Table of Contents

List of Tables ii
List of Figures ii
1.0 Background 1
2.0 Turtle Lake 1
2.1 Stewardship Activities 2
2.2 Purpose and Scope 2
2.3.1 Field Measurements 4
2.3.2 Laboratory Analysis 4
2.3.3 Stewardship Involvement 4
3.0 Trophic Status 4
4.0 Water Quality Index Summary 5
5.0 Results 6
5.1 Field Measurements 6
5.2 Turtle Lake Water Quality Index 7
6.0 Discussion and Recommendations 9
7.0 References 9
8.0 Appendix A – Water Quality Summary Tables 10
9.0 Appendix B 18
9.1 Lake Stewardship Manual 18
9.2 Parameter Summary 19

List of Tables

Table 1 Water Quality Index Objectives ... 10
Table 2 Field Measurements from Turtle Lake Baseline Site, 2003 ... 10
Table 3 Dissolved Oxygen, Temperature, and Conductivity Profiles for Turtle Lake Baseline Site, 2003 ... 11
Table 4 Field Measurements at Turtle Lake Baseline Site, 2004 ... 11
Table 5 Dissolved Oxygen, Temperature, and Conductivity Profiles for Turtle Lake Baseline Site, 2004 ... 12
Table 6 Turtle Lake Surface Baseline Parameters Measured in 2003 and 2004 ... 14
Table 7 June 9, 2004 Comparison Between Surface, Integrated, and Bottom Parameters for Turtle Lake Baseline Site ... 15
Table 8 July 13, 2004 Comparison Between Surface, Integrated, and Bottom Parameters for Turtle Lake Baseline Site ... 16
Table 9 August 10, 2004 Comparison Between Surface, Integrated, and Bottom Parameters for Turtle Lake Baseline Site ... 17

List of Figures

Figure 1 Turtle Lake 2003 and 2004 Sampling Station ... 4
Figure 2 Turtle Lake Water Quality Index Score for 1998 - 2004 ... 7

1.0 Background

Saskatchewan Watershed Authority (SWA) developed the *Lake Stewardship Program* in September 1997 to support stewardship groups throughout Saskatchewan. The mandate of this 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 Turtle Lake

Turtle Lake is a popular recreational lake, located approximately 120 km northwest of North Battleford and 35 km north of Glaslyn, Saskatchewan. Development around the lake includes a number of villages, hamlets, and resort communities. Currently, approximately 23% of the shoreline is characterized by residential and commercial development (Liaw 1999). Turtle Lake has a maximum depth of 14.3 meters (m) and a mean depth of 5.6 m. The Turtle Lake River outlet located at the south end of the lake does not have a control structure and consequently lake levels fluctuate naturally. Since 1964, Turtle Lake has fluctuated approximately one meter reaching a maximum 655.272 meters above seas level (masl) in 1975. In 2003, the lake level ranged from 654.028 masl to 654.272 masl. Turtle Lake's water levels are primarily maintained by surface inflow and precipitation.

In 2003, stewards at Turtle Lake became involved in the Saskatchewan Watershed Authority, *Lake Stewardship Program*. At this time a water quality monitoring program was established to provide information on the current water quality of Turtle Lake in order to assess lake health. The monitoring program is a cooperative effort between local volunteers and Saskatchewan Watershed Authority staff to collect water samples from one baseline station on Turtle Lake. This report presents the results from the 2003 and 2004 water quality monitoring program.

2.1 Stewardship Activities

Turtle Lake Watershed Inc. (TLWI) is an enthusiastic and productive group. As part of the Lake Stewardship Program TLWI volunteers have assisted SWA with water quality monitoring throughout 2003 and 2004. Additional funding was provided to the TLWI by the Department of Fisheries and Oceans under their Fish Habitat Stewardship-In-Action Program. TLWI used Stewardship-In-Action funding to: incorporate as a non-profit organization, tour Turtle Lake to identify water quality and riparian concerns, establish a website, and hold board meetings.

TLWI representatives are active on many committees and keep current by attending stewardship conferences. Turtle Lake representatives sit on both the North Saskatchewan River Watershed planning committee and the Saskatchewan Network of Watershed Stewards (SNOWS) committee. Group representatives have also attended pertinent conferences such as the *Erosion & Sediment Control* workshop hosted by the Department of Fisheries and Oceans (DFO) and the *People for Watershed – The Power of Partnerships* conference held jointly by Saskatchewan Network of Watershed Stewards and the Canadian Water Resource Association (CWRA).

In 2005, the Turtle Lake Watershed Partnership plans to be an active member in the *Lake Stewardship Program*. The group will participate in a number of programs organized by the Saskatchewan Watershed Authority. These projects will include a Centennial Lakeshore Cleanup and Living-By-Water workshops. Dr. Dennis Lawson will provide a workshop on July 23 and 24 to further educate TLWI members on healthy shoreline living. These programs will provide community outreach and education to facilitate riparian area enhancement around Turtle Lake.

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 Turtle 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 Turtle Lake in 2003 and 2004. A sampling station was established near the point of maximum depth near the center of the lake (Figure 1). This station is referred to as baseline station. The baseline sampling station's global positioning satellite (G.P.S.) co-ordinates were referenced so that the same location was sampled each time. Samples collected in 2003 - 2004 from the baseline sampling station

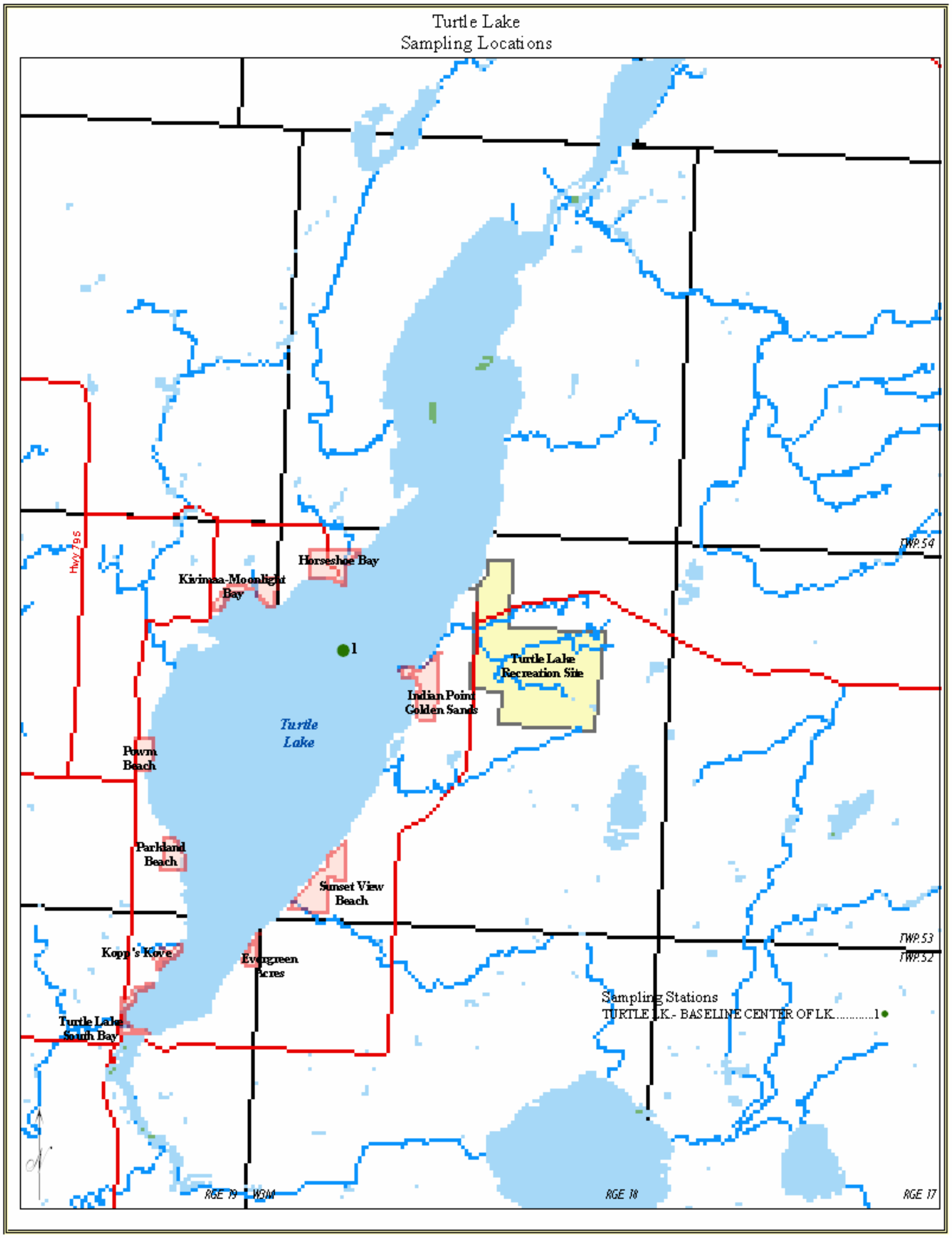

Figure 1 **Turtle Lake 2003 and 2004 Sampling Locations**

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. Sample collection and field monitoring of the baseline station was conducted initially on October 15, 2003. In 2004, sampling was conducted four times: March 1, June 9, July 13, and August 10.

2.3.1 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.

2.3.2 Laboratory Analysis

Baseline samples were analyzed for nutrients, major ions, chlorophyll *a*, dissolved and suspended solids, and bacteria (See Tables 6 to 9). All water samples were collected in plastic bottles and shipped in coolers to the Provincial Laboratory in Regina, Saskatchewan.

2.3.3 Stewardship Involvement

Volunteers are essential to the water monitoring program providing transportation to sampling locations, sample collection assistance, and provide local knowledge. In 2004, Merle Robinson and Bob Gourlay assisted Saskatchewan Watershed Authority technologist Sheldon Ofukany with sampling Turtle 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 as 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 Summary

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.

5.0 Results

5.1 Field Measurements

Surface water quality parameters measured at the baseline station have been summarized in Tables 2 to 5. There are five important field measurements to examine when assessing water quality: dissolved oxygen and temperature profiles, conductivity, turbidity, and secchi disk 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. Temperature profiles indicate Turtle Lake is well-mixed and typically does not stratify. Dissolved oxygen concentrations are maintained throughout the water column decreasing at the lake bottom. Profiles show low dissolved oxygen concentrations were experienced in the bottom meter of the lake and normal levels were maintained throughout the remaining water column. The lowest dissolved oxygen concentration of 0.5 mg/L was experienced at 11 meters in depth on July 13, 2004. This anoxic condition may have resulted from oxygen consumption by decomposition or the probe may have been too close to the sediment which adversely affected the measurement. Based on the dissolved oxygen profiles presented in Tables 3 and 5 it may be concluded that dissolved oxygen concentrations are generally maintained above the 5 mg/L objective for the protection of aquatic life supporting a diverse community of biota in Turtle Lake.

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. Conductivity is influenced by watershed geology and soil composition. In 2004, Turtle Lake conductivity at the surface ranged from 602 to 672 µS/cm (Table 5).

The secchi disk reading is a measure of water transparency. Transparency is affected by 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 depth ranged from 1.6 to 3.1 meters, exceeding the 1.2 meter objective for recreational use. As a result, Turtle Lake is a clear lake desirable for lake recreation.

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. Turbidity is low in Turtle Lake with values between 1.25 and 3.04 NTU.

5.2 <u>Turtle Lake Water Quality Index</u>

The Water Quality Index (WQI) value for Turtle Lake in 2004 was 90.1, giving the lake a rating of good water quality (Figure 2).

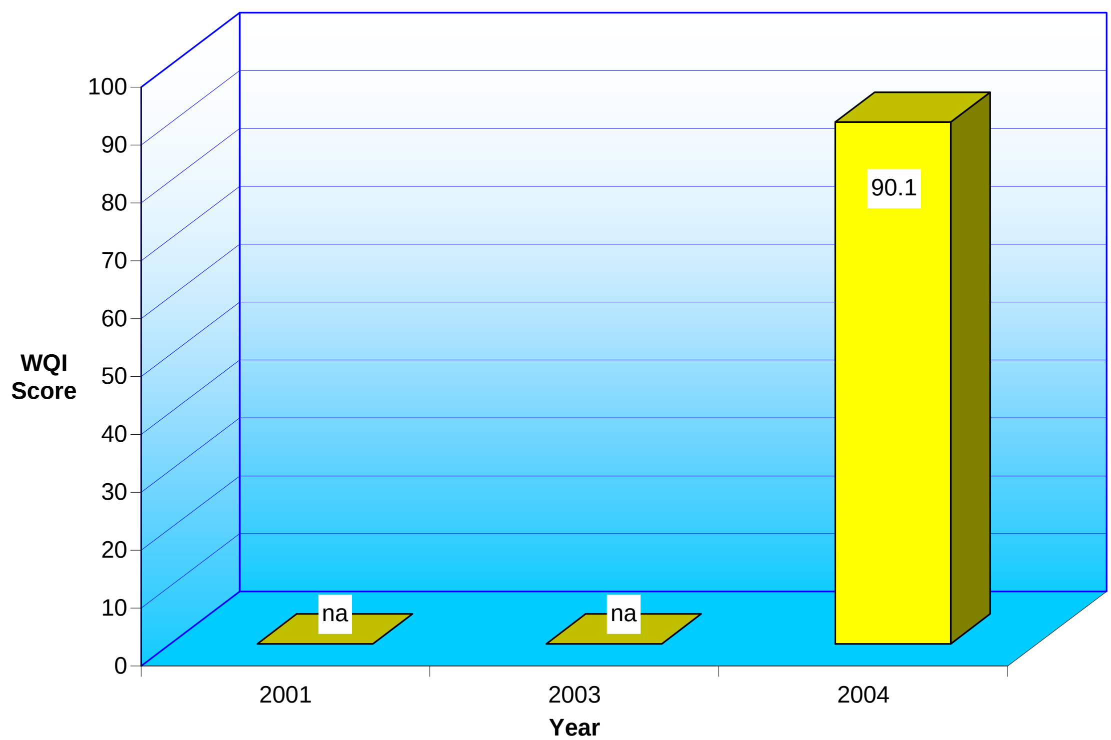

Figure 2 Turtle Lake Water Quality Index Score for 2001 - 2004

The Water Quality Index (WQI) requires at least three sampling events to determine the annual WQI score, although higher confidence is gained with an increased sample size. As a result, insufficient data prevented WQI scores from being calculated for 2001 and 2003. In 2004, the WQI score was 90.1 indicating good water quality. Good water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels. Two parameters measured at Turtle Lake, pH and TDS, exceeded the WQI objectives.

Turtle Lake is an alkaline lake with a pH ranging from 8.80 to 9.38. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a pH range of 6.50 to 8.50 as optimal for surface waters. All samples collected from Turtle Lake had a pH value which exceeds the Water Quality Index objective of 8.50 (Tables 2 and 4).

Cations (calcium magnesium, sodium, and potassium) and their associated anions (bicarbonate, sulphate, and chloride) are the main ions which contribute to the total dissolved solids (TDS) of a water supply. The quantity 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 compared to precipitation additions. A high mineral concentration can restrict the use of the water, depending on the specific minerals present and their individual concentration. The Saskatchewan *Surface Water Quality Objectives* (1997) recommends TDS below 1,000 mg/L for livestock watering and 700 mg/L for irrigation. The water quality objective for TDS is 700 mg/L. In Turtle Lake TDS concentrations ranged between 576 and 750 mg/L.

The remaining parameters used to calculate the WQI score such as fecal coliform bacteria, total phosphorus, and chlorophyll *a* maintained concentrations well below their objective (Table 6). In Saskatchewan, the bacteriological quality of the water is assessed using traditional bacterial indicators such as fecal streptococci or fecal and total coliforms. 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. Saskatchewan's *Surface Water Quality Objectives* (1997) states that the density of fecal coliform bacteria should not exceed 200 organisms per 100mL of water for contact recreation. In all four sample years, fecal coliform bacteria concentrations were measured below 10 orgs/100 mL. Total phosphorus concentrations in Turtle Lake ranged between 0.04 and 0.07 mg/L, well below the 0.10 mg/L WQI objective. The WQI objective for chlorophyll *a* is 50 µg/L. Recorded chlorophyll *a* concentrations range between 1.90 and 7.54 µg/L in all years monitored.

In 2004, water quality samples were collected from the surface, integrated, and bottom of the water column to assess the variation within the water column (Tables 7 to 9). Results showed that there were no significant difference in 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, surface sampling will be resumed at the baseline station to maintain monitoring activities while minimizing associated cost and time constraints.

6.0 Discussion and Recommendations

Turtle Lake has good quality water which meets the Saskatchewan Surface *Water Quality Objectives* (1997) for contact and non-contact recreation. Turtle Lake is an alkaline lake with a pH of 9. Turtle Lake did not experience summer stratification and was well mixed with temperature and dissolved oxygen conditions maintained throughout the water column. In 2004, during the open water season and under winter conditions dissolved oxygen concentrations were maintained at concentrations sufficient to protect fish populations and other aquatic life.

Turtle Lake is an ideal location for recreational water based activities. The bacterial water quality of Turtle Lake is very good with fecal and total coliform bacteria concentrations below laboratory detection limits. The water clarity was excellent with low turbidity and chlorophyll *a* concentrations. As a result, Turtle Lake is a healthy and aesthetically pleasing recreational area ideal for the enjoyment of recreational users.

Turtle Lake has good quality water which should be maintained for the enjoyment of future generations. Residents and other lake users who are interested in the preservation of Turtle Lake are encouraged to become actively involved in the *Turtle Lake Watershed Inc.* 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.

7.0 References

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

Liaw, W.K. (1999). Turtle Lake Fish Habitat Mapping, 1997. Fish Habitat GIS Mapping Report, 10 p., *Turtle Lake habitat mapping*

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

8.0 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 Coliform Bacteria (units/100mL)	200
Total Phosphorus (mg/L)	0.1
Dissolved Nitrate and Nitrite (mg/L)	1
Total Dissolved Solids (mg/L)	700
Chlorophyll *a* (µg/L)	50

Table 2 Field Measurements from Turtle Lake Baseline Site, 2003

Field Data	October 15
Surface Parameters	
Water Temperature (ºC)	9.4
Dissolved Oxygen (mg/L)	9.55
pH (pH units)	9.17
Conductivity (µS/cm)	660
Secchi Disk (meters)	1.9
Turbidity (NTU)	3.04

Table 3 Dissolved Oxygen, Temperature, and Conductivity Profiles for Turtle Lake Baseline Site, 2003

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
15/11/03	0	9.55	9.4	660
	1	8.62	9.5	657
	2	8.19	9.6	659
	3	8.02	9.6	660
	4	7.93	9.6	662
	5	7.94	9.6	663
	6	7.77	9.6	664
	7	7.75	9.6	665
	8	7.81	9.6	667
	9	7.95	9.6	668
	10	8.00	9.8	668
	11	2.10	9.8	656

Table 4 Field Measurements at Turtle Lake Baseline Site, 2004

Field Data	March 1	June 9	July 13	Aug 10
Surface Parameters				
Air Temperature (ºC)	na	na	20	na
Water Temperature (ºC)	3.2	12.5	19.6	18.0
Dissolved Oxygen (mg/L)	10.12	9.47	7.44	7.24
pH (pH units)	9.38	9.01	8.88	8.83
Conductivity (µS/cm)	671	672	659	602
Secchi Disk (meters)	2.0	2.0	3.1	1.6
Turbidity (NTU)	1.36	1.62	1.25	1.49

Table 5 Dissolved Oxygen, Temperature, and Conductivity Profiles for Turtle Lake Baseline Site, 2004

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
1/3/04	0	10.12	3.2	671
	1	8.40	3.1	670
	2	7.97	3.2	670
	3	7.76	3.3	668
	4	7.45	3.3	668
	5	7.38	3.4	667
	6	7.61	3.5	667
	7	7.50	3.7	668
	8	7.36	4.0	666
	9	7.16	4.1	667
	10	1.10	3.9	667
9/6/04	0	9.47	12.5	672
	1	9.50	12.4	670
	2	9.49	12.4	674
	3	9.45	12.3	674
	4	9.35	12.3	674
	5	9.36	12.3	674
	6	9.29	12.2	674
	7	9.28	12.2	674
	8	9.27	12.2	674
	9	9.25	12.2	675
	10	8.77	12.1	675
	11	8.24	11.7	675

Table 5 continued Dissolved Oxygen, Temperature, and Conductivity Profiles for Turtle Lake Baseline Site, 2004

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
13/7/04	0	7.44	19.6	659
	1	7.42	18.5	657
	2	7.92	17.9	663
	3	7.89	17.4	669
	4	7.75	17.0	670
	5	7.41	16.9	670
	6	7.54	16.8	672
	7	7.27	16.6	672
	8	5.76	16.0	670
	9	5.67	15.6	667
	10	4.63	15.0	672
	11	0.50	14.7	698
10/8/04	0	7.24	18.0	602
	1	7.20	18.0	617
	2	7.17	18.0	616
	3	7.18	18.0	616
	4	7.12	18.0	616
	5	7.15	17.9	617
	6	7.09	17.9	617
	7	7.07	17.8	617
	8	7.09	17.8	618
	9	7.00	17.8	618
	10	7.01	17.8	618
	11	7.03	17.8	618
	12	6.94	17.8	620
	13	6.67	17.7	619
	14	4.87	17.2	661

Table 6 Turtle Lake Surface Baseline Parameters Measured in 2003 and 2004

Parameters	Oct 15 2003	Mar 1 2004	June 9 2004	July 13 2004	Aug 10 2004
Nutrients (mg/L)					
Dissolved Organic Carbon	18.0	22.0	93.6	19.1	18.6
Nitrate, as Nitrogen	0.11	0.14	<0.04	<0.04	0.16
Ammonia, as Nitrogen	0.02	0.04	0.03	0.02	0.04
Total Kjedahl Nitrogen	1.4	1.4	1.3	1.2	1.3
Total Phosphorous	0.07	0.06	0.05	0.04	0.05
Ortho-Phosphate, as P	0.05	0.05	0.03	0.03	0.04
Solids (mg/L)					
Total Dissolved	584	750	583	576	583
Suspended, Fixed	2	<1	1	<1	1
Suspended, Volatile	4	2	3	2	4
Suspended, Total	6	2	4	3	5
Bacteria (orgs/100 mL)					
Fecal Coliform	<10	<2	<10	<10	<10
Fecal Streptococci	<10	230	<10	<10	<10
Total Coliform	10	4	<10	<10	<10
Major Ions (mg/L)					
Alkalinity, Total	366	458	361	359	362
Alkalinity, Phenol	26	na	24	25	26
Bicarbonate	383	559	382	377	378
Calcium	20	23	21	21	22
Carbonate	31.2	na	28.8	30.0	31.2
Chloride	2.0	4.0	3.7	3.4	4.4
Hardness, Total	260	300	271	267	273
Magnesium	51	59	53	52	53
Potassium	11	13	11	11	11
Sodium	58	67	56	55	57
Sulphate	28.0	25.0	27.4	26.7	26.0
Other					
Chlorophyll *a* (µg/L)	7.54	1.90	5.11	2.30	6.04
Conductivity (µS/cm)	674	707	669	662	673
pH (pH units)	8.80	9.38	8.80	8.80	8.90
Turbidity (N.T.U.)	2.20	0.60	1.50	0.98	1.30
Biochemical Oxygen Demand (mg/L)	1.8	<2.0	<2.0	<2.0	<2.0
Chemical Oxygen Demand (mg/L)	51.4	56.4	51.8	50.0	51.4
Metals					
Preserved Mercury (µg/L)	na	na	<0.02	<0.02	<0.02
Aluminum (mg/L)	na	na	<0.02	<0.02	<0.02
Arsenic (mg/L)	na	na	0.001	0.001	0.001

Table 7 June 9, 2004 Comparison Between Surface, Integrated, and Bottom Parameters for Turtle Lake Baseline Site

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	93.6	92.2	94.2
Nitrate, as Nitrogen	<0.04	0.10	<0.04
Ammonia, as Nitrogen	0.03	0.03	0.03
Total Kjedahl Nitrogen	1.3	1.4	1.4
Total Phosphorous	0.05	0.07	0.06
Ortho-Phosphate, as P	0.03	0.03	0.03
Solids (mg/L)			
Total Dissolved	583	583	585
Suspended, Fixed	1	14	1
Suspended, Volatile	3	6	5
Suspended, Total	4	20	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	361	363	361
Alkalinity, Phenol	24	24	23
Bicarbonate	382	384	384
Calcium	21	21	21
Carbonate	28.8	28.8	27.6
Chloride	3.7	3.6	3.8
Hardness, Total	271	267	271
Magnesium	53	52	53
Potassium	11	11	11
Sodium	56	56	57
Sulphate	27.4	26.2	27.2
Other			
Chlorophyll *a* (µg/L)	5.11	2.30	4.52
Conductivity (µS/cm)	669	671	671
pH (pH units)	8.8	8.8	8.8
Turbidity (N.T.U.)	1.5	8.8	2.3
Biochemical Oxygen Demand (mg/L)	<2	2	<2
Chemical Oxygen Demand (mg/L)	51.8	52.7	53.9
Metals			
Preserved Mercury (µg/L)	<0.02	<0.02	<0.02
Aluminum (mg/L)	<0.02	<0.02	<0.02
Arsenic (mg/L)	0.001	0.001	0.001

Table 8 July 13, 2004 Comparison Between Surface, Integrated, and Bottom Parameters for Turtle Lake Baseline Site

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	19.1	18.6	18.4
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.02	<0.02	0.04
Total Kjedahl Nitrogen	1.2	1.3	1.3
Total Phosphorous	0.04	0.07	0.06
Ortho-Phosphate, as P	0.03	0.03	0.03
Solids (mg/L)			
Total Dissolved	576	572	583
Suspended, Fixed	<1	1	3
Suspended, Volatile	2	3	3
Suspended, Total	3	4	5
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	359	360	364
Alkalinity, Phenol	25	25	21
Bicarbonate	377	378	393
Calcium	21	20	20
Carbonate	30.0	30.0	25.2
Chloride	3.4	3.4	3.7
Hardness, Total	267	256	256
Magnesium	52	50	50
Potassium	11	10	11
Sodium	55	54	54
Sulphate	26.7	26.6	26.0
Other			
Chlorophyll *a* (µg/L)	2.30	2.22	5.11
Conductivity (µS/cm)	662	664	671
pH (pH units)	8.8	8.8	8.7
Turbidity (N.T.U.)	0.98	1.20	1.00
Biochemical Oxygen Demand (mg/L)	<2	<2	<2
Chemical Oxygen Demand (mg/L)	50.0	46.2	45.3
Metals			
Preserved Mercury (µg/L)	<0.02	<0.02	<0.02
Aluminum (mg/L)	<0.02	0.02	<0.02
Arsenic (mg/L)	0.001	0.002	0.002

Table 9 **August 10, 2004 Comparison Between Surface, Integrated, and Bottom Parameters for Turtle Lake Baseline Site**

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	18.6	18.7	18.8
Nitrate, as Nitrogen	0.16	0.15	0.14
Ammonia, as Nitrogen	0.04	0.04	0.05
Total Kjedahl Nitrogen	1.3	1.2	1.4
Total Phosphorous	0.05	0.07	0.05
Ortho-Phosphate, as P	0.04	0.04	0.04
Solids (mg/L)			
Total Dissolved	583	583	577
Suspended , Fixed	1	1	1
Suspended, Volatile	4	4	4
Suspended, Total	5	5	5
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	<10
Fecal Streptococci	<10	<10	120
Total Coliform	<10	10	<10
Major Ions (mg/L)			
Alkalinity, Total	362	364	362
Alkalinity, Phenol	26	24	26
Bicarbonate	378	386	378
Calcium	22	21	21
Carbonate	31.2	28.8	31.2
Chloride	4.4	4.1	4.2
Hardness, Total	273	262	262
Magnesium	53	51	51
Potassium	11	11	11
Sodium	57	55	55
Sulphate	26.0	25.6	25.8
Other			
Chlorophyll *a* (µg/L)	6.04	4.59	4.59
Conductivity (µS/cm)	673	674	672
pH (pH units)	8.9	8.9	8.9
Turbidity (N.T.U.)	1.3	2.1	2.3
Biochemical Oxygen Demand (mg/L)	<2	<2	<2
Chemical Oxygen Demand (mg/L)	51.4	52.0	54.7
Metals			
Preserved Mercury (µg/L)	<0.02	<0.02	<0.02
Aluminum (mg/L)	<0.02	<0.02	<0.02
Arsenic (mg/L)	0.001	0.001	0.001

9.0 Appendix B

9.1 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.

9.2 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* which is 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 Transparency 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. Total Dissolved Solids (TDS) - 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. Total Suspended Solids (TSS) - 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. Total Hardness - 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. Salinity - 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.