Table of Contents

List of Tables

List of Figures

1.0 Background

Saskatchewan Watershed Authority (SWA) developed The *Lake Stewardship Program* in September 1997 to support stewardship groups throughout Saskatchewan. The mandate of the program is to foster communication, collect and share information, and help develop partnerships between stewardship groups and other agencies to protect and preserve water quality and aquatic life.

The Authority provides support to individual stewardship groups based on their specific needs and interests which may include water quality monitoring, environmental education, and community outreach. Stewardship group activities depend on the groups' size, interest, goals, and objectives.

Lake stewards are ambassadors for their lake and community. Knowledge of community achievements and challenges enable stewards to effectively tailor environmental awareness and educational outreach programs to the needs of their community. The *Lake Stewardship Program* will improve understanding and decision making within the watershed and foster relationships between various agencies and stewardship groups to ensure source water protection.

2.0 Last Mountain Lake

Last Mountain Lake is located between Saskatoon and Regina, in south-central Saskatchewan. Residents from both major urban centers can easily access the lake and consequently it is an important recreational and tourist attraction. The southern end of Last Mountain Lake is surrounded by one provincial and three regional parks, numerous resort facilities and cottages. In contrast, the northern end of the lake is less developed located within the boundaries of the oldest national bird sanctuary in North America. Approximately 86 % of the lakeshore is adjacent to agricultural land while 13 % is under cottage or recreational development. Last Mountain Lake is a long narrow lake with a maximum length of approximately 81 km and surface area of 233 square kilometers. The mean and maximum depths are 7.6 meters (m) and 31.5 m, respectively with an operating range between 489.66 and 490.27 meters above sea level (masl). During the 2004 open water season, the lake level fluctuated between 489.91 and 490.29 masl.

In 2003, *Last Mountain Lake Stewardship Group* (LMLSG), together with the Saskatchewan Watershed Authority established a water quality monitoring program at the lake. The monitoring program was established to provide current water quality information about the lake as part of the *Lake Stewardship Program*. The water quality monitoring program is a co-operative effort between local volunteers and Saskatchewan Watershed Authority staff to collect water samples from two baseline and seven shoreline stations on Last Mountain Lake. This report represents the results from the 2003 and 2004 water quality monitoring program.

2.1 Stewardship Activities

The Last Mountain Lake Stewardship Group was formed in 2002 as a result of concerns regarding effluent release from Regina. Effluent is released into Wascana River which flows into the Qu'Appelle System and into Last Mountain Lake depending on water levels. As a result**,** group activities have primarily focused on water quality monitoring. Volunteer assistance is essential to allow for the extensive sampling conducted by the Saskatchewan Watershed Authority.

Currently, the group's main objective is to appoint an executive committee which will facilitate the incorporation process, enabling the formation of a non-profit organization. As a non-profit organization the group would increase their eligibility for grants and community funding. This would enable the LMLSG to plan and implement educational activities and programs within the watershed.

At the Annual General Meeting held on September 9, 2004 Dr. Dennis Lawson and Margaret Skeel of Nature Saskatchewan previewed a Living-By-Water -Shoreline presentation on shoreline erosion. In July 2005, Dr. Dennis Lawson will deliver a weekend workshop to stewards focusing on areas around the lake that are currently experiencing erosion or slumping problems. The workshop will provide details and examples of preventative and corrective measures. In 2005, the LMLSG also plan to increase their profile by distributing a newsletter to community residents detailing their mission and goals, current activities in the watershed and future projects they intend to accomplish. The LMLSG have also applied for funding from the Department of Fisheries and Oceans, under their Stewardship-In-Action program. Funding will support these outreach campaigns as well as fund a signage project to post signs indicating water quality sampling sites around the lake. These projects will increase the profile of the LMLSG and increasing interest and participation in programs offered by the LMLSG.

2.2 Purpose and Scope

Water quality monitoring is a key component of any lake stewardship activity. Water quality monitoring can serve three primary purposes for local groups and residents:

1. to understand the characteristics of a lake,
2. to understand how activities around a lake can impact water quality, and
3. as a means of assessing water quality.

The scope and purpose of the water quality monitoring program is to assess the current water quality conditions in Last Mountain Lake. The program is designed to collect water quality data representative of the lake that may be used to establish changes or trends in water quality over time.

2.3 Water Sampling Procedure

Saskatchewan Watershed Authority personnel facilitated the collection of all field measurements and water sampling at Last Mountain Lake in 2003 and 2004. Two sampling stations were established on Last Mountain Lakes near the point of maximum depth at the center of the lake (Figure 1), located at Pelican Point and Fox's Point.

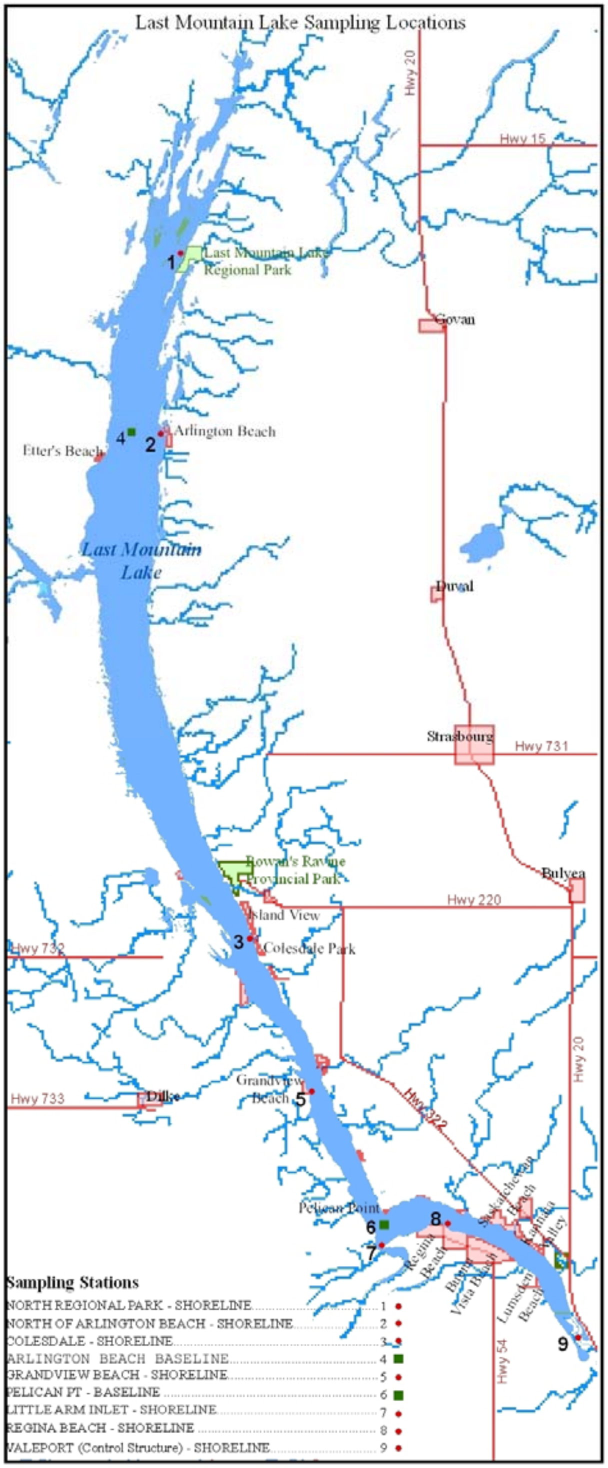

Figure 1 **Last Mountain Lake 2003 and 2004 Baseline and Shoreline Sampling Locations**

These stations are referred to as baseline station #1 for Pelican Point and baseline station #2 for Fox's Point. Each baseline sampling station's global positioning satellite (G.P.S.) co-ordinates were referenced so that the same location was sampled each time. Sample location consistency enables current and historic water quality data to be compared. Baseline water samples collected in 2003 were grab samples collected just below the water's surface. Samples collected in 2004 from the baseline stations included discrete top and bottom water samples taken using a horizontally orientated Van Dorn water sampler, and an integrated water sample taken from the surface to two times the secchi depth. Shoreline stations included Arlington Beach, Regina Beach, North Regional Park Beach, Colesdale Beach, Grandview Beach, Little Arm Outlet, and the Valeport control structure (Figure 1).

2.3.1 Baseline Stations

The water quality monitoring program for Last Mountain Lake included two baseline sampling stations. Pelican Point baseline sample collection and field monitoring was conducted four times during 2003; January 28, May 13, July 8, and August 25. In 2004, sampling was conducted five times: February 17, March 25, June 2, August 3, and September 28. Fox's Point was sampled four times in 2003: January 28, March 18, July 8, and August 25. The Fox's Point baseline station is located in an exposed area often preventing sampling activities. As a result, in 2004 it was only sampled twice: March 25 and August 3. Consequently, in 2005 this baseline station will be relocated to a more northern location close to Arlington Beach.

2.3.2 Shoreline Stations

Shoreline stations were monitored in 2003 and 2004 to determine if the water quality of the lake was being impacted by localized activities. At the shoreline stations parameters are monitored which may impact recreational activity, such as bacteria, chlorophyll *a*, and total suspended solids (Tables 17 to 29). Shoreline stations were monitored on the same day as the baseline stations listed above.

2.3.3 Field Measurements

Field measurements were taken at the baseline station and included air temperature, water temperature, cloud cover, wind speed, secchi disk transparency, pH, turbidity, conductivity, and dissolved oxygen. Dissolved oxygen, conductivity, and temperature were measured using a YSI 85D oxygen/temperature/conductivity meter. Calibrations were made using standard reference solutions. pH was determined using a hand held WTW 330i pH meter; calibrated using a two-point calibration with reference solutions at pH 7 and 10. Turbidity was determined using a Lamotte Model 2020 nephelometric turbidity meter. Calibrations were performed with reference solutions of 1.0 and 10 NTU.

2.3.4 Laboratory Analysis

Baseline and shoreline samples were analyzed for nutrients, major ions, chlorophyll *a*, dissolved and suspended solids, and bacteria (See Tables 6, 7, and 12 to 29). All water samples were collected in plastic bottles and shipped in coolers to the Provincial Laboratory in Regina, Saskatchewan for analysis.

2.3.5 Stewardship Involvement

Volunteers are essential to the water monitoring program providing transportation to sampling locations, sample collection assistance, and local knowledge. In 2003 and 2004 Malcom Campbell, Ron Mann, Rueben Loewen, Jamie Liebel, John Unrau, George Grassick, Rae Bjarnason, and Todd Richter assisted Saskatchewan Watershed Authority technologists Rob Walcer and Kevin O'Neill with sampling on Last Mountain Lake.

3.0 Trophic Status

Trophic status is a lake classification system based on the amount of nutrients in the lake and its' resulting biological productivity. Several water quality parameters are measured and used as indicators to determine the trophic status of a lake. The most commonly used "trophic indicators" include nutrients, chlorophyll *a*, and secchi disk transparency (water clarity). Nutrient additions increase biological productivity, which may be measured as chlorophyll *a*, which in turn decreases water clarity, measured by secchi disk transparency. As a result, biological productivity is used to determine lake trophic status. There are four trophic states: oligotrophic, mesotrophic, eutrophic and hypertrophic, which range from low to extreme biological productivity respectively. Oligotrophic lakes have low inputs if nutrients, organic matter and sediment and consequently, little biological productivity. In contrast, eutrophic lakes are very productive with high levels of nutrients, organic matter and sediments. Lakes on the prairies are typically classified as eutrophic lakes due to high nutrient concentrations. As a result, the Water Quality Index has been employed to more accurately assess the quality of water in recreational lakes throughout Saskatchewan.

4.0 Water Quality Index

The Water Quality Index (WQI) is an effective means for summarizing a large number of water quality parameters. Similar to the UV index or an air quality index, it provides an indication of the overall water quality for watershed health.

The advantage of the WQI is that it summarizes key water quality parameters in a single index and is especially meaningful to people who want to know about the state of their local water body. The index also allows water quality data to be reported in a consistent manner.

Values for various water quality parameters (*e.g.,* dissolved oxygen, nutrients, and fecal coliform bacteria) are compared to specific water quality objectives. The results of the comparisons are combined to provide a water quality ranking (*e.g.,* Good, Fair, Poor) for individual water bodies. To assess overall watershed health the Saskatchewan Watershed Authority has selected seventeen parameters to be incorporated into the water quality index including nutrients, minerals, metals, pesticides, and bacteria. The parameters and their corresponding objectives used in the Water Quality Index are shown in Table 1.

The index is based on three components that relate to water quality objectives:

Scope - How many? - The number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured.

Frequency - How often? – The number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest.

Amplitude - How much? - The amount by which measurements which do not meet objectives depart from those objectives.

Water Quality Index (WQI) values range between 1 and 100. One represents the worst water quality and 100 represents the best water quality. Once the WQI value has been calculated the value can be further simplified by assigning it to one of several descriptive categories:

Excellent: (WQI value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.

Good: (WQI value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (WQI value 60-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: (WQI value 45-59) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor: (WQI value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

At least three different sampling dates per year are required to calculate the WQI.

5.0 Results

5.1 Baseline Stations

Field water quality parameters measured at Pelican and Fox's Point baseline stations have been summarized in Tables 2 to 5 and 8 to 11. There are five important field measurements to examine when assessing Last Mountain Lake water quality. These include dissolved oxygen and temperature profile, conductivity, turbidity, and secchi disk transparency depth.

Dissolved oxygen concentrations are variable based on time, weather, and temperature. Consequently, sampling needs to be repeated within the same time frame each year to enable year to year comparisons. Dissolved oxygen levels of 1 or 2 mg/L will not support fish populations. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a minimum dissolved oxygen concentration of 5 mg/L for the protection of all stages of warm water biota. Fox's Point has a depth of 24 m, which is four times the 6m depth at Pelican Point, yet temperature profiles indicate Last Mountain Lake is well mixed and typically does not stratify. During the open water season atmospheric oxygen and dissolved oxygen production by algae and aquatic plants is mixed throughout the water column. During the open water season in 2003 and 2004, dissolved oxygen concentrations were maintained above 8 mg/L at depths greater than 19 m (Tables 3, 5, and 9 to 11). As a result, during the open water season dissolved oxygen concentrations at baseline stations were maintained above the 5 mg/L objective for the protection of aquatic life.

Winter dissolved oxygen depletion results from biotic respiration and decomposition processes which require oxygen. In winter sources of oxygen are limited by ice cover which prohibits atmospheric mixing and decreases light penetration decreasing photosynthetic activity and associated oxygen production. Pelican Point maintained dissolved oxygen concentrations above 5 mg/L under winter conditions but at Fox's Point dissolved oxygen concentrations are quickly depleted during winter months with concentrations less than 5 mg/L at depths greater than 5 m (Tables 2, 4, 8 and 10).

Specific conductivity is a measure of waters ability to conduct an electric current, which depends on the concentration of dissolved ions in solution. It is determined by the concentration of specific ions and lake temperature. Specific conductivity is influenced by watershed geology and soil composition. At Last Mountain Lake specific conductivity at the surface ranged from 1,678 to 2,373 µS/cm (Tables 2, 4, 8, and 10).

Turbidity is the measure of water clarity. A reduction or lack of water clarity is caused by solids suspended in the water including clay, silt, and plankton (small plants and animals). Sources of turbidity are soil erosion, waste discharge, urban runoff, boating, algal growth or abundant bottom feeders that stir up bottom sediment. Increases in turbidity may decrease light penetration, destroy or modify fish habitat and increase water temperature which decreases oxygen concentrations. Baseline turbidity values for Last Mountain Lake are moderate ranging from 0.02 to 8.26 NTU during the open water season. (Tables 2, 4, 8, and 10).

The secchi disk reading is a measure of water transparency. Transparency is affected by turbidity, suspended sediment, algae, and water colour. The Saskatchewan *Surface Water Quality Objectives* (1997), state that for bathing waters the secchi disk should be visible at 1.2 m. The secchi disk transparency depth of Last Mountain Lake measured at Pelican and Fox's Point ranged from 0.9 to 1.9 m. Increases in chlorophyll *a* were not always correlated with decreases in secchi disk readings. For example on August 3, 2004, the chlorophyll *a* concentration was at its maximum level of 43.45 µg/L while the secchi disk transparency depth was 1.4 m. On September 28, 2004 the secchi disk transparency depth was 1.3 m with a decreased level of chlorophyll *a* to12.54 µg/L. As a result, it may be concluded that turbidity, suspended sediment, algae, and water colour all collectively affect the secchi disk transparency depth.

5.2 Shoreline Stations

All shoreline stations sampled during the open water season in 2003 and 2004 maintained dissolved oxygen concentrations above the 5 mg/L WQI objective (Tables 17 to 29). Moderate turbidity levels below 10 NTU characterized all shoreline stations with the exception of the Valeport control structure. In 2003, turbidity at the Valeport control structure ranged from 11.1 to 38.7 mg/L. In contrast, the following year turbidity levels were moderately high but showed less variation ranging between 15.5 and 21mg/L at the Valeport control structure.

6.0 Water Quality Index for Last Mountain Lake

6.1 Pelican Point Baseline Station

The WQI value for Pelican Point baseline station ranged from 67.8 to 61.2 giving the lake a rating of fair water quality (Figure 2). Of the 17 parameters that were measured six parameters exceeded the WQI objectives.

Water quality was fair at Pelican Point baseline station on Last Mountain Lake with a WQI score in the 60s in both 2003 and 2004. The parameters that exceeded the WQI objectives and therefore reduced the index score included: pH, total dissolved solids (TDS), chloride, sodium, sulphate, and total phosphorus. In both years four parameters consistently exceeded the WQI objectives. The pH was 9 pH units with the exception of a single sample which measured 8 pH units. The TDS levels ranged from 1,515 to 1,863 mg/L. Hammer (1971) recorded chloride and sodium concentrations from Last Mountain Lake in the 1960s and values found currently are consistent to historic levels. Sodium and chloride concentrations were high in Last Mountain Lake ranging between 273 and 341 mg/L and 112.2 to 146.0 mg/L, respectively. Sulphate concentrations ranged from 652.1 to 775.0 mg/L. As a result, these five parameters exceed the WQI objectives. In 2003, total phosphorus concentrations ranged from 0.09 to 0.27 mg/L, while in 2004 total phosphorous concentrations were lower ranging between 0.05 and 0.12 mg/L.

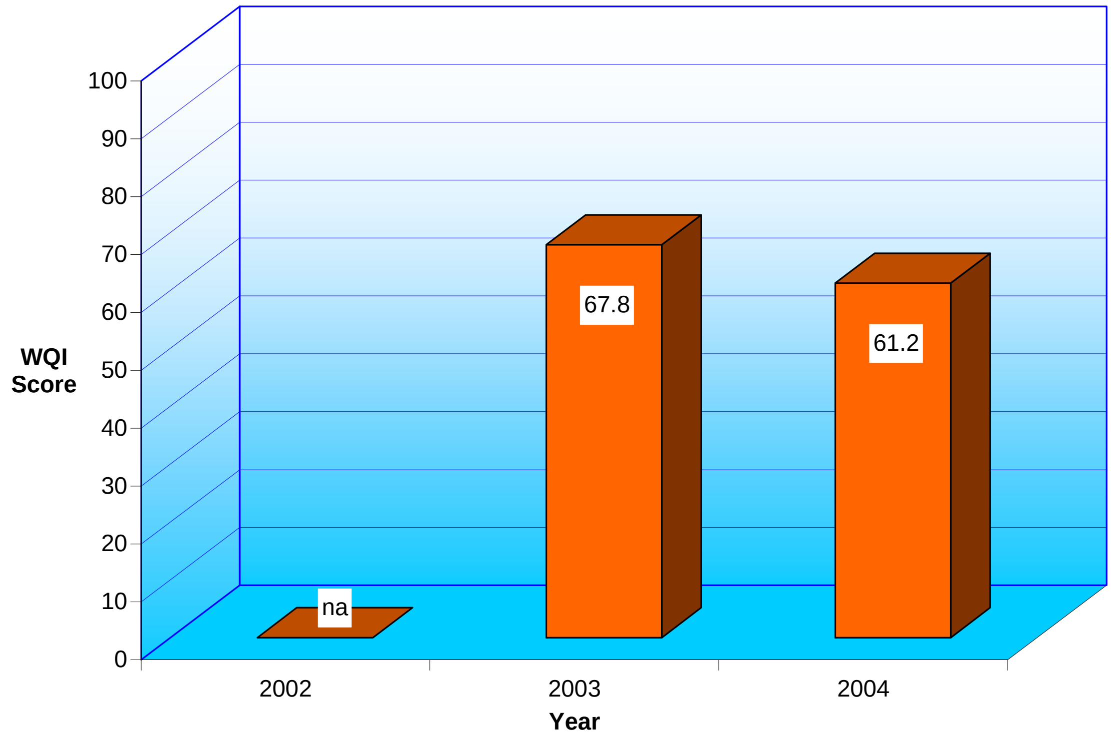

Figure 2 Last Mountain Lake, Pelican Point Baseline Water Quality Index Scores, 2003 - 2004

6.2 Fox's Point Baseline Station

The WQI value for Fox's Point, Last Mountain Lake in 2003 was 54.2 giving the lake a rating of marginal water quality (Figure 3). Of the 17 parameters that were measured six parameters exceeded the WQI objectives. The parameters exceeding WQI objectives were consistent at both Fox's and Pelican Point.

Water quality at Fox's Point baseline station on Last Mountain Lake rated marginal in 2003 with a WQI score of 54.2. There was insufficient data to determine the WQI score for 2004 with less than three sample collection events. The parameters that most often exceeded the objectives set in the water quality index and also reduced the index rating to "marginal", were the same six parameters (pH, TDS, chloride, sodium, sulphate, and total phosphorous) identified at Pelican's Point baseline station. However, five parameters at Fox's Point including: pH, TDS, chloride, sodium, and sulphate all had a higher minimum value than the concentration found at Pelican Point. These increased concentrations contributed to a lower WQI score at Fox's Point as compared to Pelican Point baseline station. Total phosphorus concentrations ranged from 0.07 to 0.14 mg/L, slightly lower than the concentrations found at Pelican's Point.

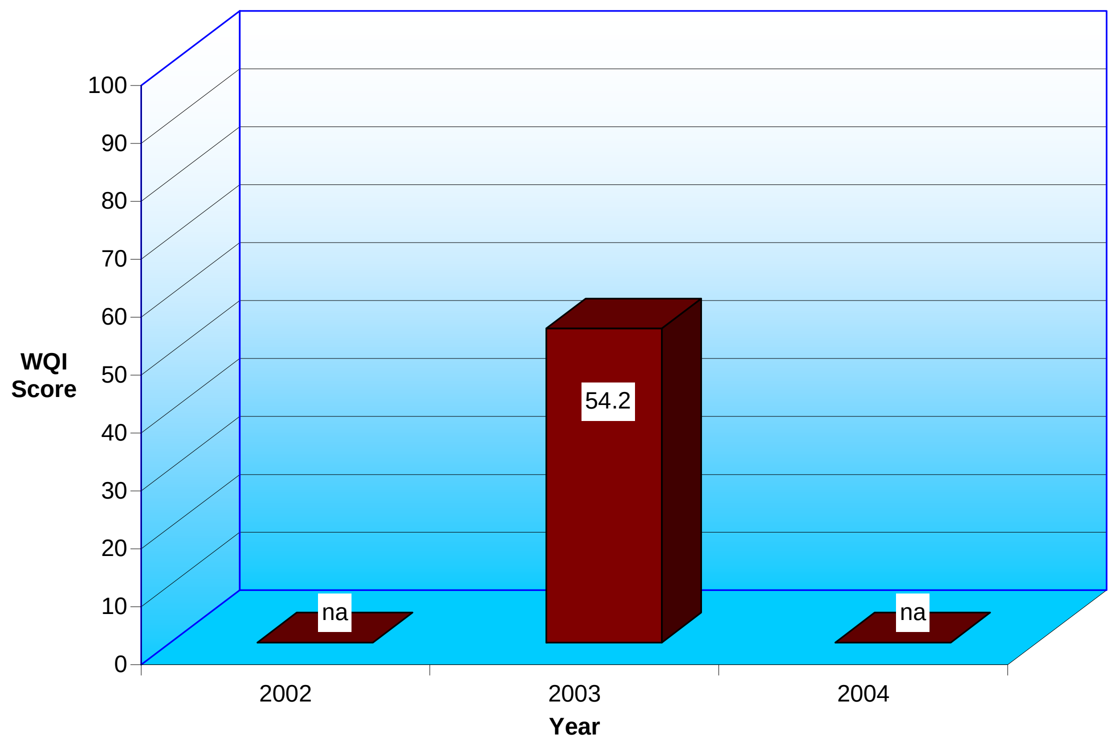

Figure 3 Last Mountain Lake, Fox's Point Baseline Water Quality Index Scores, 2003 - 2004

In 2004, water quality samples were collected from the surface, surface integrated, and bottom of the water column to assess the variation within the water column (Tables 14, 15, and 16). Results showed that there was no significant difference in the water quality parameters measured at the top, integrated, and bottom of the water column. Surface samples were indicative of conditions throughout the water column and consequently, may be used to assess lake water quality. In 2005, only the surface sampling will resume at the baseline station to maintain monitoring activities while minimizing associated cost and time constraints.

6.3 Shoreline Stations

Parameters such as fecal coliform bacteria, chlorophyll *a*, turbidity, and nutrients (nitrate and total phosphorus) can be used to assess water quality at shoreline stations. In Saskatchewan, the bacteriological quality of the water is assessed using traditional bacterial indicators such as fecal streptococci or fecal and total coliform. Fecal coliform bacteria are present in the lower intestine of warm blooded animals and are rare in unpolluted waters; their presence is used as an indicator of sewage or human fecal contamination. For contact recreation, the Province sets water quality objectives using fecal coliform bacteria as an indicator of microbial water quality. The Saskatchewan *Surface Water Quality Objectives* (1997), state that for contact recreation the density of fecal coliform bacteria should not exceed 200 organisms per 100mL of water. At all shoreline stations fecal coliform bacteria concentrations typically ranged from less than 10 orgs/100mL to 200 orgs/100mL (Tables 17 to 29). Arlington Beach shoreline had the highest fecal coliform bacteria concentration of all sites with a reading of 740 orgs/100 mL as measured on July 8, 2003. However, the following sample collected August 25, 2003 had a fecal coliform concentration of 10 orgs/100mL. At all shoreline stations fecal coliform bacteria concentrations near the 200 orgs/100 mL objectives were found but these elevated concentrations were not maintained throughout the open water season.

Once bacteriological quality is known to be good, water clarity is the second concern which recreational users have for beach areas. Three parameters: total phosphorus, chlorophyll *a*, and turbidity primarily affect the clarity of the water and recreational enjoyment. The shoreline results show that increases in total phosphorus are typically correlated with increased chlorophyll *a* concentrations. When chlorophyll *a* concentrations are high there is a greater abundance of algae and consequently the water appears “green”. Total phosphorus concentrations at the shoreline stations ranged from 0.04 to a maximum of 0.27 mg/L at Regina Beach. Chlorophyll *a* concentrations ranged from <0.20 to a maximum of 47.32 µg/L at Little Arm Beach. Turbidity values were low, typically less than 10 N.T.U.

Six shoreline stations were located at recreational beaches around the lake. In contrast, the seventh shoreline station was conducted at the Valeport structure. This station sampling is dependant on the flow of the Qu’Appelle River and the lake level. When the Qu’Appelle River is above the structure height, water flows into Last Mountain Lake. Conversely, when lake levels are high and the river levels are low water flows out of Last Mountain Lake in to the Qu’Appelle River. Sampling is conducted downstream of the structure on the Qu’Appelle River, therefore the sample may represent either lake or river water quality depending which way water is flowing. As a result, parameters measured at the Valeport control structure were significantly higher than those recorded at other shoreline stations (Tables 17 to 29). Total phosphorus concentrations ranged from 0.15 to 1.48 mg/L, substantially higher than WQI objective of 0.1 mg/L. Chlorophyll *a* concentrations ranged from 16.30 to 174.63 µg/L at the Valeport control structure, contrasting to the beach stations where the maximum chlorophyll *a* concentration was 47.32 µg/L. The Valeport control structure station was relatively turbid with values between 10.41 and 170.00 N.T.U.

7.0 Discussion and Recommendations

Last Mountain Lake is an alkaline lake with predominantly sodium-sulphate water which is well buffered and rich in nutrients. Parameters including pH, TDS, sodium, chloride, sulphate, and total phosphorous frequently exceeded WQI objectives and therefore lowered the WQI score. As a result, water quality at Last Mountain Lake is fair to marginal. Fair water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels. Marginal water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Baseline water quality is indicative of overall lake health. Last Mountain Lake has nutrient rich productive water which enables substantial algae growth. As a result, chlorophyll *a* concentrations exceeded the 50 µg/L objective but the secchi disk transparency level was still maintained within the 1.2 m objective for bathing waters. Both baseline stations on Last Mountain Lake had good bacteriological quality. Although Last Mountain Lake is a nutrient rich system, it still meets contact and non-contact recreation objectives and is ideal for recreational water based activities.

Shoreline beach stations have fair bacteriological quality. Often increases in fecal coliform bacteria concentrations are the result of natural processes such as bird defecation. As long as elevated fecal coliform bacteria levels are not maintained, concentration peaks are not a concern to recreational users. Therefore, it is important to resample areas when bacterial concentrations are elevated above 200 orgs/100mL to ensure the safety of recreational users. Minimizing nutrient enrichment from the watershed may minimize algal blooms and associated chlorophyll *a* concentrations.

Last Mountain Lake is an important recreational area which should be maintained and enhanced for the enjoyment of future generations. Residents and other lake users are encouraged to become actively involved in the *Last Mountain Lake Stewardship Group* who are dedicated to the stewardship of Last Mountain Lake. The Saskatchewan Watershed Authority encourages lake users to follow healthy shoreline living practices outlined in *On the Living Edge – Your Handbook for Waterfront Living*, published by Nature Saskatchewan (See References). This handbook provides excellent tips and facts focused on shoreline landscaping, erosion, construction, and septic systems.

8.0 References

Hammer, U.T.. (1971) *Limnological studies of the lakes and streams of the upper Qu'Appelle river system, Saskatchewan, Canada*. I. Chemical and physical aspects of the lakes and drainage system. Hydrobiologia **37:** 473-507.

Kipp, Sarah & Callaway, Clive. (2003). *On The Living Edge: Your Handbook For Waterfront Living.* Saskatchewan/Manitoba Edition. Federation of British Columbia Naturalist: British Columbia.

Wetzel, Robert G. (2001). *Limnology: Lake and River Ecosystems, 3rd Edition.* Academic Press: San Diego, CA.

9.0 Appendix A - Water Quality Summary Tables

Table 1 Water Quality Index Objectives

Parameter	Objective
Total Arsenic (µg/L)	50
Dissolved Chloride (mg/L)	100
Total Chromium (mg/L)	0.02
Mercury (µg/L)	0.1
Total Ammonia (mg/L)	calculated
Dissolved Oxygen (mg/L)	5
pH (units)	6.5-8.5
Dissolved Sodium (mg/L)	100
2'4-D (µg/L)	4
MCPA (µg/L)	0.025
Total Aluminum (mg/L)	5
Sulphate (mg/L)	500
Fecal Coliforms (units/100mL)	200
Total Phosphorus (mg/L)	0.1
Dissolved Nitrate & Nitrite (mg/L)	1
Total Dissolved Solids (mg/L)	700
Chlorophyll a (µg/L)	50

Table 2 Field Measurements from Fox's Point Baseline, Last Mountain Lake, 2003

Field Data	Jan 28	March 18	July 8	Aug 25
Surface Parameters				
Air Temperature (ºC)	-20	3	22	28
Water Temperature (ºC)	0.4	0.3	18.8	21.9
Dissolved Oxygen (mg/L)	8.92	7.52	9.07	9.50
pH (pH units)	8.70	8.62	8.68	8.85
Conductivity (µS/cm)	2,337	1,986	2,133	2,118
Secchi Disk (meters)	na	na	1.5	>1.0
Turbidity (NTU)	1.02	0.02	1.88	2.97

Table 3 Dissolved Oxygen, Temperature, and Conductivity Profiles for Fox's Point Baseline, Last Mountain Lake, 2003

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
28/1/03	0	8.92	0.4	2,337
	1	8.88	0.3	2,346
	2	8.88	0.3	2,346
	3	8.56	0.3	2,344
	4	8.08	0.6	2,330
	5	8.13	0.8	2,319
	6	8.05	1.1	2,307
	7	7.41	1.2	2,306
	8	6.41	1.5	2,297
	9	5.55	1.7	2,306
	10	4.35	1.9	2,316
	11	4.80	2.0	2,319
	12	4.3	2.1	2,327
	13	3.74	2.1	2,337
	14	3.57	2.2	2,344
	15	2.94	2.3	2,346
	16	2.82	2.3	2,360
	17	2.26	2.4	2,367
	18	2.35	2.4	2,375
	19	2.46	2.4	2,377
	20	2.98	2.4	2,382
	21	2.31	2.5	2,394
	22	2.08	2.6	2,405
	23	2.42	2.5	1,382
18/5/03	0	7.52	0.3	1,986
	1	6.36	0.7	2,221
	2	5.83	0.8	2,220
	3	5.64	1.0	2,214
	4	5.43	1.2	2,205
	5	5.36	1.3	2,209
	6	5.05	1.3	2,213
	7	4.74	1.4	2,213
	8	4.27	1.7	2,204
	9	3.96	1.9	2,203
	10	3.31	2.0	2,204
	11	3.18	2.1	2,206
	12	3.25	2.1	2,216

Table 3 Dissolved Oxygen, Temperature, and Conductivity Profiles for Fox's Point Baseline, Last Mountain Lake, 2003 continued

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
18/5/03	13	2.86	2.1	2,225
	14	2.86	2.2	2,228
	15	2.54	2.2	2,244
	16	2.08	2.3	2,254
	17	2.01	2.3	2,274
	18	1.67	2.3	2,267
	19	1.74	2.3	2,276
	20	0.76	2.4	2,279
	21	0.83	2.4	2,293
	22	0.07	2.5	2,297
	23	0.04	2.9	2,296
	24	0.03	3.0	2,299
	25	0.04	2.9	2,301
	26	0.02	2.8	2,311
	27	0.02	3.2	2,305
	28	0.02	3.2	2,310
8/7/03	0	9.07	18.8	2,133
	1	8.93	18.7	2,148
	2	8.98	18.7	2,146
	3	8.97	18.7	2,147
	4	8.99	18.6	2,145
	5	8.95	18.7	2,146
	6	8.95	18.6	2,146
	7	8.94	18.6	2,147
	8	8.89	18.6	2,146
	9	8.82	18.6	2,145
	10	8.74	18.5	2,146
	11	8.81	18.6	2,147
	12	8.80	18.5	2,146
	13	8.73	18.5	2,147
	14	8.78	18.5	2,145
	15	8.74	18.5	2,145
	16	8.70	18.5	2,145
	17	8.68	18.5	2,145
	18	8.57	18.5	2,145
	19	8.5	18.4	2,142

Table 4 Field Measurements from Fox's Point Baseline, Last Mountain Lake, 2004

Field Data	Feb. 16	March 25	August 3
Surface Parameters			
Water Temperature (ºC)	0.3	0.5	20.1
Dissolved Oxygen (mg/L)	5.95	10.70	11.90
pH (pH units)	8.51	8.77	8.82
Conductivity (µS/cm)	2,327	2,154	2,062
Secchi Disk (meters)	na	na	1.9
Turbidity (NTU)	0.44	1.00	8.26

Table 5 Dissolved Oxygen, Temperature, and Conductivity Profiles for Fox's Point Baseline, Last Mountain Lake, 2004

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
16/2/04	0	5.95	0.3	2,327
	1	5.95	0.4	2,330
	2	5.22	1.6	2,296
	3	5.45	1.6	2,302
	4	5.38	1.6	2,302
	5	5.15	1.8	2,297
	6	4.73	2.1	2,282
	7	3.78	2.2	2,287
	8	3.41	2.4	2,286
	9	3.70	2.4	2,291
	10	2.65	2.6	2,300
	11	2.39	2.7	2,308
	12	1.81	2.8	2,325
	13	1.19	2.9	2,331
	14	1.25	3.0	2,334
	15	1.48	2.9	2,348
	16	1.54	2.9	2,348
	17	1.80	2.9	2,357
	18	2.04	2.9	2,359
	19	2.25	2.9	2,364
	20	2.52	2.9	2,371
	21	2.37	2.9	2,376
	22	1.97	3.0	2,380
	23	1.83	3.1	2,390
	24	1.52	3.1	2,410

Table 5 Dissolved Oxygen, Temperature, and Conductivity Profiles for Fox's Point Baseline, Last Mountain Lake, 2004 continued

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
	25	0.40	3.3	2,422
	26	0.10	3.4	2,429
	27	0.08	3.6	2,422
25/03/04	0	10.7	0.5	2,154
	1	9.98	0.9	2,351
	2	8.54	2.4	2,336
	3	8.24	2.4	2,337
	4	7.82	2.4	2,337
	5	6.46	2.4	2,338
	6	3.72	2.6	2,341
	7	2.13	2.7	2,346
	8	2.15	2.7	2,354
	9	1.26	2.8	2,361
	10	0.66	2.9	2,368
	11	0.11	3.0	2,384
	12	0.09	3.0	2,401
	13	0.11	3.1	2,409
	14	0.09	3.1	2,412
	15	0.18	3.0	2,417
	16	0.29	3.1	2,421
	17	0.38	3.0	2,430
	18	0.67	3.0	2,440
	19	1.49	3.0	2,443
	20	2.65	2.8	2,453
	21	2.70	2.9	2,455
	22	1.60	3.0	2,464
	23	1.71	2.9	2,480
	24	2.75	3.1	2,494
	25	1.18	3.1	2,494
	26	1.08	3.1	2,495
	27	0.85	3.1	2,500
	28	0.21	3.3	2,499
	29	0.15	3.4	2,501

Table 5 Dissolved Oxygen, Temperature, and Conductivity Profiles for Fox's Point Baseline, Last Mountain Lake, 2004 continued

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
03/08/04	0	11.90	20.1	2,062
	1	11.60	20.2	2,062
	2	11.15	20.0	2,066
	3	11.10	19.9	2,068
	4	10.70	19.7	2,070
	5	10.33	19.6	2,073
	6	9.65	19.4	2,074
	7	8.64	19.2	2,077
	8	9.10	19.0	2,079
	9	8.40	19.1	2,075
	10	8.15	19.1	2,079
	11	8.01	18.9	2,079
	12	7.58	19.0	2,079
	13	7.53	18.9	2,079
	14	7.31	18.9	2,075
	15	7.50	18.9	2,071

Table 6 Summary of Fox's Point Baseline Surface Parameters, 2003

Parameters	Jan 28	Mar 18	July 8	Aug 25
Nutrients (mg/L)				
Dissolved Organic Carbon	12	13	10	12
Nitrate, as Nitrogen	0.06	0.05	<0.02	0.04
Ammonia, as Nitrogen	0.07	0.12	0.03	0.14
Total Kjedahl Nitrogen	1.3	1.4	1.6	2.0
Total Phosphorous	0.11	0.08	0.07	0.14
Ortho-Phosphate, as P	0.05	0.07	0.03	0.08
Solids (mg/L)				
Total Dissolved	1,772	1,746	1,653	1,647
Suspended, Fixed	3	2	3	2
Suspended, Volatile	1	1	4	7
Suspended, Total	2	3	7	9
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<10	<10	<10
Fecal Streptococci	10	<10	<10	110
Total Coliform	<10	<10	<100	na
Major Ions (mg/L)				
Alkalinity, Total	310	312	292	296
Alkalinity, Phenol	na	10	16	22
Bicarbonate	378	356	317	307
Calcium	52	56	52	53
Carbonate	na	12	19.2	26.4
Chloride	130	137	125	129
Hardness, Total	560	564	529	532
Iron	0.007	<0.100	na	na
Magnesium	100	103	97	97
Manganese	0.006	<0.100	na	na
Potassium	39	na	29	29
Sodium	320	314	292	290
Sulphate	772	768	722	716
Other				
Chlorophyll *a* (µg/L)	<2.00	1.48	12.62	9.57
Conductivity (µS/cm)	2,250	2,360	2,220	2,200
pH (pH units)	8.3	8.4	8.7	8.7
Turbidity (N.T.U.)	1.02	0.02	1.79	4.85
Biochemical Oxygen Demand (mg/L)	na	na	1.7	1.9
Chemical Oxygen Demand (mg/L)	na	na	30.7	37.3
Metals				
Preserved Mercury (µg/L)	<0.05	na	na	na
Aluminum (mg/L)	<0.005	na	na	na

Table 7 Summary of Fox's Point Baseline Surface Parameters, 2004

Parameters	Mar 25/04	Aug 3/04
Nutrients (mg/L)		
Dissolved Organic Carbon	13.2	12
Nitrate, as Nitrogen	na	0.1
Ammonia, as Nitrogen	0.04	0.05
Total Kjedahl Nitrogen	1.2	1.5
Total Phosphorous	0.06	0.09
Ortho-Phosphate, as P	na	<0.02
Solids (mg/L)		
Total Dissolved	1,848	1,701
Suspended, Fixed	1	1
Suspended, Volatile	2	6
Suspended, Total	3	8
Bacteria (orgs/100 mL)		
Fecal Coliform	<2	<10
Fecal Streptococci	1,190	<10
Total Coliform	<2	10
Major Ions (mg/L)		
Alkalinity, Total	316	290
Alkalinity, Phenol	14	20
Bicarbonate	351	305
Calcium	59	61
Carbonate	16.8	24
Chloride	147.0	119.1
Hardness, Total	609	597
Magnesium	112	108
Potassium	32	31
Sodium	338	333
Sulphate	792	720.2
Other		
Chlorophyll *a* (µg/L)	10.31	70.94
Conductivity (µS/cm)	2,410	2,180
pH (pH units)	8.5	8.7
Turbidity (N.T.U.)	0.84	9.90
Biochemical Oxygen Demand (mg/L)	1.0	3.9
Chemical Oxygen Demand (mg/L)	39.7	31.1
Metals		
Preserved Mercury (µg/L)	na	<0.02
Aluminum (mg/L)	na	0.02
Arsenic (mg/L)	na	0.005

Table 8 Field Measurements at Pelican Point, Last Mountain Lake, 2003

Field Data	Jan 28	May 13	July 8	Aug 25
Surface Parameters				
Air Temperature (ºC)	na	16	na	25
Water Temperature (ºC)	0.7	12.3	19.7	22.6
Dissolved Oxygen (mg/L)	9.40	12.39	10.85	10.61
pH (pH units)	8.58	na	8.73	9.10
Conductivity (µS/cm)	2,292	2,075	2,220	2,130
Secchi Disk (meters)	na	0.9	1.0	1.0
Turbidity (NTU)	1.15	2.76	3.93	5.40

Table 9 Dissolved Oxygen, Temperature, and Conductivity Profiles for Pelican Point Baseline, Last Mountain Lake, 2003

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
28/1/03	0	9.40	0.7	2,292
	1	9.45	0.6	2,296
	2	8.91	0.8	2,287
	3	8.74	0.9	2,281
	4	7.95	1.4	2,263
	5	6.35	2.2	2,255
	6	5.07	2.6	2,244
13/5/03	0	na	12.3	na
	1	12.39	12.1	2,075
	2	12.87	10.5	2,079
	3	12.80	10.3	2,080
	4	12.77	10.0	2,080
	5	12.53	9.8	2,082
	6	7.63	8.4	2,036
	7	7.68	8.2	2,139
8/7/03	0	10.85	19.7	2,220
	1	10.66	19.7	2,224
	2	10.71	19.6	2,226
	3	10.61	19.6	2,225
	4	10.62	19.6	2,226
	5	10.30	19.5	2,227
	6	10.09	19.5	2,229
	7	9.65	19.4	2,230

Table 9 Dissolved Oxygen, Temperature, and Conductivity Profiles for Pelican Point Baseline, Last Mountain Lake, 2003 continued

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
25/8/03	0	10.61	22.6	2,130
	1	10.62	22.5	2,137
	2	10.50	22.0	2,170
	3	9.26	21.4	2,165
	4	8.46	21.4	2,164
	5	8.35	21.3	2,164
	6	4.56	21.0	2,172

Table 10 Field Measurements from Pelican Point Baseline, Last Mountain Lake, 2004

Field Data	Feb 11	Mar 25	June 2	Aug 3	Sept 28
Surface Parameters					
Air Temperature (ºC)	na	1	15	na	na
Water Temperature (ºC)	0.1	0.8	12.7	19.9	13.4
Dissolved Oxygen (mg/L)	9.75	11.40	9.55	11.95	8.57
pH (pH units)	8.42	9.04	8.71	8.88	na
Conductivity (µS/cm)	2,025	2,373	1,794	2,010	1,678
Secchi Disk (meters)	na	na	1.7	1.4	1.3
Turbidity (NTU)	1.28	0.77	2.78	7.46	4.40

Table 11 Dissolved Oxygen, Temperature, and Conductivity Profiles for Pelican Point Baseline, Last Mountain Lake, 2004

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
17/2/04	0	9.75	0.1	2,010
	1	9.51	0.2	2,018
	2	8.75	1.2	2,116
	3	8.61	1.5	2,246
	4	9.60	1.4	2,288
	5	9.70	1.5	2,302
	6	13.05	1.2	2,520
25/03/04	0	11.40	0.8	2,303
	1	11.15	1.1	2,312
	2	9.82	1.7	2,351
	3	10.86	1.7	2,353
	4	10.61	1.7	2,353
	5	9.58	1.8	2,356
	6	7.65	2.0	2,417
02/06//04	0	9.55	12.7	1,794
	1	9.90	12.4	1,792
	2	10.47	11.6	1,772
	3	9.53	11.4	1,779
	4	8.55	11.4	1,785
	5	9.34	11.3	1,797
	6	6.92	11.1	1,817

Table 11 Dissolved Oxygen, Temperature, and Conductivity Profiles for Pelican Point Baseline, Last Mountain Lake, 2004 continued

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
03/08//04	0	11.95	19.9	2,010
	1	11.50	20.0	2,012
	2	11.81	20.0	2,015
	3	11.30	20.0	2,014
	4	11.12	19.9	2,010
	5	10.31	19.9	2,010
	6	8.60	19.3	2,007
28/09//04	0	8.57	13.4	1,678
	1	8.61	13.3	1,679
	2	8.65	13.3	1,679
	3	8.61	13.3	1,679
	4	8.60	13.3	1,679
	5	8.54	13.3	1,679
	6	8.45	13.3	1,678
26/02//05	0	9.91	0.0	2,119
	1	10.11	0.0	2,204
	2	9.75	0.2	2,250
	3	10.62	0.2	2,276
	4	10.72	0.2	2,284
	5	11.17	0.3	2,295
	6	7.11	1.1	2,436
07/03//05	0	11.95	0.1	2,431
	1	11.90	0.1	2,433
	2	11.35	0.2	2,428
	3	11.38	0.3	2,431
	4	11.74	0.4	2,431
	5	11.15	0.9	2,414
	6	6.05	1.6	2,483

Table 12 Summary of Pelican Point Baseline Surface Parameters, 2003

Parameters	Jan 28	May 13	July 8	Aug 25
Nutrients (mg/L)				
Dissolved Organic Carbon	13	13	11	13
Nitrate	<1	na	na	na
Nitrate, as Nitrogen	0.25	<0.02	<0.02	0.04
Ammonia, as Nitrogen	0.3	<0.02	0.04	0.03
Total Kjedahl Nitrogen	1.6	1.6	1.6	2.1
Total Phosphorous	0.12	0.08	0.08	0.27
Ortho-Phosphate, as P	0.07	<0.02	<0.02	0.21
Solids (mg/L)				
Total Dissolved	1,709	1,666	1,714	1,671
Suspended, Fixed	2	6	6	4
Suspended, Volatile	2	5	6	11
Suspended, Total	4	10	12	15
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<10	<10	<10
Fecal Streptococci	<10	30	<10	<10
Total Coliform	<10	<10	<10	<10
Major Ions (mg/L)				
Alkalinity, Total	316	302	304	310
Alkalinity, Phenol	na	28	18	36
Bicarbonate	386	300	327	290
Calcium	61	57	55	54
Carbonate	na	33.6	21.6	43.2
Chloride	137	138	126	132
Hardness, Total	560	534	553	545
Iron	<0.1	na	0.13	0.067
Magnesium	99	95	100	99
Manganese	0.070	na	0.026	0.042
Potassium	39	28	30	30
Sodium	296	301	280	310
Sulphate	730	713	750	728
Other				
Chlorophyll *a* (µg/L)	9.00	17.17	30.4	39.18
Conductivity (µS/cm)	2,210	2,190	2,300	2,250
pH (pH units)	8.2	8.9	8.7	9.0
Turbidity (N.T.U.)	na	3.06	6.92	6.27
Biochemical Oxygen Demand (mg/L)	na	2.8	3.1	3.7
Chemical Oxygen Demand (mg/L)	na	35.3	33.5	43.3
Metals				
Preserved Mercury (µg/L)	<0.05	na	<0.05	<0.05
Aluminum (mg/L)	<0.005	na	0.170	0.053
Arsenic (mg/L)	na	na	8.2	15.0

Table 13 Summary of Pelican Point Baseline Surface Parameters, 2004

Parameters	Feb 17	Mar 25	June 2	Aug 3	Sept 28
Nutrients (mg/L)					
Dissolved Organic Carbon	13.0	12.8	11.0	12.1	12.3
Nitrate, as Nitrogen	0.11	na	<0.04	0.09	<0.04
Ammonia, as Nitrogen	0.04	0.05	0.04	0.04	0.05
Total Kjedahl Nitrogen	1.1	1.3	1.1	1.7	1.3
Total Phosphorous	0.05	0.06	0.06	0.09	0.12
Ortho-Phosphate, as P	0.03	na	<0.02	<0.02	0.05
Solids (mg/L)					
Total Dissolved	1,863	1,829	1,515	1,584	1,644
Suspended, Fixed	<1	1	2	2	2
Suspended, Volatile	2	2	2	7	7
Suspended, Total	2	3	4	9	8
Bacteria (orgs/100 mL)					
Fecal Coliform	<2	<2	<10	<10	60
Fecal Streptococci	<10	10	<10	<10	na
Total Coliform	2	<2	80	<10	320
Major Ions (mg/L)					
Alkalinity, Total	326	328	270	286	286
Alkalinity, Phenol	14	24	14	24	20
Bicarbonate	364	342	295	290	300
Calcium	59	60	52	45	54
Carbonate	16.8	28.8	16.8	28.8	24.0
Chloride	144.0	146.0	112.2	116.8	121.8
Hardness, Total	600	607	492	450	538
Magnesium	110	111	88	82	98
Potassium	31	32	26	24	28
Sodium	341	334	273	293	310
Sulphate	797.0	775.0	652.1	704.0	708.1
Other					
Chlorophyll *a* (µg/L)	9.77	8.06	8.71	43.45	12.54
Conductivity (µS/cm)	2,420	2,480	2,010	2,130	2,180
pH (pH units)	8.6	8.7	8.6	8.8	8.7
Turbidity (N.T.U.)	0.65	0.77	1.70	8.30	3.20
Biochemical Oxygen Demand (mg/L)	0.7	1.3	2.0	4.1	2.2
Chemical Oxygen Demand (mg/L)	32.6	41.9	27.5	35.9	39.1
Metals					
Preserved Mercury (µg/L)	na	na	na	<0.02	na
Aluminum (mg/L)	na	na	na	0.02	na
Arsenic (mg/L)	na	na	na	0.008	na

Table 14 June 2, 2004 Comparison Between Surface, Integrated, and Bottom Parameters, Pelican Point, Last Mountain Lake

Parameters	**June 2**		
Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	11.0	11.0	11.1
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.04	0.03	0.02
Total Kjedahl Nitrogen	1.1	1.1	1.2
Total Phosphorous	0.06	0.07	0.07
Ortho-Phosphate, as P	<0.02	<0.02	<0.02
Solids (mg/L)			
Total Dissolved Solids	1,515	1,506	1,509
Suspended Solids, Fixed	2	4	2
Suspended Solids, Volatile	2	2	2
Suspended Solids, Total	4	6	4
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	<10
Fecal Streptococci	<10	<10	<10
Total Coliform	80	100	20
Major Ions (mg/L)			
Alkalinity, Total	270	270	270
Alkalinity, Phenol	14	12	10
Bicarbonate	295	300	305
Calcium	52	51	51
Carbonate	16.8	14.4	12.0
Chloride	112.2	110.8	111.9
Hardness, Total	492	486	486
Magnesium	88	87	87
Potassium	26	25	25
Sodium	273	271	271
Sulphate	652.1	647.0	646.5
Other			
Chlorophyll *a* (µg/L)	8.71	10.02	10.97
Conductivity (µS/cm)	2,010	1,990	2,000
pH (pH units)	8.6	8.6	8.6
Turbidity (N.T.U.)	1.7	2.2	2.1
Biochemical Oxygen Demand (mg/L)	2.0	2.4	2.5
Chemical Oxygen Demand (mg/L)	27.5	27.2	26.2

Table 15 August 3, 2004 Comparison Between Surface, Integrated, and Bottom Parameters, Pelican Point, Last Mountain Lake

Parameters	**August 3**		
Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	12.1	12.2	12.3
Nitrate, as Nitrogen	0.09	0.09	0.09
Ammonia, as Nitrogen	0.04	0.03	na
Total Kjedahl Nitrogen	1.7	1.5	1.7
Total Phosphorous	0.09	0.13	0.09
Ortho-Phosphate, as P	<0.02	<0.02	0.04
Solids (mg/L)			
Total Dissolved	1,584	1,618	1,615
Suspended, Fixed	2	2	2
Suspended, Volatile	7	8	4
Suspended, Total	9	9	6
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	10
Fecal Streptococci	<10	<10	<10
Total Coliform	<10	10	<10
Major Ions (mg/L)			
Alkalinity, Total	286	288	288
Alkalinity, Phenol	24	24	24
Bicarbonate	290	293	293
Calcium	45	53	53
Carbonate	28.8	28.8	28.8
Chloride	116.8	117.4	116.6
Hardness, Total	450	519	519
Magnesium	82	94	94
Potassium	24	28	28
Sodium	293	295	299
Sulphate	704.0	708.8	702.1
Other			
Chlorophyll *a* (µg/L)	43.45	32.88	14.96
Conductivity (µS/cm)	2,130	2,130	2,120
pH (pH units)	8.8	8.8	8.8
Turbidity (N.T.U.)	8.3	6.8	4.7
Biochemical Oxygen Demand (mg/L)	4.1	4.8	<2.0
Chemical Oxygen Demand (mg/L)	35.9	36.1	27.6
Metals			
Preserved Mercury (µg/L)	<0.02	<0.02	<0.02
Aluminum (mg/L)	0.02	0.02	0.02
Arsenic (mg/L)	0.008	0.007	0.007

Table 16 September 28, 2004 Comparison Between Surface, Integrated, and Bottom Parameters, Pelican Point Baseline, Last Mountain Lake

Parameters	**September 28**		
Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	12.3	12.1	12.1
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.05	0.04	0.03
Total Kjedahl Nitrogen	1.3	1.4	1.3
Total Phosphorous	0.12	0.12	0.13
Ortho-Phosphate, as P	0.05	0.05	0.05
Solids (mg/L)			
Total Dissolved	1,644	1,636	1,652
Suspended, Fixed	2	2	2
Suspended, Volatile	7	7	7
Suspended, Total	8	8	9
Bacteria (orgs/100 mL)			
Fecal Coliform	60	20	30
Total Coliform	320	150	200
Major Ions (mg/L)			
Alkalinity, Total	286	286	288
Alkalinity, Phenol	20	18	18
Bicarbonate	300	305	307
Calcium	54	54	54
Carbonate	24.0	21.6	21.6
Chloride	121.8	121.8	122.2
Hardness, Total	538	534	543
Magnesium	98	97	99
Potassium	28	28	29
Sodium	310	301	309
Sulphate	708.1	707.8	710.0
Other			
Chlorophyll *a* (µg/L)	12.54	5.43	9.09
Conductivity (µS/cm)	2,180	2,180	2,180
pH (pH units)	8.7	8.7	8.7
Turbidity (N.T.U.)	3.2	3.0	3.0
Biochemical Oxygen Demand (mg/L)	2.2	2.2	2.4
Chemical Oxygen Demand (mg/L)	39.1	37.6	35.0

Table 17 Arlington Beach Shoreline Field and Laboratory Water Quality Data, 2003

Surface Parameters	May 13	July 8	Aug. 25
Field Measurements			
Air Temperature (ºC)	13.5	17.0	20.0
Water Temperature (ºC)	13.0	18.9	20.4
Dissolved Oxygen (mg/L)	10.26	11.04	10.45
pH (pH units)	8.88	8.85	9.13
Conductivity (µS/cm)	1,761	2,039	2,072
Secchi Disk (meters)	>1.1	<1.0	0.9
Turbidity (NTU)	1.48	3.85	9.00
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	11	10	12
Nitrate, as Nitrogen	<0.02	<0.02	0.04
Total Kjedahl Nitrogen	1.3	1.6	2.9
Total Phosphorous	0.07	0.08	0.10
Ortho-Phosphate, as P	0.02	<0.02	0.04
Solids (mg/L)			
Suspended, Fixed	16	6	4
Suspended, Volatile	3	6	12
Suspended, Total	20	12	16
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	740	10
Fecal Streptococci	10	10	20
Total Coliform	<100	700	1,700
Other			
Chlorophyll *a* (µg/L)	6.15	<0.20	35.29
Turbidity (N.T.U.)	1.07	2.99	10.08
Biochemical Oxygen Demand (mg/L)	1.2	1.7	3.5
Chemical Oxygen Demand (mg/L)	25.6	28.9	44.9

Table 18 Arlington Beach Shoreline Field and Laboratory Water Quality Data, 2004

Surface Parameters	June 1	July 20	Sept 27
Field Measurements			
Air Temperature (ºC)	12	25	16
Water Temperature (ºC)	12.1	23.9	14.4
Dissolved Oxygen (mg/L)	13.55	8.40	11.42
pH (pH units)	8.77	8.76	9.13
Conductivity (µS/cm)	1,918	2,171	1,770
Secchi Disk (meters)	>1.0	1.1	1.0
Turbidity (NTU)	2.10	8.95	3.15
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	11.9	11.3	11.8
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.03	0.04
Total Kjedahl Nitrogen	1.5	1.5	1.3
Total Phosphorous	0.05	0.05	0.07
Ortho-Phosphate, as P	<0.02	<0.02	0.02
Solids (mg/L)			
Suspended, Fixed	2	2	2
Suspended, Volatile	2	7	6
Suspended, Total	4	9	7
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	120	190
Fecal Streptococci	30	<10	n/a
Total Coliform	40	90	1,400
Other			
Chlorophyll *a* (µg/L)	5.10	21.63	3.56
Turbidity (N.T.U.)	1.6	10.0	2.8
Biochemical Oxygen Demand (mg/L)	<2.0	3.1	2.2
Chemical Oxygen Demand (mg/L)	29.6	35.5	33.4

Table 19 Colesdale Beach Shoreline Field and Laboratory Water Quality Data, 2003 and 2004

Surface Parameters	**2003**	**2004**		
	August 25	**June 1**	**July 20**	**Sept 27**
Field Measurements				
Air Temperature (ºC)	26	12	27	16
Water Temperature (ºC)	21.8	9.7	22.8	15.9
Dissolved Oxygen (mg/L)	8.77	10.03	9.21	12.3
pH (pH units)	8.95	8.82	8.78	9.01
Conductivity (µS/cm)	2,116	1,980	2,089	1,817
Secchi Disk (meters)	1.15	>1.10	>1.00	0.85
Turbidity (NTU)	4.45	3.25	4.04	2.90
Laboratory Analyzed Parameters				
Nutrients (mg/L)				
Dissolved Organic Carbon	12.0	12.5	11.1	11.8
Nitrate, as Nitrogen	0.05	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	na	0.03	0.03	0.03
Total Kjedahl Nitrogen	1.7	1.3	1.2	1.3
Total Phosphorous	0.13	0.07	0.04	0.08
Ortho-Phosphate, as P	0.07	<0.02	<0.02	0.03
Solids (mg/L)				
Suspended, Fixed	2	8	2	1
Suspended, Volatile	8	8	3	5
Suspended, Total	10	16	4	7
Bacteria (orgs/100 mL)				
Fecal Coliform	>1,000	10	50	80
Fecal Streptococci	40	10	<10	na
Total Coliform	<100	40	60	210
Other				
Chlorophyll *a* (µg/L)	45.46	36.02	5.71	7.07
Turbidity (N.T.U.)	6.45	3.20	3.00	4.10
Biochemical Oxygen Demand (mg/L)	2.5	2.0	<2.0	2.0
Chemical Oxygen Demand (mg/L)	42.3	36.0	29.3	36.7

Table 20 Grandview Beach Shoreline Field and Laboratory Water Quality Data, 2003

Surface Parameters	May 13	July 8	Aug. 25
Field Measurements			
Air Temperature (ºC)	15.5	18.0	23.0
Water Temperature (ºC)	7.6	19.4	22.4
Dissolved Oxygen (mg/L)	10.80	7.22	11.20
pH (pH units)	8.78	8.64	9.03
Conductivity (µS/cm)	2,203	2,134	2,126
Secchi Disk (meters)	1.96	<1.20	>1.10
Turbidity (NTU)	3.28	6.05	5.43
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	13	10	12
Nitrate, as Nitrogen	<0.02	<0.02	0.04
Total Kjedahl Nitrogen	1.7	1.4	1.9
Total Phosphorous	0.13	0.10	0.16
Ortho-Phosphate, as P	0.03	<0.02	0.09
Solids (mg/L)			
Suspended, Fixed	8	7	4
Suspended, Volatile	6	6	8
Suspended, Total	14	13	12
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	180	20
Fecal Streptococci	60	130	10
Total Coliform	100	200	<100
Other			
Chlorophyll *a* (µg/L)	36.19	11.42	38.26
Turbidity (N.T.U.)	2.47	6.10	5.90
Biochemical Oxygen Demand (mg/L)	1.7	2.6	2.5
Chemical Oxygen Demand (mg/L)	35.3	30.9	45.3

Table 21 Grandview Beach Shoreline Field and Laboratory Water Quality Data, 2004

Surface Parameters	**June 2**	**July 21**	**Sept. 28**
Field Measurements			
Air Temperature (ºC)	10	15	10
Water Temperature (ºC)	10.1	19.5	13.4
Dissolved Oxygen (mg/L)	11.95	8.25	8.86
pH (pH units)	8.76	8.76	8.87
Conductivity (µS/cm)	1,923	2,134	1,698
Secchi Disk (meters)	>1.2	<1.5	1.2
Turbidity (NTU)	2.98	6.41	3.10
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	11.0	11.1	11.8
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.02	0.04
Total Kjedahl Nitrogen	1.2	1.1	1.2
Total Phosphorous	0.06	0.04	0.10
Ortho-Phosphate, as P	<0.02	<0.02	0.04
Solids (mg/L)			
Suspended, Fixed	6	1	2
Suspended, Volatile	5	3	5
Suspended, Total	11	3	7
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	170	10
Fecal Streptococci	20	110	na
Total Coliform	1,100	170	130
Other			
Chlorophyll *a* (µg/L)	25.60	12.59	12.63
pH (pH units)	na	na	8.6
Turbidity (N.T.U.)	2.2	2.6	3.4
Biochemical Oxygen Demand (mg/L)	<2	<2	<2
Chemical Oxygen Demand (mg/L)	33.0	30.7	38.7

Table 22 Little Arm Beach Shoreline Field and Laboratory Water Quality Data, 2003

Surface Parameters	**May 13**	**July 8**	**Aug. 25**
Field Measurements			
Air Temperature (ºC)	18	19	29
Water Temperature (ºC)	12.1	20.5	23.0
Dissolved Oxygen (mg/L)	6.72	8.56	11.75
pH (pH units)	8.30	8.92	9.17
Conductivity (µS/cm)	2,078	2,185	2,175
Secchi Disk (meters)	0.6	na	0.6
Turbidity (NTU)	6.58	12.50	7.20
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	14	11	13
Nitrate, as Nitrogen	<0.02	<0.02	0.04
Total Kjedahl Nitrogen	1.7	2.1	2.3
Total Phosphorous	0.13	0.19	0.25
Ortho-Phosphate, as P	0.04	<0.02	0.12
Solids (mg/L)			
Suspended, Fixed	9	8	7
Suspended, Volatile	5	9	14
Suspended, Total	14	17	21
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	50
Fecal Streptococci	20	530	10
Total Coliform	300	<100	na
Other			
Chlorophyll *a* (µg/L)	20.57	47.32	46.14
Turbidity (N.T.U.)	3.98	10.86	9.57
Biochemical Oxygen Demand (mg/L)	1.6	5.1	5.6
Chemical Oxygen Demand (mg/L)	38.4	38.0	51.2

Table 23 Little Arm Beach Shoreline Field and Laboratory Water Quality Data, 2004

Surface Parameters	**June 2**	**July 21**	**Sept 28**
Field Measurements			
Air Temperature (ºC)	12	18	20
Water Temperature (ºC)	13.3	18.4	13.8
Dissolved Oxygen (mg/L)	9.73	7.94	10.75
pH (pH units)	8.69	8.65	na
Conductivity (µS/cm)	1,810	2,125	1,716
Secchi Disk (meters)	0.9	1.1	0.6
Turbidity (NTU)	4.65	4.68	5.20
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	12.0	11.2	12.8
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.02	<0.02	0.03
Total Kjedahl Nitrogen	1.3	1.2	1.4
Total Phosphorous	0.09	0.08	0.12
Ortho-Phosphate, as P	<0.02	<0.02	0.04
Solids (mg/L)			
Suspended, Fixed	5	3	3
Suspended, Volatile	3	4	7
Suspended, Total	8	7	11
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	200	40
Fecal Streptococci	20	380	n/a
Total Coliform	30	400	900
Other			
Chlorophyll *a* (µg/L)	10.96	18.30	11.36
pH (pH units)	na	na	8.8
Turbidity (N.T.U.)	3.2	4.3	3.8
Biochemical Oxygen Demand (mg/L)	2.6	2.4	2.9
Chemical Oxygen Demand (mg/L)	31.0	31.7	39.0

Table 24 North Regional Park Beach Shoreline Field and Laboratory Water Quality Data, 2003

Surface Parameters	May 13	July 8	Aug. 25
Field Measurements			
Air Temperature (ºC)	na	17	20
Water Temperature (ºC)	na	18.0	19.5
Dissolved Oxygen (mg/L)	na	11.4	8.52
pH (pH units)	na	9.15	9.07
Conductivity (µS/cm)	na	2,015	2,100
Secchi Disk (meters)	na	<1.3	0.9
Turbidity (NTU)	na	2.12	6.03
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	11	11	14
Nitrate, as Nitrogen	<0.02	<0.02	0.05
Total Kjedahl Nitrogen	1.2	1.4	2.1
Total Phosphorous	0.06	0.05	0.09
Ortho-Phosphate, as P	<0.02	<0.02	0.03
Solids (mg/L)			
Suspended, Fixed	5	2	4
Suspended, Volatile	3	5	11
Suspended, Total	8	6	15
Bacteria (orgs/100 mL)			
Fecal Coliform	10	220	<10
Fecal Streptococci	10	30	150
Total Coliform	800	400	500
Other			
Chlorophyll *a* (µg/L)	4.25	<0.20	23.35
Turbidity (N.T.U.)	1.47	2.43	5.42
Biochemical Oxygen Demand (mg/L)	1.1	1.7	3.5
Chemical Oxygen Demand (mg/L)	32.1	31.6	46.8

Table 25 North Regional Park Beach Shoreline Field and Laboratory Water Quality Data, 2004

Surface Parameters	**June 1**	**July 20**	**Sept 27**
Field Measurements			
Air Temperature (ºC)	15	25	16
Water Temperature (ºC)	12.0	24.4	13.7
Dissolved Oxygen (mg/L)	12.30	9.06	11.04
pH (pH units)	8.74	8.87	9.24
Conductivity (µS/cm)	1,863	2,191	1,784
Secchi Disk (meters)	0.7	>1.5	>1.0
Turbidity (NTU)	3.02	3.85	7.91
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	12.2	12.2	13.9
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.04	0.04
Total Kjedahl Nitrogen	1.9	1.4	1.6
Total Phosphorous	0.09	0.05	0.07
Ortho-Phosphate, as P	<0.02	<0.02	<0.02
Solids (mg/L)			
Suspended, Fixed	28	1	5
Suspended, Volatile	5	3	4
Suspended, Total	33	4	9
Bacteria (orgs/100 mL)			
Fecal Coliform	10	150	60
Fecal Streptococci	<10	180	na
Total Coliform	150	70	300
Other			
Chlorophyll *a* (µg/L)	8.15	8.00	3.51
Turbidity (N.T.U.)	2.7	2.2	3.1
Biochemical Oxygen Demand (mg/L)	2.8	<2.0	2.3
Chemical Oxygen Demand (mg/L)	34.1	26.0	44.0

Table 26 Regina Beach Shoreline Field and Laboratory Water Quality Data, 2003

Surface Parameters	**May 13**	**July 8**	**Aug. 25**
Field Measurements			
Air Temperature (ºC)	17	18	25
Water Temperature (ºC)	11.1	19.7	22.6
Dissolved Oxygen (mg/L)	9.50	8.51	10.54
pH (pH units)	8.85	8.77	9.08
Conductivity (µS/cm)	1,963	2,189	2,174
Secchi Disk (meters)	0.80	0.95	0.90
Turbidity (NTU)	4.36	6.28	4.52
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	13	11	13
Nitrate, as Nitrogen	<0.02	<0.02	0.04
Total Kjedahl Nitrogen	1.5	1.6	1.9
Total Phosphorous	0.10	0.11	0.27
Ortho-Phosphate, as P	<0.02	<0.02	0.2
Solids (mg/L)			
Suspended, Fixed	10	9	4
Suspended, Volatile	7	7	11
Suspended, Total	17	16	15
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	20
Fecal Streptococci	10	10	80
Total Coliform	30	<100	100
Other			
Chlorophyll *a* (µg/L)	18.68	22.88	40.77
Turbidity (N.T.U.)	4.48	7.85	6.24
Biochemical Oxygen Demand (mg/L)	2.9	3.4	4.1
Chemical Oxygen Demand (mg/L)	35.3	40.2	45.7

Table 27 Regina Beach Shoreline Field and Laboratory Water Quality Data, 2004

Surface Parameters	June 2	July 21	Sept. 28
Field Measurements			
Air Temperature (ºC)	18	20	20
Water Temperature (ºC)	13.0	21.8	14.1
Dissolved Oxygen (mg/L)	11.05	6.85	9.46
pH (pH units)	8.83	8.72	na
Conductivity (µS/cm)	1,643	2,050	1,695
Secchi Disk (meters)	0.80	1.10	0.95
Turbidity (NTU)	5.78	5.26	5.80
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	11.0	11.2	12.3
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.02	0.09	0.03
Total Kjedahl Nitrogen	1.1	1.2	1.3
Total Phosphorous	0.07	0.09	0.14
Ortho-Phosphate, as P	<0.02	0.03	0.06
Solids (mg/L)			
Suspended, Fixed	4	4	4
Suspended, Volatile	3	4	8
Suspended, Total	7	7	12
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	180	<10
Fecal Streptococci	<10	1,060	na
Total Coliform	<10	150	210
Other			
Chlorophyll *a* (µg/L)	15.53	16.00	12.05
pH (pH units)	na	na	8.7
Turbidity (N.T.U.)	3.2	4.0	5.4
Biochemical Oxygen Demand (mg/L)	2.5	<2.0	3.0
Chemical Oxygen Demand (mg/L)	23.0	34.8	43.6

Table 28 Valeport Control Structure Shoreline Field and Laboratory Water Quality Data, 2003

Surface Parameters	May 13	July 8	Aug 25
Field Measurements			
Air Temperature (ºC)	14	22	28
Water Temperature (ºC)	na	20.6	22.9
Dissolved Oxygen (mg/L)	na	9.51	8.14
pH (pH units)	na	9.15	8.93
Conductivity (µS/cm)	na	596	651
Secchi Disk (meters)	0.6	>1.0	na
Turbidity (NTU)	11.1	38.7	15.1
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	13	7	8
Nitrate, as Nitrogen	<0.02	0.90	1.14
Ammonia, as Nitrogen	0.02	0.08	na
Total Kjedahl Nitrogen	1.9	2.9	2.1
Total Phosphorous	0.15	0.34	0.26
Ortho-Phosphate, as P	0.02	0.03	0.08
Solids (mg/L)			
Total Dissolved	1,556	na	na
Suspended, Fixed	20	22	16
Suspended, Volatile	6	20	13
Suspended, Total	26	43	29
Bacteria (orgs/100 mL)			
Fecal Coliform	10	200	20
Fecal Streptococci	30	420	30
Total Coliform	600	200	100
Other			
Chlorophyll *a* (µg/L)	31.93	174.63	107.83
Conductivity (µS/cm)	2,070	na	na
pH (pH units)	8.8	na	na
Turbidity (N.T.U.)	10.41	40.40	17.35
Biochemical Oxygen Demand (mg/L)	2.6	11.0	6.9
Chemical Oxygen Demand (mg/L)	35.3	42.8	37.8

Table 29 Valeport Control Structure Shoreline Field and Laboratory Water Quality Data, 2004

Surface Parameters	June 2	July 20	Sept. 27
Field Measurements			
Air Temperature (ºC)	15	25	14
Water Temperature (ºC)	14.6	25.4	13.0
Dissolved Oxygen (mg/L)	6.93	3.94	10.54
pH (pH units)	7.78	7.85	na
Conductivity (µS/cm)	687	986	1,527
Turbidity (NTU)	na	21.0	15.5
Laboratory Analyzed Parameters			
Nutrients (mg/L)			
Dissolved Organic Carbon	10.2	10.4	14.5
Nitrate, as Nitrogen	0.78	0.75	<0.04
Ammonia, as Nitrogen	0.56	0.41	0.04
Total Kjedahl Nitrogen	3.3	1.9	2.1
Total Phosphorous	1.48	0.39	0.22
Ortho-Phosphate, as P	0.09	0.20	0.04
Solids (mg/L)			
Suspended, Fixed	956	22	14
Suspended, Volatile	80	7	12
Suspended, Total	1,036	29	26
Bacteria (orgs/100 mL)			
Fecal Coliform	330	100	30
Fecal Streptococci	620	90	na
Total Coliform	4,000	70	230
Other			
Chlorophyll *a* (µg/L)	27.19	36.43	16.30
Turbidity (N.T.U.)	170	21	16
Biochemical Oxygen Demand (mg/L)	4.4	4.4	6.4
Chemical Oxygen Demand (mg/L)	50.0	33.3	54.6

10.0 Appendix B

10.1 Lake Stewardship Manual

This manual is intended to provide lake stewards with an explanation of the parameters commonly analyzed as part of a water quality monitoring program. Water quality monitoring is a key component of any lake stewardship activity. Monitoring enables local groups and residents to understand the characteristics of their lake and how activities around a lake may impact water quality. This knowledge enables stewards to set goals and objectives to improve and protect lake water quality. Lake stewardship groups may aid in the collection of water quality data, share acquired information, educate the public on sound lake and drainage basin management, foster partnerships with government and research personnel, and develop lake enhancement and protection projects.

The Saskatchewan Watershed Authority, *Lake Stewardship Program* provides technical assistance and guidance in order to facilitate lake stewardship goals and objectives. The *Lake Stewardship Program* may include a water monitoring program. The scope and purpose of water quality monitoring programs are to assess current water quality conditions by collecting representative data which may be used to examine changes or trends in water quality over time. Baseline stations are typically located close to the center of the lake at the deepest point. Shoreline sampling sites, identified by lake stewards, may also be included in the monitoring program to assess localized point or non-point source pollution from the watershed. These cooperative efforts result in a well planned sampling program which over time provides information on temporal changes in water quality resulting from storm events, drought, season, or increased lake use.

In Saskatchewan, *Surface Water Quality Objective* (1997) are set for various uses of water including protection of aquatic life, contact and non-contact recreation, irrigation, livestock, watering, municipal, and domestic uses. As a result, no one set of objectives or guidelines can be used in the assessment of surface water quality. Consequently, water quality parameters are discussed in this manual, in terms of the Saskatchewan *Surface Water Quality Objectives* (1997), for contact and non-contact recreation, as well as the protection of aquatic life.

10.2 Parameter Summary

1. Trophic Status - is a lake classification system based on the amount of nutrients in the lake and its' resulting biological productivity. Several water quality parameters are measured and used as indicators to determine the trophic status of a lake. The most commonly used "trophic indicators" include nutrients, chlorophyll *a*, and secchi disk transparency (water clarity). Nutrient additions increase biological productivity, which may be measured as chlorophyll *a*, which decreases water clarity, measured by secchi disk transparency. As a result, biological productivity is used to determine lake trophic status. There are four trophic states: oligotrophic, mesotrophic, eutrophic, and hypertrophic, which range from low to extreme biological productivity respectively. Oligotrophic lakes have low inputs if nutrients, organic matter and sediment and consequently, little biological productivity. In contrast, eutrophic lakes are very productive with high levels of nutrients, organic matter and sediments.

2. Nutrients - primary productivity, aquatic plant and algae growth, is dependent on nutrients to stimulate and sustain growth. As a result, the availability of particular essential nutrients such as phosphorus and nitrogen often determines lake productivity.

3. Phosphorus - there are numerous forms of phosphorus. The two most commonly measured forms of phosphorus are total phosphorus (TP) and orthophosphate (PO_4). Total phosphorus is a measure of all phosphorus forms including dissolved and particulate organic phosphates from algae and other organisms, inorganic particulate phosphorus from soil particles and other solids, and polyphosphates from detergents and dissolved orthophosphates. Orthophosphate is the only directly usable form of soluble inorganic phosphorus by aquatic plants and algae.

4. Nitrogen - there are five forms of nitrogen found in freshwater lakes: elemental nitrogen (N_2), organic nitrogen, ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2). Only three forms of nitrogen (ammonia, nitrate, and nitrite) are readily available to aquatic plants and algae for growth. As a result, these three nitrogen compounds, plus total kjeldahl nitrogen (TKN), a measurement of organic and ammonia nitrogen, are usually analyzed in most monitoring programs. Common anthropogenic nitrogen sources include sewage, feedlots and fertilizers.

   Ammonia-nitrogen is the preferred form of nitrogen for uptake by aquatic plants and algae. Typically concentrations are low in healthy lakes at less than 1 mg/L. Decomposing organic material produces ammonia as a byproduct. Ammonia concentrations increase with corresponding increases in lake temperature and/or pH. As a result, in eutrophic lakes ammonia concentration can reach toxic levels due to favorable conditions including: decomposing organic matter, high temperatures and pH.

Nitrate-nitrogen is used by aquatic plants and algae but must be reduced to ammonia prior to use. As a result, ammonia is the preferred form of nitrogen. Nitrate concentrations are less than 0.05 mg/L in healthy lakes, most surface waters are less than 0.3 mg/L. In eutrophic lakes nitrate will be depleted at the top due to algae consumption and high at the bottom from release by decomposing organic material.

Nitrite-nitrogen is readily oxidized to nitrate. As a result, nitrite is typically found at very low concentrations, less than 0.005 mg/L. When nitrite concentrations are high it may indicate organic pollution by sewage systems.

Total Kjehldahl nitrogen is a measure of the organic and ammonia nitrogen. When samples are analyzed for TKN and nitrate the values may be subtracted to estimate the ammonia concentration.

5. Chlorophyll *a* - all plants and algae contain the photosynthetic pigment, chlorophyll *a*, used to absorb light energy and produce living matter. In the laboratory chlorophyll *a* is easily extracted from algae and measured. As a result, chlorophyll *a* is used to determine the amount of algae in a water sample and therefore the intensity of lake primary productivity. This parameter is commonly used as a trophic status indicator.

6. pH - is an important water quality parameter. It affects most chemical and biological reactions within the lake. Extremes in pH or rapid changes in pH can be detrimental to aquatic life. pH is a measurement of the hydrogen ion concentration, expressed on a logarithmic scale, ranging from 0 (acidic) to 14 (alkaline). Waters with a pH of 7 are neutral. The logarithmic scales means that with every unit increase in pH the hydrogen ion concentration increases ten times. Lake pH is influenced by the addition of salts, acids, bases, and increased photosynthesis. Lakes may be acidified by the accumulation of acidic runoff and humic substances drained from igneous deposits in the watershed. Normal rainwater has a pH of 5.6 making it another acidic addition. In contrast, drainage of calcareous or limestone deposits are basic additions. Photosynthesis also depletes the carbon dioxide and hydrogen ions, which increase the pH, and the lake may become more basic. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a pH range of 6.5 to 8.5 as optimal for surface waters.

7. Total Alkalinity - is a measure of water's acid-neutralizing capacity. pH is the measure of acid and base reactions in water, while alkalinity is a measure of the ability of water to resist acid and base reactions through buffering. Lakes with low alkalinity have large daily pH fluctuations indicating they are poorly buffered. The capability of the system to buffer additions is dependent on the carbonate, bicarbonate and hydroxide content. Water with an abundance of buffering materials is more resistant to changes in pH. As a result, soft water lakes have poor buffering capacity and are therefore vulnerable to the addition of acid. A total alkalinity level of 100 to 200 mg/L will stabilize the pH of most

water bodies. Consequently, lakes with total alkalinity levels greater than 200 mg/L are typically well buffered and should resist sudden changes in pH.

8. Conductivity - is a measure of the ability of water to conduct an electric current, which is dependent on the concentration of dissolved ions in solution. Conductivity is variable and is dependent on the geology and soil in the watershed and is determined by the concentration of specific ions and lake temperature. As a result, once the ion concentration is known, changes in conductivity reflect modifications of ion concentrations. Conductivity is corrected to 25°C and reported as specific conductance (umhos/cm @ 25°C) to enable direct comparison of samples collected at different temperatures.

9. Turbidity - is the measure of water clarity. A reduction or lack of water clarity is indicative of turbidity. Turbidity is caused by solids suspended in the water including clay, silt and plankton (small plants and animals). Sources of turbidity are soil erosion, waste discharge, urban runoff, algal growth, or abundant bottom feeders, such as carp, that stir up bottom sediment. Increases in turbidity may decrease light penetration, destroy or modify fish habitat and increase water temperature which decreases oxygen concentrations. As a result, the Saskatchewan *Surface Water Quality Objectives* (1997), state that turbidity should not be increased by more than 25 turbidity unit above ambient values. Turbidity may be measured using a secchi disk or a more precise turbidimeter.

10. Secchi Disk Readings - is a measure of water transparency. Transparency is affected by suspended sediment, algae, and water colour. Secchi depth is determined by lowering a weighted black and white disk, 20 cm in diameter, from the shaded side of a boat and averaging the depth were the disk disappears and then reappears from view. Volunteers taking secchi measurements must remember to remove their sunglasses which enhance their ability to look down into the water. The secchi disk reading is a simple measurement that may be used as a trophic status indicator. The Saskatchewan *Surface Water Quality Objectives* (1997), state that for bathing waters the secchi disk should be visible at 1.2 m.

11. Biological Oxygen Demand (BOD 5-Day) - Aerobic bacteria decompose organic matter such as plants and animals. In this process, bacteria breakdown organic matter and oxidize it by adding oxygen. Biological oxygen demand is the quantity of oxygen used in the oxidation of organic matter. When organic matter is decomposed and oxidized, nutrients are released and plant growth is stimulated. This increases the amount of organic material requiring decomposition and leads to an increased biological oxygen demand (BOD). Consequently, when BOD levels are high, oxygen is being consumed by decomposition processes and this limits the oxygen available for other organisms such as invertebrates and fish. Biological oxygen demand can be measured in the laboratory to determine the amount of dissolved oxygen consumed by oxidative processes in water over a 5 day period at 20°C. *Surface Water Quality Objectives* (1997), state the BOD must not exceed a limit which would create dissolved oxygen content of less than 5 mg/L.

12. Chemical Oxygen Demand (COD) - is the quantity of oxygen consumed by biological and non-biological oxidation of organic matter in water. In contrast to BOD, COD may be measured in a matter of hours. As a result, COD is often used to measure the oxygen demand of waste water discharged, including sewage and industrial effluent.

13. Dissolved Oxygen - oxygen is readily dissolved in water and is supplied to surface water through the diffusion of atmospheric oxygen and the production of oxygen by aquatic plants and algae during photosynthesis. Although oxygen is very soluble in water, a number of factors can determine the amount of dissolved oxygen found in a lake including: water temperature, atmospheric pressure (or altitude), wind and wave action (mixing), salinity, respiratory and decomposition processes, and the shape and depth of a lake.

    In lakes, dissolved oxygen levels can fluctuate with depth and taking dissolved oxygen and temperature profiles can provide information on the mixing patterns in the water. Dissolved oxygen and temperature profiles are measured at the baseline monitoring stations. Dissolved oxygen is more soluble in cold water than in warm water. Consequently, dissolve oxygen concentrations may vary throughout the day with temperature. The solubility of oxygen is greater in water than in the atmosphere. As a result, oxygen from the atmosphere diffuses into water. Oxygen diffusion is enhanced by wind and wave action which distributes oxygen throughout the water. Dissolved oxygen concentrations are variable based on time, weather and temperature. Consequently, sampling needs to be repeated within the same time frame to enable year to year comparisons.

    Dissolved oxygen is essential to aquatic life. Fish, invertebrates, and aerobic bacteria all require oxygen for respiration. If dissolved oxygen levels are depleted, aquatic organisms may become stressed or die. Some organisms are more tolerant of low oxygen levels than others. The amount of oxygen required depends on the species and life stage. Dissolved oxygen levels of 1 or 2 mg/L will not support fish populations. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a minimum dissolved oxygen concentration of 5 mg/L for the protection of all stages of warm water biota.

14. Dissolved Organic Carbon (DOC) - is responsible for making lake water look "tea" coloured. DOC is decomposed organic material in the form of humic and fulvic acids which are relatively stable with low solubility. Precipitation, leaching and decomposing from surrounding terrestrial and wetland areas are the primary source of dissolved organic carbon additions to freshwater lakes. Plants and algae within the lake can also provide a contribution to DOC concentrations within a lake. Lake productivity, nutrient cycling, temperature, and light penetration are all affected by DOC concentrations. Currently, research is focused on the attenuation of UV radiation by DOC for the protection of aquatic life.

15. Microbiological Water Quality - the bacterial quality of surface water supplies is of importance for a number of water uses, including contact and non-contact

recreation such as swimming, boating, or fishing. The bacterial quality of a water supply can also be important for irrigation of certain crops, such as fruits and vegetables, and as a supply for domestic or municipal systems. All surface waters are open to the environment and will contain a variety of bacterial species. These organisms play an important role in the decomposition of organic material and recycling of nutrients. While bacteria are present in all surface waters, it is the sanitary quality of the reservoir that is of concern.

In Saskatchewan, the bacterial quality of surface waters is assessed by the presence of indicator organisms, such as total coliform and fecal coliform bacteria. The Saskatchewan *Surface Water Quality Objectives* set guidelines for the number of these organisms acceptable within a surface water body based on the various uses of the water. For contact recreation, the *Surface Water Quality Objectives* (1997) state that the mean density of fecal coliforms should not exceed 200 organisms per 100 mL of water. For non-contact recreation and general surface water quality, the *Surface Water Quality Objectives* state that the density of fecal coliforms should not exceed 1,000 organisms per 100 mL of water, nor should the total coliforms exceed a density of 5,000 organisms per 100 mL of water.

16. <u>Total Dissolved Solids (TDS)</u> - is a measure of the dissolved ions (minerals) in water. The cations (calcium, magnesium, sodium, and potassium), and their associated anions (bicarbonate, sulphate, and chloride) are the main ions that contribute to the total dissolved solids of a water supply. The amount of minerals found in a water supply depends mainly on the types of rock or soil the water comes into contact with and the amount of water lost to evaporation relative to precipitation. A high mineral concentration can restrict the use of the water, depending on the specific minerals present and their individual concentration. TDS can also be used as an indicator of the salinity of a water body. While a high TDS can affect the use of water for irrigation, livestock watering, municipal and domestic uses, it generally does not have a significant impact on lake recreation activities.

17. <u>Total Suspended Solids (TSS)</u> - is organic and inorganic material present in the water including: algae, plant material, micro-organisms, and sand, silt, and clay particles. Total suspended solids can be divided into categories: fixed and volatile suspended solids.

18. <u>Total Hardness</u> - is the concentration of calcium and magnesium ions in the water, expressed as calcium carbonate. Calcium carbonates precipitates from hard waters encrusting water pipes and forming scale deposits when heated. Hard waters are usually found were water drainage is derived from calcareous deposit. In contrast, soft waters have low ions concentration, low salinity, and are usually derived from acidic igneous rock drainage.

19. <u>Salinity</u> - is defined as the sum concentration of all ionic components dissolved in fresh and saline water. Ionic concentration is dependent on ion exchanges with

the atmosphere and watershed including rock, soil, human activity, the ocean, and lake sediment. Four major cations: calcium, magnesium, sodium, and potassium, and four major anions: bicarbonate, carbonate, sulphate, and chloride determine 99% of total ionic salinity. Consequently, other elements such as nitrogen, phosphorus, iron, and manganese contribute little to the total ionic salinity of the water.

20. Cations: Calcium, Magnesium, Sodium & Potassium - The concentration of cations in lake water is primarily determined by the watershed geology. Calcium is derived from the watershed from weathering of rocks and soil, especially limestone. Calcium is readily soluble in water and is one of the most abundant cations in lake water. Magnesium is a component of igneous rock as ferromagnesium minerals and sedimentary rock as magnesium carbonates, and is the eighth most abundant natural element. Industrial and municipal wastes in addition to natural weathering determine calcium and magnesium concentrations. Together calcium and magnesium salts determine the hardness of the water.

Calcium concentrations are strongly influenced by biological metabolism. In contrast, concentrations of magnesium, sodium and potassium are not modified substantially by biological use. Calcium is an essential nutrient used by algae in physiological process. Magnesium helps form chlorophyll and consequently is a micronutrient required by all plants and algae. Magnesium concentrations are relatively unaffected by biological use because quantities consumed are significantly less than the quantity available. Sodium and potassium may be used by certain types of algae but concentrations remain relatively stable.

21. Anions: Sulphate, Chloride, Bicarbonate & Carbonate - Sulphate is the primary form of dissolved sulfur. Sulfur is required by all living organisms. The cycling of sulphur within a lake is complex and results in variable concentrations spatially and seasonally. Chloride concentrations are also determined by spatial and season distribution, relatively unaffected by biological uptake. In contrast, bicarbonate and carbonate concentrations are determined by the lake's alkalinity and productivity.

22. Elements: Iron & Manganese - Iron and manganese are essential elements to physiological processes of algae, plant and animals. Although these elements are biologically important they also have a role in phosphorus cycling within the lake and affect phosphorus availability. As a result, iron and manganese concentrations are often measured as part of a water quality sampling program.

23. Metals: Mercury, Aluminum, and Arsenic - Mercury, aluminum, and arsenic are metals which naturally occur in all rock types. Natural rock weathering and erosion results in the addition of these elements to lake water. However, the concentration of these metals may be dramatically higher than natural concentration due to human activity causing pollution.

Mercury is used in the chlor-alkali, paint, pulp and paper industries. Products include chlorine, hydrogen, paint pigments, and preservatives, electrical equipment such as thermometers, batteries and lamps. In the lake mercury is transformed by microorganisms into methlymercury. There are two forms of methlymercury: monomethylmercury, and dimethylmercury. The amount of each form is dependent on amount of mercury, presence of microbes, organic carbon concentrations, pH and lake temperature. Dimethylmercury is produced under high pH conditions, while monomethlymercury formation is favoured under acidic conditions. These methylated forms of mercury accumulate in aquatic organisms, such as fish and invertebrates. Mercury is an acute neurotoxin, which negatively affects the biota of a polluted lake. Biological organisms may accumulate mercury directly from the water or through the food chain. Bioconcentration of mercury are high in aquatic organisms due to the rapid uptake of methylmercury by organisms. The concentration of mercury is magnified up the food chain. As a result, organisms at the bottom of the food chain have lower concentrations of mercury accumulated from the water. In contrast, predatory fish, such as lake trout, accumulate higher concentrations of mercury from their food source as well as the water. Consequently, it is said that mercury concentrations are biomagnified up the food chain. The Saskatchewan *Surface Water Quality Objectives* (1997) specifies that mercury concentration should be less than 0.001 mg/L or 1 µg/L for the protection of aquatic life and wildlife.

Aluminum is abundant in the natural environment but typically inorganic and biological processes maintain aluminum in an unreactive form. Acidic precipitation and poorly buffered soils result in reactive aluminum additions from upland soil and rock weathering. The primary source of aquatic aluminum pollution is from effluent produced by industries using aluminum in their processing or alum as a flocculent. Aluminum may enter the lake from local or long distance atmospheric transportation and deposition. The concentration of reactive aluminum increases with water acidity. As a result, decreases in pH and increases in organic carbon result in increased concentrations of aluminum in the lake water. Aluminum is highly reactive and can be toxic to biological organisms at low concentrations. The Saskatchewan *Surface Water Quality Objectives* (1997) for livestock watering, aluminum concentrations should be less than 5 mg/L or 5,000 µg/L.

Arsenic is naturally released into the environment by rock weathering and volcanic release. However, human activities can cause twice as much arsenic to be released into the environment as natural sources. Arsenic is used in many industrial processes and products. Common products which may be used around lakes are pesticides and herbicides containing arsenic. Aquatic arsenic concentrations are dependent on geological chemistry, industrial and human activity in the watershed. In the lake, arsenic is removed from the water and deposited in the sediment by adsorbing to suspended organic matter which settles to the bottom of the lake. Consequently, arsenic may form a wide variety of compounds with elements found in lake water. Arsenic is toxic at low concentrations to aquatic organisms. Aquatic organisms bioaccumulate arsenic in their tissue and organs. Accumulated arsenic concentrations depend on the organism, its age, water temperature and the concentration of arsenic present. In contrast to mercury, there is no evidence of arsenic biomagnification. The Saskatchewan *Surface Water Quality Objectives* (1997), for the protection of aquatic life and wildlife, arsenic concentrations should be less than 0.05 mg/L or 50 µg/L.