Watershed Improvement Review Board Grant – Final Report

Project 5017-006 Lake Storm Lake Watershed

Final Report – June 30, 2009

Project Summary

The Lake Preservation Association for Storm Lake, Inc was awarded a grant in March 2006 for improvements in the Storm Lake watershed specifically improvements in the City of Storm Lake. The City of Storm Lake was a joint partner in the grant project and oversaw the administration of the entire project and the administration of the grant.

Specifically the grant project included the construction of the following three components:

1. Construction of a 2-cell detention pond located in an existing city park that would be designed to filter storm water runoff from an area that included two of the city's largest industrial facilities.
2. Construction of two larger commercial sized rain gardens to filter storm water runoff from two newly constructed parking lots that were being built as part of Project AWAYSIS (www.awaysis.com) in the City of Storm Lake.
3. Construction of eight (8) residential rain gardens built around existing storm water intakes along HWY 7/East Lakeshore Drive in Storm Lake.

The project also consisted of some additional piping and other general storm water collection system work. The overall project impacted 504 acres of urban watershed for Lake Storm Lake.

At the completion of the project in December 2008 all three components were constructed and operational as designed and providing the intended benefits to the Storm Lake Watershed.

Financial Summary

The following chart shows the construction costs and engineering/administration costs for all three projects with a breakdown of the cost share between the grant funds and the city matching funds. All matching funds were provided by the City of Storm Lake.

Project Component	Total Project Cost	WIRB Portion	City Portion
Storm Water Detention Ponds	$434,095.52	$192,470.22	$241,625.30
Commercial Rain Gardens	$278,440.05	$214,119.78	$ 64,320.27
Residential Rain Gardens	$163,384.16	$ 70,410.00	$ 92,974.16
Engineering	$118,627.36	$ -0-	$118,627.39
Totals	**$994,547.09**	**$477,000.00**	**$517,547.09**

During the grant period there was one amendment to the grant reallocating funds between the Storm Water Detention Ponds (item #1) and the Residential Rain Gardens (item #3). This change moved $18,775 from item #1 to Item #3 based on bid award amounts.

The original project costs were estimated at $1.2 million and while actual project costs were about $200,000 less than the original estimated costs there were several in-kind donations throughout the project that reduced the actual cash cost of the project to the City. Two specific examples are as follows:

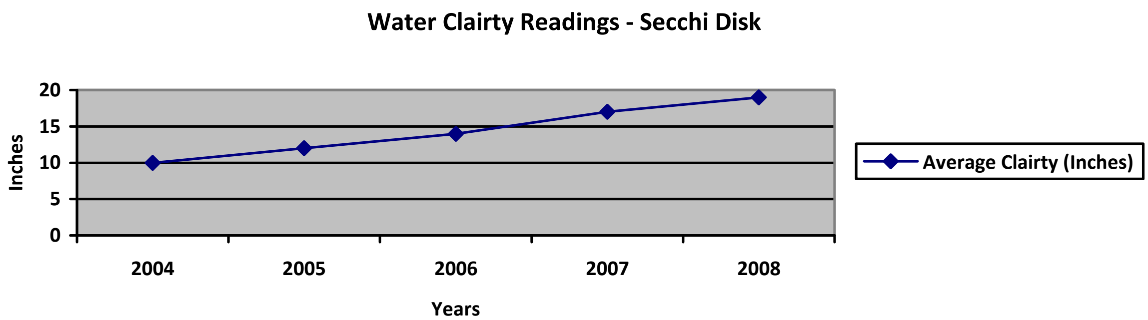
1. The City of Storm Lake originally planned to have the contractor for the residential rain garden project purchase and plan the plants in the rain gardens; however, after reviewing the project and analyzing cost it was determined that the City could save money by purchasing the plants through the Iowa DNR and utilizing city staff, plant the plants ourselves. The cost of the plants and the labor is estimated at $15,000.
2. Part of the overall Project AWAYSIS was the development of condo's near an area where the city was planning to construct another storm water basin (the cost for this project was included in the city's cash match). Once the land was purchased by a private developer the developer agreed as part of the purchase to construct and install the storm water components as part of the purchase price. This agreement saved the project an estimated $200,000.

Funding Source	Cash		In-Kind Contributions		Total	
	Approved Application Budget	Actual	Approved Application Budget	Actual	Approved Application Budget	Actual
WIRB	477,000.00	477,000.00	-	-	477,000.00	477,000.00
City of Storm Lake	721,200	517,547.09	-	15,000.00	721,200	532,547.09
Private Developer	-	-	-	200,000.00	-	200,000.00
Totals	1,198,200	994,547.09	-	215,000.00	1,198,200	1,209,547.09

Over the entire project, including engineering, the WIRB Grant funded 48% of the total project costs while the City of Storm Lake funded the other 52% of the project.

Environmental Accountability

Prior to the implementation of the projects included in the WIRB Grant the City of Storm Lake was sampling water quality at various points in the Lake. That sampling continues today and through a combined effort of the work done through this project and the Lake Dredging Project water quality has improved in Lake Storm Lake.



We don't have specific data, prior to the project and after, for the specific outlets that were included in the project; however, we do have some qualitative data that accounts for the success of these projects in helping to protect the water quality.   Additional data on Storm Lake water quality monitoring is provided as an attachment to this report.

In December of 2008 Tyson Fresh Meats had a sewer line spill at their facility and raw sewage from their plant entered the city's storm water system. The two large detention ponds, constructed as part of this project, acted as a buffer between the city's storm water system and the lake. A very minimal amount of the sewage made it to the lake with the rest collected by the detention ponds.

The City of Storm Lake and the Lake Preservation Association for Storm Lake, Inc. have also partnered on some educational and training opportunities for contractors and citizens in the community. These educational events along with good press coverage of the construction of Project AWAYSIS including the storm water components have helped to increase awareness within the community of the things that each individual can do to help promote water quality.

Additionally, the City's engineer using a computer modeling program (P8) determined that these implemented components/practices could remove approximately 65% of the total suspended sediments in the watershed affected by these projects. The expected removal rates for phosphorus, E coli, and fecal coli form are expected to be in the range of 25% to 35%.

Program Accountability

Many of the activities that have resulted from this project to expand the outreach of water quality in the Storm Lake community are educational and informational based. The City of Storm Lake has implemented a storm water curriculum piece that targets 2nd grade students in the local schools (public and private) teaching them about water quality, what they can do, and what the city is doing to help preserve and enhance the water quality in Lake Storm Lake. The curriculum utilizes some of the components built as part of this grant project.

Additionally, the projects are front and center in one of Iowa's largest and certainly one of Western Iowa's most recognizable projects, Project AWAYSIS. Since the opening of King's Pointe Outdoor Water Park over 100,000 people have visited the park and parked in the lots adjacent to the two large commercial rain gardens. Many of them also drive right by the residential rain gardens and the two large detention ponds.

Future plans include the development of educational pieces that will help visitors to the area understand the benefits of the installed pieces and how they affect water quality in the Storm Lake Watershed. Some examples of these future components include an environmental interpretive center and educational interpretive pieces that might be located at the actual site of the water quality components.

Additionally, the City is currently showcases these projects to groups and individuals who are building new projects in the area as an alternative solution to handle storm water drainage on their projects. In the summer of 2009 we will also be participating in an Urban Storm Water Education event in which these components will be showcased and information on their effectiveness and purpose will be distributed to the general public.

Local businesses have also seen the benefit of these types of storm water components and while some have already been developed many more are looking into the potential for similar scaled down version for their commercial or residential properties.

Both the City of Storm Lake and the Lake Preservation Association for Storm Lake, Inc. plan to continue to utilize the components of this project as an example when working with homeowners and developers on new and existing projects. Additionally, the City of Storm Lake will continue to promote these projects in their educational information.

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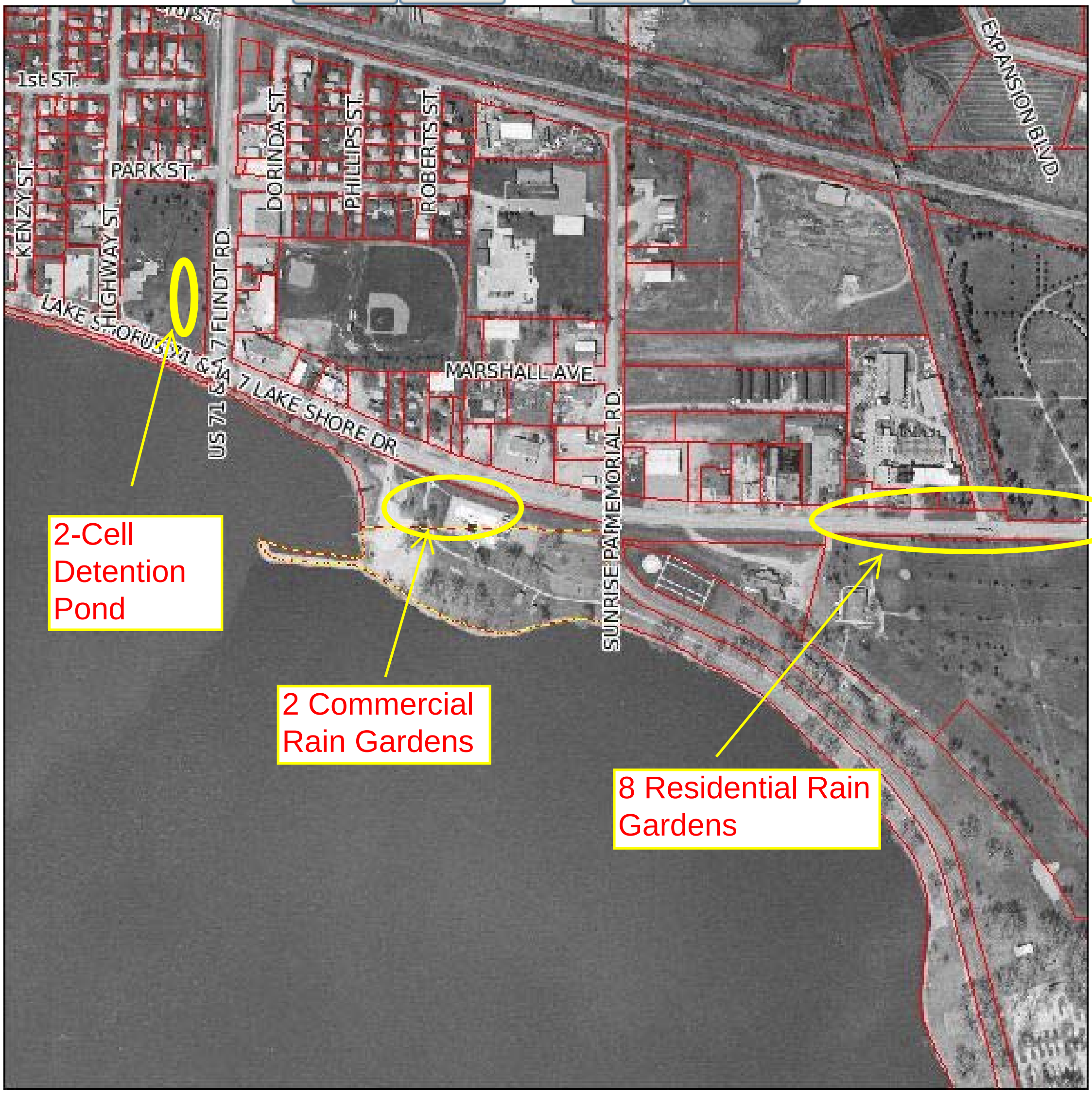

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[Explanation](#)

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Feet: 3732

Dots: 600x600

S90°E 6848'

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Water Quality Monitoring in the Storm Lake Watershed

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January 2008

Introduction

Storm Lake is located the northwest portion of Iowa in Buena Vista County on the south edge of the City of Storm Lake. The lake is a natural lake with an area of 3,097 acres and a maximum depth of about 3 meters (m). The lake was placed on Iowa's impaired waters list in 1998 due to excessive turbidity. A watershed improvement plan or Total Maximum Daily Load (TMDL) was completed for Storm Lake in 2005 to address the turbidity problems. The TMDL suggested that the main cause of turbidity problems at Storm Lake was resuspension of bottom sediments due to wind action. Current dredging projects aim to decrease this source of sediment to the water column.

Multiple monitoring programs are currently in place in Storm Lake and its watershed. These programs allow managers of the lake to prioritize sites for restoration as well as evaluate the success of these restoration programs. The ambient lake monitoring program has been measuring water quality at 131 lakes throughout the state, including Storm Lake, since 2000. Samples have also been taken since 2004 at storm water outfalls from the City of Storm Lake. Beaches on Storm Lake are also monitored for bacteria to ensure that they are safe for swimming. Finally, volunteers monitor water quality at multiple sites in the watershed using IOWATER methods to analyze the quality of water entering the lake. Data from each of these programs are discussed below.

Ambient Lake Monitoring Program

In 2000 the Iowa Department of Natural Resources (IDNR) began a multi-year ambient monitoring program on 132 lakes throughout the state. The objective of the program is to characterize the current water quality of these lakes. Storm Lake has been monitored routinely as part of this program.

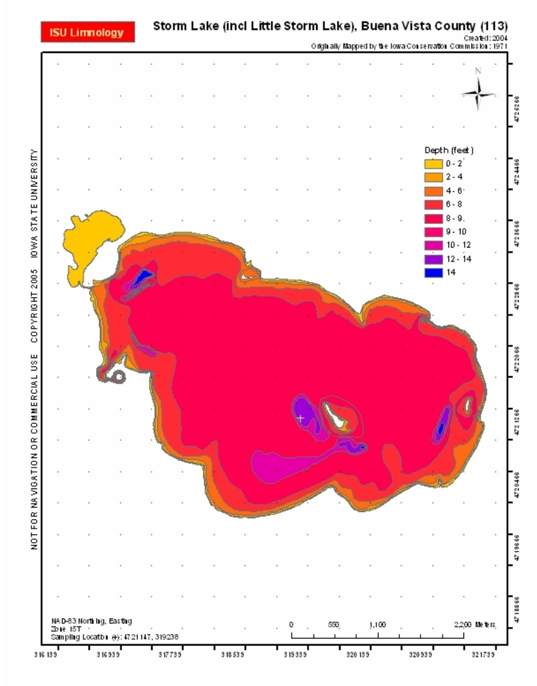
Methods

Storm Lake was sampled three times during the summers of 2000-2004, six times during 2005, eight times during 2006 and six times during 2007. Sampling rounds are designed to capture seasonal variability in the lakes, with samples being taken in spring-early summer, mid-summer, and late summer-fall.

Field crews sampled at the deepest point in the lake, as determined by sonar and bathymetric maps (Figure 1). The crew then used a multi-parameter water quality meter to provide profile data for temperature, dissolved oxygen, specific conductivity, pH and turbidity.

The profile data was then used to determine the depth or absence of the thermocline. The thermocline depth was defined as the region of maximum rate of temperature decrease (>1 ºC per meter) with respect to depth. After the depth of the thermocline was determined, an integrated sampler was used to collect water from the upper mixed zone of the lake. If no thermocline was present, the field crews sampled the entire water column to a maximum of 9 m or 2 m. depending on sampling crew. This integrated water sample was then emptied into a clean bucket or bottle, mixed and poured into bottles to be sent to the laboratory. This method was used to collect water for nutrient, chlorophyll, suspended solids, and phytoplankton analysis.

Figure 1. Bathymetric Map of Storm Lake, Iowa



Zooplankton was collected by vertically towing a Wisconsin net (63 µm mesh size) through the upper mixed zone of the lake (or entire water column if no thermocline was present)

Secchi depth was measured by lowering the Secchi disk into the water on the shady side of the boat without wearing sunglasses, recording the depth at which the disk disappears from view; lowering the disk further, then slowly raising the disk and recording the depth at which it reappears into view. The average of these two values is the Secchi depth.

<u>Results and Discussion</u>

In-Lake Conditions

Temperature and dissolved oxygen profiles were taken at 1 meter (m) intervals at the sampling location on each visit. The data from 2006 were used for this discussion because there were 5 sampling dates ranging from early May to early October, giving the greatest seasonal spread of all years of sampling. The temperature profiles show temperature does not change with depth and thermal stratification did not occur in Storm Lake (Figure 2). The lake was well mixed throughout the summer, which is expected based on its shallow depth.

Figure 3 shows the dissolved oxygen profiles for Storm Lake in 2006. Dissolved oxygen concentrations were also consistent throughout the water column on most sampling dates

(Figure 3). This occurs because of the lack of thermal stratification and sufficient wind action to mix the water. The October 2, 2006 sample had high levels of dissolved oxygen at the surface, possibly related to algae, before dissolved oxygen started to decrease at 0.5 m. Overall, dissolved oxygen was always above 5 mg/L, which is the level necessary to adequately support a warm-water fishery.

Figure 2. Temperature profiles for Storm Lake – 2006.

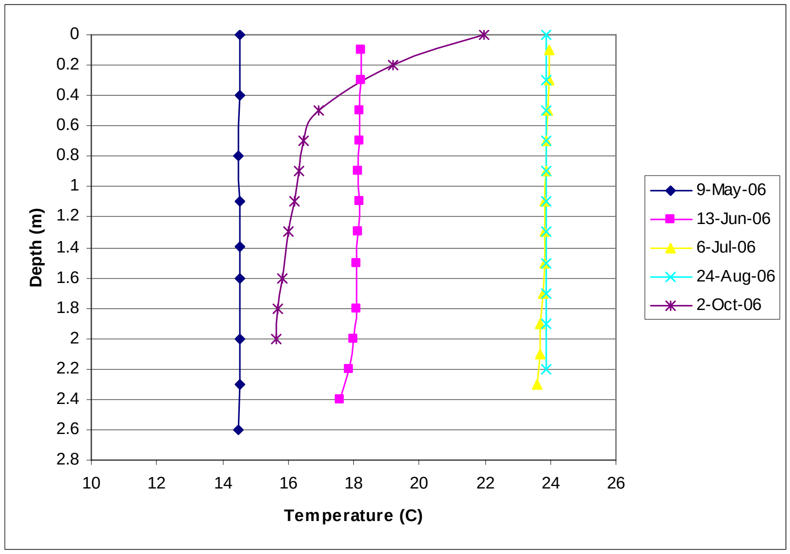
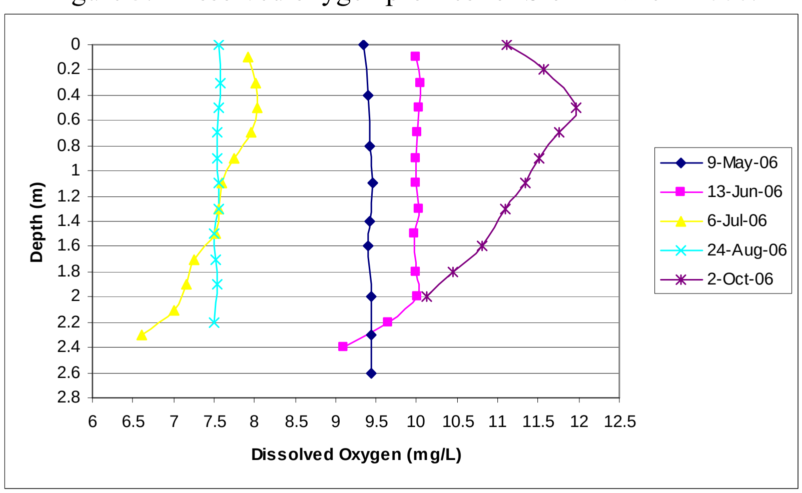


Figure 3. Dissolved oxygen profiles for Storm Lake – 2006.



Phosphorus is an essential nutrient for plant growth in lakes. Total phosphorus (TP) concentrations, which include particulate and soluble phosphorus, ranged from 45 micrograms per liter (µg/L) on 6/18/07 to 363 µg/L on 5/17/01 with a median value of 80 µg/L. The median value for Storm Lake was lower than the median for all monitored natural lakes in Iowa (110 µg/L) and was similar to the median for all monitored lakes in Iowa (81 µg/L). Phosphorus concentrations can vary greatly within lakes. Algal uptake of TP as well as sedimentation and resuspension of TP in the lake can affect concentrations in the water column.

Soluble reactive phosphorus (SRP) is a measure of the filterable (soluble, organic) form of phosphorus. This is the form that is taken up directly by plants. SRP in Storm Lake ranged from 3 µg/L to 50 µg/L with a median value of 20 µg/L. The median for Storm Lake is equal to the median for all monitored natural lakes (20 µg/L) and higher than the median for all monitored lakes (16 µg/L).

Nitrogen is another nutrient that is important for plant growth in lakes. Total nitrogen (TN) is the combination of all dissolved forms of inorganic and organic nitrogen. TN concentrations ranged from 0.7 milligrams per liter (mg/L) on 7/27/05 to 2.8 mg/L on 5/21/07 with a median value of 1.2 mg/L. The median value for Storm Lake was slightly lower than the medians for all monitored natural lakes (1.7 mg/L) and all monitored lakes (1.5 mg/L). TN varies greatly throughout the year. TN concentrations are generally highest in the spring when fertilizers are being applied to the land and spring rains occur.

Nitrate + nitrite nitrogen are water soluble chemicals made of nitrogen and oxygen. Nitrate + nitrite concentrations follow a similar seasonal pattern to TN. The median nitrate + nitrite concentration for Storm Lake (0.7 mg/L) was higher than the median for all monitored natural lakes (0.3 mg/L) and all monitored lakes (0.4 mg/L).

Ammonia (NH_4^+) concentrations were relatively low in Storm Lake (median, 63 µg/L) when compared to other monitored natural lakes (median, 110 µg/L) and all monitored lakes (103 µg/L). Ammonia is the least stable form of nitrogen and is readily converted to nitrate in well oxygenated conditions therefore ammonia concentrations tend to be high when low oxygen levels in the water column exist. Low oxygen conditions were never present when sampling occurred therefore high ammonia values would not be expected.

Chlorophyll *a* concentrations are used as an estimate of algal production in a lake. Chlorophyll *a* concentrations in Storm Lake ranged from 1.0 µg/L on 5/8/07 to 75.3 µg/L on 7/25/05 with a median of 19.3 µg/L. The median concentration was lower than the median chlorophyll *a* for all monitored natural lakes (35.5 µg/L) and for all monitored lakes (25.9 µg/L). Chlorophyll *a* concentrations typically increase from spring to summer, with the highest concentrations occurring in late summer. Phytoplankton wet mass was also analyzed at Storm Lake as a measure of algal production. The median phytoplankton wet mass was 15.9 mg/L, which is also less than the medians for all monitored natural lakes (39.7 mg/L) and for all monitored lakes (22.1 mg/L).

Secchi depth is a measure of the transparency of water. Suspended materials in the water (algae, sediment) decrease the Secchi depth of a lake. Secchi depth ranged from 0.2 m on multiple dates to 1.0 m on 5/23/02. Secchi depths are generally deepest in the spring before decreasing in the summer as algal production increases. The median Secchi depth for Storm Lake was 0.4 m, which was equal to the median for all monitored natural lakes (0.4 m) and slightly shallower than the median for all monitored lakes (0.8 m).

Total Suspended Solids (TSS) is a measure of the amount of suspended material in the water, this includes organic (algae) and inorganic forms (sediment). TSS ranged from 5.9

mg/L to 117.0 mg/L with a median value of 29.0 mg/L, which is greater than the median for all monitored natural lakes (24.0 mg/L) and for all monitored lakes (11.7 mg/L).

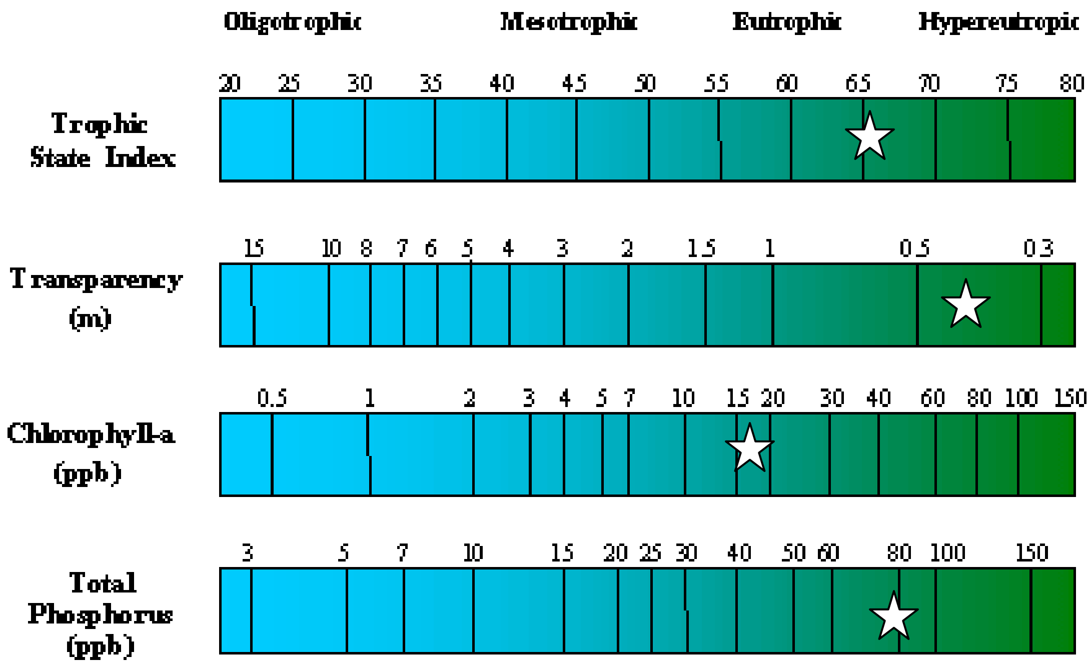
Total Fixed Suspended Solids (TFSS) is a measure of the amount of fixed or inorganic suspended (sediment) material in the water. TFSS was high in Storm Lake (median, 21.0 mg/L) compared to all other monitored natural lakes (median, 11.0) and all monitored lakes (median, 5.2 mg/L).

Trophic status in Storm Lake

Trophic status refers to the overall biological production in a lake. The amount of algae or production is determined by several factors, mainly the availability of nitrogen, phosphorus and light. A trophic state index (TSI) condenses large amounts of water quality data into a single numerical index that can be related to the productivity of a lake. The most widely used and accepted TSI, called the Carlson TSI, was developed by Bob Carlson (1977). Carlson TSI values range from 0 to 100. Each increase of 10 TSI points (10, 20, 30, etc) represents a doubling in algal biomass. TSI scores can be calculated based on total phosphorus, Secchi depth, or chlorophyll *a*. The Carlson TSI is divided into four main lake productivity categories: *oligotrophic* (least productive), *mesotrophic* (moderately productive), *eutrophic* (very productive), and *hypereutrophic* (extremely productive). The productivity of a lake can therefore be assessed with ease using the TSI score for one or more parameters. Mesotrophic lakes, for example, tend to have a good balance between water quality and algae/fish production. Eutrophic lakes have less desirable water quality and an overabundance of algae or fish. Hypereutrophic lakes have poor water quality and experience frequent nuisance algal blooms and a lack of oxygen in deep water.

Median values for the trophic variables in Storm Lake and the Carlson TSI value are shown in Figure 4. Based on these values, Storm Lake is on the border of the *eutrophic* and *hypereutrophic* category. The TSI value based on total phosphorus (75) and Secchi depth (74) are greater than the value based on chlorophyll *a* (60). When total phosphorus and Secchi depth scores are higher than the chlorophyll *a* score it indicates that algal production is limited by light. Light is not available for algae growth due to shading by high levels of sediment particles in the water column.

Figure 4. Storm Lake trophic state index and associated variables (adapted from http://www.beltramiswcd.org/TSI.html).



Water quality trends

By collecting yearly data through the ambient lake monitoring program, there is an opportunity to see how the lakes are changing over time. There are now 8 years of lake monitoring data from Storm Lake, which can be used to assess trends in the data. While 8 years is not a long time period, we can still use the data to assess the lake. The mean Secchi depth for Storm Lake has been deeper in 2005-2007 when compared to 2000-2004 based on visual estimates (Figure 5). Overall, Secchi depth does appear to be improving slightly. Total phosphorus concentrations can be analyzed similarly. Figure 6 shows that total phosphorus concentrations were very high in 2001 and have not changed much from 2002-2007. These trends are not statistically significant because there are too few years of data available.

Figure 5. Storm Lake yearly mean Secchi depth

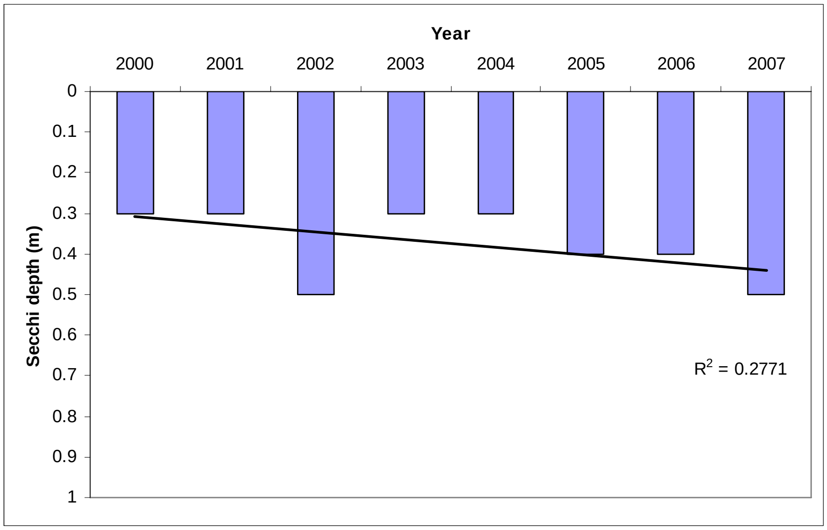
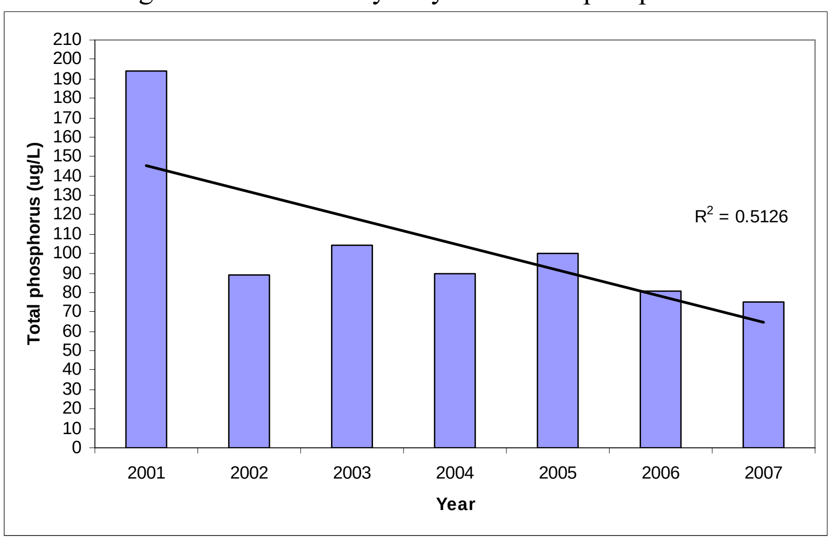


Figure 6. Storm Lake yearly mean total phosphorus



The TMDL for Storm Lake and the associated watershed improvements and dredging project have the goal of reducing sediment and turbidity in the lake. The TMDL set targets of a Secchi depth of 0.7 m and a TSS concentration of 20 mg/L for Storm Lake. The monitoring data from the ambient lake program is essential to see if the lake is improving over time. Both turbidity (Figure 7) and TSS (Figure 8) appear to have a decreasing trend (based on visual assessment) from 2000 to 2007. As of 2007, however, the TMDL targets have not been met (2007 average Secchi depth, 0.5 m; 2007 average TSS 25 mg/L).

Figure 7. Turbidity 2000-2007.

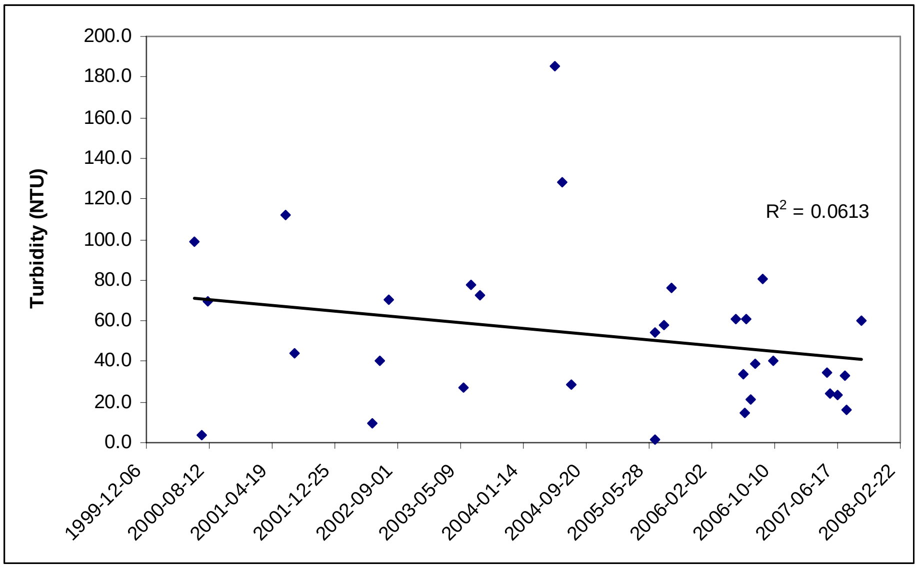
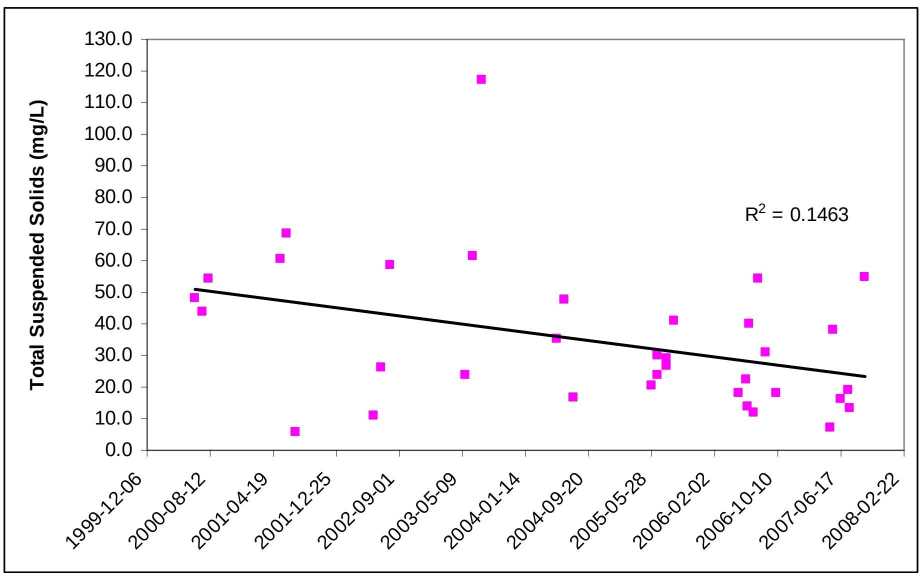


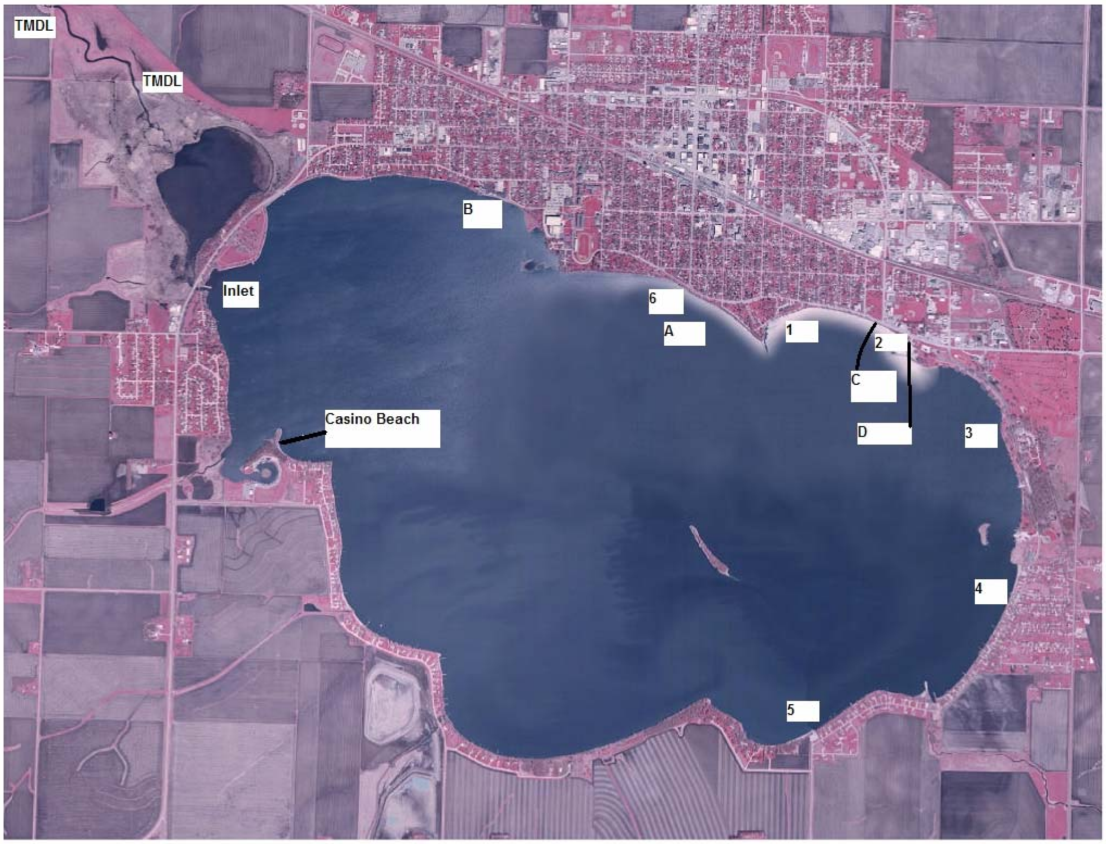
Figure 8. Total Suspended Solids 2000-2007.



Outfall Monitoring

In 2004 monitoring began on 4 storm water outfalls that empty into the lake from the City of Storm Lake. The outfalls are located east of the old water plant (A), at Methodist manor (B), at flindt and lakeshore (C) and at lake patrol (D) (Figure 9). The parameters monitored at each outfall include: ammonia, chloride, nitrate+nitrite, ortho phosphate, total Kjeldahl nitrogen, total phosphate, E. coli, and fecal coliform.

Figure 9. Outfall and Beach Sampling Locations.



Key: Outfalls: A= Old Water Plant, B= Methodist Manor, C= Flindt Lake Shore, D= Lake Patrol. Beaches: 1= Chautauqua Park Beach, 2= Proposed Destination Park Beach, 3= Campground Beach, 4= Edson Park Beach, 5=Bel Air Beach, 6=Old Water Plant Beach.

Flindt Lake Shore

Ammonia nitrogen at the Flindt site ranged from 0.05 mg/L to 0.6 mg/L with a median of 0.05 mg/L. The median ammonia concentration at Flindt was the lowest for all sites. Nitrate-nitrite nitrogen ranged from 0.44 mg/L to 9.4 mg/L at the Flindt site. The median nitrate-nitrite concentration was 5.2 mg/L, which was the 2nd lowest for all sites. Total Kjeldahl nitrogen (TKN) ranged from 0.05 mg/L to 4.1 mg/L at the Flindt site. The median TKN concentration at the Flindt site (0.6 mg/L) was the 2nd highest compared to all sites.

Total phosphorus concentrations at the Flindt site ranged from 0.05 mg/L to 0.4 mg/L with a median of 0.09 mg/L. The median total phosphorus concentration at the Flindt site was the 2nd lowest compared to all sites. Ortho phosphate ranged from 0.02 to 0.2 at the Flindt site. The median ortho phosphate (0.03 mg/L) was the 2nd lowest compared to all sites.

Chloride values at the Flindt site ranged from 32 mg/L to 390 mg/L. The Flindt site had the highest median chloride value (210 mg/L).

Bacteria concentrations varied greatly at the Flindt site. E. coli ranged from 10 E. coli organisms/100 ml to 36,000 E. coli organisms/100 ml. The median E. coli concentration at the Flindt site was 160 E. coli organisms/100ml, which was tied for the highest median concentration of all sites. Fecal coliform concentrations ranged from 10 colony forming units (CFU)/100 ml to 200,000 CFU/100 ml. The median fecal coliform concentration (160 CFU/100 ml) was the lowest of all sites.

<u>Lake Patrol</u>

Ammonia nitrogen concentrations at the Lake Patrol site ranged from 0.05 mg/L to 6.4 mg/L, which was the highest individual ammonia concentration of all sites. The Lake Patrol site also had the 2nd highest median ammonia concentration (0.06 mg/L). Nitrate-nitrite concentrations ranged from 0.05 mg/L to 7.6 mg/L. The median nitrate-nitrite concentration at Lake Patrol was 3.8 mg/L, which was the lowest of all sites. TKN concentrations ranged from 0.1 mg/L to 7.8 mg/L. The median TKN concentration at the Lake Patrol site (0.6 mg/L) was the highest of all sites.

Total phosphorus concentrations at the Lake Patrol site ranged from 0.05 mg/L to 0.86 mg/L with a median of 0.15 mg/L. The median total phosphorus concentration at the Lake Patrol site was the highest compared to all sites. Ortho-phosphate ranged from 0.02 to 0.58 at the Lake Patrol site. The median ortho-phosphate (0.13 mg/L) was the highest compared to all sites.

Chloride values at the Lake Patrol site ranged from 16 mg/L to 140 mg/L. The Lake Patrol site had the 2nd lowest median chloride value (81 mg/L).

Bacteria concentrations varied greatly at the Lake Patrol site. E. coli ranged from 10 E. coli organisms/100 ml to 290,000 E. coli organisms/100 ml, which was the highest individual E. coli concentration of all sites. The median E. coli concentration at the Lake Patrol site was 135 E. coli organisms/100ml, which was tied for the highest median concentration of all sites. Fecal coliform concentrations ranged from 10 colony forming units (CFU)/100 ml to 350,000 CFU/100 ml. The median fecal coliform concentration (215 CFU/100 ml) was the 2nd highest of all sites.

Overall, the Lake Patrol outfall site had the highest median concentrations of total phosphate, ortho-phosphate, and TKN and the highest maximum E. coli and fecal coliform concentrations.

<u>Methodist Manor</u>

Ammonia nitrogen concentrations at the Methodist Manor site ranged from 0.05 mg/L to 0.15 mg/L. The Methodist Manor site had the lowest median ammonia concentration (0.05 mg/L). Nitrate-nitrite concentrations ranged from 0.35 mg/L to 9.8 mg/L. The median nitrate-nitrite concentration at Methodist Manor was 5.5 mg/L, which was the 2nd highest of all sites. TKN concentrations ranged from 0.2 mg/L to 1.1 mg/L. The median TKN concentration at the Methodist Manor site (0.3 mg/L) was the lowest of all sites.

Total phosphorus concentrations at the Methodist Manor site ranged from 0.05 mg/L to 0.27 mg/L with a median of 0.05 mg/L. The median total phosphorus concentration at the Methodist Manor site was the lowest of all sites. Ortho-phosphate ranged from 0.02 to 0.16 at the Methodist Manor site. The median ortho-phosphate (0.02 mg/L) was the lowest of all sites.

Chloride values at the Methodist Manor site ranged from 4 mg/L to 190 mg/L. The Methodist Manor site had the highest median chloride value (140 mg/L).

Bacteria concentrations varied greatly at the Methodist Manor site. E. coli ranged from 10 E. coli organisms/100 ml to 6000 E. coli organisms/100 ml. The median E. coli concentration at the Methodist Manor site was 33 E. coli organisms/100ml, which was the lowest median concentration of all sites. Fecal coliform concentrations ranged from 10 colony forming units (CFU)/100 ml to 56,000 CFU/100 ml. The median fecal coliform concentration (48 CFU/100 ml) was the lowest of all sites.

<u>Old Water Plant</u>

Ammonia nitrogen concentrations at the Old Water Plant site ranged from 0.05 mg/L to 1.6 mg/L. The Old Water Plant site had the highest median ammonia concentration (0.09 mg/L). Nitrate-nitrite concentrations ranged from 0.05 mg/L to 10 mg/L. The median nitrate-nitrite concentration at the Old Water Plant was 6.0 mg/L, which was the highest of all sites. TKN concentrations ranged from 0.2 mg/L to 2.5 mg/L. The median TKN concentration at the Old Water Plant site (0.4 mg/L) was the 2nd lowest of all sites.

Total phosphorus concentrations at the Old Water Plant site ranged from 0.05 mg/L to 0.24 mg/L with a median of 0.12 mg/L. The median total phosphorus concentration at the Old Water Plant site was the 2nd highest compared to all sites. Ortho-phosphate ranged from 0.02 to 0.12 at the Old Water Plant site. The median ortho-phosphate (0.06 mg/L) was the 2nd highest compared to all sites.

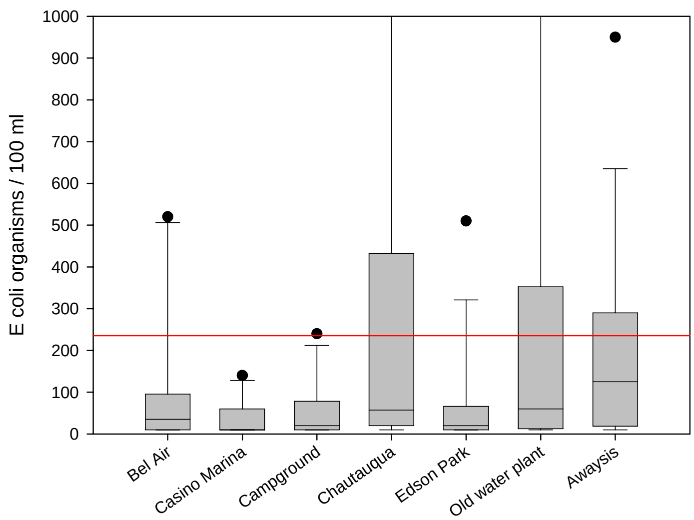
Chloride values at the Old Water Plant site ranged from 6 mg/L to 86 mg/L. The Old Water Plant site had the lowest median chloride value (54 mg/L).

Bacteria concentrations varied less at the Old Water Plant site when compared to other sites. The Old water plant site had the highest median concentrations of bacteria, but had the lowest mean concentrations compared to other sites. This indicates that this site had more consistent bacteria concentrations with fewer really high concentrations. E. coli ranged from 10 E. coli organisms/100 ml to 4000 E. coli organisms/100 ml. The median E. coli concentration at the Old Water Plant site was 160 E. coli organisms/100ml, which was the highest of all sites. Fecal coliform concentrations ranged from 10 colony forming units (CFU)/100 ml to 8700 CFU/100 ml. The median fecal coliform concentration (300 CFU/100 ml) was the highest of all sites.

Beach Monitoring

Since 2004 monitoring has also occurred at 7 beaches on Storm Lake: Chautauqua Park Beach (1), the proposed location for the Destination Park beach (2), campground beach (3), Edson Park beach (4), Bel Air beach (5), the old water plant beach and wading area (6) and Casino Marina beach (Figure 9). At each beach samples are taken for *Escherichia coli* (E. coli) and Fecal Coliform bacteria, two types of indicator bacteria. Indicator bacteria are bacteria that are not themselves dangerous to human health, but are used to indicate the presence of a human health risk. Potential sources of bacteria in water include: human wastes (failed septic systems, sewer systems), agricultural animal waste, pet waste, and bird waste (geese, etc.).

Figure 10. E. coli concentrations at Storm Lake Beaches (2004-2007)

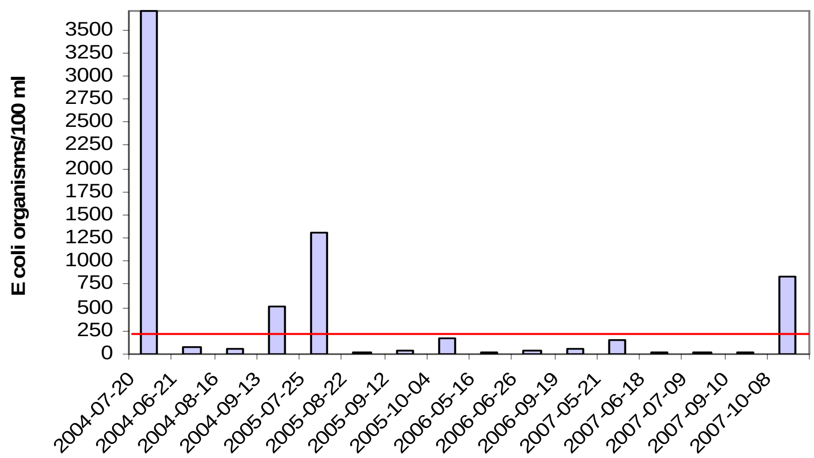


Iowa has water quality standards related to bacteria in water. There are two parts of the bacteria standard: (1) the geometric mean based on 5 samples within a 30 day period must be less than 126 E. coli organisms/100 ml, and (2) the single-sample maximum concentration may not exceed 235 E. coli organisms/100 ml. In order to assess whether the lake will fully support recreational uses for Clean Water Act requirements the geometric means based on 5 samples in a 30 day period must be less than the state's geometric mean criterion of 126 E. coli organisms/100 ml and the single-sample maximum of 235 E coli organisms/100 ml may not be exceeded in more than 10% of the samples during any one recreation season. Because E. coli is used for Iowa's water quality standards and E. coli concentrations and fecal coliform concentrations tend to be similar the following discussion focuses on E. coli only.

<u>Chautauqua Park Beach</u>

Chautauqua Park beach E. coli levels ranged from 10 E. coli organisms/100 ml to 3700 E. coli organisms/100 ml. The median E. coli concentration was 57 E. coli organisms/100 ml, which was the 3rd highest median concentration of all beaches (Figure 10). On four occasions the bacteria concentrations at Chautauqua Park beach did not meet the water quality standard of 235 E. coli organisms/100 ml (Figure 11).

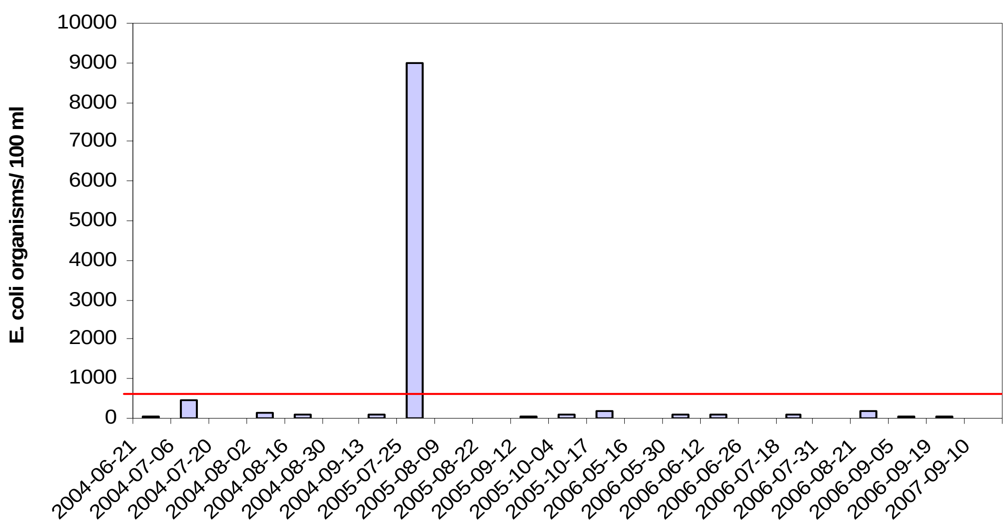
Figure 11. E. coli concentrations at Chatauqua Park Beach (2004-2007). Red line is the one-time maximum state water quality standard (235 E. coli organisms/100 ml)



<u>Proposed Destination Park Beach</u>

Destination Park beach E. coli levels at the center transect- chest depth (to compare to other beaches) ranged from 10 E. coli organisms/100 ml to 9000 E. coli organisms/100 ml. The median E. coli concentration was 54 E. coli organisms/100 ml, which was the 4rd highest median concentration of all beaches (Figure 10). On one occasion the bacteria concentration at Destination Park beach did not meet the water quality standard of 235 E. coli organisms/100 ml (Figure 12). .

Figure 12. E. coli concentrations at Destination Park Beach (2004-2007). Red line is the one-time maximum state water quality standard (235 E. coli organisms/100 ml)

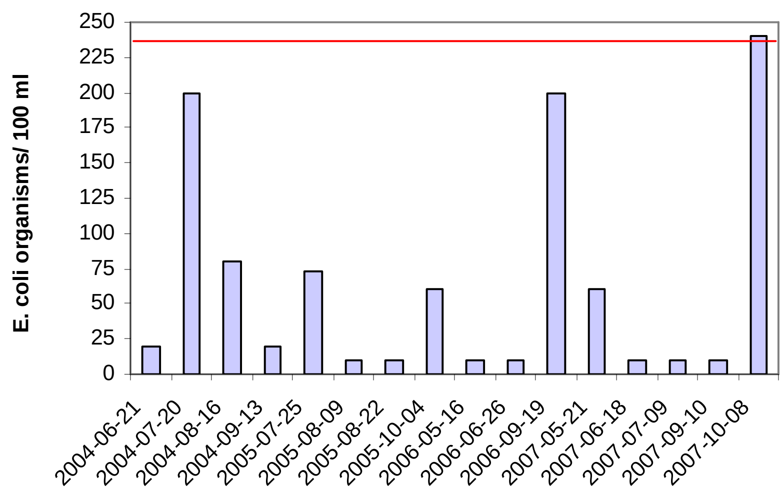


In 2004 and 2005 multiple other sites were monitored at the Destination Park beach. Six points on three transects (north, center, south) were monitored at three different depths (ankle, knee, chest) to get a better understanding of the spatial variation of E. coli at the beach. The north transect had the most violations of the E. coli standard (19), while the center and south transects had 11 violations each. The samples taken at ankle depth had the most violations of the depths (20). Samples taken at knee and chest depth had 10 and 11 violations, respectively.

<u>Campground Beach</u>

Campground beach E. coli levels ranged from 10 E. coli organisms/100 ml to 240 E. coli organisms/100 ml. The median E. coli concentration was 20 E. coli organisms/100 ml, which was the 2nd lowest median concentration of all beaches (Figure 10). On one occasion the bacteria concentration at Campground beach did not meet the water quality standard of 235 E. coli organisms/100 ml (Figure 13).

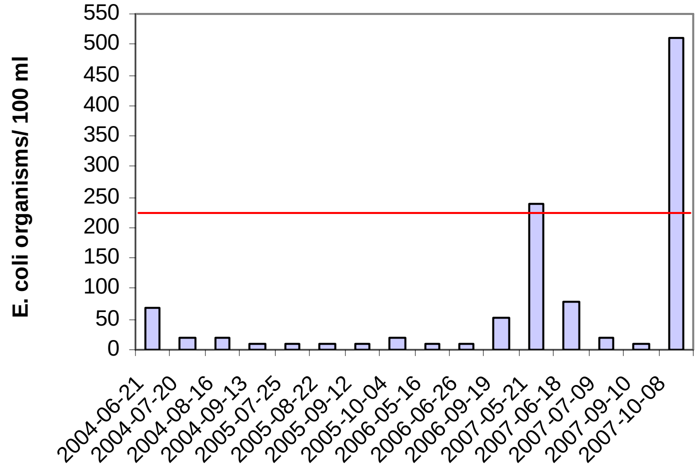
Figure 13. E. coli concentrations at Campground Beach (2004-2007). Red line is the one-time maximum state water quality standard (235 E. coli organisms/100 ml)



<u>Edson Park Beach</u>

Edson Park beach E. coli levels ranged from 10 E. coli organisms/100 ml to 510 E. coli organisms/100 ml. The median E. coli concentration was 20 E. coli organisms/100 ml, which was the 2nd lowest median concentration of all beaches (Figure 10). On two occasions the bacteria concentration at Edson Park beach did not meet the water quality standard of 235 E. coli organisms/100 ml (Figure 14).

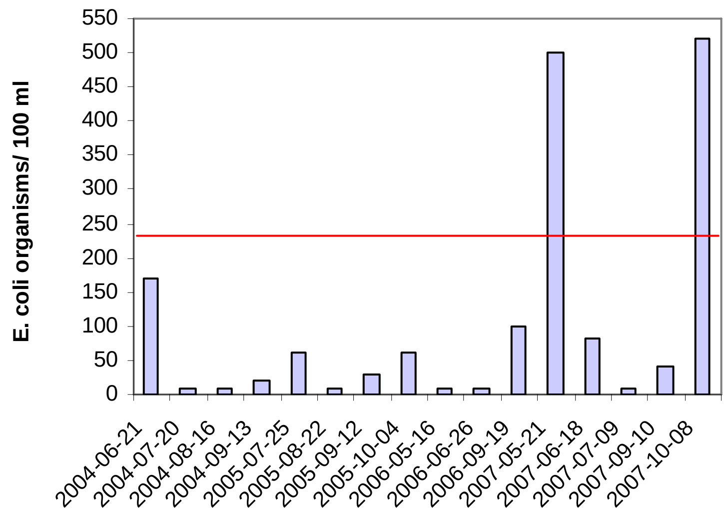
Figure 14. E. coli concentrations at Edson Park Beach (2004-2007). Red line is the one-time maximum state water quality standard (235 E. coli organisms/100 ml)



Bel Air Beach

Bel Air beach E. coli levels ranged from 10 E. coli organisms/100 ml to 520 E. coli organisms/100 ml. The median E. coli concentration was 35 E. coli organisms/100 ml, which was the 3rd lowest median concentration of all beaches (Figure 10). On two occasions the bacteria concentration at Bel Air beach did not meet the water quality standard of 235 E. coli organisms/100 ml (Figure 15). .

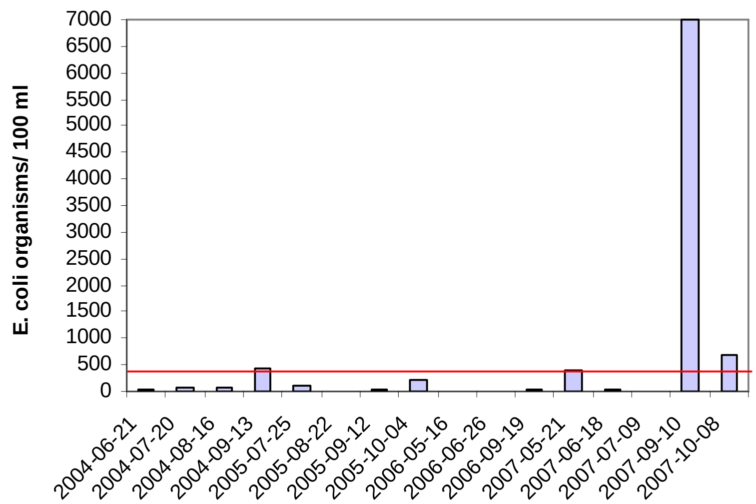
Figure 15. E. coli concentrations at Bel Air Beach (2004-2007). Red line is the one-time maximum state water quality standard (235 E. coli organisms/100 ml)



Old Water Plant Beach

Old Water Plant beach E. coli levels ranged from 10 E. coli organisms/100 ml to 7000 E. coli organisms/100 ml. The median E. coli concentration was 60 E. coli organisms/100 ml, which was the 2nd highest median concentration of all beaches (Figure 10). On four occasions the bacteria concentration at Old Water Plant beach did not meet the water quality standard of 235 E. coli organisms/100 ml (Figure 16).

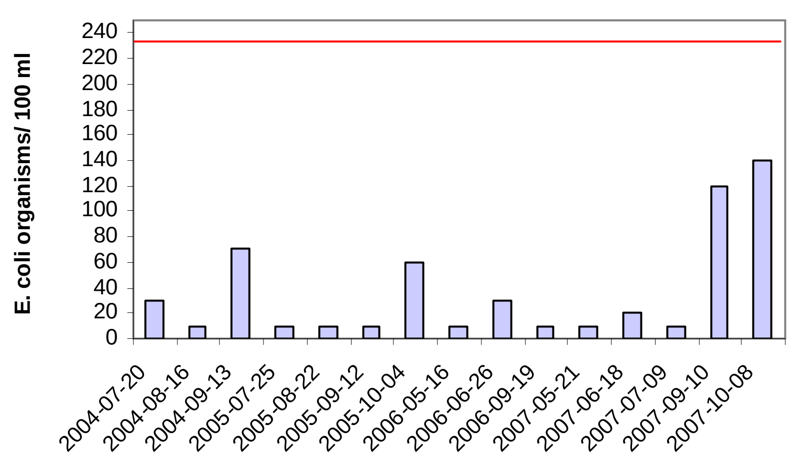
Figure 16. E. coli concentrations at Old Water Plant Beach (2004-2007). Red line is the one-time maximum state water quality standard (235 E. coli organisms/100 ml)



Casino Marina Beach

Casino Marina beach E. coli levels ranged from 10 E. coli organisms/100 ml to 140 E. coli organisms/100 ml. The median E. coli concentration was 10 E. coli organisms/100 ml, which was the lowest median concentration of all beaches (Figure 10). The bacteria concentration at Casino Marina beach never exceeded the water quality standard of 235 E. coli organisms/100 ml (Figure 17) on the sampling dates in these 4 years.

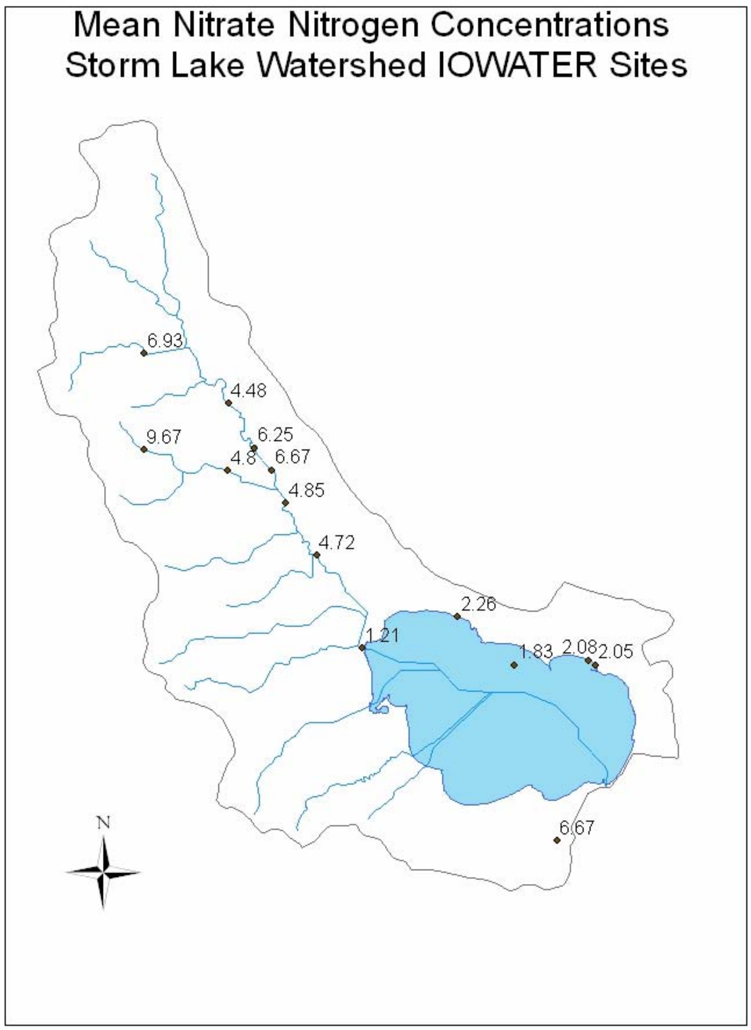
Figure 17. E. coli concentrations at Casino Marina Beach (2004-2007). Red line is the one-time maximum state water quality standard (235 E. coli organisms/100 ml)



IOWATER Monitoring

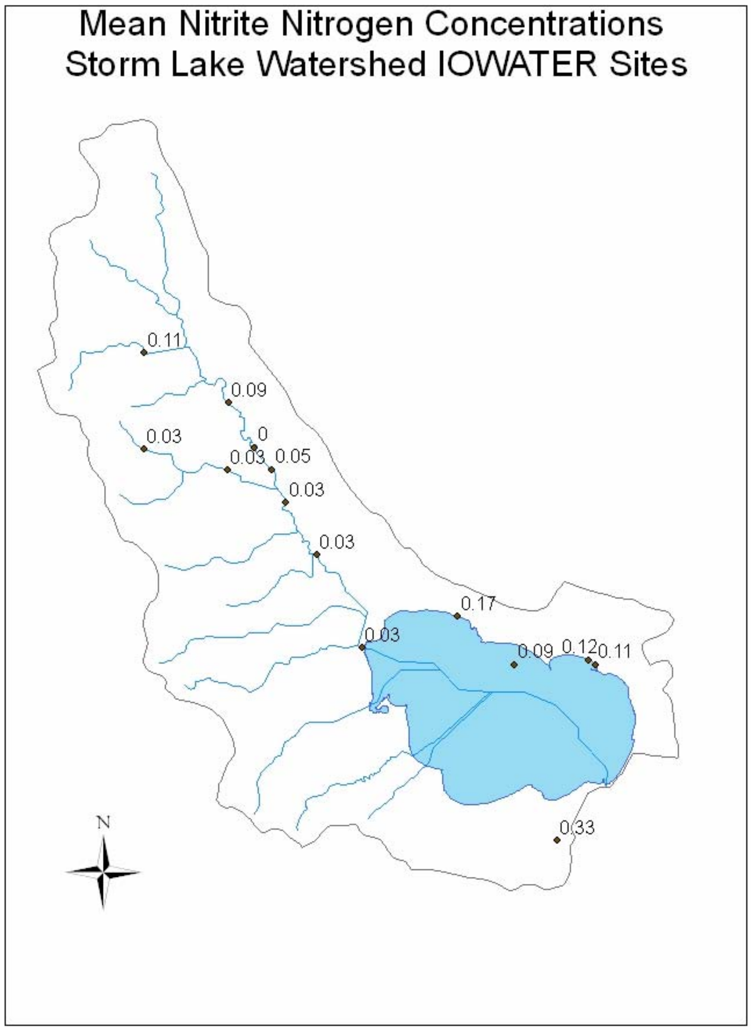
IOWATER is Iowa's volunteer water monitoring program. The program trains volunteers throughout the state to monitor surface water using field test kits. Parameters included in the IOWATER program include: nitrate, nitrite, phosphate, chloride, dissolved oxygen, transparency, and pH. Thirteen sites were monitored throughout the Storm Lake watershed using IOWATER methods. The sites varied in how many samples were taken and when they were monitored. Below are the results for each parameter.

Figure 18. Mean IOWATER Nitrate Nitrogen Concentrations.



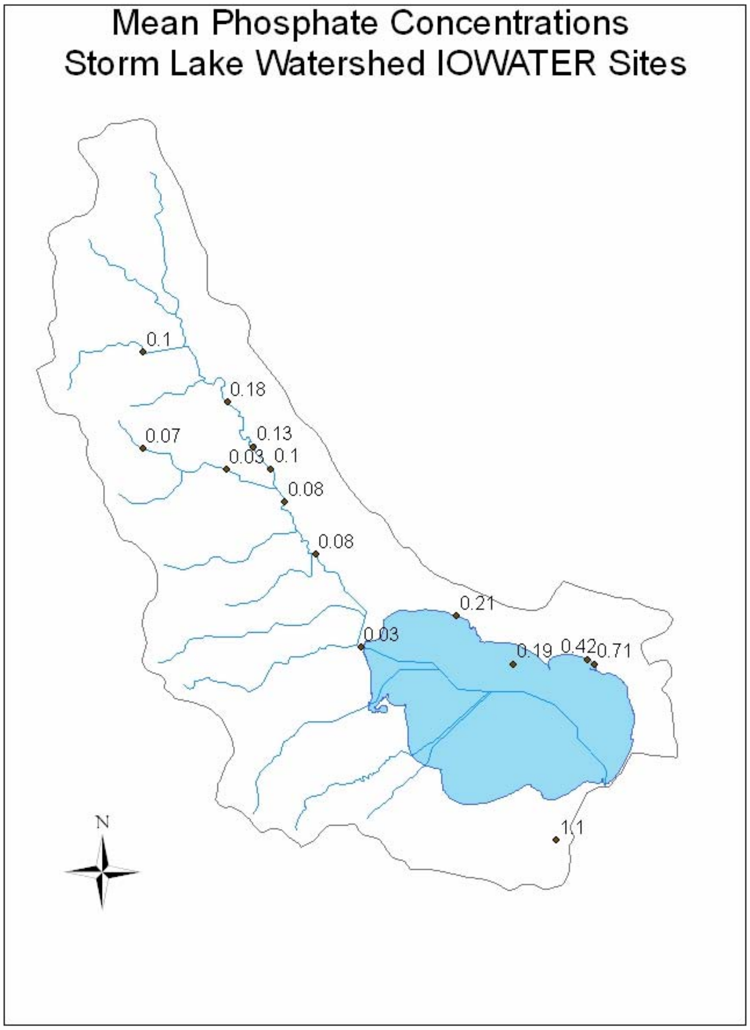
Nitrate concentrations were higher in the upper portion of the watershed, which is mainly agricultural areas, when compared to the storm sewer outfalls. Mean nitrate concentrations in the agricultural areas ranged from 4.48 mg/L to 9.67 mg/L, while mean concentrations ranged from 1.83 mg/L to 2.26 mg/L in the storm sewer outfalls. Higher nitrate concentrations are expected in the agricultural areas due to application of nitrogen fertilizers.

Figure 19. Mean IOWATER Nitrite Nitrogen Concentrations.



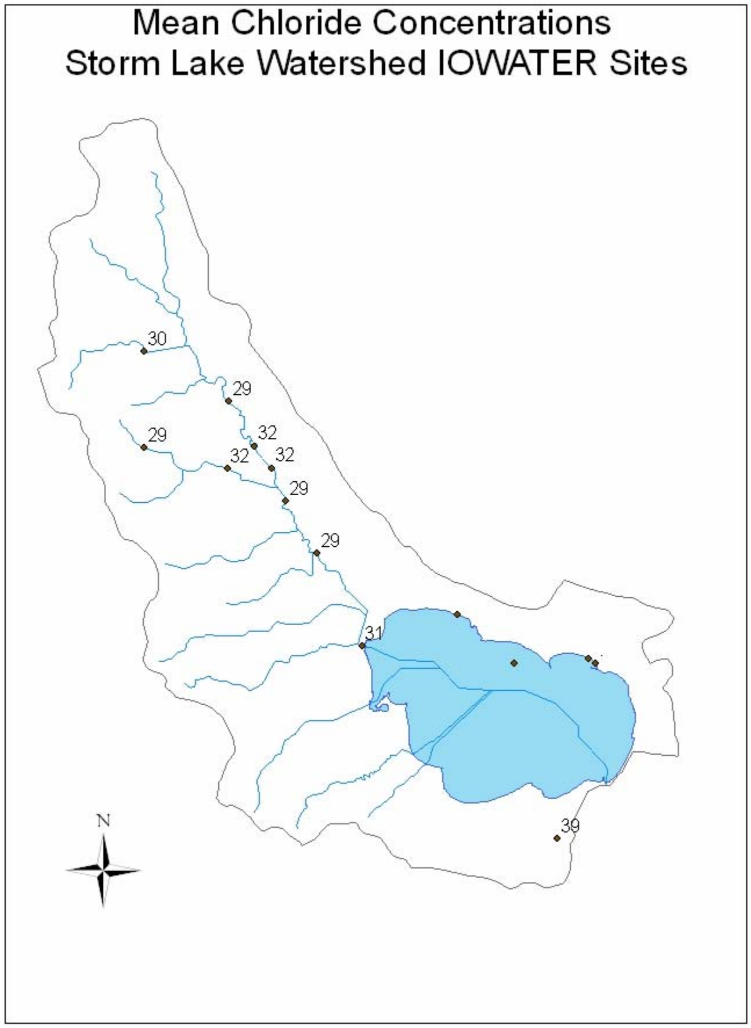
Nitrite concentrations were generally higher in the storm sewer outfalls when compared to the agricultural areas with the exception of the northernmost and southernmost sites. Nitrite concentrations are generally low because nitrite is readily converted to nitrate in the presence of oxygen. The storm sewer sites as well as the southernmost site had the lowest levels of dissolved oxygen and were therefore capable of having more nitrite.

Figure 20. Mean IOWATER Phosphate Concentrations.



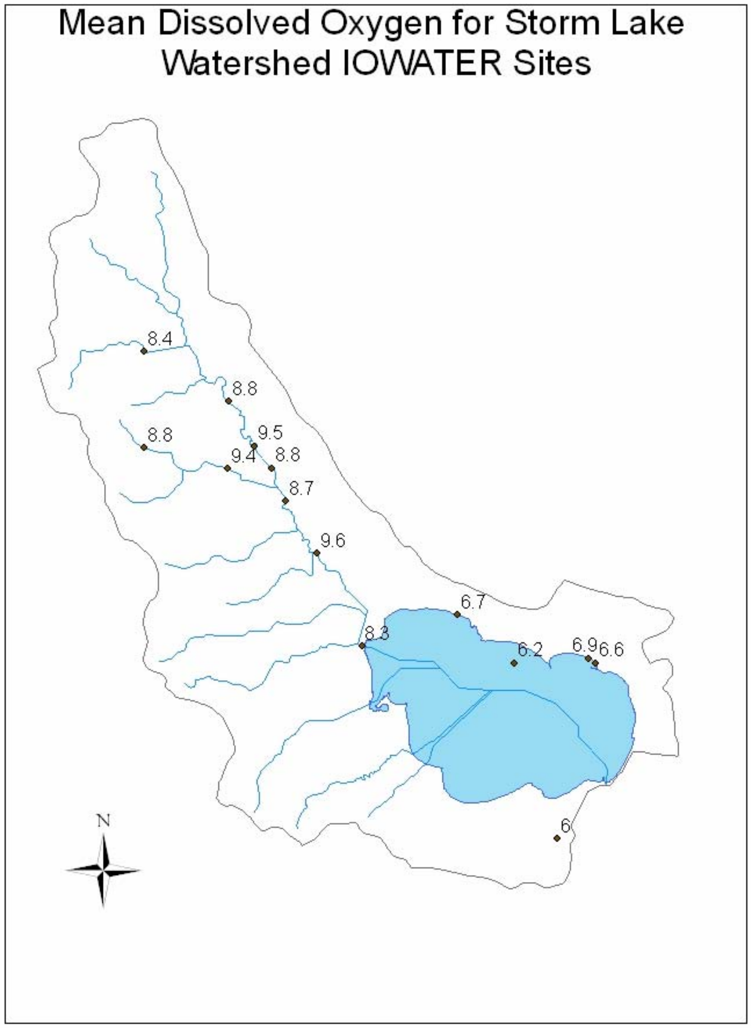
Phosphate concentrations were highest at the storm sewer sites (mean 0.19-0.71 mg/L) and the southernmost site (mean 1.1 mg/L) compared to the agricultural sites. Phosphorus is found in fertilizers, detergents, manure, municipal and domestic sewage, industrial waste, and naturally in soil.

Figure 21. Mean IOWATER Chloride Concentrations.



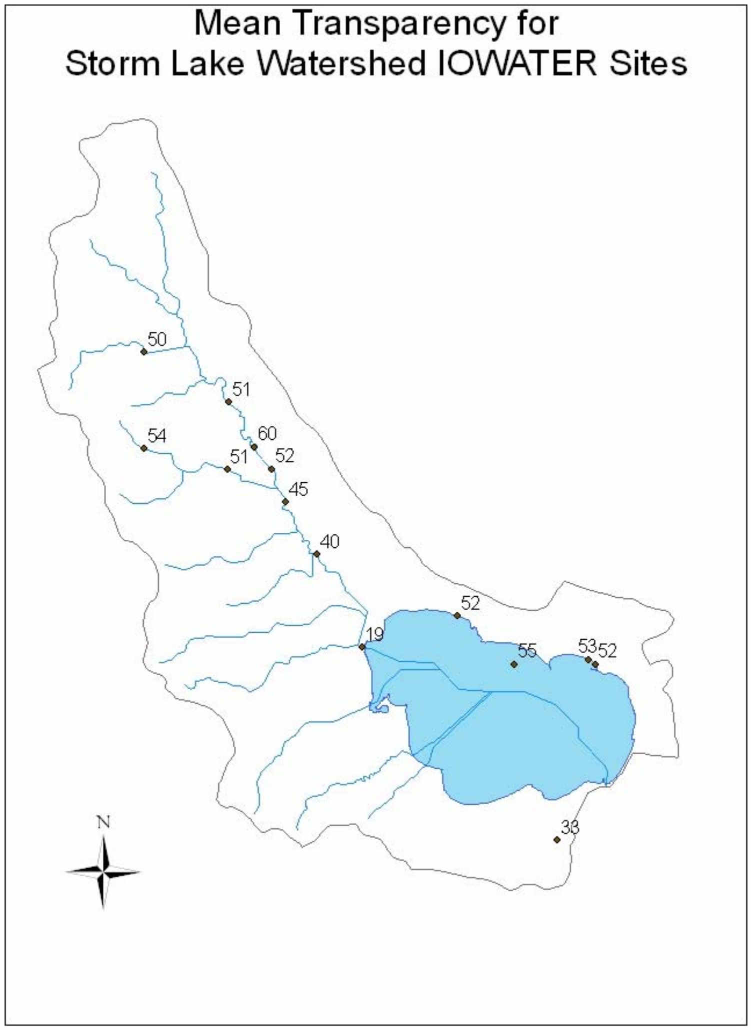
Chloride is a component of salt and is a measure of human or animal waste inputs to a stream or lake. Elevated levels of chloride may indicate inputs of human or animal waste or inputs of fertilizers, many of which contain salts. Mean chloride concentrations ranged from 29 mg/L at many sites to 39 mg/L at the southernmost site. Average chloride concentrations in Iowa streams range from 20 to 30 mg/L. All sites in the Storm Lake watershed were slightly above this range.

Figure 22. Mean IOWATER Dissolved Oxygen Concentrations.



Mean dissolved oxygen concentrations were lowest at the storm sewer sites (mean 6.2-6.9 mg/L) and the southernmost site (6 mg/L). Mean dissolved oxygen concentrations in the upper watershed ranged from 8.4 to 9.6 mg/L. The streams have higher dissolved oxygen as expected because streams are able to incorporate more oxygen from the air than enclosed storm sewers.

Figure 23. Mean IOWATER Transparency.



Mean transparencies were generally around 50 centimeters (cm) with the exception of the southernmost site (30 cm), the outlet of Little Storm Lake (19 cm), and the pasture site on Powell Creek (40 cm). Mean pH values for all sites ranged between 6 and 8. All sites fall within the aquatic life range for pH of 6-9.

One of the major influences on transparency is rainfall. As rain falls on the land, it collects sediment before running into streams. This sediment causes the water to become cloudy and decreases transparency. Transparency measurements at the IOWATER sites can be compared to rainfall measurements in the watershed to better understand how much sediment is entering the streams when it rains. The rainfall and transparency data can be difficult to analyze because it is difficult to know when the peak flow occurs after a rain event. Therefore, sampling may occur before or after the greatest amount of sediment has passed through the stream and may not be an accurate prediction of how much sediment has run off the landscape. Below are graphs of transparency and rainfall data for the six IOWATER sites with that information. There are some instances where the transparency is lower with higher rainfall, as expected, however there are also multiple occasions where transparency is high with higher rainfall. Overall, it is difficult to see trends in the data, however there are occasions where transparency is lower due to rainfall.

Figure 24. Corner Pasture IOWATER Site Transparency and Rainfall.

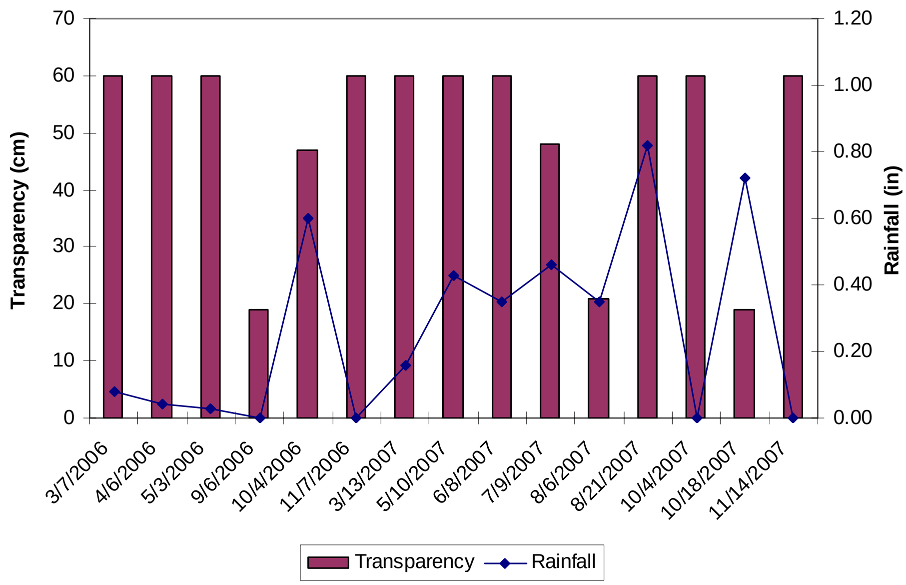


Figure 25. Highway 7 IOWATER Site Transparency and Rainfall.

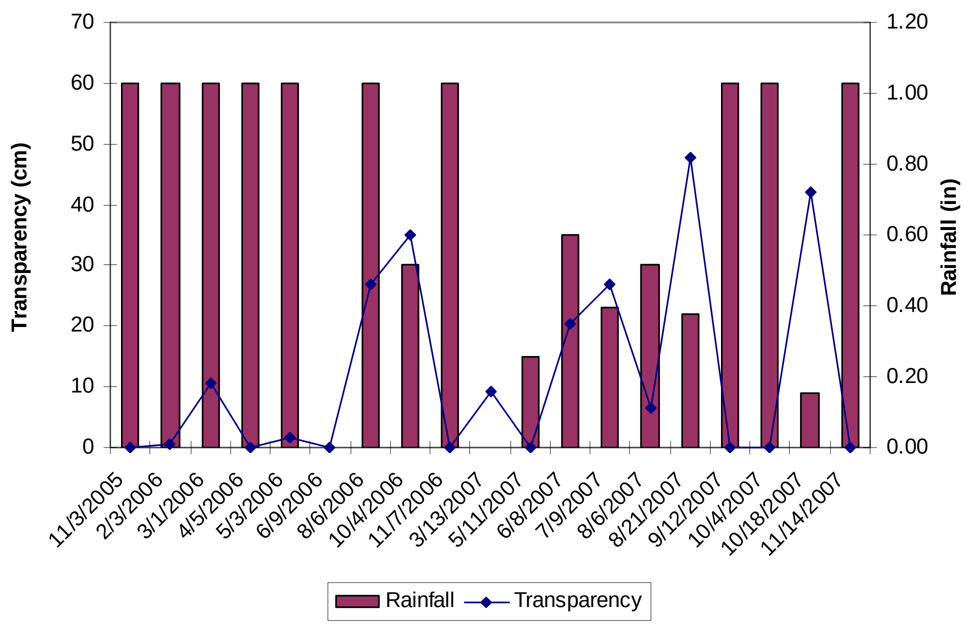


Figure 26. Outlet Creek IOWATER Site Transparency and Rainfall.

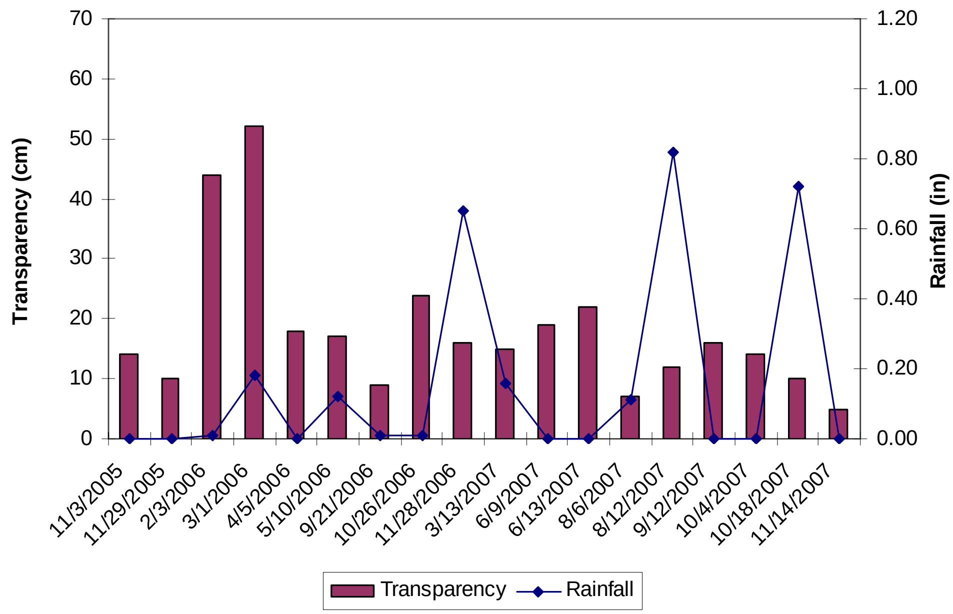


Figure 27. Pasture IOWATER Site Transparency and Rainfall.

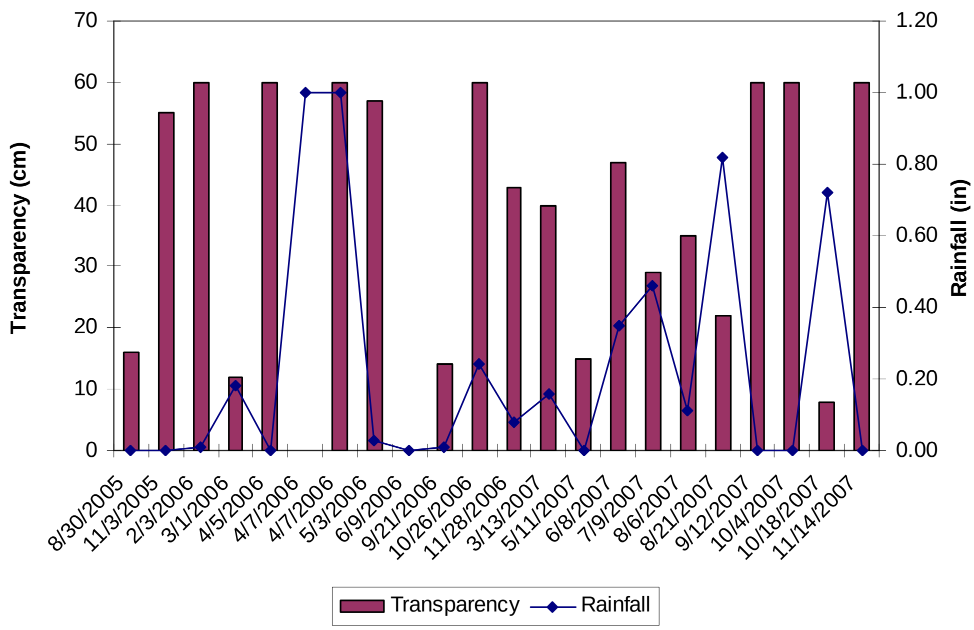


Figure 28. Turnquist Buffer IOWATER Site Transparency and Rainfall.

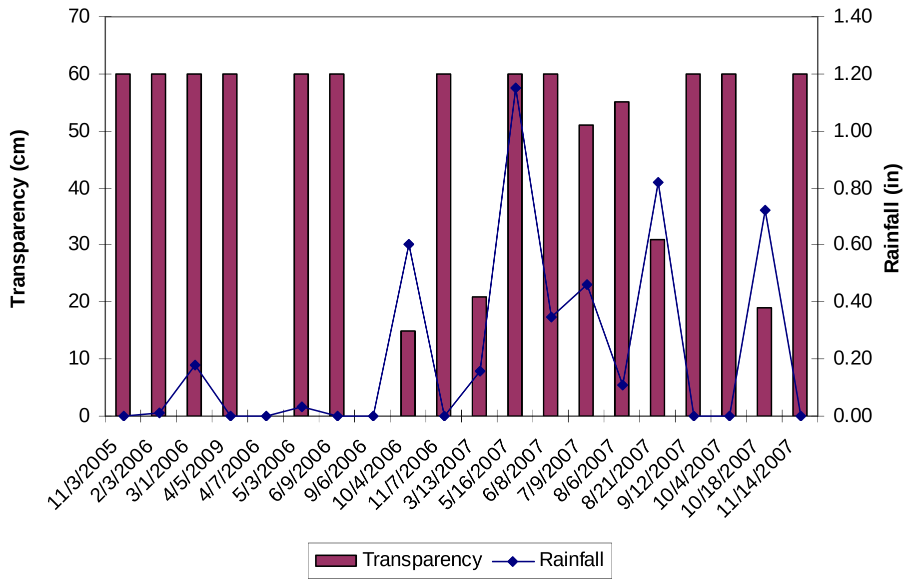
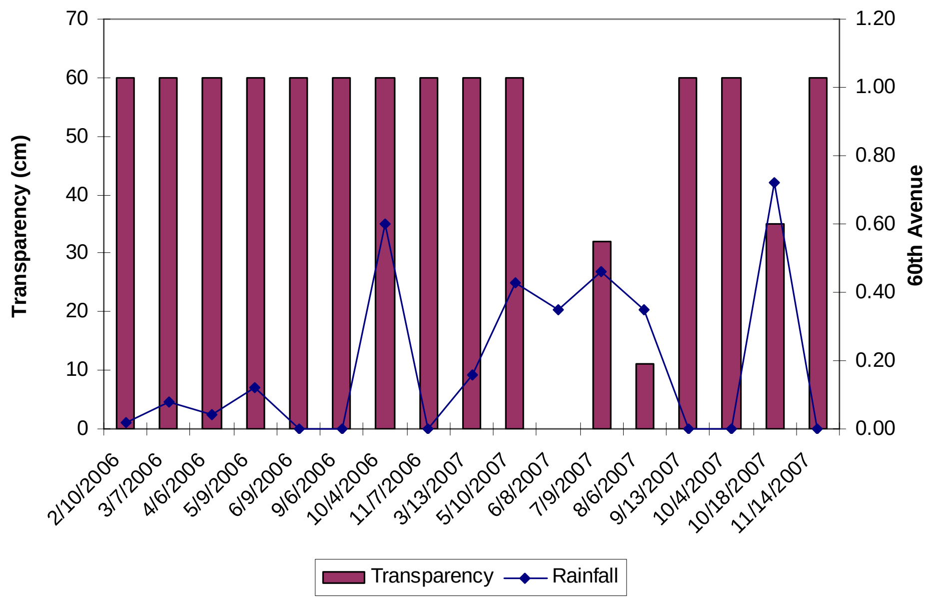


Figure 29. 60th Avenue IOWATER Site Transparency and Rainfall.



Conclusions

Storm Lake and its watershed have been monitored by a number of different programs. Each program provides specific information that is useful in the management of the lake. The data helps prioritize sites for restoration activities. Continued monitoring will be able to detect changes in the lake's water quality and determine if goals of current restoration programs are being met.

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University Hygienic Laboratory (2004-2007), Storm Lake Beach and Outfall Sampling Results.

Appendix A. Summary table of median values for parameters in the ambient lake monitoring program.

Parameter	**Storm Lake**	**All Natural Lakes**	**All Ambient Program Lakes**
Lake Depth (m)	2.6	2.7	5.5
Thermocline Depth (m)	0	0	2.8
Secchi Depth (m)	0.4	0.4	0.8
Water Temp (°C)	23.5	23.7	24.4
Dissolved Oxygen (mg/L)	8.6	8.9	8.7
pH	8.6	8.6	8.6
Specific Conductivity (µS/cm)	510	481	370
Turbidity (NTU)	43.9	35.7	18.2
Chlorophyll *a* (µg/L)	19.3	35.5	25.9
Total Phosphorus (µg/L)	80	110.0	81.7
Soluble Reactive Phosphorus (µg/L)	20.0	20.0	15.8
Total Nitrogen (mg/L)	1.2	1.7	1.5
Total Kjeldahl Nitrogen (mg/L)	0.8	1.7	1.2
Ammonia (µg/L)	62.9	110.0	103
Unionized ammonia (µg/L)	2.0	8.4	7
Nitrate + Nitrite (mg/L)	0.7	0.3	0.4
Alkalinity (mg $CaCO_3$/L)	160	170	136
Silica (mg/L)	7.2	7.7	4.1
Total Organic Carbon (mg/L)	6.7	11.0	9.4
Dissolved Organic Carbon (mg/L)	5.2	9.3	7.6
Total Dissolved Solids (mg/L)	300.0	300.0	213
Total Fixed Suspended Solids (mg/L)	21.0	11.0	5.2
Total Volatile Suspended Solids (mg/L)	7.7	11.5	6.0
Total Suspended Solids (mg/L)	29.0	24.0	11.7
Phytoplankton Wet Mass (mg/L)	15.9	39.7	22.1
Zooplankton Wet Mass (mg/L)	100.7	181.8	116.8
Cyanobacteria Wet Mass (mg/L)	11.2	36.2	16.0
Carlson's TSI (Secchi)	74	72	63
Carlson's TSI (Chlorophyll *a*)	60	66	62
Carlson's TSI (Total Phosphorus)	67	72	68