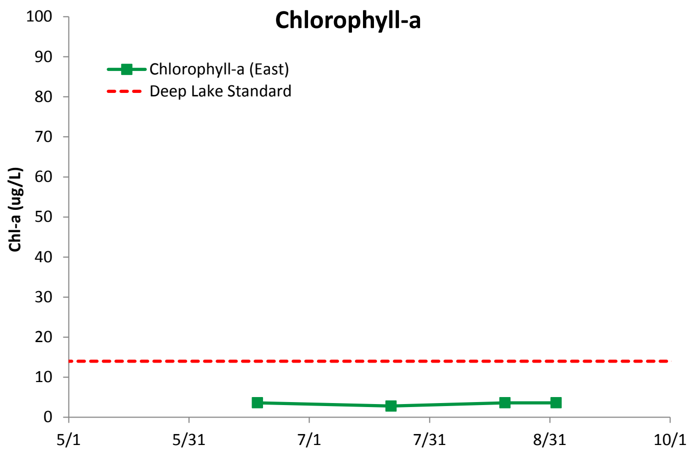
Prepared By: WENCK ASSOCIATES

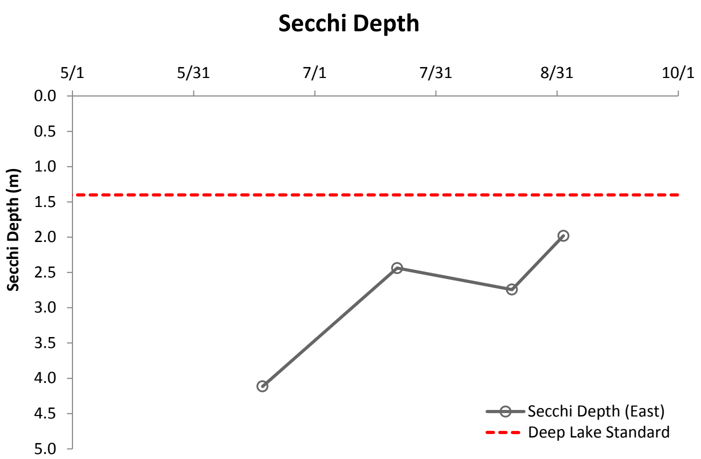
CLEARWATER LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

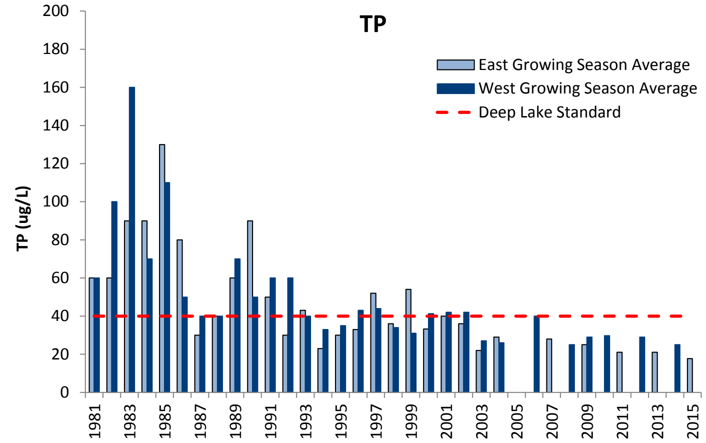
2015 Water Quality

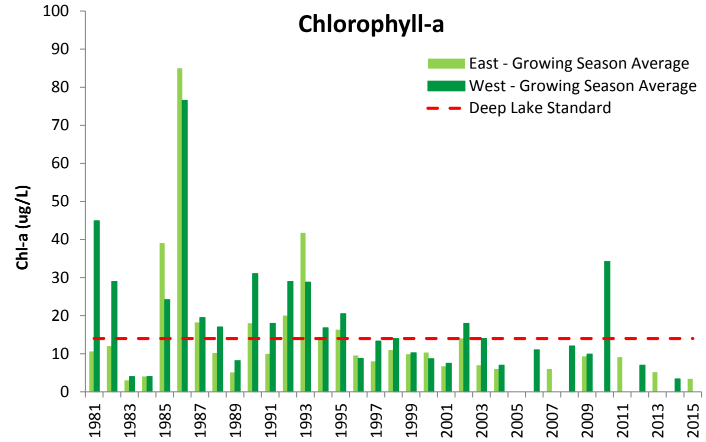


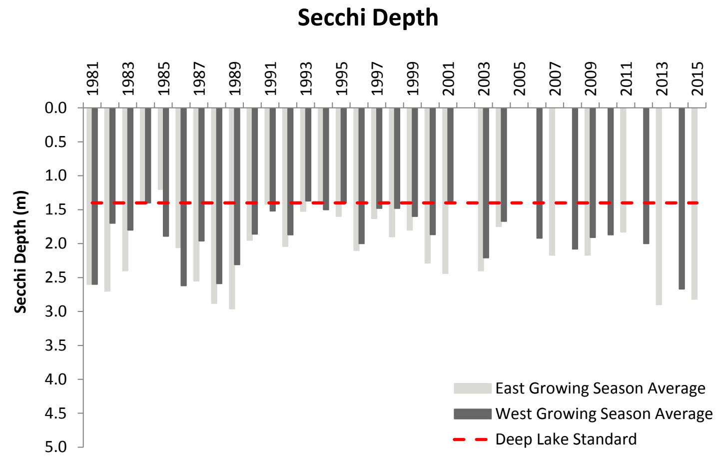




Historic Water Quality







Prepared By: WENCK ASSOCIATES

GRASS LAKE

QUICK FACTS

Littoral Area: 62 acres

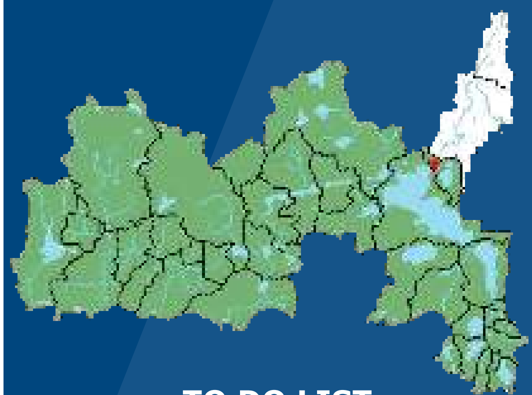
Surface Area: 71 acres

Subwatershed Area: 101,508 acres

Maximum Depth: 35 feet

Upstream Waters: None

Common Fish	Bluegill, Northern Pike, Yellow Bullhead
Dominant Vegetation	No Recent Survey
Invasive Species	Unknown
Status	Not Impaired



TO DO LIST

- Protect
- Manage upstream loads

Secchi

2015: 2.8 m
Standard >1.4 m

Chl-a

2015: 3 ug/L
Standard <14 ug/L

Management Strategy

Protect:
Continue to implement upper watershed management

TP

2015: 20 ug/L
Standard <40 ug/L

Key Issues

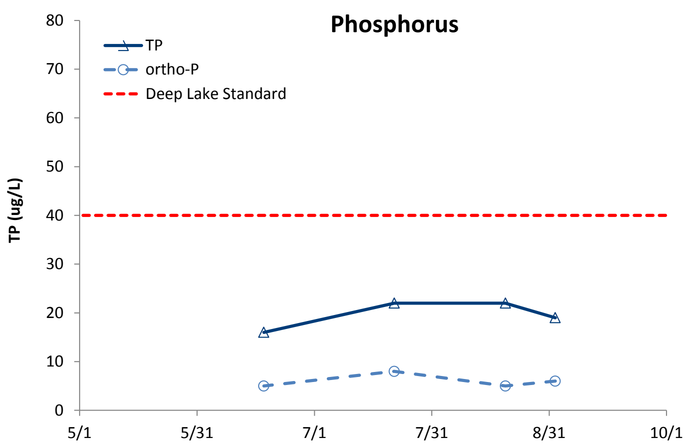
▲ Watershed load

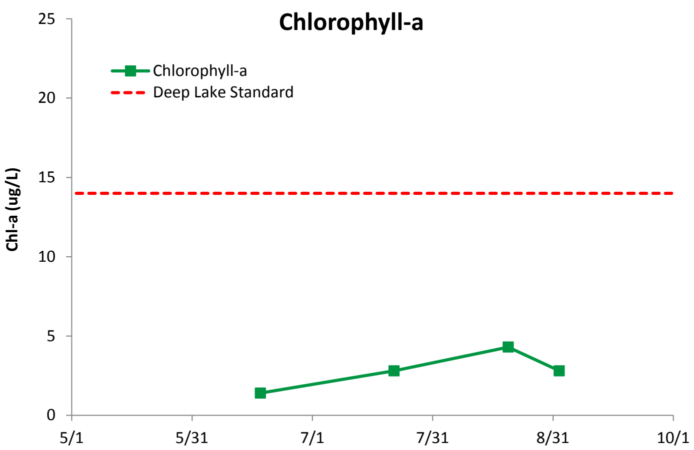
STATUS
(Meeting goals)

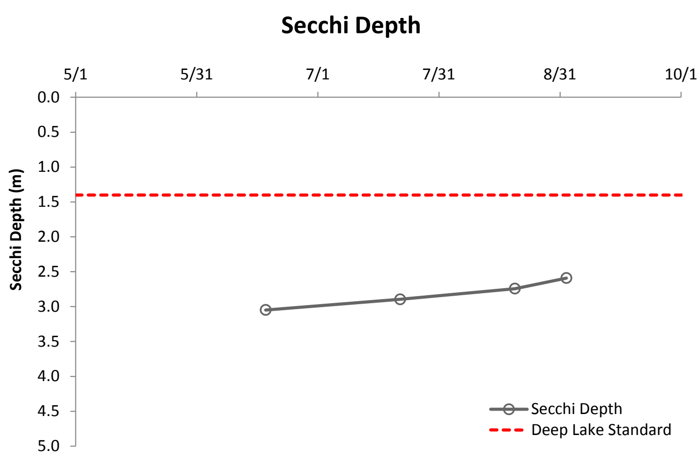
Prepared By: WENCK ASSOCIATES

GRASS LAKE

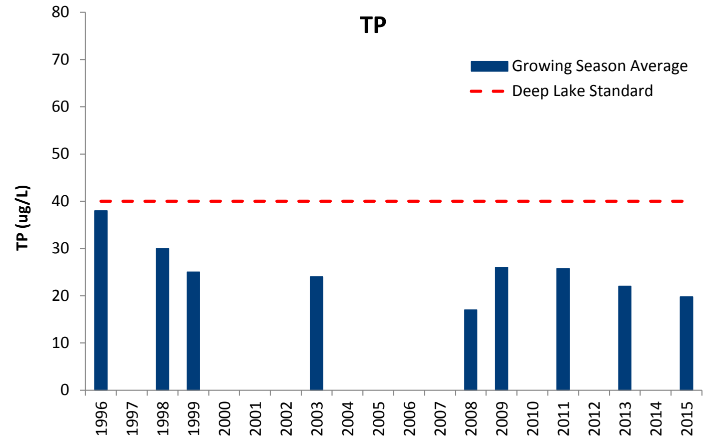
2015 Water Quality

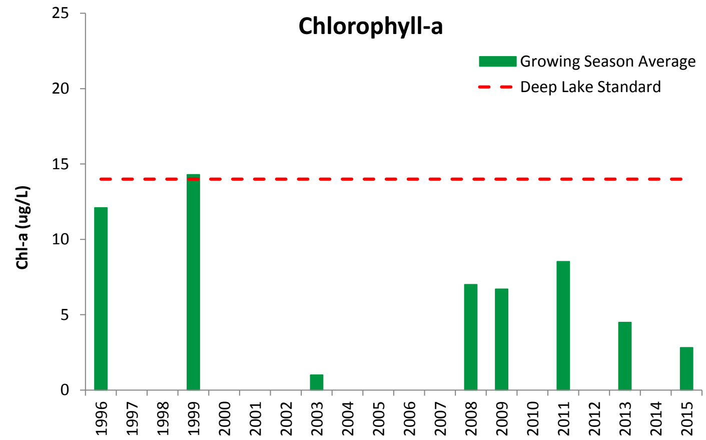


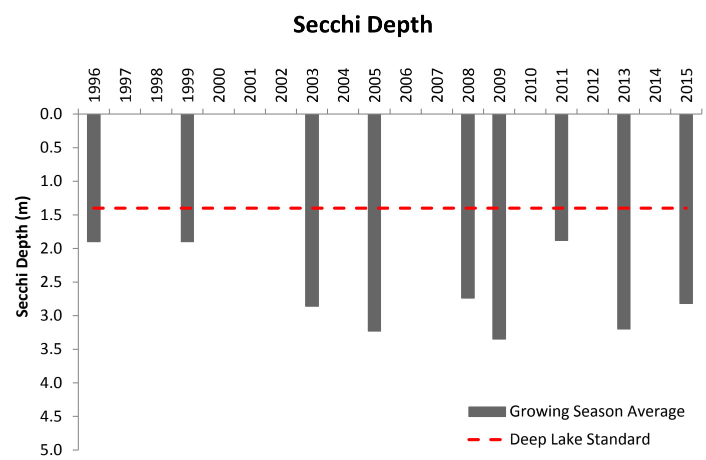




Historic Water Quality







Prepared By:

HENSHAW LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 271 acres

Residence Time: 1,697 days

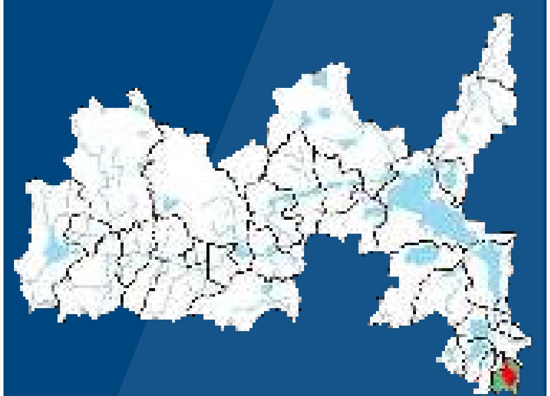
Surface Area: 903 acres

Subwatershed Area: 903 acres

Maximum Depth: 8 feet

Upstream Waters: None

Common Fish	Black Bullhead, Common Carp
Dominant Vegetation	Sago pondweed, Coontail, Bushy pondweed
Invasive Species	Curly-leaf pondweed
Status	Impaired, TMDL Completed 2010



TO DO LIST

- Rough fish management
- Curly-leaf pondweed management

Secchi

2015: not monitored*
Standard >1.0 m

Chl-a

2015: not monitored*
Standard <20 ug/L

Management Strategy

Monitor:
Continue to reduce internal load through ecosystem

TP

2015: 140 ug/L
Standard <60 ug/L

STATUS
(Impaired)

Key Issues

- **Rough fish**
- **Internal load**
- **Watershed load**

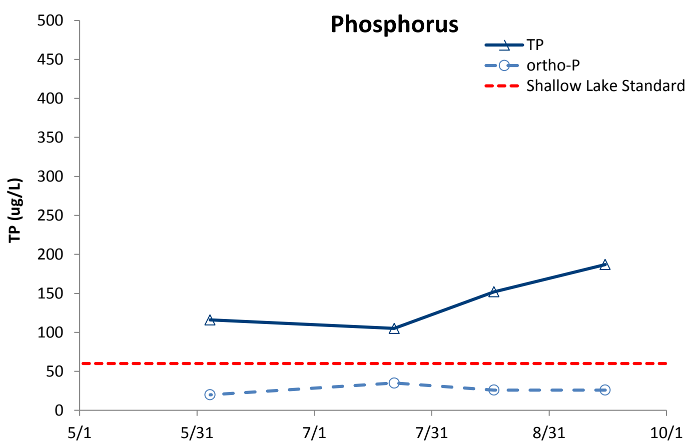
* too much vegetative growth on lake hindered access to conduct sampling

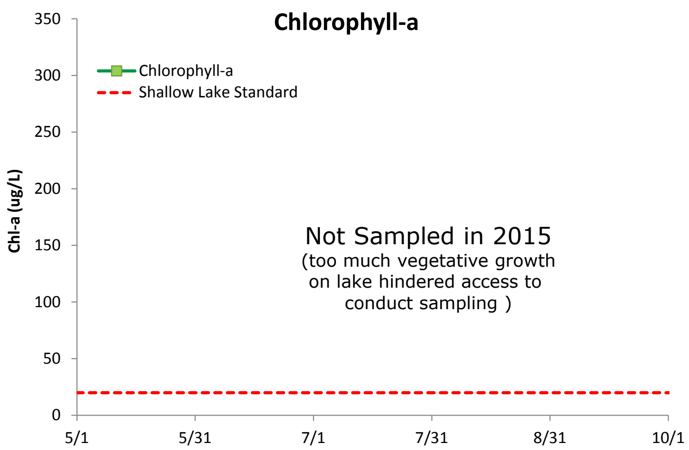
Prepared By: WENCK ASSOCIATES

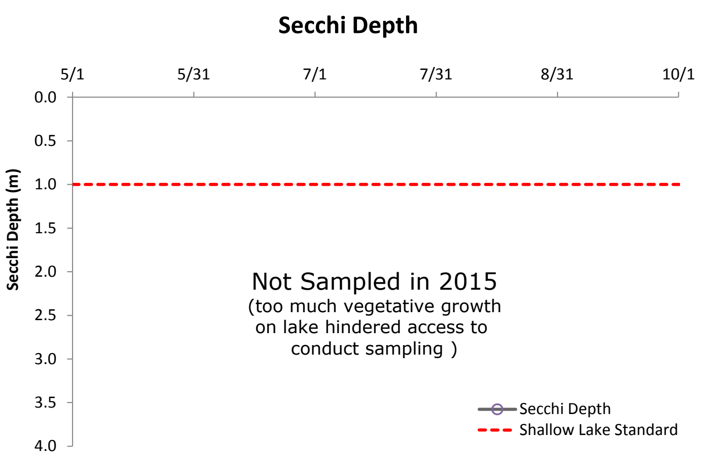
HENSHAW LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

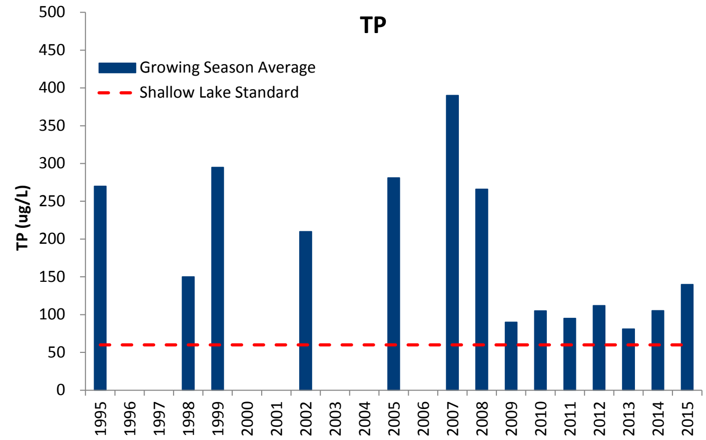
2015 Water Quality

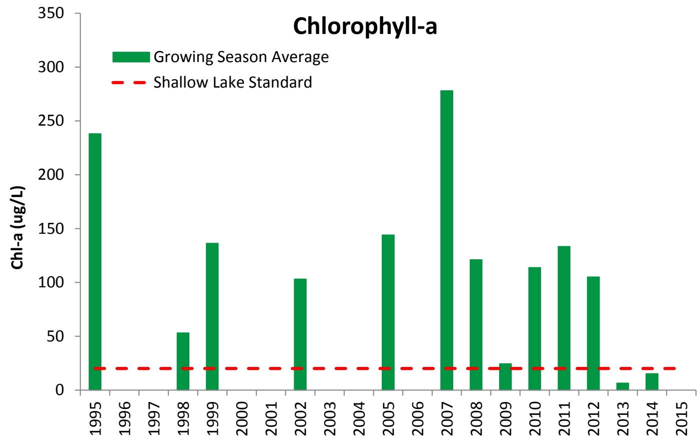


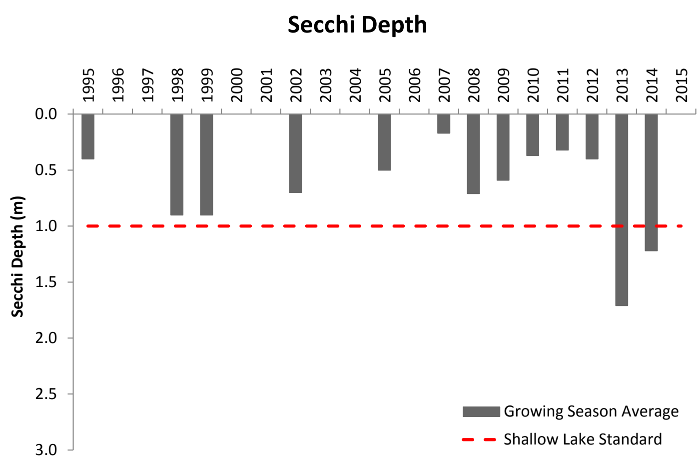




Historic Water Quality







Prepared By:
WENCK
ASSOCIATES

LAKE AUGUSTA

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 65 acres

Residence Time: 55 days

Surface Area: 187 acres

Subwatershed Area: 62,936 acres

Maximum Depth: 82 feet

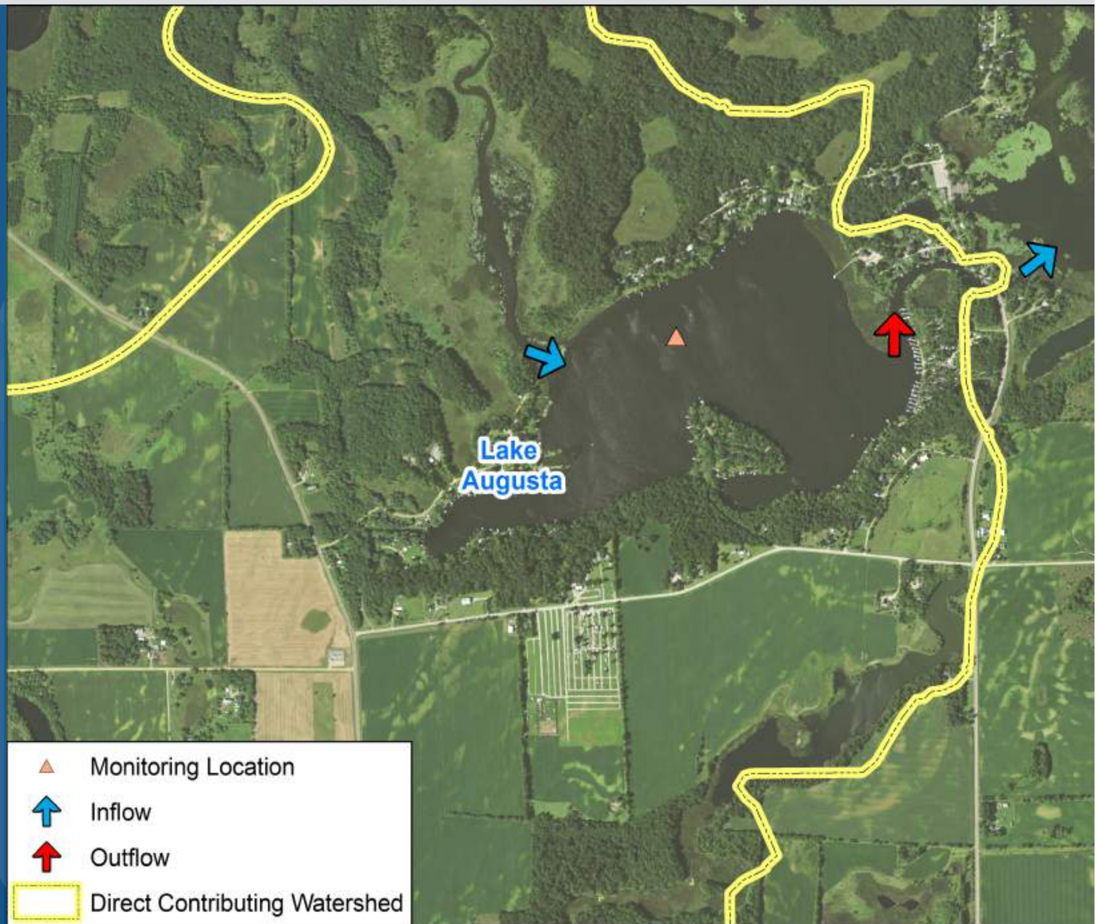
Upstream Waters: Caroline, Louisa, Marie

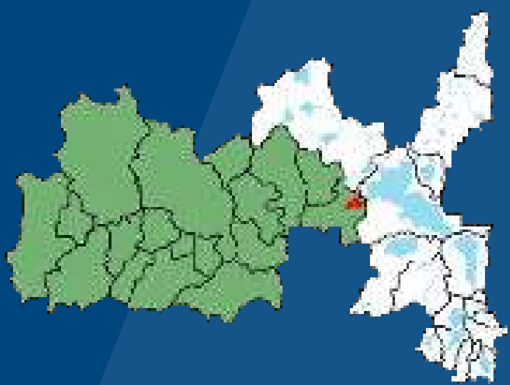
Common Fish: Bluegill, Northern Pike, Crappie, Yellow Bullhead, Common Carp

Dominant Vegetation: No Recent Survey

Invasive Species: Eurasian water milfoil, curly-leaf pondweed

Status: Impaired, TMDL completed in 2010





TO DO LIST

- Manage upstream loads
- AIS management

Secchi
2015: 2.3 m
Standard >1.4 m

Chl-a
2015: 12 ug/L
Standard <14 ug/L

Management Strategy
Protect:
Continue to implement upper watershed management

TP
2015: 46 ug/L
Standard <40 ug/L

Key Issues
- Upstream lakes
- Internal load
- Watershed load

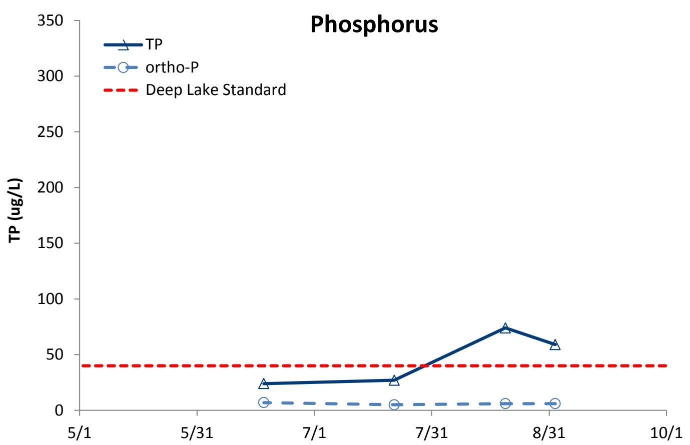
STATUS
(Meeting goals)

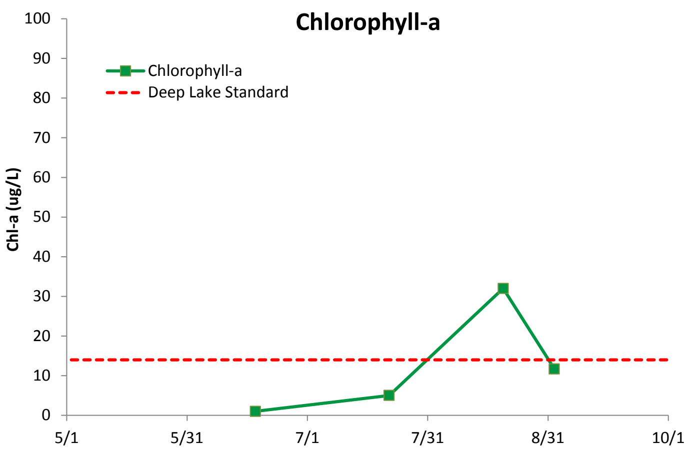
Prepared By: WENCK ASSOCIATES

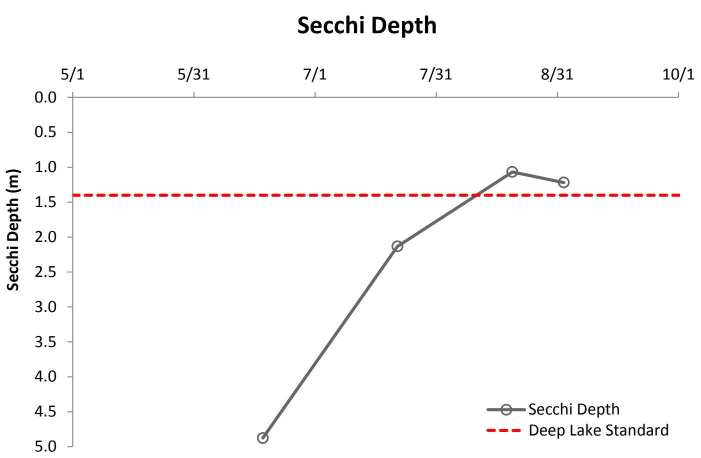
LAKE AUGUSTA

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

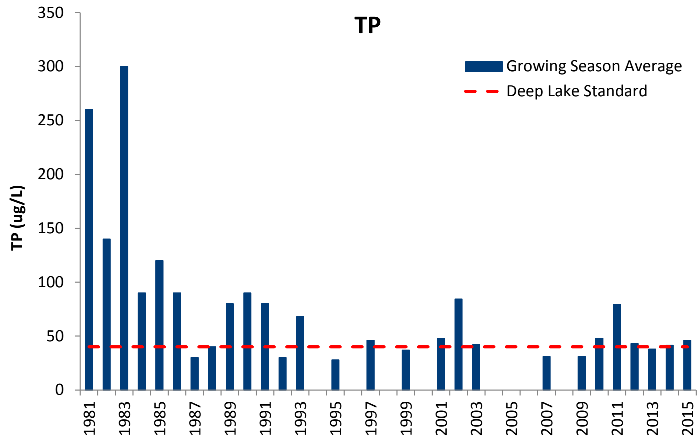
2015 Water Quality

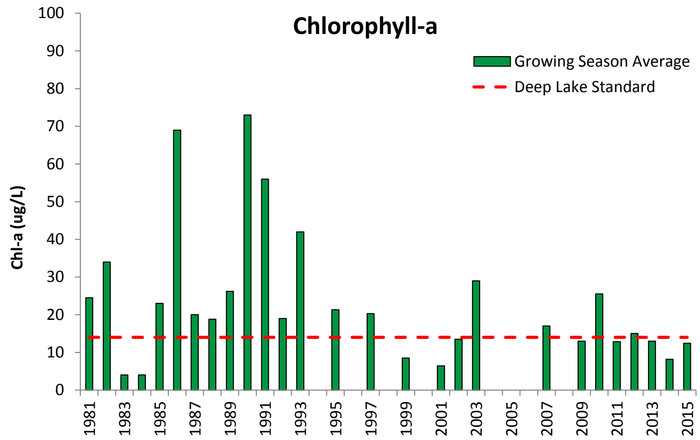


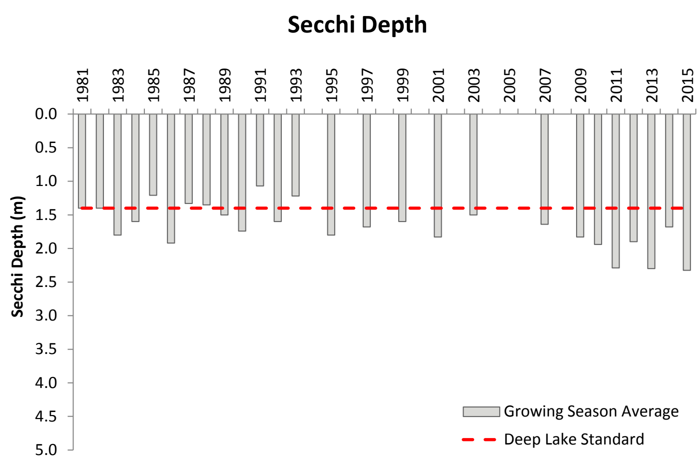




Historic Water Quality







Prepared By: WENCK ASSOCIATES

LAKE BETSY

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 90 acres

Residence Time: 33 days

Surface Area: 154 acres

Subwatershed Area: 43,789 acres

Maximum Depth: 29 feet

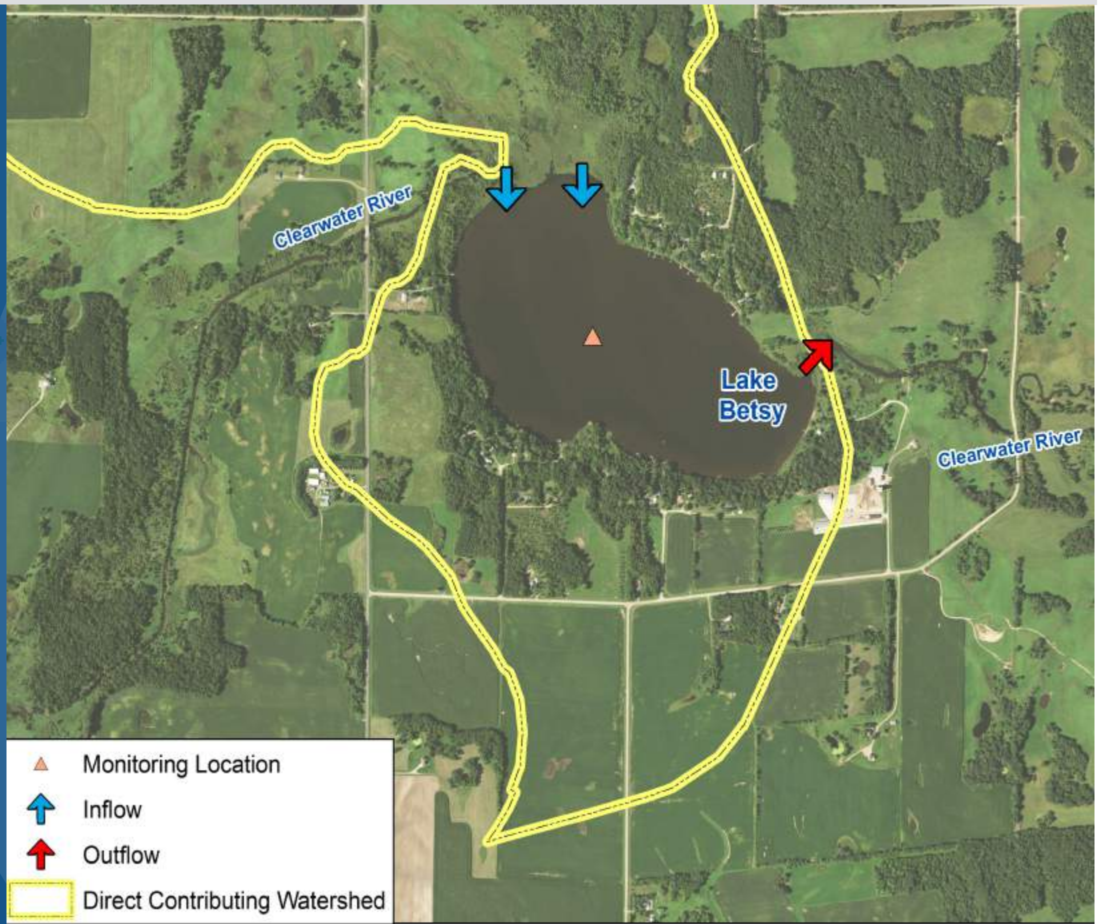
Upstream Waters: Clearwater River

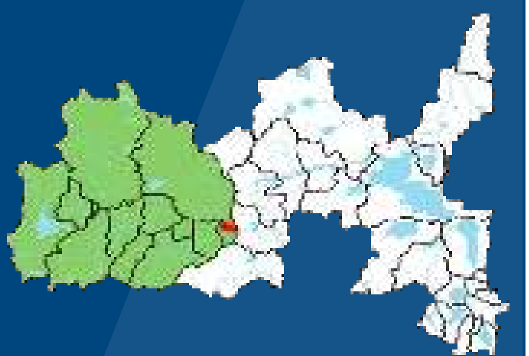
Common Fish: Channel Catfish, Northern Pike, Black Crappie, Bluegill, Common Carp

Dominant Vegetation: Coontail, Curly-leaf pondweed

Invasive Species: Curly-leaf pondweed

Status: Impaired, TMDL completed in 2009





TO DO LIST

- Rough fish management
- Internal load reduction study and implementation
- Upstream projects

Secchi

2015: 2.1 m
Standard >1.4 m

Chl-a

2015: 14 ug/L
Standard <14 ug/L

Management Strategy

Monitor:
Continue to evaluate and implement watershed and internal load management strategies

TP

2015: 158 ug/L
Standard <40 ug/L

Key Issues

- **Watershed load**
- **Internal load**
- **Upstream lakes**

STATUS
(Impaired)

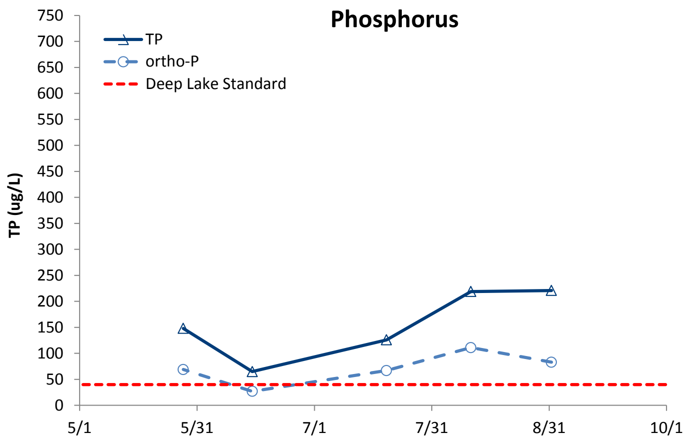
Prepared By: WENCK ASSOCIATES

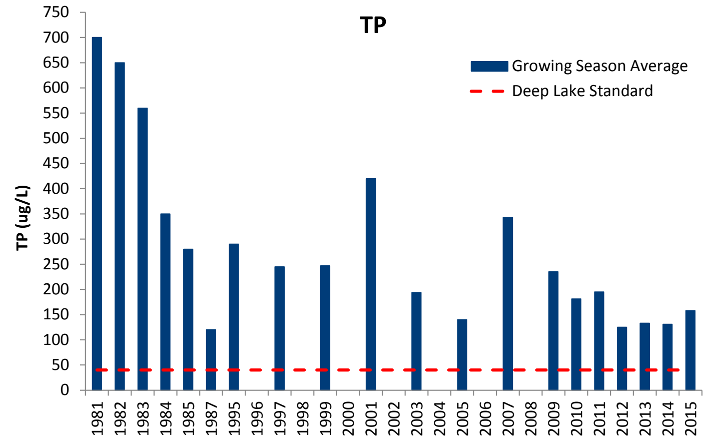
LAKE BETSY

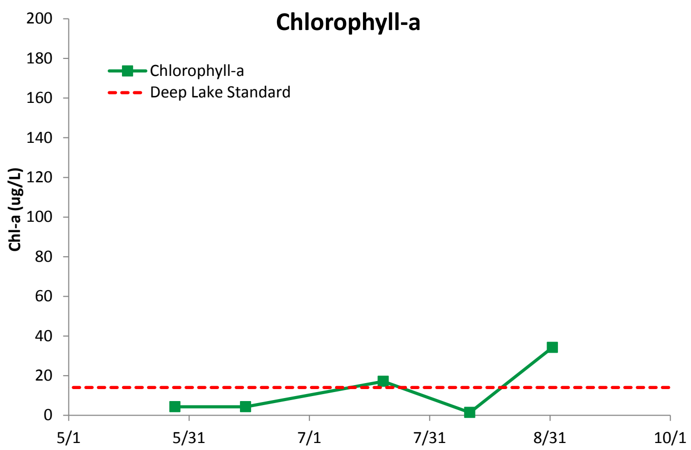
Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

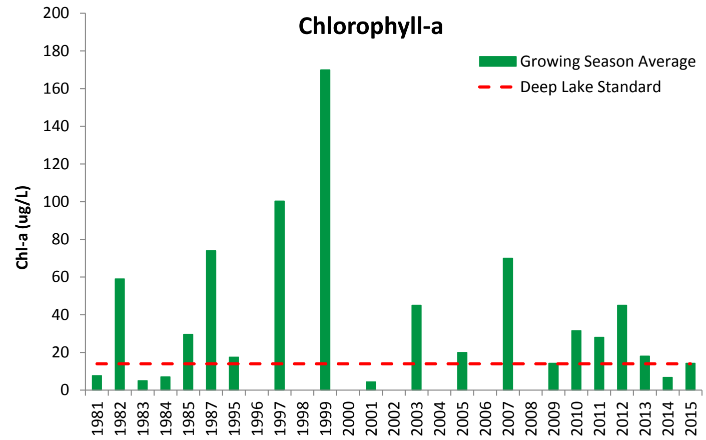
2015 Water Quality

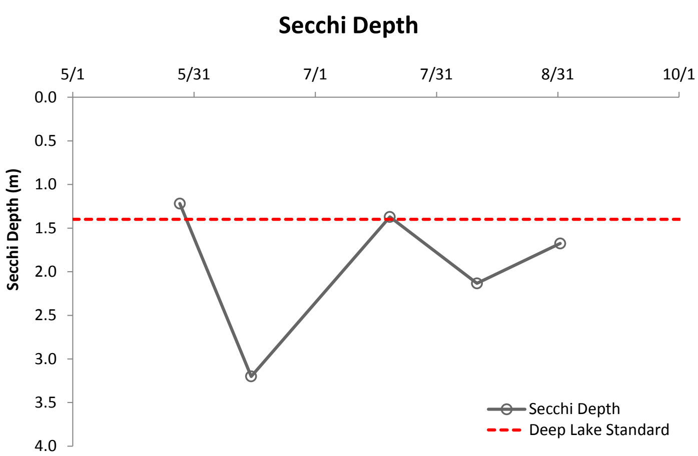
Historic Water Quality

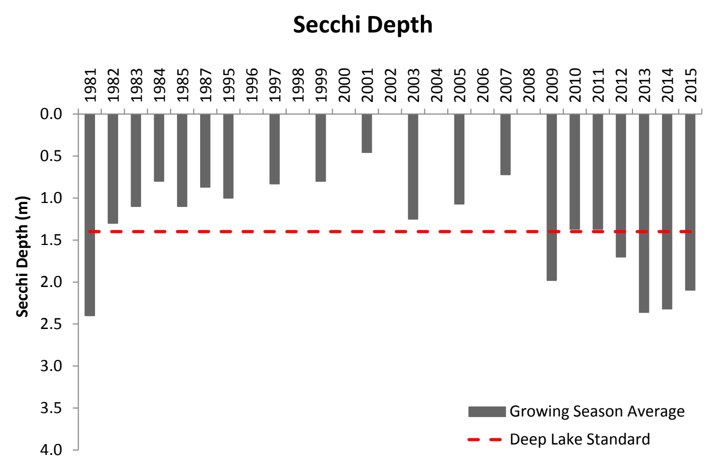












Prepared By: WENCK ASSOCIATES

LAKE CAROLINE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 46 acres

Residence Time: 26 days

Surface Area: 135 acres

Subwatershed Area: 60,132 acres

Maximum Depth: 45 feet

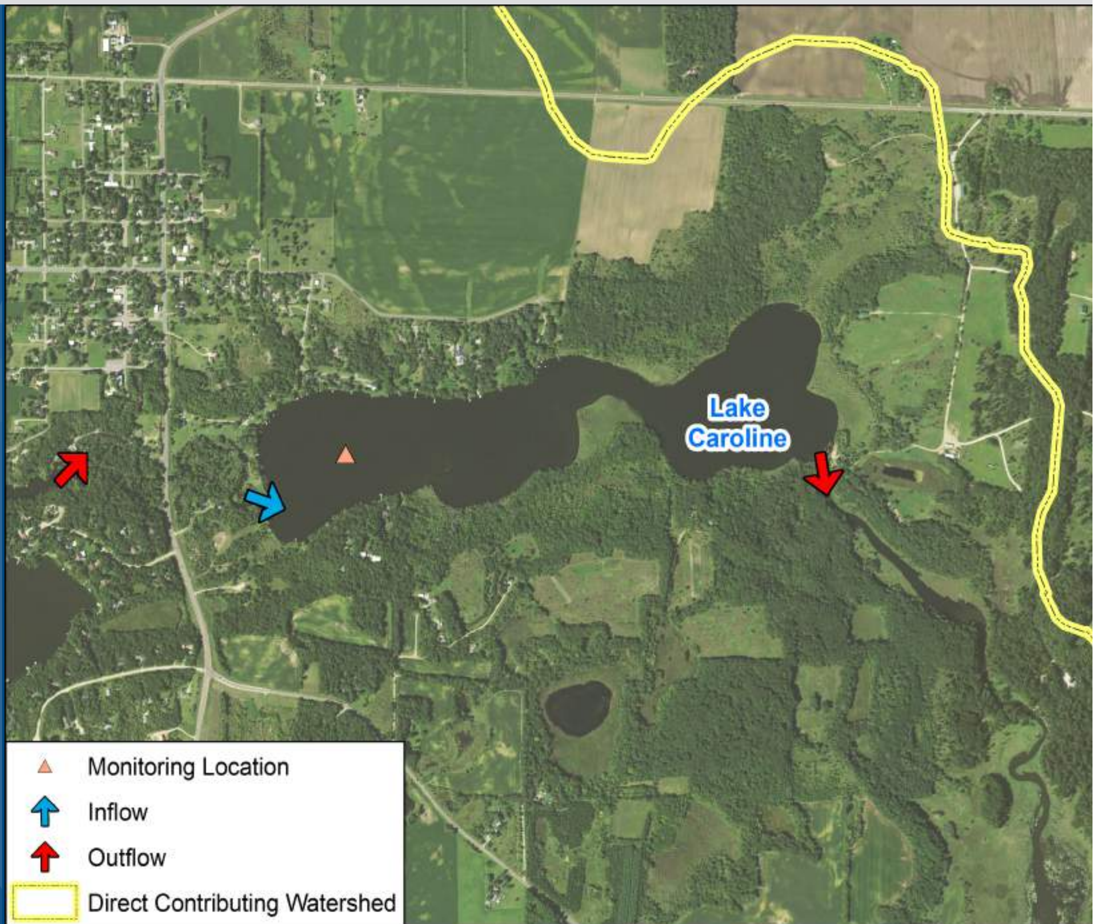
Upstream Waters: Louisa, Marie

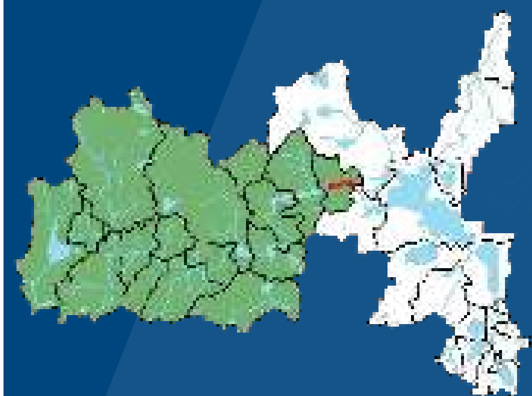
Common Fish: Black Crappie, Bluegill, Northern Pike, Largemouth Bass, Common Carp, Walleye, White Sucker

Dominant Vegetation: No Recent Survey

Invasive Species: Curly-leaf pondweed

Status: Impaired, TMDL completed in 2010





TO DO LIST

- Manage upstream loads
- AIS management

Secchi

2015: 1.6 m
Standard >1.4m

Chl-a

2015: 14 ug/L
Standard <14 ug/L

Management Strategy

Monitor:
Continue to implement upper watershed management

TP

2015: 80 ug/L
Standard <40 ug/L

Key Issues

- **Upstream lakes**
- **Internal load**
- **Watershed load**

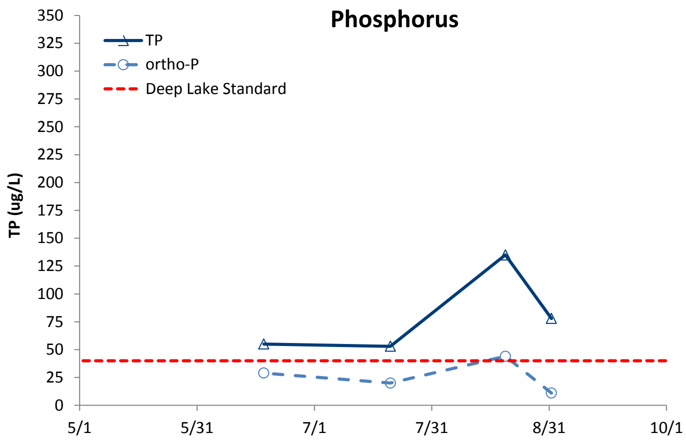
STATUS
(Impaired)

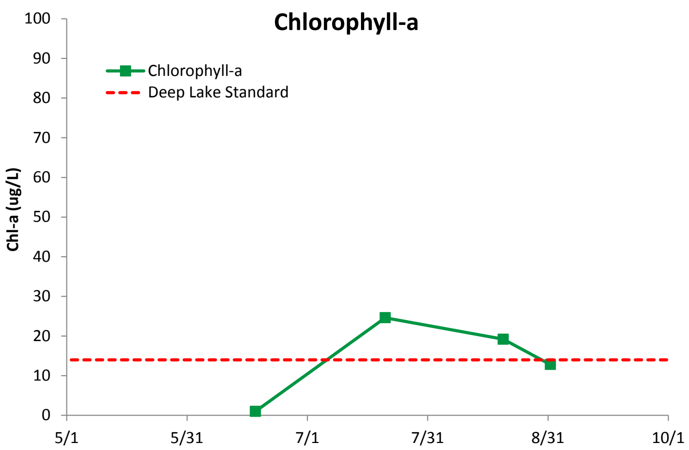
Prepared By: WENCK ASSOCIATES

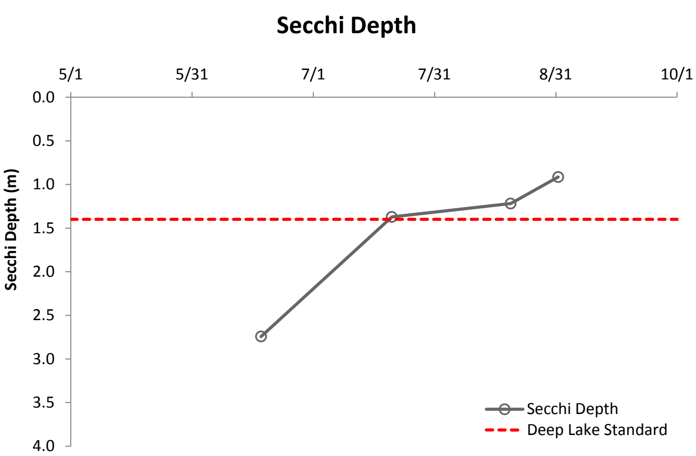
LAKE CAROLINE

Clearwater River WATERSHED DISTRICT
Promote | Protect | Preserve

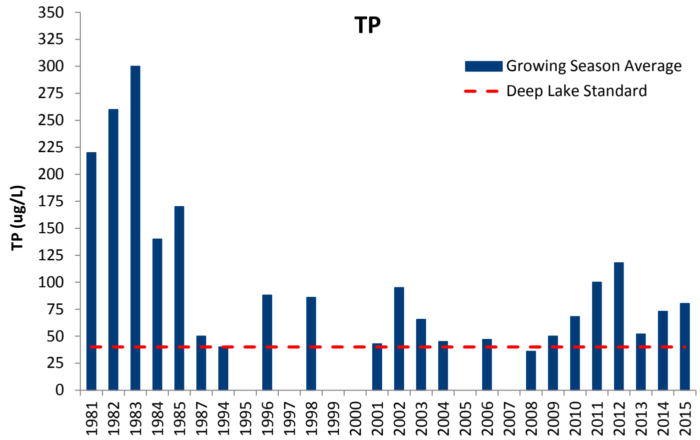
2015 Water Quality

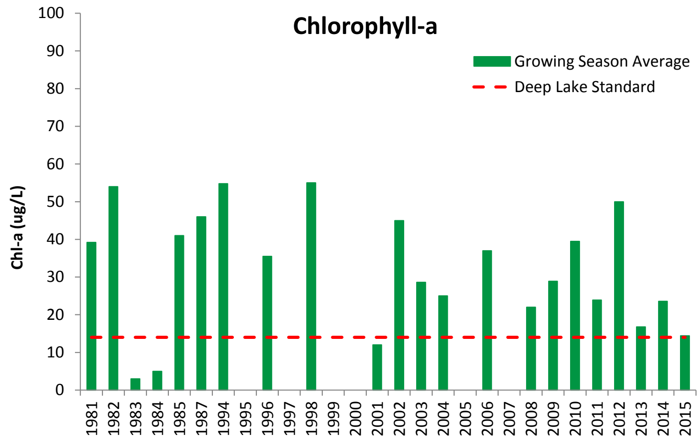


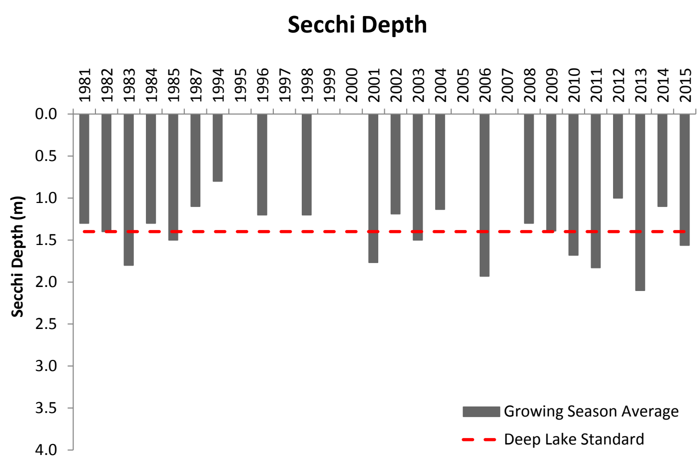




Historic Water Quality







Prepared By: WENCK ASSOCIATES

LAKE LOUISA

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 122 acres

Residence Time: 17 days

Surface Area: 189 acres

Subwatershed Area: 58,881 acres

Maximum Depth: 44 feet

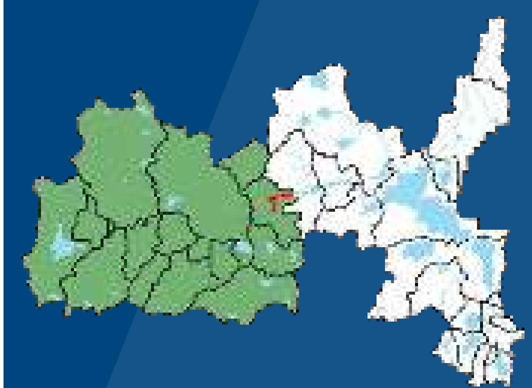
Upstream Waters: Clearwater River, Lake Betsy

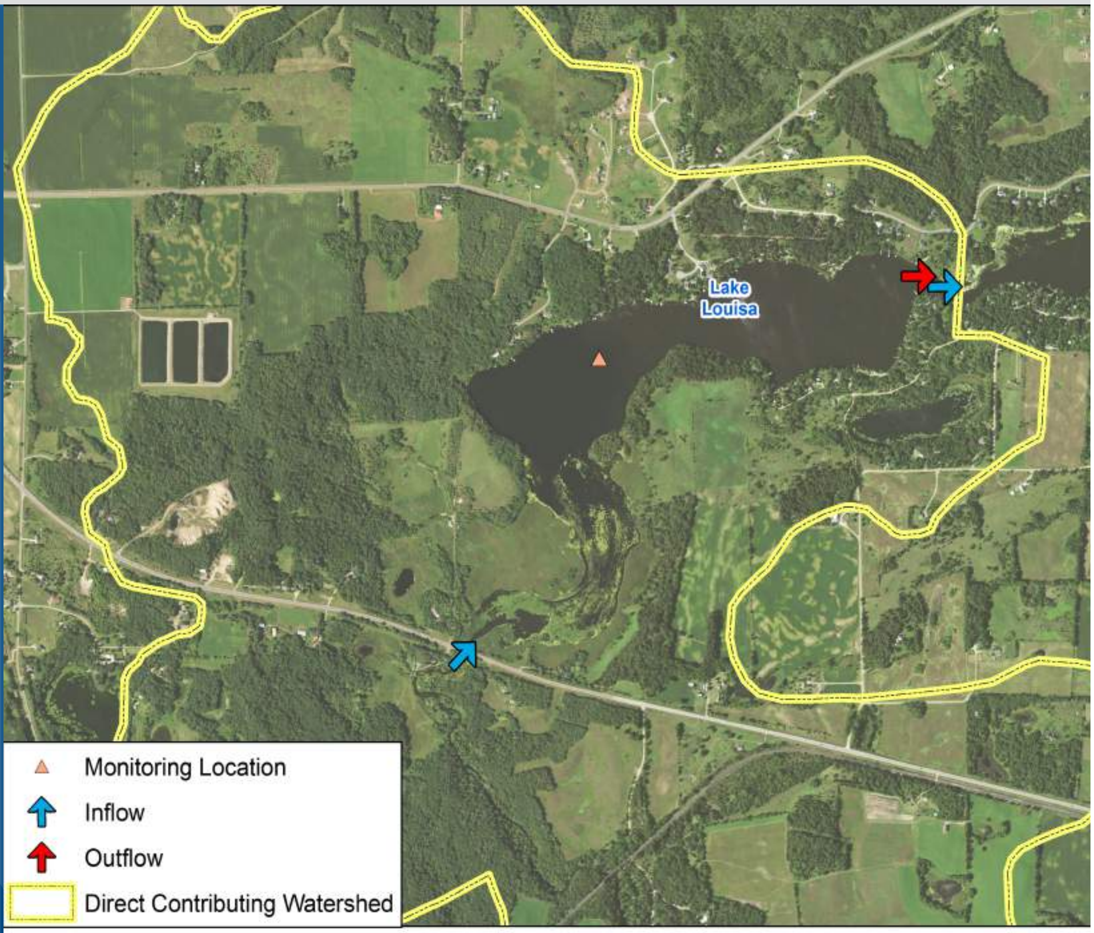
Common Fish: Bluegill, Northern Pike, Largemouth Bass, White Sucker

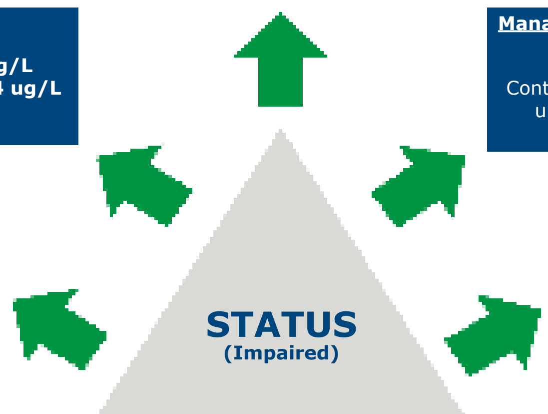
Dominant Vegetation: No Recent Survey

Invasive Species: Curly-leaf pondweed

Status: Impaired, TMDL Completed 2009







Secchi
2015: 1.8 m
Standard >1.4 m

Chl-a
2015: 12 ug/L
Standard <14 ug/L

Management Strategy
Monitor: Continue to implement upper watershed management

TP
2015: 100 ug/L
Standard <40 ug/L

Key Issues
- Upstream lakes
- Watershed load

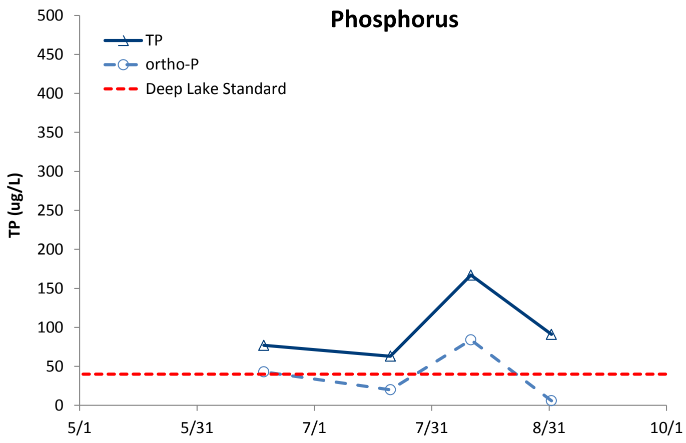
TO DO LIST

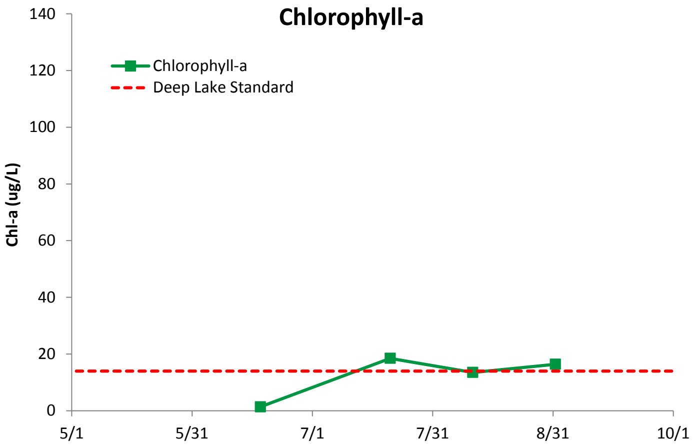
- Manage upstream loads
- AIS management

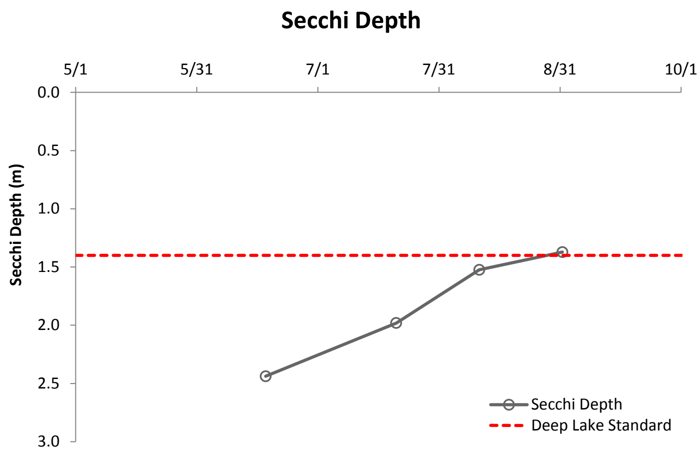
Prepared By: WENCK ASSOCIATES

LAKE LOUISA

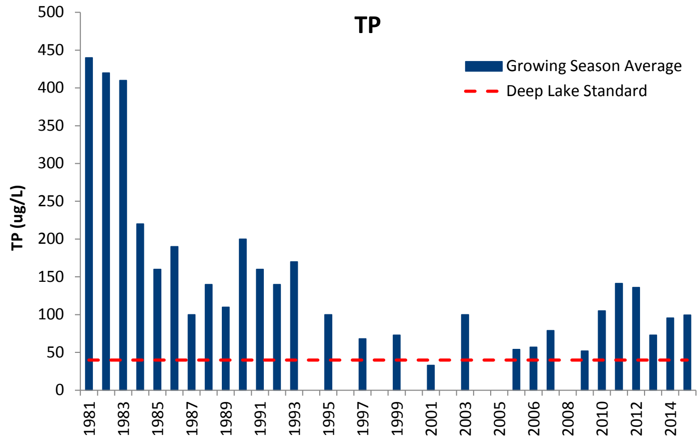
2015 Water Quality

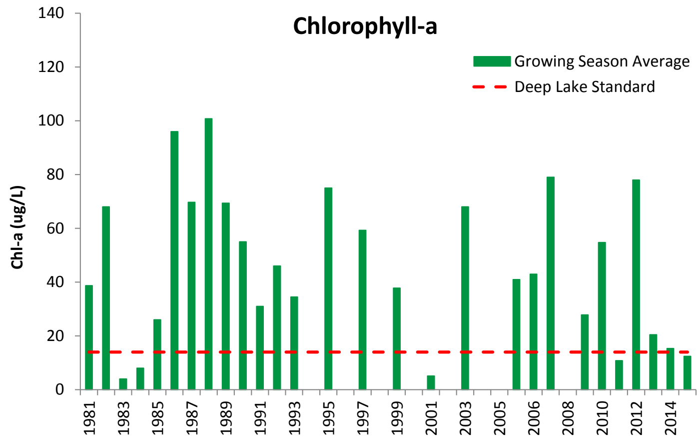


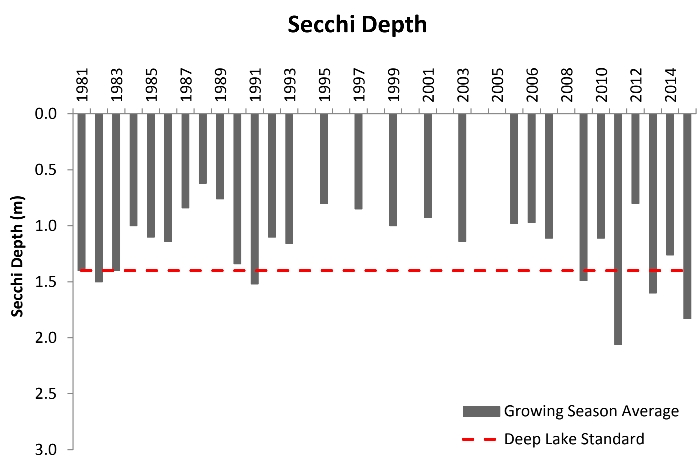




Historic Water Quality







Prepared By: WENCK ASSOCIATES

LAKE MARIE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 107 acres

Residence Time: 24 days

Surface Area: 146 acres

Subwatershed Area: 59,837 acres

Maximum Depth: 36 feet

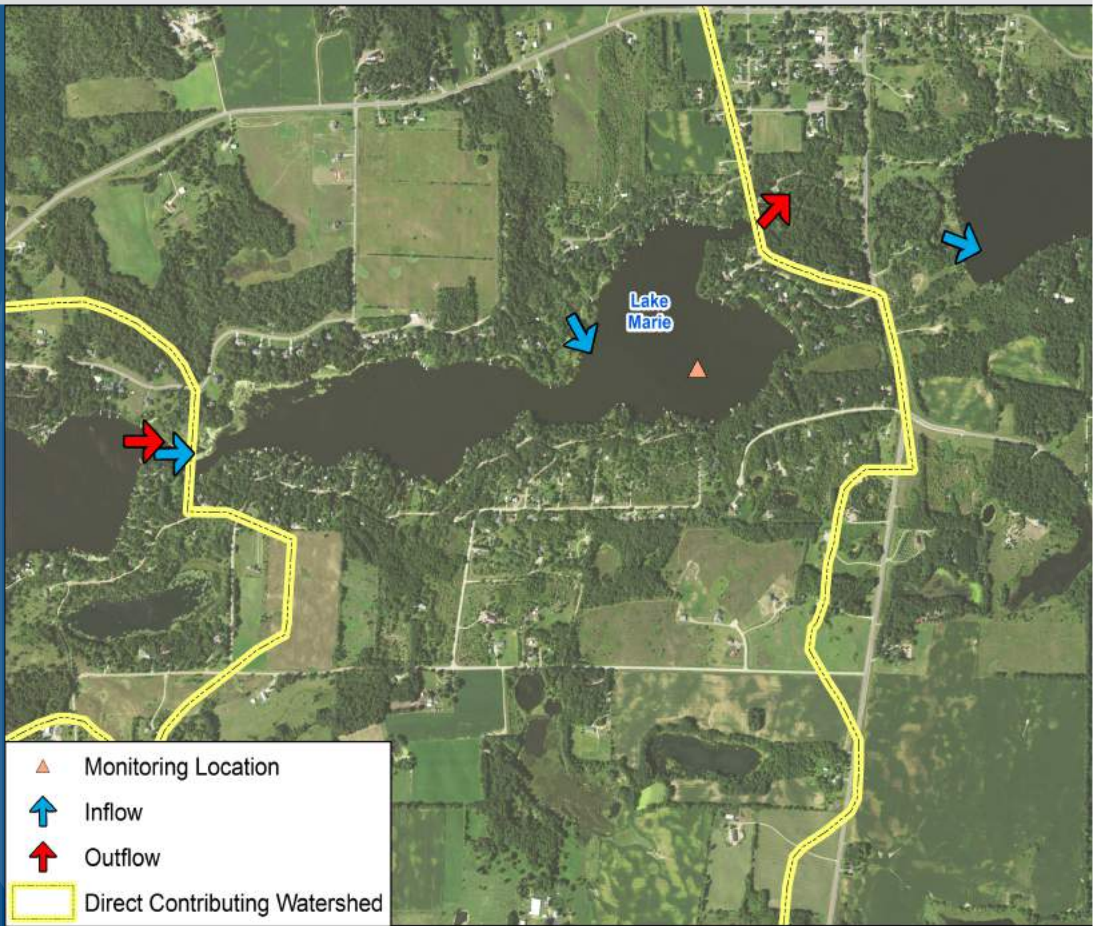
Upstream Waters: Clearwater River, Louisa

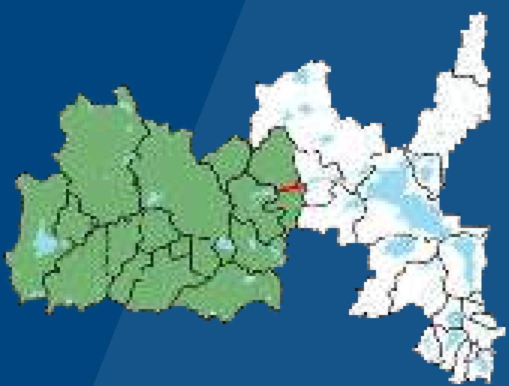
Common Fish: Black Crappie, Bluegill, Northern Pike, White Sucker, Yellow Perch

Dominant Vegetation: No Recent Survey

Invasive Species: Curly-leaf pondweed

Status: Impaired, TMDL Completed 2009





Secchi
2015: 1.3 m
Standard >1.4 m

Chl-a
2015: 36 ug/L
Standard <14 ug/L

Management Strategy
Restore:
Continue to implement upper watershed management

TP
2015: 88 ug/L
Standard <40 ug/L

Key Issues
- Upstream lakes
- Watershed load
- Internal load

STATUS
(Impaired)

TO DO LIST

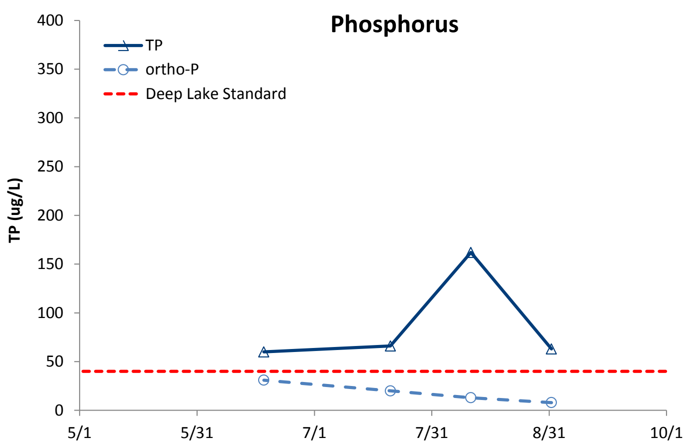
- Manage upstream loads
- AIS management

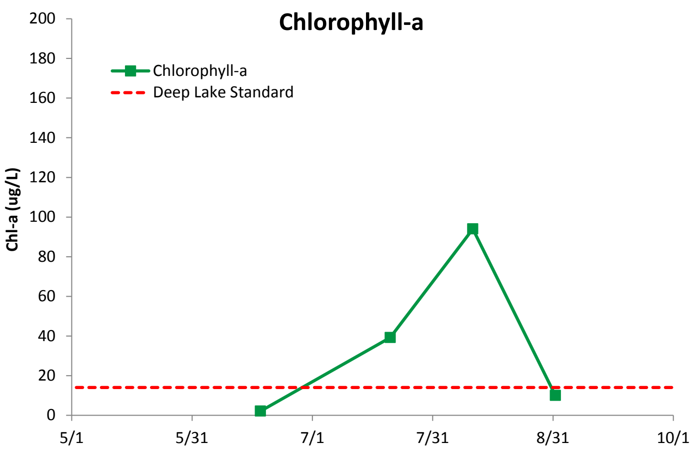
Prepared By: WENCK ASSOCIATES

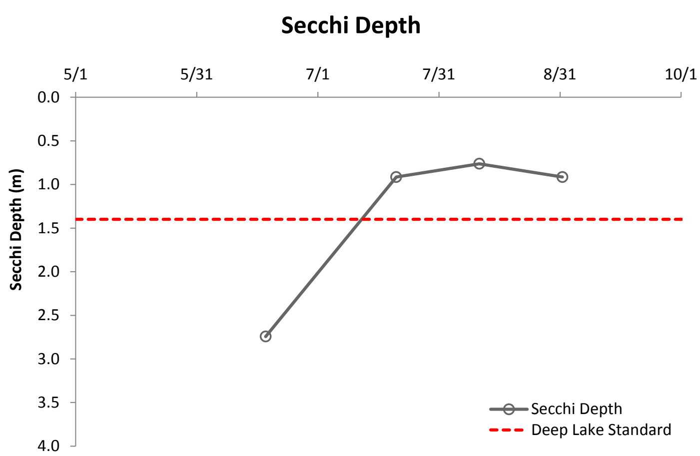
LAKE MARIE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

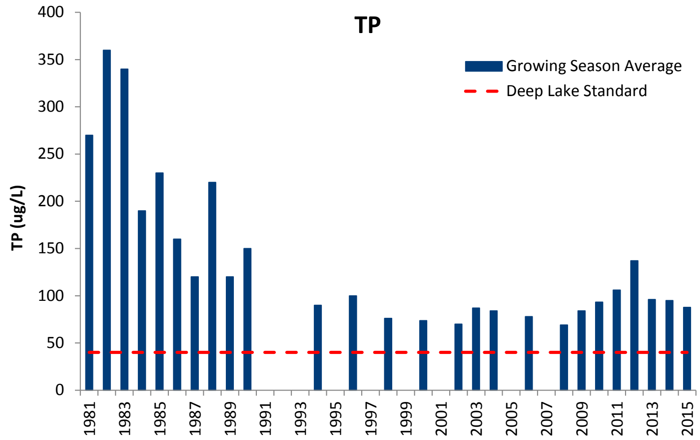
2015 Water Quality

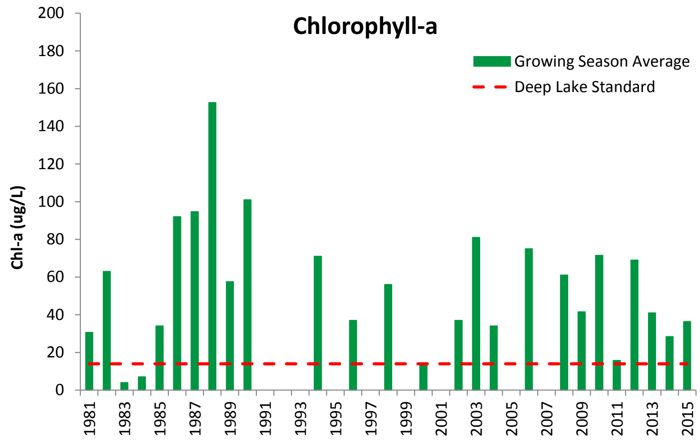


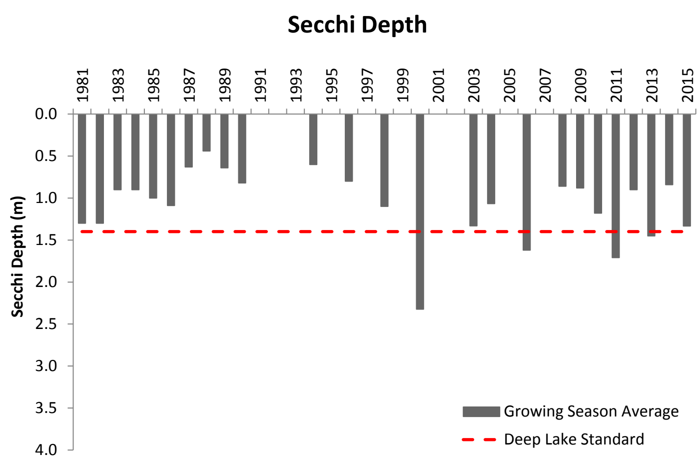




Historic Water Quality







Prepared By: WENCK ASSOCIATES

OTTER LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 32 acres

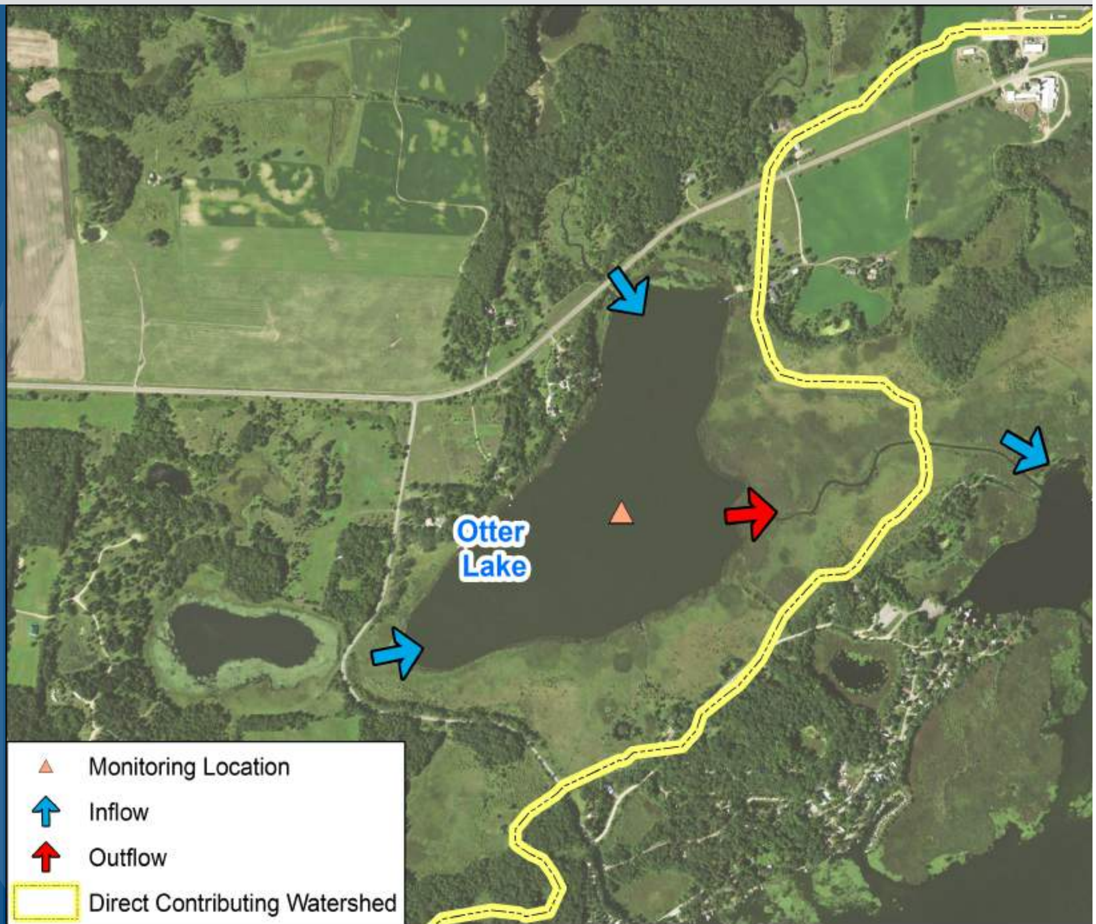
Surface Area: 92 acres

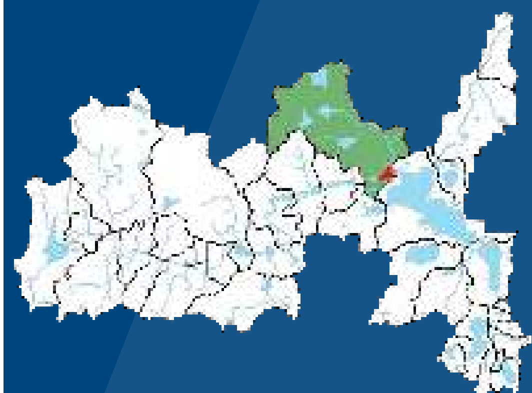
Subwatershed Area: 10,574 acres

Maximum Depth: 51 feet

Upstream Waters: Lake Laura

Common Fish	Black Crappie, Bluegill, Northern Pike, Largemouth Bass, Walleye
Dominant Vegetation	Diverse community
Invasive Species	Curly-leaf pondweed, Eurasian water milfoil
Status	Not impaired





Secchi

2015: 2.4 m
Standard >1.4 m

Chl-a

2015: 6 ug/L
Standard <14 ug/L

Management Strategy

Protect:
Continue to monitor lake and watershed loads

TP

2015: 19 ug/L
Standard <40 ug/L

Key Issues

▲ Upstream lakes
▲ Watershed load

STATUS
(Meeting goals)

TO DO LIST

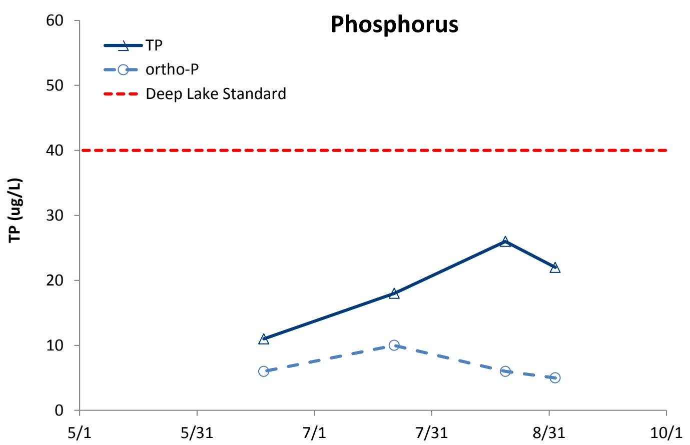
- Manage watershed loads
- Protect

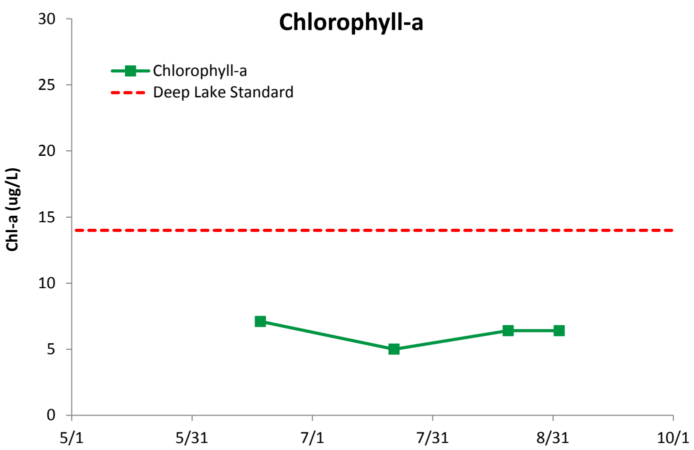
Prepared By: WENCK ASSOCIATES

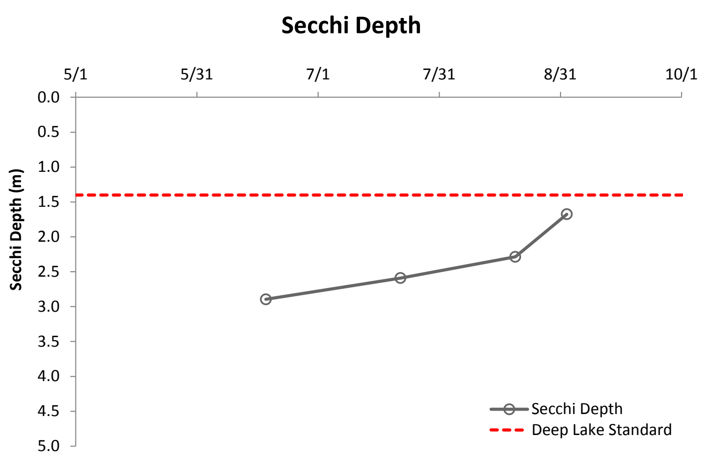
OTTER LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

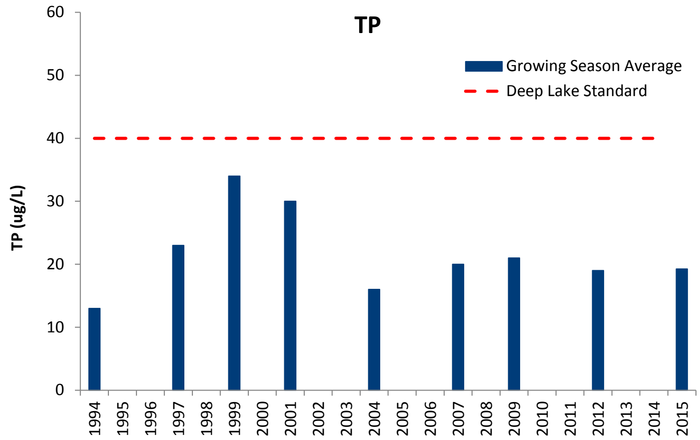
2015 Water Quality

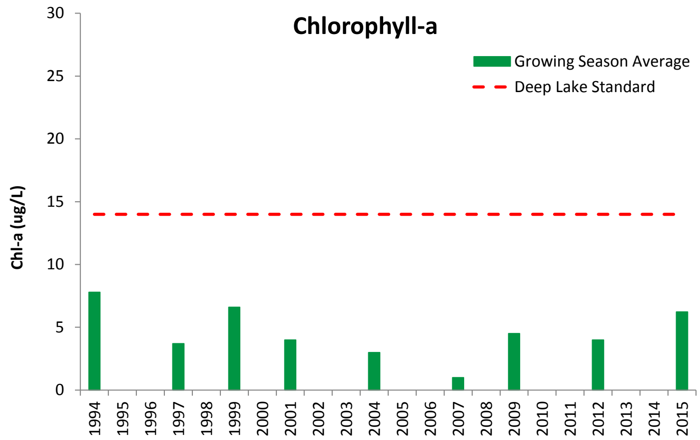


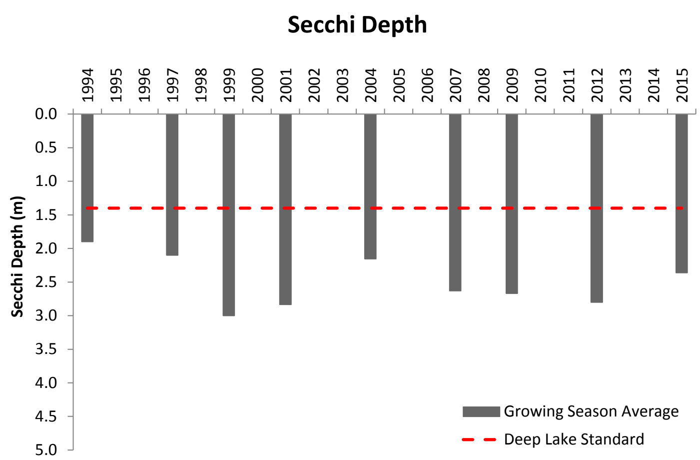




Historic Water Quality







SCHOOL SECTION LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 188 acres

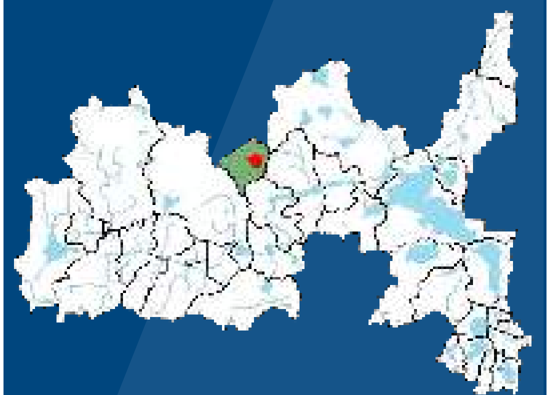
Surface Area: 193 acres

Subwatershed Area: 1,843 acres

Maximum Depth: 12 feet

Upstream Waters: None

Common Fish	Black bullhead, Bluegill, Northern Pike
Dominant Vegetation	Northern water milfoil, Illinois pondweed, muskgrass
Invasive Species	Curly-leaf pondweed
Status	Not impaired



Secchi

2015: 4.2 m
Standard >1.0 m

Chl-a

2015: 2 ug/L
Standard <20 ug/L

Management Strategy

Protect:
Continue to monitor lake and watershed loads

TP

2015: 14 ug/L
Standard <60 ug/L

Key Issues

▲ **Watershed load**

STATUS
(Meeting goals)

TO DO LIST

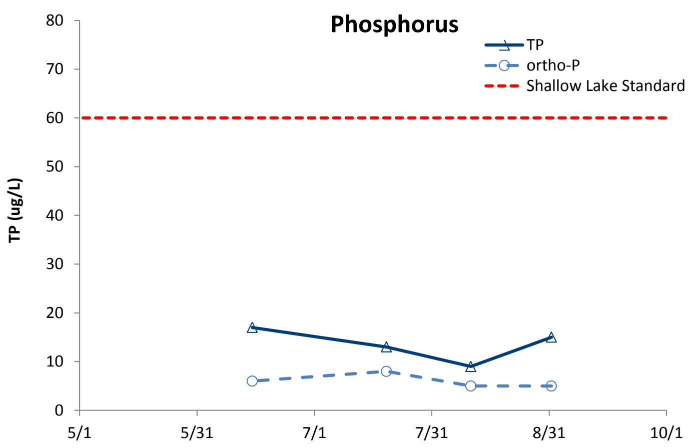
- Operate outlet to prevent flooding
- Protect water quailty

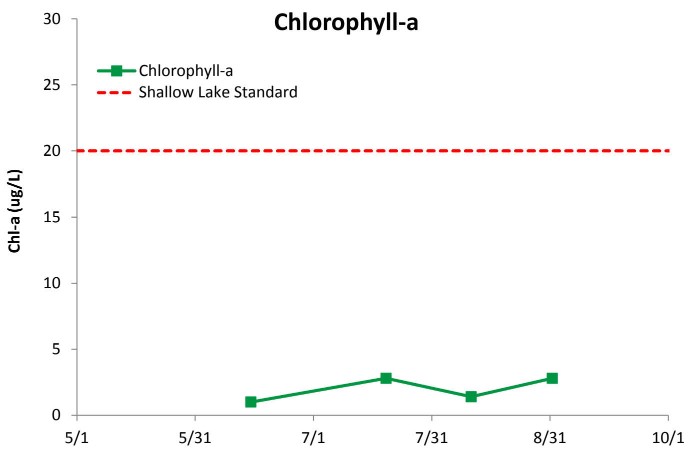
Prepared By: WENCK ASSOCIATES

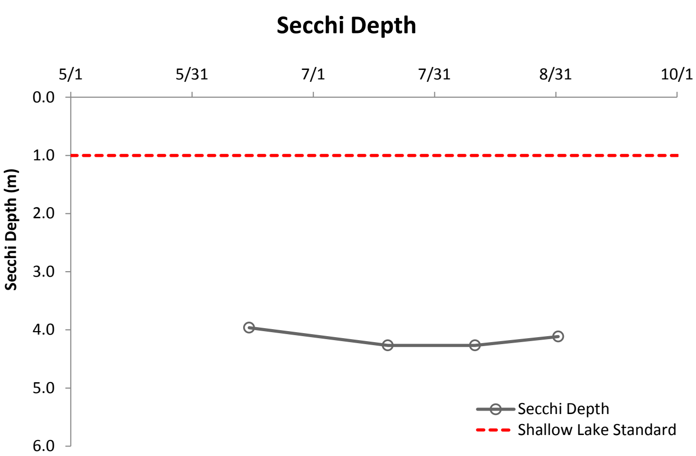
SCHOOL SECTION LAKE

Clearwater River WATERSHED DISTRICT Promote | Protect | Preserve

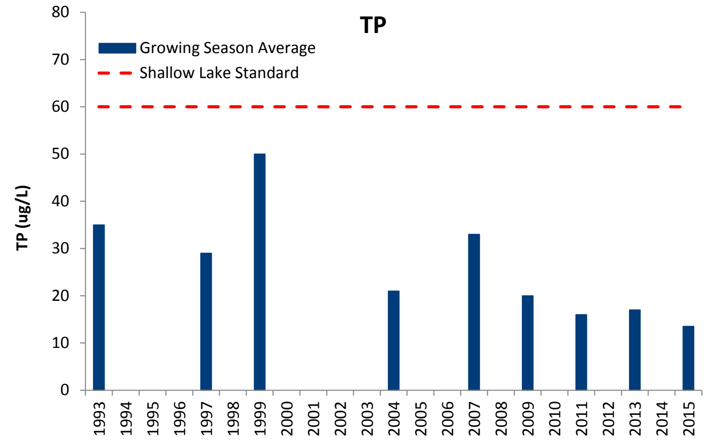
2015 Water Quality

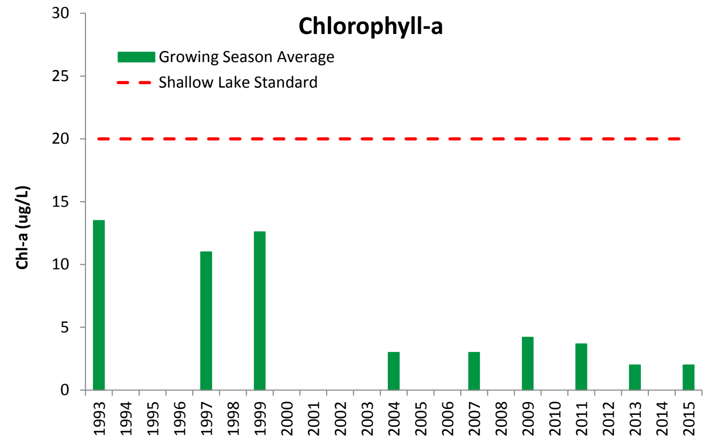


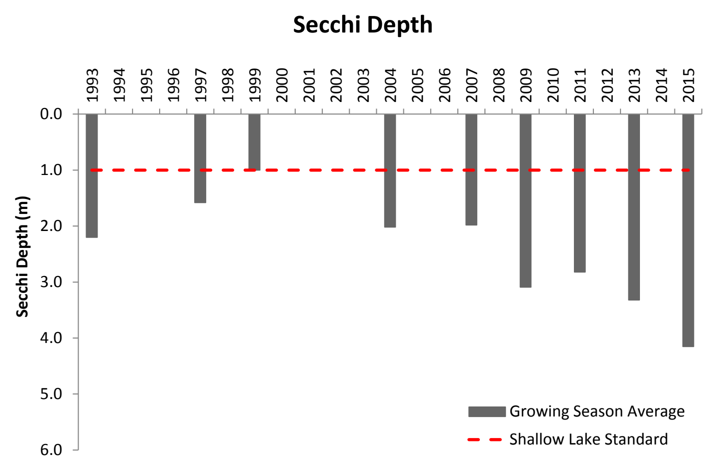




Historic Water Quality







Prepared By: WENCK ASSOCIATES

SCOTT LAKE

Clearwater River WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 52 acres

Resodence Time: 12 days

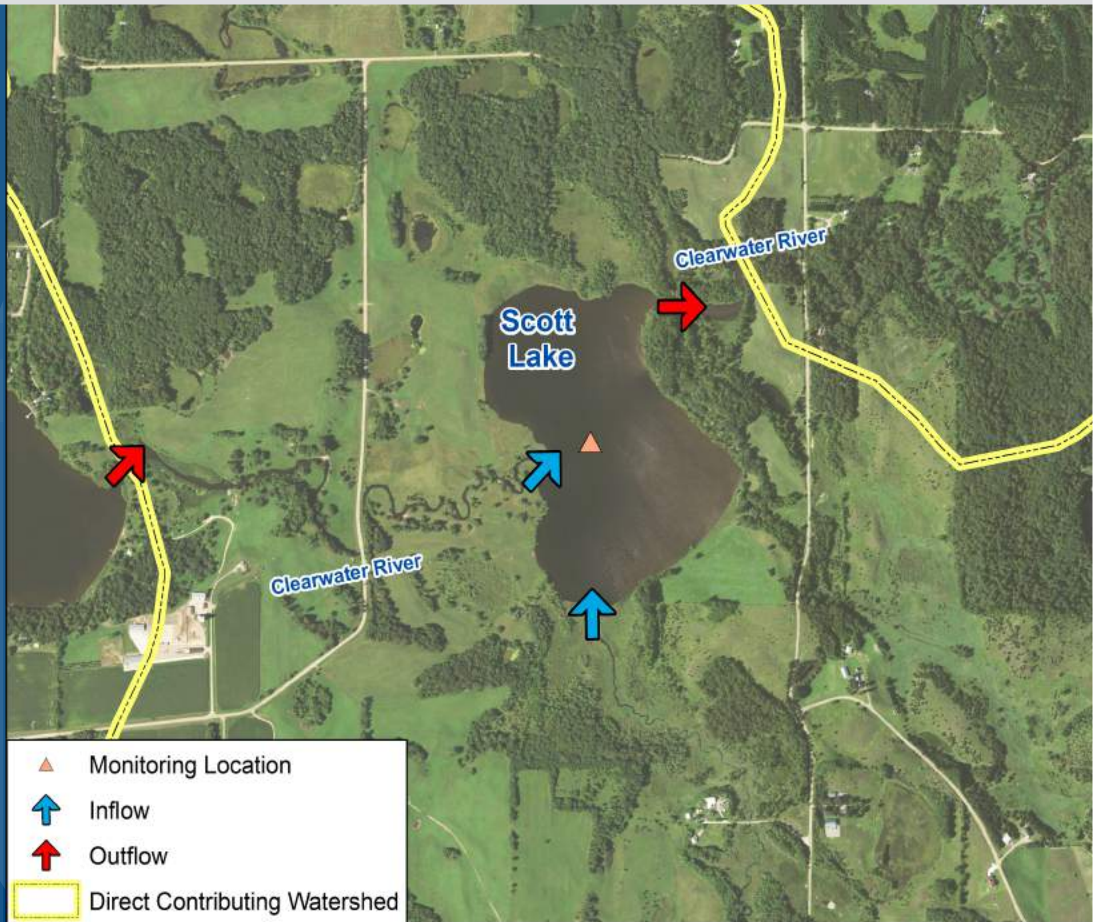
Surface Area: 80 acres

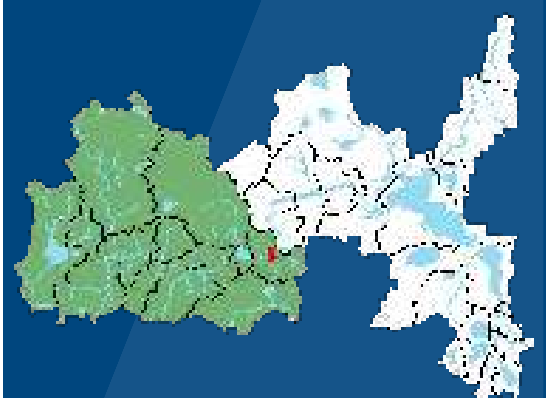
Subwatershed Area: 51,000 acres

Maximum Depth: 23 feet

Upstream Waters: Clearwater River, Lake Betsy, Union Lake

Common Fish	Black Crappie, Bluegill, Channel Catfish, White Sucker
Dominant Vegetation	No Recent Survey
Invasive Species	Curly-leaf pondweed
Status	Impaired, TMDL Completed 2009





TO DO LIST

- Upstream projects
- Rough fish management

Secchi
2015: 1.5 m
Standard >1.4 m

Chl-a
2015: 31 ug/L
Standard <14 ug/L

Management Strategy
Restore:
Continue to implement upper watershed management

TP
2015: 134 ug/L
Standard <40 ug/L

Key Issues
- **Watershed load**
- **Internal load**
- **Upstream lakes**

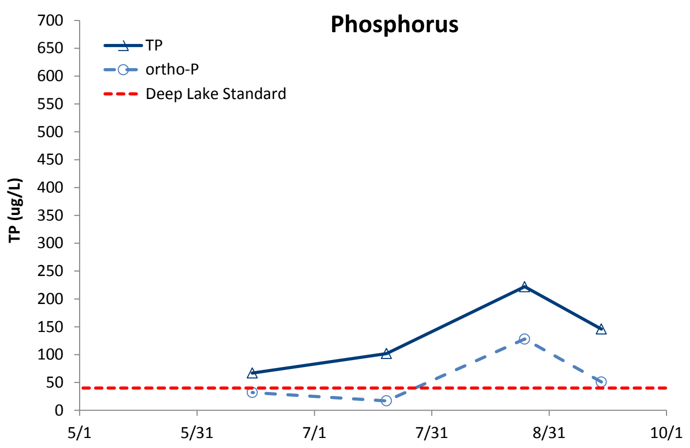
STATUS
(Impaired)

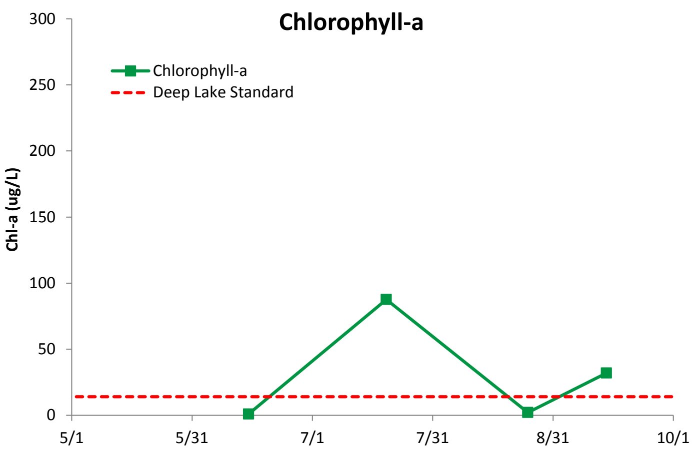
Prepared By: WENCK ASSOCIATES

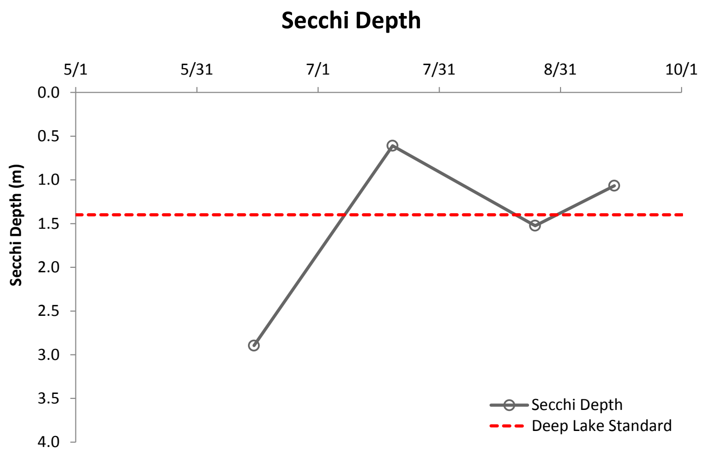
SCOTT LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

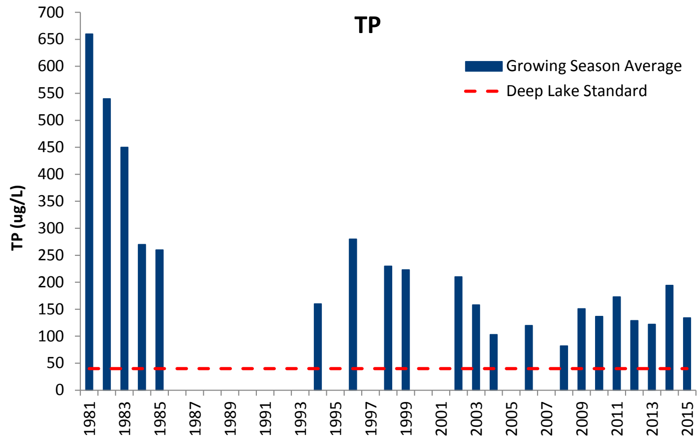
2015 Water Quality

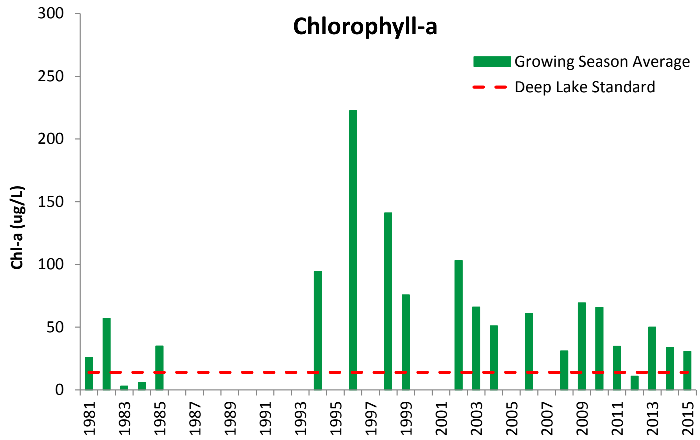


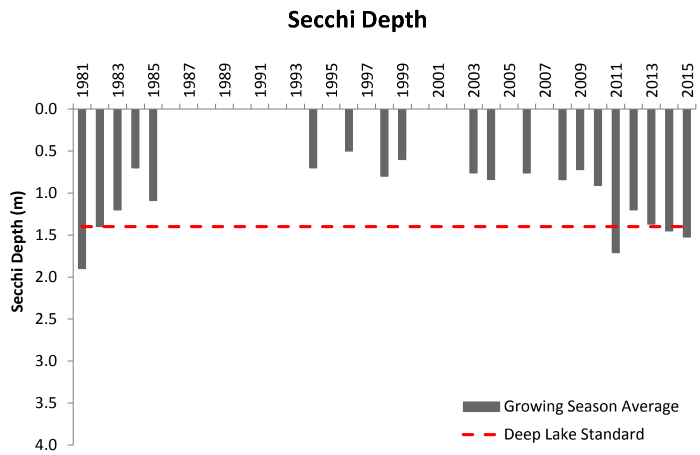




Historic Water Quality







Prepared By: WENCK ASSOCIATES

SWARTOUT LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 171 acres

Residence Time: 460 days

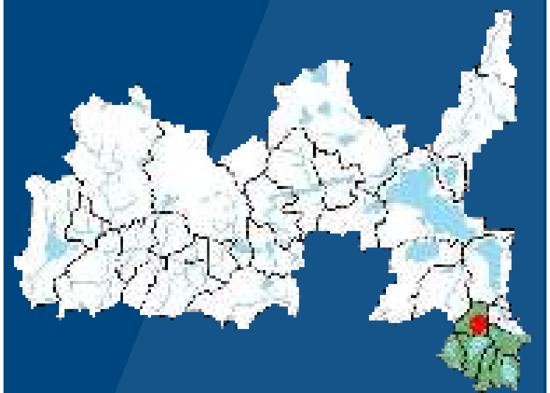
Surface Area: 171 acres

Subwatershed Area: 5,551 acres

Maximum Depth: 12 feet

Upstream Waters: Henshaw, Albion

Common Fish	Black Bullhead, Black Crappie, Common Carp
Dominant Vegetation	Coontail, sago pondweed, bushy pondweed
Invasive Species	None
Status	Impaired, TMDL Completed 2010



Secchi

2015: 0.8 m
Standard >1.0 m

Chl-a

2015: 66 ug/L
Standard <20 ug/L

Management Strategy

Restore:
By reducing internal load through ecosystem restoration

TP

2015: 166 ug/L
Standard <60 ug/L

Key Issues

- **Watershed load**
- **Internal load**
- **Upstream lakes**
- **Rough fish**

STATUS
(Impaired)

TO DO LIST

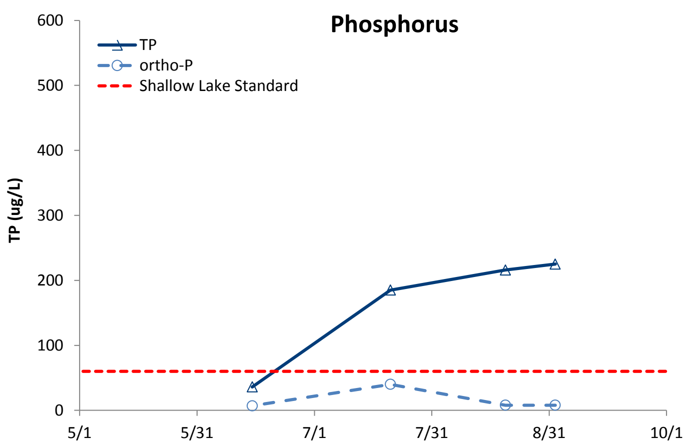
- Curly-leaf pondweed management
- Rough fish management

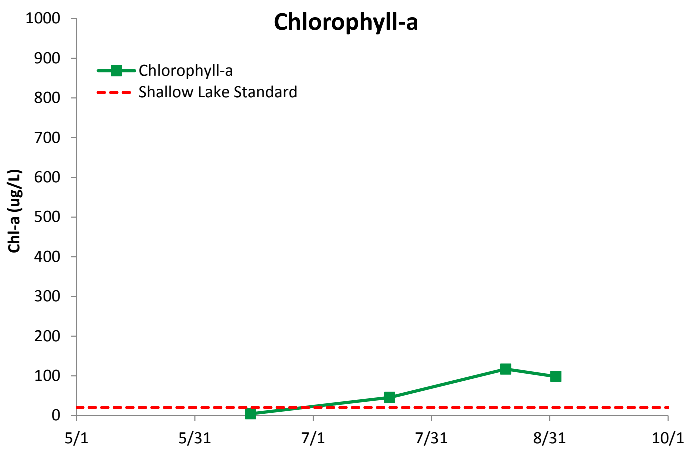
Prepared By: WENCK ASSOCIATES

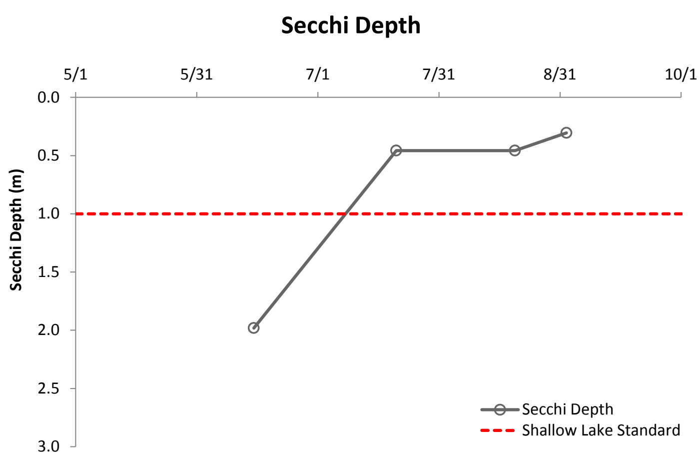
SWARTOUT LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

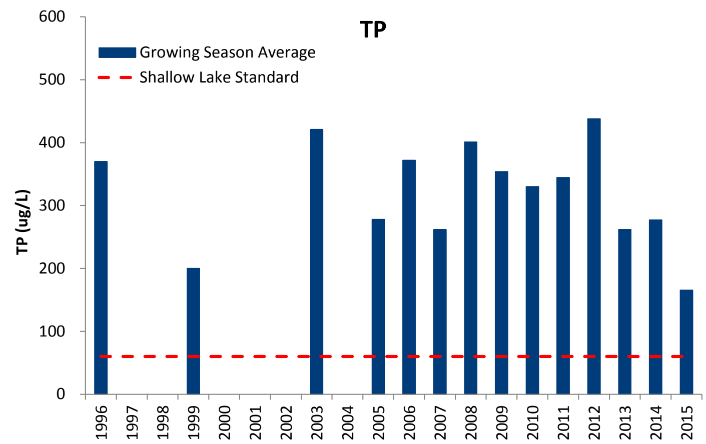
2015 Water Quality

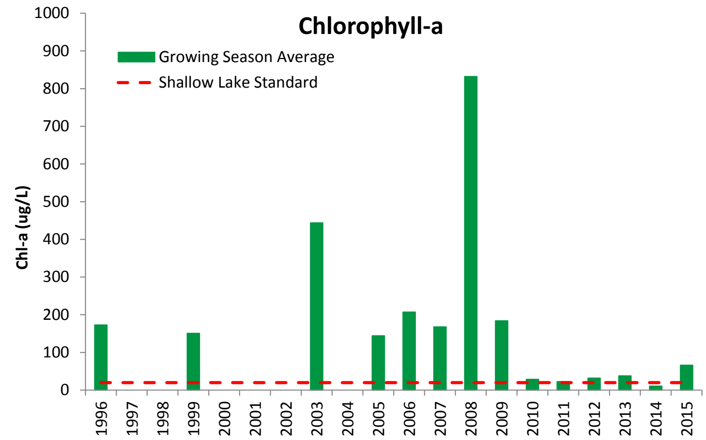


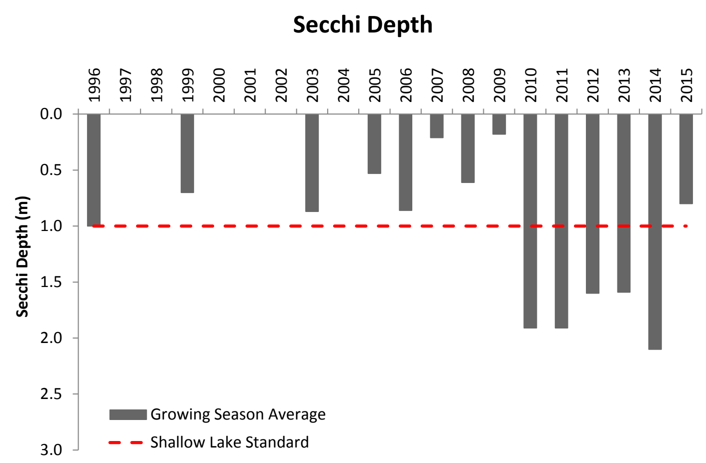




Historic Water Quality







Prepared By: WENCK ASSOCIATES

UNION LAKE

Clearwater River
WATERSHED DISTRICT
Promote | Protect | Preserve

QUICK FACTS

Littoral Area: 27 acres

Residence Time: 291 days

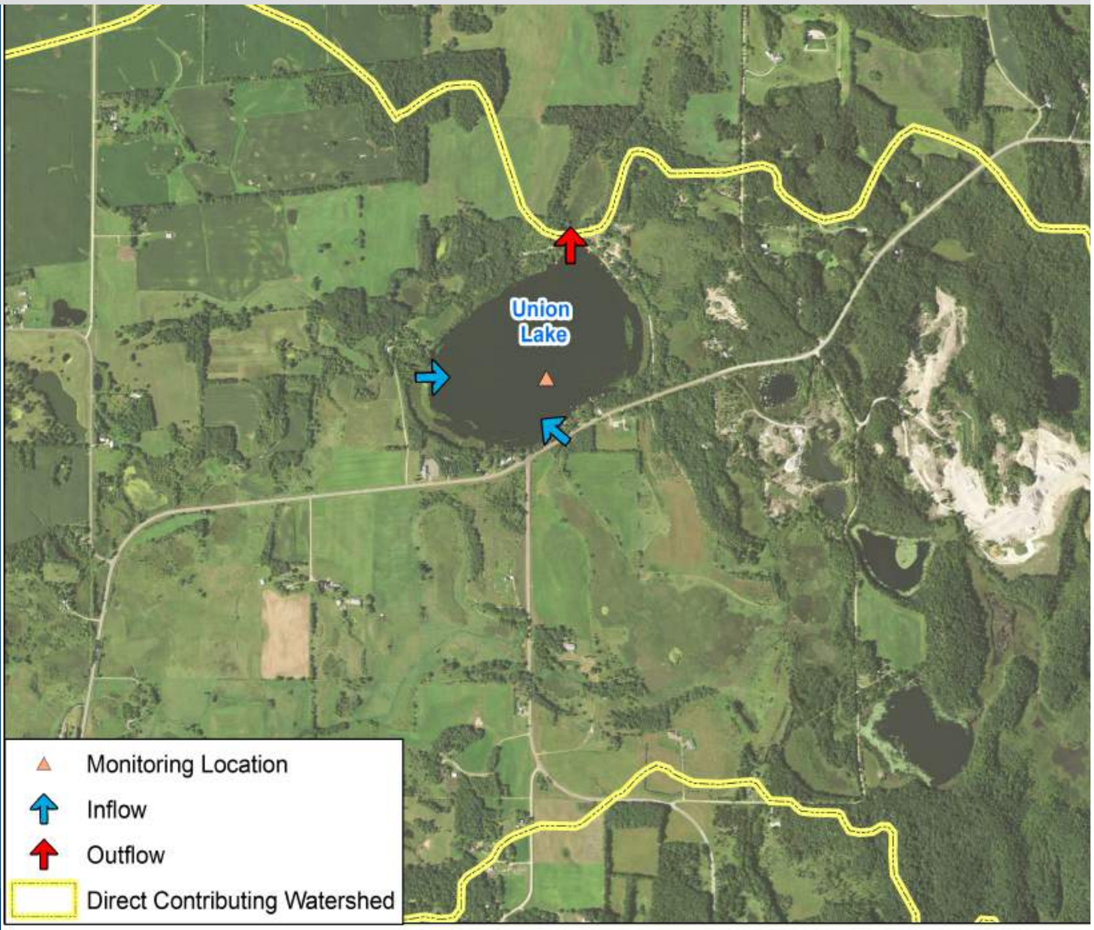
Surface Area: 93 acres

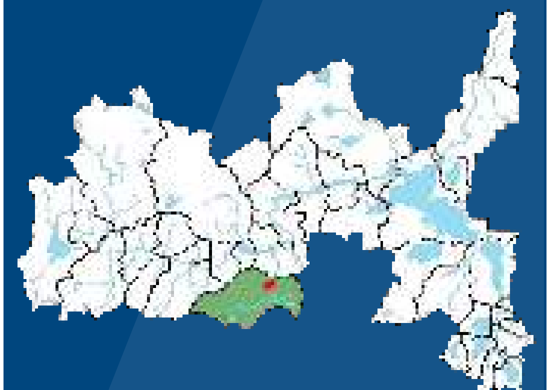
Subwatershed Area: 4,741 acres

Maximum Depth: 35 feet

Upstream Waters: None

Common Fish	Black Crappie, Bluegill, Northern Pike, Largemouth Bass
Dominant Vegetation	No Recent Survey
Invasive Species	Curly-leaf pondweed
Status	Impaired, TMDL Completed 2009





Secchi
2015: 1.2 m
Standard >1.4 m

Chl-a
2015: 12 ug/L
Standard <14 ug/L

Management Strategy
Monitor:
Continue to monitor lake and watershed loads

TP
2015: 51 ug/L
Standard <40 ug/L

Key Issues
▲ Watershed load
▲ Internal load

STATUS
(Impaired)

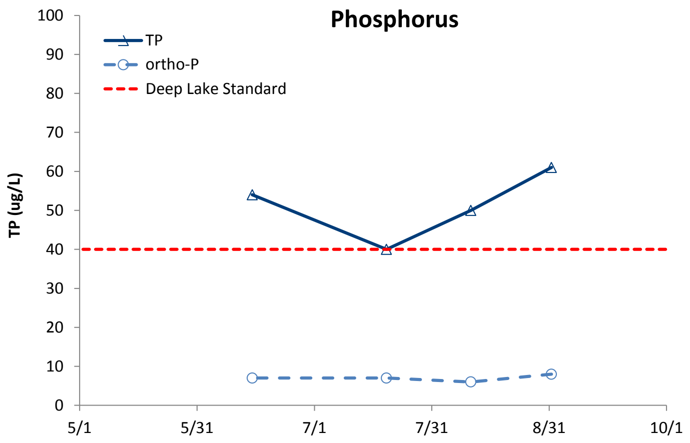
TO DO LIST

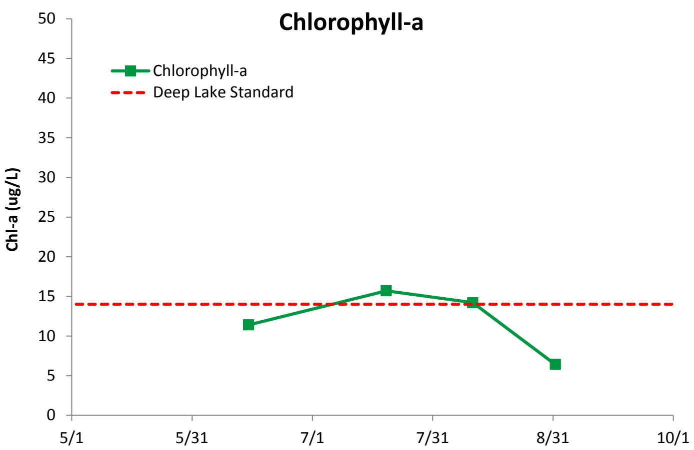
- Manage direct watershed loads
- Monitor tributary inflows

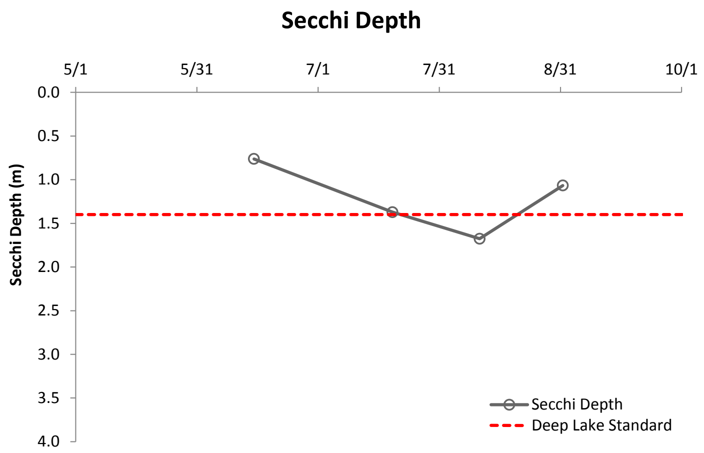
Prepared By: WENCK ASSOCIATES

UNION LAKE

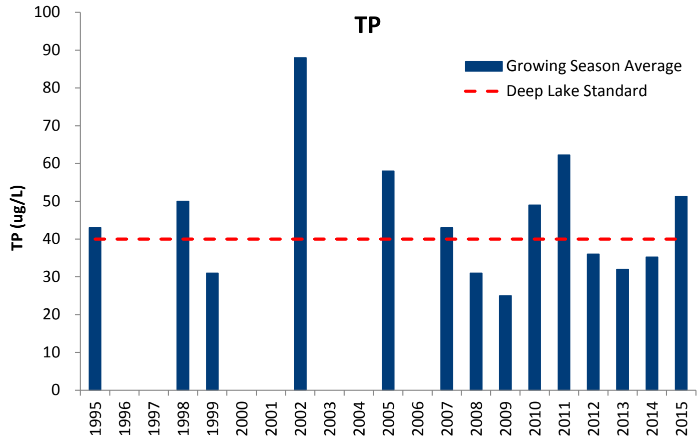
2015 Water Quality

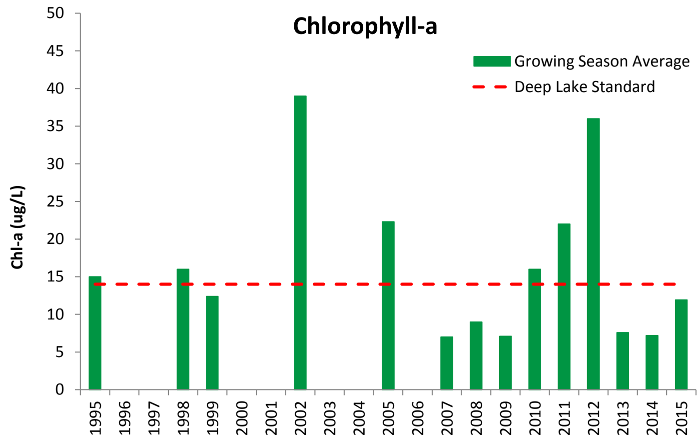


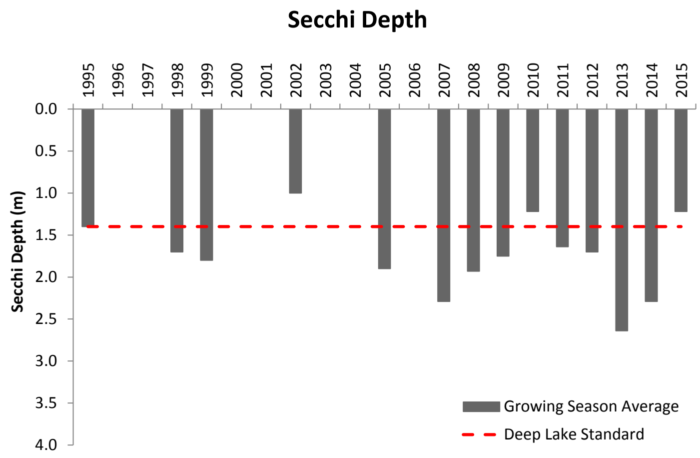




Historic Water Quality

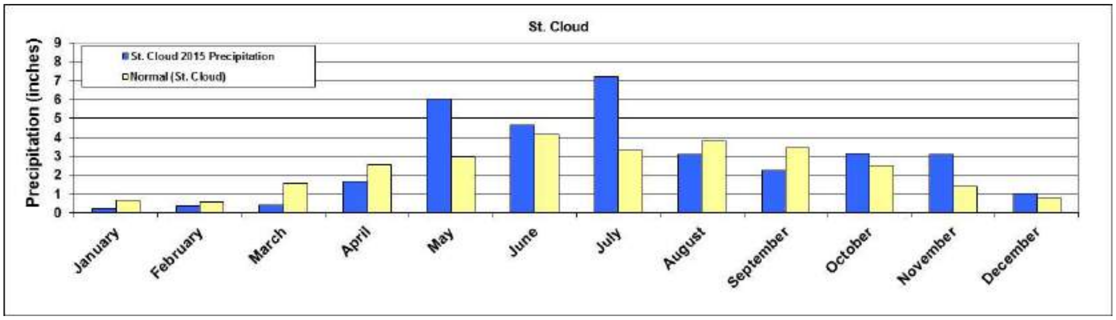


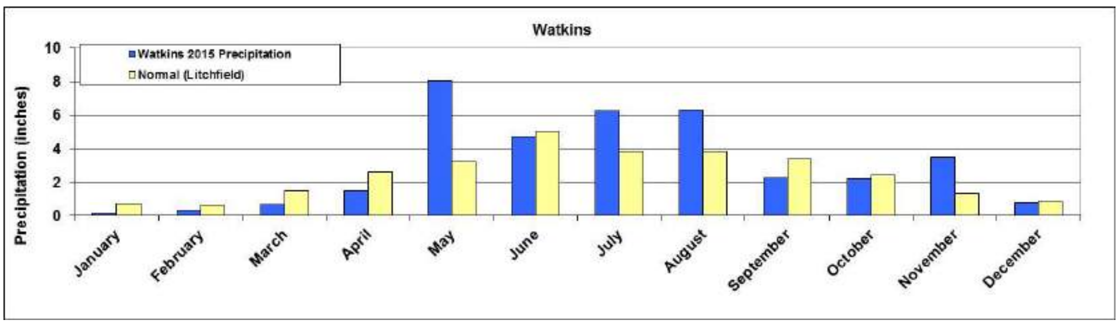


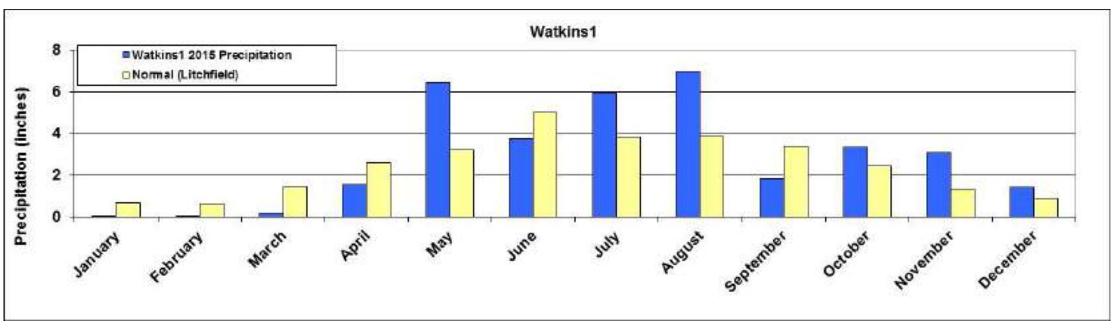


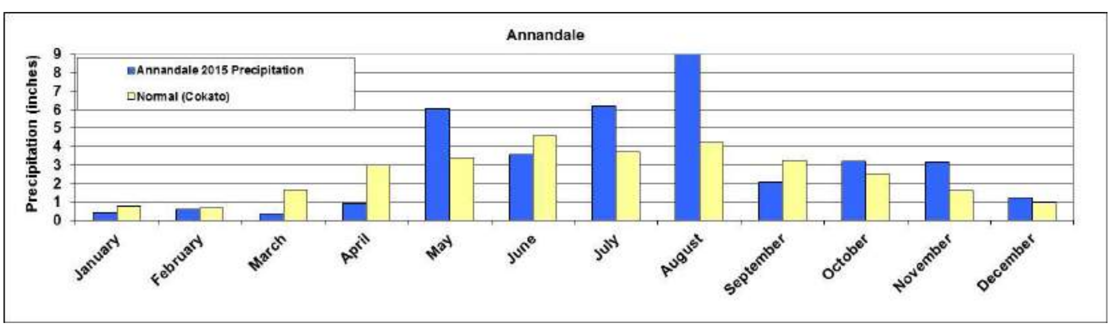
Prepared By:

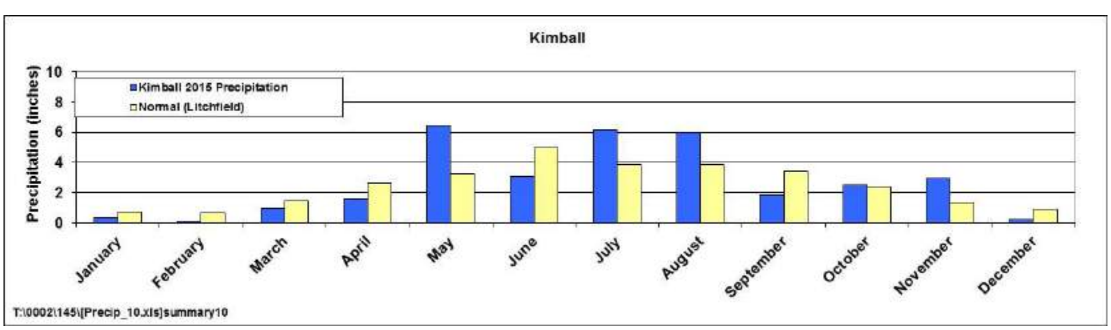
Appendix D
Figure 1
Clearwater River Watershed District 2015
Annual Report











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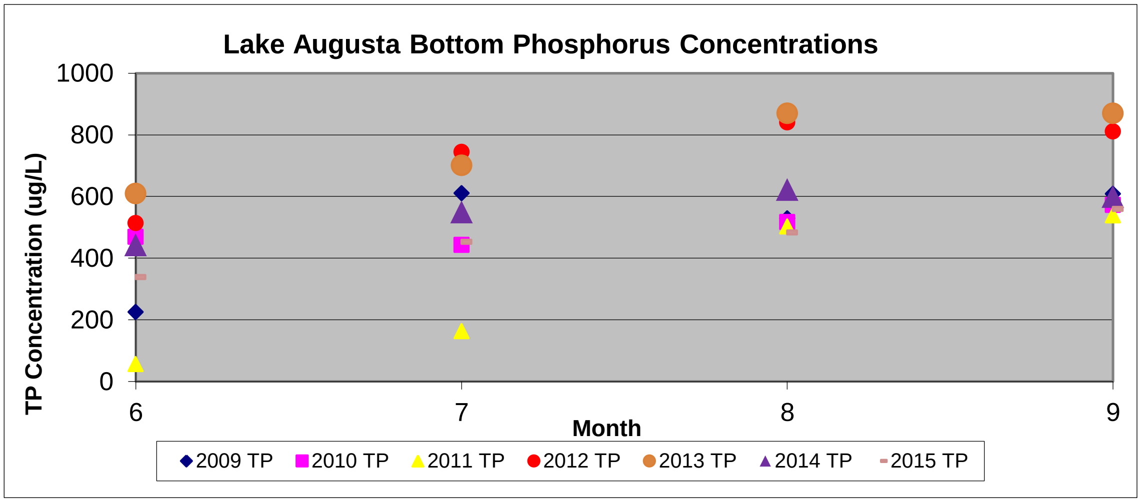
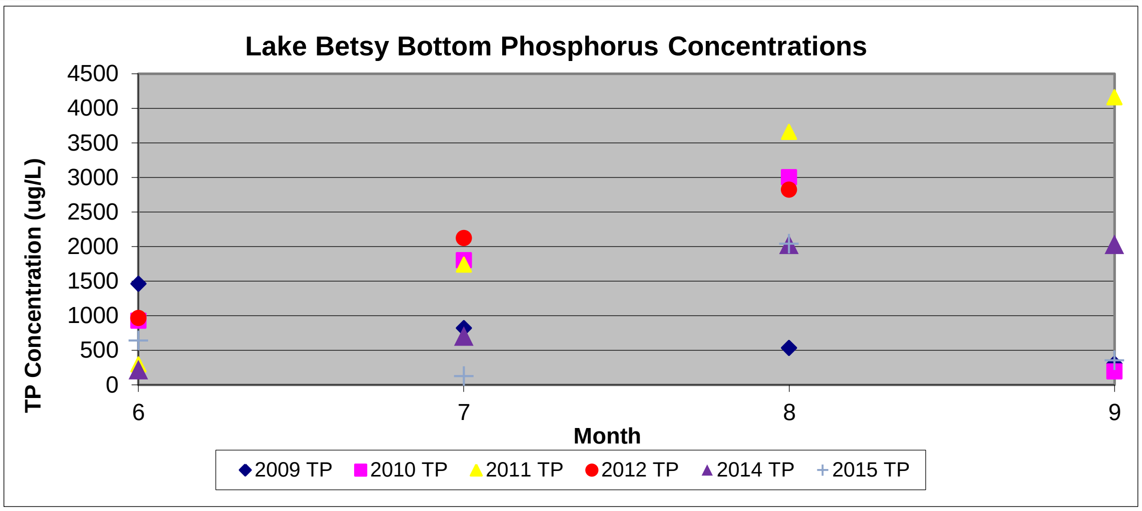
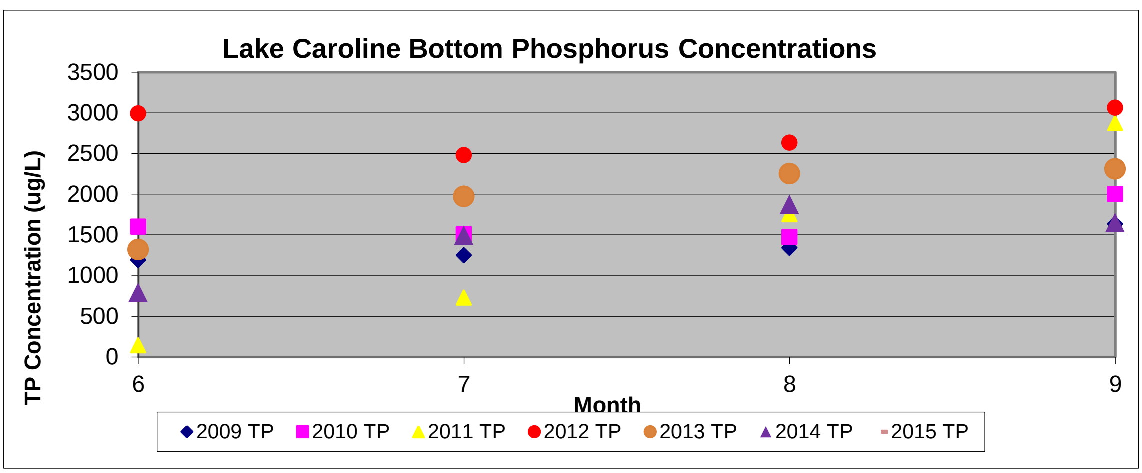
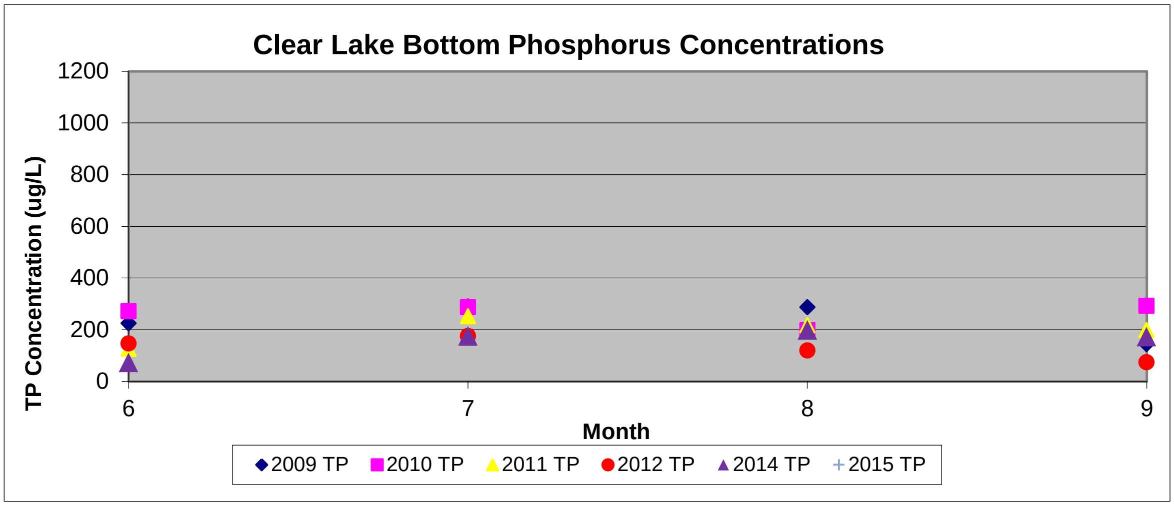
Clearwater River Watershed District
2015 Annual Monitoring Report
Appendix H

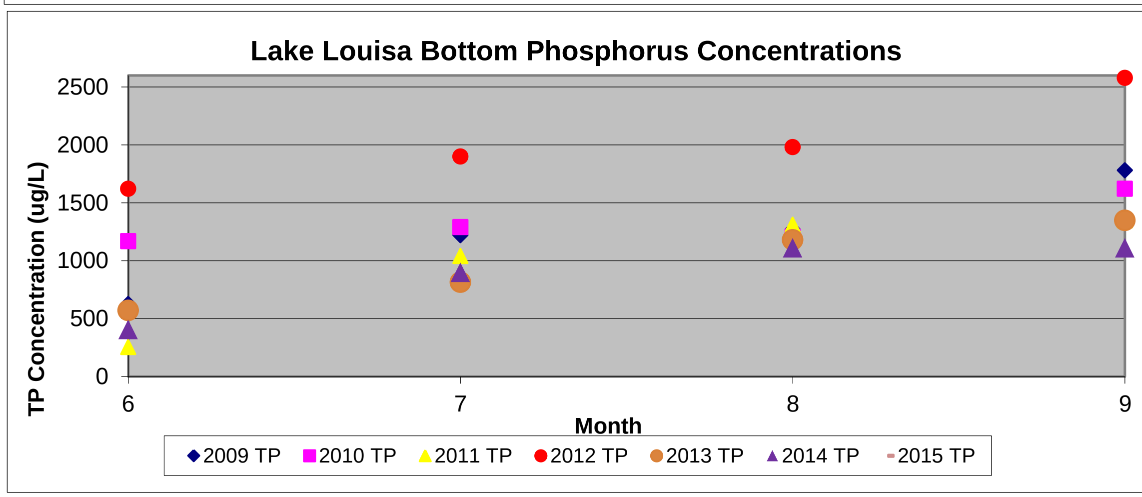


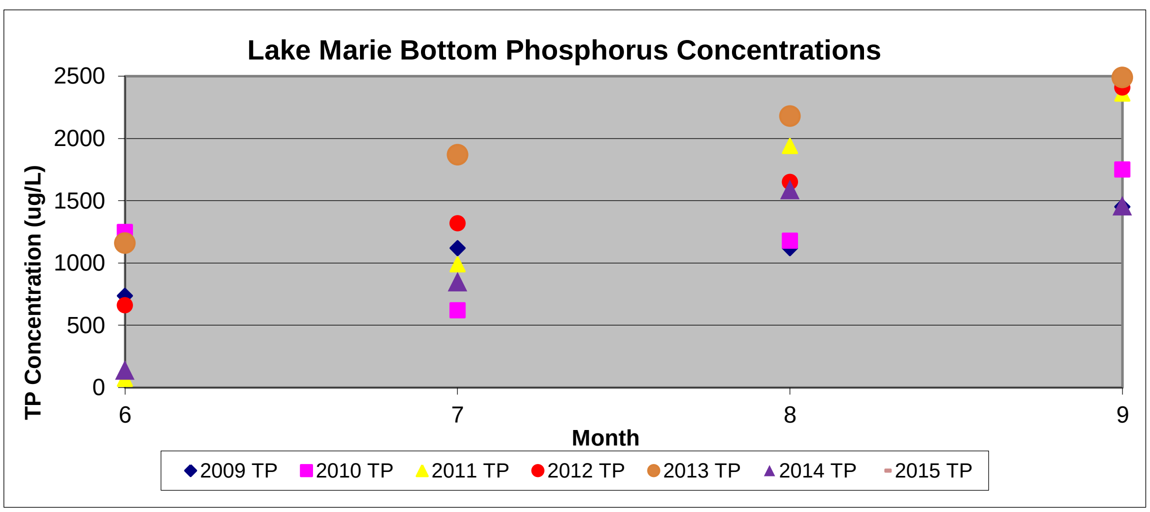




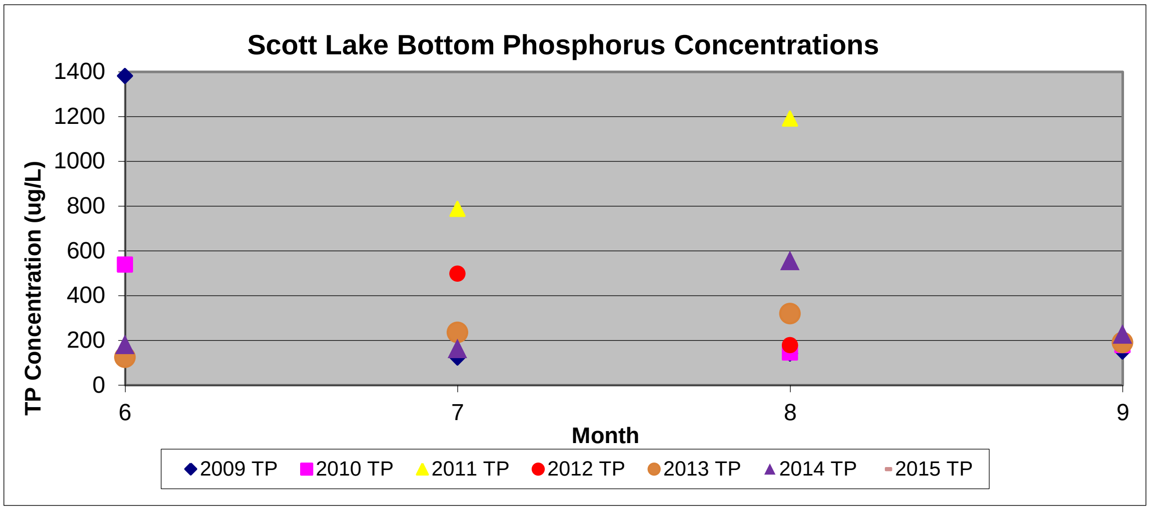
Clearwater River Watershed District
2015 Annual Monitoring Report
Appendix H

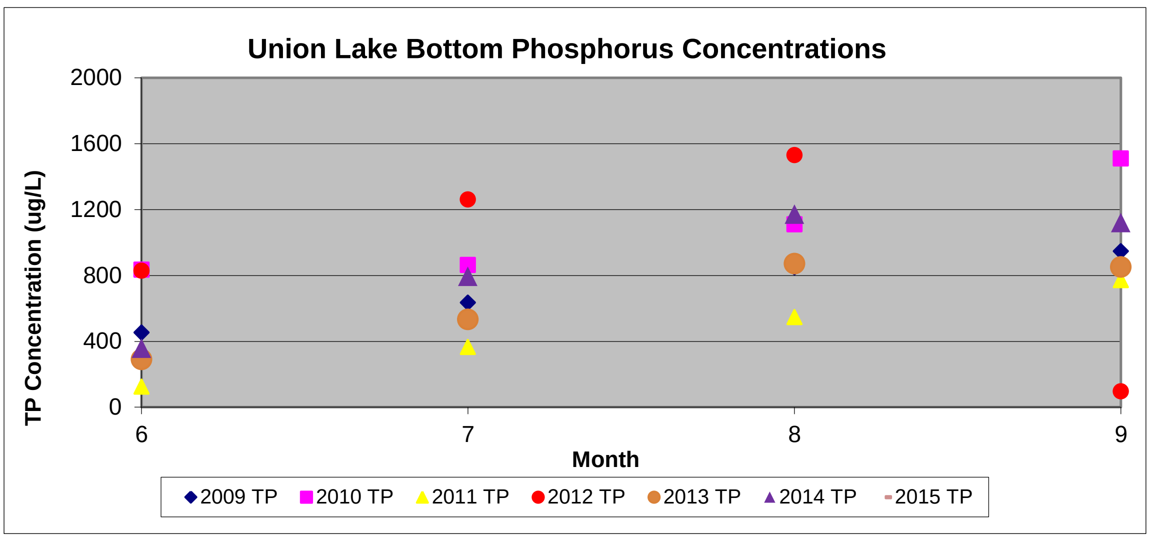




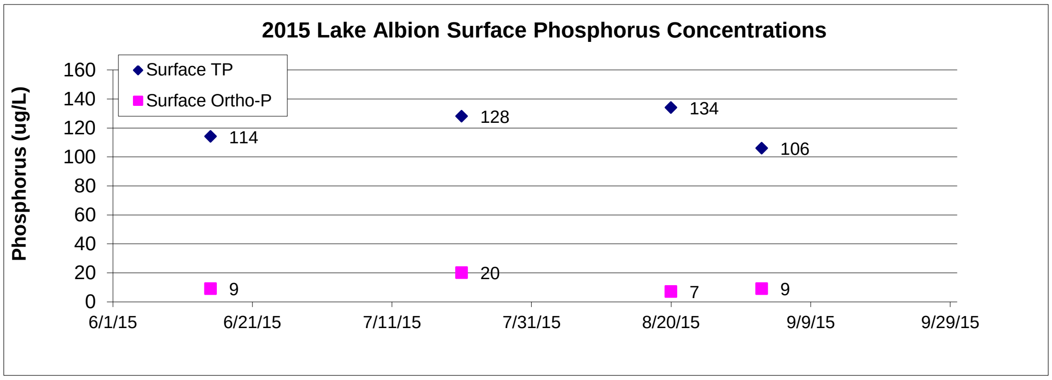


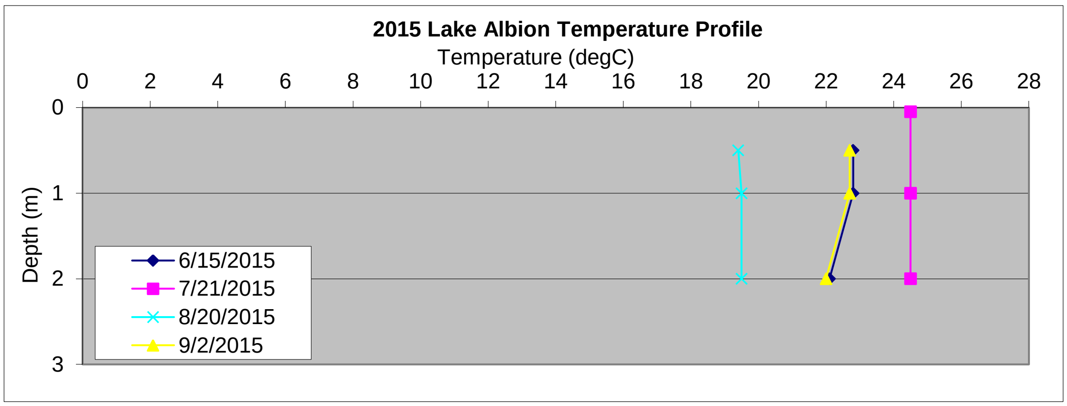
Clearwater River Watershed District
2015 Annual Monitoring Report
Appendix H

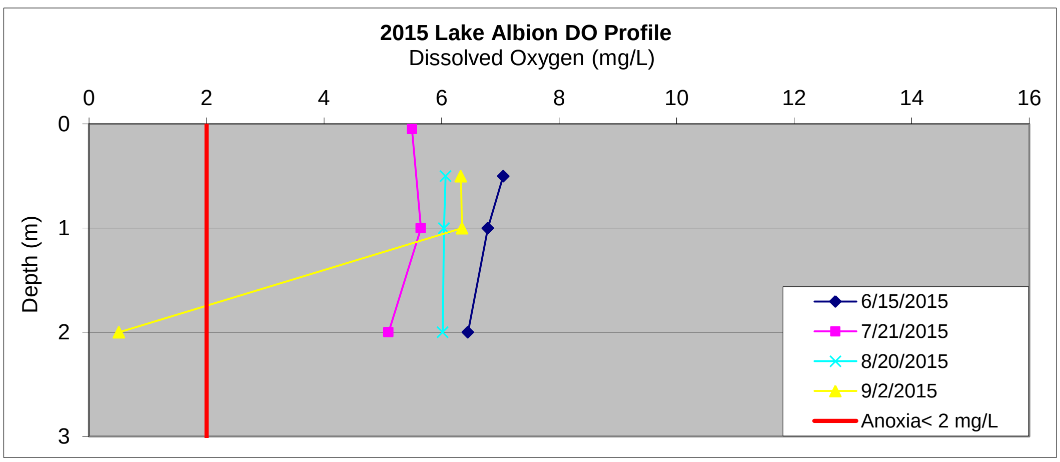




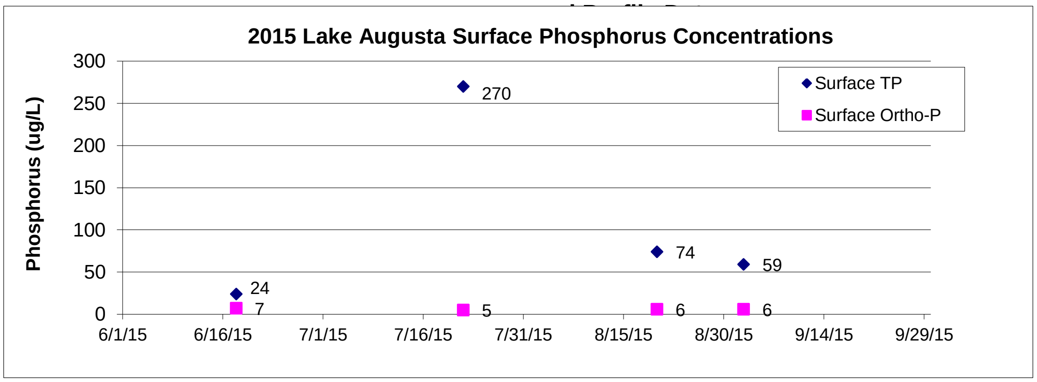
CRWD 2015 Water Quality Report
Appendix E-Lake Phosphorus
and Profile Data

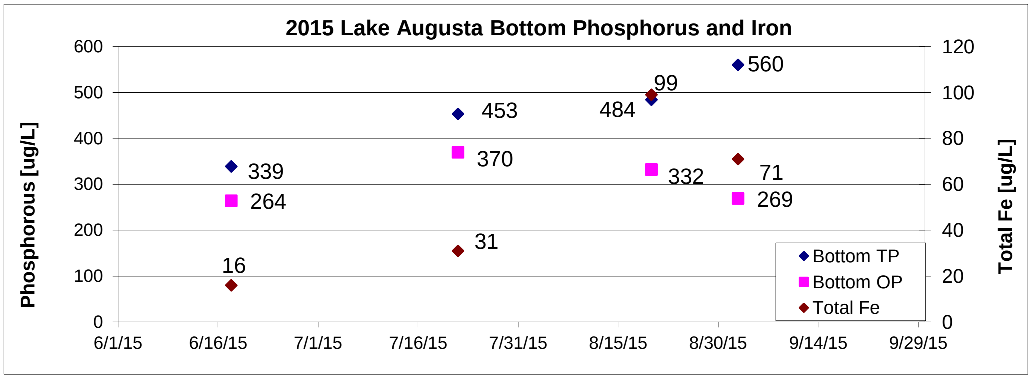


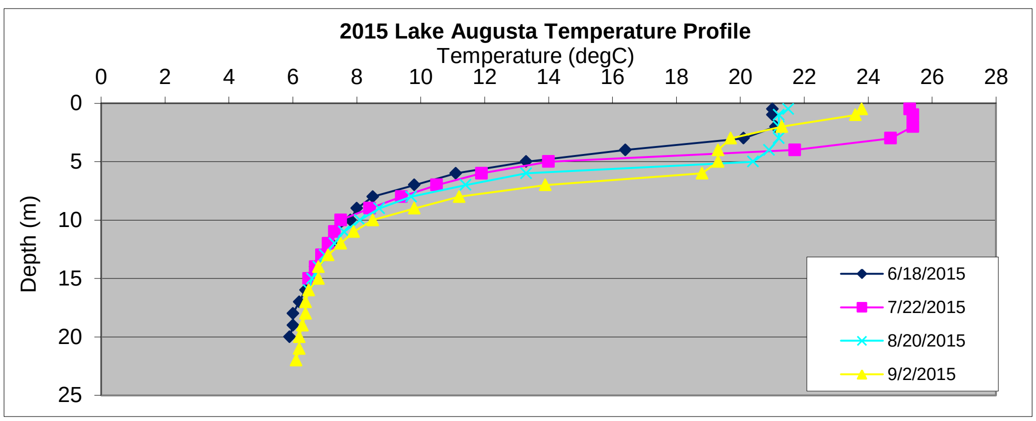


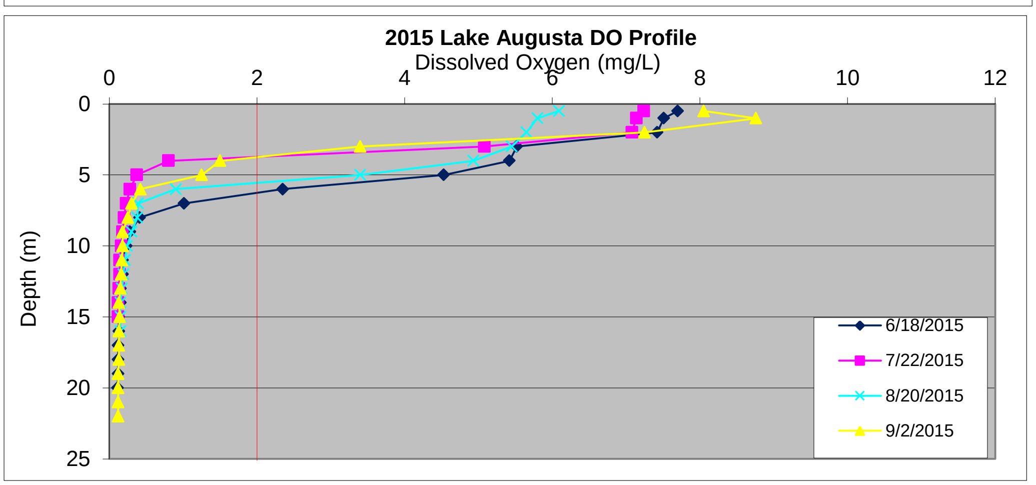


CRWD 2015 Water Quality Report
Appendix E-Lake Phosphorus









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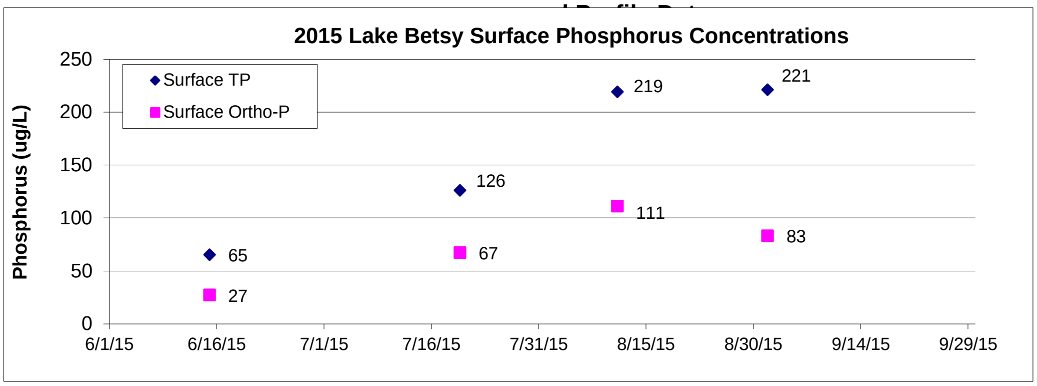
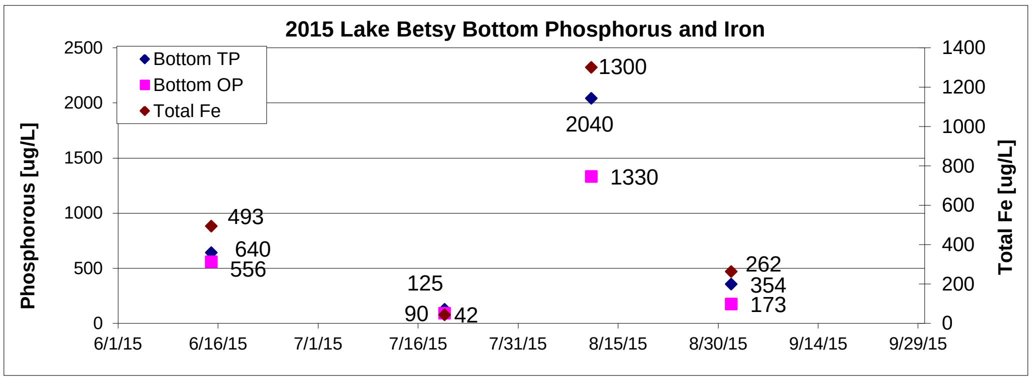
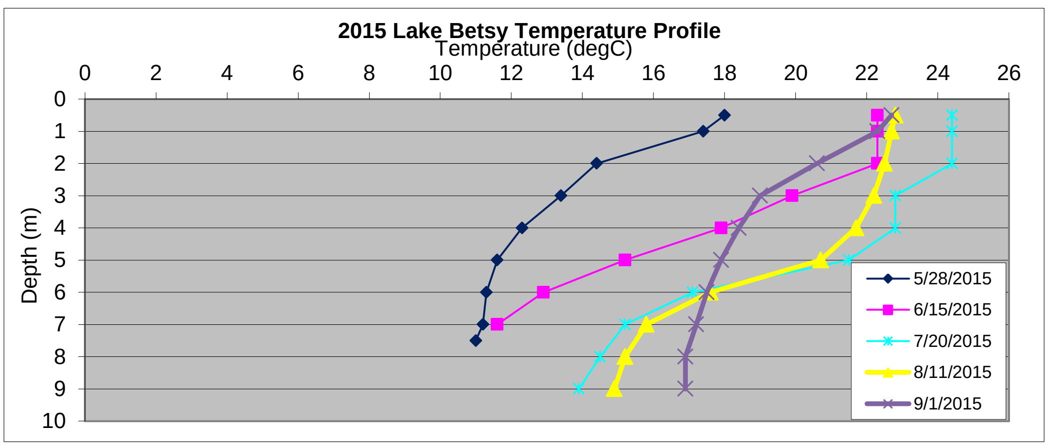
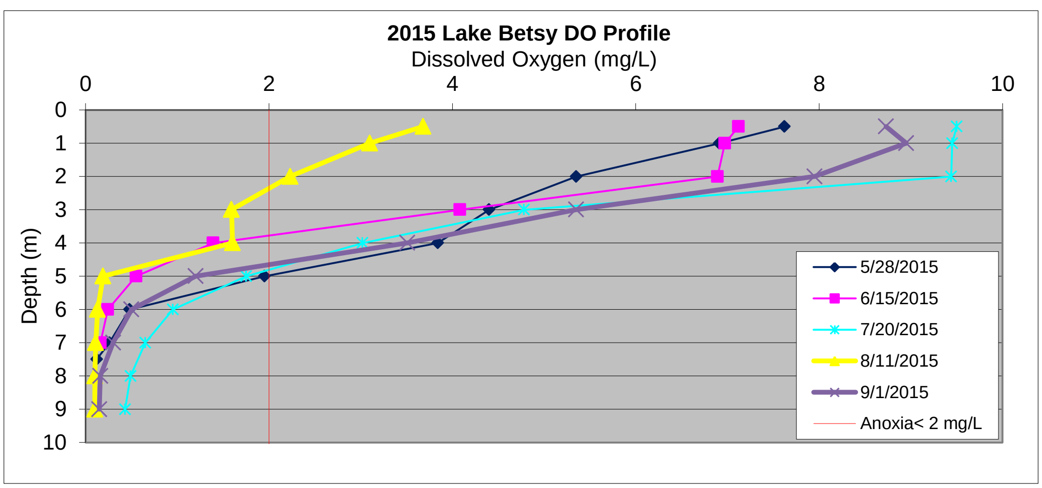
CRWD 2015 Water Quality Report
Appendix E-Lake Phosphorus

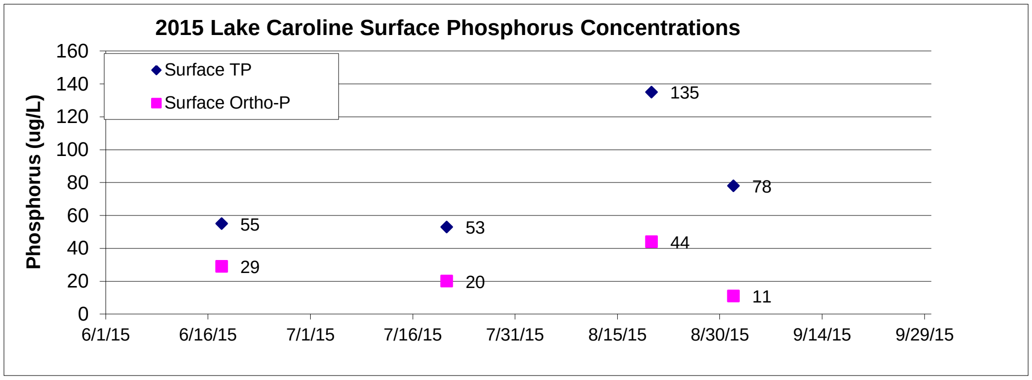


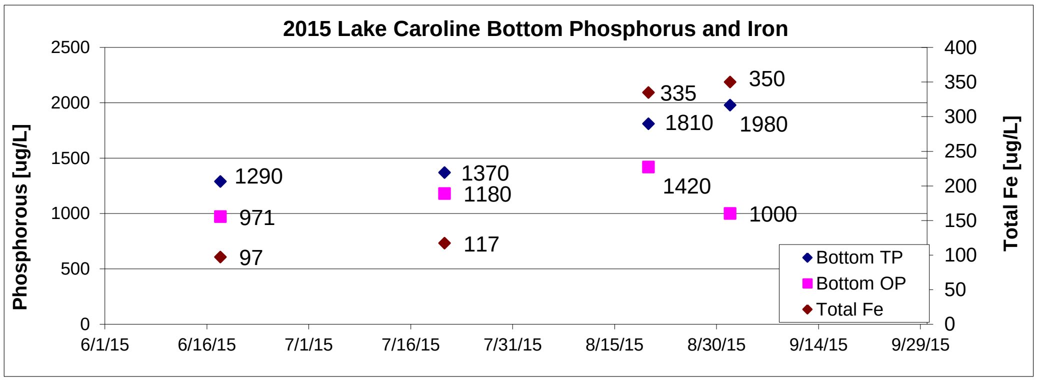


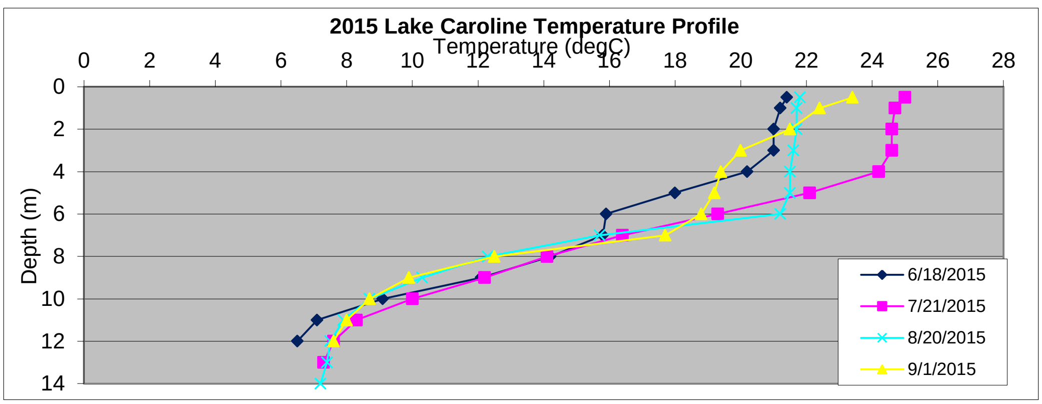


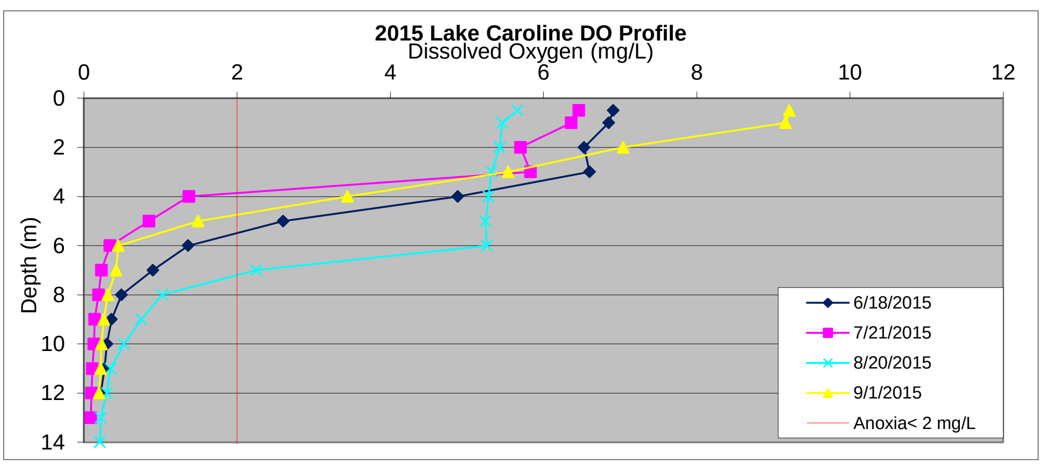


CRWD 2015 Water Quality Report
Appendix E-Lake Phosphorus and Profile Data









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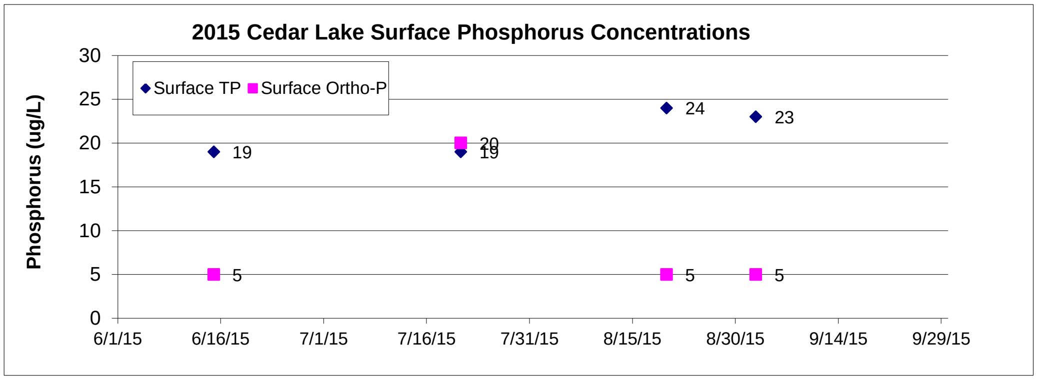
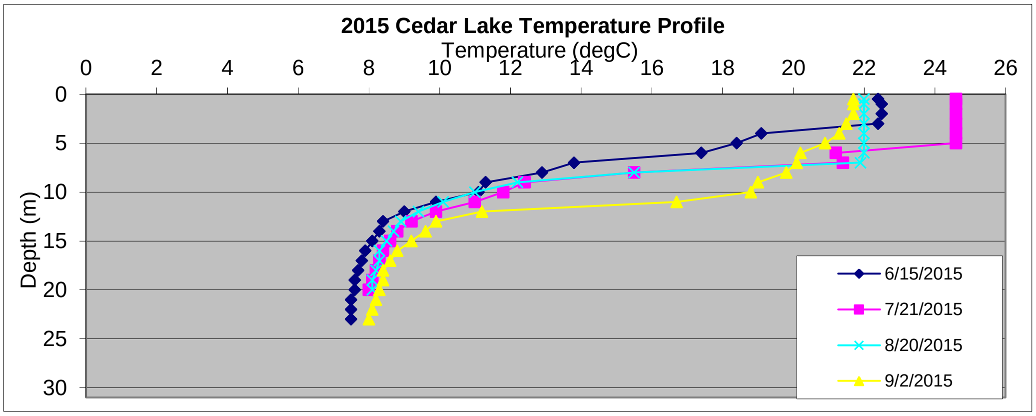
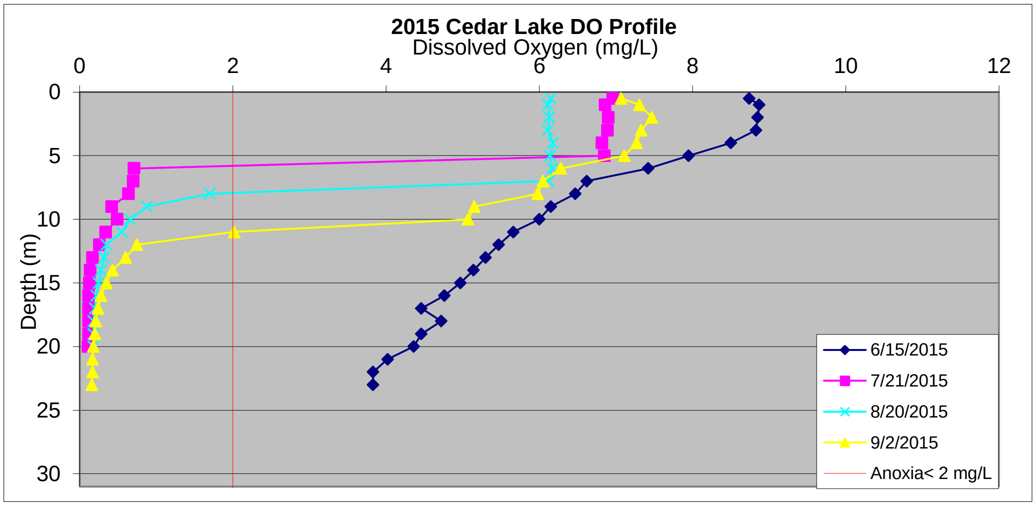
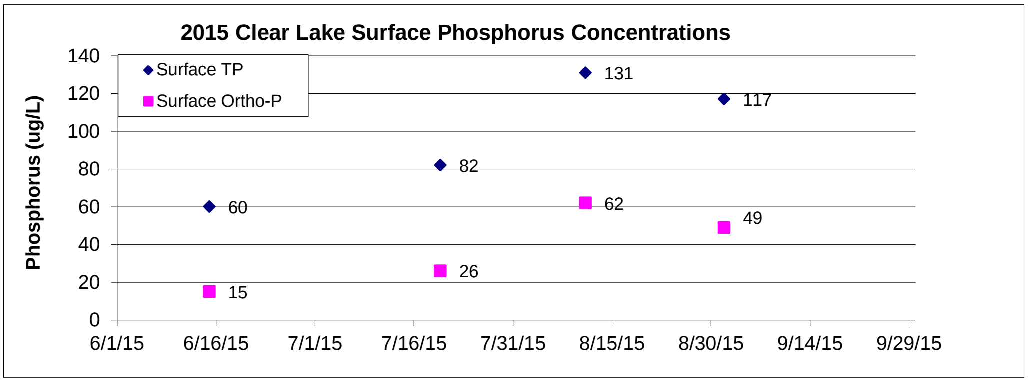
CRWD 2015 Water Quality Report
Appendix E-Lake Phosphorus
and Profile Data

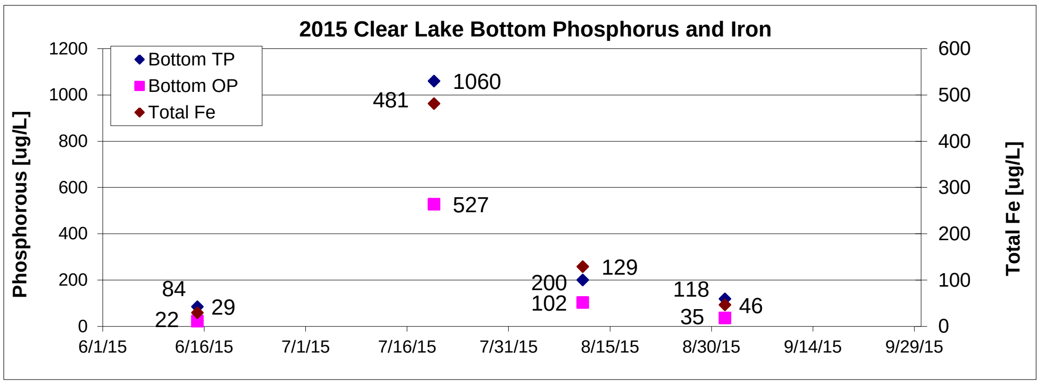


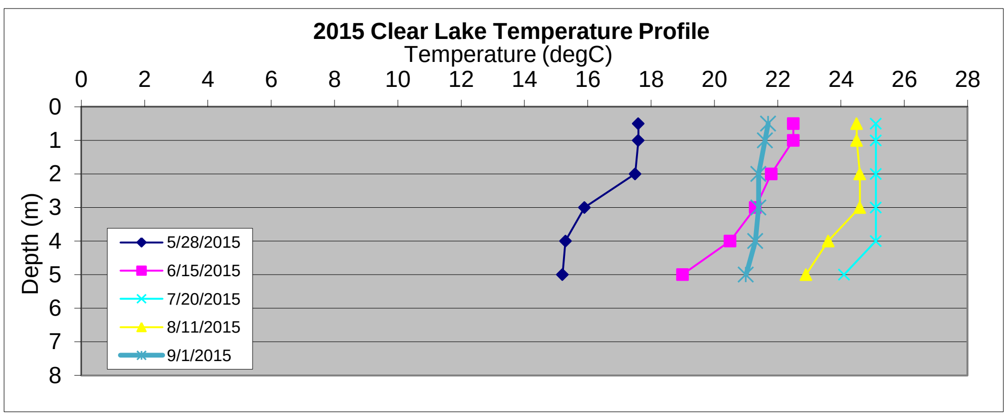


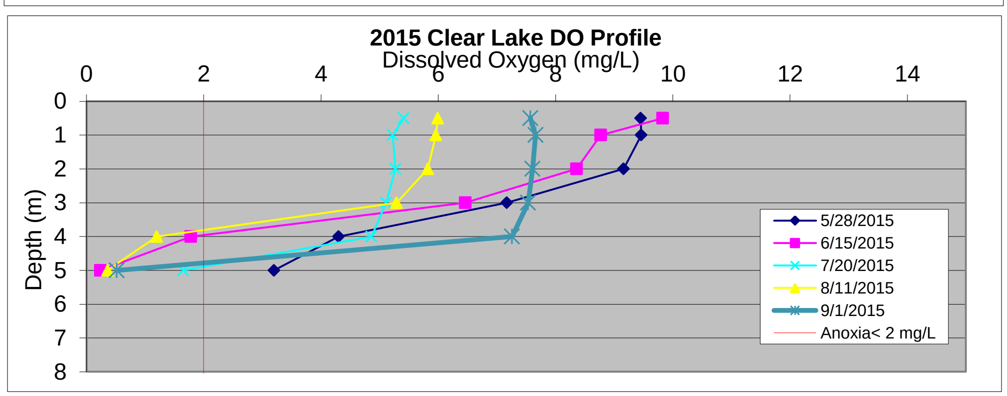


CRWD 2015 Water Quality Report
Appendix E-Lake Phosphorus
and Profile Data

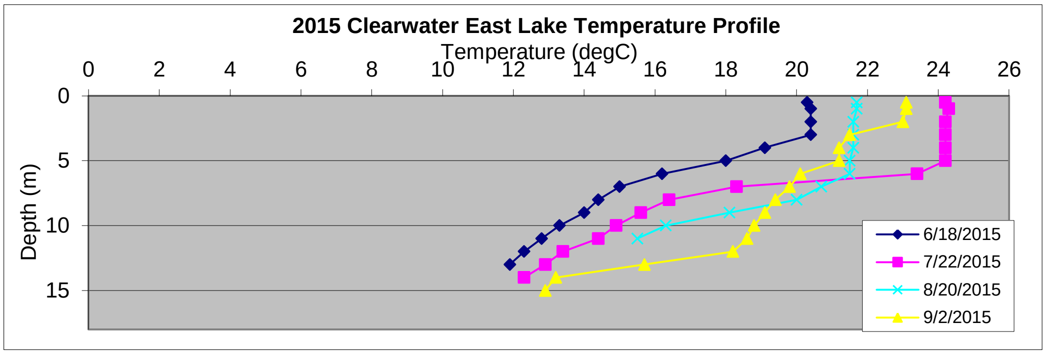


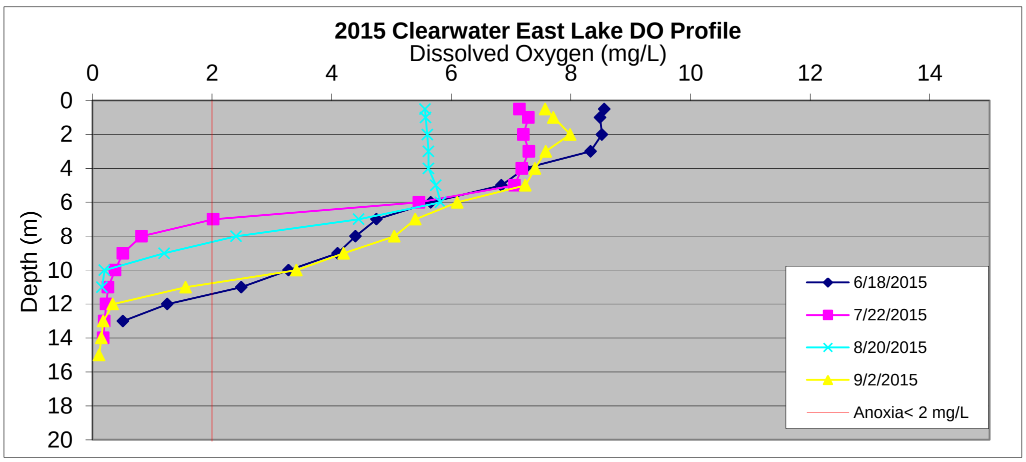






CRWD 2015 Water Quality Report
Appendix E-Lake Phosphorus
and Profile Data





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Appendix E-Lake Phosphorus
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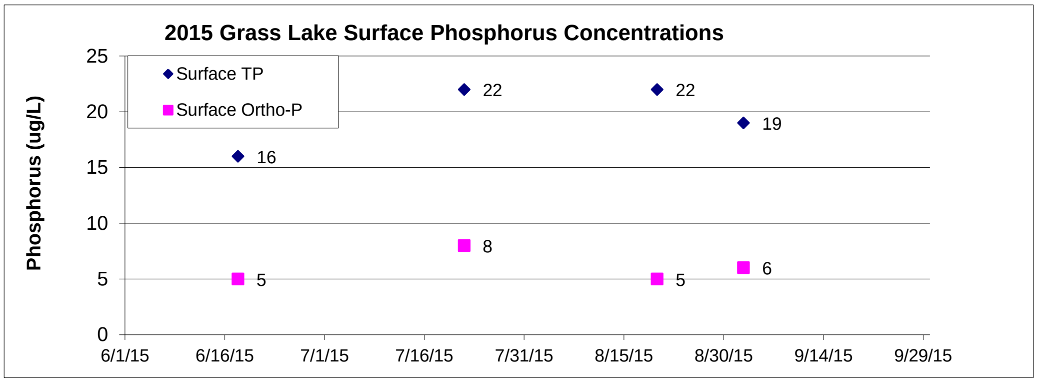

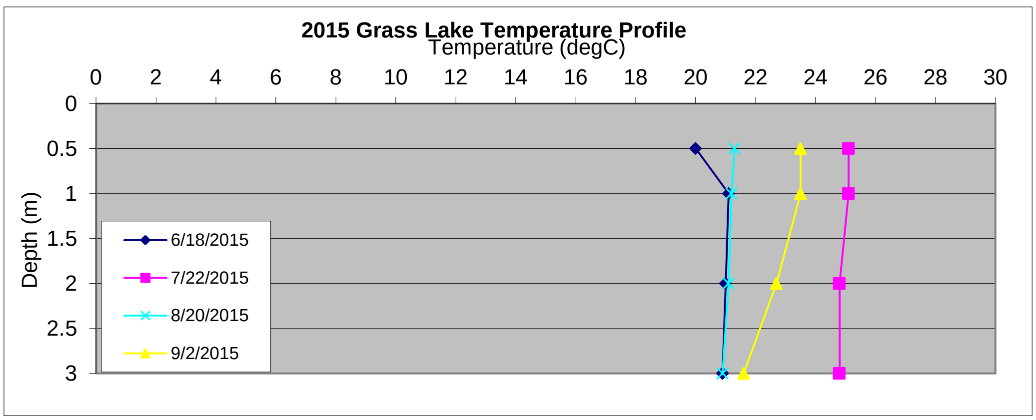

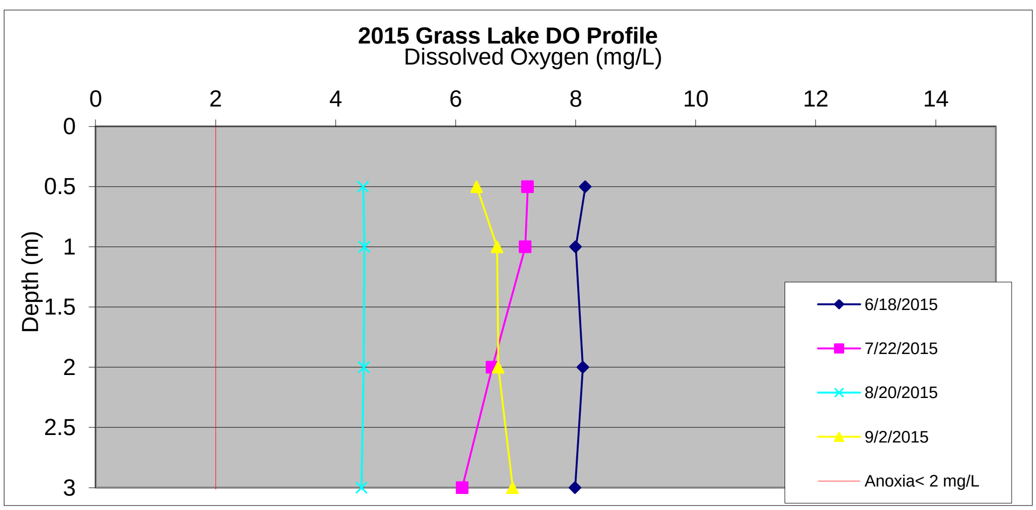

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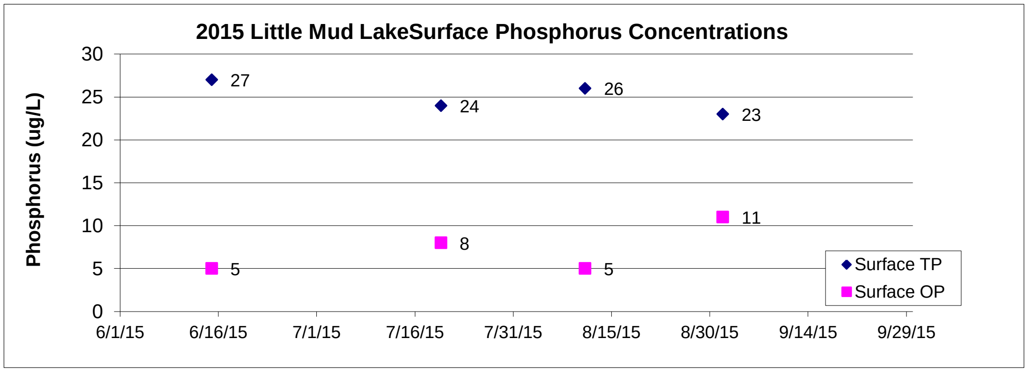

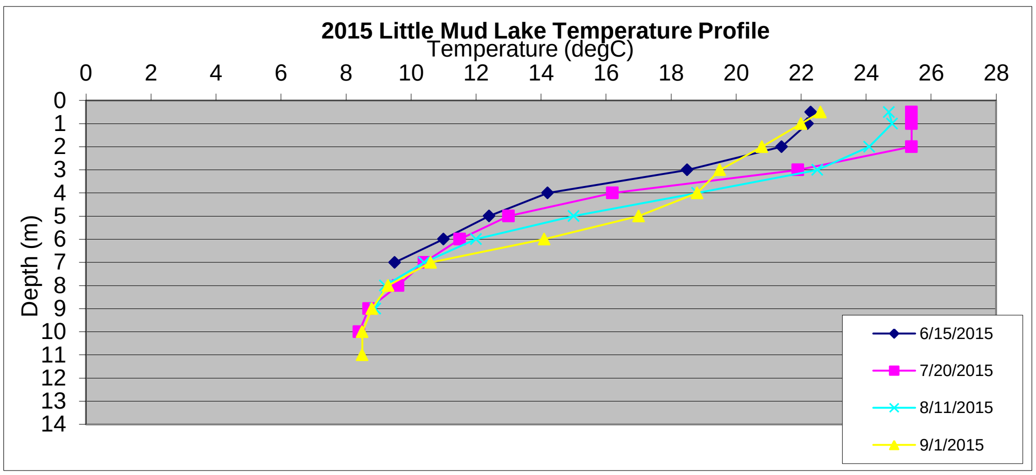

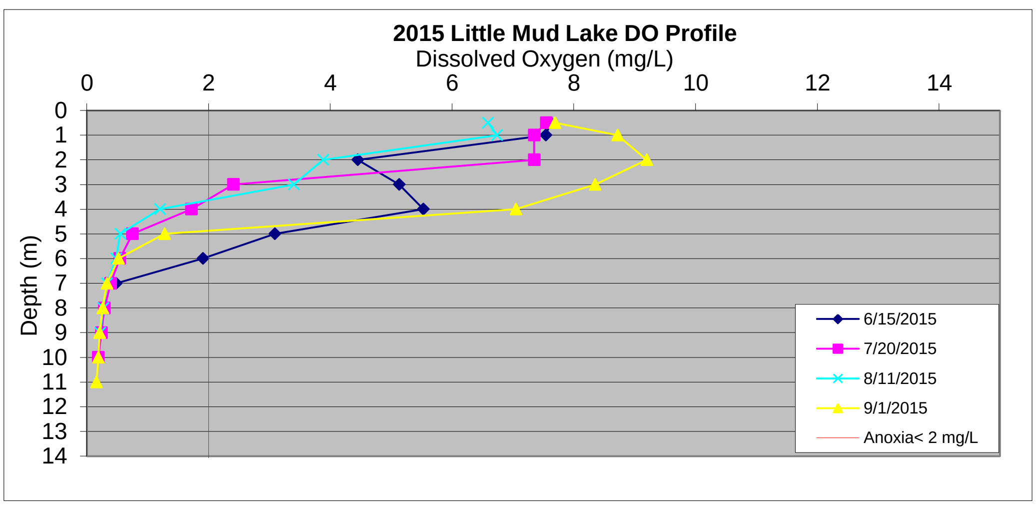

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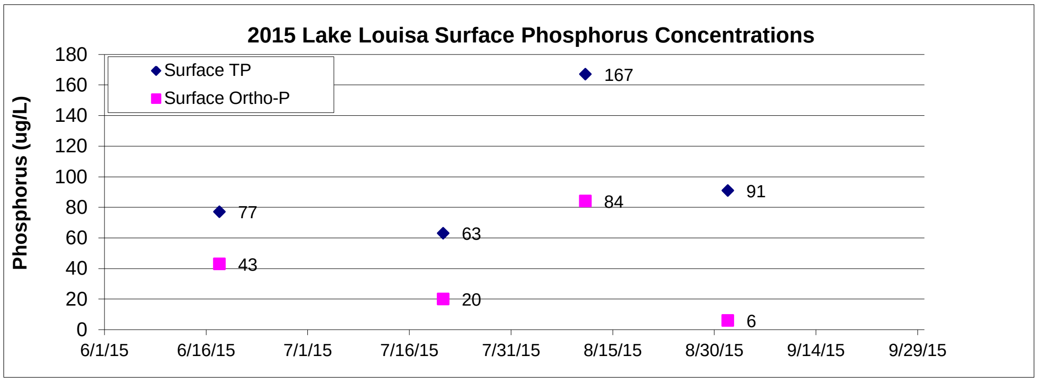

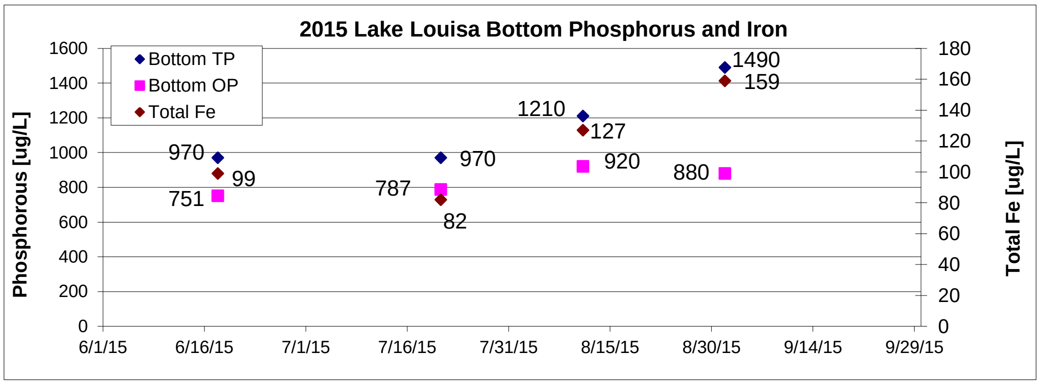

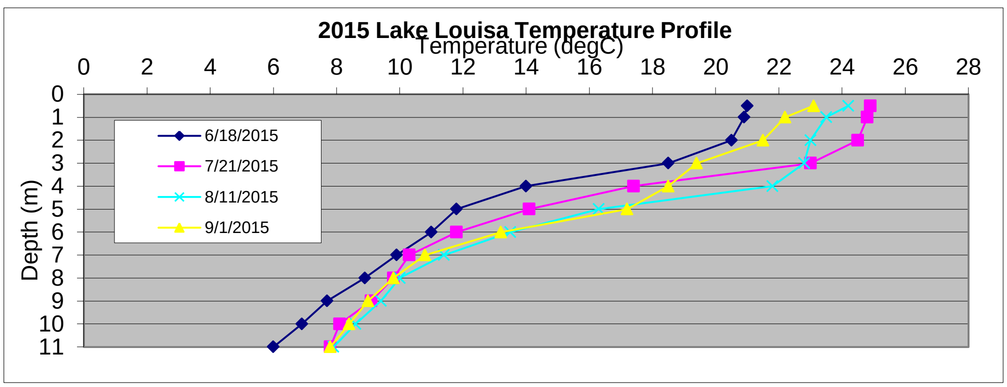

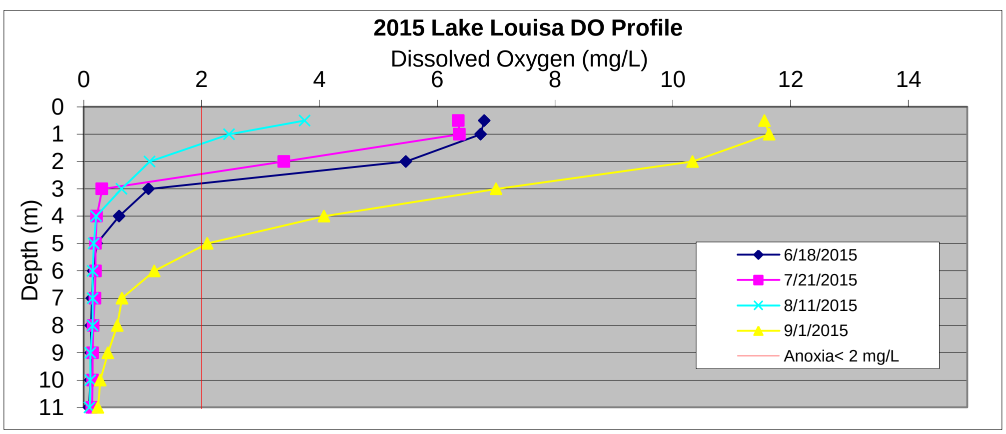

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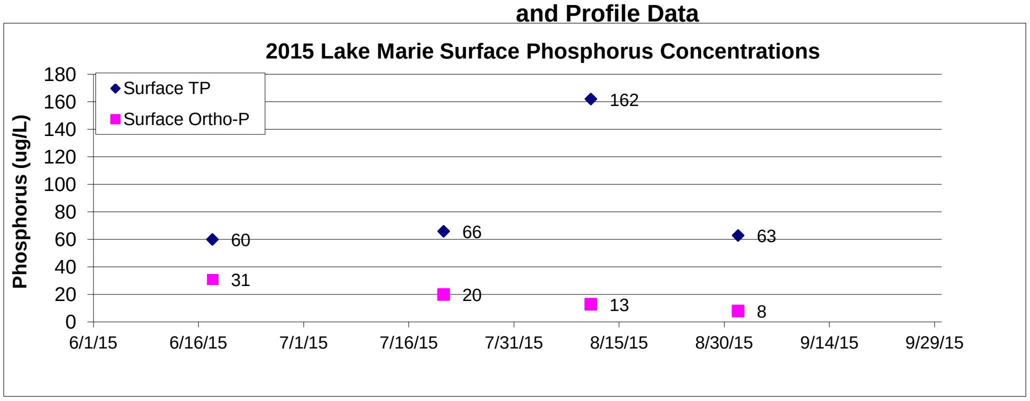

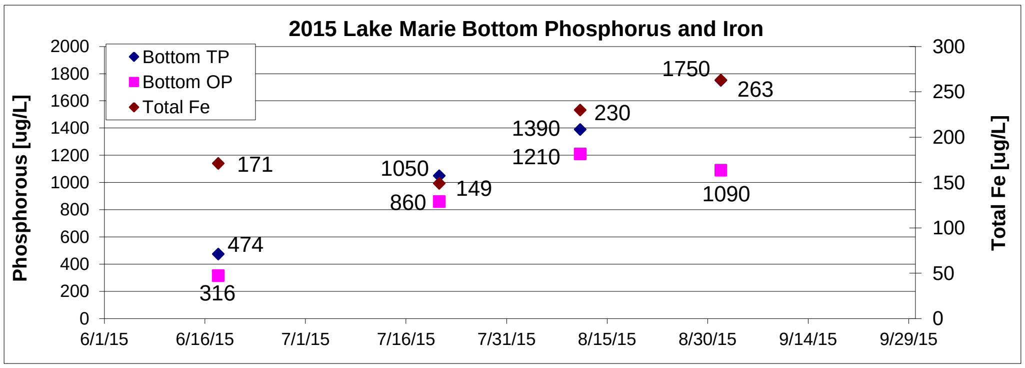

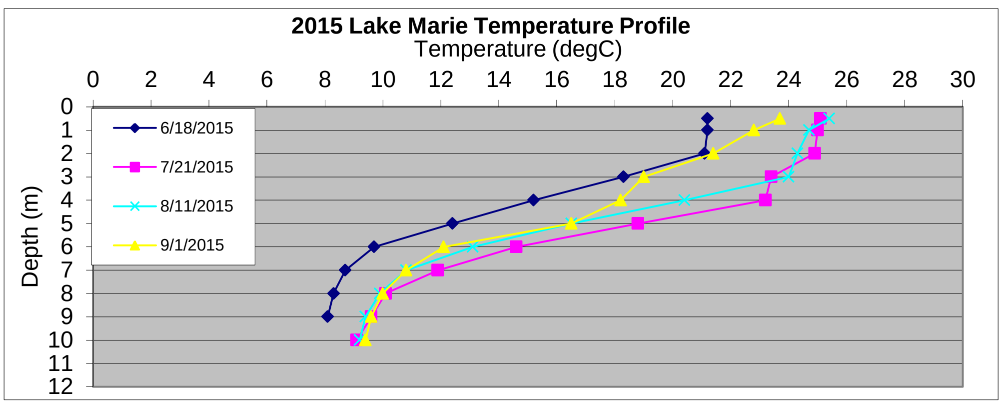

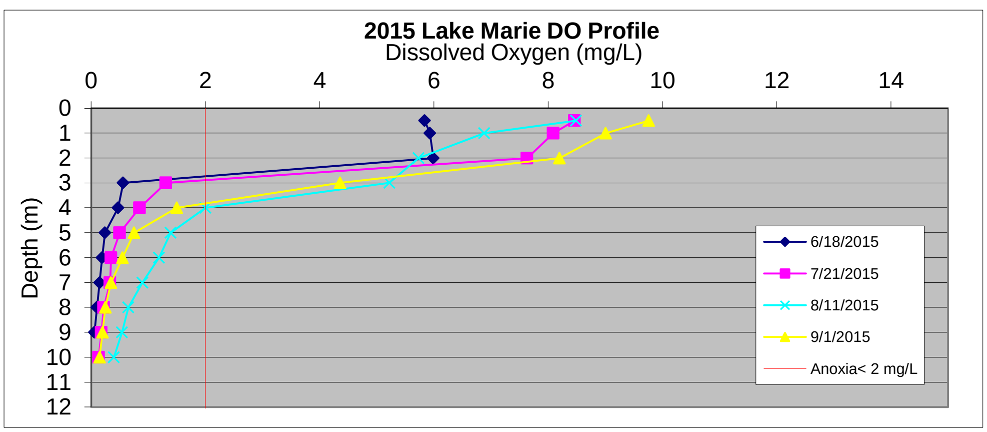

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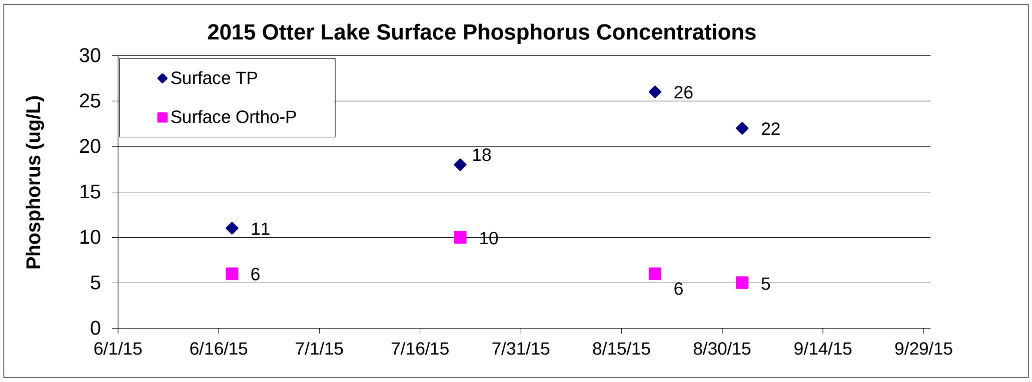

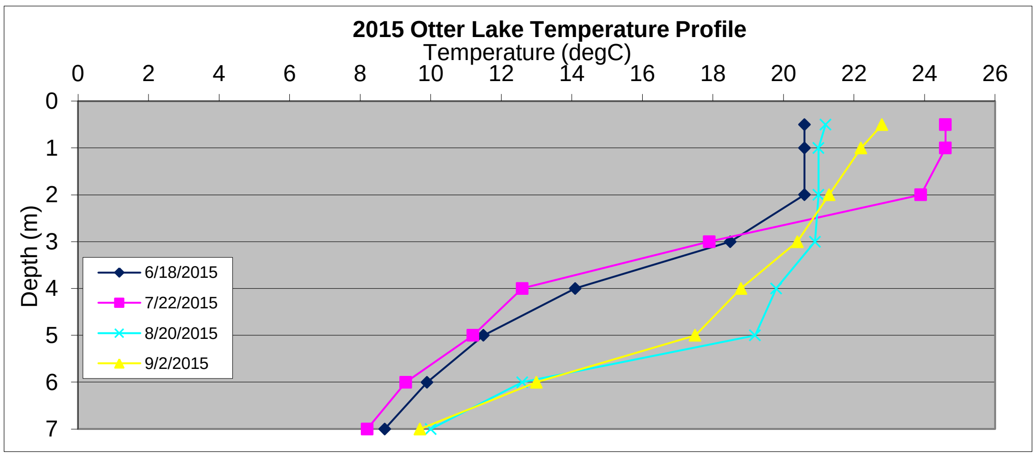

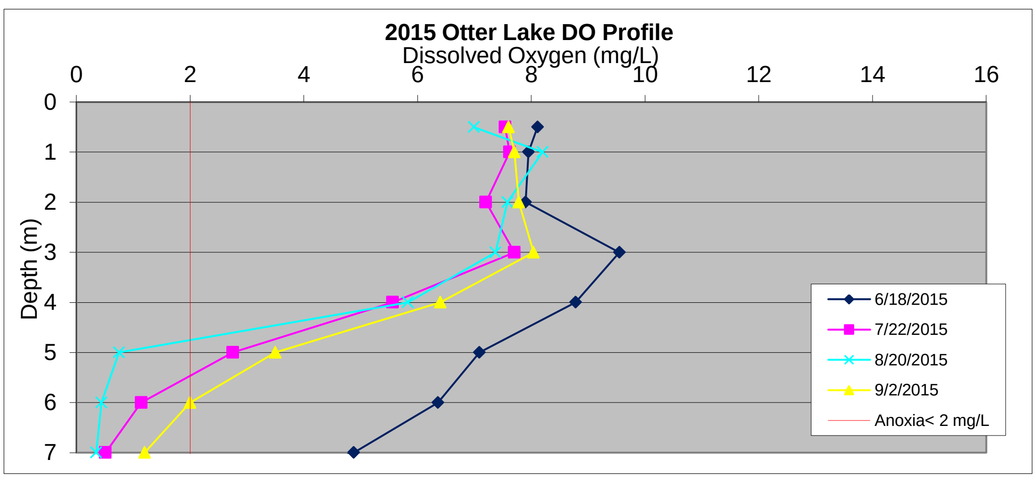

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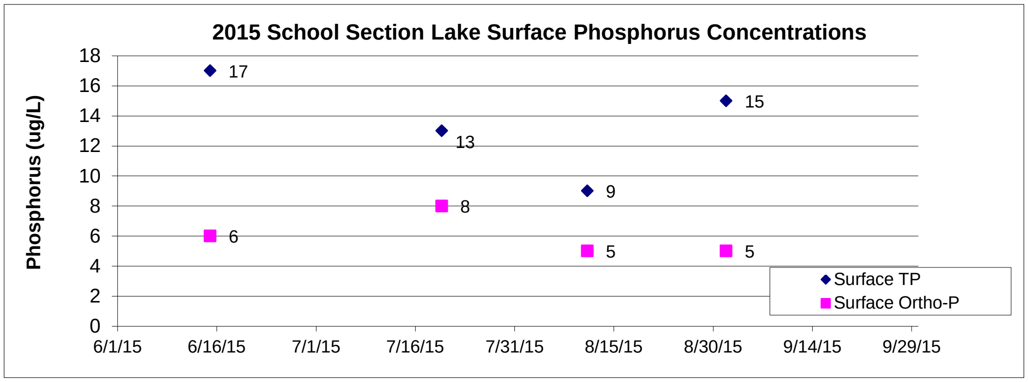

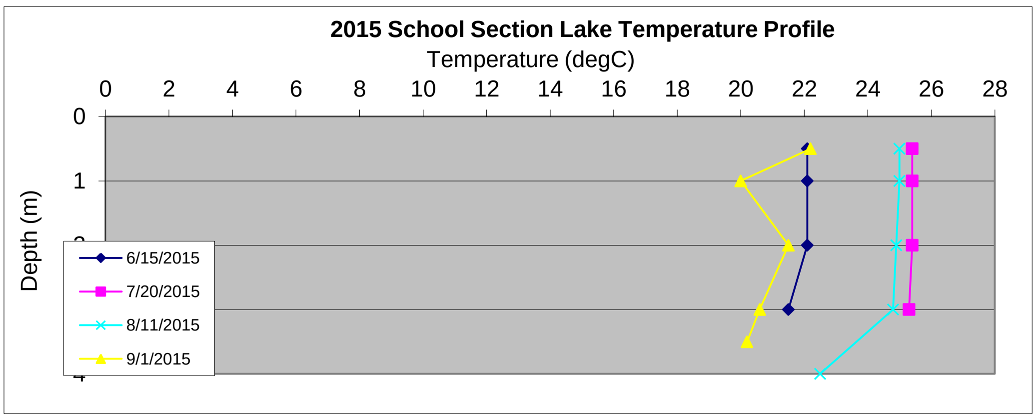

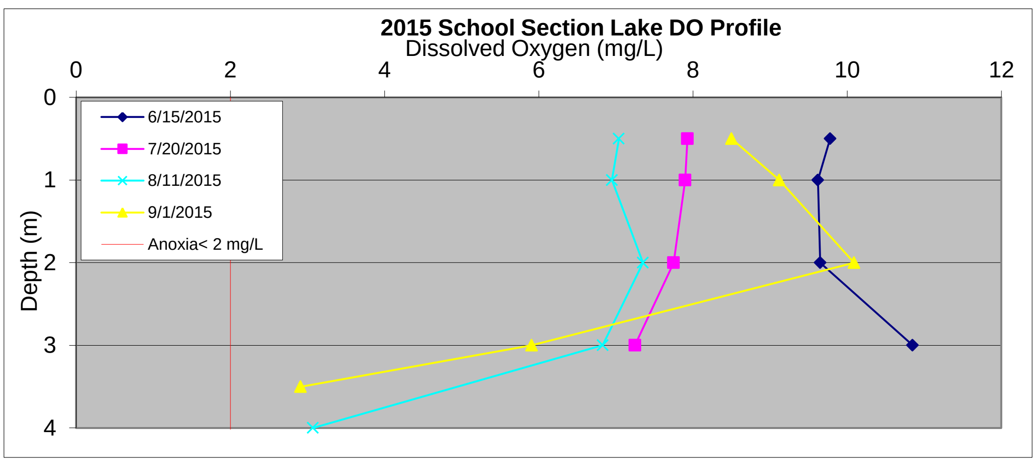

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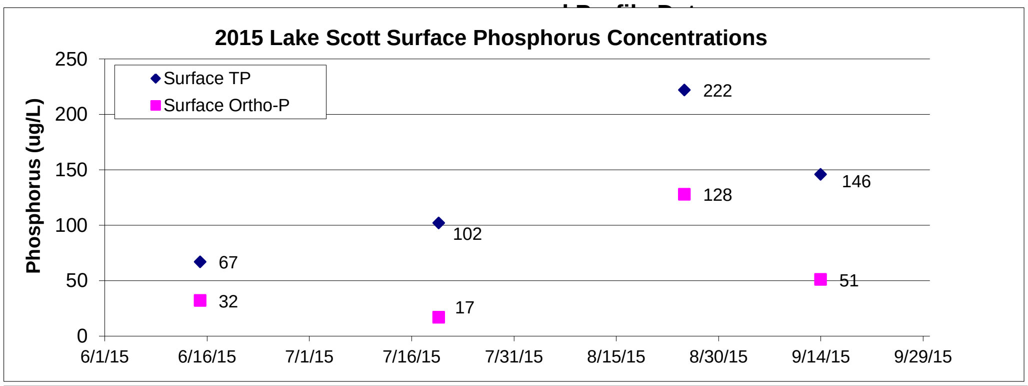
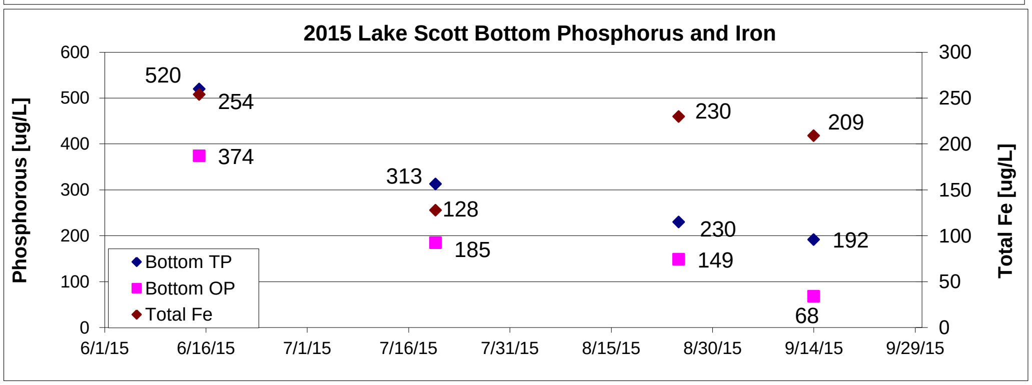
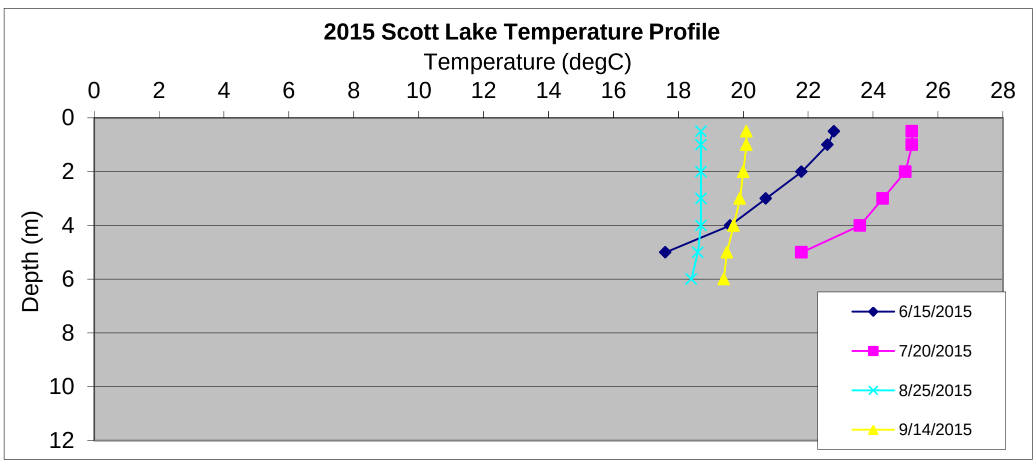
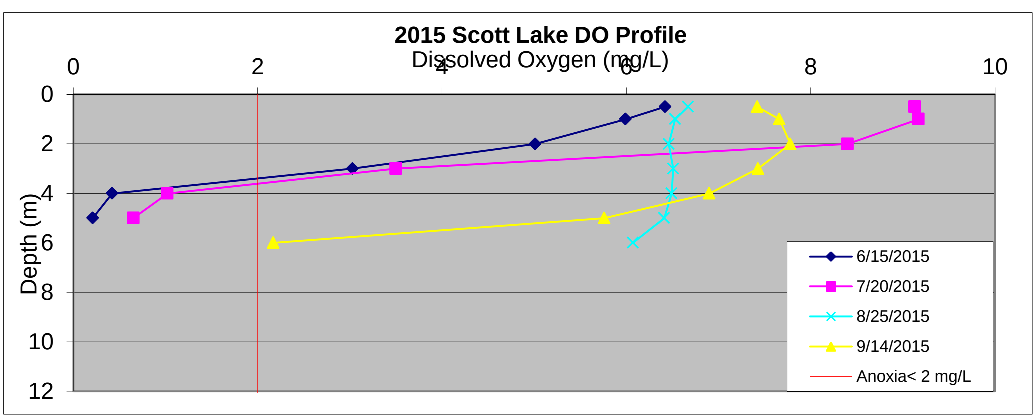
Appendix E-Lake Phosphorus









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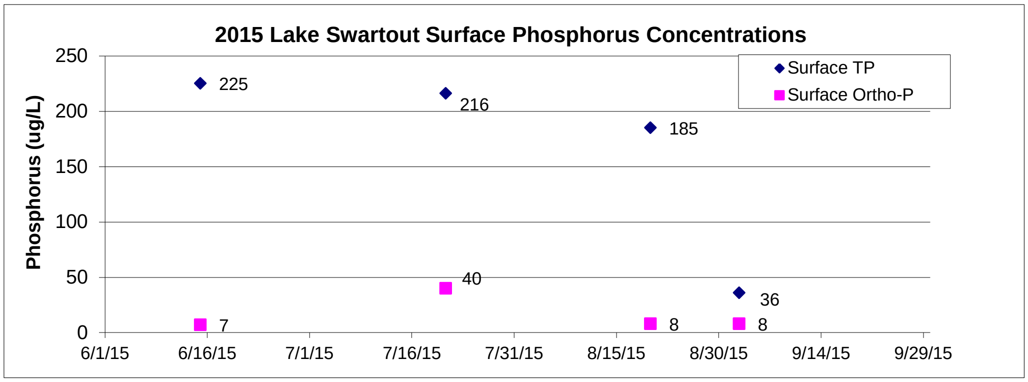

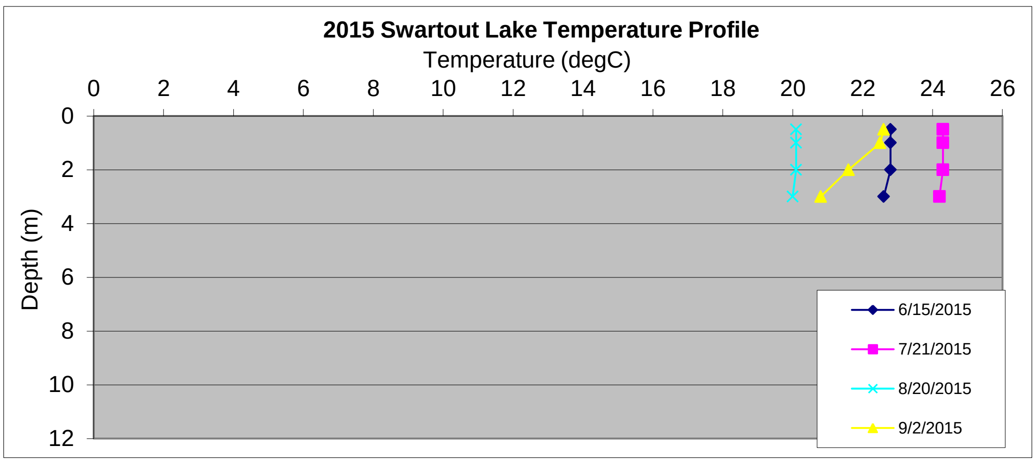

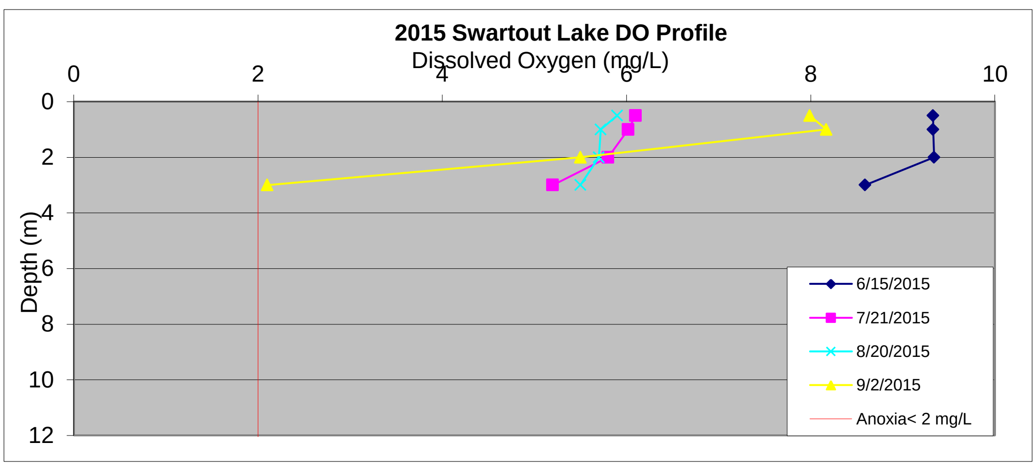

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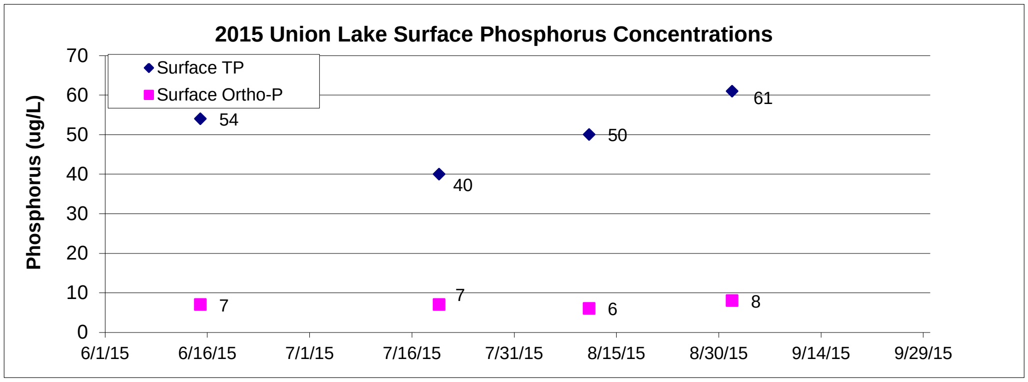

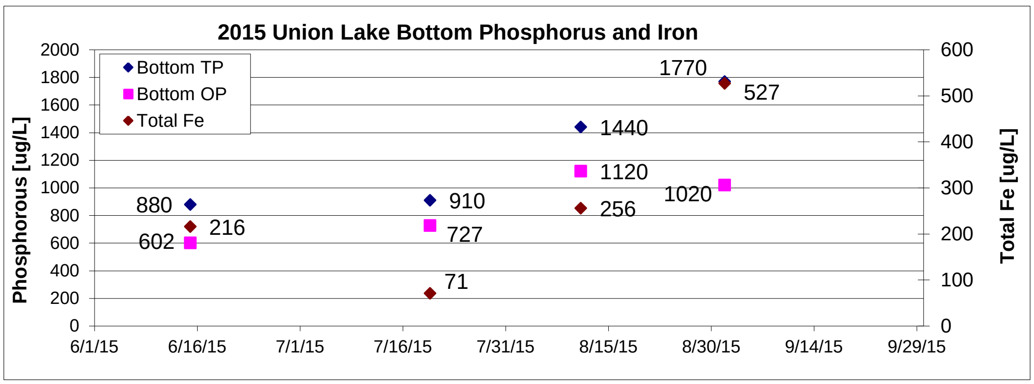

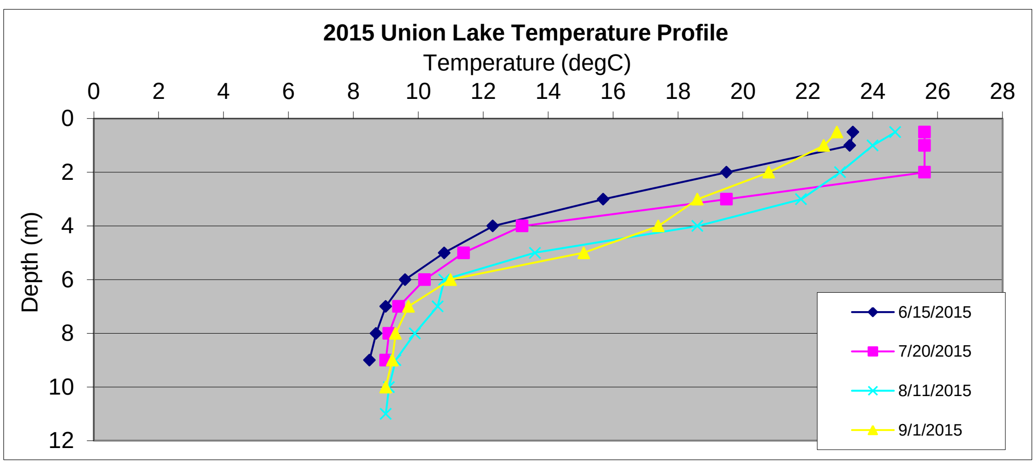

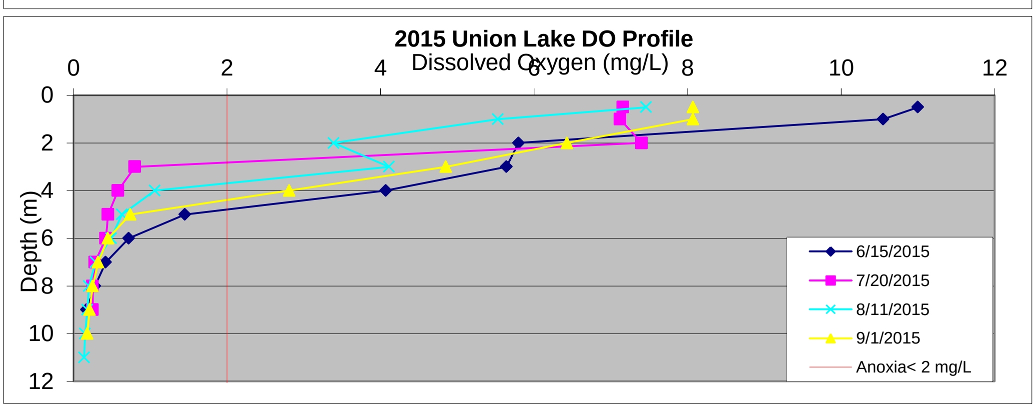

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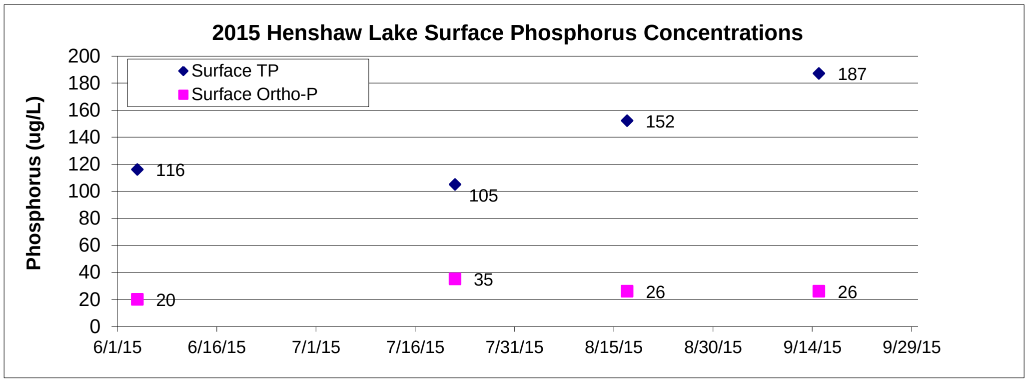

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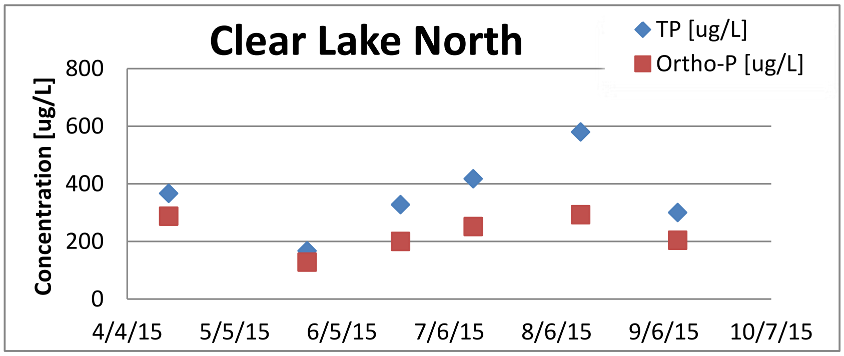

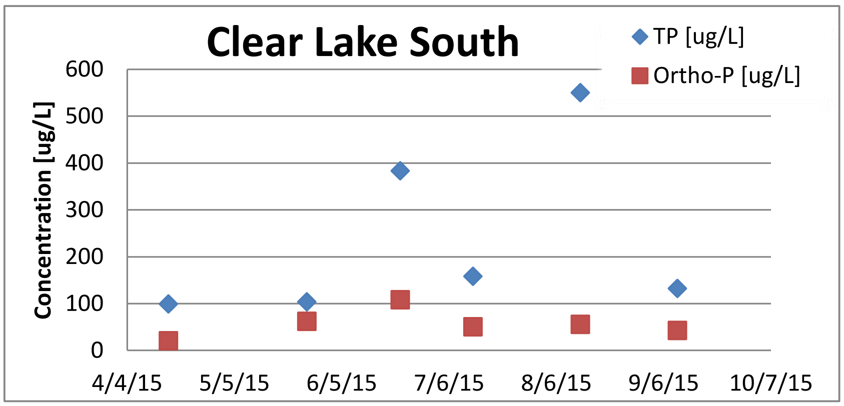

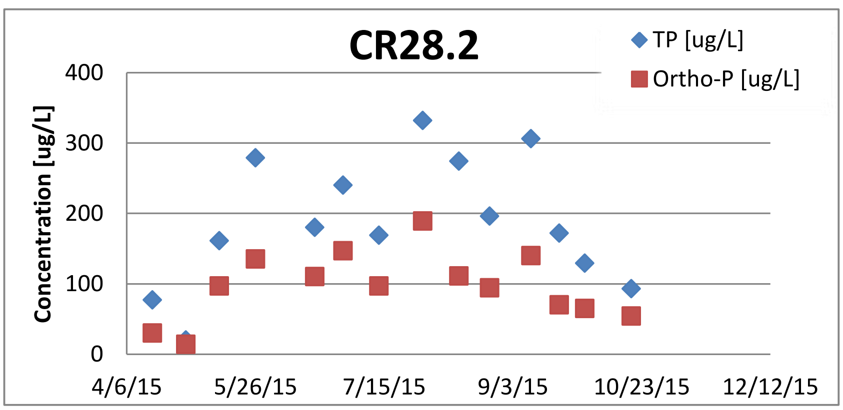

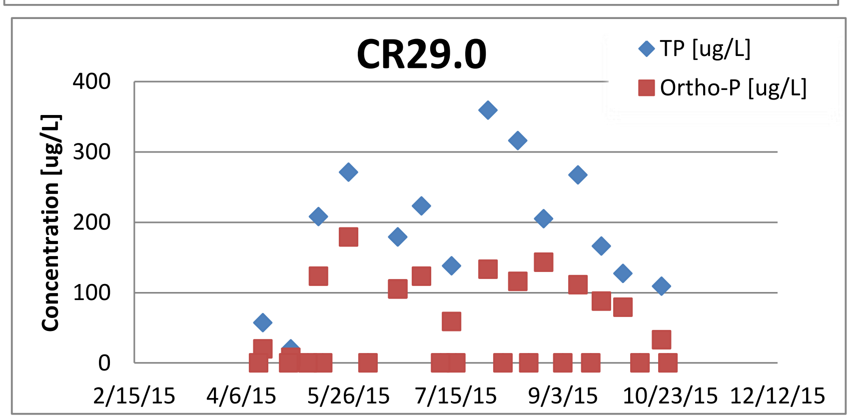

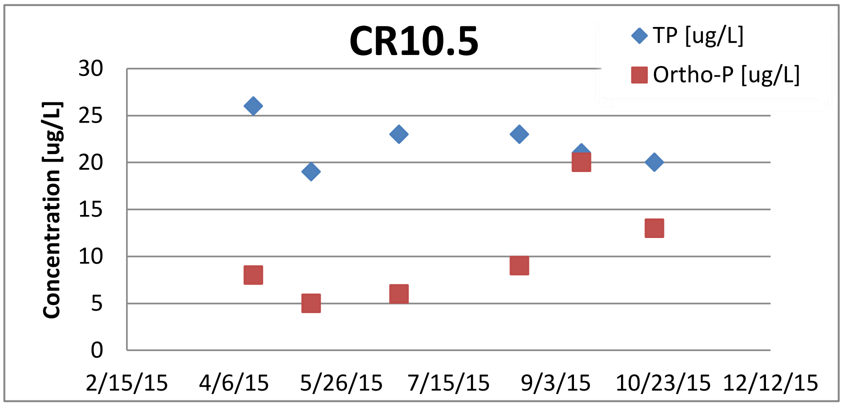
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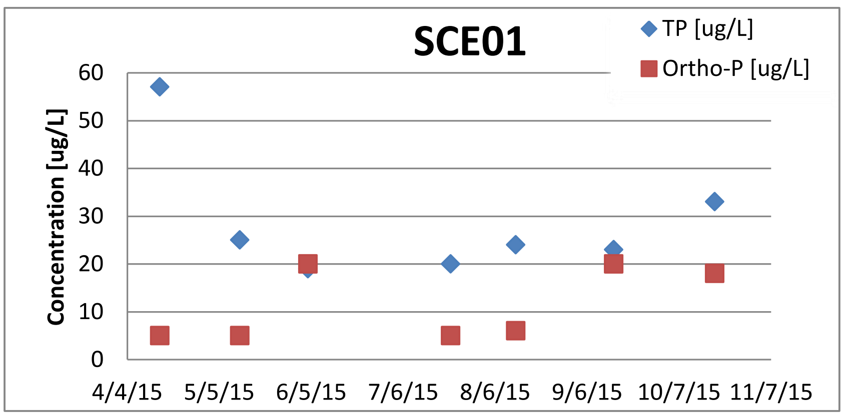
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50
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20
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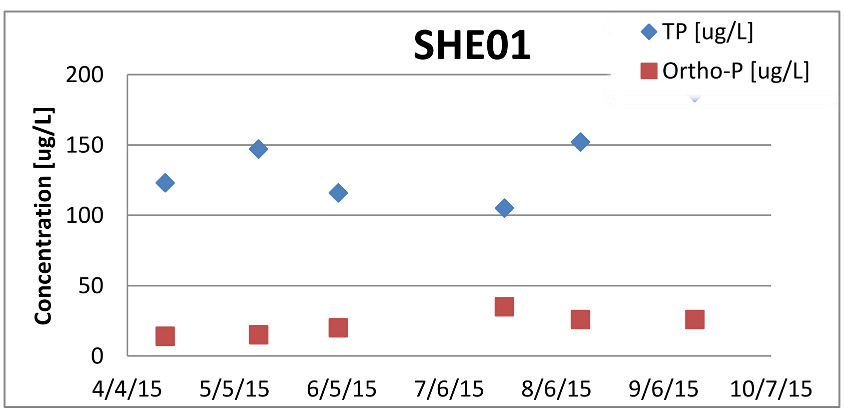
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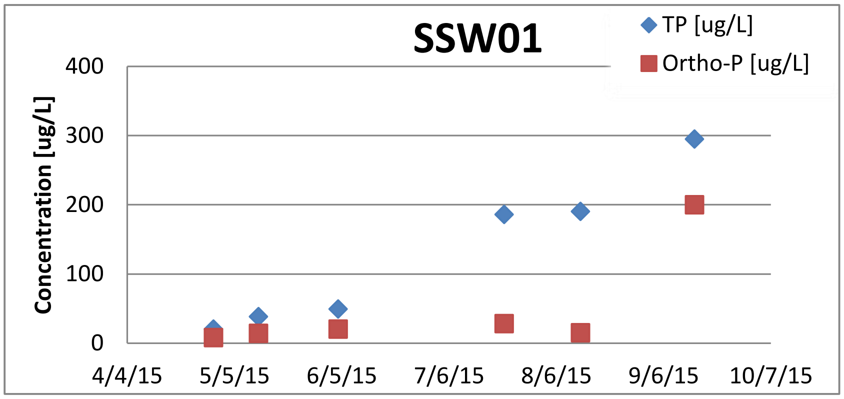

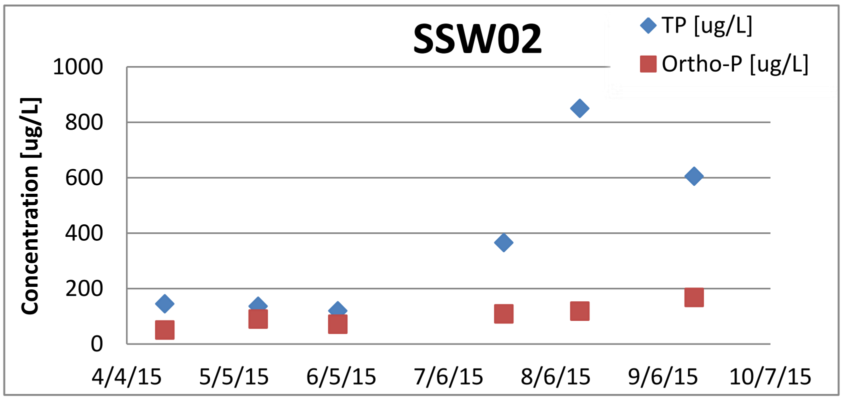

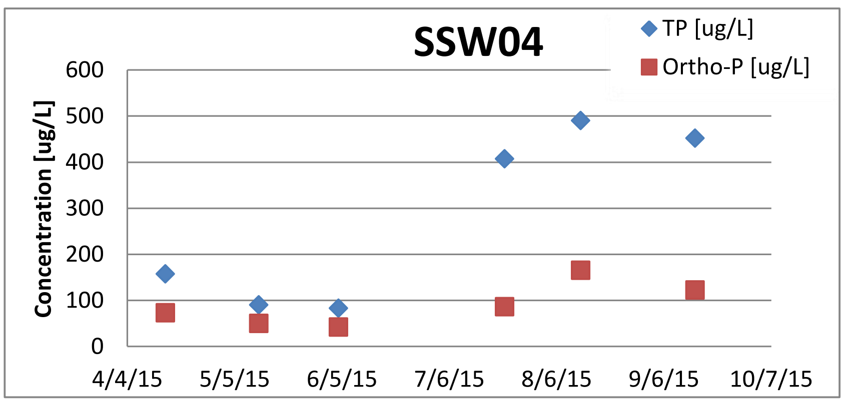

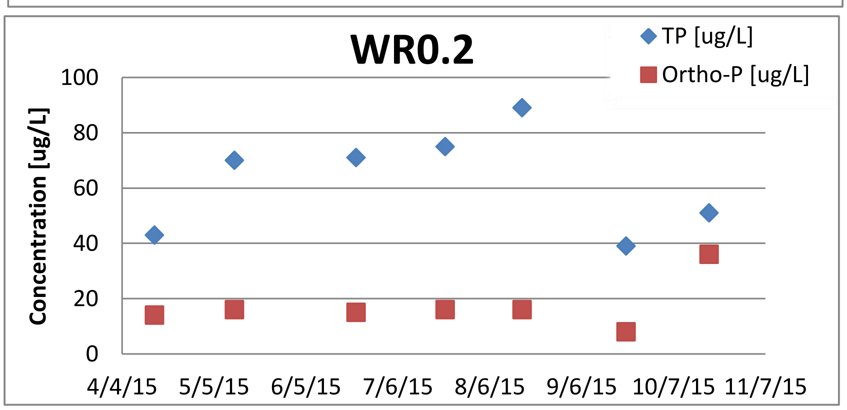

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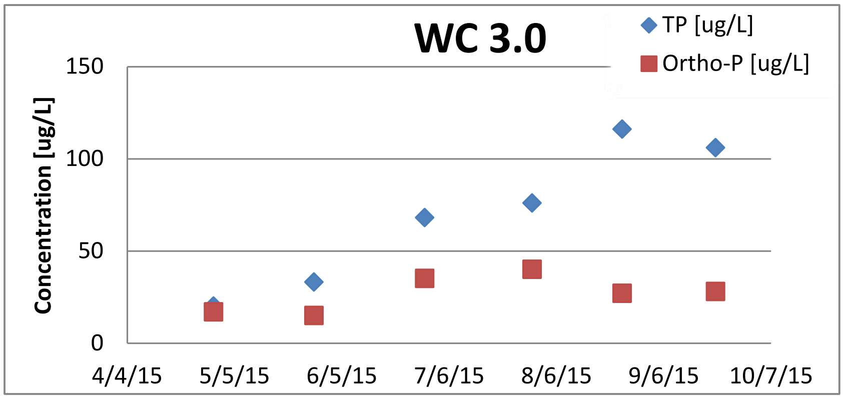

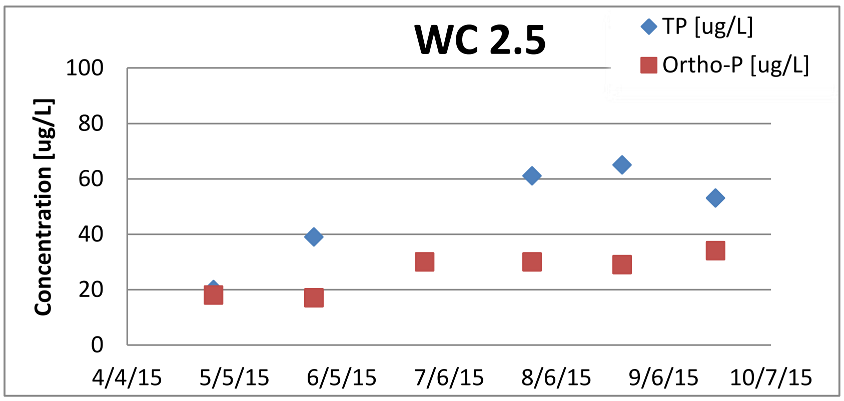

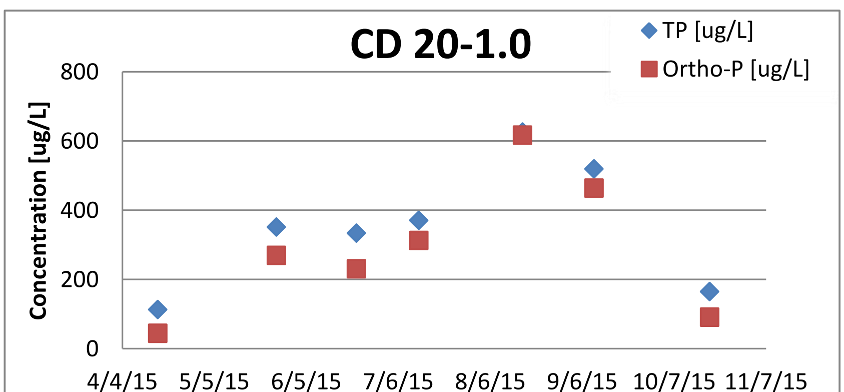

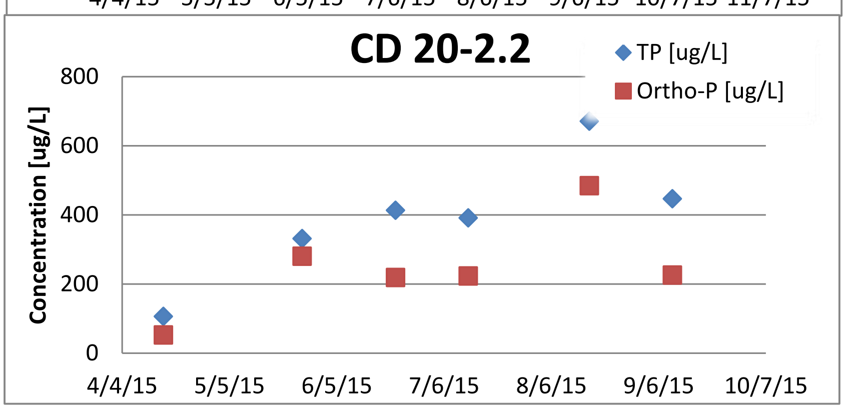

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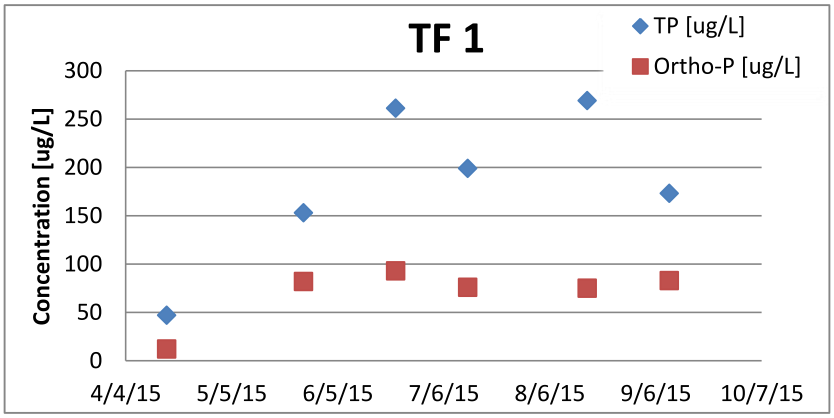

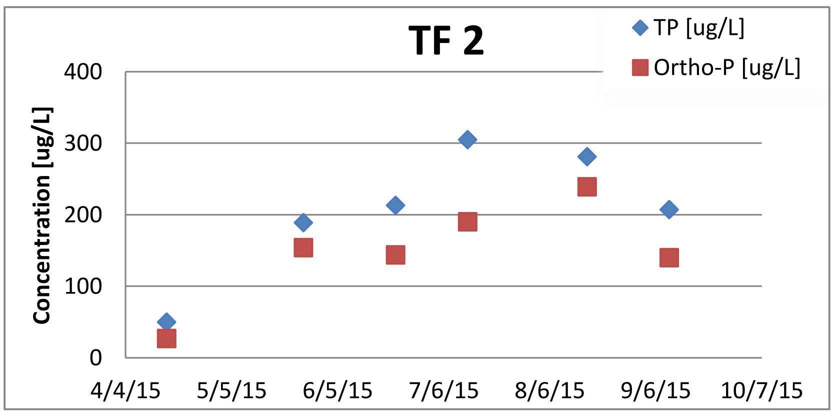

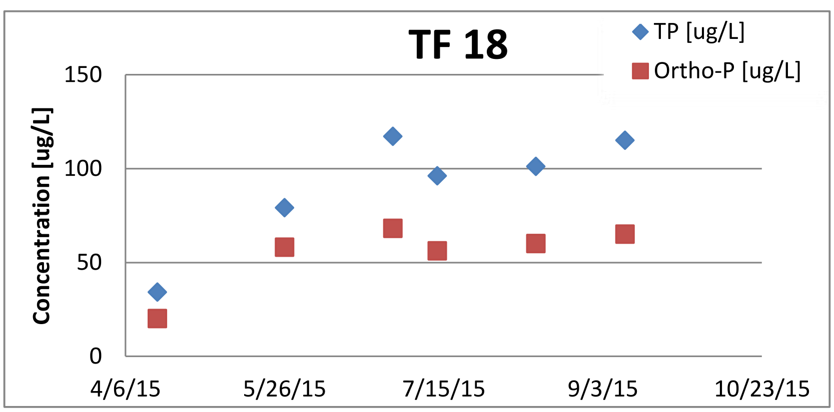

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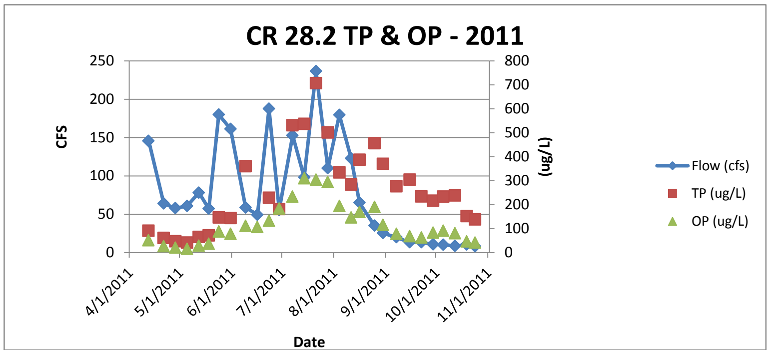

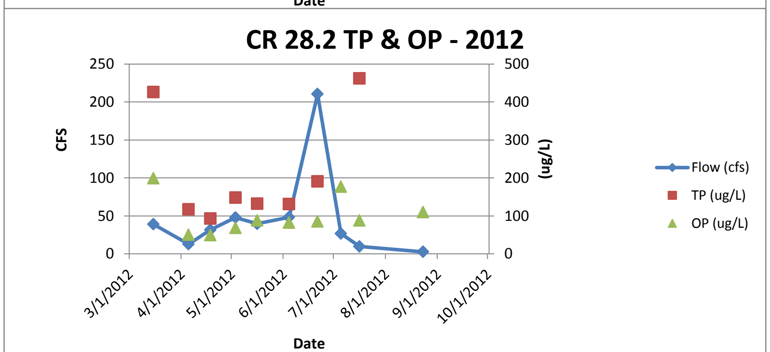

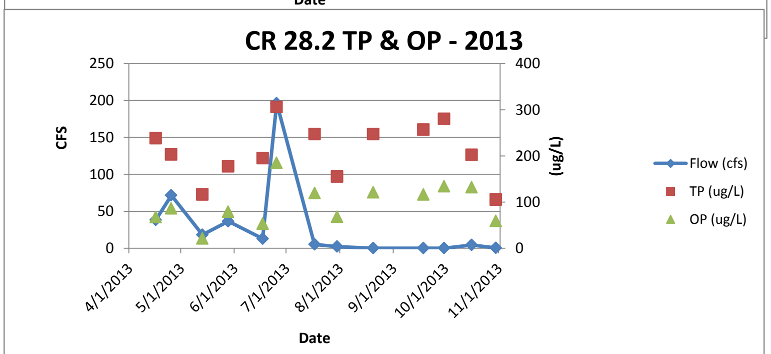

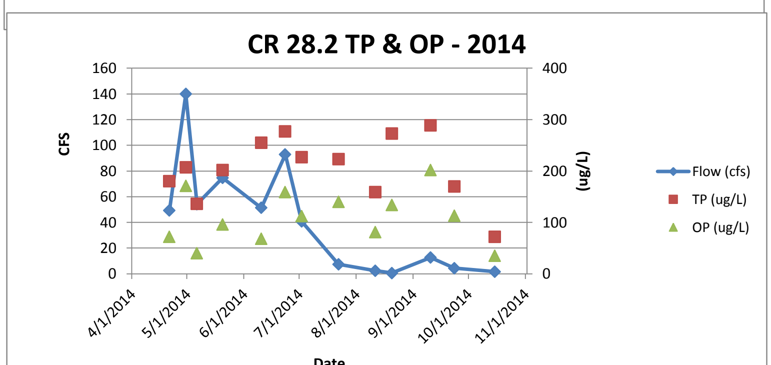

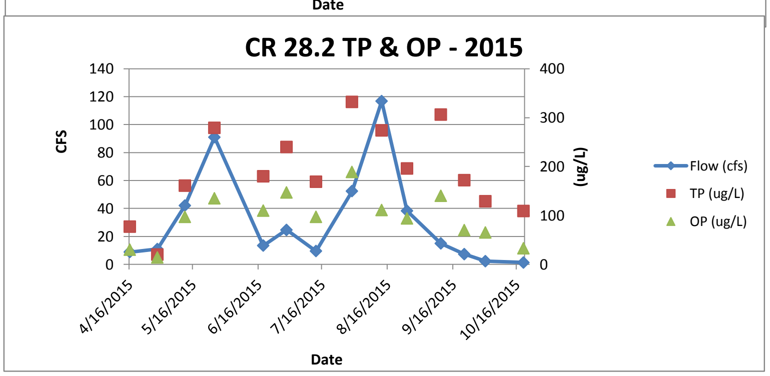

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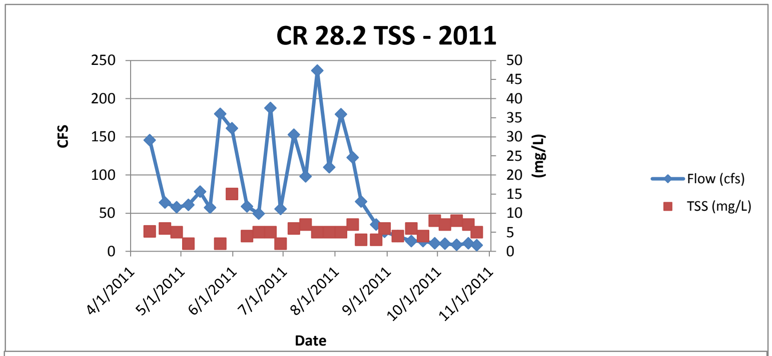

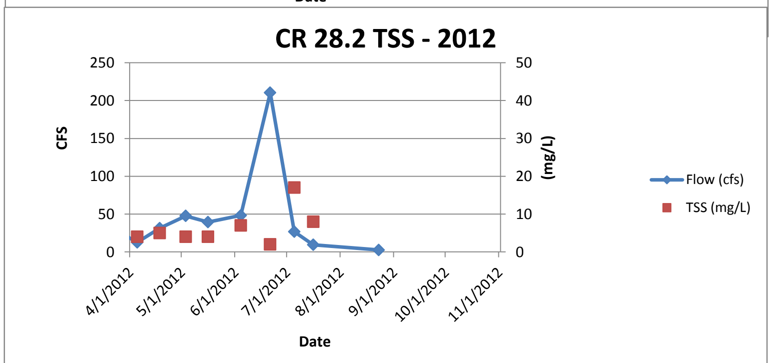

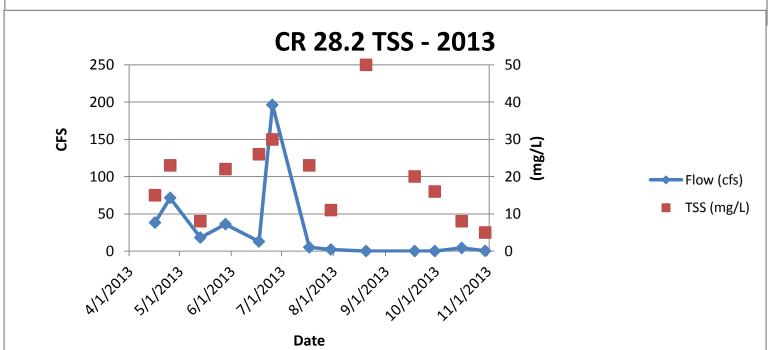

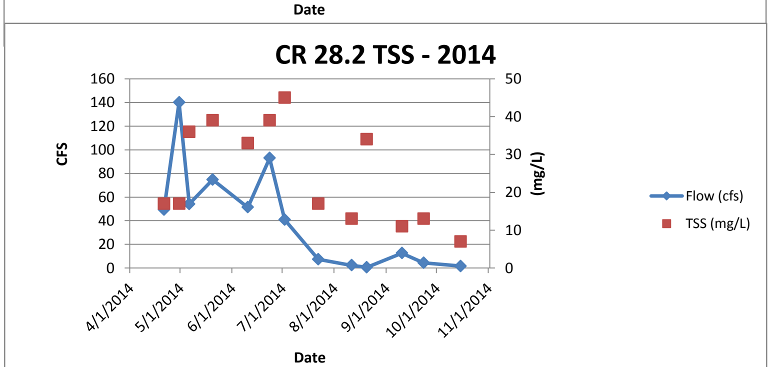

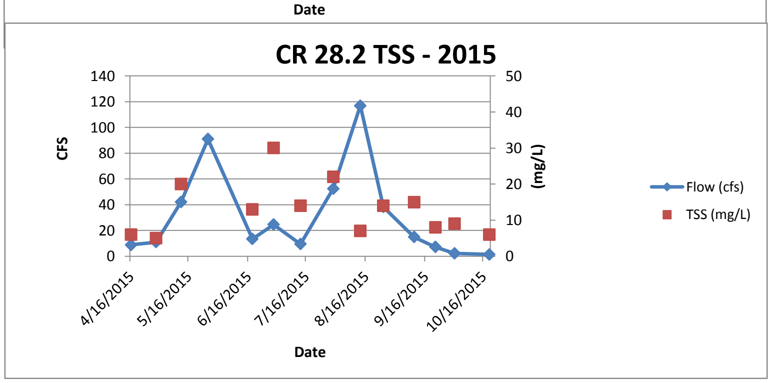

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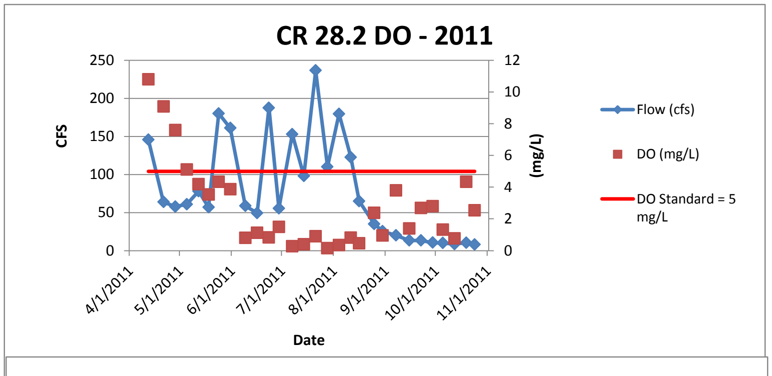

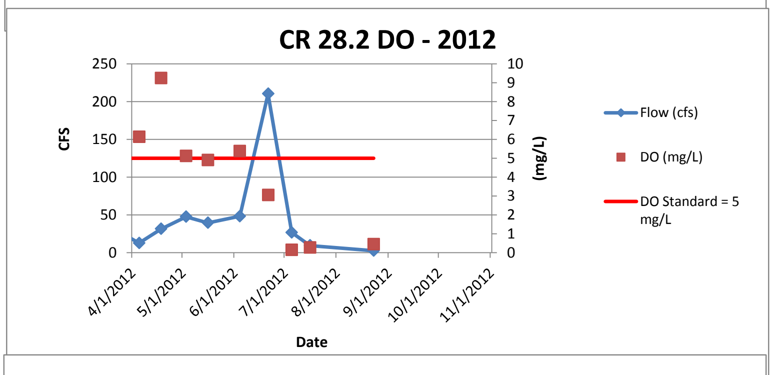

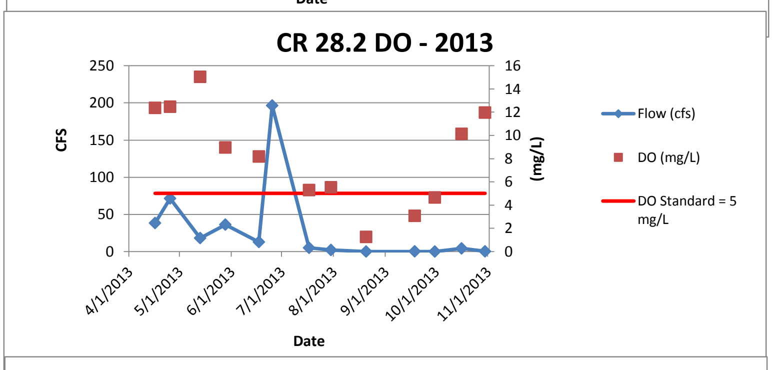

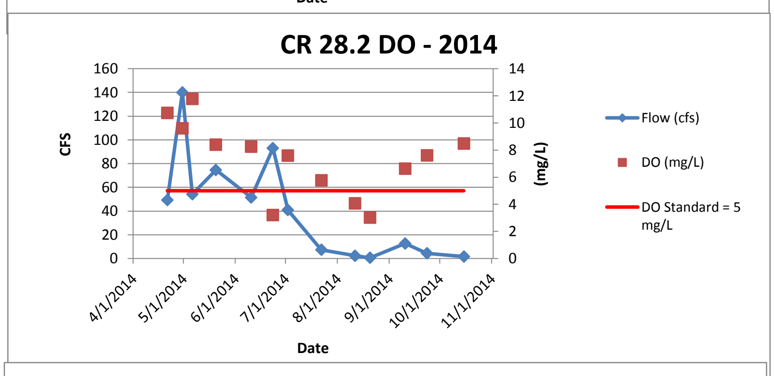

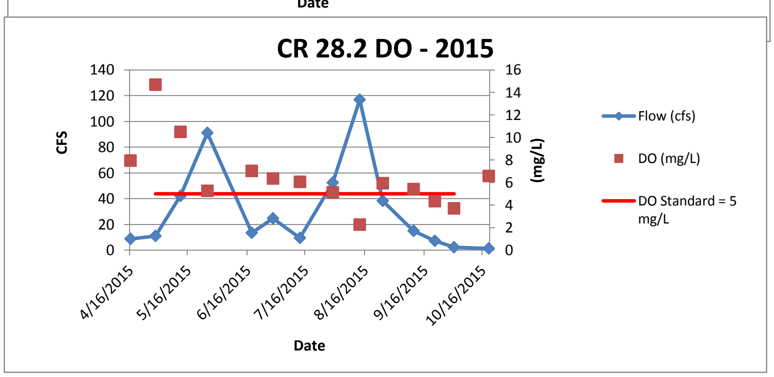

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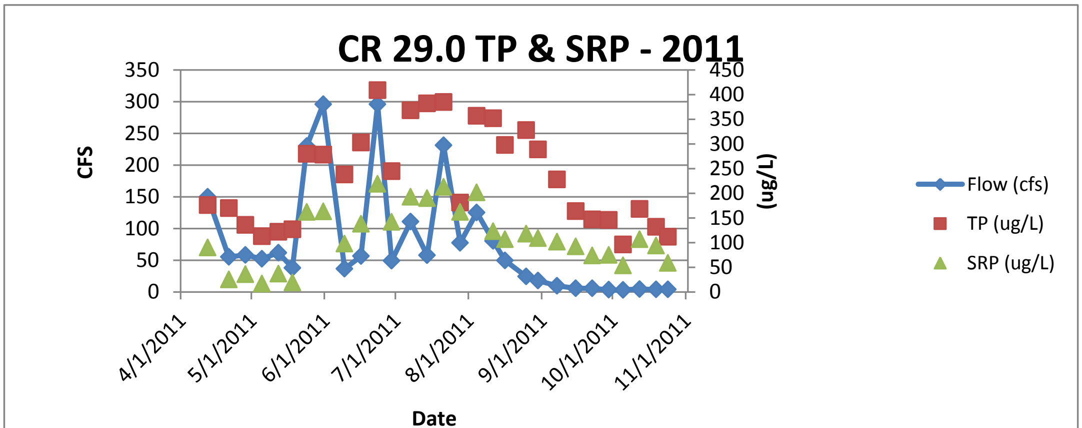

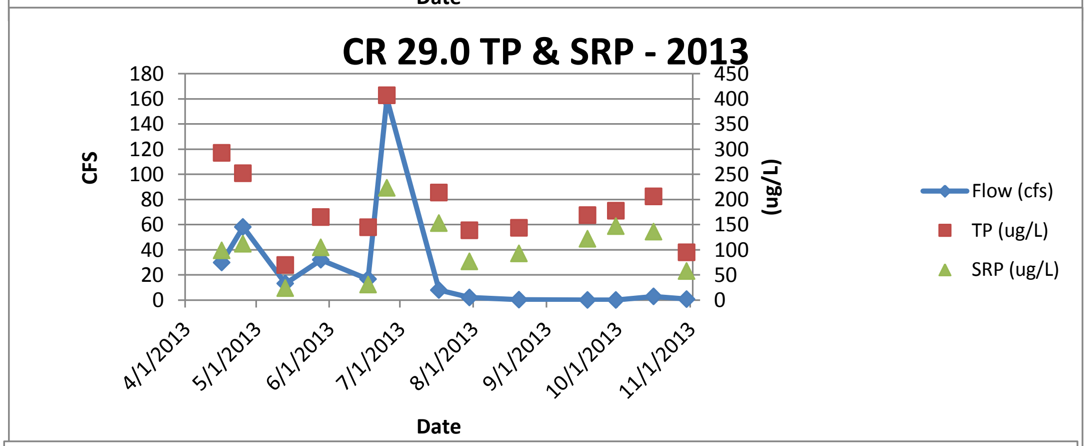

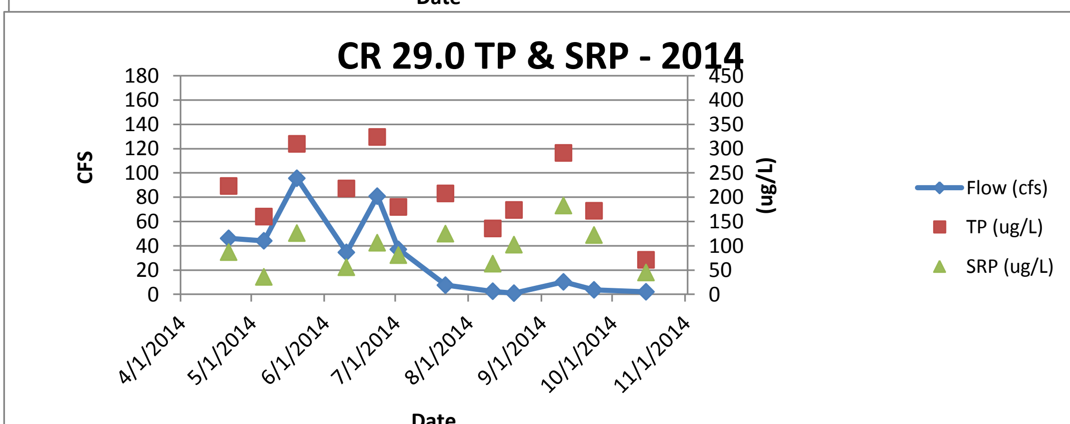

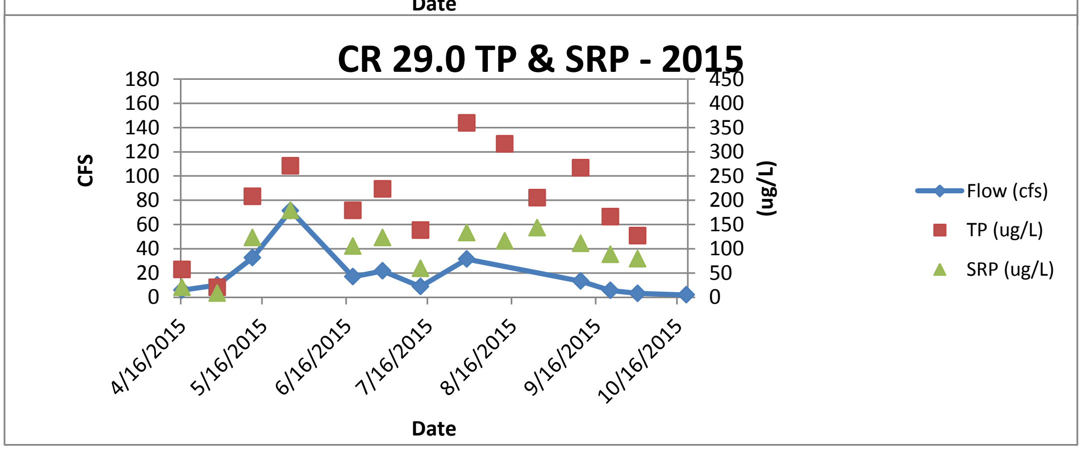

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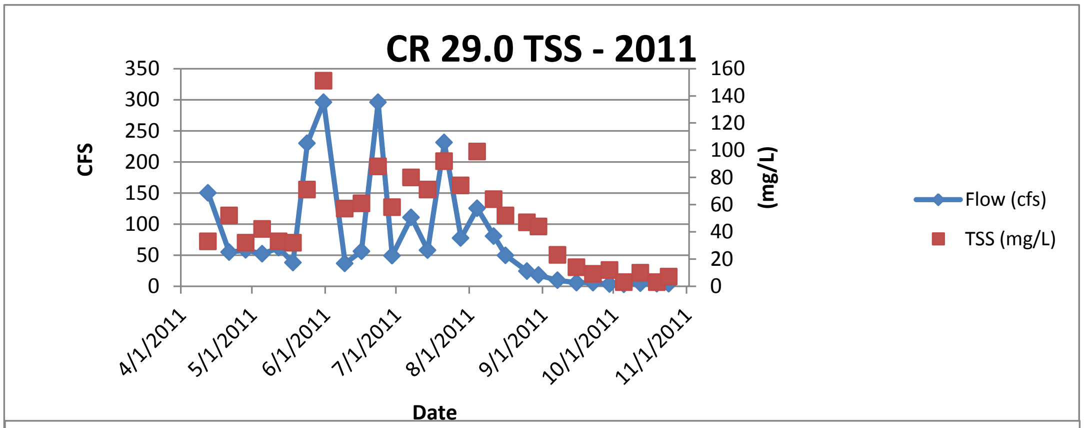

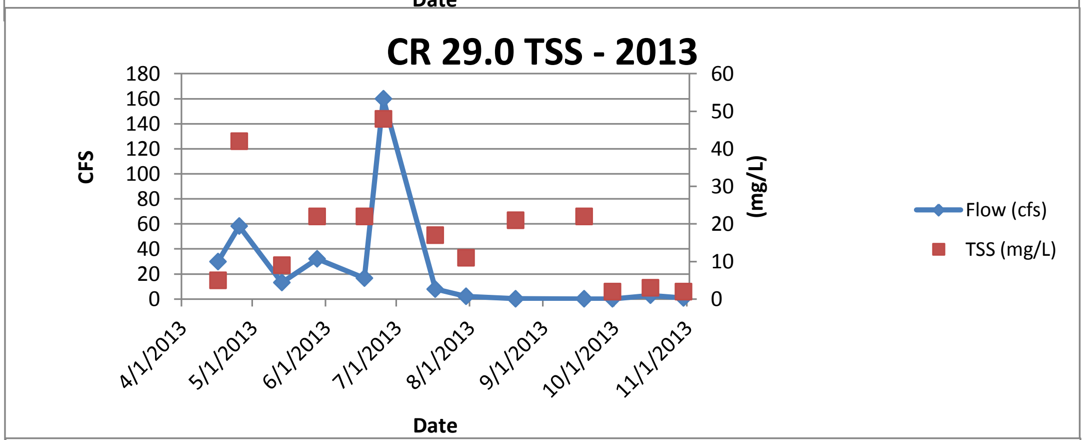

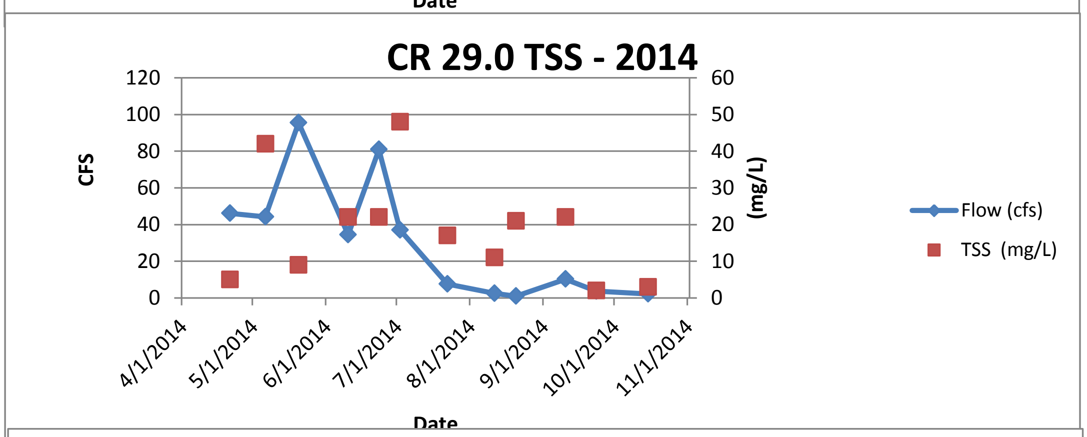

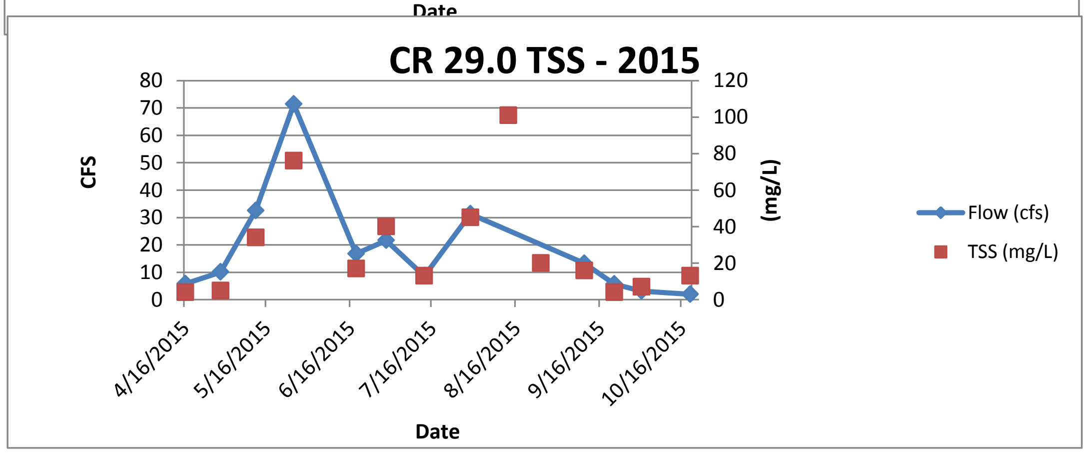

Appendix G-Kingston Wetland Monitoring Data