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2013 Forest Lake Water Quality Review

Introduction:
The goal of this testing protocol was to monitor various water quality parameters of the lake, compare results to historical data, and identify any potential risks to the health of Forest Lake. Water samples were taken at two different locations and tested for 15 different parameters. Tests were conducted on a monthly basis from April through August. Tests were conducted with a Hanna Multiparameter Water Quality Meter with 20m cable, LaMotte SMART2 Colorimeter, or LaMotte ColiQuant EZ Test Kit.

Test results were compared to the most recent historical data available. In this case, the historical data was from the report "2012 Forest Lake Water Quality Review" by LakePro, Inc.

General Discussion
Forest Lake's water quality remains in good condition. The lake still has some areas of concern, but has shown improvement in many areas since testing began.

The long term trends for certain parameters should compliment each other to tell the story of how the lake is changing. Generally, increasing nutrients leads to more chlorophyll, which decreases transparency. In Forest Lake, the opposite has been true. Since testing began in 2010, the nutrient levels (Total Phosphorus, Phosphate, Nitrate) decreased and the Chlorophyll concentrations followed. Less plant production led to clearer water, evidenced by the increase in transparency over the years.

Aggressive plant management aided these trends. Mechanical harvesting removes nutrients as they are bound into plant material. Herbicide treatments kill plants, which then decompose and release their nutrients into the water. This results in a temporary increase of nutrients in the water, but free-floating nutrients are diluted and flushed from the lake.

The temperature of the lake has increased slightly over the testing history, which drives the oxygen solubility lower. However, the dissolved oxygen has actually increased during this period, meaning the water is carrying a higher percent of oxygen. The oxygen values remained sufficient to support a healthy fishery.

The water chemistry parameters (pH, TDS, Conductivity, Alkalinity) all decreased over the testing history but remain within their target ranges. This shows a general reduction in the load of dissolved molecules in the lake. The alkalinity is approaching its lower limit, but should replenish as more groundwater enters the lake bringing in beneficial carbonate ions.

Finally, the Sulfate, Fluoride, and Chloride all have decreased since testing began. This is a positive trend for the lake that coincides with the decrease of TDS. These parameters are all indicators of pollution, so it is important that they stay within their target ranges. The only parameter outside its target range is Chloride, which will be discussed further in the Salinity Report.

In summary, the water quality of Forest Lake is good and is actually improving in some areas. The main area of concern remains the elevated salinity (Chloride), for which the FLMC is currently seeking a solution.

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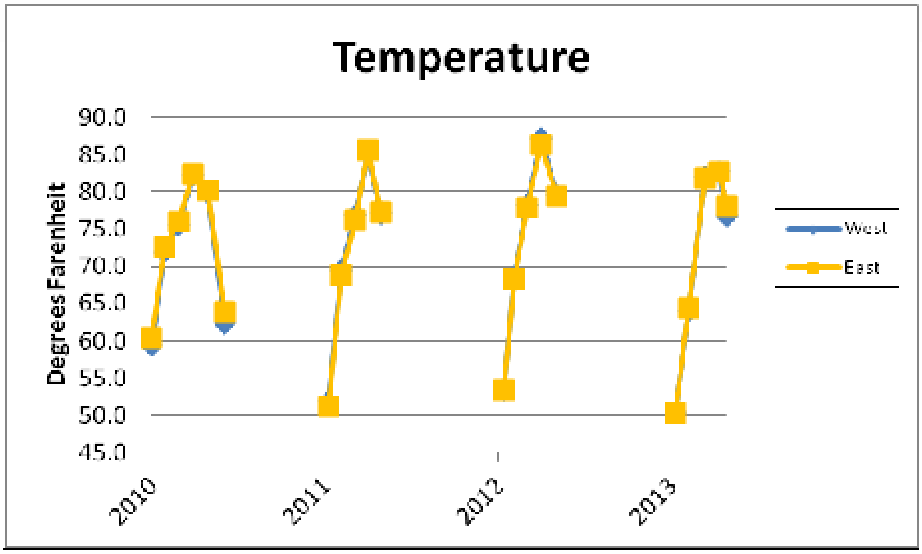
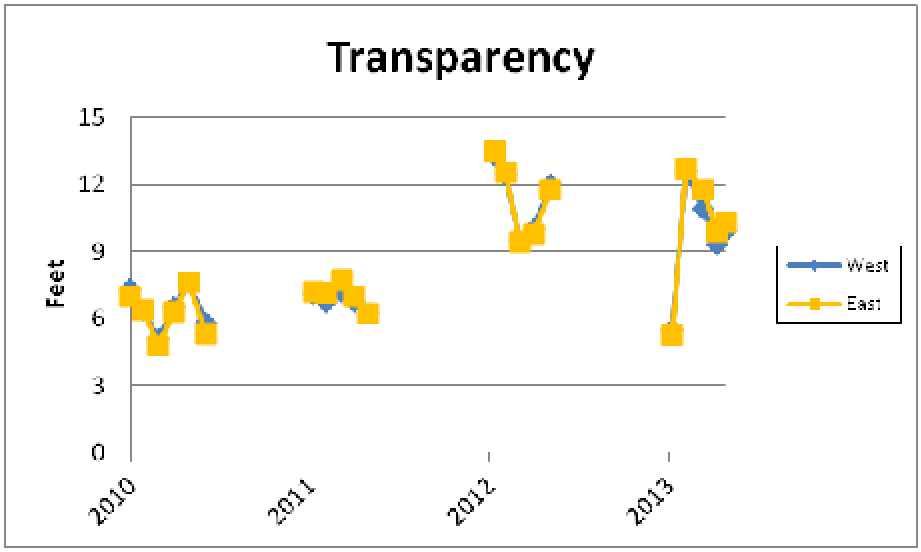


(˚F)	West	East
April	50.4	50.3
May	64.1	64.3
June	82.0	81.9
July	82.8	82.7
August	76.7	78.1

Discussion

Plants and algae usually begin their spring growth when water temperatures rise through 50's and reach 60 ˚F. The water temperatures of the lake were much better than in 2012, especially in April and May. The lake started very cool in April, keeping the plant growth down as long as possible. The cold start also helped ensure summer water temperatures were not extremely high.



Target Range: >6.5 feet

Trophic State Index: 45
Trophic State: Mesotrophic

(m)	West	East
April	5.5	5.3
May	12.6	12.7
June	10.9	11.8
July	9.3	9.9
August	9.9	10.3

Discussion

In April, the transparency was less than the target range, but increased quickly and stayed very high for the rest of the summer despite abundant rainfall that mixed the lake. The transparency also showed an upward trend from 2010 to 2013. This means the clarity of the lake is getting better which is generally good, but it can also lead to increases of plant growth due to increased sunlight penetration.

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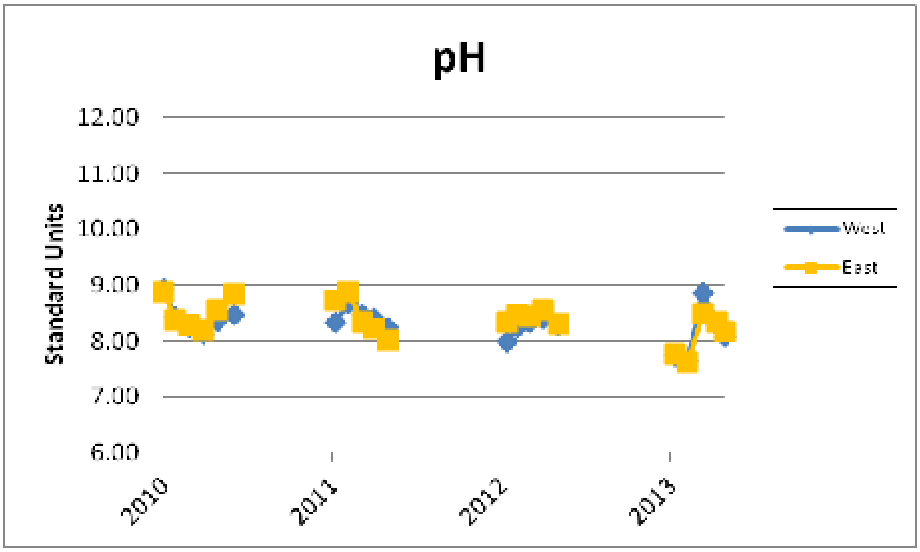
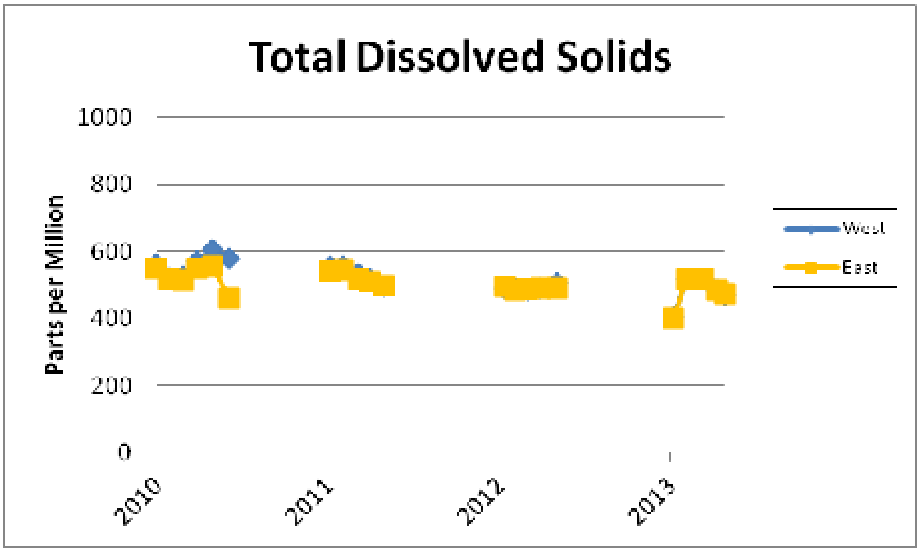


(S.U.)	West	East
April	7.73	7.76
May	7.65	7.62
June	8.86	8.50
July	8.29	8.32
August	8.09	8.17

Target Range: 7.0 – 9.0 S.U.

Discussion

The pH varied slightly throughout the summer, but no changes were severe enough to cause any negative impacts on aquatic life. The season average of 8.10 is normal for lower-Michigan lakes and slightly lower than in 2012. The pH showed a slightly downward trend from 2010 to 2013.



(ppm)	West	East
April	405	401
May	518	519
June	520	519
July	485	485
August	470	472

Target Range: 0 – 1,000 ppm

Discussion

From April to May there was a large increase in TDS, likely due to snowmelt and spring rains bringing foreign substances into the lake. However, continued rain and the draining of the lake helped flush these excess molecules throughout the rest of the year. The season average of 479 indicates a decrease in total dissolved solids from 2012. Because the TDS measurement includes nutrients and salt ions, this is a positive trend for the health of the lake.

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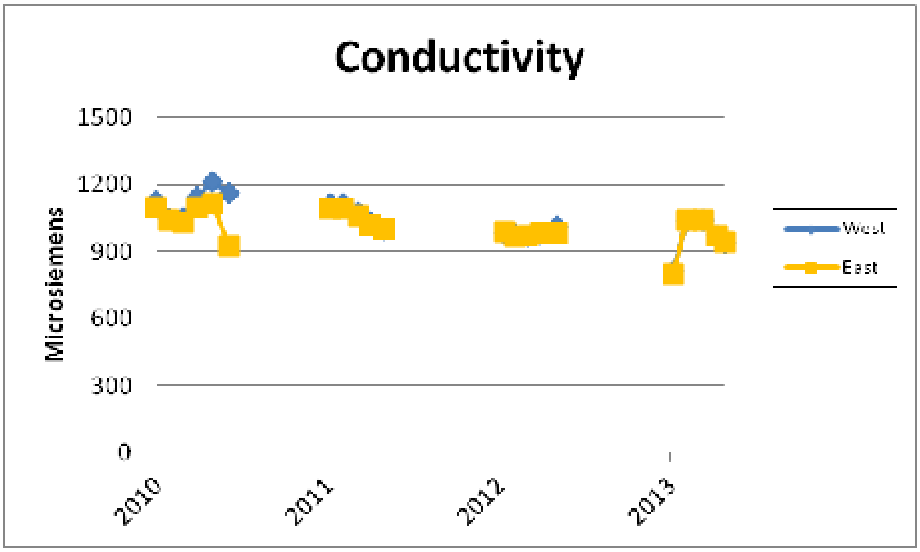
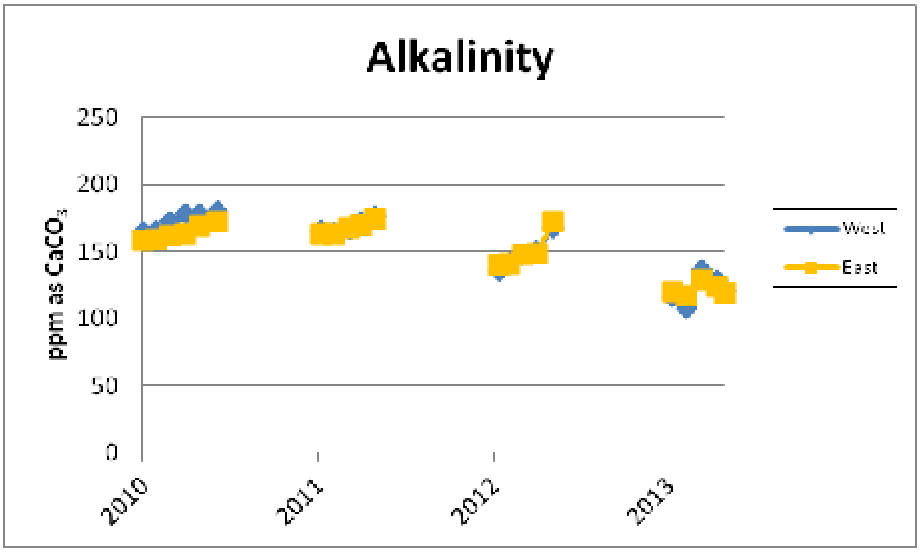


Target Range: 0 – 1,500 µS

(µS)	West	East
April	813	800
May	1,037	1,039
June	1,039	1,038
July	971	971
August	938	943

Discussion

The season average of 959 µS is a decrease from 2012. This confirms the TDS readings that there are fewer ionic molecules (salts) in the water than last year, indicating a positive trend for the lake.



Target Range: 100 – 250 ppm

(ppm)	West	East
April	116	120
May	108	117
June	136	129
July	129	124
August	121	119

Discussion

The Alkalinity is normal for a freshwater lake. Alkalinity refers to the ability of the water to neutralize acids, mainly through the hydrogenation of carbonate ions. This is why the alkalinity is expressed as "ppm as $CaCO_3$". The alkalinity decreased from last year, consistent with the downward trend of the pH. Both of these parameters are still within their target ranges, but the downward trend does support the need to rid the lake of salts in order to improve the water quality.

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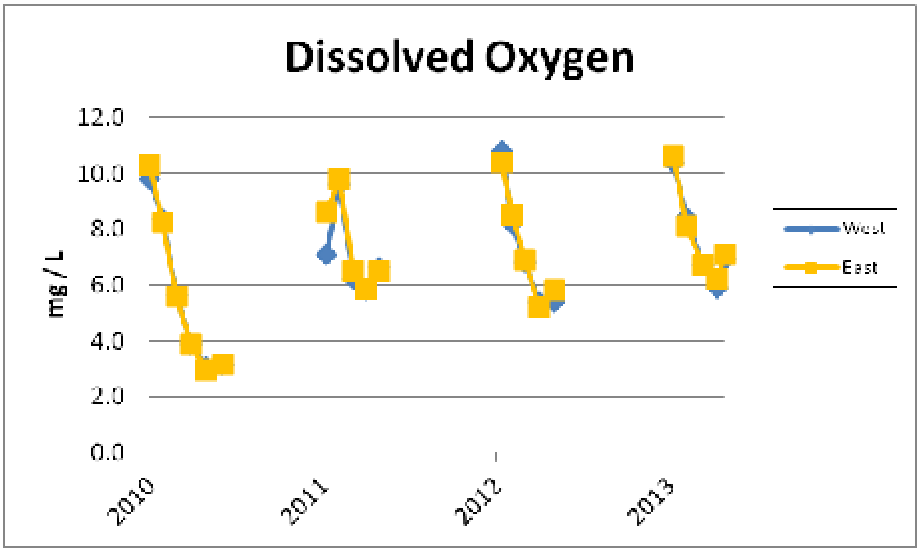
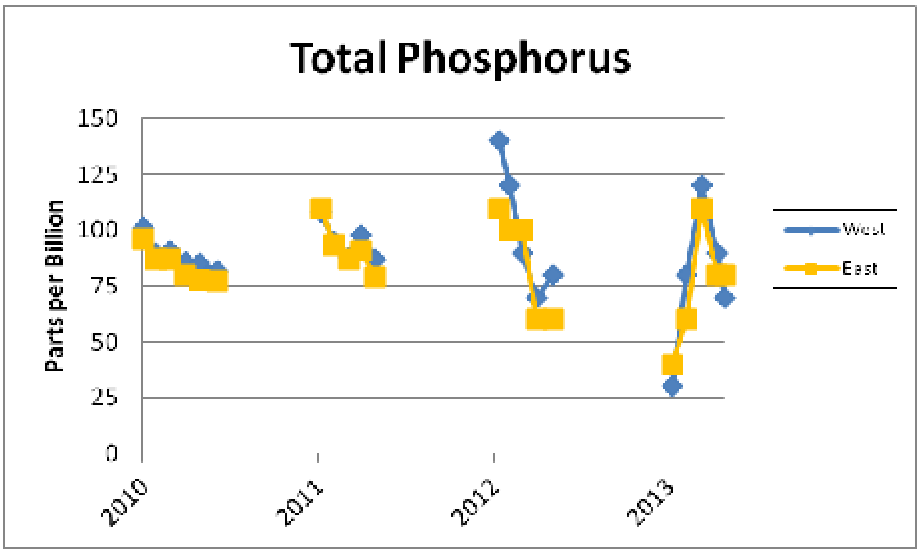


Target Range: 4.0 – 12.0 mg/L

(mg/L)	West	East
April	10.4	10.6
May	8.4	8.1
June	6.7	6.7
July	5.9	6.2
August	6.9	7.1

Discussion

The dissolved oxygen remained at a very healthy level most of the year. Oxygen dissolution is dependent upon water temperatures, so the D.O. generally decreased as water temperatures increased. However, the D.O. concentrations remained at very healthy levels that will sustain the fish population through harvesting and chemical treatments. Despite the temperature trend sloping upward, the dissolved oxygen has also increased over the testing history.



Target Range: 0 – 100 ppb

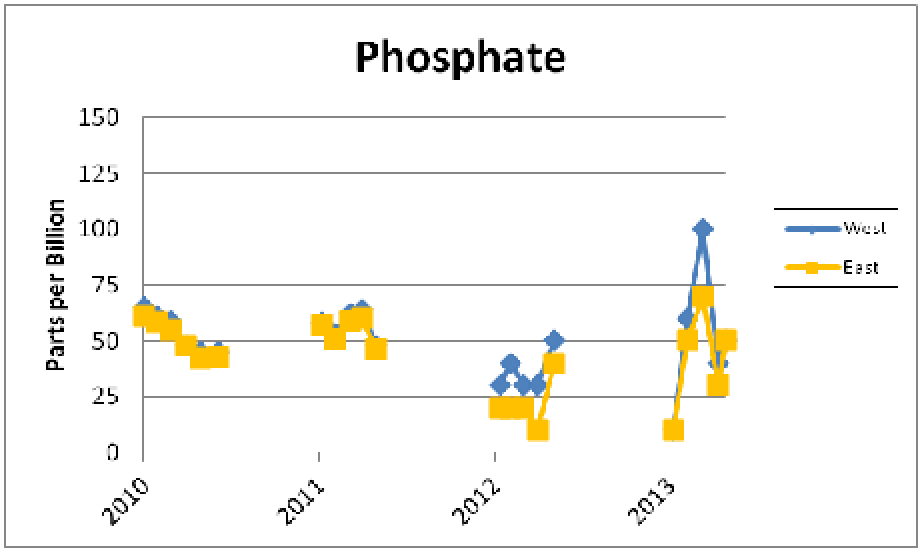
Trophic State Index: 66
Trophic State: Eutrophic

(ppb)	West	East
April	30	40
May	80	60
June	120	110
July	90	80
August	70	80

Discussion

The Total Phosphorus test includes all forms of organic and inorganic phosphorus. At 76 ppb, the average concentration in Forest Lake is at the high end of the target range, but is still at an acceptable level. Harvesting, which removes organically-bound nutrients, has kept the lake from accumulating nutrients beyond target levels.

Furthermore, responsible land use by the residents around the lake will limit the amount of this nutrient that reaches the lake.

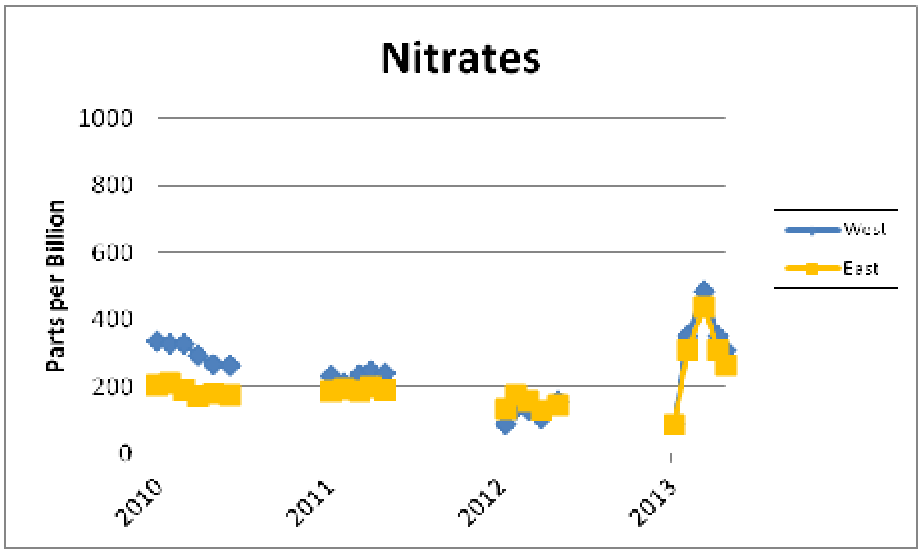


(ppb)	West	East
April	10	10
May	60	50
June	100	70
July	40	30
August	50	50

Target Range: 0 – 100 ppb

Discussion

The amount of Orthophosphate in the lake increased from 2012. Despite a drop in total phosphorus, the usable phosphates increased. This shift could be due to many factors. Although the concentrations were higher than last year, they still remained within the target range and the long term trend was downward.



(ppb)	West	East
April	88	88
May	352	308
June	484	440
July	352	308
August	308	264

Target Range: 0 – 1,000 ppb

Discussion

The season average decreased from 2012 to 299 ppb, suggesting that increased rainfall and excess runoff led to more of this nutrient entering the lake. Although the concentrations were higher than last year, they still remained within the target range and the long term trend was downward.

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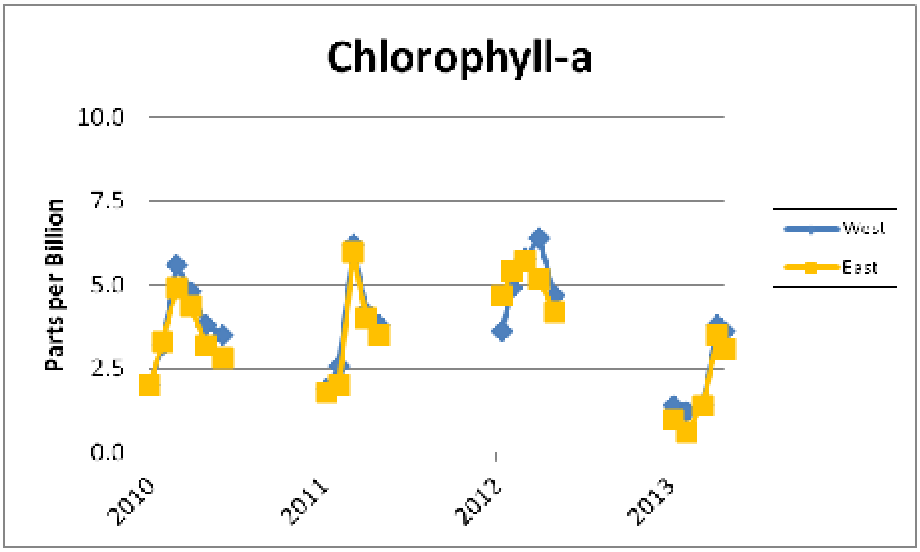


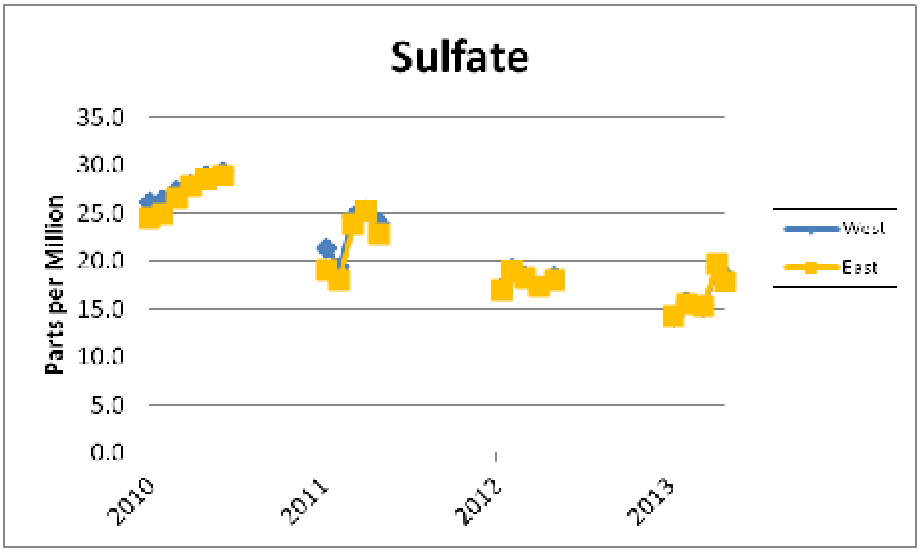
Target Range: 0 – 7.3 ppb

Trophic State Index: 36
Trophic State: Oligotrophic

(ppb)	West	East
April	1.4	1.0
May	1.2	0.6
June	1.4	1.4
July	3.8	3.5
August	3.6	3.1

Discussion

Chlorophyll-a measurement is the most direct indicator of the plant (algae) growth of the lake. The season average of 2.1 ppb was the lowest since we began testing the lake. Lower water temperatures, less sunlight, and aggressive plant management all contributed to less plant production in 2013.



Target Range: 3 – 30 ppm

(ppm)	West	East
April	14.3	14.2
May	15.7	15.5
June	15.4	15.4
July	19.4	19.8
August	18.5	17.9

Discussion

The Sulfate concentrations were the lowest they have been since we began testing in 2010. This could be attributed to the limited Copper Sulfate treatments made to the canals. Also, abundant rainfall throughout the summer helped to flush excess molecules from the lake.

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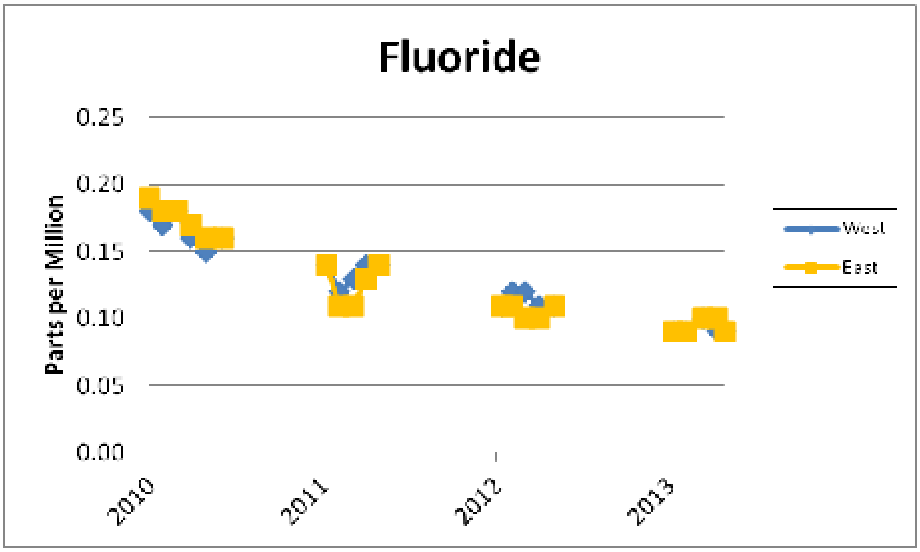
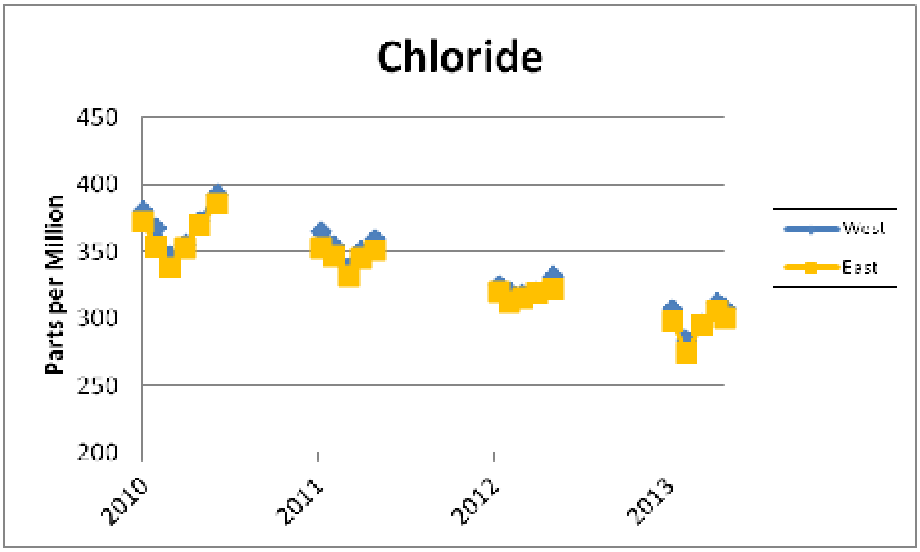


(ppm)	West	East
April	0.09	0.09
May	0.09	0.09
June	0.10	0.10
July	0.09	0.10
August	0.09	0.09

Target Range: 0.01 – 0.30 ppm

Discussion

The Fluoride concentrations were at normal levels. The season average of 0.10 ppm was the lowest since we began testing in 2010.



(ppm)	West	East
April	307	298
May	284	274
June	296	295
July	311	306
August	308	300

Target Range: 0 – 230 ppm

Discussion

The concentrations decreased each year since we began testing in 2010. The season average of Chloride was 298 ppm, above the target range, so the need to draw water from the bottom of the lake to improve water quality remains.

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Analysis Information

Temperature:	The water temperature directly affects the amount of oxygen that is able to dissolve into the water. The temperature of surface waters is not indicative of the entire water column.
Transparency:	The ability of light to penetrate the water column is determined by the amount of dissolved and suspended particles in the water. Although aesthetically desirable, transparent water allows increased light to reach the lake bed and may result in vegetation growth.
pH:	pH is a measure of acidity or alkalinity. pH is a general measure of lake health and can roughly indicate the range of other measurements such as alkalinity and hardness.
TDS:	Total Dissolved Solids is the amount of all organic and inorganic substances in the water in a molecular or ionized state. Higher values generally indicate richer and more productive water. Lower values usually indicate cleaner and less productive water.
Conductivity:	Conductivity is a measure of the ability of water to conduct electricity. Dissolved ions in the water increase conductivity, thus TDS and Conductivity are closely related.
Alkalinity:	Alkalinity refers to the ability of the water to neutralize acids, mainly through the hydrogenation of carbonate ions. This is why the alkalinity is expressed as "ppm as $CaCO_3$". However, other basic molecules in the water can also contribute to alkalinity.
Dissolved Oxygen:	D.O. is a measure of the amount of oxygen dissolved in the water. This oxygen is available to fish and other animals for respiration. Vegetation generally increases DO, particularly during the day and early evening. Animals and other respiring organisms consume the oxygen, mostly during the day. Oxygen is also added to the lake through wave action, rain, fountains and aerators.
Total Phosphorus:	Phosphorus is an essential nutrient for plant growth. However, concentrations exceeding 100 ppb can impair the water and results in nuisance vegetation growth.
Phosphates:	Phosphate is the form of phosphorous that is most readily available to plants and algae.
Nitrate:	Nitrogen is also essential for plant growth. Nitrate is the predominant form of nitrogen in water. Excessive nitrate concentrations may also result in pollution and increased vegetation.
Chlorophyll-a:	Chlorophyll-a is a direct measurement of the amount of green pigment produced by plants and phytoplankton. This indicates the amount of plant growth and is used to calculate a Trophic State Index.
Sulfate:	Sulfate occurs naturally as minerals, such as calcium sulfate and magnesium sulfate. In fresh water, sulfate is usually the second or third most abundant anion. Other sources of sulfate include water material from pulp mills, steel mills, food processing operations, and municipal wastes. Under low oxygen conditions, sulfate can by reduced to hydrogen sulfide gas, which smells like rotten eggs.
Fluoride:	Fluoride may occur naturally or be added to public drinking water supplies.
Chloride:	Chloride is one of the major anions found in water and sewage. The presence of chlorides may be due to water passing through salt formations in the earth or pollution from industrial processes, domestic wastes, or road salt. The salt content of water affects the

distribution of plant and animal life in an aquatic system, based on the amount of slat they can tolerate.

Fecal Coliforms: Non-fecal coliforms are naturally found as soil organisms. Fecal Coliforms, such as *E. coli*, are coliforms found in the intestines of warm-blooded animals and humans. The presence of fecal coliforms indicates contamination from either animals or humans.

Trophic States

Oligotrophic: Water is very clear. Nutrient levels are generally low. Plant and algae productivity is also low. Sufficient dissolved oxygen in the bottom, cooler waters allows cold-water fish to survive, such as salmon and trout.

Mesotrophic: Water is moderately clear. Nutrient levels are slightly elevated. Plant and algae productivity is present, but generally not a nuisance. Oxygen and temperature in the lower portion of the lake allow walleye and perch to survive.

Eutrophic: Water is not clear due to high nutrients levels, increased turbidity, and excessive algal growth. There is no oxygen in the bottom, cooler waters, restricting the lake to warm water species, such as bass and bluegill.

Hypereutrophic: Nutrient levels are extremely high, promoting very high algae productivity. Blue-green algae blooms are likely. High turbidity and algae growth make the water opaque. Little plant growth is restricted to invasive plants. The only fish that can survive this environment are rough fish, such as carp, catfish, and mudminnows.

Sample Sites: