Middle St. Croix Watershed Management Organization 2012 Water Monitoring Report

Prepared For:

Prepared by:

Washington Conservation District

ACKNOWLEDGEMENTS

Multiple agencies and individuals were directly involved in many aspects of this project, such as data collection, data analysis, as well as technical and administrative assistance.

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The WCD would also like to thank the volunteers and landowners who assist with data collection and access to our monitoring locations.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

BCWD	Brown's Creek Watershed District
biweekly	Every other week
BMP	Best Management Practice
cf	cubic feet
cfs	cubic feet per second
Chl-*a*	Chlorophyll-*a*
DO	Dissolved Oxygen
E. Coli	*Escherichia coli*
MCES	Metropolitan Council Environmental Services
mg/L	milligram per liter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MSCWMO	Middle St. Croix Watershed Management Organization
NCHFE	North Central Hardwood Forest Ecoregion
OHW	Ordinary High Water level
SOP	Standard Operating Procedure
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSMP	Trout Stream Mitigation Project
TSS	Total Suspended Solids
µg/L	microgram per liter
µmhos/cm	micromhos per centimeter
VSS	Volatile Suspended Solids
WCD	Washington Conservation District

EXECUTIVE SUMMARY

This report focuses on the summary and comparison of lake and stream water quality data collected by the Washington Conservation District (WCD) in 2012 as well as previous years. In 2012 the Middle St. Croix Watershed Management Organization (MSCWMO) monitored water quality on Brick Pond, elevation on Perro Pond, and both water quality and elevation on McKusick Lake and Lily Lake. Discharge and water quality were monitored on Perro Creek (Figure 1). Information from the Brown's Creek Diversion Structure site is also included in this report as this affects the water quality of McKusick Lake. The purpose of the monitoring program is to assess and document current water quality conditions of the lakes and streams as well as continuing a long-term monitoring program that will enable the MSCWMO to identify trends associated with land use changes in their watershed.

Brick Pond was classified as eutrophic (Table 2), and received a lake grade of a C+ (Table 3) in 2012. Brick Pond was worse than the North Central Hardwood Forest Ecoregion (NCHFE) range for Total Phosphorus (TP), but was within the NCHFE range for chlorophyll-*a* (chl-*a*) and Secchi disk transparency. Using samples collected from June through September, the Minnesota Pollution Control Agency (MPCA) has set threshold standards of lakes for TP, chl-*a*, and Secchi disk transparency. Four of the five samples exceeded the MPCA shallow lake impairment threshold for TP, with one sample not being analyzed due to an error at the Metropolitan Council Environmental Services (MCES) Laboratory. Only one of the six samples exceeded the threshold for chl-*a*. All readings exceeded the MPCA impairment threshold for Secchi disk transparency due to the shallowness of the pond (APPENDIX A).

Lily Lake was classified as eutrophic (Table 2) and received a C+ for a lake grade in 2012 (Table 3). TP, chl-*a*, and Secchi disk transparency readings were all within the NCHFE range for the 2012 monitoring season. Using samples collected from June through September, the Minnesota Pollution Control Agency (MPCA) has set threshold standards of lakes for TP, chl-*a*, and Secchi disk transparency. Six of the eleven samples collected exceeded the MPCA threshold for TP, and four of the eleven samples collected exceeded the MPCA threshold for chl-*a*. Three of the Secchi disk transparency readings exceeded the MPCA threshold (APPENDIX A).

In 2012 McKusick Lake was classified as eutrophic (Table 2), and received a lake grade of a B (Table 3). McKusick Lake was above the NCHFE range for TP and within the NCHFE range for chl-*a* and Secchi disk transparency. Using samples collected from June through September, the Minnesota Pollution Control Agency (MPCA) has set threshold standards of lakes for TP, chl-*a*, and Secchi disk transparency. Metals were tested for and no samples collected exceeded MPCA thresholds (Table 4). Only two of the fourteen water quality samples collected exceeded the MPCA shallow lake threshold for TP, and no samples collected exceeded the MPCA threshold for chl-*a* or for Secchi disk transparency readings (APPENDIX A).

Perro Creek had similar discharge in 2012 and 2011, discharging 28,264,823 cubic feet (cf) in 2012, and 28,986,610 (cf) in 2011. The estimated total load of phosphorus discharged from Perro Creek in 2012 was 129 lb, an increase of 47 lb from what was estimated in 2011. Perro Creek also discharged approximately 204,141 lb of suspended solids to the St. Croix River, a decrease of 175,493 lb from the 2011 estimation (Table 6). This ends the 5 year trend of nearly doubling every year since 2008. Causes for the recent high TSS loads may be due to the further degradation of the up-stream channel.

The Brown's Creek Diversion Structure site showed a decrease in discharge of 29,451,867 cf, discharging 52,981,553 cf in 2011, and 23,529,686 cf in 2012. TP also decreased from 2,099 lb in 2011 to 260 lb in 2012. TSS also showed a decrease of 1,258,940 lb exported to McKusick Lake, from 1,387,050 lb in 2011, to 128,110 lb in 2012 (Table 10, Table 15). Decreases in loading amounts are likely due to the lack of precipitation for the last half of the year, causing less runoff.

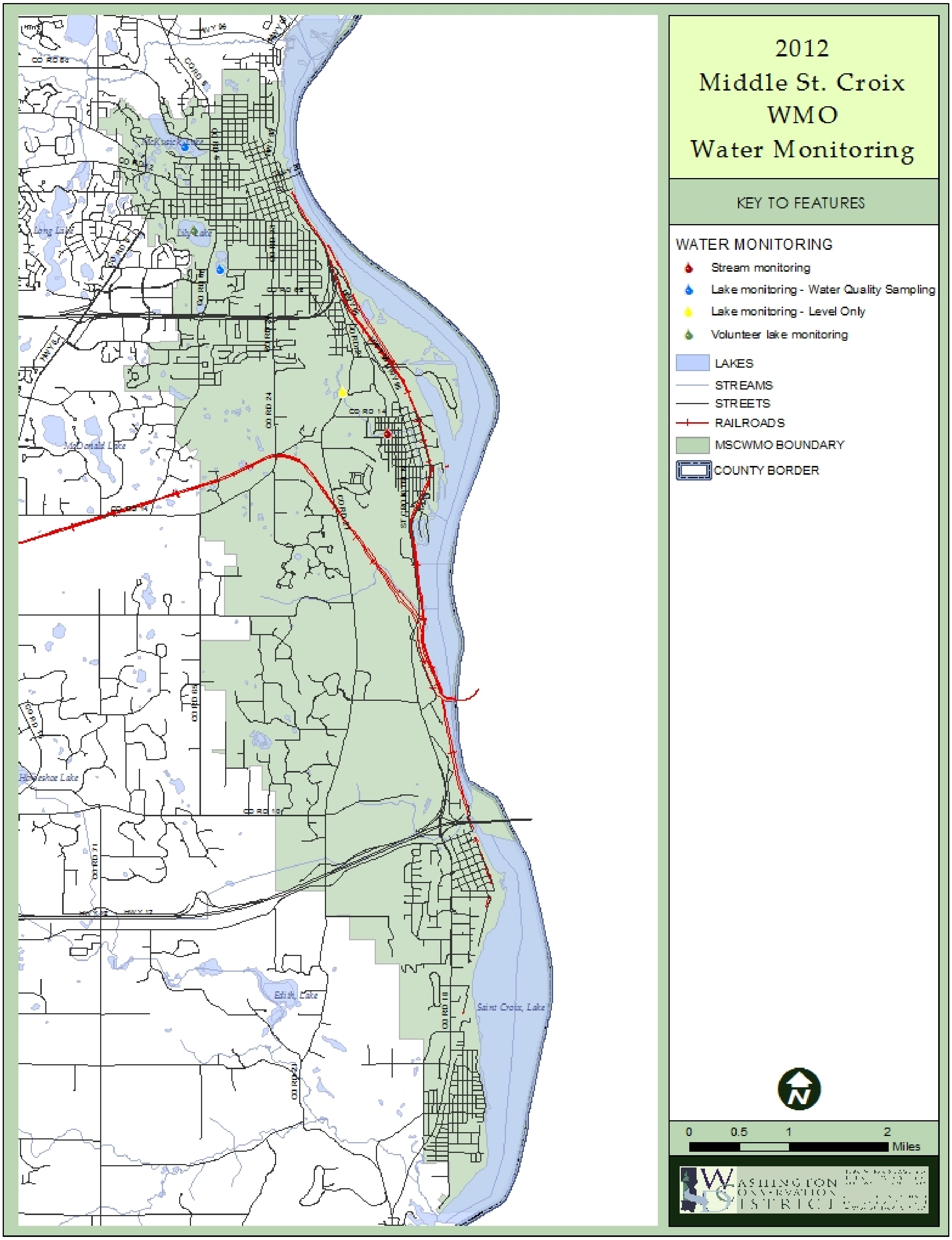

Figure 1. MSCWMO 2012 Water Monitoring Location

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2012 water quality data was collected monthly on Brick Pond and biweekly on Lily and McKusick Lakes, over seven consecutive months (April–October). Measurements obtained during the summer sampling season (June 1-September 30) are averaged for a comparison of individual lake dynamics from year to year between lakes within the watershed, and to the average NCHFE values. Average values for all parameters, as well as typical ranges for lakes in the NCHFE are presented in APPENDIX A. Figure 5, Figure 6, Figure 7, and Figure 8 show the current and historic summer averages for each parameter at each site. Water quality samples were collected with a two-meter (6.56 feet) integrated surface water column sampler. The MCES Laboratory analyzed the surface water samples for TP, chl-*a*, total Kjeldahl nitrogen (TKN) on all MSCWMO lakes and heavy metals only on McKusick. A full description of WCD Standard Operating Procedures is available on the Washington Conservation District website at http://www.mnwcd.org/water_monitoring_standards.php.

Total phosphorus is analyzed as it is a major nutrient involved in the eutrophication of lakes and is generally associated with the growth of aquatic plants and/or algal blooms. Common sources of TP include runoff from agricultural fields, livestock areas, urban areas, lakeshore lawns, and improperly operating septic systems. With most lakes in this region, TP is the least available nutrient; therefore, its abundance, or scarcity, controls the extent of algal growth. Algal growth, in turn, affects the clarity, or transparency, and light penetration of the water. The typical range of the NCHFE for TP is 0.023 – 0.050 mg/L. The MPCA has set thresholds for impairment of nutrients with TP limits of 0.040 mg/L or 0.060 mg/L, depending on the depth of the lake (greater than or less than 15 feet). The 2012 summer average TP values of MSCWMO lakes can be found in Figure 5.

Chlorophyll-*a* is measured as it is the photosynthetic component found in algae and aquatic plants and is an indication of algal productivity. The typical range of the NCHFE for chl-*a* is 5 – 22 µg/L. The MPCA has also set thresholds for impairment with limits of 14 µg/L, or 20 µg/L depending on the depth of the lake (greater than or less than 15 feet). The 2012 summer average chl-*a* concentrations of MSCWMO lakes can be found in Figure 6.

There are several forms of nitrogen that can be tested and the form tested for in MSCWMO lakes is Total Kjeldahl nitrogen (TKN). Nitrogen is tested because as it can increase the rate of lake eutrophication and can be responsible for many health problems in the very old and very young. The NCHFE range for TKN is 0.60-1.20 mg/L. There is no threshold for TKN set by the MPCA. The 2012 summer average TKN concentrations of MSCWMO lakes can be found in Figure 7.

2012 MSCWMO Lakes Summer Averages (June-September)					
Lake/Units	**Total Phosphorus (mg/L)**	**Chlorophyll-a (ug/L)**	**Kjeldahl Nitrogen (mg/L)**	**Secchi Disk (meters)**	**Deep Or Shallow**
Eco-Region Value	*0.023-0.050*	*5.0-22.0*	*0.60-1.20*	*1.5-3.2*	
MPCA Deep Lake Impairment Threshold	*0.040*	*14.0*		*1.40*	
MPCA Shallow Lake Impairment Threshold	*0.060*	*20.0*		*1.00*	
Brick Pond	0.109	9.9	0.77	0.70	Shallow
Lily	0.044	14.8	1.18	1.64	Deep
McKusick	0.060	7.3	1.02	2.46	Shallow

Table 1. North Central Hardwood Forest Ecoregion Values and Average 2012 Parameters

2012 was the first year metals have been tested for in area lakes, with McKusick lake the only MSCWMO lake tested. Heavy metals are tested because many are known to be extremely toxic to aquatic organisms. Results can be found in Table 4

Field measurements are also recorded while collecting lake samples. Measurements include Secchi disk transparency, dissolved oxygen (DO) and temperature profiles, and lake elevation.

The measurement of light penetration using a Secchi disk gives a simple measure of water transparency, or clarity. It is a possible indication of turbidity in the water and an indication of the trophic state of the lake. A reduction in water transparency is typically the result of turbidity composed of suspended sediments, organic matter and/or phytoplankton (algae). Typical ranges for transparency in the NCHFE are between 1.5 – 3.2 meters. The MPCA has set thresholds for

Secchi disk readings of 1.4 meters or 1.0 meters depending on the depth of the lake (greater than or less than 15 feet).

Temperature and dissolved oxygen profiles were measured by the WCD at each lake during each sampling event. Volunteers that monitor lakes do not collect temperature and dissolved oxygen profiles as they do not have the proper instrumentation. Profiles are recorded at meter increments from the water surface to the lake bottom. The data show the extent of summer stratification and are useful in identifying the development of a thermocline (the layer of water in which the temperature rapidly declines). As a lake stratifies, the water column becomes more stable and mixing is less likely to occur. If mixing occurs during the growing season, nutrients from the bottom become available and can result in increased algal production. Lake DO profile data is useful in determining excessive production (algae/plants) in a lake. Increased production creates more DO, for a time, but as plants and algae die off and decay, they turn from producers of DO into consumers through respiration. Data collected from these profiles are contained in a database at the WCD.

A user perception ranking, a physical and recreational suitability of the lake, was also recorded at the time of sample collection. A full description of WCD Standard Operating Procedures is available on the Washington Conservation District website at http://www.mnwcd.org/water_monitoring_standards.php.

The Carlson Trophic State Index (TSI) is used to quantify the relationship between water quality data and trophic status. Many water quality scientists classify lakes according to their trophic state. Average summer values of TP, chl-*a*, and transparency (measured using a Secchi disk) are the parameters most often used to determine a lake's trophic state. Oligotrophic lakes, such as lakes common in the northeastern part of Minnesota, have low biological activity as a result of low phosphorus concentrations, low chl-*a* concentrations, and high Secchi disk transparency readings. A good local example of an oligotrophic lake is Square Lake, located in Section 23 of May Township. Mesotrophic lakes have slightly more biological production, and are characteristic of the majority of the lakes found in the NCHFE of Minnesota. On the other end of the spectrum, lakes with high biological productivity are characterized by high TP concentrations, high chl-*a* concentrations, and low Secchi disk transparencies are classified as eutrophic or even hypereutrophic. Lakes classified as eutrophic or hypereutrophic typically receive excess nutrient loading from sources within their watersheds and receive large amounts of runoff from the surrounding drainage area. Some percentage of these nutrients, however, can also be attributed to internal loading within the lake itself, which is typical of shallow, sediment-rich lakes (Table 2).

Table 2. Trophic State Index and Ranges

	Trophic State Index	TP (ug/L)	Chl-*a* (ug/L)	Secchi (m)
Oligotrophic	<40	<12	<2.6	>4.0
Mesotrophic	40-50	12 - 24	2.6 - 6.4	4.0 - 2.0
Eutrophic	50-70	24 - 96	6.4 - 56	2.0 – 0.5
Hypereutrophic	>70	>96	>56	<0.5

A Lake Grading System is also used in this report to allow for a better understanding of lake water quality data and to aid in the comparison of lakes. The lake water quality grading system was developed following the 1989 sampling season by Dick Osgood, formerly of the Metropolitan Council. The concept of the lake grading system is a ranking of water quality characteristics by comparing measured values to those of other metro area lakes. The grading system represents percentile ranges for three water quality indicators: the June through September average values of TP, chl-*a*, and Secchi disk transparency. These percentiles use ranked data from 119 lakes sampled from 1980-1988 and are shown in Table 3 The variables used in the grading system strongly correlate to open-water nuisance aspects of a lake (i.e. algal blooms), which can indicate accelerated aging (cultural eutrophication). Comparing the Lake Trophic Status and the Lake Grading System shows a good correlation between the two systems. Summaries of all lake results are presented in APPENDIX A.

Table 3. Lake Grade Ranges

Grade	Percentile	TP (ug/l)	CLA (ug/l)	SD (m)
A	<10	<23	<10	>3.00
B	10-29	23-31	10-19	2.20-3.00
C	30-69	32-67	20-47	1.20-2.19
D	70-90	68-152	48-77	0.70-1.19
F	>90	>152	>77	<0.70

Lake elevation gages monitored by WCD staff are located on two MSCWMO lakes, Lily and McKusick, and one wetland, Perro Pond and are compared to the lakes Ordinary High Water level (OHW)[1]. All three water bodies reflected significant decreases in elevation towards the end of the 2012 monitoring season, when precipitation was below normal (Figure 9). Complete lake elevation data for 2012 can be found in Figure 2, Figure 3, and Figure 4. For historical lake elevations, visit the MN DNR Lake Finder webpage at http://www.dnr.state.mn.us/lakefind/index.html.

1. BRICK POND

The 2012 summer average concentration of TP was 0.109 mg/L, up from 0.078 mg/L in 2011 and the highest summer average concentration since 2008. It also exceeds the NCHFE range for TP (Figure 5). Brick Pond exceeded the MPCA shallow lake water quality threshold for TP in four of five samples in 2012. One sample result is missing due to an error at the MCES Laboratory. There are not enough years of data to determine any statistically significant trend for TP on Brick Pond at this time. The summer average concentration for chl-*a* in 2012 was 9.9 µg/L, 3.1 µg/L lower than the 2011 value and the second highest concentration seen in the five years of monitoring but still within the NCHFE range for chl-*a* (Figure 6). Only one sample exceeded the shallow lakes MPCA threshold for chl-*a* in 2012, the same as in 2011. Brick Pond had an average summer TKN concentration of 0.77 mg/L, very close to the concentrations seen in the previous two years of 0.80 mg/L in 2011 and 0.79 mg/L in 2010 (Figure 7). The values for TKN are all within the NCHFE range. All Secchi disk readings exceeded (were poorer than) the NCHFE range in 2012. It should be noted that it is difficult for transparency results to fall within the NCHFE range due to the shallowness of Brick Pond, with a maximum depth of

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[1] Minnesota State Statutes defines the ordinary high water level (OHW) as follows: Minnesota Statutes 103G.005 Subd. 14. Ordinary High Water Level. “Ordinary high water level” means the boundary of water basins, watercourses, public waters and public waters wetlands, and:

1) The ordinary high water level is an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial;
2) For watercourses, the ordinary high water level is the elevation of the top of the bank of the channel; and
3) For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool.

approximately 1.52 meters, just over the minimum NCHFE value (Figure 8). The Kendall Tau correlation test is not run for transparency on shallow lakes like Brick Pond when there is rooted vegetation, or the secchi disk is visible to the lake bed. When those types of conditions are present too much error can alter long term trends. Brick Pond did not stratify during the summer of 2012, allowing it to mix throughout the summer and allowing for internal loading. Based on 2012 data and utilizing the Carlson's TSI, Brick Pond is classified as eutrophic, the same as in 2011. Data also showed that the water quality has improved slightly over what was seen in 2011 and has received a grade of C+ for 2012. Summaries of all lake results are presented in APPENDIX A.

2. LILY LAKE

Lily Lake had an average summertime TP concentration of 0.044 mg/L in 2012, slightly above the MPCA lake nutrient impairment threshold, but falls within the NCHFE range. This shows a decline in Lily Lake from the 2009 and 2010 values (Lily Lake was not monitored in 2011), but is near values of years previous (Figure 5). Six of the eleven samples had values greater than the MPCA lake nutrient impairment threshold for TP. There was no statistically significant trend found in the historical summer TP data. The 2012 average summertime concentration of chl-*a* was 14.8 μg/L, which is half of the value seen in 2010, and within the NCHFE range (Figure 6). The last four out of the eleven samples collected for chl-*a* were above the MPCA lake impairment threshold. Lily Lake had an average summertime TKN concentration of 1.181 mg/L in 2012, within the upper limits of the NCHFE range (Figure 7). Secchi disk readings were measured in 2012 with a summertime average of 1.64 meters, within the NCHFE range (Figure 8). Three of the eleven transparency measurements taken with a Secchi disk were worse than the MPCA lake impairment threshold. No significant trend in Secchi disk transparency could be determined. Lily Lake was monitored by a volunteer in 2012 therefore; water temperatures were measured at the water surface only. Without temperature and DO readings measured throughout the water column, no determination can be made if Lily Lake developed a thermocline, or was allowed to mix throughout the summer. It is likely that Lily Lake stratified during the summer of 2012 due to the deep depth of the lake, but this was never confirmed. Last year Lily Lake was not monitored and therefore was not classified using the trophic index. In 2010 Lily Lake was classified as mesotrophic, but has declined in water quality since then being classified as eutrophic in 2012. Lily Lake also received a grade of C+ in 2010 and has kept the same grade for 2012. At the start of the monitoring season the level of Lily Lake was below the OHW, but quickly rebounded. The level fluctuated near 845.0 to 845.5 from the end of April until the beginning of August, reaching its peak on 6/20/2012. At the beginning of August, Lily Lake again fell below the OHW level and continued to fall for the remainder of the monitoring season, reaching its lowest recorded elevation on 10/30/2012 at 843.68 ft. (Figure 2). Summaries of all lake results are presented in APPENDIX A.

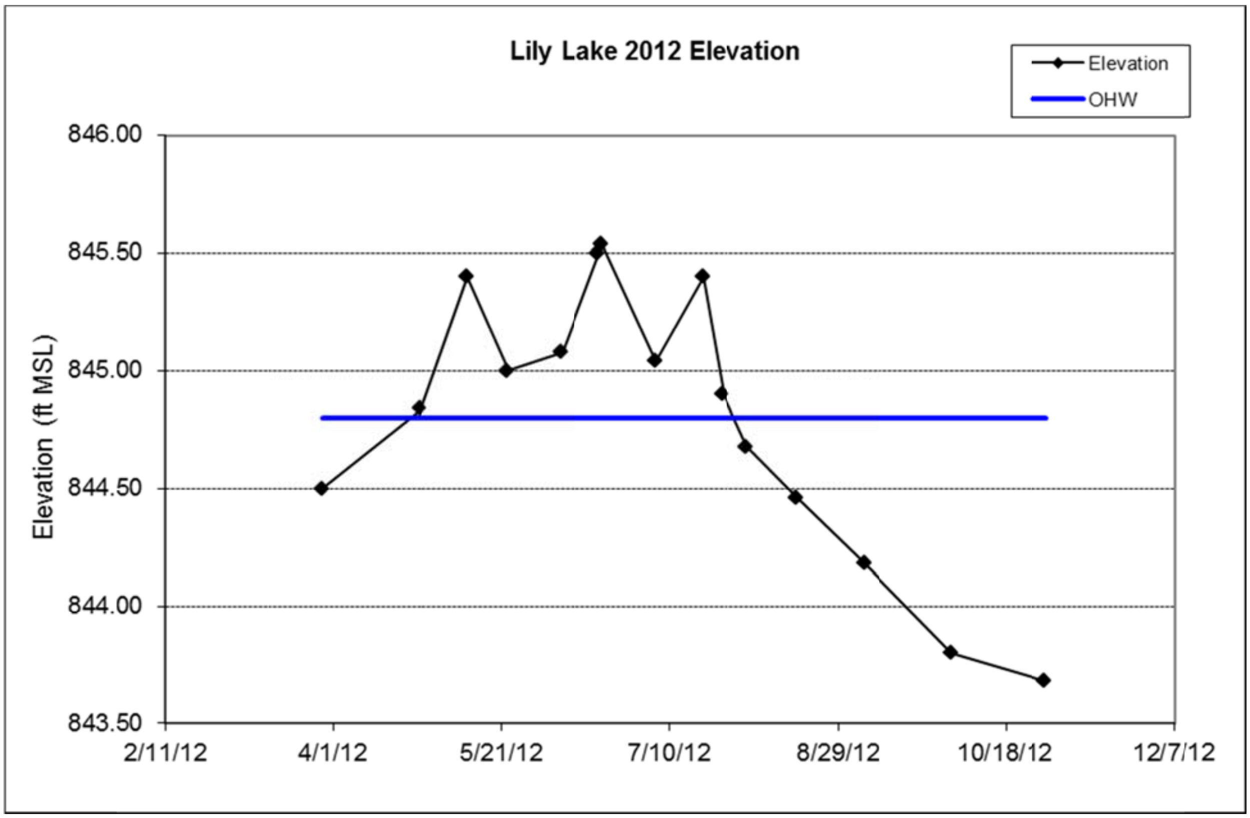

Figure 2 . Lily Lake 2012 Elevations

3. MCKUSICK LAKE

TP summer average concentrations in 2012 were 0.060 mg/L, which is down from the summertime average of 0.081 mg/L in 201 and now within the NCHFE range. McKusick Lake exceeded the shallow lake water quality threshold for TP in two of the fourteen samples in 2012, down from eight of the fourteen samples in 2011. Overall, McKusick Lake has seen statistically significant improvements ($p<0.01$) for TP from 1994 to the present (Figure 5). McKusick Lake had a summer average concentration of 7.32 μg/L chl-*a*, which is lower than the 2011 summer average value of 26 μg/L, and is within the NCHFE value range (Figure 6). Of the fourteen samples collected in 2012, none exceeded the MPCA shallow lakes threshold for chl-*a*. That number is down from when four samples exceeded the threshold in 2011 and back to what was seen in 2010 when there were no threshold exceedances. The average summer TKN concentration for 2012 was 1.021 mg/L, down from 1.085 mg/L in 2011 and within the NCHFE range (Figure 7). The 2012 summer average water transparency measured by Secchi disk was 2.45 meters, which is better than the average of 2.08 in 2011 (Figure 8). All Secchi disk readings in 2012 were within the MCHFE range. There has seen statistically significant improvements ($p<0.01$) in Secchi transparency from 1994 through the present. McKusick Lake exhibited thermal stratification during the summer months of 2012 with the thermocline around 3 meters; therefore the lake was less likely to completely mix. McKusick Lake also showed low DO levels, around 3 mg/L at the surface, starting in late-July and lasting until mid-August. 2012 marked the first year that metals were analyzed on McKusick Lake and none of the samples exceeded the threshold limits for any of the metals analyzed (Table 4). Based upon the 2012 data and utilizing the Carlson's TSI, McKusick Lake is classified as mesotrophic, an upgrade from its 2011 classification of eutrophic. The overall water quality of McKusick Lake has improved when compared to last year, receiving a grade of B for 2012, up from a C- in 2011. The elevation of McKusick Lake remained above the OHW for the entire 2012 monitoring season reaching its highest recorded level on 5/9/2012 with a level of 855.14 ft. and falling to its lowest recorded level on 10/10/2012 with an elevation of 853.26 ft. (Figure 3). Summaries of all lake results are presented in APPENDIX A.

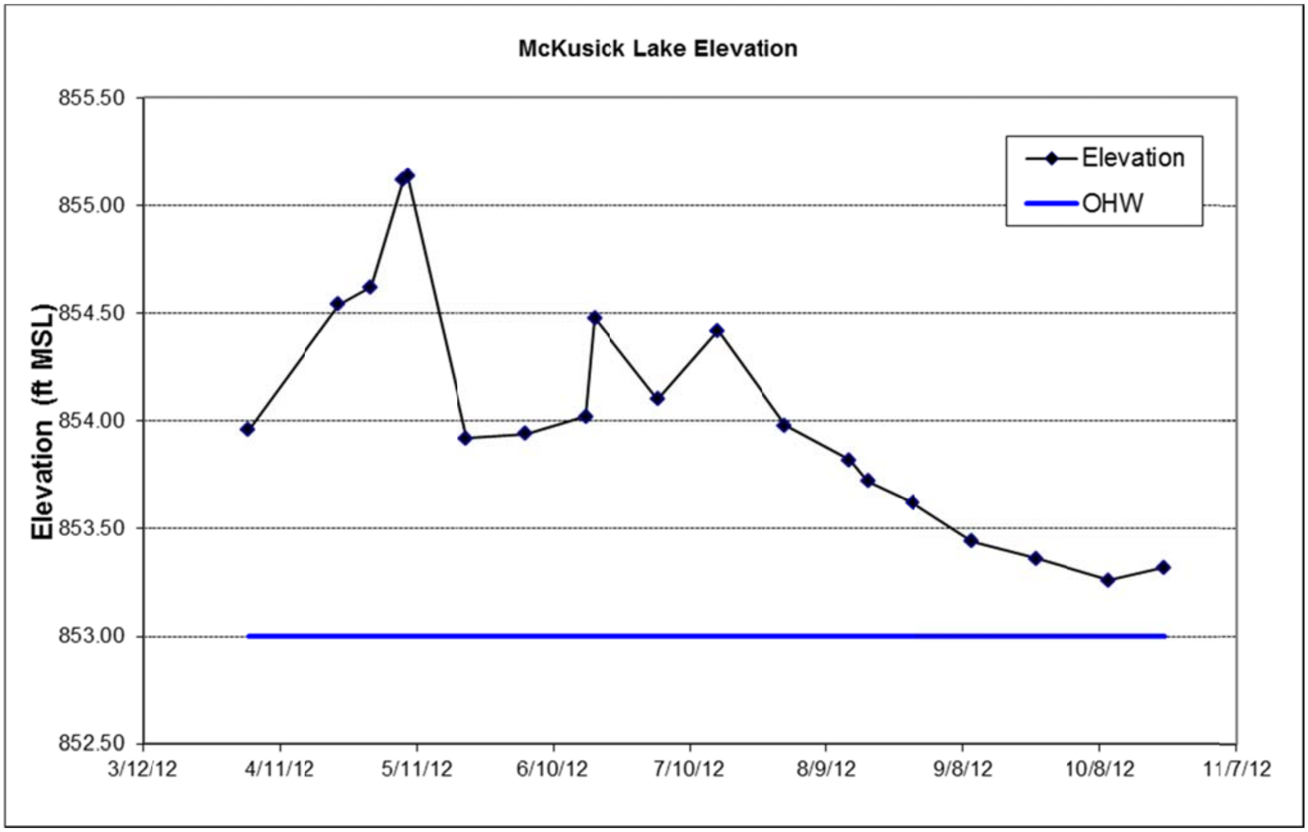

Figure 3. McKusick Lake 2012 Elevations

Table 4. McKusick Lake 2012 Sample Metal Chemistry Results

Sample Type	Sample Date	Copper (mg/L)	Lead (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Hardness (mg/L_CaCO3)
Surface	4/23/2012 15:31	0.0008	0.0003	0.0005	0.0056	0.00020	0.00016	126
Surface	5/22/2012 8:11	0.0016	0.0003	0.0005	0.0111	0.00020	0.00016	100
Surface	6/19/2012 8:09	0.0007	0.0005	0.0004	0.0093	0.00020	0.00016	92
Surface	7/18/2012 8:41	0.0015	0.0003	0.0004	0.0079	0.00027	0.00013	80
Benthic	7/18/2012 8:41	0.0061	0.0007	0.0003	0.0176	0.00020	0.00010	100
Surface	8/14/2012 8:32	0.0050	0.0004	0.0003	0.0060	0.00047	0.00008	76
Surface	9/10/2012 8:40	0.0006	0.0002	0.0008	0.0082	0.00033	0.00050	88
Surface	10/22/2012 8:40	0.0014	0.0004	0.0010	0.0053	0.00028	0.00013	104
Benthic	10/22/2012 8:40	0.0005	0.0002	0.0010	0.0133	0.00020	0.00009	100

(yellow)	Exceeds Chronic Standard
(cyan)	Exceeds Max Standard
(dark red)	Exceeds Final Acute Standard
(gray)	No Exceedance Determinable

4. PERRO POND

Perro Pond was monitored for water level elevation throughout the 2012 monitoring season and has no OHW established for comparison purposes. A small dam retains water in Perro Pond, and was opened in the beginning of May, keeping water elevations high in before then. The highest recorded level for the year came on 4/27/2012 at 747.12 ft. On May 2, 2012 the dam was opened, drawing from Perro Pond and discharging water into Perro Creek. Water level elevations after that remained mainly between 745.0 and 745.5 ft. reaching its lowest recorded elevation on 8/30/2012 with an elevation of 745.10 ft. (Figure 4).

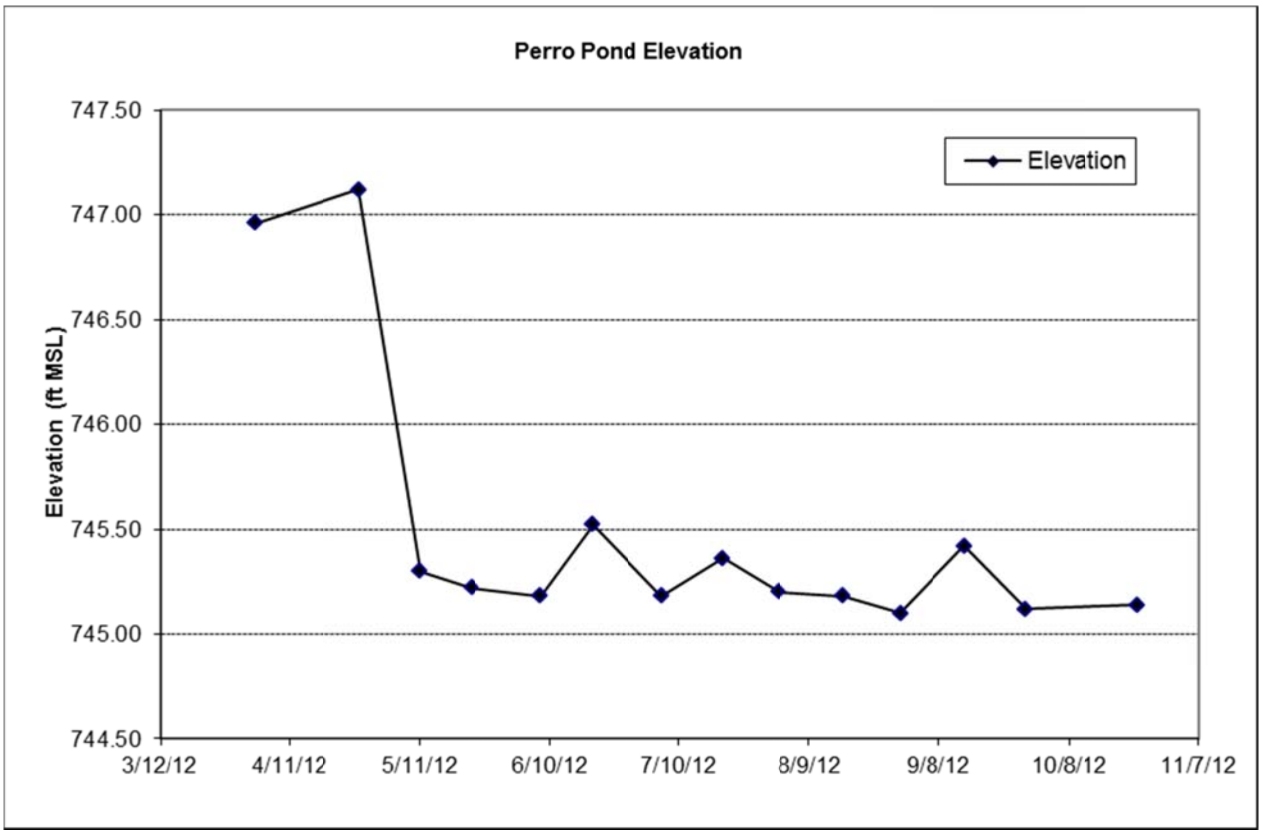

Figure 4. Perro Pond 2012 Elevations

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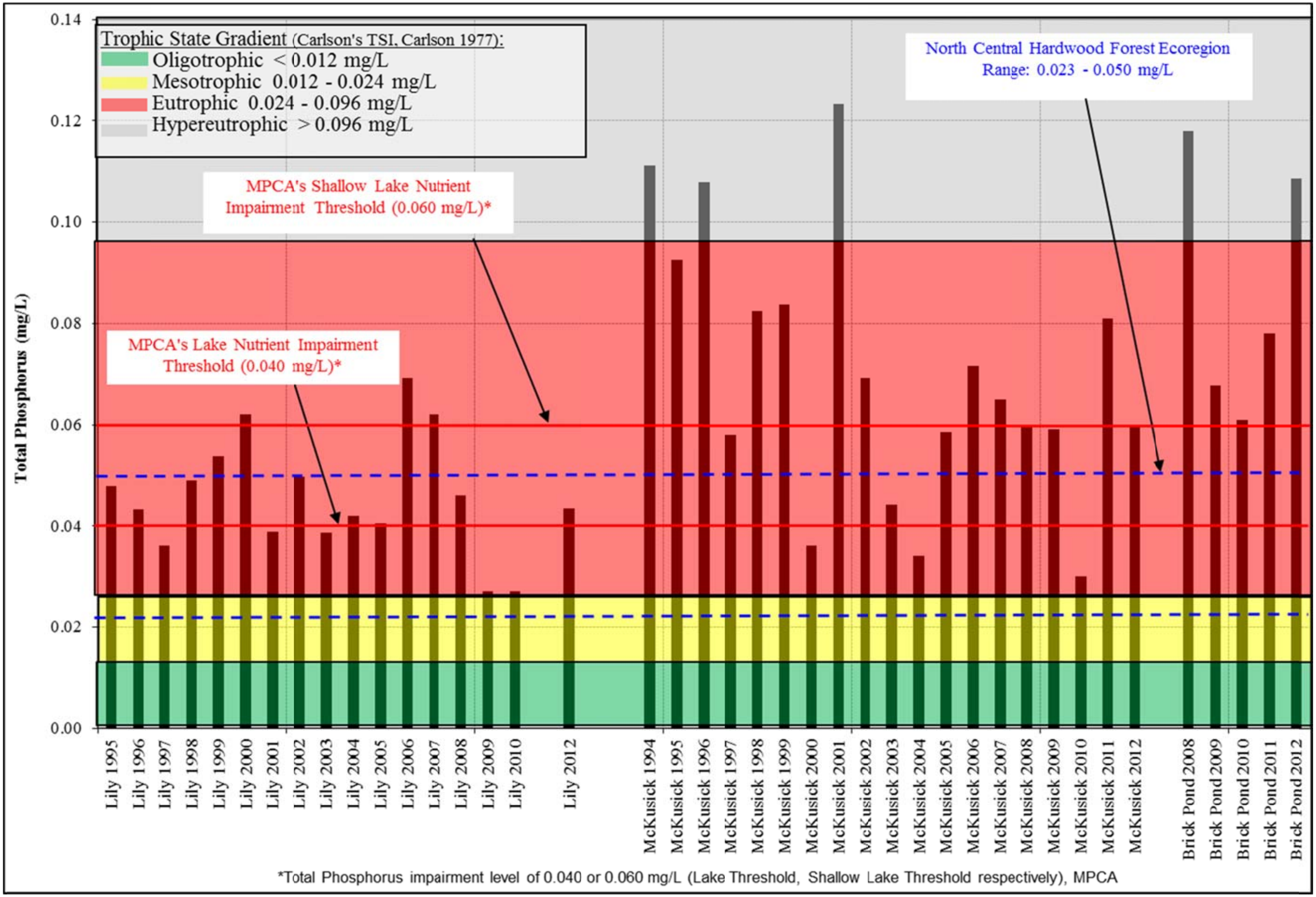


Figure 5. MSCWMO Historic Summer Average Total Phosphorus Data

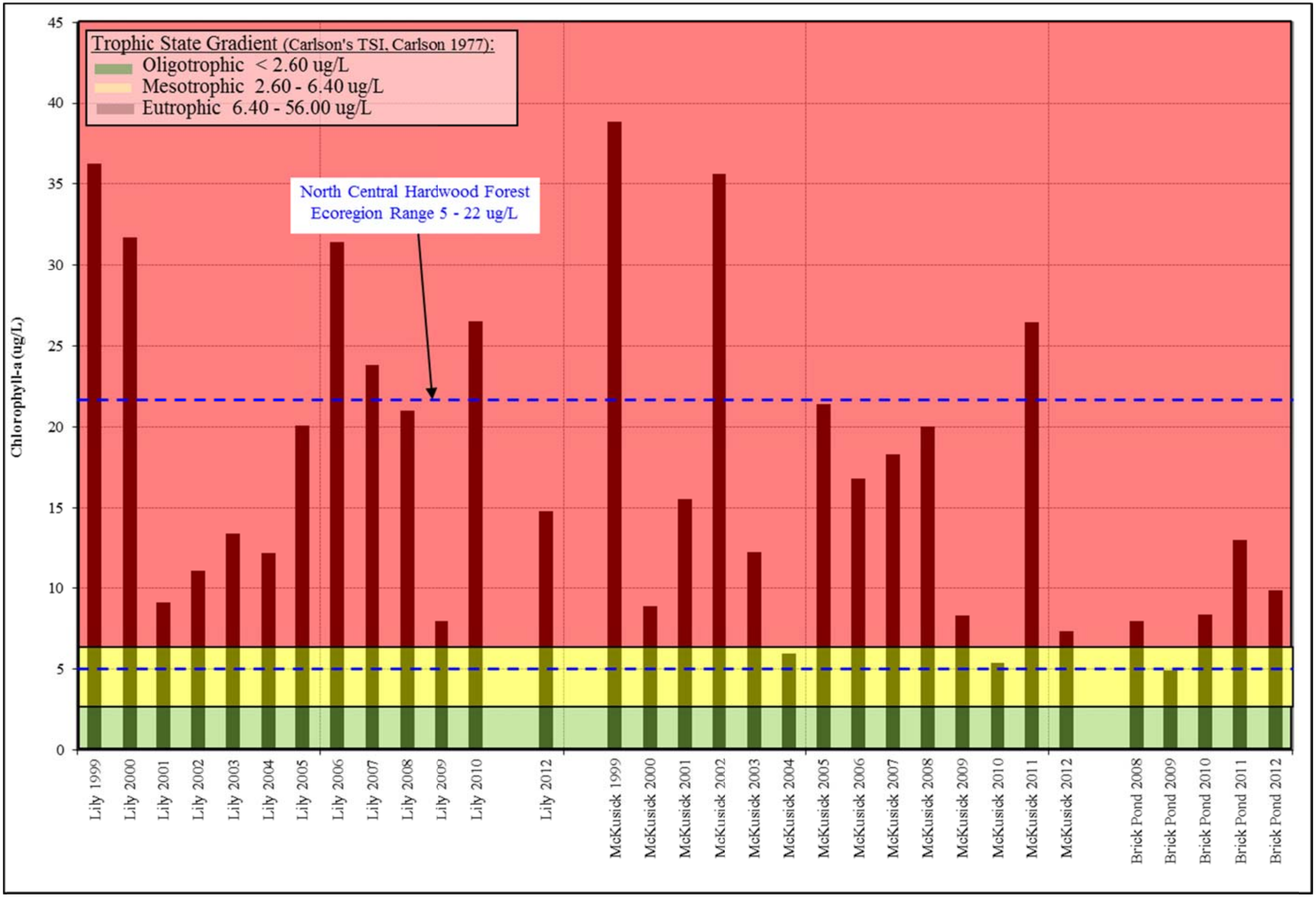


Figure 6. MSCWMO Historic Summer Average Chlorophyll-*a* Data

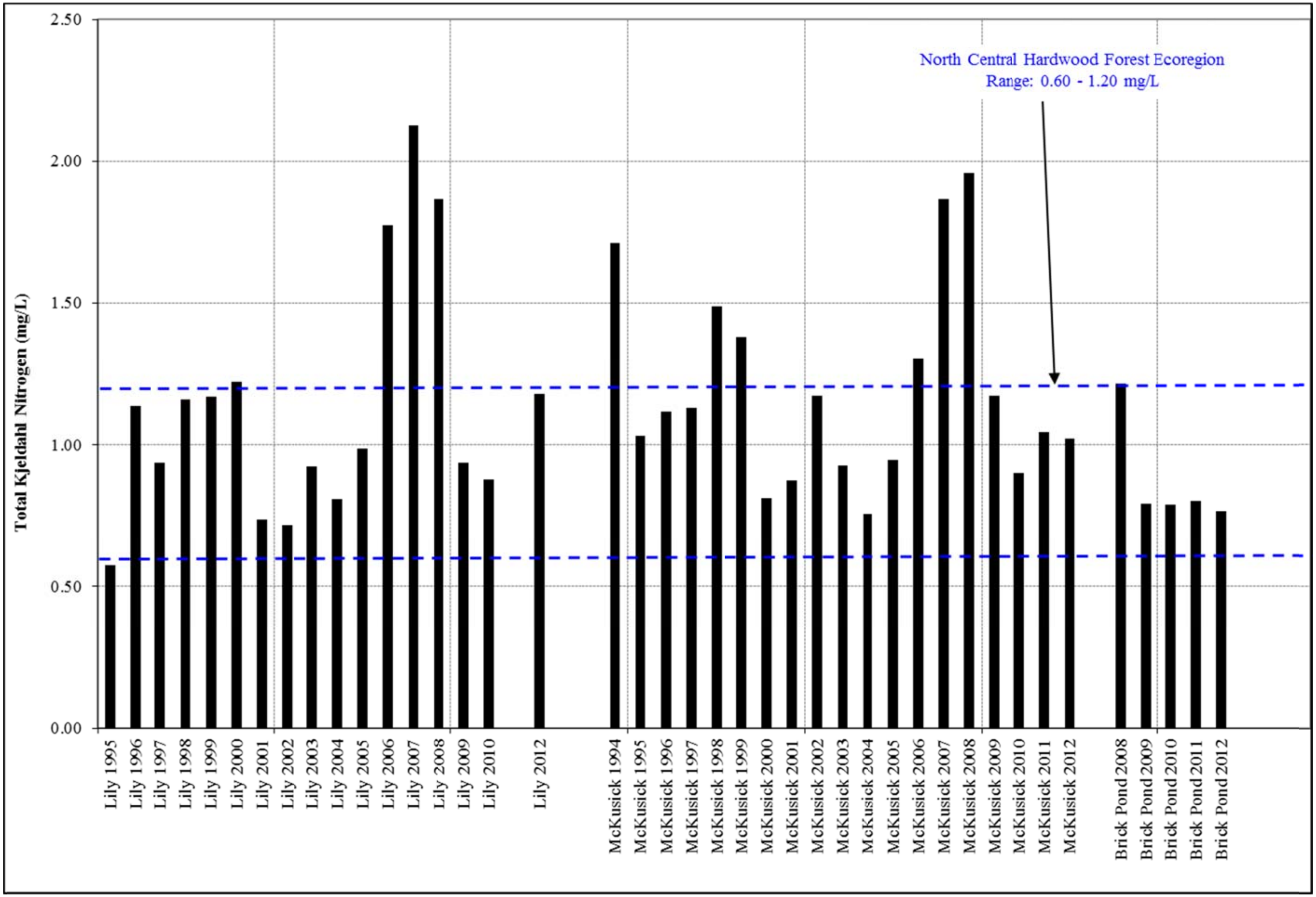


Figure 7. MSCWMO Historic Summer Average Total Kjeldahl Nitrogen Data

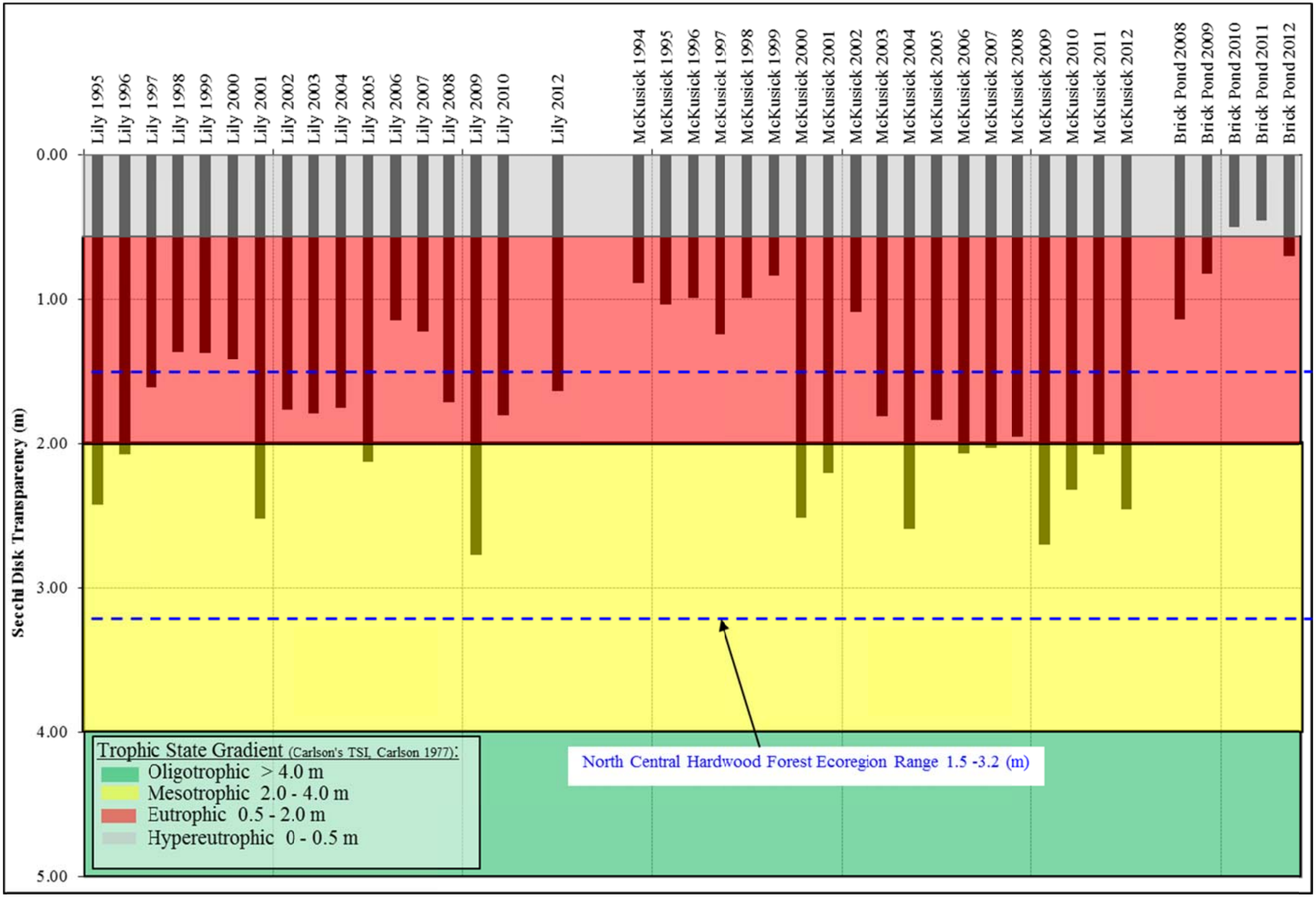


Figure 8. MSCWMO Historic Summer Average Secchi Data

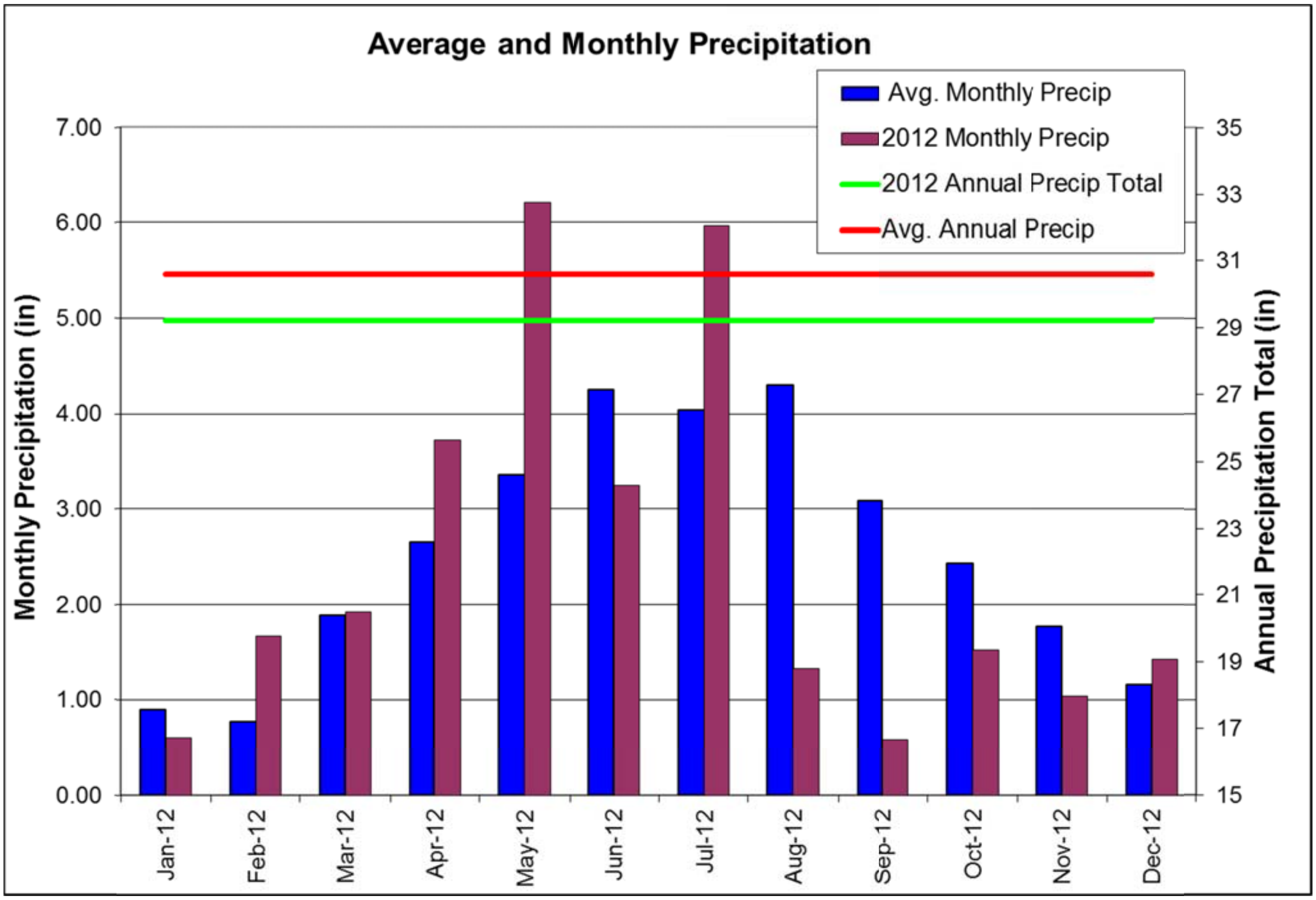


Figure 9. 2012 Annual Precipitation; Historical 30-Year* Average Annual Precipitation; Historical 30-Year* Average Monthly Precipitation; and 2012 Monthly Precipitation

2012 Data from WCD Precipitation Gage T 30N R 20W Sec 32

*Average monthly precipitation totals derived from historical 30-year (1981-2010) average for this region

B. MSCWMO LAKES: CONCLUSIONS AND RECOMMENDATIONS

Lake monitoring in MSCWMO continues to provide valuable baseline water quality information. To determine the health of the lakes in MSCWMO, physical and chemical parameters are compared on a year-to-year basis and to other lakes in the region. Water quality in a lake depends on a number of different variables such as: size of the contributing watershed, external nutrient sources, depth of the lake, and the current amount of nutrients available to be periodically released from the lake bottom. Low water quality ratings of MSCWMO lakes are most likely due to long-term periods of urban runoff (Lily Lake) or from the shallowness of the lake (Brick Pond and McKusick Lake). Shallow lakes typically exist in a low algal production, clear-water state or a high-algal production, turbid water state. Shallow lakes may not completely stratify in the summer, such as Brick Pond, and therefore have the capability to continually mix throughout the summer. That mixing causes TP to be distributed throughout the water column, causing more frequent and thick algal blooms. This is unlike deeper, stratified lakes where TP below the thermocline is not available for primary production.

The MPCA has listed both Lily and McKusick Lake on the 303(d) Impaired Waters list for nutrient/eutrophication impairment, with McKusick Lake now being considered for delisting. If a water body is listed, it indicates that it is not currently meeting water quality criteria. In order to meet those criteria, a total maximum daily load (TMDL) must be implemented. A TMDL outlines what pollutants are degrading the water quality and what will need to be done in order to meet current water quality standards. The MPCA had tentatively scheduled a three lake TMDL for Long Lake (Brown's Creek Watershed District), Lily Lake, and McKusick Lake in 2010, but because of improving water quality trends in those lakes over recent years, the MPCA, along with the MSCWMO, BCWD, and City of Stillwater decided to postpone the TMDL. The MSCWMO, BCWD, and the City of Stillwater will utilize the City's exiting Lake Management Plan as well as the completed Lily and McKusick Lake subwatershed assessments to further guide project implementation in an effort to continue to improve the lakes water quality. The MPCA will consider the need for a TMDL again in the future.

In 2012 Brick Pond, Lily Lake, and McKusick Lake had average water quality ratings, with overall water quality grades of C+, C+ and B, respectively. The classifications were eutrophic for Brick Pond and Lily Lake, and mesotrophic for McKusick Lake. When compared to historical data, Brick Pond improved slightly in 2012 receiving a lake grade of a C+. With only five years of data on Brick Pond it should be noted that no statistically significant trend can be determined about the water quality at this time (whether it is improving or declining as a whole). Lily Lake was not monitored in 2011, but the 2012 grade was the same as the 2010 grade, a C+. McKusick Lake showed an improvement in water quality in 2012 compared to what was seen in 2011, bringing its lake grade up from a C- in 2011 to a B in 2012.

2012 marked the fifth year that Brick Pond was monitored for water quality. TP showed an increase over the values seen in years prior. TP values have been worse than the NCHFE range every year the lake has been monitored (Figure 5). The 2012 summer average for TP should be interpreted with caution, as one of the sample values was not analyzed due to an error at the MCES Laboratory. Four of five samples collected were above the MPCA's Shallow Lake Nutrient Impairment Threshold. Chl-*a* showed a decrease from 2011, but was still the second highest summer average concentration to be seen since monitoring began in 2008 and still within the chl-*a* NCHFE range (Figure 6). Only one of six samples exceeded the MPCA shallow lake impairment threshold. There is no MPCA lake impairment threshold for TKN, but the average 2012 summertime value for TKN was slightly better than the average in 2011 (Figure 7). Secchi disk transparency increased in 2012, but was still worse than the NCHFE range with all measurements taken exceeding the MPCA shallow lake impairment threshold (Figure 8). It should be noted that it is difficult for transparency results to fall within the NCHFE range due to the shallowness of Brick Pond (the maximum depth of the pond is about 1.52 meters, just over the minimum NCHFE value). Temperature and DO profiles were taken in Brick Pond in 2012 and show that Brick Pond did not stratify. As a result nutrients were made available throughout the water column during the summer.

Lily Lake was monitored by a volunteer throughout the summer of 2012. Data shows that Lily Lake summertime average for TP was within the NCHFE range, but still above the MPCA lake threshold for TP (Figure 5). Six of the eleven samples exceeded the MPCA threshold. Average summertime value for chl-*a* was within the NCHFE range (Figure 6) with four of the eleven water quality samples exceeding the MPCA lake threshold for chl-*a* impairment. There is no

MPCA lake impairment threshold for TKN, but the average 2012 summertime TKN result for Lily Lake was higher than the 2010 result and still within the NCHFE range (Figure 7). Lily Lake was also within the NCHFE range for Secchi disk transparency with three of the eleven water quality readings exceeding the MPCA lake threshold for Secchi disk transparency impairment. Summertime (June-September) TP, chl-*a*, and Secchi disk transparency averages have remained relatively consistent over the last ten years in Lily Lake with the exceptions of 2001 and 2009 where overall water quality dramatically improved (Figure 8). In 2011 Lily Lake was scheduled to have a volunteer collect water quality samples. Due to unforeseen circumstances, that volunteer was unable collect any water quality samples and therefore there is no data for Lily Lake in 2011. In 2012 temperature readings were recorded at the water's surface of Lily Lake by a volunteer, but no temperature or DO profiles of the lake were recorded over the summer, as a result, a thermocline was never observed. Due to the depth of Lily Lake, it is likely that a thermocline did develop during the summer of 2012, trapping nutrients at the bottom of the lake. In 2001 chl-*a* levels and the lake grade improved significantly and may indicate a copper sulfate treatment in Lily Lake. In 2006 and 2007, summer average TP, chl-*a*, and Secchi disk transparency all deteriorated when compared to the averages seen from 2001 to 2005. In 2009 Lily Lake improved over previously recorded years and received a B+ lake grade, with 2010 sample results indicating that Lily Lake returned back to the long term normal. The cause of these one-year increases (2009, 2001, and 1995) in water quality is presently unknown, and there may be many possible explanations which could be investigated further in the future. Lake water quality management practices known to WCD staff are the completion of a native buffer planting at the public access in mid-2010, and copper sulfate treatments, but the dates of the treatments are unknown to the WCD. The Lily Lake watershed underwent a sub-watershed assessment in 2010. As a result, in 2011 fifteen raingardens were constructed in the Lily Lake watershed, and more residential raingardens were completed in 2012. With a new round of funding there are seven more raingardens planned for installation in the spring of 2013. The effects of these raingardens were not seen in the 2012 monitoring season, but remain hopeful the results will be seen the longer the BMPs are installed. For more information about the Lily Lake sub-watershed assessment refer to the Lily Lake Stormwater Retrofit Assessment found at http://mscwmo.org/wp-content/subwatershed/LILY-Assessment-Report-FINAL.pdf

McKusick Lake was within the NCHFE range for TP, chl-*a*, and Secchi disk transparency in 2012. Only two of the fourteen water quality samples collected from McKusick Lake exceeded the MPCA TP impairment threshold for shallow lakes. That is down from 2011 when eight samples exceeded the threshold, and back to what was observed in 2010 and 2009 when no samples, and three samples respectively exceeded the TP threshold values (Figure 5). The average 2012 summertime TKN value was within the NCHFE range for TKN (Figure 7). None of the fourteen water quality samples exceeded the MPCA threshold value for chl-*a*. 2012 marked the first year that metals were analyzed for in McKusick Lake samples. Metals are tested because many are known to be extremely toxic to aquatic organisms. No samples exceeded the limits for any heavy metals thresholds analyzed. (Table 4) McKusick Lake showed very low DO levels starting in late-July, when daytime high temperatures ranged from 90 – 100 degrees Fahrenheit, and lasting until mid to late-August. Surface DO readings were near 4 mg/L on 7/31/2012 and near 3 mg/L on 8/14/2012. This is considerably higher than in 2011 when surface DO readings were near 0 mg/L for more than a month during the summer. The low DO levels are likely due to the decomposition of algae and plants that had overtaken McKusick Lake earlier in the year. The City of Stillwater completed the Trout Stream Mitigation Project (TSMP) in June 2003 that has been functioning to divert stormwater from the 1,800-acre annexation area away from Brown's Creek, through McKusick Lake and ultimately to the St. Croix River. This diversion structure is designed to keep the warmer, urban stormwater from the southern tributary of Brown's Creek out of the temperature and nutrient sensitive Brown's Creek Ravine. Local residents' concerns about the amount of water and nutrients entering McKusick Lake are being investigated by the Brown's Creek Watershed District (BCWD) and the City of Stillwater. In 2006 the BCWD initiated stream flow monitoring and water quality sampling on the diversion structure drainage to assist in answering some of the water quality and quantity concerns. All associated data can be found in Figure 11, Table 10, Table 11, Table 12, Table 13 and Table 15. There was a sub-watershed assessment conducted on the McKusick Lake watershed in 2010. In 2011 six raingardens were constructed as a result of the sub-watershed assessment. With renewed funding there are seven additional raingardens to be installed in the McKusick Lake watershed. The impact of previously installed raingardens could not be seen in the 2012 results, but are hopeful results will be seen the longer the best management practices (BMPs) are installed. For more information on the McKusick Lake sub-watershed assessment refer to the

McKusick Lake Stormwater Retrofit Assessment found at http://mscwmo.org/wp-content/subwatershed/McKUSICK-Assessment-Report-FINAL.pdf

There were two lakes and one wetland monitored for water elevation from April to October 2012 (Figure 2, Figure 3, Figure 4). The highest recorded elevations in 2012 occurred around the first part of the summer for each water body. The level on Lily Lake had a high reading of 845.54 ft. on 6/20/2012. McKusick Lake recorded a high elevation of 855.14 ft. on 5/9/2012. Elevations on Perro Pond do not respond the same because the level is less dependent on precipitation and more dependent on a small dam that can allow water to discharge into Perro Creek. This dam was opened on 5/2/2012, keeping the elevation of Perro Pond high up to that date. The high elevation for Perro Pond was 747.12 ft. recorded on 4/27/2012. Changes in lake/wetland elevation are attributed to the changes in monthly precipitation. As shown in Figure 9, precipitation was normal to above normal from January through July. From August until the end of the year, precipitation was well below normal and all MSCWMO lake/wetland elevations dropped during that time period. The low elevation on Lily Lake was recorded on 10/30/2012 with an elevation of 843.68 ft., and McKusick Lake has its lowest reading on 10/10/2012 with an elevation of 853.26 ft. The low elevation recorded on Perro Pond was 745.10 ft. and that occurred on 8/30/2012. Total annual precipitation for 2012 was 29.22 inches, with the majority of that occurring in the first half of the year. That is 1.39 inches below the 30 year (1981-2010) historical annual average of 30.61 inches.

The following are WCD recommendations to the MSCWMO:

- Continue to monitor water levels of MSCWMO lakes and wetland.
- Continue to monitor the water quality of MSCWMO lakes.

STREAM MONITORING

A. METHODS, RESULTS, AND DISCUSSION

The WCD monitors one stream, Perro Creek, in the MSCWMO. Perro Creek flows 1.8 miles from its source, Perro Pond, through an urban landscape and outlets into the St. Croix River. In the upper reaches, much of the creek flows through the residential backyards of Bayport, MN. The lower reaches of the creek have been substantially channelized through the use of pipes and concrete structures. The lower reaches also flow through a more urban, industrial environment where it is prone to more runoff from the surrounding area.

Data from the Brown's Creek Diversion Structure is included in this report as an evaluation of TP loading to McKusick Lake. Continued efforts at this location will allow for evaluation of water quality impacts to McKusick Lake. To eliminate confusion between watershed boundaries and political ownership, Perro Creek is the only stream monitoring site referenced as being within the MSCWMO.

A list of the WCD standard operating procedures can be referenced at http://www.mnwcd.org/water_monitoring_standards.php .

1. PERRO CREEK

The WCD collected base flow grab samples, automated flow-weighted storm composite samples and duplicate samples according to the WCD Standard Operating Procedures (SOP) during the 2012 monitoring season at the Perro Creek site. An automated sampler, located about 1 mile upstream of the St. Croix River, (Figure 1) continuously monitored stream flow discharge and collected event flow composite samples from March 21, 2012 until November 5, 2012. Data collected at this site by the WCD included total discharge, precipitation, and water quality analysis. All stream flow and chemistry data from 2012 can be found in Figure 10, Table 5, Table 6, Table 7, Table 8, and Table 9.

Total discharge during the 2012 monitoring season for Perro Creek was 28,264,823 cf, and total precipitation was 17.62 in. compared to 22.49 inches in 2011. Peak 15 minute average discharge for this site was 16.24 cubic feet per second (cfs), which occurred after the dam opening and an addition of a rain event on May 3. The highest values for TP, TSS, VSS and TKN were all from a composite sample collected from a large storm event on April 15th, with values of 1.47 mg/L for TP, 13,400 mg/L for TSS, 632 mg/L for VSS, and 8.6 mg/L for TKN. Thirteen water quality samples were collected throughout the year, six of them were base flow grab samples and seven of them were storm/event flow composite samples. No base flow samples that were analyzed exceeded water quality standards. Of the seven storm/event flow samples collected, four of them exceeded the water quality standard for turbidity (Table 7).

The 2012 TP and TSS data were used to calculate the total load discharged to the St. Croix River from Perro Creek. In 2012, Perro Creek discharged an estimated load of 129 lb of TP (an increase of 47 lb from the 2011 estimate) and an estimated load of 204,141 lb of TSS (a decrease of 175,493 lb from the 2011 estimate) to the St. Croix River (Table 14). This load is lower than the 2011 estimate, but still remains higher than the previous four years. A possible cause for the load increase could be the further degradation of the up-stream channel. Near the location of the monitoring station location, the stream banks have steadily degraded over the past five monitoring seasons, with large sections sloughing into the creek channel. It is likely that this degradation is occurring along the entirety of the channel, and would certainly contribute to the increase in the TSS loading that has been observed. Stream bank stabilization projects along degraded portions of the creek would help decrease pollutant loads to the St. Croix River and should be investigated further. Other activities such as the Perro Creek clean-up are helpful and can possibly reduce loads to the St. Croix River.

Many heavy metals are known to be extremely toxic to aquatic organisms. All samples collected at Perro Creek were tested for heavy metals. The base flow samples collected did not exceeded any thresholds for heavy metals. Three of the event flow samples exceeded not only the chronic standard threshold, but the maximum standard for copper and five event flow samples that exceeded the chronic standard threshold for lead (Table 8).

Escherichia coli (E. coli) is a bacteria that can be characterized by its ability to grow at elevated temperatures. Perro Creek is impaired for *E. coli*, and data have shown numerous samples where values were above what the MPCA has set as a water quality standard. The following is the description for the *E. coli* standard:

> "Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31"[2].

When looking at all monitored years of data, Perro Creek exceeds the *E. coli* standard, where the geometric mean of at least five samples collected during the month exceeds the value of 126 #/100 mL, for the months of June, July, August, and September. In 2012 there were five *E. coli* samples collected at the Perro Creek site. Of those five, three of them exceeded the water quality standard for *E. coli* (Table 5). Continued monitoring of *E. coli* at this site will help in

[2] MPCA water quality standards for class 2B waters can be found at https://www.revisor.leg.state.mn.us/rules/?id=7050.0222

determining if Perro Creek continues to exceed the water quality standards during the summer months.

Table 5. Perro Creek *E. coli* Monthly Geometric Mean

	May	June	July	August	September	October
6/14/06 11:10		150				
7/25/06 8:45			249			
8/10/06 9:12				318		
9/6/06 9:50					291	
9/10/06 10:20					252	
5/2/07 12:00	276					
6/13/07 10:14		185				
7/16/07 9:51			488			
8/28/07 8:04				1986		
10/18/07 12:15						114
6/5/08 10:18		276				
6/26/08 9:43		153				
7/17/08 8:30			194			
8/27/08 10:20				1553		
7/29/09 9:30			261			
8/27/09 10:25				1120		
9/30/09 8:50					163	
5/25/10 9:00	99					
6/24/10 9:15		225				
7/28/10 11:25			93			
8/26/10 9:49				111		
9/30/10 9:51					95	
6/9/11 10:24		345				
7/7/11 8:32			262			
8/11/11 8:53				40		
9/8/11 8:07					196	
10/5/11 9:03						133
5/31/12 9:13	41					
6/26/12 10:25		96				
7/24/12 11:30			291			
8/30/12 9:44				345		
9/26/12 9:17					145	
Perro Creek Monthly Geometric Mean	Insufficient Data	189.37	238.29	401.53	178.43	Insufficient Data

(Green) Exceeds geometric mean of 126 #/100mL from not less than 5 samples in a calendar month

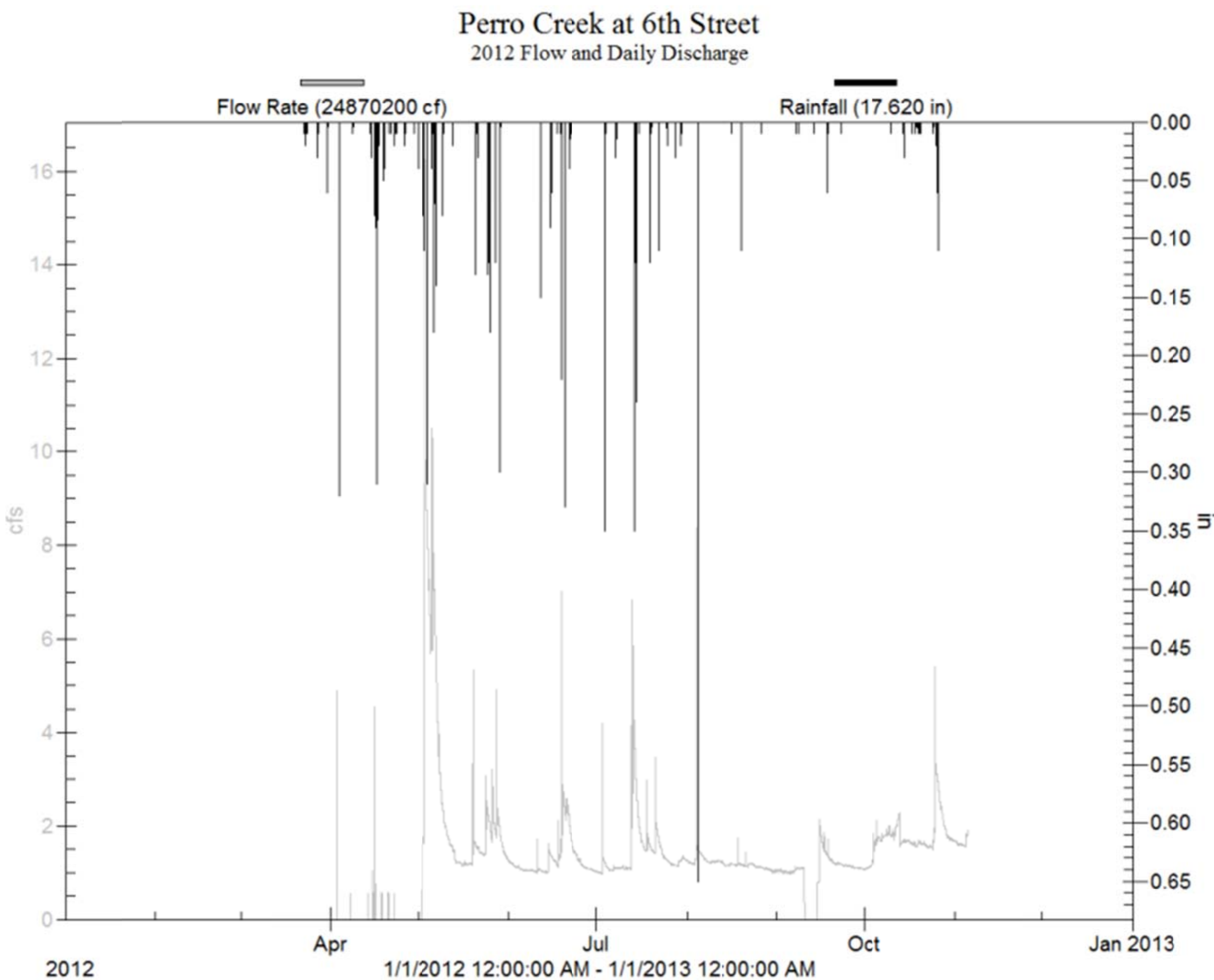


Figure 10. Perro Creek 2012 Discharge and Daily Rainfall

Table 6. Perro Creek 2012 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

	Sample Collection Time				Loading Interval					
Sample Type	**Start**	**End**	**TSS (mg/L)**	**TP (mg/L)**	**Start**	**End**	**Interval Volume (cf)**	**Interval Volume (ac-ft)**	**Interval TSS (lb)**	**Interval TP (lb)**
Snowmelt Grab	3/6/12 13:47	3/6/12 13:47	68	0.689	1/1/12 0:00	3/21/12 15:30	154,158	3.54	654	6.63
Intermittent flow			*2739*	*0.574*	*3/21/12 15:30*	*4/15/12 9:30*	*17,511*	*0.40*	*2,994*	*0.63*
Storm Composite	4/15/12 20:19	4/15/12 20:56	13400	1.47	4/15/12 9:30	4/16/12 5:00	38,701	0.89	32,374	3.55
Intermittent flow			*2739*	*0.574*	*4/16/12 5:00*	*5/2/12 11:45*	*23,773*	*0.55*	*4,065*	*0.85*
Dam Open/Storm			*2739*	*0.574*	*5/2/12 11:45*	*5/3/12 11:45*	*246,234*	*5.65*	*42,096*	*8.82*
Base			*3*	*0.052*	*5/3/12 11:45*	*5/5/12 15:00*	*1,460,797*	*33.54*	*274*	*4.74*
Storm			*2739*	*0.574*	*5/5/12 15:00*	*5/5/12 15:45*	*21,441*	*0.49*	*3,666*	*0.77*
Base			*3*	*0.052*	*5/5/12 15:45*	*5/6/12 2:45*	*252,704*	*5.80*	*47*	*0.82*
Storm			*2739*	*0.574*	*5/6/12 2:45*	*5/6/12 6:00*	*95,027*	*2.18*	*16,246*	*3.40*
Base Grab	5/7/12 10:49	5/7/12 10:49	3	0.031	5/6/12 6:00	5/19/12 20:30	2,591,584	59.49	485	5.02
Storm			*2739*	*0.574*	*5/19/12 20:30*	*5/19/12 21:30*	*10,088*	*0.23*	*1,725*	*0.36*
Base			*3*	*0.052*	*5/19/12 21:30*	*5/24/12 1:30*	*535,301*	*12.29*	*114*	*1.74*
Storm Composite	5/24/12 8:07	5/25/12 8:43	21	0.093	5/24/12 1:30	5/25/12 8:45	240,908	5.53	316	1.40
Base			*3*	*0.052*	*5/25/12 8:45*	*5/26/12 10:30*	*174,268*	*4.00*	*37*	*0.57*
Storm			*2739*	*0.574*	*5/26/12 10:30*	*5/26/12 16:30*	*46,263*	*1.06*	*7,910*	*1.66*
Base			*3*	*0.052*	*5/26/12 16:30*	*5/27/12 23:30*	*218,568*	*5.02*	*46*	*0.71*
Storm			*2739*	*0.574*	*5/27/12 23:30*	*5/28/12 4:45*	*42,917*	*0.99*	*7,337*	*1.54*
Base Grab	6/7/12 11:43	6/7/12 11:43	6	0.079	5/28/12 4:45	6/17/12 23:45	2,178,992	50.02	816	10.75
Storm			*2739*	*0.574*	*6/17/12 23:45*	*6/18/12 0:30*	*4,437*	*0.10*	*759*	*0.16*
Base			*3*	*0.052*	*6/18/12 0:30*	*6/19/12 3:30*	*141,308*	*3.24*	*30*	*0.46*
Storm Composite	6/19/12 4:54	6/19/12 9:37	1630	0.224	6/19/12 3:30	6/19/12 12:30	86,431	1.98	8,795	1.21
Base			*3*	*0.052*	*6/19/12 12:30*	*7/3/12 3:45*	*1,661,031*	*38.13*	*353*	*5.41*
Storm			*2739*	*0.574*	*7/3/12 3:45*	*7/3/12 11:30*	*38,127*	*0.88*	*6,518*	*1.37*
Base Grab	7/9/12 12:00	7/9/12 12:00	6	0.085	7/3/12 11:30	7/13/12 5:30	932,913	21.42	349	4.95
Storm Composite	7/13/12 5:51	7/13/12 7:29	2250	0.261	7/13/12 5:30	7/13/12 12:00	71,198	1.63	10,000	1.16
Base			*3*	*0.052*	*7/13/12 12:00*	*7/13/12 17:45*	*60,186*	*1.38*	*13*	*0.20*
Storm			*2739*	*0.574*	*7/13/12 17:45*	*7/13/12 22:45*	*71,462*	*1.64*	*12,219*	*2.56*
Base			*3*	*0.052*	*7/13/12 22:45*	*7/18/12 10:45*	*848,689*	*19.48*	*180*	*2.77*
Storm			*2739*	*0.574*	*7/18/12 10:45*	*7/18/12 17:00*	*39,584*	*0.91*	*6,768*	*1.42*
*Power Failure**			*3*	*0.052*	*7/18/12 17:00*	*7/19/12 1:00*	*46,960*	*1.08*	*10*	*0.15*
Base			*3*	*0.052*	*7/19/12 1:00*	*7/21/12 6:30*	*289,247*	*6.64*	*61*	*0.94*
Storm			*2739*	*0.574*	*7/21/12 6:30*	*7/21/12 13:30*	*49,355*	*1.13*	*8,439*	*1.77*
Base			*3*	*0.052*	*7/21/12 13:30*	*8/3/12 23:45*	*1,514,377*	*34.77*	*321*	*4.93*
Storm Composite	8/4/12 0:04	8/4/12 0:29	1650	0.947	8/3/12 23:45	8/4/12 4:45	36,595	0.84	3,769	2.16
Base Grab	8/21/12 11:55	8/21/12 11:55	1	0.023	8/4/12 4:45	9/14/12 15:30	3,711,398	85.20	232	5.33
Dam Open			*2739*	*0.574*	*9/14/12 15:30*	*9/15/12 12:30*	*66,330*	*1.52*	*11,340*	*2.38*
Base			*3*	*0.052*	*9/15/12 12:30*	*10/25/12 5:00*	*5,061,544*	*116.20*	*1,074*	*16.49*
Storm Composite	10/25/12 6:15	10/25/12 7:26	151	0.333	10/25/12 5:00	10/25/12 12:30	83,549	1.92	788	1.74
Base Grab	10/29/12 10:38	10/29/12 10:38	1	0.043	10/25/12 12:30	11/5/12 15:15	1,860,726	42.72	116	4.99
*Base**			*3*	*0.052*	*11/5/12 15:15*	*12/1/12 0:00*	*3,180,884*	*73.02*	*675*	*10.37*
Intermittent flow			*2739*	*0.574*	*12/1/12 0:00*	*1/1/13 0:00*	*59,258*	*1.36*	*10,131*	*2.12*
Storm Average			2739	0.574						
Base Average			3	0.052						
All Average			1744	0.386						
Total							**28,264,823**	**649**	**204,141**	**129**
Perro Creek Major Subwatershed Total Acres							1,063			
Total TSS/TP (lb/ac/yr)									192.13	0.12
Total TSS/TP (kg/ha/yr)									215.34	0.14

Italics indicate estimated concentrations based on average base and storm flow concentrations

*Interval volume from 01/01/2012 00:00 to 03/21/2012 15:30, and 11/05/2012 to 12/1/2012 were estimated based on intermittent flow conditions. Interval volume from 07/18/2012 17:00 to 07/19/2012 01:00 were estimated based upon previous and post flow conditions.

Table 7. Perro Creek 2012 Water Quality Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	*E. coli* (mpn/100 mL)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)
Base Grab	5/7/12 10:49	5/7/12 10:49	3	~2	0.37	~0.031	<0.010		<0.05	<0.03	<0.02
Base Grab	6/7/12 11:43	6/7/12 11:43	6	~2	0.51	0.079	0.081		<0.05	<0.03	~0.04
Base Grab	7/9/12 12:00	7/9/12 12:00	6	~2	0.52	0.085	0.052		0.24	0.03	~0.05
Base Grab	8/21/12 11:55	8/21/12 11:55	~1	~1	0.39	~0.023	~0.019		0.08	<0.03	<0.02
Base Grab	8/21/12 11:55	8/21/12 11:55	~1	~1	0.41	~0.026	~0.024		0.08	<0.03	~0.02
Base Grab	10/29/12 10:38	10/29/12 10:38	<1	<1	0.36	~0.043	<0.020		0.03	0.88	0.14
Snowmelt Grab	3/6/12 13:47	3/6/12 13:47	68	21	3.20	0.689	0.525		0.19	0.04	0.50
Storm Composite	4/15/12 20:19	4/15/12 20:56	13400	632	8.60	1.470					
Storm Composite	5/24/12 8:07	5/25/12 8:43	21	6	0.60	0.093	0.079		<0.05	<0.03	<0.02
Storm Composite	6/19/12 4:54	6/19/12 9:37	1630	82	1.40	0.224	~0.012		0.22	0.05	0.08
Storm Composite	7/13/12 5:51	7/13/12 7:09	2250	388	1.50	0.261	~0.023		0.69	<0.03	0.24
Storm Composite	8/4/12 0:04	8/4/12 0:29	1650	156	4.20	0.947	0.138		0.58	<0.03	0.14
Storm Composite	10/25/12 6:15	10/25/12 7:26	151	35	1.90	0.333	~0.049		0.05	0.63	~0.05
E. Coli Grab	5/31/12 9:13	5/31/12 9:13						41			
E. Coli Grab	6/26/12 10:25	6/26/12 10:25						96			
E. Coli Grab	7/24/12 11:30	7/24/12 11:30						291			
E. Coli Grab	8/30/12 9:44	8/30/12 9:44						345			
E. Coli Grab	9/26/12 9:17	9/26/12 9:17						145			

(green) Water Quality Standard Exceedance

(pink) Exceeds Water Quality Standard for Turbidity (TSS value used to calculate)

Table 8. Perro Creek 2012 Sample Metal Chemistry Results

Sample Type	Start Date	End Date	Copper (mg/L)	Lead (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Hardness (mg/L_CaCO3)
Base Grab	5/7/12 10:49	5/7/12 10:49	~0.00040	~0.00025	<0.00030	<0.0050	<0.00020	0.00032	168
Base Grab	6/7/12 11:43	6/7/12 11:43	~0.00055	0.00060	<0.00030	0.0016	<0.00020	<0.00050	168
Base Grab	7/9/12 12:00	7/9/12 12:00	<0.00100	0.00053	<0.00030	~0.0012	<0.00020	0.00026	202
Base Grab	8/21/12 11:55	8/21/12 11:55	<0.00030	<0.00010	<0.00030	<0.0008	<0.00020	~0.00011	190
Base Grab	8/21/12 11:55	8/21/12 11:55	<0.00030	<0.00010	<0.00030	<0.0008	<0.00020	~0.00014	190
Base Grab	10/29/12 10:38	10/29/12 10:38	<0.00030	~0.00010	<0.00100	<0.0050	<0.00020	0.00057	226
Snowmelt Grab	3/6/12 13:47	3/6/12 13:47	0.0070	0.00490	0.00250	0.0301	<0.00020	0.00280	32
Storm Composite	5/24/12 8:07	5/25/12 8:43	0.0022	0.00120	~0.00048	0.0044	<0.00020	0.00078	174
Storm Composite	6/19/12 4:54	6/19/12 9:37	0.0064	0.00990	0.00240	0.0211	<0.00020	0.00350	132
Storm Composite	7/13/12 5:51	7/13/12 7:29	0.0155	0.02680	0.00680	0.0603	~0.00031	0.01390	74
Storm Composite	8/4/12 0:04	8/4/12 0:29	0.0154	0.03010	0.00700	0.0711	~0.00033	0.01020	80
Storm Composite	10/25/12 6:15	10/25/12 7:26	0.0047	0.00630	0.00200	0.0241	<0.00020	0.00600	150

Exceeds Chronic Standard (yellow)
Exceeds Max Standard (blue)
Exceeds Final Acute Standard (red)
No Exceedance Determinable (gray)

Table 9. Perro Creek 2012 Field Measurement Results

Date	Transparency (cm)	Water Temperature (C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
3/6/12 13:47	17	1.9	13.39	125	6.6
5/31/12 9:13	>100	18.4	8.85	363	8.1
6/7/12 11:43	>100	24.3	6.47		
7/9/12 12:00	>120	26.5	6.99	429	8.3
8/21/12 11:55	>120	19.9	8.66	406	8.0
9/26/12 9:17	>120	12.2	8.89	440	8.3
10/29/12 10:38	>100	4.3	11.47	485	8.2

(Green shading:) Water Quality Standard Exceedance

2. BROWN'S CREEK DIVERSION STRUCTURE

As additional data provided to the MSCWMO, the WCD took grab samples and automated flow-weighted samples during both base flow and storm event conditions at the Brown's Creek Diversion Structure for BCWD in 2012. The City of Stillwater constructed the diversion structure in June of 2003, as part of the completion of the TSMP. It has been functioning to divert water from the 1,800-acre annexation area, away from Brown's Creek through McKusick Lake, and ultimately to the St. Croix River. While this diversion structure will keep the warmer urban stormwater runoff from the southern tributary out of the temperature and nutrient sensitive Brown's Creek Ravine, it means that this water will be entering McKusick Lake, and could affect the lake water quality. Data collected at this site by the WCD includes total discharge and water quality sample analysis. All stream flow and chemistry data from 2012 can be found in Figure 11, Table 10, Table 11, Table 12, Table 13 and Table 15.

Using a combination of composite and grab samples, TP and TSS loads were calculated at the Brown's Creek Diversion Structure site. TP exported from the Brown's Creek Diversion Structure decreased from 2,099 lb in 2011, to 260 lb of TP in 2012. TSS also showed a decrease between 2011 and 2012, with 1,387,050 lb of TSS being exported to Lake McKusick in 2011 and 128,110 lb of TSS exported in 2012 (Table 10, Table 15).

Water quality results showed all sixteen storm samples exceeded the standard for TSS, which includes an unexplained discharge sample. The source of the unexplained discharge sample is still unknown, but is being further investigated. Three of the five *E. coli* samples showed water quality standard exceedances (Table 11). There were fifteen event flow samples and five base flow samples that were tested for metals in 2012. There were no exceedances of metal standard thresholds for base flow samples. Eight event flow samples exceeded the chronic standard for copper, including two that exceeded the maximum standard. Nine event flow samples exceeded the chronic standard for lead. There were no other exceedances of metals (Table 12). No field data measurements exceeded any standard thresholds (Table 13).

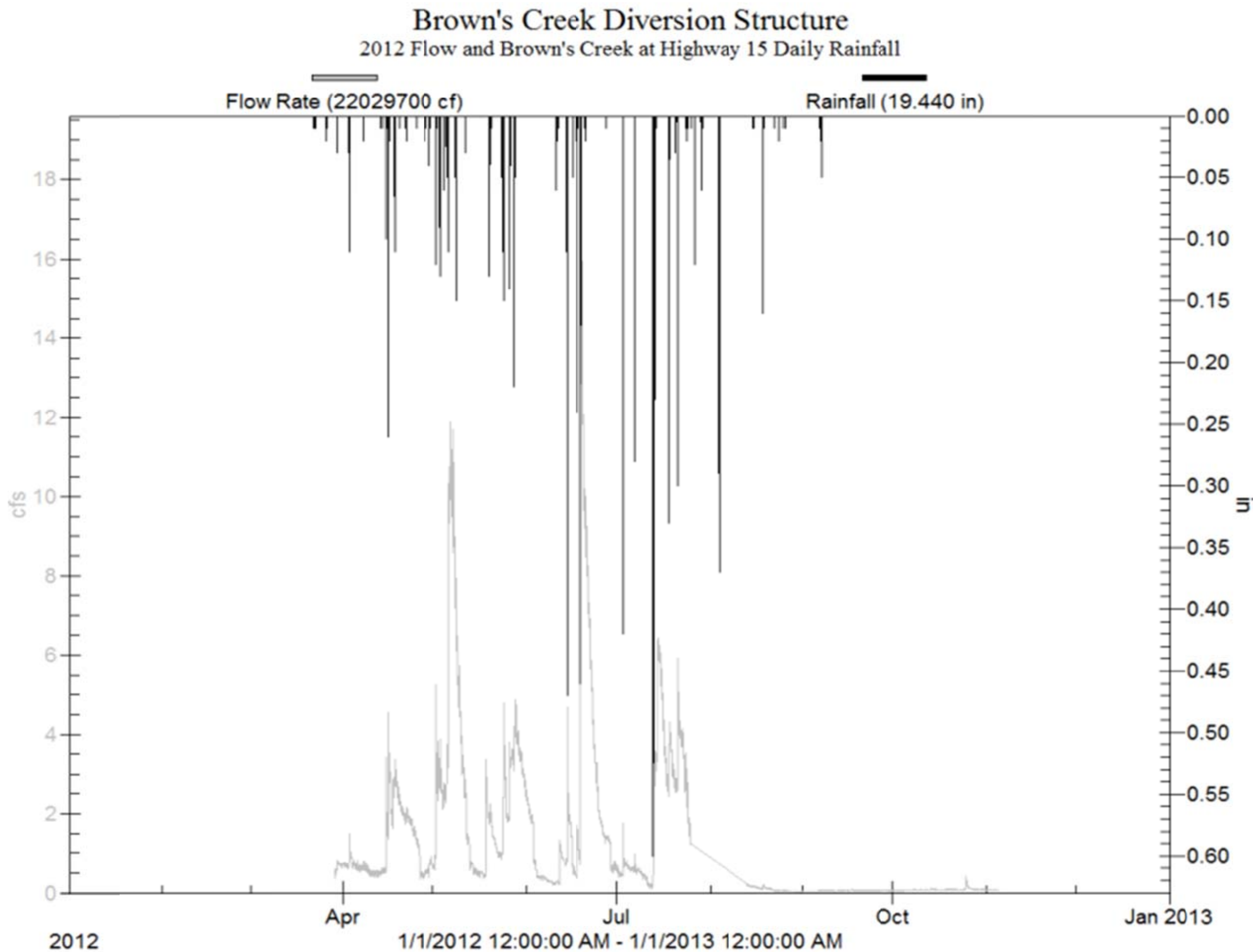


Figure 11. Brown's Creek Diversion Structure Drainage 2012 Flow and Brown's Creek at Highway 15 Rainfall

Table 10. Brown's Creek Diversion Structure Drainage 2012 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

	Sample Collection Time				Loading Interval					
Sample Type	Start	End	TSS (mg/L)	TP (mg/L)	Start	End	Interval Volume (cf)	Interval Volume (ac-ft)	Interval TSS (lb)	Interval TP (lb)
Base**			5	0.082	1/1/2012 0:00	3/29/2012 9:00	76,356	1.75	24	0.39
Base			5	0.082	3/29/2012 9:00	4/3/2012 0:00	284,246	6.53	89	1.46
Storm			513	0.632	4/3/2012 0:00	4/3/2012 6:00	25,337	0.58	811	1.00
Base			5	0.082	4/3/2012 6:00	4/15/2012 2:00	618,869	14.21	193	3.17
Storm Composite	4/15/12 4:15	4/15/12 9:06	210	0.514	4/15/2012 2:00	4/15/2012 10:00	60,184	1.38	789	1.93
Base			5	0.082	4/15/2012 10:00	4/15/2012 18:00	48,081	1.10	15	0.25
Storm Composite	4/15/12 18:47	4/16/12 9:58	100	0.277	4/15/2012 18:00	4/16/2012 10:00	178,100	4.09	1,112	3.08
Base			5	0.082	4/16/2012 10:00	4/24/2012 10:00	1,491,360	34.25	465	7.63
Base Grab	4/25/12 14:30	4/25/12 14:30	8	0.051	4/24/2012 10:00	4/26/2012 10:00	221,683	5.09	111	0.71
Base			5	0.082	4/26/2012 10:00	5/1/2012 22:00	282,114	6.48	88	1.44
Storm Composite	5/2/12 0:53	5/2/12 5:34	1280	0.371	5/1/2012 22:00	5/2/2012 6:00	90,989	2.09	7,271	2.11
Base			5	0.082	5/2/2012 6:00	5/2/2012 17:00	110,596	2.54	35	0.57
Storm Composite	5/2/12 17:40	5/2/12 18:21	293	0.384	5/2/2012 17:00	5/2/2012 18:30	15,693	0.36	287	0.38
Storm Composite	5/2/12 18:34	5/2/12 19:13	372	0.686	5/2/2012 18:30	5/2/2012 19:15	9,757	0.22	227	0.42
Storm Composite	5/2/12 19:26	5/2/12 20:05	341	0.518	5/2/2012 19:15	5/2/2012 20:15	13,574	0.31	289	0.44
Base			5	0.082	5/2/2012 20:15	5/3/2012 10:00	157,331	3.61	49	0.81
Storm			513	0.632	5/3/2012 10:00	5/3/2012 14:00	49,066	1.13	1,571	1.94
Base			5	0.082	5/3/2012 14:00	5/5/2012 14:00	444,990	10.22	139	2.28
Storm			513	0.632	5/5/2012 14:00	5/5/2012 19:00	58,261	1.34	1,866	2.30
Base			5	0.082	5/5/2012 19:00	5/6/2012 3:00	95,464	2.19	30	0.49
Storm			513	0.632	5/6/2012 3:00	5/7/2012 4:00	895,519	20.57	28,679	35.33
Base			5	0.082	5/7/2012 4:00	5/18/2012 10:00	2,895,990	66.52	904	14.82
Unexplained Discharge	5/18/12 10:48	5/18/12 21:14	764	0.696	5/18/2012 10:00	5/18/2012 22:00	123,370	2.83	5,884	5.36
Base			5	0.082	5/18/2012 22:00	5/19/2012 19:00	155,241	3.57	48	0.79
Storm Composite	5/19/12 19:52	5/20/12 2:13	188	0.206	5/19/2012 19:00	5/20/2012 3:00	58,942	1.35	692	0.76
Base			5	0.082	5/20/2012 3:00	5/24/2012 2:00	424,141	9.74	132	2.17
Storm Composite	5/24/12 8:34	5/25/12 3:22	258	0.571	5/24/2012 2:00	5/25/2012 4:00	258,844	5.95	4,169	9.23
Base			5	0.082	5/25/2012 4:00	5/26/2012 10:00	213,173	4.90	67	1.09
Storm Composite	5/26/12 11:08	5/26/12 16:27	566	0.512	5/26/2012 10:00	5/26/2012 17:00	78,591	1.81	2,777	2.51
Base			5	0.082	5/26/2012 17:00	5/28/2012 0:00	379,339	8.71	118	1.94
Storm			513	0.632	5/28/2012 0:00	5/28/2012 15:00	244,517	5.62	7,831	9.65
Base			5	0.082	5/28/2012 15:00	6/6/2012 15:00	1,515,780	34.82	473	7.76
Base Grab	6/7/12 10:38	6/7/12 10:38	7	0.094	6/6/2012 15:00	6/8/2012 15:00	58,402	1.34	26	0.34
Base			5	0.082	6/8/2012 15:00	6/11/2012 20:00	70,813	1.63	22	0.36
Unexplained Discharge			513	0.632	6/11/2012 20:00	6/12/2012 4:00	33,792	0.78	1,082	1.33
Base			5	0.082	6/12/2012 4:00	6/14/2012 10:00	169,295	3.89	53	0.87
Storm Composite	6/14/12 13:20	6/14/12 18:41	1100	1.570	6/14/2012 10:00	6/14/2012 19:00	77,292	1.78	5,308	7.58
Base			5	0.082	6/14/2012 19:00	6/18/2012 0:00	282,955	6.50	88	1.45
Storm			513	0.632	6/18/2012 0:00	6/18/2012 4:00	20,791	0.48	666	0.82
Base			5	0.082	6/18/2012 4:00	6/19/2012 3:00	85,538	1.96	27	0.44
Storm Composite	6/19/12 3:45	6/19/12 9:15	570	0.910	6/19/2012 3:00	6/19/2012 19:00	796,917	18.30	28,357	45.27
Base			5	0.082	6/19/2012 19:00	7/3/2012 4:00	3,720,380	85.45	1,161	19.04
Storm			513	0.632	7/3/2012 4:00	7/3/2012 7:00	14,724	0.34	472	0.58
Base			5	0.082	7/3/2012 7:00	7/8/2012 7:00	288,653	6.63	90	1.48
Base Grab	7/9/12 14:43	7/9/12 14:43	6	0.093	7/8/2012 7:00	7/10/2012 7:00	87,420	2.01	33	0.51
Base			5	0.082	7/10/2012 7:00	7/13/2012 5:00	66,456	1.53	21	0.34
Storm Composite	7/13/12 6:43	7/13/12 13:41	721	1.050	7/13/2012 5:00	7/14/2012 1:00	257,278	5.91	11,580	16.86
Base			5	0.082	7/14/2012 1:00	7/18/2012 10:00	1,649,420	37.89	515	8.44
Storm			513	0.632	7/18/2012 10:00	7/18/2012 19:00	122,877	2.82	3,935	4.85
Base			5	0.082	7/18/2012 19:00	7/21/2012 7:00	671,015	15.41	209	3.43
Storm Composite	7/21/12 8:39	7/21/12 14:08	721	0.528	7/21/2012 7:00	7/21/2012 14:00	123,217	2.83	5,546	4.06
Base			5	0.082	7/21/2012 14:00	7/25/2012 10:00	1,048,580	24.08	327	5.37
Base**			5	0.082	7/25/2012 10:00	8/13/2012 11:00	1,645,200	37.79	514	8.42
Base			5	0.082	8/13/2012 11:00	8/18/2012 21:00	69,322	1.59	22	0.35
Storm			513	0.632	8/18/2012 21:00	8/19/2012 4:00	4,375	0.10	140	0.17
Base Grab	8/21/12 9:24	8/21/12 9:24	1	0.059	8/19/2012 4:00	8/22/2012 4:00	28,201	0.65	2	0.10
Base			5	0.082	8/22/2012 4:00	9/20/2012 4:00	120,221	2.76	38	0.62
Base Grab	9/13/12 9:08	9/13/12 9:08	3	0.117	9/20/2012 4:00	9/22/2012 4:00	9,474	0.22	2	0.07
Base			5	0.082	9/22/2012 4:00	10/13/2012 14:00	116,161	2.67	36	0.59
Storm			513	0.632	10/13/2012 14:00	10/13/2012 22:00	2,991	0.07	96	0.12
Base			5	0.082	10/13/2012 22:00	10/25/2012 5:00	75,821	1.74	24	0.39
Storm			513	0.632	10/25/2012 5:00	10/25/2012 19:00	12,896	0.30	413	0.51
Base Grab	10/30/12 8:41	10/30/12 8:41	7	0.075	10/25/2012 19:00	10/31/2012 19:00	46,462	1.07	20	0.22
Base			5	0.082	10/31/2012 19:00	11/5/2012 12:00	30,801	0.71	10	0.16
Base**			5	0.082	11/5/2012 12:00	1/1/2013 0:00	146,448	3.36	46	0.75
Storm Average			513	0.632						
Base Average			5	0.082						
All Average			376	0.464						
Total							**23,529,686**	**540**	**128,110**	**260**
Brown's Creek Major Subwatershed Total Acres							3,837			
Total TSS/TP(lb/ac/yr)									33.39	0.07
Total TSS/TP (kg/ha/yr)									37.42	0.08

*Italics indicate estimated concentrations based on average base and storm flow concentrations

**Interval volumes from 01/01/12 to 03/29/12; and 11/05/12 to 1/1/13 were estimated using recorded base flow

Table 11. Brown's Creek Diversion Structure Drainage 2012 Primary Water Quality Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	*E coli* (mpn/100mL)
Base Grab	4/25/12 14:30	4/25/12 14:30	8	3	0.58	0.051	~0.017	
Base Grab	6/7/12 10:38	6/7/12 10:38	7	3	0.73	0.094	0.056	
Base Grab	7/9/12 14:43	7/9/12 14:43	6	3	0.77	0.093	~0.049	
Base Grab	8/21/12 9:24	8/21/12 9:24	~1	~1	0.47	0.059	0.055	
Base Grab	9/13/12 9:08	9/13/12 9:08	3	~1	0.31	0.117	0.073	
Base Grab	10/30/12 8:41	10/30/12 8:41	7	3	0.33	0.075		
Storm Composite	4/15/12 4:15	4/15/12 9:06	210	65	3.80	0.514	~0.038	
Storm Composite	4/15/12 18:47	4/16/12 9:58	100	34	2.20	0.277	0.057	
Storm Composite	5/2/12 0:53	5/2/12 5:34	1280	422	0.82	0.371	~0.030	
Storm Composite	5/2/12 17:40	5/2/12 18:21	293	114	3.40	0.384	~0.027	
Storm Composite	5/2/12 18:34	5/2/12 19:13	372	154	6.20	0.686	~0.039	
Storm Composite	5/2/12 19:26	5/2/12 20:05	341	150	5.70	0.518	0.056	
Unexplained Discharge	5/18/12 10:48	5/18/12 21:14	764	336	5.70	0.696	0.054	
Storm Composite	5/19/12 19:52	5/20/12 2:13	188	66	2.10	0.206	~0.041	
Storm Composite	5/24/12 8:34	5/25/12 3:22	258	89	3.60	0.571	0.053	
Storm Grab	5/24/12 9:23	5/24/12 9:23	174	61	2.40	0.402	0.071	
Storm Composite	5/26/12 11:08	5/26/12 16:27	566	164	3.10	0.512	~0.036	
Storm Composite	6/14/12 13:20	6/14/12 18:41	1100	424	6.70	1.570	~0.041	
Storm Grab	6/14/12 14:44	6/14/12 14:44	408	180	3.30	0.680	0.059	
Storm Composite	6/19/12 3:45	6/19/12 9:15	570	151	4.60	0.910	0.126	
Storm Composite (Duplicate)	6/19/12 3:45	6/19/12 9:15	568	150	3.70	0.645	0.111	
Storm Composite	7/13/12 6:43	7/13/12 13:41	721	242	6.10	1.050	0.067	
Storm Grab	7/13/12 8:55	7/13/12 8:55	263	83	3.30	0.477	0.083	
Storm Composite	7/21/12 8:39	7/21/12 14:08	721	183	2.80	0.528	~0.049	
E. coli Grab	5/31/12 9:53	5/31/12 9:53						50
E. coli Grab	6/26/12 11:33	6/26/12 11:33						34
E. coli Grab	7/24/12 11:59	7/24/12 11:59						435
E. coli Grab	8/30/12 8:52	8/30/12 8:52						435
E. coli Grab	9/26/12 8:45	9/26/12 8:45						199

(green) Exceeds Water Quality Standard

(pink) Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate)

Table 12. Brown's Creek Diversion Structure Drainage 2012 Secondary Water Quality Results

Sample Type	Start Date	End Time	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite (mg/L)	Nitrate mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L_CaCO3)
Base Grab	4/25/12 14:30	4/25/12 14:30	0.00066	0.00065	~0.00014	<0.0050	<0.00020	0.00034	20	<0.03	0.26	~0.03	112
Base Grab	6/7/12 10:38	6/7/12 10:38	0.00060	0.00074	~0.00017	~0.0015	<0.00020	0.00054	63	<0.03	0.72	0.07	202
Base Grab	7/9/12 14:43	7/9/12 14:43	<0.00100	~0.00059	~0.00019	~0.0012	<0.00020	0.00034	76	<0.03	0.42	~0.05	130
Base Grab	8/21/12 9:24	8/21/12 9:24	0.00065	~0.00055	<0.00010	0.0019	<0.00020	0.00034	72	<0.03	0.73	0.07	172
Base Grab	9/13/12 9:08	9/13/12 9:08							59	<0.03	1.21	~0.02	264
Base Grab	10/30/12 8:41	10/30/12 8:41	0.00091	<0.00100	~0.00012	<0.0050	<0.00020	0.00050	58	<0.03	0.94	~0.05	274
Storm Composite	4/15/12 4:15	4/15/12 9:06	0.02150	0.00480	0.00440	0.0250	~0.00035	0.00440	39	<0.03	1.04	~0.05	158
Storm Composite	4/15/12 18:47	4/16/12 9:58	0.01920	0.00270	0.00230	0.0148	~0.00026	0.00230	45	<0.03	1.16	~0.04	148
Storm Composite	5/2/12 0:53	5/2/12 5:34	0.01140	0.00700	0.00530	0.0260	~0.00030	0.00590	37	<0.03	0.73	~0.04	128
Storm Composite	5/2/12 17:40	5/2/12 18:21							55				
Storm Composite	5/2/12 18:34	5/2/12 19:13							57				
Storm Composite	5/2/12 19:26	5/2/12 20:05							57				
Unexplained Discharge	5/18/12 10:48	5/18/12 21:14	0.01420	0.01220	0.00700	0.0533	0.00060	0.00870	70	<0.03	0.16	0.12	64
Storm Composite	5/19/12 19:52	5/20/12 2:13	0.00500	0.00250	0.00180	0.0122	<0.00020	0.00210	67	<0.03	0.20	<0.02	86
Storm Composite	5/24/12 8:34	5/25/12 3:22	0.00550	0.00460	0.00350	0.0162	<0.00020	0.00440	42	<0.03	0.27	~0.04	110
Storm Grab	5/24/12 9:23	5/24/12 9:23	0.00410	0.00390	0.00300	0.0146	<0.00020	0.00440	43	<0.03	0.26	~0.04	134
Storm Composite	5/26/12 11:08	5/26/12 16:27	0.00800	0.00620	0.00520	0.0272	~0.00047	0.00550	53	<0.03	0.24	~0.04	100
Storm Composite	6/14/12 13:20	6/14/12 18:41	0.01730	0.01440	0.01110	0.0487	0.00050	0.01440	49	<0.03	0.33	~0.02	132
Storm Grab	6/14/12 14:44	6/14/12 14:44	0.00370	0.00370	0.00290	0.0123	<0.00020	0.00390					116
Storm Composite	6/19/12 3:45	6/19/12 9:15	0.00880	0.00800	0.00620	0.0270	~0.00025	0.00710	14	<0.03	0.57	~0.06	66
Storm Composite (Duplicate)	6/19/12 3:45	6/19/12 9:15	0.00800	0.00720	0.00520	0.0238	~0.00021	0.00630	14	<0.03	0.57	0.06	72
Storm Composite	7/13/12 6:43	7/13/12 13:41	0.01120	0.01060	0.00700	0.0379	~0.00045	0.00960	29	<0.03	0.48	~0.03	100
Storm Grab	7/13/12 8:55	7/13/12 8:55	0.00520	0.00470	0.00320	0.0165	<0.00020	0.00480	31	<0.03	0.58	0.07	98
Storm Composite	7/21/12 8:39	7/21/12 14:08	0.00840	0.00650	0.00540	0.0259	~0.00031	0.00470	56	<0.03	0.13	<0.02	48
E. coli Grab	5/31/12 9:53	5/31/12 9:53											
E. coli Grab	6/26/12 11:33	6/26/12 11:33											
E. coli Grab	7/24/12 11:59	7/24/12 11:59											
E. coli Grab	8/30/12 8:52	8/30/12 8:52											
E. coli Grab	9/26/12 8:45	9/26/12 8:45											

Exceeds Chronic Standard (yellow)
Exceeds Max Standard (blue)
Exceeds Final Acute Standard (dark red)

Table 13. Brown's Creek Diversion Structure Drainage 2012 Field Measurement Results

Date/Time	Transparency (cm)	Water Temperature (C)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	pH
4/25/12 14:30	>100	18.3	7.27	362	7.80
6/7/12 10:38	64	17.4	8.93		8.09
6/14/12 14:44	16	16.4	8.19	338	7.20
7/9/12 14:43	110	25.8	5.85	442	7.80
8/21/12 9:24	>120	12.5	9.61	501	7.60
9/13/12 9:08	>120	10.8	7.30	622	7.50
10/29/12 10:14	>100	2.6	11.58	652	7.65
10/30/12 8:41	>120	1.5	12.83	650	8.01

Exceeds Water Quality Standard

B. MSCWMO STREAMS: CONCLUSIONS AND RECOMMENDATIONS

While Perro Creek had a slight decrease in discharge and the amount of TSS, there was an increase of TP exported to the St. Croix River in 2012, when compared to 2011. When looking at the historical loading data, there is no increasing or decreasing trend in TP, whereas TSS has plateaued in 2012 after increasing exponentially since 2007, after a large decrease from 2006 (Table 14). Monitoring of Perro Creek started at the end of the monitoring season in 2005 and there was not enough data to calculate loading values for that year.

Table 14. Perro Creek Historical Annual Discharge and Loading Amounts

	2012	2011	2010	2009	2008	2007	2006
Perro Creek							
Discharge (cf)	28,264,823	28,986,610	38,802,342	16,272,950	25,428,457	16,703,958	39,748,331
Subwatershed Total Acres	1,063	1,063	1,063	1,063	1,063	1,063	1,063
Total pounds of Phosphorus exported	129	82	179	242	87	212	241
TP (lb/ac/yr)	0.12	0.08	0.17	0.23	0.08	0.20	0.23
Total pounds of TSS exported	204,141	379,634	191,200	51,874	29,343	13,023	162,938
TSS (lb/ac/yr)	192.13	357.29	179.95	48.82	27.62	12.26	153.35

Changes in discharge from Perro Creek appear to be directly related to precipitation (Figure 9), but are also related to anthropogenic sources, such as the small dam that holds back Perro Pond and releases water into Perro Creek. This dam was not opened until May 2, 2012 and Perro Creek did not flow continuously until the dam was opened. In previous years WCD staff has observed artificial blockages in the channel as well as the dumping of yard waste into the creek. The changes in discharge caused by artificial means (such as channel blocking) can and has caused deterioration in the stability of the stream bank and has created difficulty in monitoring. Additional waste dumped into the stream causes larger loads observed in the stream, more nutrients, and more waste products discharged to the St. Croix River.

The Brown's Creek Diversion Structure Drainage data is extremely valuable for determining current and future impacts to McKusick Lake. The large load observed coming from this site is likely one of the major impacts on the water quality of the lake. 2012 has resulted in the lowest discharge from the diversion structure drainage since monitoring began, as well as the lowest load of total phosphorus and the second lowest load of total suspended solids exported to McKusick Lake (Table 15). Brown's Creek Watershed District has implemented more intense monitoring of the entire diversion area drainage to identify potential load sources. This monitoring also includes components to determine the types of BMP that will be most effective in reducing the loads entering McKusick Lake. Goals have been established through the City of Stillwater's Lake Management Plan for McKusick Lake and accurately monitored loading data from the Brown's Creek Diversion Structure Drainage will continue to provide evidence of reductions in the total phosphorus load to McKusick Lake from water quality improvement projects. For more information on the monitoring of the Brown's Creek Diversion Structure and the Brown's Creek Diversion Drainage, refer to the Brown's Creek Watershed District 2012 Water Monitoring Report.

Table 15. Brown's Creek Diversion Structure Drainage Historical Annual Discharge and Loading Amounts

	2012	2011	2010	2009	2008	2007	2006
Brown's Creek Diversion Structure							
Discharge (cf)	23,529,686	52,981,553	38,197,468	31,166,264	29,397,219	49,768,967	33,916,362
Total pounds of Phosphorus exported	260	2,099	608	544	206	653	676
TP (lbs/ac/yr)	0.678	0.547	0.160	0.140	0.050	0.170	0.176
Total pounds of TSS exported	128,110	1,387,050	353,007	227,372	59,313	232,190	455,793
TSS (lbs/ac/yr)	33.39	361.49	92.00	59.26	15.46	60.51	118.79

The following are WCD recommendations to the MSCWMO:

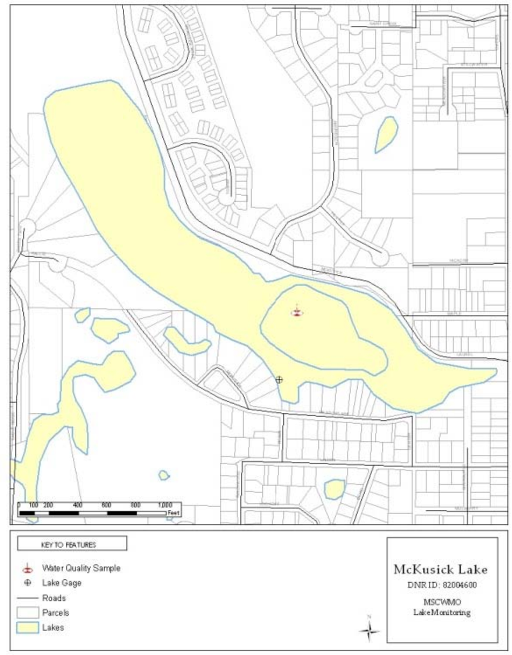
- Continue to monitor Perro Creek for any potential water quality trends and water quality standard exceedances.
- Work with Perro Creek's neighboring landowners to improve stewardship along the creek to prevent future channel blockage and excess waste dumping.
- Investigate future stream bank stabilization projects along Perro Creek.
- Establish a record keeping protocol for the opening and closing of the Perro Pond Outlet, to enhance future monitoring data interpretation
- Continue to evaluate loading estimates at the Brown's Creek Diversion Structure Drainage site to determine if future water quality improvement projects are helping to reduce loading to McKusick Lake.

APPENDIX A
Water Quality Data– McKusick Lake, Lily Lake, and Brick Pond

McKusick Lake

2012 Lake Grade: B

- DNR ID #: 820020
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2012): 16 ft
- Ordinary High Water Mark: 853 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



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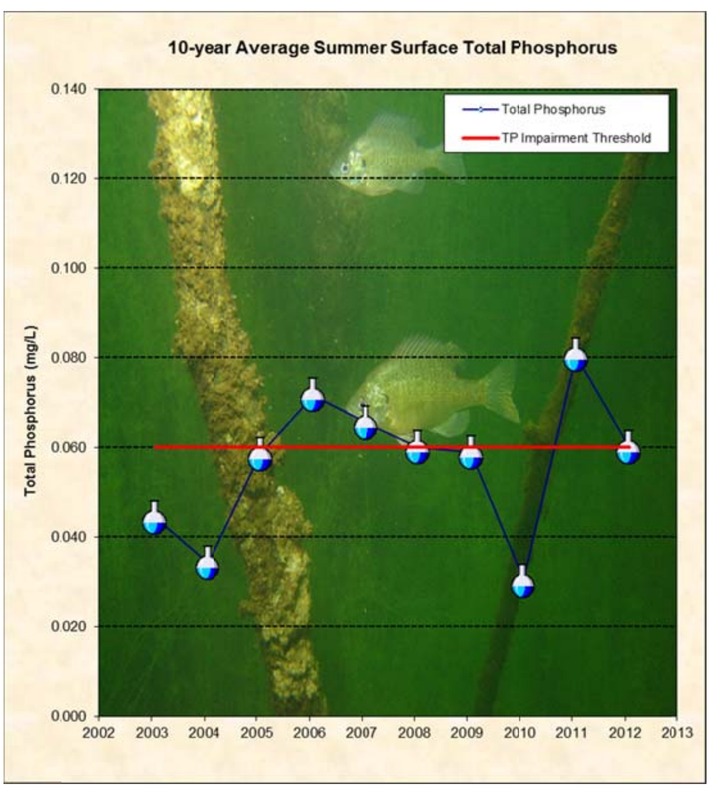
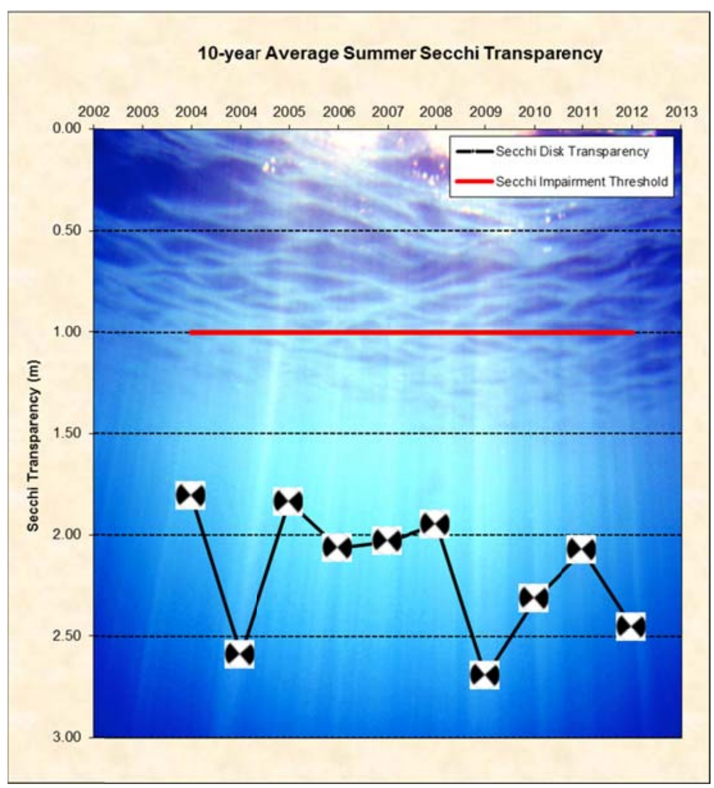


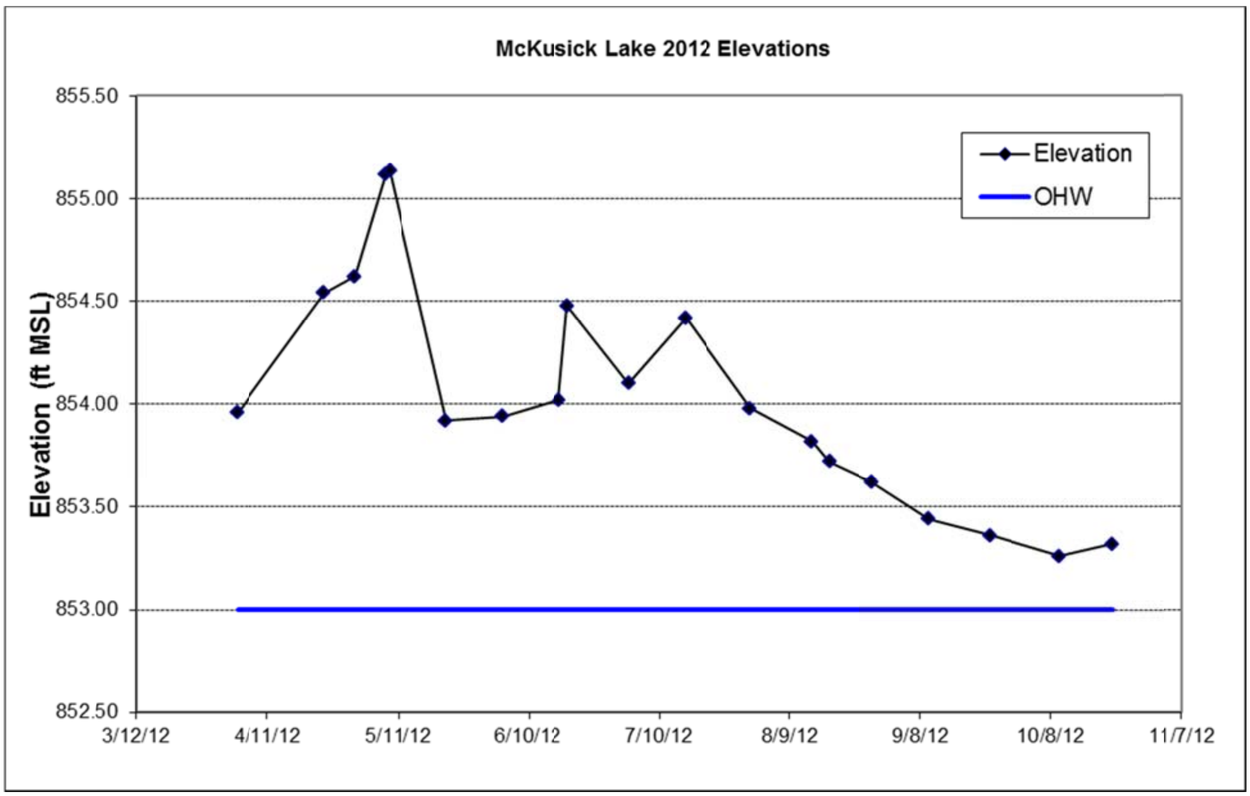


Date	Total Phosphorus (mg/l)	Chlorophyll-*a* (ug/l)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Dissolved Oxygen Levels (mg/l)	Surface Temperature Levels (Celsius)
4/23/2012	0.043	5.0	0.93	3.51	10.67	13.8
5/9/2012	0.047	7.3	0.87	1.52	8.14	17.1
5/22/2012	0.049	5.2	0.88	2.74	8.54	19.5
6/5/2012	0.119	3.9	0.94	3.05	9.30	25.3
6/19/2012	0.059	6.9	0.92	3.05	7.79	22.1
7/3/2012	0.056	8.8	0.83	2.13	7.45	28.9
7/18/2012	0.051	12.0	1.20	1.68	6.09	27.2
7/31/2012	0.048	3.7	0.95	2.13	4.43	26.1
8/14/2012	0.053	8.0	1.20	2.44	3.12	22.2
8/28/2012	0.052	14.0	0.95	2.13	6.81	22.8
9/10/2012	0.069	4.0	1.20	2.44	5.01	19.5
9/24/2012	0.033	4.6	1.00	3.05	9.01	13.7
10/10/2012	0.042	3.0	0.91	3.20	11.52	8.6
10/22/2012	0.056	1.0	1.60	3.66	11.48	10.7
2012 Average	0.056	6.2	1.03	2.62	7.81	19.8
2012 Summer Average	0.060	7.3	1.02	2.46	6.56	23.1

Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*

	High	High Date	Low	Low Date	Average
2012 Elevation (ft)	855.14	5/9/2012	853.26	10/10/2012	854.04

*MPCA description of Impaired Lake's Listing criteria: "At a minimum, a decision that a given lake is impaired for the 303(d) list due to excessive nutrients will be supported by data for both causal and response factors. Data requirements for 303(d) listing consist of 12 or more TP measurements collected from June through September over the most recent 10-year period. Ideally this should represent 12 separate visits to the lake over the course of two summers; however it might also reflect four monthly samples over the course of three years (a typical sampling regimen for many lake monitoring programs). In addition to exceeding the TP guideline thresholds, lakes to be considered for 303(d) listing should have at least 12 Secchi measurements and 12 chlorophyll-a measurements. This amount of data will allow for at least one season (preferably more) of paired TP, chlorophyll-a, and Secchi disk data and provide a basis for evaluating their interrelationships and hence the trophic status of the lake."

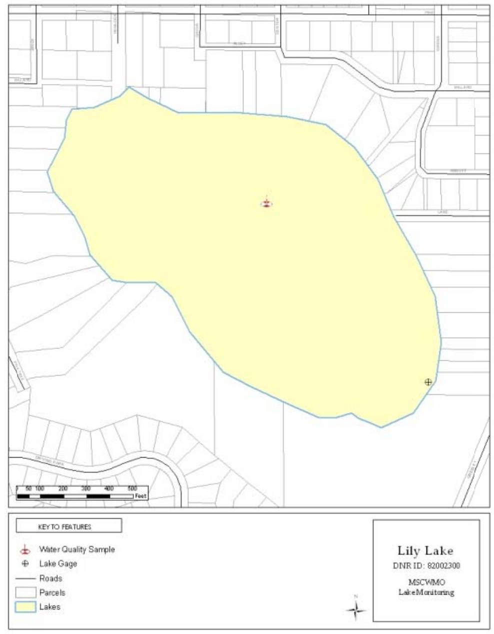


Lake Water Quality Summary											
	Trophic Status 2012	**Summertime Lake Grades**									
		2012	2011	2010	2009	2008	2007	2006	2005	2004	2003
Total Phosphorus (mg/L)	**Eutrophic**	**C**	D	B	C	C	C	D	C	C	C
Chlorophyll-*a* (ug/L)	**Eutrophic**	**A**	C	A	A	B	B	B	B	A	B
Secchi depth (ft)	**Mesotrophic**	**B**	C	B	B	C	C	C	C	B	C
Overall	**Eutrophic**	**B**	**C-**	**B+**	**B**	**C+**	**C+**	**C**	**C+**	**B**	**C+**

Lily Lake

2012 Lake Grade: C+

- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth: 51 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Public access and public beach present



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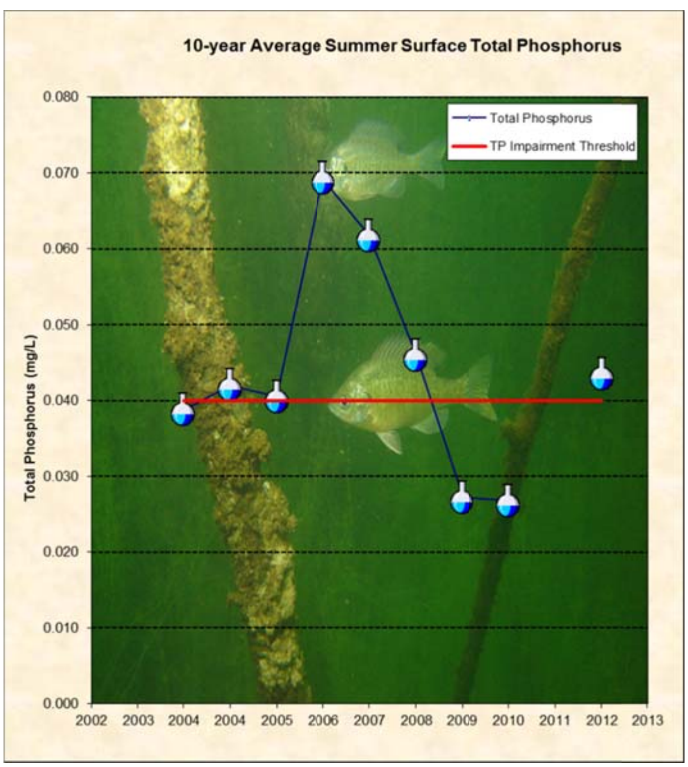
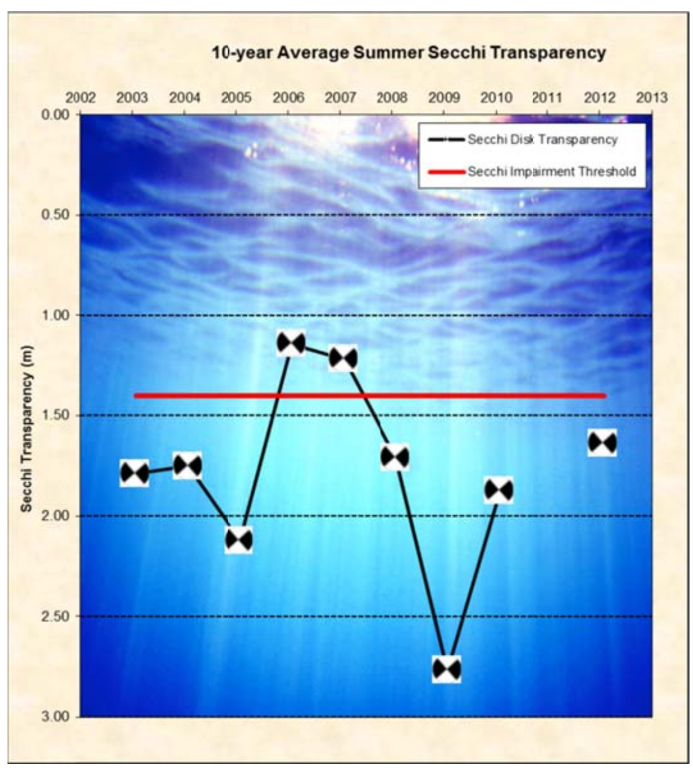


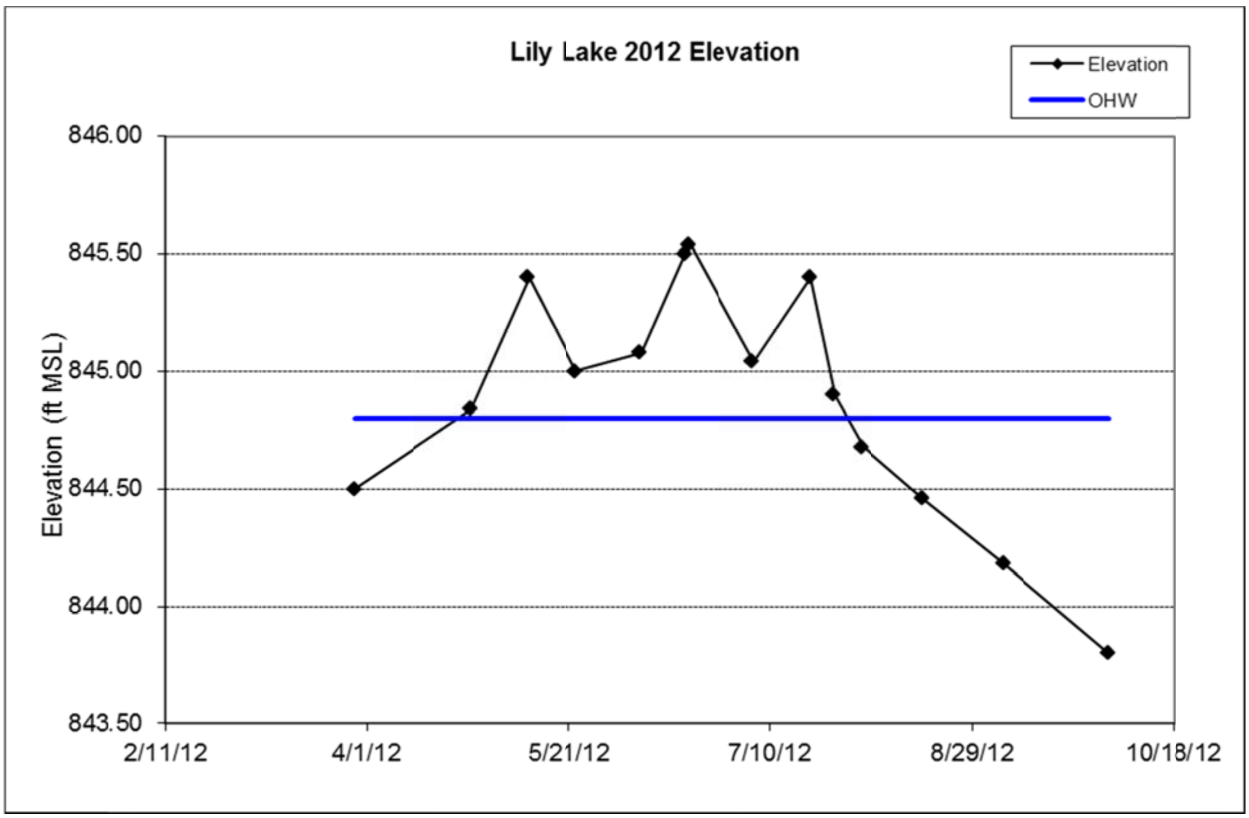


Date	Total Phosphorus (mg/l)	Chlorophyll-*a* (ug/l)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Dissolved Oxygen Levels (mg/l)	Surface Temperature Levels (Celsius)
5/18/2012	0.028	5.7	0.56	2.5	N/A	20.1
5/31/2012	0.178	4.8	0.80	3.0	N/A	20.9
6/18/2012	0.027	13.0	1.10	2.0	N/A	21.9
6/25/2012	0.087	13.0	1.10	2.0	N/A	23.4
7/10/2012	0.023	2.4	0.85	2.0	N/A	28.7
7/26/2012	0.042	1.8	1.20	2.3	N/A	N/A
8/7/2012	0.043	8.2	1.20	1.0	N/A	N/A
8/23/2012	0.046	33.0	1.30	1.0	N/A	22.6
9/6/2012	0.024	27.0	1.40	1.2	N/A	24.4
9/18/2012	0.056	20.0	1.30	1.6	N/A	18.2
10/2/2012	0.024	15.0	1.00	1.6	N/A	16.8
2012 Average	0.053	13.1	1.07	1.8	N/A	21.9
2012 Summer Average	0.044	14.8	1.18	1.6	N/A	23.2

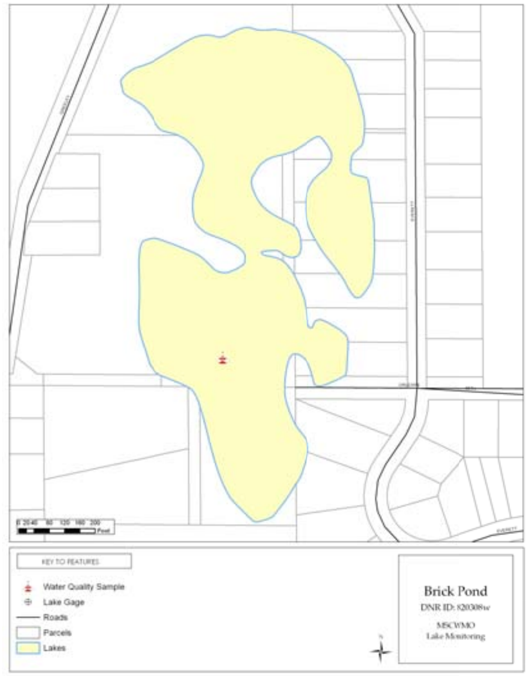
Water quality thresholds are 0.04 mg/L TP, 14 µg/L CL-a, 1.4 m Secchi depth*

	High	**High Date**	**Low**	**Low Date**	**Average**
2012 Elevation (ft)	845.54	6/20/2012	843.68	10/30/2012	844.8

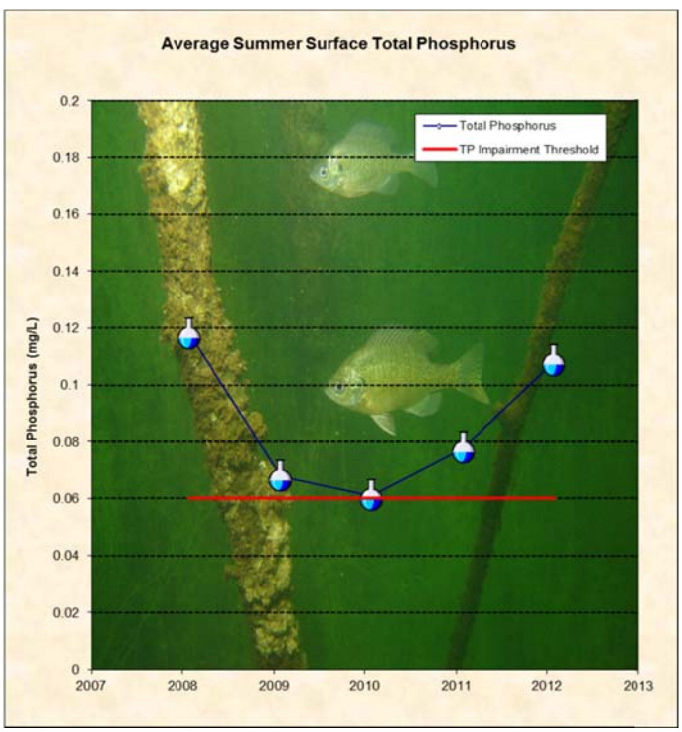
*MPCA description of Impaired Lake's Listing criteria: "At a minimum, a decision that a given lake is impaired for the 303(d) list due to excessive nutrients will be supported by data for both causal and response factors. Data requirements for 303(d) listing consist of 12 or more TP measurements collected from June through September over the most recent 10-year period. Ideally this should represent 12 separate visits to the lake over the course of two summers; however it might also reflect four monthly samples over the course of three years (a typical sampling regimen for many lake monitoring programs). In addition to exceeding the TP guideline thresholds, lakes to be considered for 303(d) listing should have at least 12 Secchi measurements and 12 chlorophyll-a measurements. This amount of data will allow for at least one season (preferably more) of paired TP, chlorophyll-a, and Secchi disk data and provide a basis for evaluating their interrelationships and hence the trophic status of the lake."

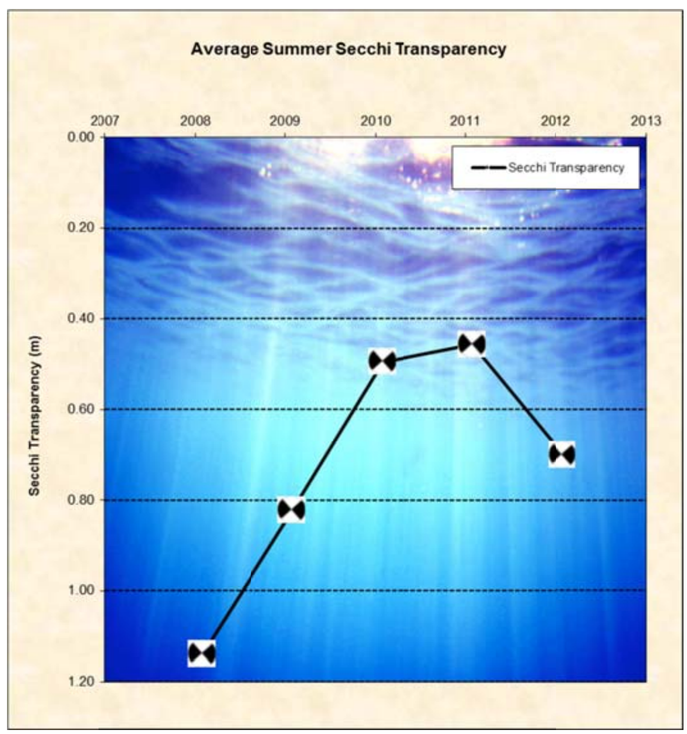


Lake Water Quality Summary											
	Trophic Status 2012	**Summertime Lake Grades**									
		2012	2011	2010	2009	2008	2007	2006	2005	2004	2003
Total Phosphorus (mg/L)	**Eutrophic**	**C**	NA	B	B	C	C	D	C	C	C
Chlorophyll-*a* (ug/L)	**Eutrophic**	**B**	NA	C	A	C	C	C	B	B	B
Secchi depth (ft)	**Eutrophic**	**C**	NA	C	B	C	C	D	C	C	C
Overall	**Eutrophic**	**C+**	**NA**	**C+**	**B+**	**C**	**C**	**D+**	**C+**	**C+**	**C+**


KEY TO FEATURES
Water Quality Sample
Lake Gage
Roads
Parcels
Lakes
Brick Pond
MSCWMO
Lake Monitoring

rall


Average Summer Surface Total Phosphorus
Total Phosphorus
TP Impairment Threshold
Total Phosphorus (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2007
2008
2009
2010
2011
2012
2013


Average Summer Secchi Transparency
Secchi Transparency
Secchi Transparency (m)
2007
2008
2009
2010
2011
2012
2013
0.00
0.20
0.40
0.60
0.80
1.00
1.20

Date	Total Phosphorus (mg/L)	Chlorophyll-a (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depths (m)	Surface Dissolved Oxygen Levels (mg/L)	Surface Temperature Levels (Celsius)
5/8/2012	0.142	47.0	0.87	0.61	9.30	18.1
6/5/2012	0.184	2.9	0.83	0.61	10.45	28.0
6/21/2012		14.0		0.61	7.88	22.7
7/19/2012	0.100	11.0	0.71	0.76	5.75	28.0
8/15/2012	0.121	17.0	0.84	0.91	3.22	21.9
9/12/2012	0.029	4.4	0.69	0.61	7.48	18.0
2012 Average	0.115	16.1	0.79	0.69	7.35	22.8
2012 Summer Average	0.109	9.9	0.77	0.70	6.96	23.7
Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*						
	High	**High Date**	**Low**	**Low Date**	**Average**	
2012 Elevation (ft)	N/A	N/A	N/A	N/A	N/A	

*MPCA description of Impaired Lake's Listing criteria: “At a minimum, a decision that a given lake is impaired for the 303(d) list due to excessive nutrients will be supported by data for both causal and response factors. Data requirements for 303(d) listing consist of 12 or more TP measurements collected from June through September over the most recent 10-year period. Ideally this should represent 12 separate visits to the lake over the course of two summers; however it might also reflect four monthly samples over the course of three years (a typical sampling regimen for many lake monitoring programs). In addition to exceeding the TP guideline thresholds, lakes to be considered for 303(d) listing should have at least 12 Secchi measurements and 12 chlorophyll-a measurements. This amount of data will allow for at least one season (preferably more) of paired TP, chlorophyll-a, and Secchi disk data and provide a basis for evaluating their interrelationships and hence the trophic status of the lake.”

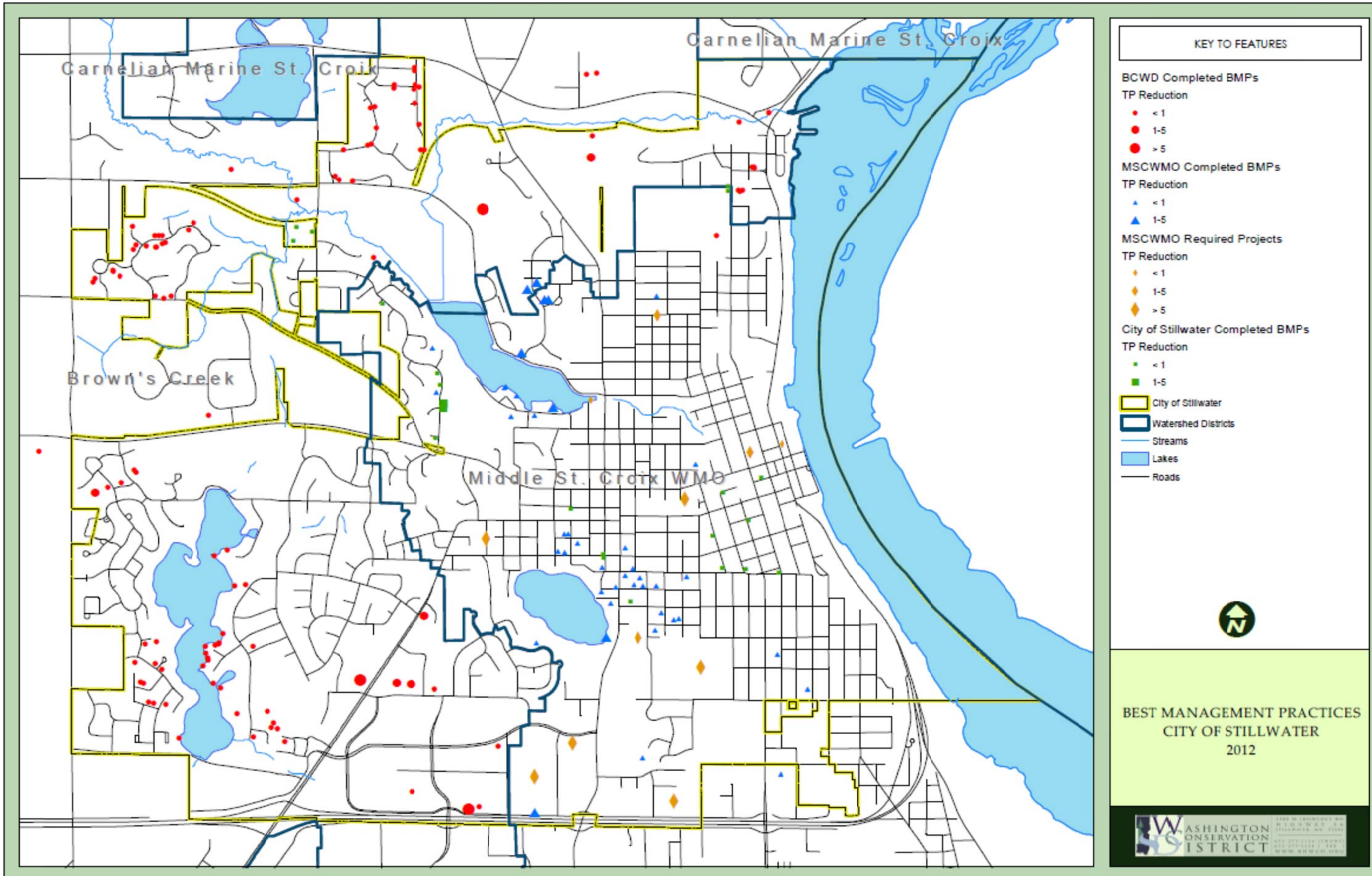
Lake Water Quality Summary

	Trophic Status	**Summertime Lake Grades**									
	2012	**2012**	2011	2010	2009	2008	2007	2006	2005	2004	2003
Total Phosphorus (mg/L)	**Hypereutrophic**	**D**	D	C*	C	D	NA	NA	NA	NA	NA
Chlorophyll-*a* (ug/L)	**Eutrophic**	**A**	B	A	A	A	NA	NA	NA	NA	NA
Secchi depth (ft)	**Eutrophic**	**C***	C*	C*	C	C	NA	NA	NA	NA	NA
Overall	**Eutrophic**	**C+**	**C**	**B-**	**B-**	**C+**	**NA**	**NA**	**NA**	**NA**	**NA**

*Adjusted for shallow lake

APPENDIX B

City Of Stillwater BMP Map


Carnelian Marine St. Croix
Carnelian Marine St. Croix
Brown's Creek
Middle St. Croix WMO
KEY TO FEATURES
BCWD Completed BMPs
TP Reduction
< 1
1-5
> 5
MSCWMO Completed BMPs
TP Reduction
< 1
1-5
MSCWMO Required Projects
TP Reduction
< 1
1-5
> 5
City of Stillwater Completed BMPs
TP Reduction
< 1
1-5
City of Stillwater
Watershed Districts
Streams
Lakes
Roads
BEST MANAGEMENT PRACTICES
CITY OF STILLWATER
2012
WASHINGTON CONSERVATION DISTRICT