BIG LAKE AND LAKE LUCILLE WATER QUALITY MONITORING FINAL REPORT

***Photo –** Public boat launch at Lake Lucille. June 19, 2004.*

Prepared for

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1 INTRODUCTION

This draft report summarizes the results of a water quality monitoring study of Lake Lucille and Big Lake, Alaska performed in May-June 2004. Lake Lucille and Big Lake are two heavily-used recreational lakes in the Matanuska Susitna Borough. Lake Lucille is a small lake (360 acres) located in Wasilla with a maximum depth of 20 feet. The north and east shores are continuously-developed residential areas. There is a large lodge, restaurant and flight service on the north shore. The south and west shores are less developed, but there are extensive recreational activities throughout the lake. The entire lake shore is private land except for a park on the south shore owned by the Mat-Su Borough. The Wasilla population in 2000 was 5,400 residents with 2,100 houses, only 140 of which are unoccupied. Lake Lucille was listed on the Alaska Department of Environmental Conservation (ADEC) 1998 Section 303(d) list of impaired waters for failure to meet the dissolved oxygen criteria. A Total Maximum Daily Load (TMDL) was completed in 2001 to determine the maximum dissolved oxygen levels that meet the 18AAC70 Alaska Water Quality Standards (AWQS). The TMDL recognizes that anthropogenic sources of phosphorus have been reduced to help meet AWQS and part of the TMDL implementation is to continue this reduction.

Big Lake is located 15 miles west of Wasilla, Alaska. It is 2500 acres in size and reaches a maximum depth of 90 feet. There is a mixture of permanent residences and recreational cabins on the lake with two marinas and one restaurant currently operating. The 2000 census recorded the population of Big Lake as 2,600 residents with 2,100 houses, approximately 1000 of which are unoccupied. Approximately 564 acres of land adjacent to the lake shore is residential, 35 acres are commercial, 652 acres are vacant and 217 acres are public land (BLMP 1998). Due to its large size and close access to Anchorage, Big Lake is a popular recreational area in Southcentral Alaska and has heavy usage throughout the year.

Monitoring was performed by OASIS Environmental, Inc. (OASIS) for ADEC at both lakes for four separate groups of parameters: bacteria, hydrocarbons, nutrients and standard physical and chemical parameters (pH, dissolved oxygen, conductivity, temperature, turbidity and salinity). Standard physical and chemical parameters were collected using in-situ multi-parameter water quality meters. Three sampling events were conducted on each lake, two in May and one in June. The first sampling event was scheduled to occur before spring overturn. Both lakes were sampled after the spring overturn when surface water temperatures were greater than 4° C (maximum density of water) indicating that thermal stratification had already begun. The second sampling event for both lakes was conducted on Memorial Day Weekend to target high recreational usage. The last sampling event occurred over two weekends in June.

This report includes the methods used to conduct the water quality monitoring at each lake, results of the monitoring and conclusions regarding each lake's water quality. Recommendations for future monitoring are also presented.

2 METHODS

Water samples were collected at Big Lake and Lake Lucille during three sampling events in May and June 2004. Samples were collected at Lake Lucille on May 8, May 30 and June 19 and at Big Lake on May 15-16, May 29 and 31 and June 12-13. During each sampling event, field parameters were collected along with three separate groups of analytical parameters: bacteria, nutrients and hydrocarbons. For detailed descriptions of the methods and quality assurance procedures, refer to the Quality Assurance Project Plan Revision 2.0, provided as Attachment A. Table 1 below shows the list of sampling sites and the parameters that were collected during each sampling event. Descriptions of activities in the area of each sampling site are also provided. Maps 1 and 2 show the sampling locations and parameters collected at each location for Big Lake and Lake Lucille, respectively. Maps are attached at the end of this report.

Table 1. Sampling Site Descriptions

Sampling Site	Nutrients	Bacteria	Hydrocarbons	Description
BL-1	X	X	X	Historic USGS sampling site at the deepest area of the west basin. There is an island with residences close to this site.
BL-2			X	Narrow area between two basins. This is a major traffic lane and there are residences on both sides.
BL-3	X	X	X	Historic USGS sampling site at the deepest area of the east basin. There is boat traffic in this area.
BL-4			X	Center of furthest east section of lake. This is the most heavily used basin in the lake.
BL-5	X	X	X	Condo development on the shore. This is also a traffic lane for the residences in the bay to the southwest.
BL-6			X	Southport Marina and residences.
BL-7	X	X	X	Outlet at Fish Creek. There are houses downstream which increases traffic passing by this site. It is also a popular area to fish.
BL-8			X	Burkeshore Marina and extensive residential development.
BL-9			X	Residential area and lodge.
BL-10		X	X	North Shore State Recreation Area. There is a boat launch, swimming area, camping and extensive small watercraft use in this area.
BL-11	X	X	X	Inlet of Meadow Creek, large wetland area associated with creek.
BL-12			X	Narrow area in west basin. Traffic associated with Klondike Restaurant and Mud and Flat lakes.
BL-13			X	Residential development on islands in west basin.
BL-14		X	X	Residential development on Long Island.
BL-16		X		Residential development in east basin.
BL-17		X		South State Recreation Area. There is a boat launch and camping at this site.
BL-18		X		Residential area.
BL-19		X		Residential area.
BL-20		X		Residential area.
BL-21		X		Residential area and lodge.
BL-22		X		Residential area.
BL-25	X			Residential area.
LL-1	X	X	X	Background site. There is a public camp ground located near to this site and also a large wetland area.
LL-2	X	X	X	Lake Lucille Lodge, flight service and residential area.
LL-3	X	X	X	Historic USGS sampling site at deepest section of the lake. There is also an island south of this site with waterfowl activity and residences on the north shore.
LL-4	X	X	X	Public boat launch on east end of lake. There is also a public park ~1/4 mile to the south and residences in this area.

2.1 Field Parameters

The following field parameters were collected using a multi-parameter water quality meter:

- pH,
- temperature,
- dissolved oxygen,
- turbidity,
- conductivity, and
- salinity.

Measurements were taken at 1 m depth intervals to the lake bottom at nutrient sample sites. At hydrocarbon sampling sites where depth profiles were collected, field parameters were measured at 1 m intervals to 5 m. At surface hydrocarbon sampling sites, field parameters were collected at 1 m. The in-situ water quality meter sensors for dissolved oxygen and pH gave unstable results during the first field event. For the second and third sampling events, alternative methods were used for measuring pH and dissolved oxygen at 5 m intervals at the USGS sampling sites. A complete description of these methods was submitted in a letter dated May 25, 2004 detailing amendments to the QAPP (OASIS 2004b), included as Attachment A.

A Secchi disk was used to determine water clarity. The disk is divided into quarters of alternating black and white. Measurements are obtained by lowering the disk on a graduated rope until it is no longer visible and recording the depth. Secchi depth was measured at all nutrient sampling sites for each sampling event.

2.2 Bacteria Sample Collection

Bacteria samples were collected for the following analyses:

- Fecal coliforms and
- *Escherichia coli.*

Fecal coliform bacteria are regulated under 18AAC70, the Alaska Water Quality Standards. Fecal coliform bacteria are naturally occurring microscopic organisms that live in the intestines of warm-blooded animals including birds. Although not necessarily disease-causing themselves, fecal coliform bacteria are used as an indicator species of possible human waste contamination. Human waste contamination can contribute to sickness at contact recreation areas, such as swimming beaches and shorelines at Lake Lucille and Big Lake. *Escherichia coli* bacteria *(E. coli)* have also been shown to correlate with illness associated with human waste in contact recreation, although it does not have a State water quality standard.

Fecal coliform and *E. coli* bacteria samples were collected at fourteen sample sites at Big Lake and four sample sites at Lake Lucille. At each sample site, fecal coliforms and *E. coli* were collected at the primary sample location and fecal coliforms were collected at two secondary sample locations parallel to the shoreline. Secondary sample locations were located 50 m in either direction along the shoreline from the primary sample location at Big Lake and 25 m in either direction at Lake Lucille. Samples were collected approximately 50 m offshore. Sampling sites were located in residential areas, which have the potential for contributing to bacteria contamination from waste systems or pet waste.

Six of the fourteen sampling sites at Big Lake and two of the four sample sites at Lake Lucille are swimming areas. These sampling sites were located directly out from shore at approximately 1 m depth in order to target the location where most contact recreation activities occur. At the swimming areas, *E. coli* samples were collected at the primary and also at the secondary sampling sites. Swimming sampling sites were selected at public land access points which may or may not have established swimming beaches and also at areas of dense residential development. Table 2 below shows the number of fecal coliforms and *E. coli* samples collected at each site for each sampling event. For the locations of sampling sites, see Maps 1 and 2 at the end of this report.

Table 2. Bacteria Samples Collected at Each Site

Sampling Site	Swimming Area	FC Samples/ Event	Total FC Samples	*E. Coli* Samples/ Event	Total *E. Coli* Samples
BL-1		3	9	1	3
BL-3		3	9	1	3
BL-5	X	3	9	3	9
BL-7		3	9	1	3
BL-10	X	3	9	3	9
BL-11		3	9	1	3
BL-14		3	9	1	3
BL-16	X	3	9	3	9
BL-17	X	3	9	3	9
BL-18		3	9	1	3
BL-19		3	9	1	3
BL-20		3	9	1	3
BL-21	X	3	9	3	9
BL-22	X	3	9	3	9
Totals		42	126	26	78
LL-1		3	9	1	3
LL-2	X	3	9	3	9
LL-3		3	9	1	3
LL-4	X	3	9	3	9
Totals		12	36	8	24

Grab samples were collected by placing a sterile sample bottle in the water 12 inches below the surface, unscrewing the cap, allowing the bottle to fill and closing the bottle before returning to the surface. Samples were collected in one event at all the sampling sites during the morning and transported to the laboratory within their respective holding times (6 hours for both fecal coliforms and *E. coli*).

2.3 Nutrient Sample Collection

Nutrient samples were collected at four sampling sites at Lake Lucille and six sampling sites at Big Lake. At each sampling site, samples were collected at 1 m depth and at 75% of total depth. Sites located at depths less than 2 m were only sampled at 1 m depth. Two of the sampling sites at Lake Lucille and three of the sampling sites at Big Lake were only sampled at one depth. These locations were LL-1, LL-4, BL-7, BL-10 and BL-25.

Nutrient sampling locations were selected in areas with possible nutrient sources. Suspect areas include lawns or other maintained areas where fertilizer is applied and residential areas with septic systems, outhouses and pet waste. Samples were collected from 1 m depth to determine the nutrients available in the euphotic zone (depth to which light penetrates). Algal blooms may result from nutrient loading in this surface layer. Samples collected from 75% of total lake depth at each sampling site indicate the degree of nutrient mixing throughout the lake. Wind and boat traffic may effectively mix shallow areas in each lake whereas deeper areas may remain stratified between the spring and fall overturns.

2.3.1 Chlorophyll a

Chlorophyll a samples were collected by sub-sampling 1 L of sample water from 1 m depth and 75% of total depth, and filtering the sample through a 90 mm glass microfiber filter. The filtering apparatus was shielded by a tote inside the boat to prevent photodegradation of the chlorophyll. A peristaltic pump was used to expedite the filtering process. Filters were stored inside a Ziploc bag, wrapped in tinfoil and placed between two gel ice packs. Sample filters were kept frozen during transport to the lab for analysis.

2.3.2 Nutrients

The nutrient parameters collected at each nutrient sampling site are listed below:

- Total organic carbon,
- Dissolved organic carbon,
- Ortho-phosphate,
- Dissolved phosphorus,
- Total phosphorus,
- Total Kjeldahl nitrogen,
- Ammonia,
- Nitrate/Nitrite,
- Alkalinity, and
- Color.

Nutrients were collected at 1 m depth and 75% of total depth using a Kemmerer water sampling bottle. Samples were collected approximately 50 m offshore. Parameters which do not require filtration were filled directly from the sample bottle. Dissolved organic carbon, ortho-phosphate and dissolved phosphorus were field-filtered through a 0.45 micron filter using a peristaltic pump.

2.4 Hydrocarbon Sample Collection

Hydrocarbon samples were collected for the following parameters:

- Total aromatic hydrocarbons (TAH) and
- Polycyclic aromatic hydrocarbons (PAH).

TAH includes the compounds benzene, toluene, ethylbenzene and xylene, which are constituents of gasoline. It captures contamination from most watercraft used on the lake. PAH includes heavier compounds present in diesel and oil. Older 2-stroke engines may contribute PAH contamination from the oil mixed with the gasoline.

There are four hydrocarbon sampling sites at Lake Lucille and fourteen sampling sites at Big Lake. Samples were collected at 0.15 m, 0.5 m, 1.5 m and 5 m depths at four of the sampling sites at Big Lake (BL-1, BL-2, BL-3 and BL-4). At the remaining ten sampling sites at Big Lake, samples were collected at 0.15 m. At Lake Lucille, samples were collected at 0.15 m and 0.5 m at all sampling sites. At sites LL-3 and LL-4, lake depth increased and samples were also collected at 1.5 m depth.

Hydrocarbon samples were collected using a volatile organic carbon (VOC) sampler designed by U.S. Geological Survey (USGS) and built by Wildco®. TAH samples were preserved with five drops of hydrochloric acid (HCl) after sample collection; PAH samples do not require preservation. For a complete description of the sampler, see the QAPP (OASIS 2004a), provided as Attachment A.

Sampling sites were selected in areas with potential hydrocarbon sources. Suspect sources include boat traffic lanes, fueling and maintenance facilities, public boat launches and residential areas with small watercraft activity. Additional sampling sites were located in less heavily used areas to indicate background conditions. Samples were collected from multiple depths in order to determine the amount of mixing in the water column.

Photo – Preserving a TAH sample. June 12, 2004.

3 RESULTS

3.1 Field Parameters

3.1.1 Big Lake

Field parameter results were recorded during nutrient and hydrocarbon sample collection. Results are presented for field parameters recorded at 1 m intervals to lake depth during the nutrient sample collection. Dissolved oxygen and pH measurements at 1 m intervals using the multi-parameter water quality meters were rejected for several dates (see Section 5).

Temperature

Temperature measurements ranged from 3-18° C at Big Lake. Charts showing the temperature change with depth at the USGS sampling sites in the east and west basin are presented in Figure 1. The epilimnion (upper warm layer) in both basins was approximately 3 m deep. The thermocline (1° C change per meter) ranged from 3-6 m and the hypolimnion (cold bottom layer) formed at approximately 6 m. The epilimnion is the upper layer heated by solar radiation and mixed by wind where most primary productivity occurs. The hypolimnion is the unmixed lower layer which is colder and darker than the epilimnion. This area is where organic matter settles and decomposes. The epilimnion of Big Lake was above the AWQS for temperature on May 31 and June 13. Woods (1992) also reported epilimnion water temperatures at 18° C in June and thermocline development at 5 m for May and June. Peak temperatures in the epilimnion were recorded as late as August and September in Woods' study.

Turbidity

All turbidity readings were below 10 NTU except for two anomalous readings of 20 and 34 at sampling sites BL-3 and BL-12, respectively. The AWQS is 5 NTU above background conditions. Background conditions were determined by averaging the turbidity results recorded at sampling site BL-1, a background site. This sampling site is located in the deepest section of the west basin, approximately 600 m from shore and 200 m from the nearest island. The average of all turbidity readings at BL-1 for May and June is 0.6 NTU. The turbidity AWQS for Big Lake is 5.6 NTU. The average of all turbidity readings was 1.1 NTU.

pH and Dissolved Oxygen

Results for pH and dissolved oxygen are presented in Table 3. Measurements were recorded using the Oakton pH meter and the colorimeteric dissolved oxygen tests at 5 m intervals at the USGS sampling sites (BL-1 and BL-3). Temperature readings are also provided. pH measurements ranged from 7.4-8.4 pH units and dissolved oxygen varied from 7-12 mg/L. All three parameters decreased with depth at both sampling sites. There are no exceedances of the AWQS for pH or dissolved oxygen. Dissolved oxygen concentrations are also dependent upon the atmospheric pressure. Higher atmospheric pressure increases the solubility of oxygen and other atmospheric gases in water. As both lakes are close to sea level, differences in dissolved oxygen due to atmospheric pressure are insignificant for this study. Charts showing temperature and dissolved oxygen at depth at both sampling sites are presented as Figure 2.

Table 3. Big Lake Field Parameter Results

Date	Sampling Location	Depth (m)	Temperature (° C)	pH (pH unit)	Dissolved Oxygen (mg/L)
31-May-04	BL - 1	1	13.40	8.1	9
		5	10.50	8.2	9
		10	5.40	8.2	10
		15	4.80	8.2	7
	BL - 3	1	13	8.2	10
		5	8.50	8	10
		10	16	8.2	7
13-Jun-04	BL - 1	1	15.50	7.4	12
		5	10.40	8	11
		10	6.20	7.8	11
		15	4.90	7.7	11
	BL - 3	1	17.10	8.4	11
		5	9.20	7.8	10
		10	6.20	7.6	8

Conductivity and Salinity

Conductivity values ranged from 87-200 uS/cm at all sampling sites and dates. Results were above 160 uS/cm during the first sampling event on May 16 and also at depths greater than 5 m. The highest result (200 uS/cm) was recorded at BL-11, the inlet of Meadow Creek, on May 29. Sampling sites BL-1 and BL-3 had the highest conductivity readings deeper in the water column. Edmundson (2002) reported conductivity measurements for Big Lake in 2001 from 126 to 144 umhos/cm (umhos=uS). All salinity measurements were 0.0, which is expected because Big Lake is a freshwater system.

Secchi Depth

Secchi depths ranged from 5-6.5 m at the deeper sampling sites. At sampling sites BL-7, BL-10 and BL-25, the Secchi disk was visible to the total lake depth during all sampling events. Results are presented in Table 4.

Table 4. **Big Lake Secchi Depths**

Date	Sample Site	Secchi Depth (meters)	Total Depth
16-May-04	BL - 1	5.00	
	BL - 3	6.50	
	BL - 5	5.00	
	BL - 7	2.00	X
	BL - 10	1.00	X
	BL - 25	2.25	X
31-May-04	BL - 1	6.00	
	BL - 3	5.50	
	BL - 5	5.00	
	BL - 7	2.00	X
	BL - 10	1.50	X
	BL - 25	2.00	X
13-Jun-04	BL - 1	9.00	
	BL - 3	6.50	
	BL - 5	6.50	
	BL - 7	2.00	X
	BL-10	1.50	X
	BL - 25	2.50	X

3.1.2 Lake Lucille

Temperature

Temperature measurements at Lake Lucille ranged from 8 to 20° C. There is no developed thermocline or hypolimnion at Lake Lucille due to shallow lake depth (~4 m). The temperature gradient is shown in Figure 3.

Turbidity

The AWQS for turbidity is 5 NTU above background conditions. Background conditions at Lake Lucille were determined by averaging the measurements recorded at sampling site LL-1, a background site. This site is located approximately 60 m from the south shore, where there is limited development. All turbidity measurements recorded at this site for May and June were 0.0. The turbidity AWQS is 5.0 NTU. All turbidity readings were < 7 NTU and three readings were above 5 NTU. The average of all turbidity readings at Lake Lucille is 1.2 NTU.

pH and Dissolved Oxygen

The pH and dissolved oxygen parameters were recorded at 1 and 4 m depths at the USGS sampling site. Temperature is also presented in Table 5. pH was above the AWQS of 8.5 pH units at both depths on both dates. Temperature was above the AWQS of 13° C at both depths and dates. Dissolved oxygen measurements were above the AWQS minimum of 7 mg/L. Dissolved oxygen readings were the same at both depths, indicating that the entire lake may be mixed by wind and wave action to the degree necessary to distribute oxygen dissolved from the atmosphere throughout the lake. Edmundson (2002) reported dissolved oxygen readings for Threemile Lake, also 4 m deep, in May 2001 of 10 mg/L to 3 m and 8 mg/L at 4 m. He also reported pH readings at seven different lakes, ranging from 6.6 to 8.2.

Table 5. Lake Lucille Field Parameter Results

Date	Sampling Location	Depth (m)	Temperature (° C)	pH (pH unit)	Dissolved Oxygen (mg/L)
30-May-04	LL - 3	1	15.40	8.9	>12
		4	15.30	8.7	-
19-Jun-04		1	20.40	8.8	12
		4	17.10	8.6	12

Conductivity and Salinity

Conductivity measurements at Lake Lucille ranged from 210-362 uS/cm. Measurements >300 uS/cm were recorded at the deepest section of the lake, below 3 m depth. Lake Lucille is a freshwater system and all salinity readings were 0.0.

Secchi Depth

The Secchi disk was visible to the total lake depth at all sampling sites and dates except for two. At sampling site BL-3, which is located in the deepest section of the lake, Secchi depths of 3.5 and 4 m were recorded on May 8 and 30, respectively. Secchi depth measurements are presented in Table 6 below.

Table 6. Lake Lucille Secchi Depths

Date	Sample Site	Secchi Depth (meters)	Total Depth
8-May-04	LL - 1	1.25	X
	LL - 2	3.00	X
	LL - 3	3.50	
	LL - 4	1.00	X
30-May-04	LL - 1	1.50	X
	LL - 2	3.00	X
	LL - 3	4.00	
	LL - 4	1.00	X
19-Jun-04	LL-1	1.00	X
	LL - 2	3.50	X
	LL - 3	5.50	X
	LL - 4	1.00	X

Figure 1. Big Lake Temperature Measurements

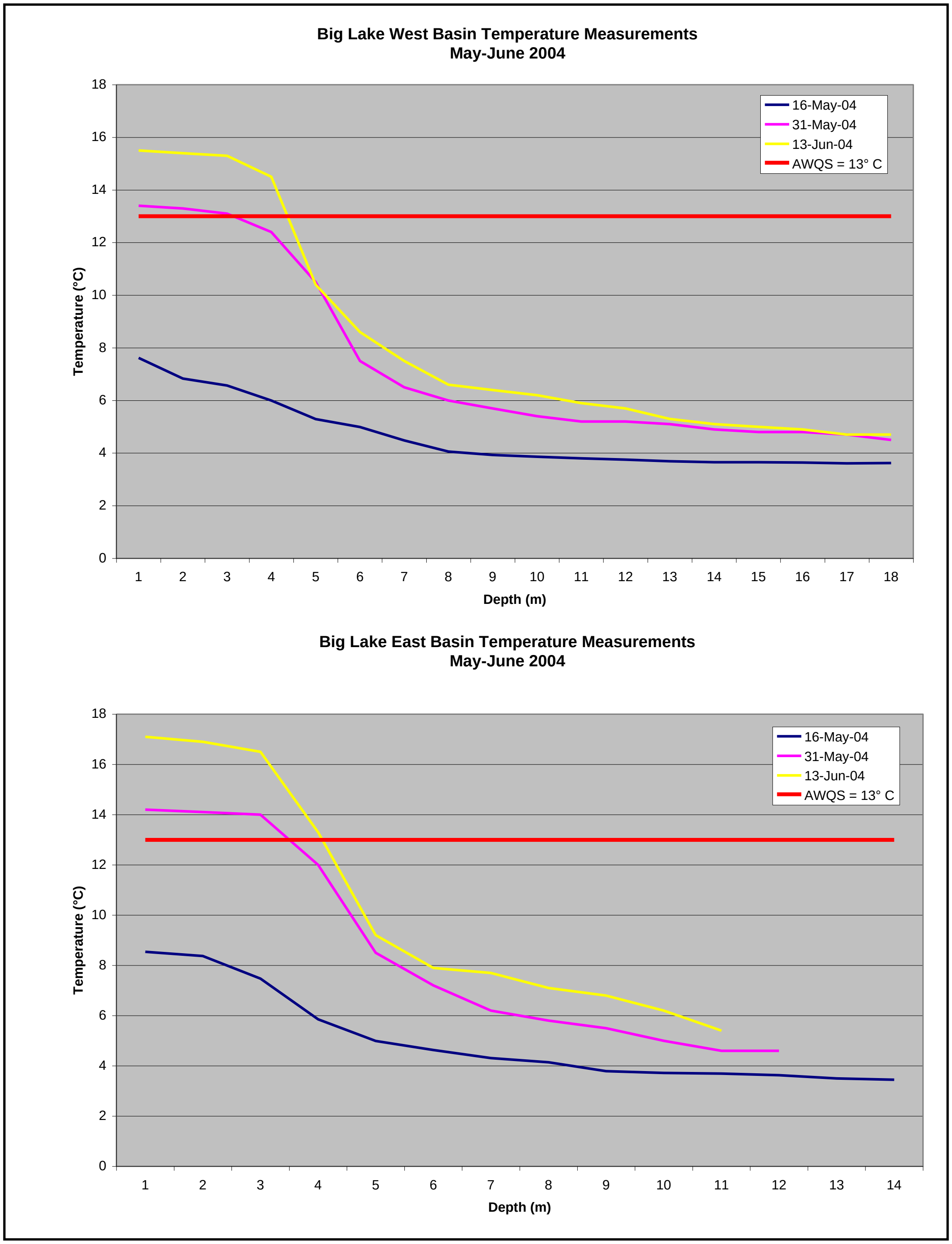


Figure 2. Big Lake Temperature and Dissolved Oxygen Measurements

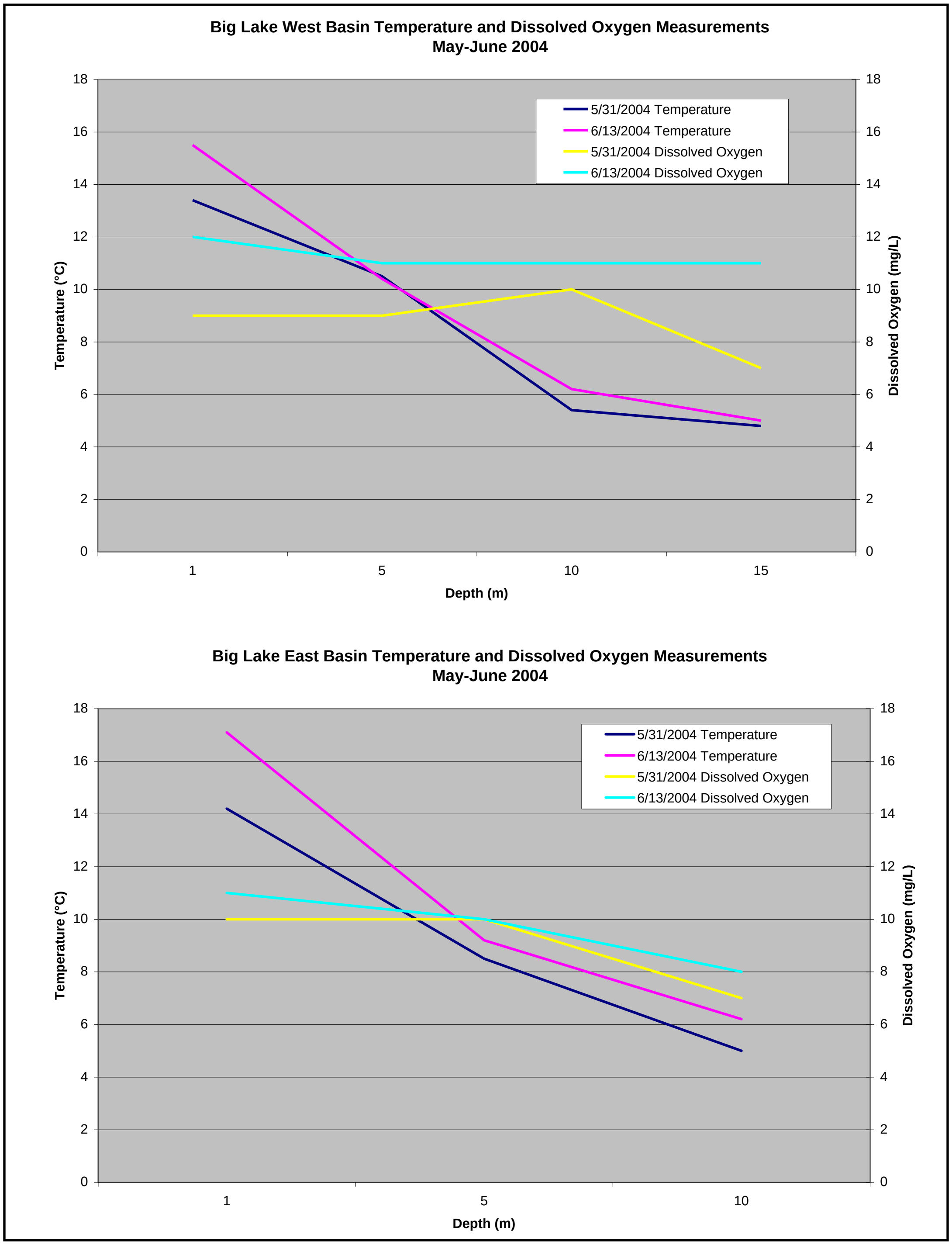
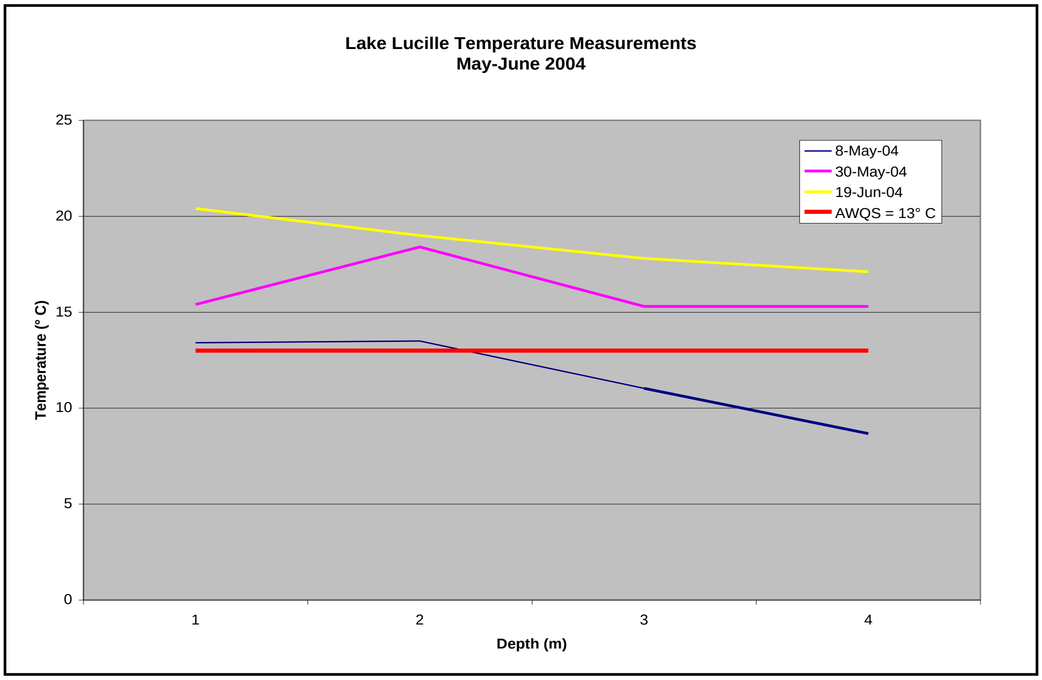


Figure 3. Lake Lucille Temperature Measurements



3.2 Bacteria

The AWQS for fecal coliform bacteria states that the geometric mean of fecal coliforms samples collected within a 30-day period may not exceed 20 col/100 mL. Not more than 10% of samples may exceed 40 col/100 mL. All fecal coliform results were compared with the 40 col/100 mL standard. The geometric mean was also calculated for the three samples collected at each site and compared with the 20 col/100 mL standard. Unless a water body is classified for a particular use type, the most stringent water quality standard is applied. The most stringent standard for fecal coliform bacteria is the drinking water supply standard, which is stated above. There is also a water quality standard for primary contact recreation which can be used as guidance for the recreational users on Big Lake. The AWQS for fecal coliforms for primary contact recreation is 100 col/100 mL for the geometric mean of samples collected within a 30-day period. Not more than 1 sample or 10% if there are more than 10 samples may exceed 200 col/100 mL.

There is no AWQS for *E. coli* bacteria. At swimming areas, three *E. coli* samples were collected in order to calculate the geometric mean. At other bacteria sampling sites, only one *E. coli* sample was collected and reported in the results. Non-detect sample results, 0 col/100 mL, were replaced with half the method detection limit in order to calculate the geometric mean (0.5 col/100 mL).

3.2.1 Big Lake

No fecal coliforms results at Big Lake were above the 40 col/100 mL standard required for 90% of the samples. A total of 126 fecal coliforms samples were collected at Big Lake. The highest result was 28 col/100 mL, collected at BL-11.

The geometric means for fecal coliform bacteria samples collected at Big Lake were all < 5 col/100 mL except for the samples collected at BL-11. The highest geometric mean of fecal coliforms was reported on June 13, 14.19 col/100 mL. No samples exceeded the AWQS for fecal coliform bacteria.

For sampling sites located at swimming areas where three E. coli samples were collected, the geometric mean was calculated. At other sites, only one sample was collected. A total of 78 *E. coli* samples were collected at Big Lake. The geometric means for the *E. coli* samples collected at swimming areas were all < 5 MPN/100 mL. *E. coli* samples collected at the other eight bacteria sampling sites were all < 5 MPN/100 mL except for the samples collected at BL-11. The highest *E. coli* concentration was 17.3 MPN/100 mL, collected at BL-11 on June 13. Results for Big Lake bacteria samples are presented in Figure 4.

3.2.2 Lake Lucille

No fecal coliforms samples were above the 40 col/100 mL standard. The highest result was 20 col/100 mL, collected at LL-3. A total of 36 fecal coliforms samples were collected at Lake Lucille.

The geometric mean for the three fecal coliforms samples collected at each of the four bacteria sites was < 5 col/100 mL for all sampling sites and dates except for sampling site LL-3 on June 19, which was 9.83 col/100 mL. No samples were above the AWQS for fecal coliforms.

All of the *E. coli* samples were < 5 MPN/100 mL except for LL-3 on June 19, which was 9.05 MPN/100 mL. Twenty-four *E. coli* samples were collected at Lake Lucille. Bacteria sampling results for Lake Lucille are presented in Figure 5.

Figure 4. Big Lake Bacteria Results

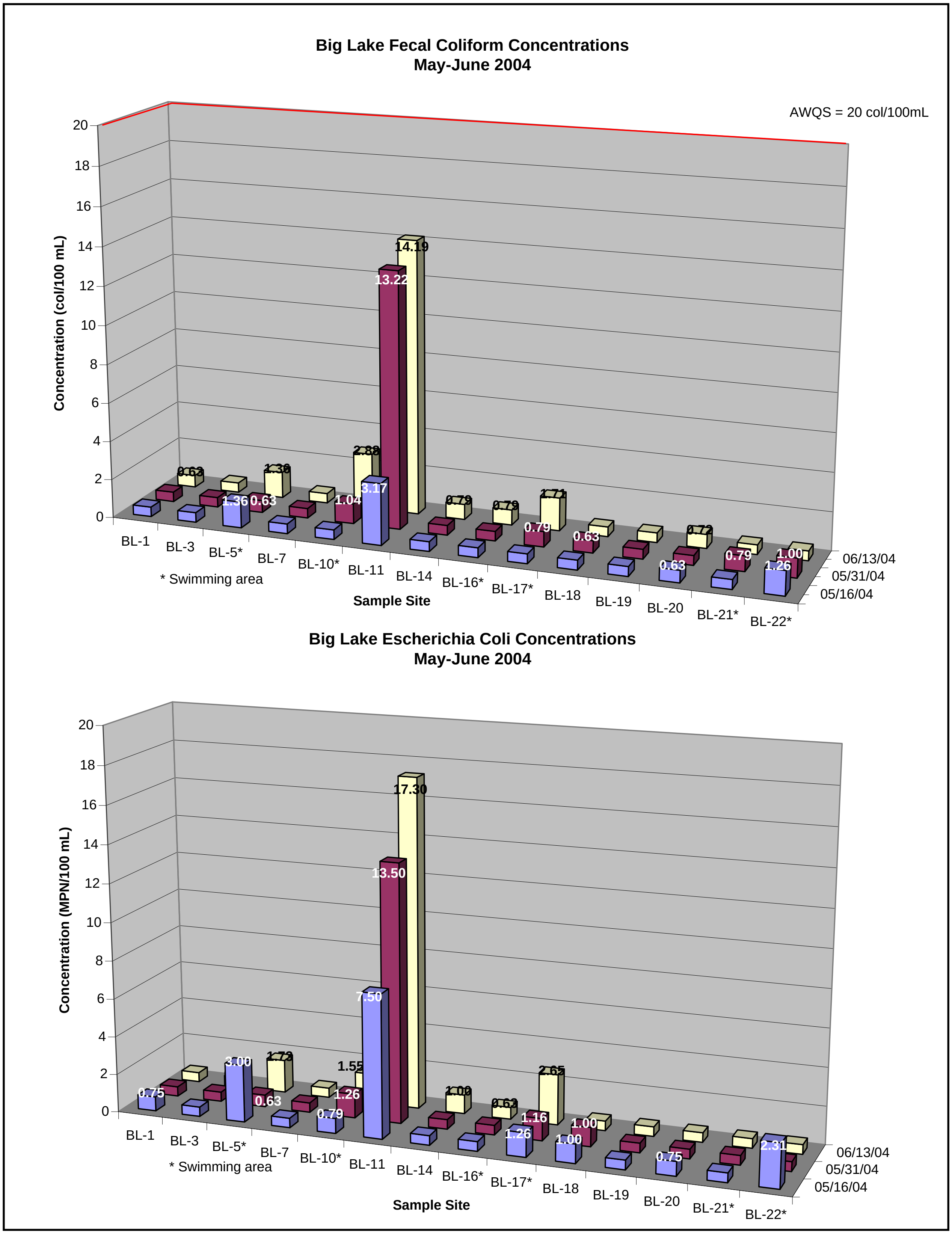
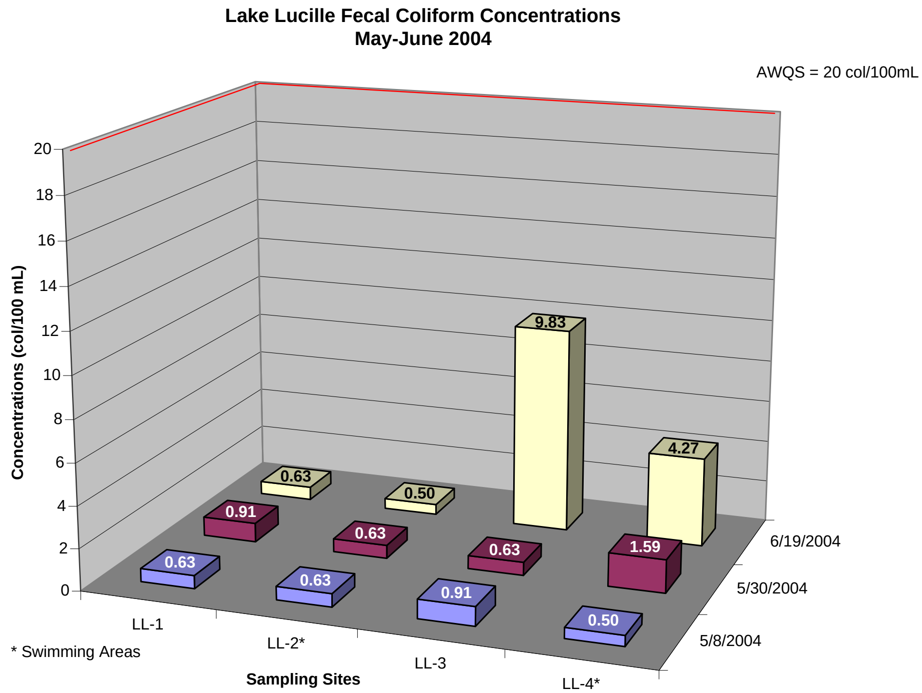
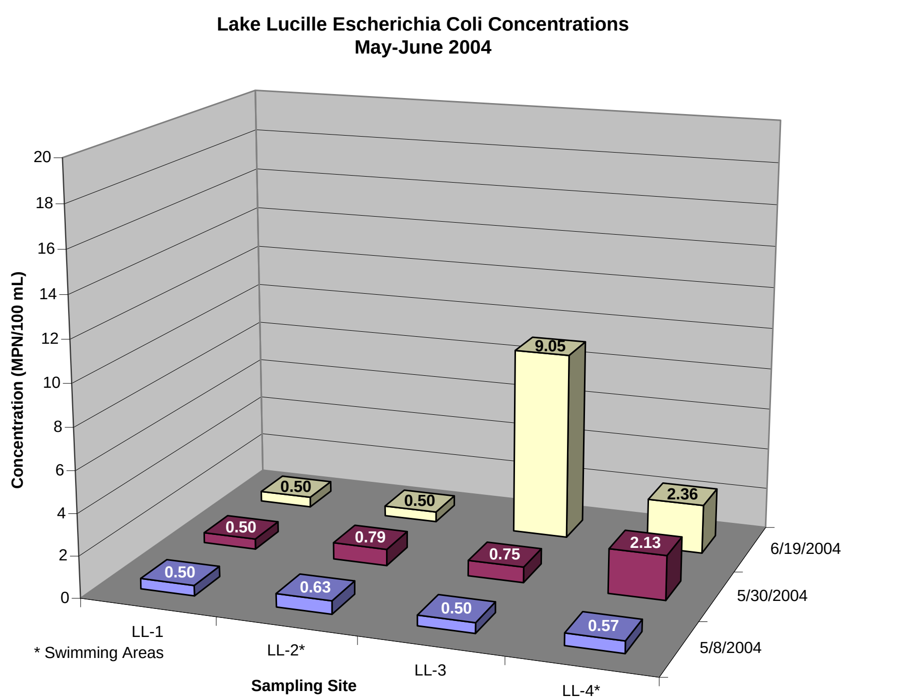


Figure 5. Lake Lucille Bacteria Results





3.3 Nutrients

3.3.1 Big Lake

Phosphorus

The reporting limits for total phosphorus, dissolved phosphorus and ortho-phosphate are 100 µg/L, 100 µg/L and 400 µg/L, respectively. Results for all sampling sites on all dates were below the reporting limit with two exceptions. Total phosphorus at BL-1 on June 13 was 154 µg/L and dissolved phosphorus at BL-3 on May 16 was 205 µg/L. Total phosphorus was not detected in the BL-3 sample. Both samples were retrieved from 1 m depth. Dissolved and total phosphorus parameters were reported as not detected (ND) at 100 µg/L and ortho-phosphate was reported ND at 400 µg/L. Edmundson et. al. (2000) reported concentrations of total phosphorus (inclusive of the dissolved phosphorus fractions) in the range of 2.2-44.2 µg/L for Mat-Su lakes. Woods (1992) reported concentrations of total phosphorus at Big Lake in May and June at 8-20 µg/L and ortho-phosphate at 1-8 µg/L.

Nitrogen

Results for nitrogen parameters (ammonia, TKN, nitrate/nitrite) were below the reporting limit for most sampling sites and dates with a few exceptions. The reporting limits for ammonia and TKN are 100 µg/L and 500 µg/L. Two sampling sites had ammonia concentrations between 100-186 µg/L on May 16. Three TKN concentrations ranged from 511 to 648 µg/L for samples collected on May 16 and May 31. Ammonia concentrations at Big Lake in 2001 were reported in the range of 1-22 µg/L by Edmundson (2002). Woods (1992) reported TKN concentrations at Big Lake in the east basin in 1983 and 1984 at 160-370 µg/L.

No nitrate/nitrite concentrations were above the reporting limit. The nitrate/nitrite reporting limit was 1000 µg/L on May 16 and June 13 and 100 µg/L on May 31. Nitrate/nitrite concentrations reported by Woods (1992) ranged from 1-60 µg/L. Nitrogen results above the reporting limit are presented in Table 7 below.

Table 7. Nitrogen Results for Big Lake

Sample Site	Depth (meters)	Date	Ammonia (mg/L)	TKN (mg/L)
BL-3	1	05/16/04	0.186	<0.500
BL-5	5.5	05/16/04	<0.100	0.551
BL-10	1	05/16/04	0.100	0.511
BL-7	1	05/31/04	<0.100	0.648

Carbon

Particulate organic carbon (POC) concentrations at Big Lake ranged from negative values to 1550 µg/L. POC is calculated by subtracting the dissolved organic carbon results from the total organic carbon results. Many of the dissolved organic carbon concentrations were reported greater than their respective total organic carbon concentrations, resulting in negative POC concentrations when calculated. Dissolved organic carbon concentrations greater than total organic carbon concentrations may result when the difference between the dissolved and total concentrations is within the accuracy range for the laboratory method used to analyze the samples. Cross-contamination in the method blank affected dissolved organic carbon samples collected on May 16. See section 5.2 for details. POC was not calculated for that date.

Edmundson (2002) reported POC concentrations at Big Lake in May and June from 161-446 µg/L.

Alkalinity

Alkalinity concentrations at Big Lake ranged from 57-74 mg/L as $CaCO_3$. This result is similar to the range reported by Edmundson (2002) for 2001, 58-64 mg/L.

Chlorophyll a

Chlorophyll a concentrations at Big Lake ranged from 0.4-7.3 µg/L. The average concentration for each sampling event was 2.5, 1.4 and 2.1 µg/L for May 16, May 31 and June 13, respectively. The highest concentration for each date was at sampling site BL-3 at 10 m. Results are presented in Figure 6. Woods (1992) reported chlorophyll a concentrations in the east basin as high as 46.5 µg/L at 10 m depth in August of 1983.

Color

Color concentrations at Big Lake ranged from 5-10 color units. No samples were above the AWQS of 20 color units.

3.3.2 Lake Lucille

Phosphorus

All total phosphorus, ortho-phosphate and dissolved phosphorus results were below the reporting limit of 100 µg/L at Lake Lucille except for one dissolved phosphorus result at LL-4 on May 8 of 170 µg/L and a total phosphorus result at LL-3 on the same date of 100 µg/L. Dissolved phosphorus concentrations at Lake Lucille reported in the Phase I Diagnostic and Feasibility Study (Eilers and Bernert 1993) were below 10 µg/L.

Nitrogen

Nitrate/nitrite results for all samples collected at Lake Lucille were below the reporting limit (1000 µg/L). Ammonia was reported in two samples on May 8 at 273 and 134 µg/L; all other samples were below the reporting limit of 100 µg/L. TKN concentrations were reported in multiple samples collected on May 8 and June 19 at 500-760 µg/L. Concentrations of TKN at Lake Lucille reported by Eilers and Bernert (1993) were above 1000 µg/L twice between 1991-93.

Carbon

Particulate organic carbon (POC) concentrations at Lake Lucille ranged from negative values to 1400 µg/L. Negative POC concentrations were calculated for samples where the dissolved organic carbon concentrations were reported greater than the total organic carbon concentrations. The highest concentration was reported at LL-4 on June 19; all other samples were below 800 µg/L. POC concentrations greater than 1000 µg/L were reported by Edmundson (2002) in the hypolimnion of Finger and Knik lakes.

Alkalinity

Alkalinity at Lake Lucille ranged from 68 to 130 mg/L. Edmundson et. al. (2000) reported average alkalinity at Lake Lucille in 1984 of 76.5 mg/L.

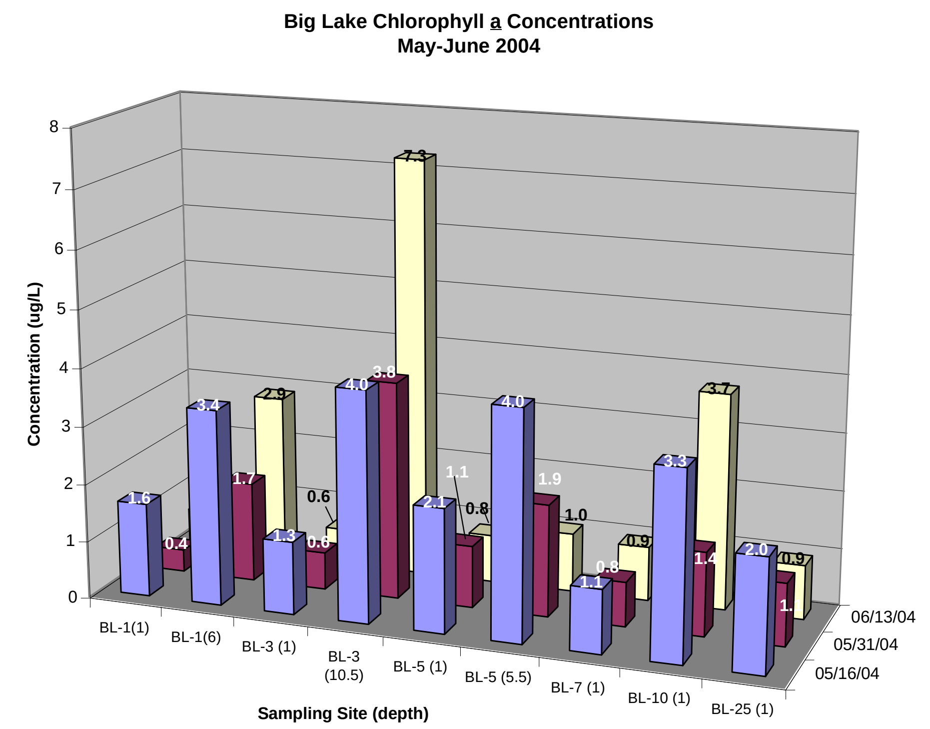
Chlorophyll a

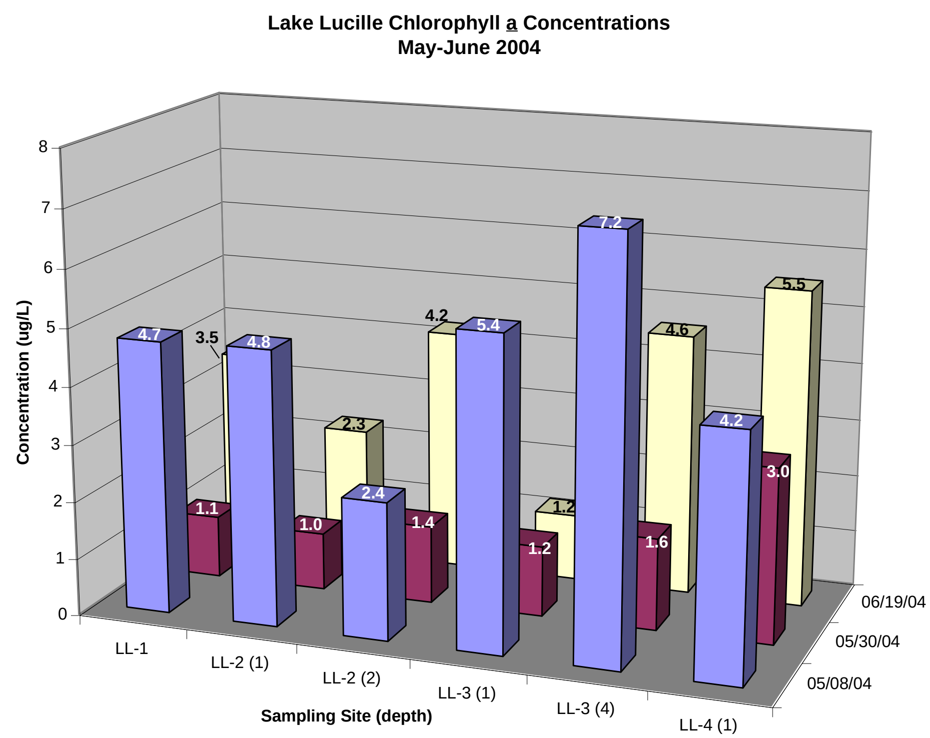
Chlorophyll a concentrations at Lake Lucille ranged from 1-7.2 µg/L. Average concentrations for the three sampling events were 4.8, 1.5 and 3.5 µg/L, respectively. The highest concentrations from each sampling event were recorded at sampling site LL-3 at 4 m and at sampling site LL-4 at 1 m (only one sample was collected at LL-4 due to shallow lake depth). Results are presented in Figure 6. The TMDL for Lake Lucille reported chlorophyll a concentrations from 1.6 to 4.7 μg/L (ADEC 2002).

Color

Color results at Lake Lucille ranged from 3-5 color units. No samples were above the AWQS.

Figure 6. Chlorophyll a Concentrations





3.4 Hydrocarbons

Total aromatic hydrocarbons (TAH) samples were collected at all sampling sites and depths on all dates. For each sampling event, polycyclic aromatic hydrocarbon (PAH) samples were collected at half of the sampling sites and depths. PAH samples were below the reporting limit at all of the sampling sites and depths.

3.4.1 Big Lake

Total aromatic hydrocarbons (TAH = benzene + ethylbenzene + xylenes + toluene) concentrations at the fourteen surface sampling sites (0.15 m depth) were > 1 µg/L at all of the sampling sites at one or more sampling events except for BL-1, BL-11 and BL-13. Concentrations were highest on May 29 and ranged from 1.78-19.30. Average concentrations for the three dates are 2.56, 7.66 and 1.73 µg/L on May 15, May 29 and June 12 respectively. An additional sample was collected on June 12 inside the swimming area at sampling site BL-10. The TAH concentration inside the swimming area, 47.04 µg/L, is two times greater than the next highest TAH result. There were eight exceedances of the AWQS for TAH, six on May 29 and two on June 12. The six exceedances reported on May 29 are 43% of the total surface TAH samples collected on that date. Four of the exceedances are located in the furthest east basin of Big Lake. The other two are located in the traffic lane separating the east and west basins and at the North Shore State Recreation Area. Figure 7 shows the TAH concentrations at the surface sampling sites.

TAH samples were collected at four depths (0.15 m, 0.5 m, 1.5 m and 5 m) at sampling sites BL-1, BL-2, BL-3 and BL-4. TAH concentrations were detected at sampling sites BL-3 and BL-4 on May 15 down to 1.5 m and ranged from 1.88-3.50 µg/L. On May 29, all four sampling sites had TAH concentrations at one or more depths. Concentrations ranged from 1.40-11.43 µg/L and were reported to the 1.5 m depth interval. Only sampling site BL-2 reported TAH concentrations at the 0.5 and 1.5 depth intervals on June 12. Concentrations were < 2 µg/L. There was one exceedance of the AWQS for TAH, at sampling site BL-2 at 0.15 m which was included in the eight exceedances reported at the surface sampling sites. Figure 8 shows the TAH concentrations at the four sampling sites where depth profiles were collected.

3.4.2 Lake Lucille

There are four hydrocarbon sampling sites at Lake Lucille. TAH were detected at all sites at all depths on both May 8 and May 30-31. On June 19, TAH was detected at sampling sites LL-3 and LL-4 and at the surface at LL-2. There were six exceedances of the AWQS for TAH at Lake Lucille. All exceedances were at sampling site LL-4, the public boat launch, at both depths sampled during all three sampling events. Results are presented in Figure 9.

Figure 7. Big Lake Surface TAH Concentrations

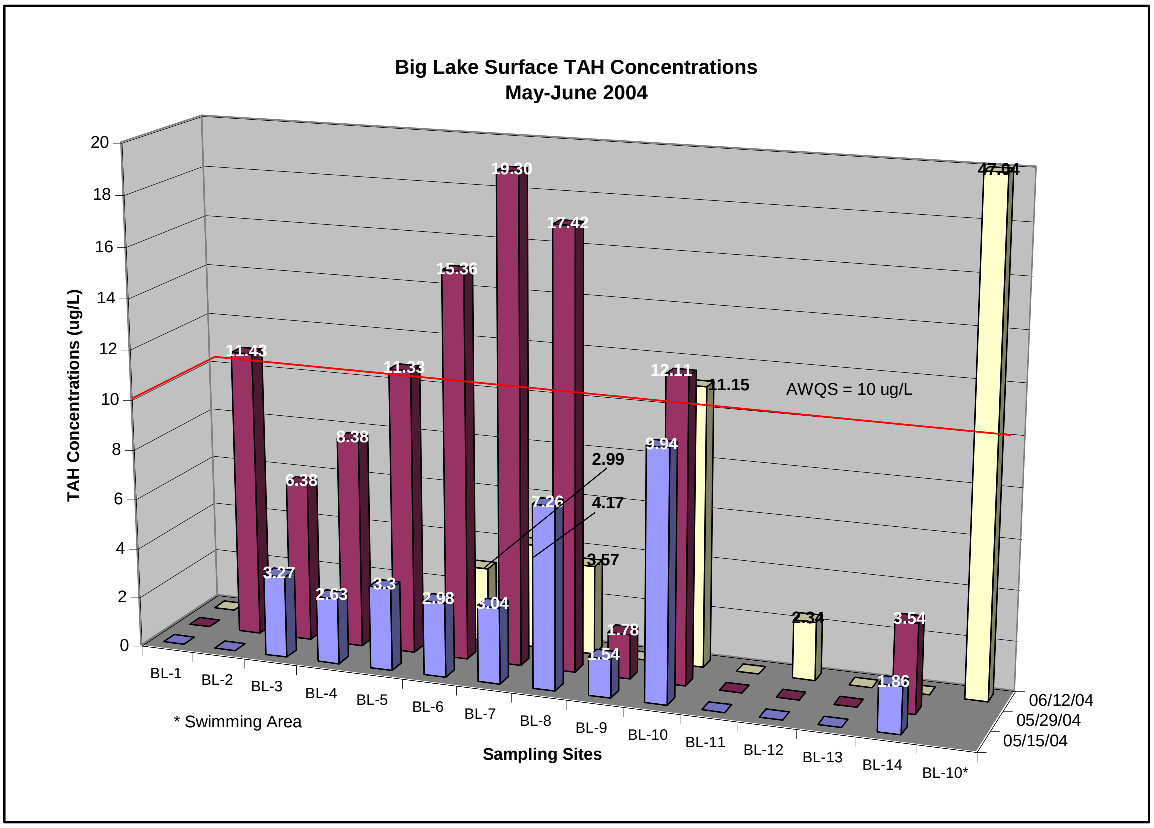


Figure 8. Big Lake Depth Profile TAH Concentrations

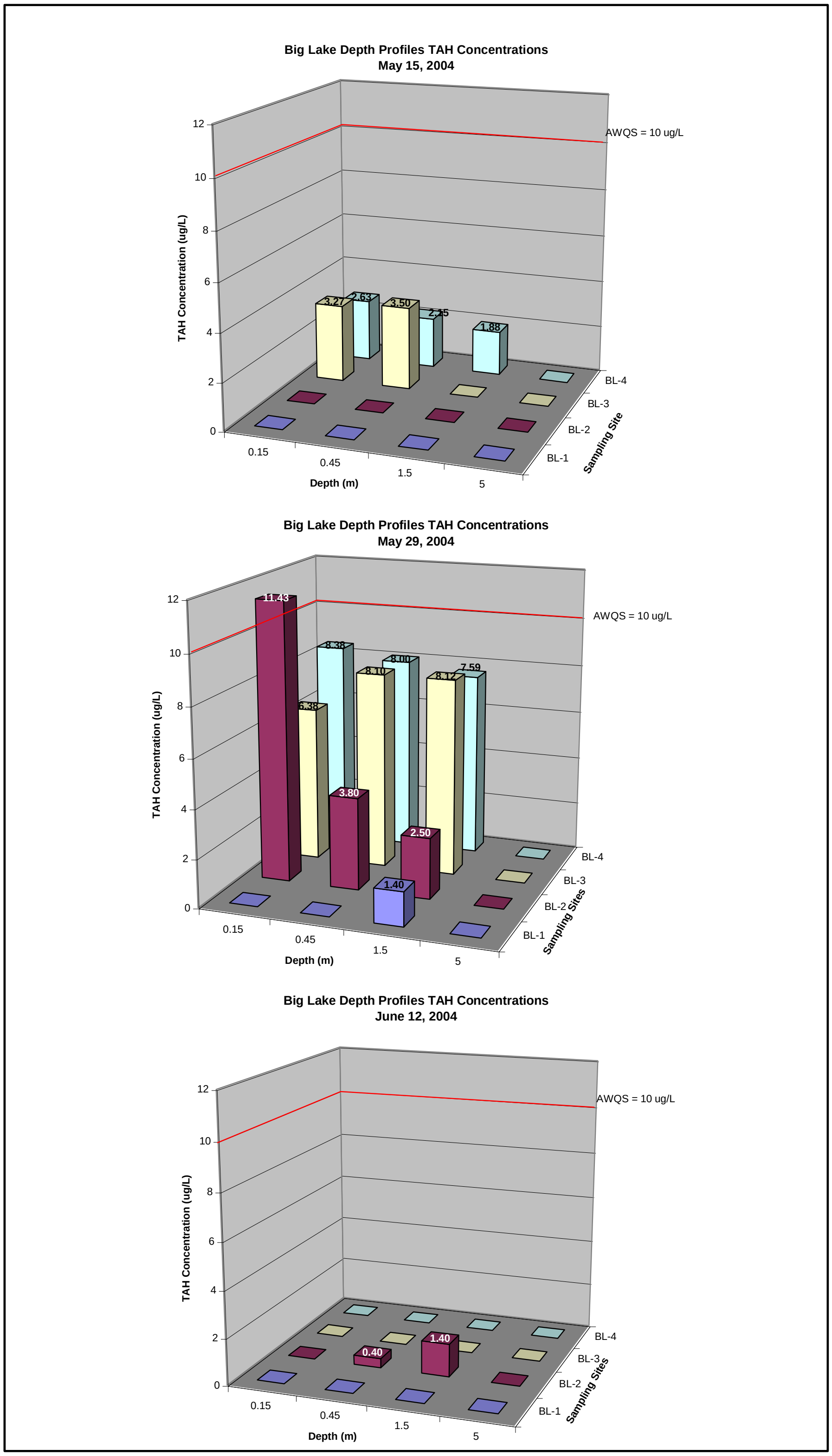
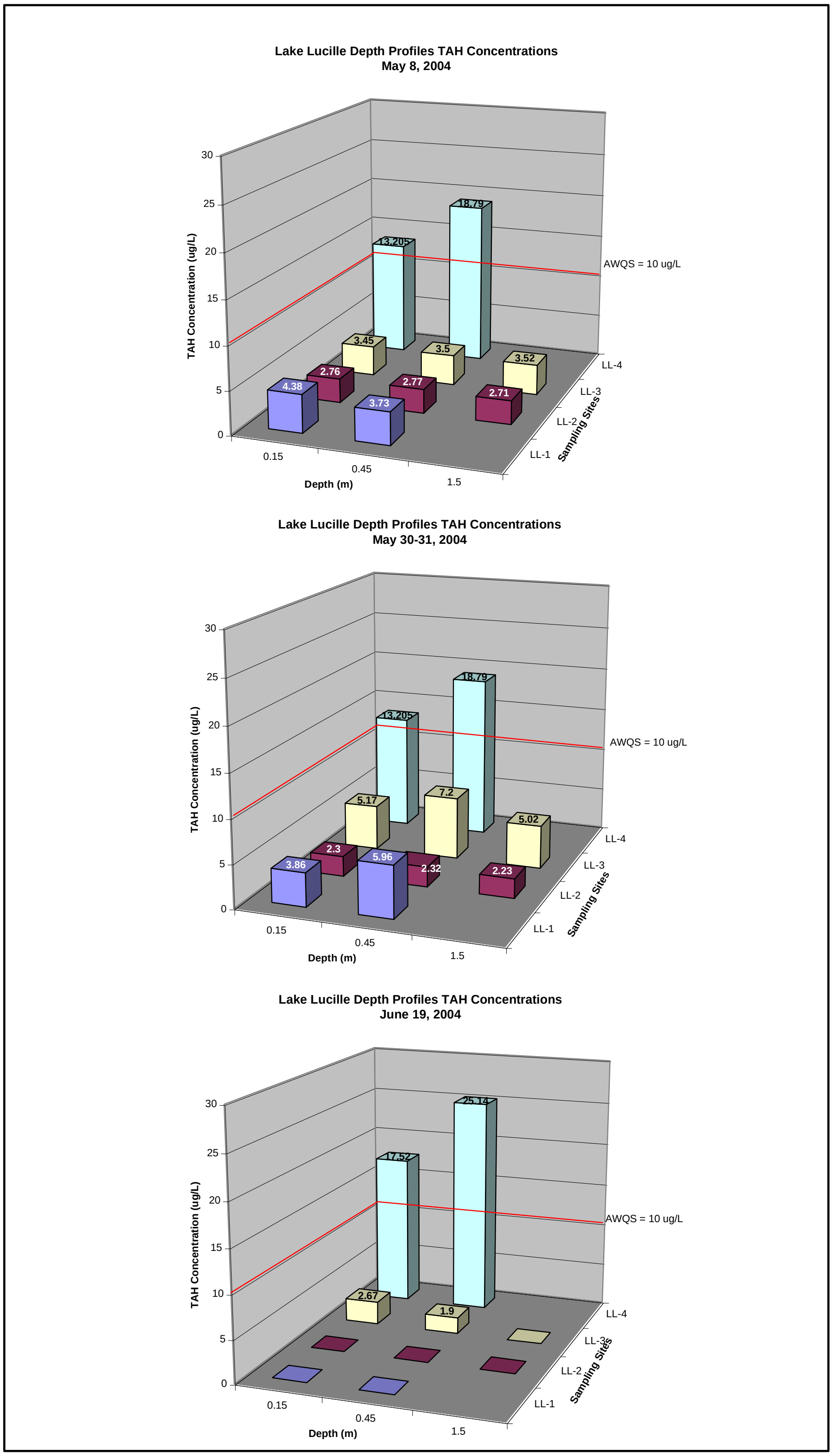


Figure 9. Lake Lucille TAH Concentrations



4 CONCLUSIONS

4.1 Field Parameters

4.1.1 Big Lake

The field parameters measured at Big Lake were within AWQS with a few exceptions. The epilimnion temperature recorded during the second two sampling events was above the AWQS of 13° C. The epilimnion layer is defined as the upper strata of the lake affected by solar radiation. The mean air temperature measured at the Wasilla airport on May 31 and June 13 was 50° F and 60° F, respectively. Previous studies reported temperatures above 13° C in the epilimnion also.

Dissolved oxygen and pH were both within the AWQS. Turbidity had two anomalous readings above 20. These readings could be from possible point sources in this area, or from disturbance of bottom lake sediment. These results have been validated because there were no problems with accuracy or precision associated with the turbidity sensor (see Section 5). There were several other readings less than 10 NTU but greater than 5 NTU that are most likely due to instrument drift. The turbidity readings above the AWQS are outliers and not representative of a water quality impairment on the lake.

Conductivity does not have a water quality standard. It is used to estimate the dissolved solids concentration in a lake. Conductivity values at Big Lake increased with depth and were highest during the first sampling event. Woods (1992) also reported increased conductivity readings at depth, which he attributed to anoxic conditions releasing dissolved solids from the lake sediments. The highest conductivity readings from Woods' study were recorded in September and October.

4.1.2 Lake Lucille

Temperature readings at Lake Lucille at the surface from the first sampling event and to lake depth from the second two sampling events are above the AWQS. Lake Lucille is a shallow lake heated by solar radiation to depth. A hypolimnion did not develop in the lake and readings were similar at all depths. Edmundson (2002) reported similar readings for Threemile Lake, also only 4 m deep, in May 2001. Surface temperatures were approximately 16° C and dropped to 12° C at 4 m.

The pH readings at Lake Lucille were slightly above the AWQS of 8.5, ranging from 8.6 to 8.9 pH units. High pH readings may result from aquatic plants photosynthesizing and fixing CO_2 in the lake water. Lake Lucille has a calcium carbonate substrate in some areas, which also may contribute to high pH concentrations. There were three turbidity readings above 5 NTU, which are attributed to instrument drift and do not reflect an impairment of lake water quality for turbidity.

The highest conductivity readings at Lake Lucille were recorded below 3 m depth. Solids in lake sediments dissolved into the water column may increase conductivity readings at depth.

4.2 Bacteria

4.2.1 Big Lake

Fecal coliforms bacteria concentrations at Big Lake were less than 5 col/100 mL except for samples collected at the Meadow Creek inlet. *E. coli* concentrations were in the same range as the fecal coliforms and were also highest at Meadow Creek. Based on sample results from May and June, bacteria concentrations are well below the AWQS standard in the areas of the lake most heavily used for swimming and other recreational activities. The highest concentrations were observed at the inlet to Big Lake, Meadow Creek. Concentrations were 3.17, 13.22 and 14.19 on May 16, 31 and June 19, respectively. No contact recreation activities were observed at this sampling site, although boats do pass through here as residences are located nearby. The Meadow Creek inlet is a large emergent wetland that may support wildlife populations such as moose and waterfowl. Duck observations at the Meadow Creek inlet were comparable to those observed on the rest of the lake, but the wetland area associated with the inlet is not visible from the sampling site.

4.2.2 Lake Lucille

The highest fecal coliforms concentration at Lake Lucille was reported at sampling site LL-3 on June 19, 9.83 col/100 mL. All results were below the AWQS of 20 col/100 mL. LL-3 is a historic sampling site used by the U.S. Geological Survey for water quality monitoring located at the deepest section of the lake off of the north shore. Dense residential development on the north shore and heavy traffic between the east and west ends of the lake contribute to high recreational use near to this site. The highest density of waterfowl activity on the lake was observed near this sampling site and may be associated with a small island to the south.

4.3 Nutrients

Nutrients are important for understanding the effects of cultural eutrophication upon both Big Lake and Lake Lucille. As discussed in the Introduction, both lakes have residential development on their shorelines, with the potential for contributing nutrients from failing waste systems, fertilizers, detergents, pet waste and other sources. Increased nutrient inputs increase the natural rate at which lakes change from oligotrophic to eutrophic classifications.

The parameters most commonly used to calculate the trophic state are total phosphorus, chlorophyll a and Secchi disk depth. Only one total phosphorus result was reported from the sampling events conducted in May and June, so the trophic state for both lakes can be determined using Secchi disk readings and chlorophyll a results. Multiple limnology studies reference Carlson’s Trophic State Index, which is summarized in Table 8 below. Ranges provided for Carlson’s TSI indices were entered into his calculations to obtain the relative total phosphorus, chlorophyll a and Secchi disk ranges for each lake trophic state.

Table 8. Carlson's Trophic State Index (MPCA 2004)

TSI Range	Total Phosphorus (µg/L)	Chlorophyll a (µg/L)	Secchi Disk (m)	Description
<30	< 6	> 8 m	< 0.9	Classic Oligotrophy; Clear water, oxygen through the year in the hypolimnion, salmonid fisheries in deep lakes.
30-40	6-12	4-8	0.9-2.6	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
40-50	12-24	2-4	2.6-7.2	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
50-60	24-48	1-2	7.2-20	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnion during the summer, macrophyte problems evident, warm-water fisheries only.
60-70	48-96	0.5-1	20-55.5	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
70-80	96-192	0.25-0.5	55.5-153.8	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
> 80	> 192	< 0.25	> 153.8	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.

4.3.1 Big Lake

Phosphorus parameters are important for evaluating the availability of this nutrient for aquatic plant growth. Total phosphorus represents the phosphorus dissolved in solution and associated with colloidal material or particulate matter. Colloidal material is defined as particles dispersed in a medium that are not filtered or settled easily. Dissolved phosphorus includes all phosphorus that passes through a 0.45 um filter and ortho-phosphate is the dissolved form of phosphorus available for plant uptake. Total phosphorus is most commonly used to evaluate the trophic state of a lake.

The method reporting limits for the phosphorus parameters in this study were above the range reported at Big Lake in previous studies. The phosphorus parameters are most likely present in concentrations below the reporting limit. Only two phosphorus results were reported, both were less than five times the reporting limit. The high reporting limits prevent a comparison of phosphorus concentrations between the sampling sites and should be considered when evaluating the limited phosphorus results.

There was one total phosphorus concentration and one dissolved phosphorus concentration reported at Big Lake. The total phosphorus concentration at sampling site BL-1 at 1 m depth was 154 µg/L. A primary sample and field duplicate were taken at this site. The primary sample concentration was reported at 258 µg/L and the field duplicate was reported non-detect at 100 µg/L. The primary sample result was averaged with half the detection limit for the duplicate. This result is over ten times the total phosphorus concentrations reported by Woods (1992) at the same sampling site and depth. Total phosphorus concentrations from that study averaged 8.6 in 1983 and 10.6 in 1984. This anomalous result may originate from a possible point source at the lake in this area or from decontamination procedures in the field or in the laboratory that cross-contaminated the sample with phosphorus.

Nitrogen parameters are also important for evaluating nutrient availability for aquatic organisms. Total nitrogen to total phosphorus ratios can determine which nutrient is limiting algal growth and also the composition of the plant community (Edmundson 2002). Inorganic nitrogen is measured by the ammonia and nitrate/nitrite components. Organic nitrogen is measured by subtracting ammonia from total Kjeldahl nitrogen (TKN). High levels of ammonia and TKN were reported at several sampling sites in the east basin during the May sampling events. Organic matter produced by plankton in the epilimnion (upper lake thermal stratum) contributed to TKN spikes in the summer in Woods' 1983-84 limnology study on Big Lake. Ammonia concentrations from two previous studies never peaked above 30 µg/L in the epilimnion (Woods 1992 and Edmundson 2002). Ammonia concentrations above 10 µg/L are usually attributed to low dissolved oxygen levels increasing heterotrophic decomposition of organic matter (Woods 1992). Dissolved oxygen levels were ~8 mg/L in the upper five meters at Big Lake in May.

The trophic state index (TSI) was calculated for chlorophyll a and Secchi disk readings taken at the two USGS sites on Big Lake. Total phosphorus was not used to calculate the TSI because no samples were reported above the detection limit. The average chlorophyll a concentration at Big Lake for all sampling sites and dates was 2.0 µg/L and the TSI calculated was 34. The average Secchi disk depth for the two USGS sampling sites at Big Lake in the east and west basins was 6.4 m. The TSI index calculated was 33. Both the chlorophyll a measurements and the Secchi disk readings classify Big Lake as oligotrophic.

4.3.2 Lake Lucille

Nutrient parameters at Lake Lucille were below reporting limits for the majority of the samples collected. Only one dissolved phosphorus concentration was above the reporting limit. TKN and ammonia were reported at sampling sites LL-3 and LL-4 on May 8. The highest ammonia concentration was reported at 4 m depth at LL-3 on May 8, 272 µg/L. Decreased oxygen levels may increase heterotrophic decomposition in the hypolimnion, increasing ammonia concentrations.

The trophic state index was calculated for Lake Lucille using the chlorophyll a results and the Secchi disk readings from the USGS site at the deepest section of the lake. Total phosphorus was not used to calculate the TSI because no samples were reported above the detection limit. The average of the chlorophyll a measurements at all sampling sites and dates was 3.3 µg/L and the TSI calculated was 42. The average Secchi disk reading from sampling site LL-3 at the deepest section of the lake was 3.3 m and the TSI calculated was 39. The average TSI for Lake Lucille is 40.5, placing it in the mesotrophic range. Mesotrophic lakes are more nutrient rich than oligotropic lakes but are not considered eutrophic.

4.4 Hydrocarbons

4.4.1 Big Lake

Eight exceedances of the AWQS for TAH were reported at Big Lake. All samples were collected from 0.15 m below the surface at sampling sites within the east basin. Sampling site BL-2 is located at the major traffic lane between the two lake basins. During all three sampling events, boats were observed passing through this area while sampling. Boat traffic on Big Lake was not quantified as part of this study, but subjective observations were made and used to qualify which sites receive heavier traffic compared to others. Sampling sites BL-5, BL-6, BL-7 and BL-8 are all located within the very easternmost portion of the east basin. BL-5 and BL-6 are located off of the south shore. BL-6 is directly out from Southport Marina where there is fueling, maintenance, launching and boat storage. The South State Recreation Area is also very close to this sampling site. A separate sampling site was not established at the South State Recreation Area because very little activity was observed there compared to other areas of the lake. BL-7 is located at the outlet of Big Lake, Fish Creek. There is extensive activity in this area associated with the Big Lake Lodge, fishing and boat traffic to houses located downstream on the creek. BL-8 is located directly out from Burkeshore Marina on the north shore. Activities are the same as those for Southport Marina. Sampling site BL-10 is located at the North Shore State Recreation Area. This area had the most heavily concentrated use observed during the three sampling events. Activities observed in this area included boating, jetskiing, waterskiing, swimming, camping and boat launching. The sample collected on June 12 from the swimming area at this site was over four times greater than any other samples collected on that date. Sample results from June 12 were considerably lower than those reported on May 29, indicating that concentrations in the swimming area may have been even higher over Memorial Day Weekend when activity at the boat launch was greater. The swimming area is located directly adjacent to the boat ramps.

Photo – *Swimming area at BL-10 (North Shore State Recreation Area) adjacent to boat launch. June 15, 2004.*

Sampling site BL-4 is also located in the easternmost portion of the east basin. It is the depth profile collected directly between sampling sites BL-6 and BL-8. The highest concentration recorded at this location was 8.38 µg/L on May 29. TAH concentrations above the AWQS are associated with activities in concentrated use areas. Sampling results from BL-4 indicate that TAH concentrations in the center of the east basin are not above the AWQS.

TAH concentrations were highest on May 29, over Memorial Day Weekend. All of the concentrations above the AWQS were recorded on this date. Concentrations in the depth profiles during this sampling event indicate that in the east basin, at sampling sites BL-3 and BL-4, TAH concentrations remain within 2 µg/L of surface concentrations to 1.5 m. No results were recorded at 5 m depth.

4.4.2 Lake Lucille

Six exceedances of the AWQS were reported at sampling site LL-4 at Lake Lucille. Samples collected from both depths on all dates were above the AWQS. This sampling site is located at the public boat launch on the eastern shore of the lake. Activities observed here include boating, launching and jet skiing. A public swim beach and associated park is located at the southeast corner of Lake Lucille, approximately ¼ mile away.

4.5 Recommendations

Results for several of the nutrient parameters sampled for laboratory analyses were below the method reporting limits. There are alternative methods that could be used for phosphorus to achieve lower reporting limits. The SM 4500 PE method can be used for all three phosphorus parameters to achieve a reporting limit of 25 µg/L at a local laboratory. The Total Maximum Daily Load (TMDL) for Lake Lucille targeted 17 µg/L for the average annual total phosphorus concentration. A lower reporting limit for the phosphorus parameters should be pursued with an Outside laboratory.

OASIS recommends collecting future dissolved oxygen readings using either an optical fluorescence sensor or a flow through cell. Optical fluorescence has two distinct advantages: it is a non-destructive technology and the sensor requires only yearly calibration. Consequently, the problems of instrument drift, sensitivity and depletion of oxygen in the vicinity of the sensor are resolved. The instrument also provides an instantaneous reading. Schlumberger® and Solinst® both market optical fluorescence instruments. Solinst® is currently reengineering their product to correct a Teflon seal defect. OASIS has employed a Solinst® oxygen sensor to collect daily oxygen readings at the River Terrace site for nearly two years and the device has worked very well. The main disadvantages of the technology are instrument limitations, i.e. another instrument would be needed to collect other water quality parameters and the design flaw, mentioned above, which will be corrected in instruments sold after January 2005.

A flow through cell would also provide more reliable dissolved oxygen values. OASIS recently purchased a YSI® water quality meter with a flow through cell. The instrument probe screws into the cell and water is pumped through the cell using a peristaltic pump. Advantages of the flow through cell include the ability to accurately collect all water parameter values using one instrument, there is no dissolved oxygen depletion in the vicinity of the probe and parameter changes can be observed directly and readings recorded when the values have stabilized. Disadvantages include the inherent instability in permeable membrane oxygen sensors and the amount of time required to collect measurements. The flow through cell must be allowed to fill with water from the desired depth and measurements collected only after the parameters stabilize, which takes from five to ten minutes. A more powerful centrifugal type of pump could speed up the process, but the different pump type would probably aerate the water and render the oxygen readings useless.

Both of these lakes are dimictic lakes, they experience both spring and fall mixing of the entire water column. The fall overturn occurs when air and wind drop surface water temperatures to 4°

C, the maximum density of water, and mixing occurs throughout the lake profile. Sampling should be continued throughout the summer and fall to understand when and if this process is occurring in both lakes and how it affects the distribution of bacteria, hydrocarbons and nutrients throughout the lake profile.

Sampling was performed at both lakes in May for this study to target concentrations before spring turnover. Both of the lakes had turned prior to sampling. A sampling event in the spring prior to turnover would target concentrations of bacteria, hydrocarbons and nutrients throughout the profile before summer stratification.

Hydrocarbon concentrations are linked to boat and other motorized recreational activities on the lake. A motorized user survey should be performed on the lake in conjunction with additional hydrocarbon sampling in order to determine the levels of activity that elevate hydrocarbon concentrations above the AWQS.

5 DATA VALIDATION

5.1 Field Parameters

All field water quality meters were calibrated according to manufacturer's specifications the morning of each sampling date using Autocal® solution. After calibrating, measurements were taken of the calibration solution to ensure accuracy within 5%. If accuracy was outside 5%, meters were recalibrated and checked again.

During the first sampling event at Lake Lucille on May 8, a Horiba U-22 was used to measure field parameters. Due to difficulty obtaining stable, accurate readings, a Horiba U-22 and a Troll 9000 were used to collect field parameters at Big Lake on May 15-16. Neither instrument provided stable, reproducible readings for dissolved oxygen and pH readings between the two instruments varied considerably. In order to obtain more accurate depth profiles for pH and dissolved oxygen, a handheld pH meter and colorimetric dissolved oxygen kits were used to measure these parameters at 5 m intervals at the USGS sampling sites for the second and third sampling events.

Precision of the water quality meters was determined by comparing results between different meters and methods. A Troll 9000 was used to collect water quality parameters concurrently with the Horiba U-22 on May 15-16. The Troll did not provide accurate, stable readings for DO and measurements for pH and conductivity were >25% different than those measured by the Horiba. Comparison of the Horiba with the pH meter and colorimetric DO tests were provided in sampling reports submitted for the second and third sampling events (see Attachment B).

Dissolved oxygen results using the multi-parameter water quality meters were rejected on May 8, May 15-16, May 31 and June 12-13. Measurements were unstable and could not be duplicated on these dates due to instrument drift from a faulty sensor. On May 31, the Horiba was dropped and failed to recalibrate. One set of measurements at sampling site LL-3 at Lake Lucille was also rejected. Measurements were recorded to 7 m although lake depth is < 5 m at this sampling site. The depth readings from the instrument may have been incorrect and an anomalous conductivity reading at the 7 m depth indicates the bottom sediments may have been disrupted.

5.2 Analytical Results

The analytical results for the surface water and associated laboratory quality assurance and quality control (QA/QC) samples were reviewed to determine the integrity of the reported analytical results and ensure they met the established data quality objectives.

Documentation associated with the surface water samples was reviewed to determine compliance with recommended holding times and sample preservation techniques. All samples were analyzed within their respective holding times except for the ortho-phosphate samples collected at Big Lake on June 13. The holding time for ortho-phosphate is 48 hours (2 days). Samples were analyzed on June 21, 7 days after sample collection. All of the results were below the reporting limit.

Several coolers were received at the lab with temperatures between 6 and 8.8°C, slightly above method requirements of 4.0°C (+/- 2.0°C). Sample results associated with cooler temperatures outside the method requirements on May 8, May 30 and June 13 may be affected. The data is not qualified as the potential for bias is minimal.

Trip blanks accompanied the samples, and were submitted for analysis of BTEX compounds. No analytes were detected at concentrations above the reporting limit in the trip blanks.

Decontamination blanks were collected with distilled water after decontaminating the water sampling equipment to evaluate the possibility of cross-contamination between sampling sites. No detections were reported above the reporting limit in any of the three decontamination blanks collected from the VOC sampler.

Four decontamination samples were collected from the Kemmerer water sampling bottle. Dissolved organic carbon was detected above the reporting limit in three of the samples collected: on May 30 and June 19 at Lake Lucille and on June 13 at Big Lake. All dissolved organic carbon results were greater than five times the dissolved organic concentration reported in the decontamination blanks. Decontamination blanks were not collected during the first sampling events at either lake. Dissolved organic carbon results less than five times the average of the concentrations reported in the decontamination blanks have been flagged ‘B’ and were not used because the decontamination procedure is the same and possible interference from cross-contamination may have occurred. Eight samples were qualified from May 16.

Color was reported at 20 color units in the decontamination sample collected at Big Lake on May 31. All color results from this sampling event at Big Lake were less than five times the result reported in the decontamination blank and have been flagged ‘B’. These results will not be reported due to possible effects from cross-contamination. Color was not detected in the other three decontamination blanks. Decontamination blanks were not collected during the first sampling events at both lakes. Color results less than five times the concentration reported in the decontamination blank have been flagged ‘B’ and were not used because the decontamination procedure is the same and possible interference from cross-contamination may have occurred. Twenty-four color samples were qualified and the data has been rejected.

Nitrate/nitrite was detected in the decontamination blank collected at Lake Lucille on June 19. All nitrate results for the project samples were non-detect. Nitrate was also reported in the laboratory method blank for this batch. The nitrate reported in the decontamination blank was greater than five times the concentration in the method blank, but a similar method of cross-contamination may have contributed to the nitrate in the decontamination blank as it was not reported in any of the project samples.

Method blanks were analyzed in the laboratory to detect instrument and sample cross-contamination. Ortho-phosphate, ammonia, TKN, nitrate/nitrite total organic carbon and benzene were detected at concentrations greater than the method detection limit, but less than the reporting limit in method blanks associated with samples on several dates. Ortho-phosphate and nitrates were non-detect in all project samples. Project samples associated with the method blank with a detected concentration of total organic carbon were all greater than five times the concentration reported in the method blank.

TKN was reported in the method blank on May 8 and in three associated project samples at less than five times the concentration reported in the method blank. Results for these samples have been flagged ‘B’. TKN was also reported in a method blank associated with samples collected at Lake Lucille on May 30. TKN concentrations in the eight project samples were all less than five times the concentration in the method blank. Nine sample results were qualified.

Ammonia and benzene were reported in the method blank associated with samples collected on June 19 at Lake Lucille. Two samples were flagged ‘B’ for ammonia and four samples were flagged for benzene because project sample concentrations were less than five times the concentration reported in the method blank. These sample results were not included in the data analysis or conclusions.

Laboratory control samples and laboratory control sample duplicates (LCS/LCSD) were analyzed to confirm acceptable recovery of target analytes. Multiple analytes in the LCS and

LCSD samples were slightly outside the method control limits. All analytes outside of method limits were not present in the project samples and are not contaminants of concern.

Matrix spikes and matrix spike duplicate (MS/MSD) samples are analyzed to evaluate possible matrix interference with analyte detection. Percent recoveries for multiple analytes in the MS and MSD samples were outside method limits. Relative percent differences for multiple analytes were also outside method limits for the MS/MSD. None of these analytes were reported in the associated project samples except for the chlorophyll a samples. Percent recoveries for the matrix spikes were low for samples collected from the first two sampling events. Matrix interference may indicate that the spiked sample has been broken down by other compounds in the matrix or adsorbed onto compounds reducing the final result.

Surrogate compounds are added by the laboratory to evaluate the accuracy of individual sample analyses. Surrogate compound recoveries were within established control limits in all samples analyzed for volatile hydrocarbons.

Field duplicates were collected during each sampling event depending on the type of parameter and the lake being sampled. At Lake Lucille, one field duplicate was collected for each of the sample analyses at each sampling event. At Big Lake, two TAH and PAH duplicates, four fecal coliforms, three *E. coli*, and one duplicate for each of the nutrient parameters were collected at each sample event. Relative percent differences (RPDs) between primary and duplicate results are calculated for analytes with concentrations greater than ten times the reporting limit. Excluding chlorophyll a, analytes were not detected at concentrations greater than ten times the reporting limit so RPDs were not calculated. The field duplicates for chlorophyll a collected at Big Lake on May 31 and at Lake Lucille on May 30 were > 20% RPD at 51% and 43% respectively. The differences between the primary and duplicate samples could result from actual differences in the sample as they were collected from separate deployments of the Kemmerer sampling bottle. Other possible reasons include differences in the filtration process or possible photo-degradation of one of the samples. Sample results have not been qualified.

Project completeness for analytical sample collection is 100%. This meets OASIS' goal of 95% established for the project in the QAPP. Project completeness measures the number of samples collected divided by the number called for in the original sampling design. The original sampling design called for collection of nutrient and hydrocarbon samples at specific lake depths that were not collected at all sites due to shallow water. Completeness was calculated using the number of sampling sites and depths established after the first sampling event at both lakes.

Completeness for measurement of dissolved oxygen and pH at Big Lake was 45% and at Lake Lucille was 40%. Measurements were rejected based on failure to meet precision or accuracy requirements using the multi-parameter meters. Repeated measurements were >25% relative percent difference and the sensors drifted >20% accuracy when placed in calibration solutions. Water quality meters were rented from a local supplier and calibrated on a daily basis. A response action was taken and methods were modified for both the dissolved oxygen and pH measurements. Alternative methods were implemented and 100% completeness was achieved. The data quality objectives for the project have been satisfied.

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