Skeleton Lake
State of the Watershed Report 2007

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Executive Summary

Skeleton Lake is located in the County of Athabasca in central Alberta, Canada. It is a popular recreational lake which has been extensively developed. Currently, the most pressing concern facing the lake is rapidly dropping water levels, which have reached a record low, dropping 1.57 meters since 1988. Factors that contribute to this decline include climate change, groundwater loss, change in land use (development) and water diversion. A sense of urgency exists among local residents to address the problem. Continued decreasing water levels brings concern over declines in water quality, loss of fish habitat and populations, deteriorating riparian areas and loss of recreational areas.

The purpose of this report is to summarize and synthesize current environmental information for the Skeleton Lake watershed. This work will be used towards the development of a Skeleton Lake watershed management plan in the near future.

There is limited lake water quality data available and limited knowledge around hydrological activity within the watershed, which may be having the greatest effect on lake levels. Groundwater interactions are largely unexplored, and this data gap needs to be addressed before a watershed management plan is written, or a water conservation objective determined. A thorough hydrologic study, including a water balance and groundwater mapping, should be completed by a qualified hydrologist to identify problem areas in the watershed. The SLSA has already retained consultants to address these data gaps.

Table of Contents

ACKNOWLEDGEMENTS .... **I**

EXECUTIVE SUMMARY .... **II**

TABLE OF CONTENTS .... **III**

LIST OF TABLES .... **V**

LIST OF FIGURES .... **VI**

1.0 INTRODUCTION **1**

1.1 Purpose of Report 1

1.2 Scope of Report 1

2.0 PUBLIC CONCERNS AND PRIOR/RECENT PLANNING INITIATIVES **1**

3.0 INSTITUTIONAL AND REGULATORY AUTHORITIES **3**

3.1 Federal Government 3

3.2 Provincial Government 3

3.3 Municipal Governments 4

4.0 WATERSHED CHARACTERISTICS **7**

4.1 History 7

4.2 Watershed Description 7

4.3 Climate 9

4.4 Geology and Topography 12

4.4.1 Soil Types and Land Use Capabilities 12

4.5 Hydrology 12

4.5.1 Surface Water 12

5.0 LAND USE AND SOCIAL / RECREATIONAL RESOURCES **15**

5.1 Land Resource Overview 15

5.2 Agricultural Use 15

5.3 Recreational Resources 15

5.4 Other Human and Industrial Influences 16

5.5 Land Use Changes 16

6.0 SURFACE WATER QUALITY **21**

6.1 Water Quality 21

6.2.1. Fisheries 26

6.2.2 Waterfowl 27

6.2.3 Other Wildlife 27

6.2.4 Phytoplankton and Zooplankton 27

7.0 SURFACE WATER QUANTITY **28**

7.1 Hydrology and Lake Levels 28
7.2 Water Withdrawals and Consumption (including Domestic Use) 34
8.0 DATA GAPS 36
9.0 CONCLUSIONS AND RECOMMENDATIONS 36
APPENDIX A 41
Lake vegetation and Fish Habitat Original Data
APPENDIX B 45
Skeleton Lake Biological Assessment

List of Tables

Table 1. Legislation and policy involving water and watershed management. 6

Table 2. Characteristics of Skeleton Lake. Adapted from Mitchell and Prepas, 1990. 9

Table 3. Select water quality parameters for Skeleton Lake. Summary of AENV (1985, 2005), ALMS (2005), and Aquality (2007) data. 21

Table 4. Summary of storage losses from 1967-2002 using the model numbers generated by the AENV Water Balance study (2003). 29

Table 5. Water diversions from Skeleton Lake to the Village of Boyle. 35

Table 6. Priority Areas of Concern and Responsibilities. 37

List of Figures

Figure 1. Bathymetry of Skeleton Lake. Adapted from Mitchell and Prepas, 1990...................... 8

Figure 2. Average summer and annual temperatures for Athabasca from 1970-2004. Adapted from SLSA, 2006B.. 10

Figure 3. Average rainfall (mm), snowfall (cm) and total precipitation (mm) for Athabasca from 1970-2004. Adapted from Environment Canada data (2004).................................... 11

Figure 4. Groundwater contamination risk map. The red arrow is pointing to Skeleton Lake. Adapted from Hydrogeological Consultants Ltd. (2000).. 14

Figure 5. Subdivisions and resorts around Skeleton Lake in 1977. Adapted from Barber, 1979.17

Figure 6. Land use around Skeleton Lake as of 2006. Map courtesy of D. Johnston, 2007. 18

Figure 7. Land use around Skeleton Lake in 1983. Adapted from Mitchell and Prepas, 1990... 19

Figure 8. Land development, deforested area and water levels in 1964 and 2003. Courtesy of WorleyParsons Komex.. 20

Figure 9. Seasonal fluctuation in total phosphorus, chlorophyll a levels and Secchi depths in the north and south lake basins over the summer and early fall of 2005. Data from ALMS (2005)... 23

Figure 10. The trophic status of Skeleton Lake based on total phosphorus levels, as compared to other Alberta Lakes. The south and north basins are indicated with red arrows. Adapted from AENV, 2006. 24

Figure 11. The trophic status of Skeleton Lake based on chlorophyll a levels, as compared to other Alberta Lakes. The south and north basins are indicated with red arrows. Adapted from AENV, 2006.. 25

Figure 12. Storage gains and losses from 1967-2003 using the estimated storage amounts generated in the AENV water balance study (2004). 30

Figure 13. Declining water levels in Skeleton Lake since 1965. Data from AENV (2007)........... 31

Figure 14. Water levels for Amisk Lake from 1969 to 2004. Data from AENV (2005).................. 32

Figure 15. Historical Lake Level for Long Lake, AB from 1969 – 2005. Graph generated from data provided by AENV 2005…………………………….. 33

1.0 Introduction

1.1 Purpose of Report

The purpose of this report is to summarize all available current and historic water quality and quantity information on the Skeleton Lake Watershed. This report will provide a benchmark against which future stewardship activities and best management practices aimed at improving watershed health can be assessed. The information will provide landowners, stakeholders, municipalities and stewardship groups the information needed to make sound management decisions, implement beneficial management practices and develop solutions to protect and/or enhance their land and water resources. This report prioritizes the issues to be addressed and recommends strategies to address those issues and opportunities.

1.2 Scope of Report

This report covers information on the watershed, lake water quality and quantity, and the potential effect of resource and land-use practices. In many cases, lake water quality data has been used as an indicator of watershed health. Each section of this report is intended to provide and summarize all known social, physical and environmental information.

The report begins by summarizing public perceptions and concerns, then details the public perceptions and concerns from the 1970s to present. Next, the report outlines how state of the basin reporting fits into the greater context of watershed management planning in Alberta under Alberta Environment's *Water for Life* Strategy, and identifies legislation and policies affecting watershed management in Alberta. The history and characteristics of the Skeleton Lake watershed are presented, including the physical aspects of the entire watershed, first at a broad scale, then focussing on land use, land cover and water resources. The report then outlines water quality information and its impact on fisheries, water fowl and other wildlife, then moves on to hydrology and water quantity issues. Finally, data gaps conclusions and recommendations are listed.

2.0 Public Concerns and Prior/Recent Planning Initiatives

A Cottage Owner Survey was conducted in 1977 by Alberta Municipal Affairs (Barber, 1979). This survey was part of a management study being prepared for Skeleton Lake at the time. It was hoped that the survey could be used to provide an estimate of the lake's recreational carrying capacity, and to assess development capabilities or alternatives for the lake (Barber, 1979). A total of 326 surveys were distributed to occupied lots in resort subdivisions around the lake; in total, 223 surveys were returned, representing a response rate of 68% (Barber, 1979). At the time of the survey, 26% of cottagers felt that Skeleton Lake had already reached its development capacity. The majority of owners felt that the lake was overcrowded, especially on long weekends. The information from this 1977 survey may be dated but it provides insight to the history of concern for the lake.

In 1977, Mewatha Beach was the largest resort subdivision at Skeleton Lake, with a total of 213 lots (Figure 1) (Barber, 1979). Bondiss was the second largest at 79 lots, while the Old Timers Place was third at 74 lots. Other subdivisions included Pickerel Point Beach (70 lots) and the Harnaha subdivision (43 lots). Fifty-four percent of respondents owned a lakefront lot. None of these subdivisions were fully developed at the time of the survey.

Cottagers indicated their reasons for originally choosing Skeleton Lake were for its natural beauty (73%), clean water at the time (69%), good fishing (62%), close access to a good highway (61%)

and the close proximity to a town or village with supplies (58%). The most popular forms of summer recreational activities were fishing, swimming, sightseeing/relaxation, power boating and waterskiing.

Two thirds of respondents to the 1979 survey felt there were deficiencies with lake water quality, namely algal growth (34%), weed growth (25%), shoreline weeds (23%), poor fishing quality (21%), polluted water (14%) and fluctuating water levels (14%).

Other concerns included inadequate drinking water supplies, poor quality beach areas, poor access to lakeshore, soft lake bottom, destruction of natural vegetation, shoreline erosion, shoreline littering, loud noise levels from boat traffic, oil residue on the water and lot flooding. A total of 16% of respondents were concerned with the environmental deterioration of Skeleton Lake. Out of the 168 respondents that felt there were too many weeds in the lake, 31.7% of them have attempted cutting the weeds at least once yearly.

The 1979, Skeleton Lake Management Study identified the general setting and listed the biophysical characteristics of the lake. The study also reviewed general resource capability, land and water based constraints and summarized the lake's development potential. From this information, three management alternatives were identified as possible methods for improving the existing situation of the lake.

As a result of the Skeleton Lake Management Study, a Skeleton Lake Area Structure Plan was developed by Alberta Municipal Affairs in 1980. The purpose of the plan was to provide goals, objectives and policies which would ensure responsible future manage-ment of Skeleton Lake and surrounding shore land area. The philosophy adopted in the Area Structure Plan was to allow additional lake development, but only within the biophysical capabilities of the lake environment. In an attempt to balance development demands with concerns over the limitations of the lake, the plan proposed that no more than 40 additional residential lots be permitted at the lake. Since 1980, approximately 600 additional lots have been approved on the lake.

More recently, residents around the lake have become alarmed by the decreasing lake levels. Since 1997, the lake level has declined nearly 2 meters. In 2005, the Skeleton Lake Stewardship Association was established and now consists of more than 1300 members from around the lake. The SLSA is currently in the process of developing a watershed management plan for Skeleton Lake and have completed a Terms of Reference for a Watershed Management Plan, which was approved by Alberta Environment in September 2006.

In public consultation for the Terms of Reference for the Watershed Management Plan, the following concerns were identified:

- Declining lake levels
- Increased development in the watershed
- The effect of land use practices
- The absence of a comprehensive watershed perspective in current land use planning of the municipalities in the watershed
- Decreasing water quality
- Algal blooms
- Unpleasant odors
- Decline of fish populations

Many of the concerns identified in the 2006 Terms of Reference are similar to those identified 30 years earlier in the 1977 survey.

3.0 Institutional and Regulatory Authorities

This section provides an overview of the main legislation protecting lakes and surface water bodies in Alberta.

3.1 Federal Government

The *Canadian Environmental Protection Act* (CEPA) is the main federal law protecting the environment. With respect to water resources, CEPA empowers the federal government to create and enforce regulations regarding toxic substances, fuels, and nutrients. CEPA enables the federal government to undertake environmental research, develop guidelines and codes of practice, and conclude agreements with provinces and territories. Environment Canada administers CEPA but assesses and manages the risk of toxic substances jointly with Health Canada.

Fisheries and Oceans Canada has the authority to protect fish and fish habitat under the *Fisheries Act* and the *Species at Risk Act*. Fish habitat by definition includes spawning grounds and nurseries, rearing, food supply and migration areas on which fish depend to carry out their life processes (Fisheries Act, 1985). It is their mandate to preserve healthy marine and freshwater aquatic ecosystems in support of scientific, ecological, social and economic interests. The *Fisheries Act* prohibits any activity that results in the harmful alteration, disruption or destruction of fish habitat, protects fish populations from pollution and recommends mitigation measures where loss of habitat is unavoidable. Work carried out near a fish-bearing watercourse must have the approval of Fisheries and Oceans Canada, and failure to comply with the *Act* may result in fines or imprisonment.

3.2 Provincial Government

The Government of Alberta is committed to sustainable development through an integrated resource management (IRM) approach to protect the environment and manage Alberta's resources (Alberta Environment, 2002A). IRM requires a compre-hensive, interdisciplinary approach to the management of water, timber, air, public land, fish, wildlife, range, oil, gas and mineral resources. The Alberta Government recently initiated a province-wide comprehensive water strategy called *Water for Life: Alberta's Strategy for Sustainability*. The purpose is to identify short-, medium- and long-term plans to effectively manage the quantity and quality of the province's water systems and supply. The three main goals of the strategy are to ensure that Albertans have a safe and secure drinking water supply, healthy aquatic ecosystems and reliable, quality water supplies for a sustainable economy (Alberta Environment, 2003). The provincial govern-ment uses both the *Water Act* and the *Environmental Protection and Enhancement Act* (EPEA) in order to enforce regulations regarding the preservation of Alberta's water supplies.

The *Water Act* supports the conservation and management of water, and allows for regional differences in water management to be reflected through the development of water management plans, as outlined in the *Framework for Water Management Planning* (2002). The *Environmental Protection and Enhancement Act* is intended to support and promote the protection, enhancement and sustainable use of all aspects of the environment, from land to water. It covers conservation, reclamation, pesticide use, waste control and wastewater and storm drainage.

Other provincial acts which can be utilized to protect Alberta's water resources include the *Agricultural Operations Practices Act* (AOPA); *Safety Codes Act* (Municipal Affairs); *Regional Health Authorities Act; Wildlife Act* (Sustainable Resource Development (SRD)); *Provincial Parks Act; Wilderness Areas, Ecological Reserve, Natural Areas and Heritage Rangelands Act;* Wetlands Policy and SRD Public Lands. Brief descriptions of these acts are provided in Table 1.

- AOPA provides guidelines and regulations regarding environmental management in livestock operations. It allows the province to manage manure runoff, odour, noise, dust, smoke or other disturbances resulting from an agricultural operation, and provides clear manure management standards.

- The *Safety Codes Act* applies to the construction, installation and maintenance of septic systems. It ensures that septic systems follow minimum engineering standards for manufacture and installation, and that their integrity is preserved through regular maintenance. Leaking septic systems are a concern throughout the province. In particular, private septic systems seen in lakeside properties and recreational sites can cause contamination of groundwater and surface water bodies.

- The *Regional Health Authorities Act* ensures the preservation of the health and safety of Albertans, and can be used with the *Safety Codes Act* in ensuring water supplies are kept free of sewage contamination.

- Alberta Sustainable Resource Development is responsible for enforcing many acts which can be used in the protection of aquatic resources. These acts include the *Wildlife Act*, which governs the management of wildlife as a Crown resource, enables the hunting and trapping of wildlife, and addresses the conservation of species at risk (endangered, threatened). The *Public Lands Act* deals with the selling and transferring of public land, riparian rights, access to bed and shores, environmental reserves, as well as the management of rangeland and activities permitted on designated land.

- The *Provincial Parks Act* and the *Wilderness Areas, Ecological Reserve, Natural Areas and Heritage Rangelands Act* ensure the preservation and conservation of natural areas as parks or reserves. These Acts prohibit development and limit access to protected areas in order to preserve their natural state and ecological integrity.

- The draft Wetlands Policy developed 1993 by Alberta Environment will soon be replaced by a newer policy which is currently under review. The original policy mainly examined preservation of wetlands in settled areas (white zone) and recommended a No Net Loss policy for wetlands. The new wetland policy will supersede the two interim policies, *Wetland Management in the Settled Area - An Interim Policy* and *Beyond Prairie Potholes - A Draft Policy For Managing Alberta's Peatland and Non-settled Area Wetlands* to form a comprehensive wetland policy for the province.

3.3 Municipal Governments

The following documents are used by municipalities in order to protect and maintain their watershed health and integrity:

- The *Municipal Government Act* (MGA) provides municipalities with authorities to regulate management of private land to control non-point sources. It also provides municipalities with the authority to enact bylaws and municipal land use to ensure that land use practices are compatible with the protection of aquatic environment.

- Land Use Bylaws divide the municipality into land use districts and establishes procedures for processing and deciding upon development applications. They set out rules that affect how each parcel of land can be used and developed and include a zoning map.

- An Area Structure Plan or Land Use Plan is a plan adopted by Council as an area structure plan bylaw pursuant to the *Municipal Government Act* that provides a framework for future subdivisions and development of an area.

- A Municipal Development Plan is a plan adopted by Council pursuant to the *Municipal Government Act.* It is a policy document that states how land will be used and how future developments will be zoned.

Current and past land use plans, guiding documents and bylaws enacted for Skeleton Lake include:

- *Draft Terms of Reference for the Skeleton Lake Watershed Management Plan* (2006)
- *County of Athabasca Land Use Bylaws and Municipal Development Plan* (2002)
- *Skeleton Lake Area Structure Plan (1980)*
- *Skeleton Lake Management Study* (1979)
- *Summer Village of Mewatha Beach Land Use Bylaw*
- *Summer Village of Bondiss Land Use Bylaw*

Table 1 summarizes the applicable government acts and legislation available to assist with watershed management planning initiatives.

The Skeleton Lake Area Structure Plan (1980) was developed using management alternatives and directions as outlined in the Skeleton Lake Management Study (1979). The County of Athabasca and the Summer Village of Mewatha Beach adopted a Management Alternative that permitted expansion of the Boy Scout development and allowed for limited residential development in certain areas around the northern basin. The Skeleton Lake Area Structure Plan was later rescinded by the County of Athabasca.

The County of Athabasca Municipal Development Plan (Bylaw No. 5) (County of Athabasca, 2002) states that there shall be no expansion of existing residential subdivisions within 400 m of the lake. A maximum number of residential lots have been established for the areas designated as country residential in the subdivisions on the northwestern shores of the main (southern) basin.

Table 1. Legislation and policy involving water and watershed management.

Legislation/Policy	Description
Federal *Fisheries Act* - Department of Fisheries and Oceans Canada (DFO)	Regulates and enforces on harmful alteration, disruption and destruction of fish habitat in Section 35.
Provincial *Water Act* – Alberta Environment (AENV)	Governs the diversion, allocation and use of water. Regulates and enforces actions that affect water and water use management, the aquatic environment, fish habitat protection practices, in-stream construction practices, storm water management.
Provincial *Environmental Protection and Enhancement Act (EPEA)* – AENV	Management of contaminated sites, storage tanks, landfill management practices, hazardous waste management practices and enforcement.
Provincial *Agricultural Operations Practices Act* (AOPA) – Natural Resources Conservation Board (NRCB)	Regulates and enforces on confined feedlot operation and environment standards for livestock operations.
Provincial *Municipal Government Act* (MGA) – Municipal Affairs	Provides municipalities with authorities to regulate water on municipal lands, management of private land to control non-point sources, and authority to ensure that land use practices are compatible with the protection of aquatic environment.
Provincial *Public Lands Act* - Sustainable Resource Development (SRD)	Regulates and enforces on activities that affect Crown-owned beds and shores of water bodies and some Crown-owned uplands that may affect nearby water bodies.
Provincial *Safety Codes Act*- Municipal Affairs	Regulates and enforces septic system management practices, including installation of septic field and other subsurface disposal systems.
Regional Health Authorities Act – Alberta Health	RHA have the mandate to promote and protect the health of the population in the region and may respond to concerns that may adversely affect surface and groundwater.
Wildlife Act - SRD	Regulates and enforces on protection of wetland-dependent and wetland-associated wildlife, and endangered species (including plants).
Provincial Parks Act & Wilderness Areas, Ecological Reserve and Natural Areas Act – SRD and Community Development	Both Acts can be used to minimize the harmful effects of land use activities on water quality and aquatic resources in and adjacent to parks and other protected areas.
Provincial Wetlands Policy (expected September 2006)	This policy will be used to protect wetlands and mitigate losses through a No Net Loss policy.
Land Use Bylaws (Municipal)	Divides the municipality into land use districts and establishes procedures for processing and deciding upon development applications. It sets out rules that affect how each parcel of land can be used and developed and includes a zoning map.
Area Structure Plans (Municipal)	Adopted by Council as a bylaw pursuant to the Municipal Government Act that provides a framework for future subdivisions, development, and other land use practices of an area, usually surrounding a lake.
Municipal Development Plans	The plan adopted by Council as a municipal development plan pursuant to the Municipal Government Act.

4.0 Watershed Characteristics

4.1 History

The lake's name is a translation of the Cree words *Cheply Sakhahigan*, which means "place of the skeletons". A Cree chief is buried near the entrance to the Boyle Old-timers Golf Course along the eastern shore of the lake, which is how the lake got its name (Mitchell and Prepas, 1990).

The early local history of the area reflects the harvest of natural resources such as fur, fish and timber (Mitchell and Prepas, 1990). Large stands of spruce around the lake attracted logging activity. One sawmill operated on the lakeshore sometime after 1915 and another operated at Bondiss from 1923 to 1940 (Mitchell and Prepas, 1990). Log booms were frequently seen on the lake during this period. The Northern Alberta Railway reached the vicinity in 1914, bringing homesteaders and providing the means to ship lumber and fish to local markets. The area immediately north of Boyle was settled mostly by Ukrainan immigrants (Mitchell and Prepas, 1990). The major economic activity in the region eventually became mixed farming.

4.2 Watershed Description

Skeleton Lake is located approximately 170 km northeast of Edmonton, Alberta in the Lakeland Region, within the County of Athabasca. The Summer Village of Mewatha Beach and the Summer Village of Bondiss are located on the shores of the lake. Skeleton Lake has a small drainage basin of approximately 3 136 hectares, excluding the lake area, which is approximately 878 hectares (Alberta Municipal Affairs, 1979). The lake itself is comprised of 2 basins, connected by a narrow channel, known locally as “The Narrows” (Figure 1). There is anecdotal information that the narrows dried up approximately 60 years ago, separating the two basins of the lake (Mitchell and Prepas, 1990).

Skeleton Lake is located in the boreal mixed wood region of Alberta. Tree cover is composed of mainly trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), white birch (*Betula papyrifera*), white spruce (*Picea glauca*) and jackpine (*Pinus banksiana*). Common shrub species include willow (*Salix* spp.), red osier dogwood (*Cornus stolonifera*), alder (*Alnus* spp.), and wild rose (*Rosa acicularis*). The wet depressional areas contain peat moss and black spruce (*Picea mariana*), tamarack (*Larix laricina*), Labrador tea (*Ledum groenlandicum*), willow (*Salix* spp.), dwarf birch (*Betula nana*), alder (*Alnus* spp.) and various species of moss.

In 1965, maximum water depths in the north basin were approximately 17 meters, while the south basin was shallower, at around 10.5 meters (Figure 1). Water levels have dropped significantly over the last 10 years or so, which is causing considerable concern among area residents and cottagers. Physical parameters of the lake are listed in Table 2.

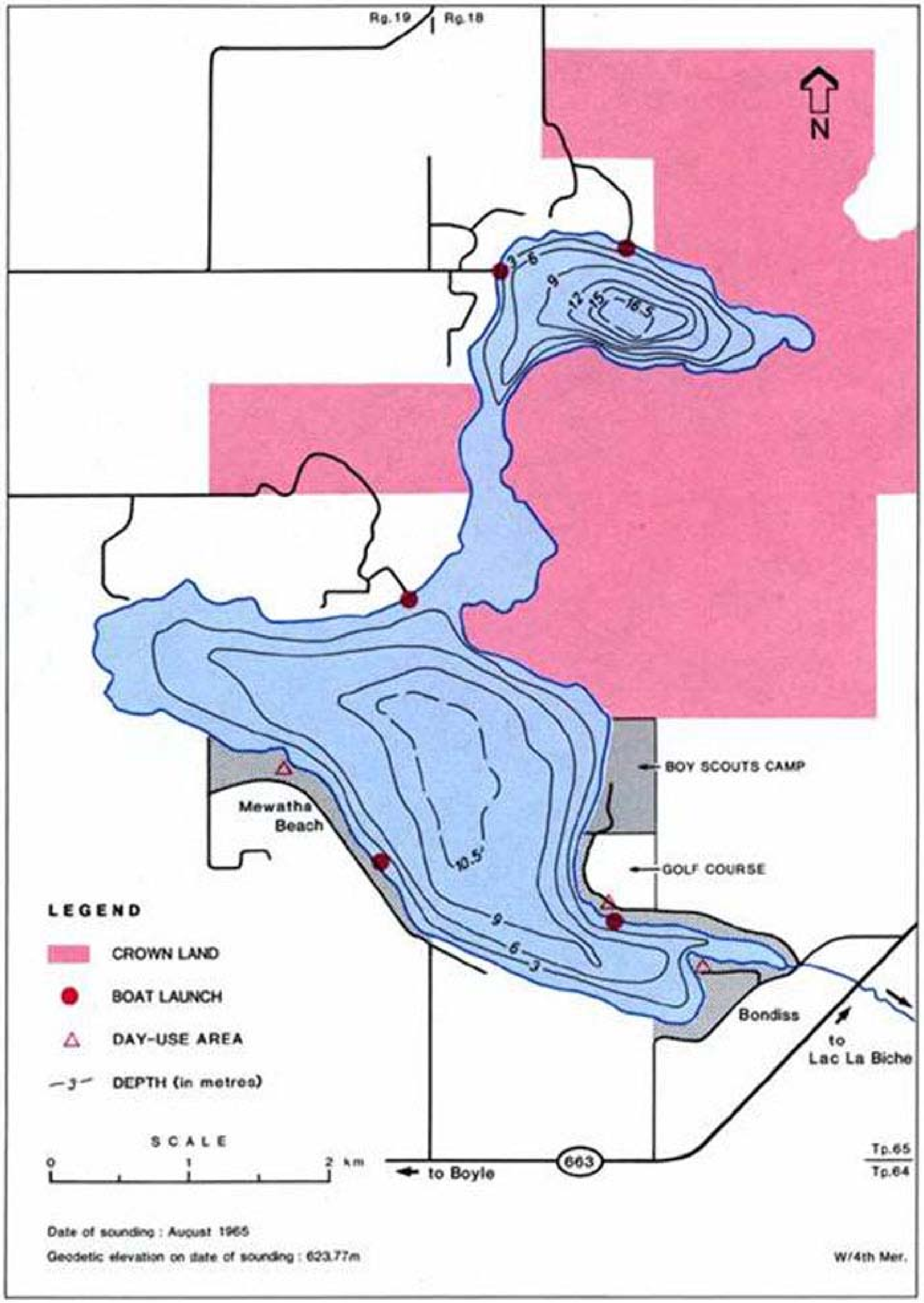


Figure 1. Bathymetry of Skeleton Lake. Adapted from Mitchell and Prepas, 1990.

NOTE: Date of sounding was August 1965 and geodetic elevation was 623.77 m.

Table 2. Characteristics of Skeleton Lake. Adapted from Mitchell and Prepas, 1990.

Parameter	
Historic Elevation [a]	623.77 m
Current Elevation [b]	622.382 m
Surface Area [a]	7.89 km^2
Volume [a]	5.14 x 10^6 m^3
Maximum depth [a]	17 m
Mean depth [a]	6.5 m
Mean annual inflow	1.78 x 10^6 m^3
Shoreline length	24.7 km
Mean annual lake evaporation	636 mm
Mean residence time [c]	61.5 yrs

a - On date of sounding: Aug 1965.
b - Elevation above sea level on May 15, 2007
c - Excluding groundwater inflow.

Measured outflow and inflow volumes were unavailable at the time of this report. The lake level has dropped enough that the outflow (Brad Creek) is no longer flowing from the lake (H. Harper, pers. comm., 2006).

4.3 Climate

The average annual temperature in Athabasca, which is the closest weather station to Skeleton Lake, is 2.2 ^oC, with summer temperatures averaging about 11.6 ^oC (Figure 2). Mean maximum temperatures from 1999 to 2005 were 8.9 ^oC and mean low temperatures for the same time range were -4.2 ^oC (Environment Canada, 2006). On average, Athabasca receives 378 mm of rain per year, 125 cm of snow, and 503 mm of total precipitation (Figure 3).

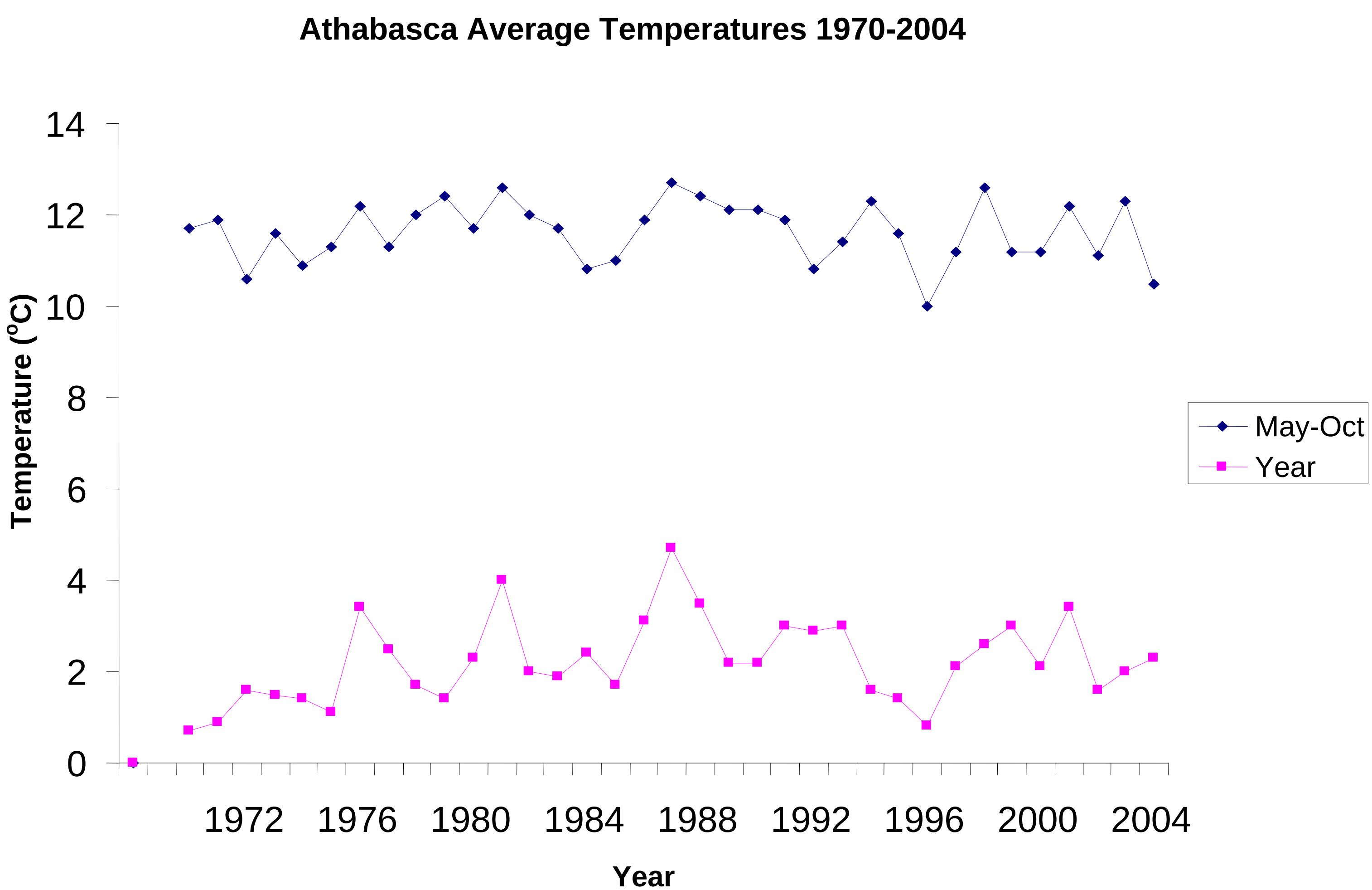


Figure 2. Average summer and annual temperatures for Athabasca from 1970-2004. Adapted from SLSA, 2006B.

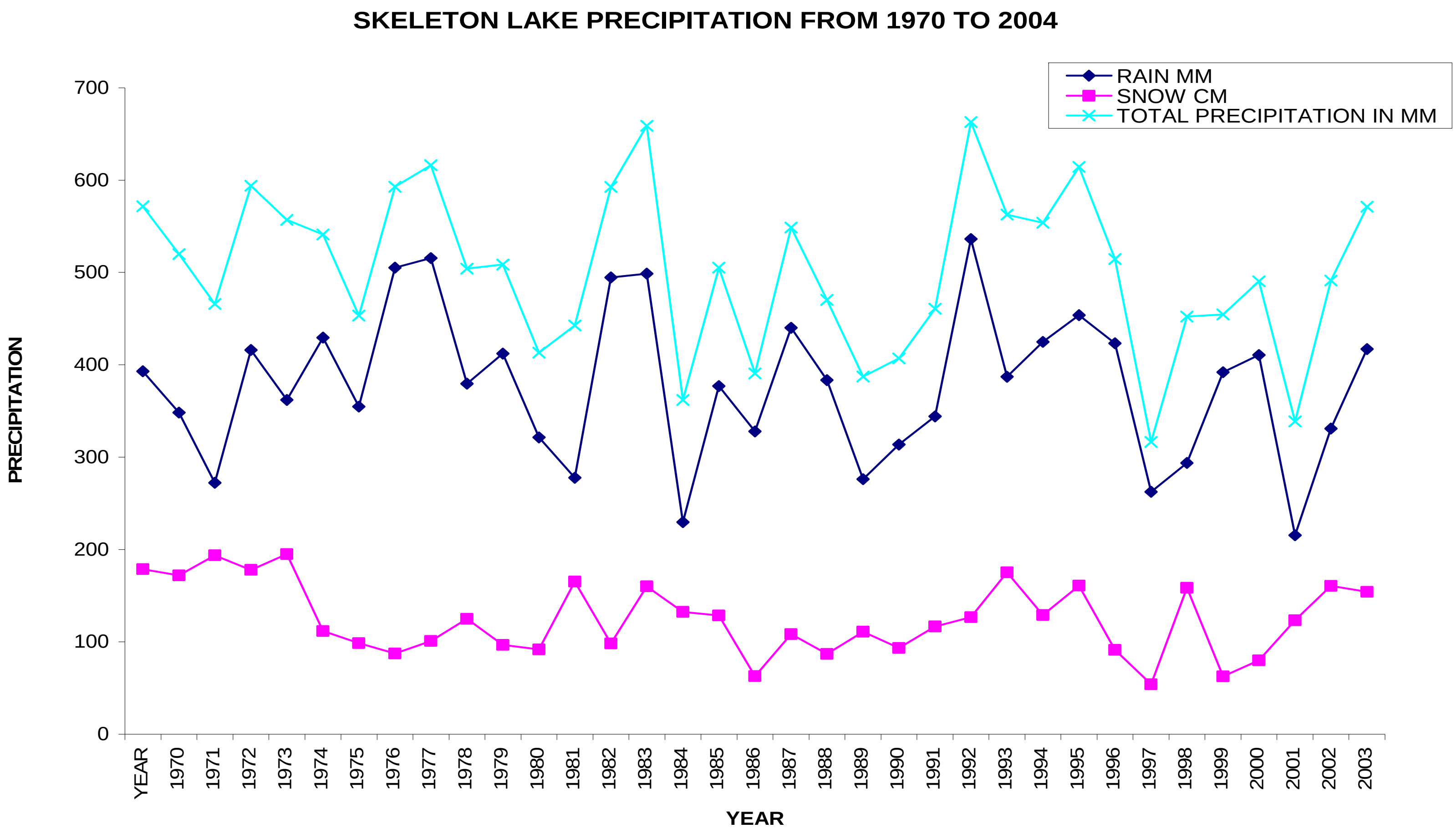


Figure 3. Average rainfall (mm), snowfall (cm) and total precipitation (mm) for Athabasca from 1970-2004. Adapted from Environment Canada data (2004).

4.4 Geology and Topography

The majority of the Skeleton Lake watershed is underlain by marine, gray, blue and black shales with fine grained sandstone beds and lenses, and clay ironstone concretions (Twardy and Carson, 1978). The formations in the watershed are overlain by several meters of morainal till developed from glacial deposits. Generally, till is a clay loam texture, approximately 10 meters in depth (Twardy and Carson, 1978). Isolated areas of sandy deposits occur on the shoreline and within the watershed there are significant deposits of peat up to 5 meters in thickness (Twardy and Carson, 1978). Moderately well-drained orthic gray luvisols are the dominant soils in the watershed (Twardy and Carson, 1978).

Topography is variable, ranging from relatively level morainal plains to hilly glaciofluvial and morainal landforms; the terrain is undulating in the western and southern portions of the watershed, and moderately to strongly rolling in the eastern and northern areas (Twardy and Carson, 1978). The steepest slopes (> 15%) are found along the south shore of the north basin near the Narrows (Alberta Municipal Affairs, 1979).

4.4.1 Soil Types and Land Use Capabilities

The soils in the Skeleton Lake watershed support an agricultural capability of Class 4 to 7, which means that they are: marginally capable of supporting cultivated crops (Class 4); capable for use as permanent pasture (Class 5); capable of supporting native grazing (Class 6) and not capable of supporting agricultural use (Class 7) (Twardy and Carson, 1978). Overall, agricultural activities are not recommended in this watershed.

Housing and building development should be limited to areas with favorable topography, while on-site sewage disposal systems located on the well to rapidly drained areas pose a groundwater contamination risk in the area due to the rapid permeability of coarse textured materials (Twardy and Carson, 1978). The organic and gleysolic soils occurring throughout the area have severe limitations for all land uses due to wetness.

4.5 Hydrology

4.5.1 Surface Water

The only outlet from Skeleton Lake occurs in the southeast portion of the watershed, where Brad Creek drains from the lake to Amisk Lake. The major source of inflow is surface runoff from the surrounding watershed. The drainage area is approximately 39.6 km^2, resulting in a lake to drainage area ratio of approximately 4:1 (Mitchell and Prepas, 1990).

According to anecdotal evidence and a topographical map provided by the Skeleton Lake Stewardship Association, there are two small inflow streams into the lake running in from the south, one of which has been dry for a few years, and one which runs intermittently (H. Harper, pers. comm. 2006). The west portion of the watershed used to be quite marshy and wet, but has now been drained and development has occurred in the area where wetlands once were (H. Harper, pers. comm. 2006).

4.5.2 Groundwater

Currently, there are records for 5,573 water wells within Athabasca County, with 5,077 of them being used for domestic or stock purposes (Hydrogeological Consultants, 2000). Many of these wells have a completion depth of less than 30 m, within surficial deposits in the vicinity of linear bedrock lows (Hydrogeological Consultants, 2000). Deeper wells within the bedrock aquifers occur mainly in the southern half of the County.

At the end of 1996, 121 groundwater allocations were licensed in the County. Of the 121 licensed groundwater users, 103 were for agricultural purposes, and the remaining 18 were for industrial, municipal, diversion and domestic purposes. The total maximum authorized diversion from the water wells associated with these licenses was 3,256 cubic metres per day (m^3/day), of which 67% is for "diversion" use, 25% was allotted for agricultural use, and 5% allotted for municipal use. The remaining 2% has been licensed for domestic and industrial use (Hydrogeological Consultants, 2000).

The largest licensed potable groundwater allocation within the County is for L & G Trucking Inc., having a diversion of 2,205 m^3/day. When a groundwater use is listed as "diversion", the activity is usually related to dewatering activities. The largest licensed potable groundwater allocation within the County is for a water supply well completed in the Upper Sand and Gravel Aquifer in 04-15-062-22 W4M owned by the County of Athabasca, having a diversion of 95 m^3/day (Hydrogeological Consultants, 2000).

Within the Skeleton Lake Watershed, approximately 280 groundwater wells (domestic, industrial and diversion) have been drilled (Alberta Environment, 2002B). This includes all wells registered since 1977, active and reclaimed. However, not all wells drilled have been reported (Alberta Environment, 2002B) and more wells may exist than Alberta Environment has records for. To determine the current number of active wells in the watershed, a survey would need to be completed. Unfortunately, there is not enough information available at this time to determine what effect the groundwater allocations are having on the overall groundwater budget in the County, or on the water budget of Skeleton Lake. A hydrological report by WorleyParsons Komex is currently underway that will address these issues.

The Risk of Groundwater Contamination map (Figure 4) shows the majority of the Skeleton Lake watershed is at low risk of groundwater contamination, but the southwest portion is ranked as high risk for contamination. The risk of groundwater contamination is high when the near surface materials are porous and permeable, and low when the materials are less porous and permeable. The high risk areas should be avoided for developments that have products or by-products that could cause groundwater contamination. Detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from contaminants. At all locations, good environmental practices should be exercised in order to ensure that contaminants do not affect groundwater quality.

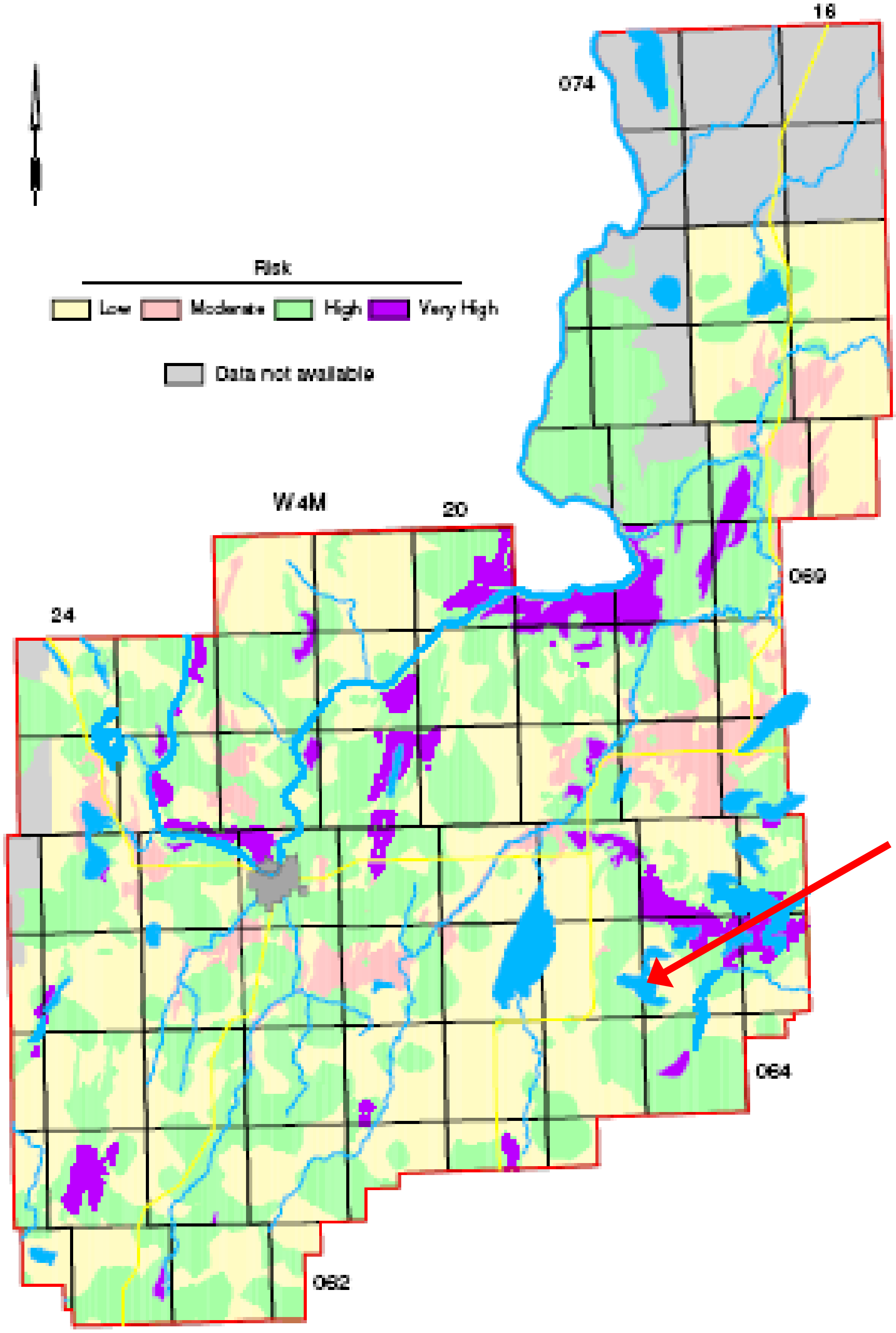


Figure 4. Groundwater contamination risk map. The red arrow is pointing to Skeleton Lake. Adapted from Hydrogeological Consultants Ltd. (2000).

5.0 Land Use and Social / Recreational Resources

5.1 Land Resource Overview

In 1946, the first recreational facility (Skeleton Lake Resort) was developed on the lake but has since been replaced by a subdivision. A Boy Scout Camp was developed on the east shore of the lake in 1956 (Alberta Municipal Affairs, 1979). The first cottage lots were subdivided in 1958, initially on the southwest and east shores (Alberta Municipal Affairs, 1979). By 1975, the developments had spread to the west and north shores of the lake and in 1978 there were 479 lots.

In 1980, the Skeleton Lake Area Structure Plan recommended no more development around the south basin or adjacent to the narrows, to prevent further increases in phosphorus loading. There was also concern over the potential loss of fish habitat in the west end of the south basin if development were allowed to occur in the area. Additional limitations to development in the south basin and narrows were confining lake shape and shallow water depth. Both act to limit boat movement and limit shoreline development. It was also recommended that some development should be allowed around the north basin (40 lots). Currently, there are approximately 1044 lots, as well as campsites and motel units within the watershed (B. Curial, pers. comm., 2007). There are approximately 200 lots that surround the north basin and over 800 lots that surround the south basin.

There are three municipalities around the lake, the Summer Village of Mewatha Beach, the Summer Village of Bondiss, and the County of Athabasca. The Summer Village of Mewatha Beach has approximately 221 lots along the lake, and the Summer Village of Bondiss has 199 lots (B. Curial, 2006). The County has a total of approximately 620 lots (B. Curial, pers. comm., 2007). There are approximately 20 subdivisions within the Skeleton Lake watershed (B. Curial, pers. comm., 2007)

5.2 Agricultural Use

Agricultural activities are limited to coarse grain and forage crop production, and livestock operations (Alberta Municipal Affairs, 1979). These activities are limited mainly to the west, northwest and south of the lake, due to topographical and soil limitations. The Statistics Canada agricultural survey for 2001 lists 960 farms in the County of Athabasca #12, on a total land area of 6,175 km^2 (Stats. Can., 2001). There are almost 500,000 cattle and calves in this region, and approximately 150,000 pigs (Stats. Can., 2001). Almost 1,800 farms use land application of manure using various methods (Stats. Can., 2001). The top five crops grown are alfalfa, barley, hay, spring wheat and oats.

5.3 Recreational Resources

The first recreational resort to be built around Skeleton Lake was the Skeleton Lake Resort, which opened in 1946 (Alberta Municipal Affairs, 1979). This site has since been subdivided and sold off; today the Shoreline Camping and Fishing Resort has approximately 170 camping sites, a boat launch, docks, a restaurant, and a bed and breakfast (Shoreline Camping and Fishing Resort 2007; SLSA 2005). There are also a small municipal park and another large commercial recreation facility adjacent to the lake. The other recreation area is the Boy Scout Camp, which was first built in 1956 (Alberta Municipal Affairs, 1979). No further development in the Boy Scout Camp is allowed until a capacity assessment is completed by the County of Athabasca (County of Athabasca, 2002). There is a 9-hole golf course with plans to expand to 18 holes, which is located just south of the Boy Scout camp (B. Curial, pers. comm., 2007).

5.4 Other Human and Industrial Influences

The shores of Skeleton Lake have moderate to severe limitations for the growth of commercial forests due to soil moisture deficiency (Alberta Municipal Affairs, 1979). At one time there were extensive stands of white spruce in the area, which were thoroughly logged in the early 1900's. This has largely changed the dominant tree species to mainly trembling aspen and balsam poplar (Alberta Municipal Affairs, 2006). The County of Athabasca MDP (2002) identifies almost the entire watershed around Skeleton Lake as a logging control area, and there are no sour gas facilities in the area.

At the time of the Management Study (1979), Golden Eagle Oil and Gas had a gas plant operation in the watershed, which produced between 10,000 and 12,000 cubic meters per day, and was expected to be in operation for another 15-20 years (Alberta Municipal Affairs, 1979). Currently there are 26 hydrocarbon producing wells in the area (T65R18W4, T65R19W4, T64R18W4, T64R19W4), and from 2002 to 2007 there were 56 wells drilled (Alberta Energy and Utilities Board, 2007).

It is likely that the Skeleton Lake region is rich in historical and archaeological resources, and arrowheads have been found along the north shore of the south bay (Alberta Municipal Affairs, 1979). Alberta Culture, at the time of the Alberta Municipal Affairs Management Study, recommended that any potential development sites undertake a historical resources impact assessment to minimize the loss of historical resources (Alberta Municipal Affairs, 1979).

5.5 Land Use Changes

Figures 5 and 6 demonstrate the expansion of land use for development from 1977 to the spring of 2007. Figure 7 shows other land use types within the watershed as of 1983. Similarly, Figure 8 demonstrates the increase in development (linear, residential, recreational and agricultural), the increase in deforested land and dramatic decreases in water levels from 1964 to 2003.

The southeast and entire western portion of the watershed has experienced the most growth with the development of 3 new subdivisions, the expansion of others and the development of a golf course. Crown land comprises 30% of the land around the lake, and is concentrated mainly in the north and east portions of the watershed (Alberta Municipal Affairs, 1979). Forested land has decreased by 16.85% since 1964. Note that developments such as the Boy Scout camp and campsites may not appear in Figure 8, as they are forested, and show up as such in the aerial photo.

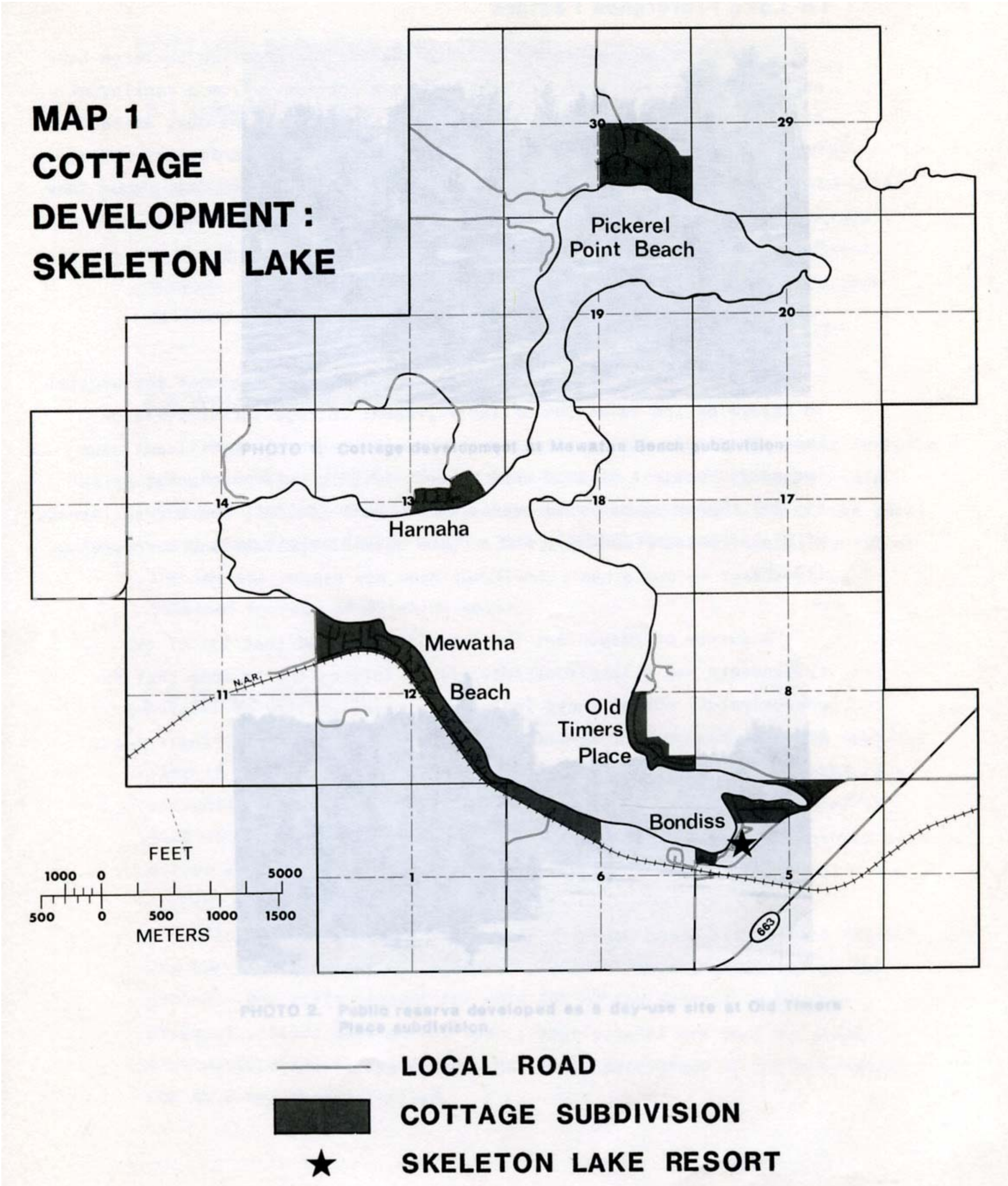
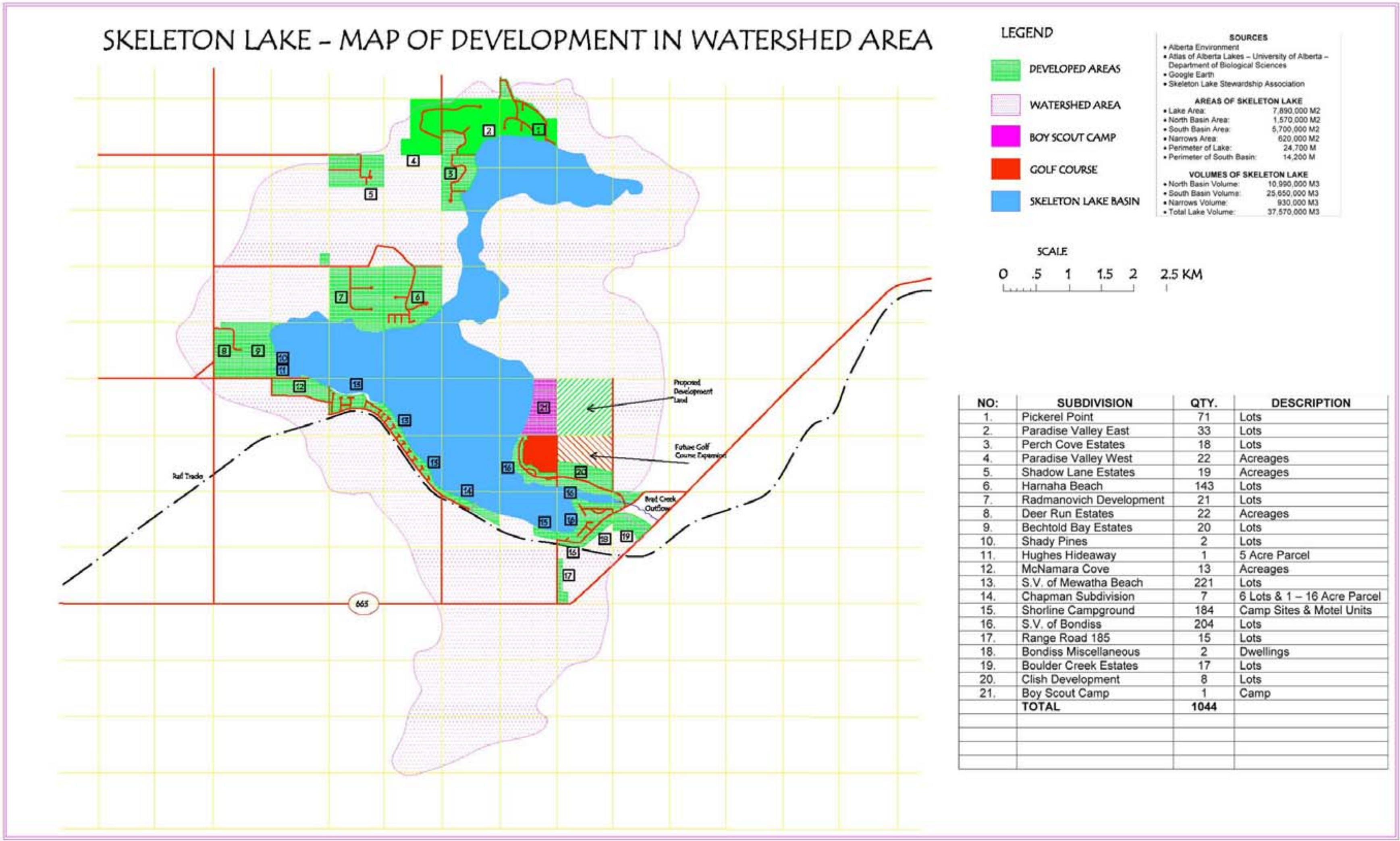


Figure 5. Subdivisions and resorts around Skeleton Lake in 1977. Adapted from Barber, 1979.



NO:	SUBDIVISION	QTY.	DESCRIPTION
1.	Pickerel Point	71	Lots
2.	Paradise Valley East	33	Lots
3.	Perch Cove Estates	18	Lots
4.	Paradise Valley West	22	Acreages
5.	Shadow Lane Estates	19	Acreages
6.	Hamaha Beach	143	Lots
7.	Radmanovich Development	21	Lots
8.	Deer Run Estates	22	Acreages
9.	Bechtold Bay Estates	20	Lots
10.	Shady Pines	2	Lots
11.	Hughes Hideaway	1	5 Acre Parcel
12.	McNamara Cove	13	Acreages
13.	S.V. of Mewatha Beach	221	Lots
14.	Chapman Subdivision	7	6 Lots & 1 – 16 Acre Parcel
15.	Shorline Campground	184	Camp Sites & Motel Units
16.	S.V. of Bondiss	204	Lots
17.	Range Road 185	15	Lots
18.	Bondiss Miscellaneous	2	Dwellings
19.	Boulder Creek Estates	17	Lots
20.	Clish Development	8	Lots
21.	Boy Scout Camp	1	Camp
	TOTAL	1044	

Figure 6. Land use around Skeleton Lake as of 2006. Map courtesy of D. Johnston, 2007.

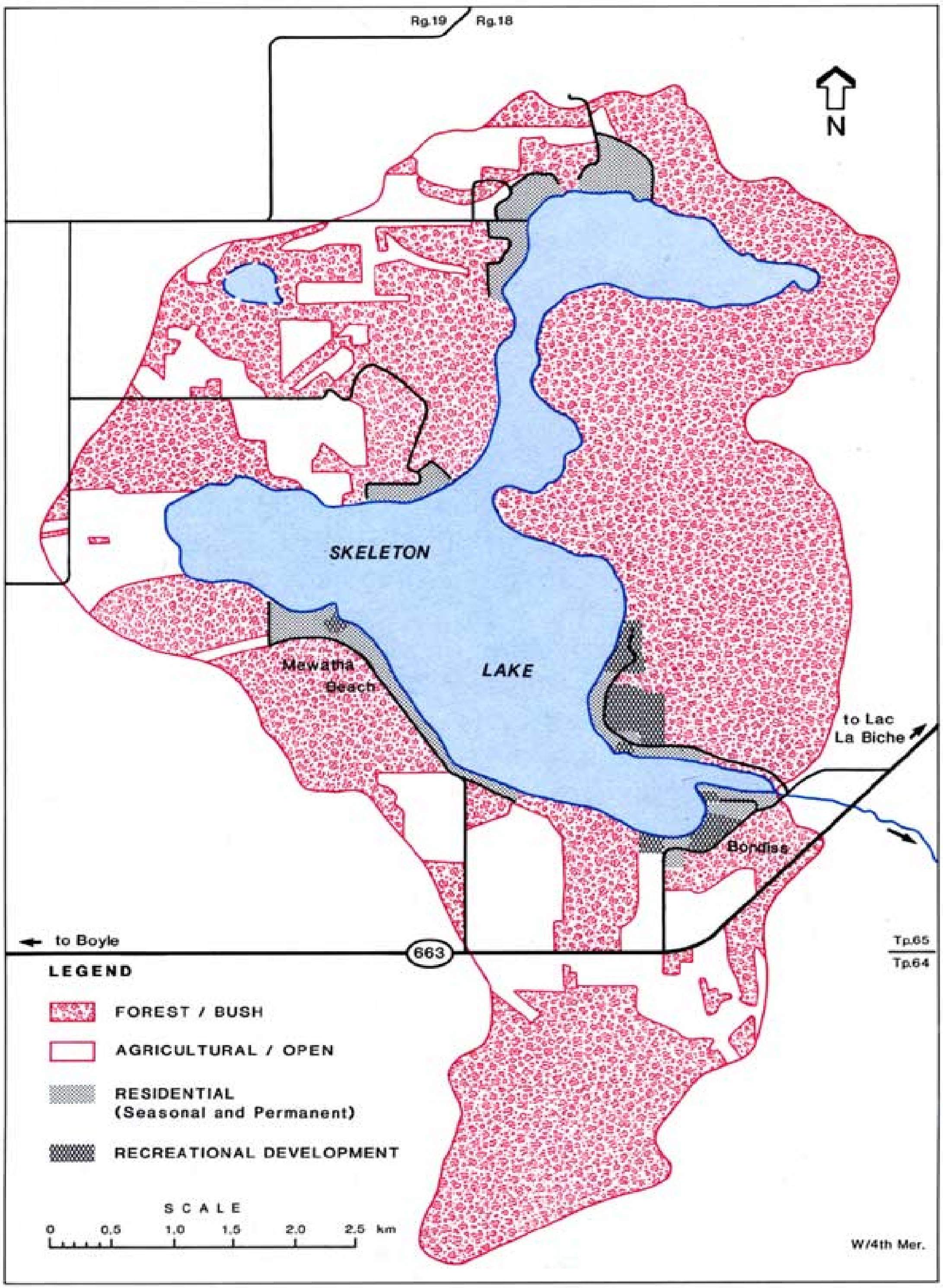


Figure 7. Land use around Skeleton Lake in 1983. Adapted from Mitchell and Prepas, 1990.

Figure 8. Land development, deforested area and water levels in 1964 and 2003. Courtesy of WorleyParsons Komex.

MAP POCKET TO GO HERE

6.0 Surface Water Quality

6.1 Water Quality

Water quality data for Skeleton Lake is limited. Some monitoring was undertaken by Alberta Environment during 1977-1979, 1985-86 and 1989, and Skeleton Lake participated in the Alberta Lake Management Society's LakeWatch Program in 2005. In the early AENV sampling, the lake was considered to be one body of water; later sampling events split results for the north and south bays. Lake sampling was performed by Aquality Environmental Consulting Ltd. in the fall of 2006 as part of a biological assessment (Aquality, 2007) (Appendix B).

The pH of the lake is generally quite basic, ranging from lows of 8.1 to highs of 8.8. The north and south basins are quite similar chemically, but the south basin appears to be slightly more productive, as indicated by higher chlorophyll *a* levels and shallower Secchi disk depths (Table 3, Figure 9). Figures 10 and 11 compare the trophic status of Skeleton Lake to other provincial lakes, using total phosphorus and chlorophyll *a* levels. Skeleton Lake falls into the eutrophic category based on both of these indicators.

Dissolved oxygen levels are sufficient enough to overwinter fish populations in both basins, but zones of anoxia exist in the deeper portions of both basins. The north basin is much deeper, and is quite protected from wind by natural vegetation. Therefore, this bay is generally not subject to deep water mixing and seasonal turnover, both of which add oxygen to the water column. Adding to the oxygen depletion in both bays is the decomposition of organic matter that falls to the lake bottom, a situation which is compounded by algal blooms that add excess plant matter to the lake bottom. This decomposition also increases the levels of ammonium in the water column, which can be toxic to fish and can encourage excessive plant growth.

Table 3. Select water quality parameters for Skeleton Lake. Summary of AENV (1985, 2005), ALMS (2005), and Aquality (2007) data.

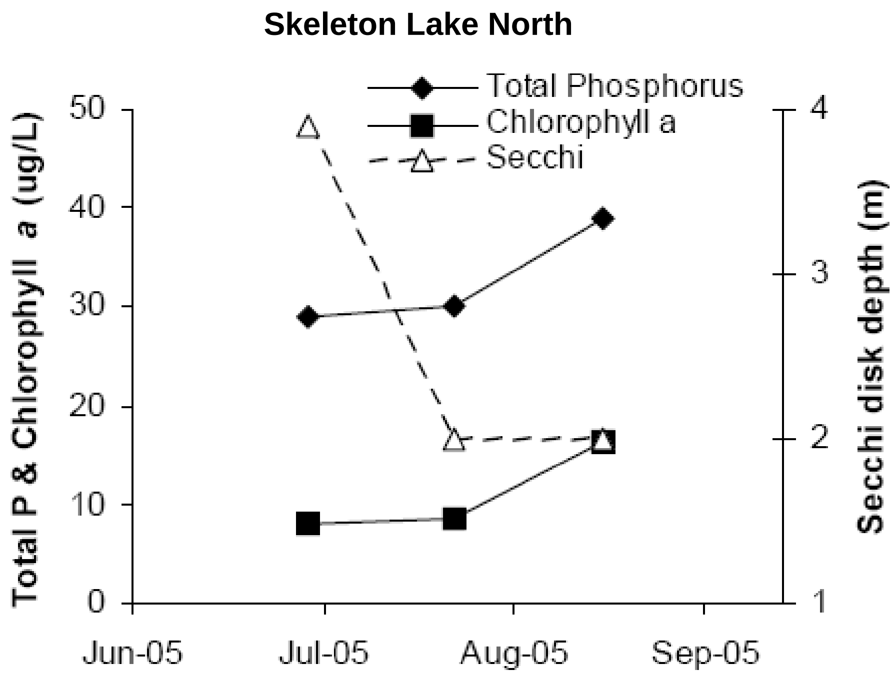
Year	pH	TDS (mg/L)	TP (µg/L)	Chl a (µg/L)	TN (µg/L)	Secchi (m)
1989	8.55	183	37	13.9		
1979	8.1	193	38.6	10.97	1400	2.1
1978	8.1	185	50	19.95	1570	2.17
1977						2.8
North Basin						
2006	8.3		47	16	1470	1.5
2005	8.8	193	33	11	1300	2.6
1986			36	11	1140	2.5
1985	8.4-8.8	172		9.2	1160	2.5
South Basin						
2006	8.45		42	17	1157	1.4
2005	8.7	204	29	12	1158	2.3
1986			47	24	1318	1.6
1985	8.5-8.8	181		16	1139	2

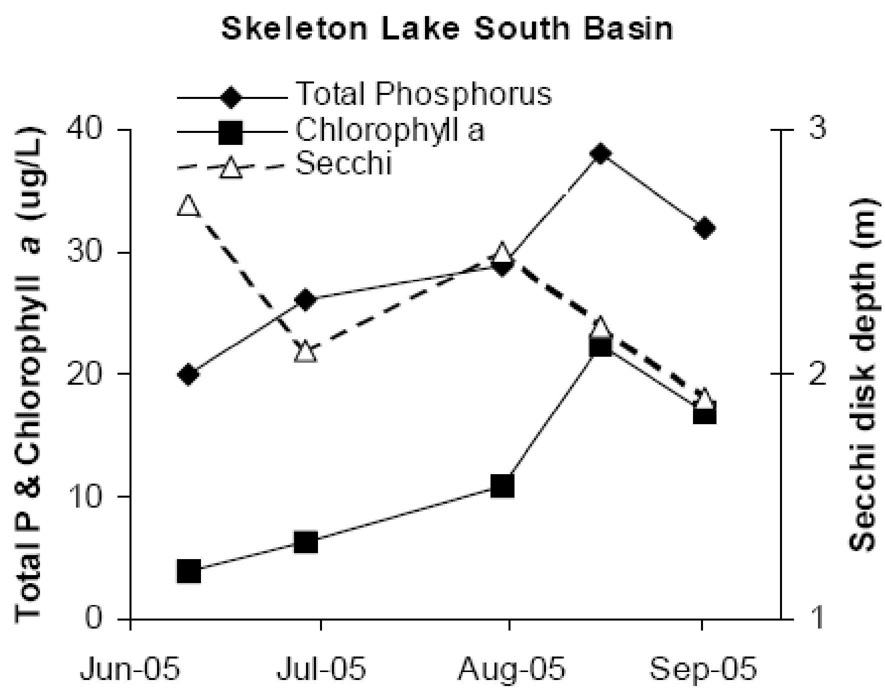
The theoretical external supply of phosphorus to Skeleton Lake is estimated to be 682 kg/year (Mitchell and Prepas, 1990). The largest contributions are made by surface runoff from forested land (33%) and precipitation and dustfall (30%) (Mitchell and Prepas, 1990). The phosphorus supply that enters the lake in sewage effluent from residential areas and campgrounds has not been measured, but was estimated to be about 21% of the external total phosphorus load (Alberta Municipal Affairs, 1979). Phosphorus loading from internal sources such as bottom sediments and groundwater has not been estimated, but is likely high in the south basin. Nutrient runoff from developed areas may negatively impact water quality in Skeleton Lake due to its relatively small watershed to lake area ratio.

A shift from predominantly diatoms in early spring to blue-green algae (cyanophytes) in summer is common in the south basin, particularly in late August (Zurawell *et al*, 1999), while the north basin typically experienced some blue-green algae growth during the month of June (Alberta Municipal Affairs, 1979). Cyanophytes (also known as cyanobacteria or blue-green algae) can produce liver toxins called microcystins, the most common of these in Alberta lakes and reservoirs is microcystin-LR (MCLR). Zurawell *et al* (1999) found that the south basin contained moderate concentrations of MCLR (213 µg/g) within the phytoplankton biomass and lake water (0.1 – 0.4 µg/L). To date, no nuisance algal blooms have been reported by the public to the Athabasca Public Health Unit, and no beach testing has been done for *E. coli* and faecal bacteria levels. The lack of bacterial testing data is consequently identified as a knowledge gap regarding the water quality of Skeleton Lake.

The Skeleton Lake Management Study (Alberta Municipal Affairs, 1979) recommended that phosphorus loading to the lake be limited, sewage should be prevented from entering the lake, riparian setbacks should be preserved and increased in areas of steep slopes and any inflows to the lake should be protected from large nutrient runoff sources, such as cattle operations.

Decreases in water levels, if they continue at rates currently seen in the lake, will increase water quality problems within the lake through concentration of solutes and nutrients. Algal blooms will become more problematic and aquatic plant growth would likely increase due to increased light penetration into the water column. Halving the lake's volume will effectively double the nutrient concentrations seen in the lake.





Basin

Figure 9. Seasonal fluctuation in total phosphorus, chlorophyll a levels and Secchi depths in the north and south lake basins over the summer and early fall of 2005. Data from ALMS (2005).

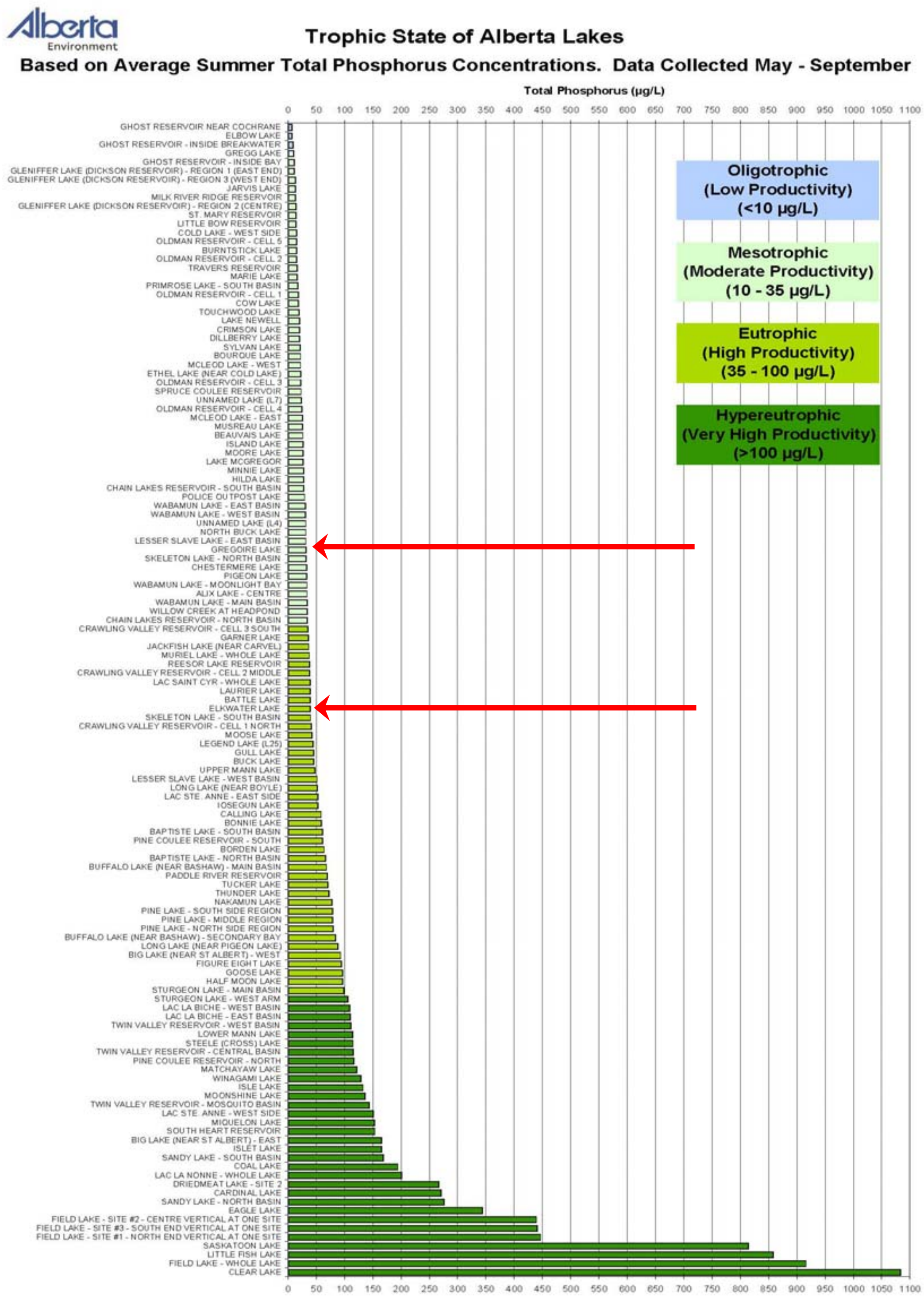


Figure 10. The trophic status of Skeleton Lake based on total phosphorus levels, as compared to other Alberta Lakes. The south and north basins are indicated with red arrows. Adapted from AENV, 2006.

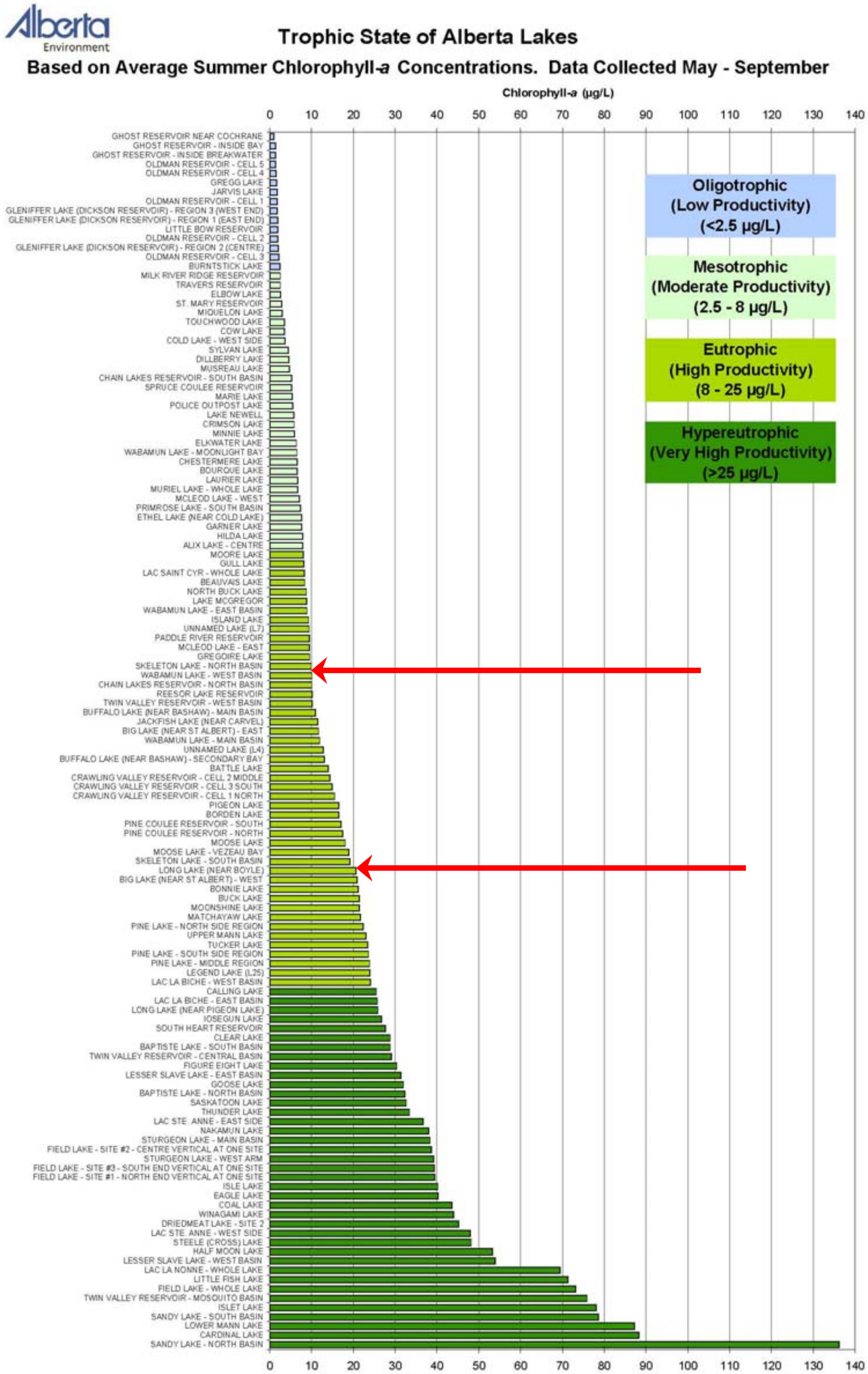


Figure 11. The trophic status of Skeleton Lake based on chlorophyll a levels, as compared to other Alberta Lakes. The south and north basins are indicated with red arrows. Adapted from AENV, 2006.

6.2 Aquatic Ecosystem Health

6.2.1. Fisheries

Alberta Municipal Affairs (1979) reported that Skeleton Lake supported abundant stocks of northern pike, yellow perch and lake whitefish, with only small numbers of walleye. Commercial fishing at the lake has occurred for 50 years with tullibee being the species most frequently caught, switching later to mainly whitefish (Alberta Municipal Affairs, 1979). However, there has been no commercial fishing since 2001 due to by-catches exceeding non-target species allowances (walleye and pike) (C. Davis, pers. comm., 2007). Trap fishing has been proposed as an alternative to netting, as target species can be released unharmed (C. Davis, pers. comm., 2007). In 1985, there was an estimated 5349 anglers on the lake with 14.5 angler hours per hectare, however, in 1997, it was estimated that there were only 387 anglers on Skeleton Lake with an estimated 0.95 angling hours per hectare (Patterson and Sullivan, 1998). This is a decrease of 93% from 1985 to 1997(Patterson and Sullivan, 1998).

Northern pike and yellow perch spawn in submerged and emergent vegetation areas in the lake, while sand and gravel shoals provide spawning grounds for whitefish and walleye (Alberta Municipal Affairs, 1979). While the fisheries biologist at the time had not confirmed spawning areas within the lake, it was speculated that spawning occurred in the east and west bays of the south basin, the east bay of the north basin and in the narrows (Alberta Municipal Affairs, 1979). There is no particular area of the lake that is more important fish habitat than another; depending on the species and the life stage, different areas of the lake will be utilized. However, there are areas that are more sensitive to development pressures, pollution and dropping water levels (i.e. cattail marshes and weed beds adjacent to the shore are more sensitive than gravel or sand beds) (C. Davis, pers. comm., 2007). Original habitat data (Alberta Municipal Affairs, 1979) show that the Narrows, the east end of the northern basin, the north eastern shore of the southern basin and the west side of the southern basin as areas with emergent vegetation (Appendix A). It has been estimated that the surface area of the lake has been reduced by approximately 70 hectares due to the drop in water level (WorleyParsons Komex, 2007). This has likely reduced the size of the weed beds in these areas and decreased available spawning habitat for pike and yellow perch.

In 2004, a fall walleye index netting survey was completed by Alberta Sustainable Development Fish and Wildlife. The survey showed that the lake currently supports a recreational fishery of northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*), along with a commercial fishery for lake whitefish (*Coregonus clupeaformis*) (Latty, 2005). However, as previously discussed, there has been no commercial fishing since 2001 due to the over harvest of northern pike (Latty, 2005).

There are also walleye (*Sander vitreus*), cisco (*Coregonus artedii*) and burbot (*Lota lota*) present in the lake. In 1985, the walleye sportfishery was reported to be collapsed (Patterson and Sullivan, 1998) and this species was almost extirpated (Latty, 2005). Restocking was completed from 1988 - 1991 and 1993 in an attempt to recover the population (Latty, 2005), however walleye populations were still collapsed in 1996 (Patterson and Sullivan 1998). Test angling completed in 2001 showed some recruitment had occurred (Latty, 2005). In the fall index netting survey, a total of 527 walleye were caught over a 2 day period, with walleye representing 39.6% of the catch, lake whitefish at 28.7%, northern pike at 15.4%, yellow perch at 7.6%, white suckers at 6.0%, cisco at 2.3% and spottail shiners at 0.4% (Latty, 2005). The walleye catch rate was similar to other Alberta lakes with vulnerable to collapsed populations, at a rate of 16.4 fish/100 m^2/24 hours (Latty, 2005). It was recommended that the walleye population remain classified as collapsed and that a zero bag limit remain in effect until recruitment has improved. However, Patterson and Sullivan (1998) reported that potential for this fishery to recover to historical levels is low.

6.2.2 Waterfowl

According to the management study completed by Alberta Municipal Affairs (1979), the shores of Skeleton Lake have limited waterfowl production potential due to adverse topography, reduced marsh edge and low soil fertility; however, the narrows are rated as having only slight limitations to waterfowl production. Skeleton Lake is not a significant regional waterfowl or nesting area but nearby Flat Lake is a significant staging and nesting area. Flat Lake water levels have declined dramatically (B. Curial, pers. comm., 2007), which could potentially make other waterbodies in the area more important for waterfowl. The major species seen in the area include grebes, scaup, loons, mallards and buffleheads (Alberta Municipal Affairs, 1979), and the major nesting and habitat areas would be found in areas having abundant emergent vegetation growth; removal of this vegetation due to development or disruption from recreational boat users could prove to be detrimental to these waterfowl areas.

In a survey conducted in June 2005 by Alberta Sustainable Resource Development, 11 species of ducks, 3 species of gull, 3 species of tern, 1 grebe, 2 raptors and 6 other species were observed. The most common species found was Forster's Tern, followed by Mallard duck, Franklin's Gull and Common Goldeneye. Several grebe nests were observed, and these birds nest near the shore on floating masses of reeds and grass. Many of the other species observed nest in tall grasses or shrubs of the riparian areas. Therefore, loss of riparian habitat will decrease the available nesting sites for a number of bird species that occur in the watershed. Of the species observed, none are listed as Species at Risk.

Although not observed during the 2005 survey, the Yellow Rail (*Coturnicops noveboracensis)* does occur in the area, and is listed as 'Special Concern' on the list of Species at Risk in Canada (Environment Canada 2006). Nesting Yellow Rails can be found in damp fields and meadows, on the floodplains of rivers and streams, and in the herbaceous vegetation of bogs. Therefore, a decline in wetlands in the Skeleton Lake watershed due to increasing development will decrease the available breeding habitat for this species.

6.2.3 Other Wildlife

The forested areas surrounding the lake provide good habitat for ungulates, black bears, game birds, small mammals and coyotes. Continued loss of forested areas will decrease the habitat available for these species.

The Cape May Warbler (*Dendroica tigrina*) is a migratory bird that breeds in the boreal forest around Skeleton Lake. Available information suggests that they require mature to old forest stands with a predominantly coniferous canopy. The Cape May Warbler is currently included on the 'Blue List' of species that may be at risk in Alberta due to concerns over habitat loss and declines in populations in some areas. The Alberta Natural Heritage Information Centre
has assigned this warbler a provincial rank of S2, indicating imperilment due to rarity.

6.2.4 Phytoplankton and Zooplankton

Mitchell (1979) found that the blue green algae *Cyanophyta* dominated the phytoplankton assemblage except during spring and early summer, at which times *Bacillariophyta* was more common. Many species of diatoms were present, with the largest biomass coming from *Fragilaria* and *Melosira* (Mitchell, 1979). These are common species found in eutrophic systems. Deeper spots in the lake experienced blooms late in the year, often in October, due to fall overturn and the subsequent release of nutrients from the lake bottom, whereas shallower areas experience blooms earlier in the year due to more frequent mixing (Mitchell, 1979).

There are abundant zooplankton populations in Skeleton Lake, namely copepods, rotifers and cladocerans (Mitchell, 1979). An analysis of phytoplankton and zooplankton populations was performed in 2006 and a complete listing of the species found and their associated densities and biomass can be found in Aquality (2007).

7.0 Surface Water Quantity

7.1 Hydrology and Lake Levels

Lake levels in Skeleton Lake remained fairly steady from 1965 to 1987, but have experienced a dramatic drop in next ten years (Figure 12). Lake levels reached record highs in 1997 (to a max of 623.885 m) then began to steadily decline again. In October 2006, lake levels were the lowest they have ever been, at 622.198 m above sea level, which is a drop of 1.69 meters in 10 years. Currently, the lake is 622.382 m above sea level (as of May 15, 2007) (AENV 2007).

Based on digitized outlines of the lake from the 1964 and 2003 air photos, it has been estimated that the surface area of the lake has been reduced by approximately 70 hectares (Worley Parsons Komex, in press). The decline in lake levels is of concern to residents in the area, and many theories as to the cause have been proposed.

In 1979 the average depth of the Narrows connecting the two basins was 1.5 m deep (with a slender 3 m deep channel in the middle) (Skeleton Lake Management Study, 1979). Based on the available bathymetry (1965) and historic water level data (AENV, 2007), the lake level would only need to drop below 622.27 m for the narrows to be close to drying up (WorleyParsons Komex, in press). If the lake drops to 620.77 m it is very likely that the Narrows will be completely dry. Field verification of narrows water depth is needed to determine a more accurate measurement of the water level at which the Narrows will be dry.

A water balance study was completed by Alberta Environment in 1996 and updated in 2003. In this study, a desktop hydrologic model was developed for Skeleton Lake, using HYDROL modeling software. Inflow and outflow measurements were unavailable for the development of this model, so estimates were used, using Flat Creek flow data for inflow estimates and a wide angled v-notch weir at the channel control for outflow estimates (AENV, 2004). The Village of Boyle diversions were included in one simulation in this model, but groundwater influence was excluded. Precipitation and evaporation estimates were also generated from Alberta Environment and Environment Canada data from other locations such as Cold Lake. The study concluded that the large fluctuations in water levels seen in the lake are part of natural variation and that no outside influences (i.e. diversions) are responsible for the changes. The study concluded that the drainage basin to lake area ratio was large enough to ensure sustainability of the lake over the long term. However, this model did not consider groundwater influence and only estimated inflow and outflow. It is important to note that this "desktop" simulation will need to be verified by on-the-ground hydrologic measurements.

If the lake storage numbers generated in this study are examined further, it is evident that there has been a natural decline in the lake levels on the order of 7,423 dam^3 since 1967, which translates to a 14% loss in storage (Table 4). Approximately 60% of the loss occurred in the period of 1988-2002 alone. When the model is adjusted for the Village of Boyle drinking water diversion, the loss in storage is increased by 1,401 dam^3, leading to a drop in total storage of 8,824 dam^3, or a 17% loss. Figure 12 graphically represents the losses and gains in storage seen in the lake during natural conditions and under diversion conditions based on the figures generated by the Alberta Environment study. The diversion is having a small effect on the lake storage levels and may be having a large impact on riparian areas and shallow habitats. There are some other variables affecting the lake as well, and these need to be quantified. It could also be a result of a combination of factors, such as a drop in precipitation having a drawdown effect on groundwater supplies, leading to a subsequent drop in the levels seen in the recharging water bodies.

Table 4. Summary of storage losses from 1967-2002 using the model numbers generated by the AENV Water Balance study (2003).

Lake Condition	Estimated Net Losses in Storage (dam^3)	Estimated Net Gains in Storage (dam^3)	Change in Storage (dam^3)	Percentage of Storage Loss
Natural Conditions	20,205	12,782	7,423	14%
Under diversion	22,796	13,972	8,824	17%

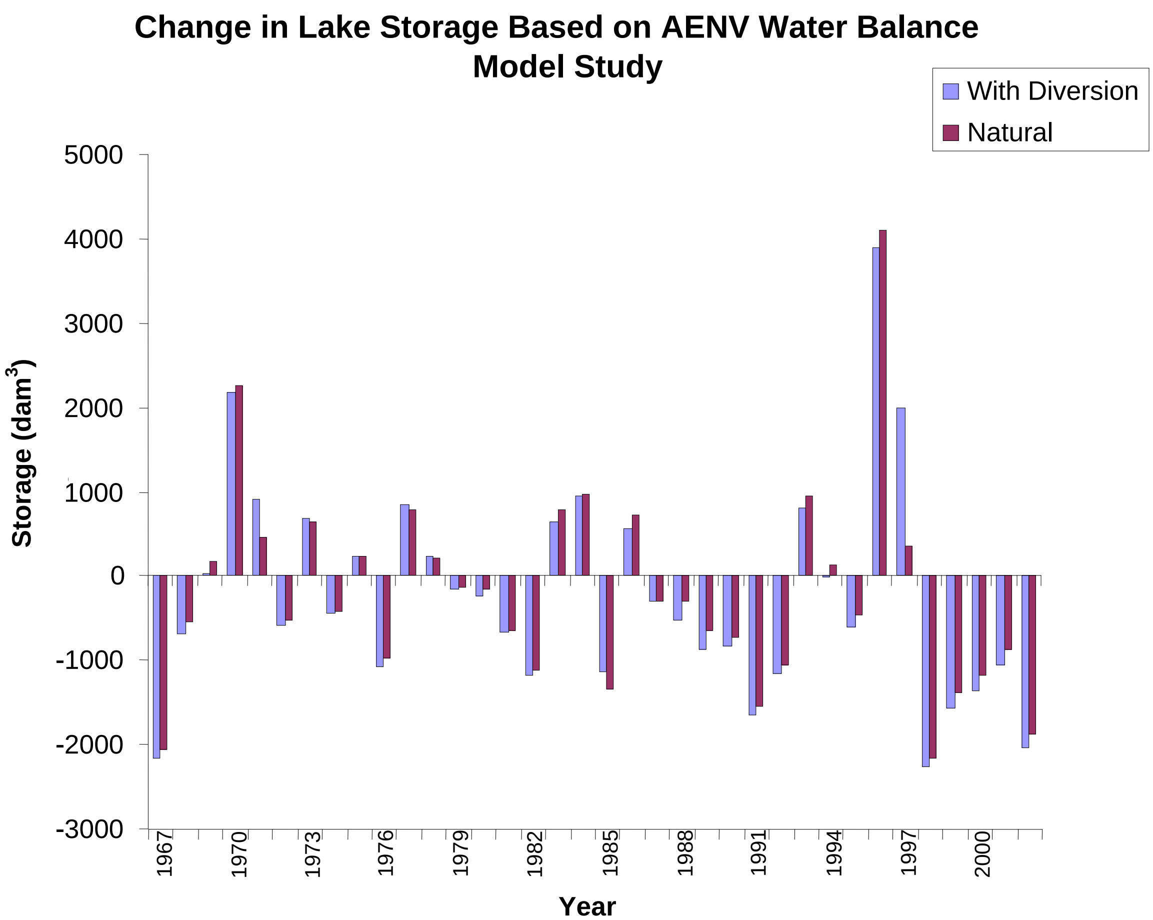
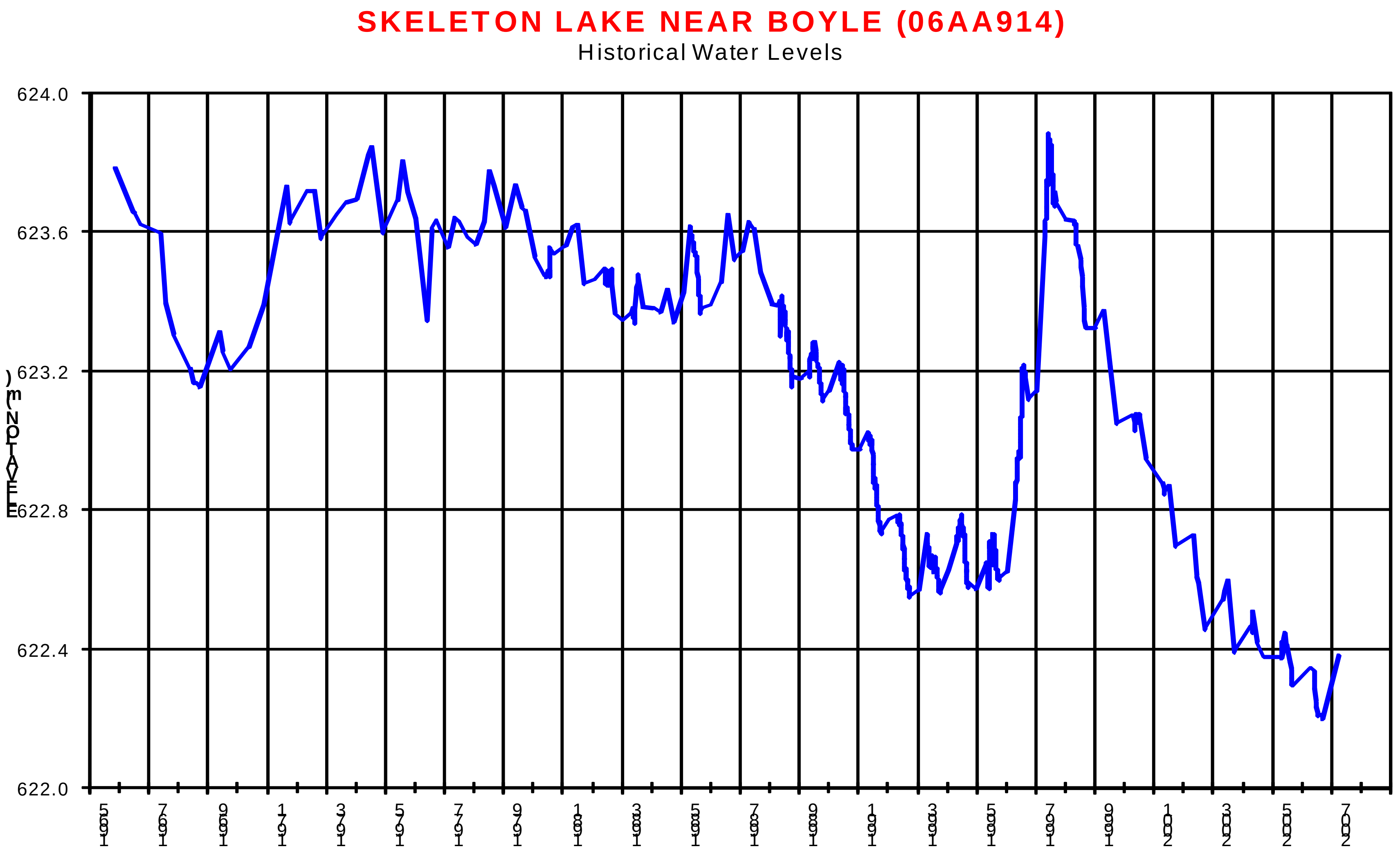


Figure 12. Storage gains and losses from 1967-2002 using the estimated storage amounts generated in the AENV water balance study (2004).

Figure 13 shows historic Skeleton Lake water levels, while Figures 14 and 15 demonstrate the changes in lake elevation for Amisk Lake and Long Lake respectively. Note that when Skeleton Lake levels decline, Amisk and Long Lake levels typically rise or remain steady. Skeleton Lake discharges into Amisk Lake which then outflows via the Amisk River and feeds areas to the west. Therefore, any draining activities, dewatering or altering of outflow rates from Amisk Lake could potentially lead to drops in the water level of Skeleton Lake. Additionally, any alterations to groundwater levels to the west could potentially lead to drops in the water level of Skeleton Lake; however, groundwater influence to lake level needs to be explored further. Amisk Lake has a larger watershed ratio and is therefore able to handle fluctuations in water levels more easily than Skeleton Lake, reducing recovery times to normal levels in times of shortage.



LATEST AVAILABLE W.L. = **622.382** M ON **MAY 15/07.**

Figure 13. Declining water levels in Skeleton Lake since 1965. Data from AENV (2007).

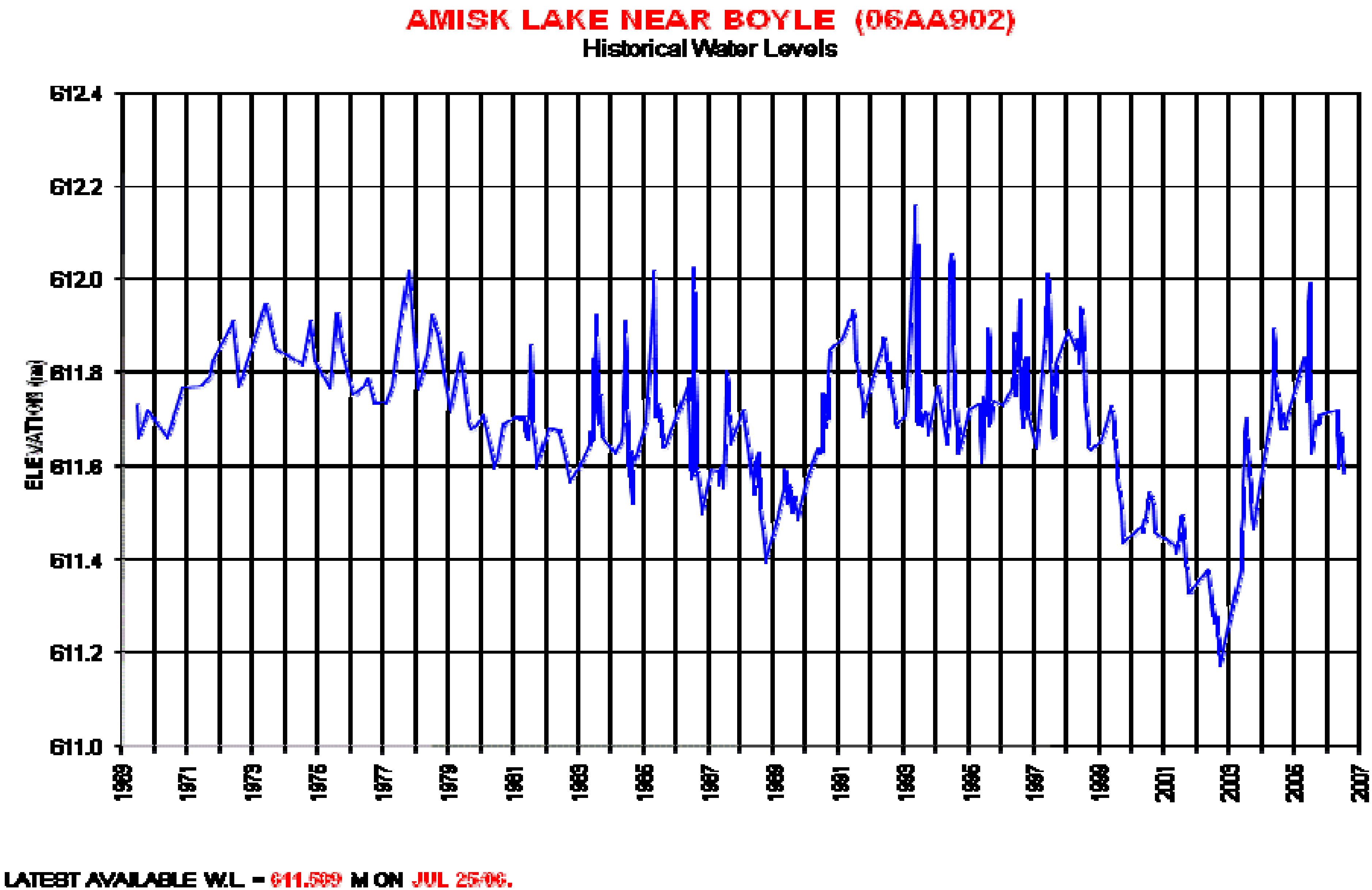
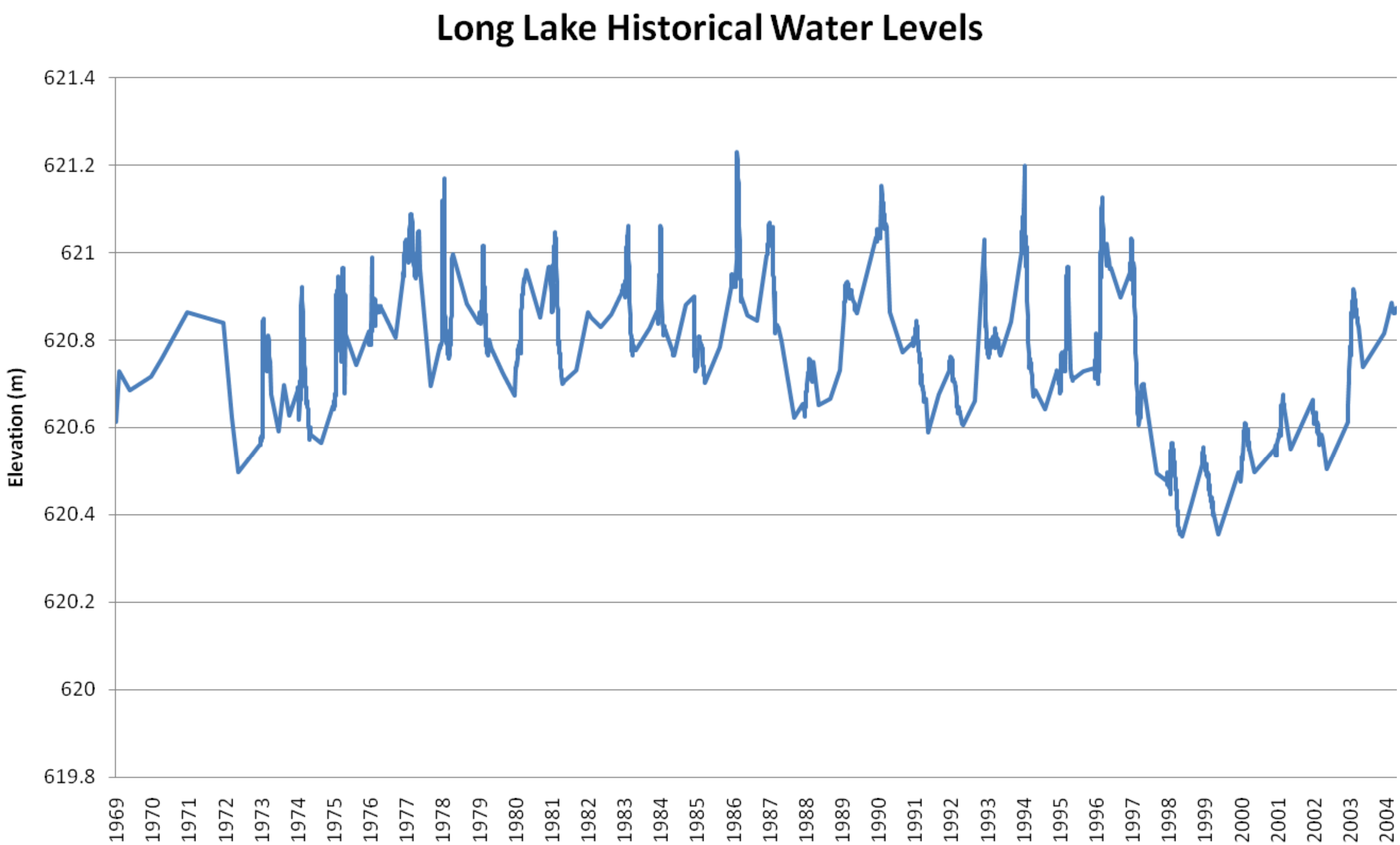


Figure 14. Water levels for Amisk Lake from 1969 to 2004. Data from AENV (2005).



Last Available W.L. = 621.027 May 17/05

Figure 15. Historical Lake Level for Long Lake, AB from 1969 – 2005. Graph generated from data provided by AENV 2005.

If water levels continue their current decline within the lake, there will be an extensive loss of riparian habitat, fish habitat and a loss of recreational use of the lake. At the current rate of loss the narrows may dry up entirely, which will separate the two bays of the lake. This could affect fish populations, water quality and limit recreational use within the lake. Examples of extreme water loss have recently occurred at other Alberta lakes including Sandy, Muriel and Beaverhill. These lakes have all lost extensive areas of shoreline, experienced declines in water quality and now have problems with aquatic ecosystem health and functionality.

7.2 Water Withdrawals and Consumption (including Domestic Use)

Water is currently diverted from Skeleton Lake by the Village of Boyle. The village withdraws an average of 647 liters per capita per day (Associated Engineering, 2003), satisfying a largely residential demand. The industrial mill draws approximately 20,950 m^3/yr, while commercial, rural and summer residents take 13,640 m^3/yr from the truckfill (Associated Engineering, 2003).

Since 1992, 2,065.4 acre feet (or 2,547,670.9 m^3) of water has been removed from the lake, with an average of 147.5 acre feet (or 181,941.3 m^3) per year (Village of Boyle, 2004), which accounts for approximately 8% of the average annual surface inflows (AENV, 2004). Table 5 indicates the increasing amount of water that has been used from the lake since 1992. The return flows are in the form of municipal wastewater and are not returned to Skeleton Lake, but to Flat Lake via Flat Creek (AENV, 2004). The original license to divert water issued by AENV to the village was for a gross diversion of up to 150.0 acre feet annually (185,025 m^3), and this level has been exceeded regularly since 1999.

The County of Athabasca recently received a temporary license (April – October 2007) to divert water from Skeleton Lake for the purposes of commercial, construction and dust control use. The license allows a total of 260 m^3 of water to be diverted from the lake (Alberta Environment 2007a).

Table 5. Water diversions from Skeleton Lake to the Village of Boyle.

Year	Acre Feet*	Truckfill (Acre Feet*)	Village Population
1992	99.2	5.6	710
1993	122.7	7.4	784
1994	134.0	10.0	811
1995	143.3	10.9	862
1996	134.8	14.6	802
1997	132.2	14.4	802
1998	148.3		868
1999	165.1		868
2000	151.9		868
2001	162.4		868
2002	165.7		840
2003	176.8		840
2004	171.0		840
2005	158.0		851
TOTAL	**2065.4**	**62.8**	
AVERAGE	**147.5**	**10.5**	

*One acre foot is equal to 1233.5 cubic meters; one cubic meter = 1,000 liters.

8.0 Data Gaps

The following data gaps have been identified in this report and should be addressed in order to help determine the best course of action to take in the protection and enhancement of the Skeleton Lake ecosystem:

- The effect of groundwater allocations (i.e. domestic, commercial and industry wells) on the water balance of Skeleton Lake
- Faecal bacteria and *E. coli* levels within the lake
- Water budget and analysis of hydrological interactions (interaction between groundwater and surface water) within the watershed
- Continuous, long term water quality data
- Septic system survey of cottage owners around the lake
- Riparian health assessments and drained wetland inventories
- Land cover and land use survey.

9.0 Conclusions and Recommendations

Water quality at Skeleton Lake is generally good with slightly better water quality seen in the north basin. The water quality in this lake is more consistent with that of a mountain lake rather than a prairie lake. This leads to the conclusion that this lake is fed to a significant extent via underground aquifer. Water quality within the lake should be monitored on an annual basis and parameters should include nutrients, bacteria, and periodic testing for the parasites *Cryptosporidium* and *Giardia*. Nutrient loadings to the lake need to be empirically quantified as they have only been estimated to date.

Continued decreases in water levels will increase water quality problems within the lake through concentration of solutes and nutrients. For example, reducing the lake volume by one half will double nutrient concentrations in the lake. Increased nutrient concentrations will result in more extensive and prolonged algal blooms which in turn can decrease available oxygen. As algae decompose in the fall, oxygen is used up and causes the lake to become anoxic and potentially unable to support fish.

Further study is required to accurately measure all natural inflow and outflow volumes from the lake. This study should be completed by a professional hydrologist, and should include a review of the Skeleton Lake Water Balance study (AENV 2004).

Since Skeleton Lake is topographically higher than Amisk Lake, the flow of groundwater should be examined to confirm if Skeleton Lake recharges regions to the east and if the current gravel pit dewatering practices that occur east of the lake have any impact on lake levels. Any drainage, hydrological alterations or dewatering activities to the east of Skeleton Lake need to be documented and the effects of these activities quantified.

Once the Town of Boyle's water diversion from the lake stops, lake water levels will need to be monitored to track the response of lake water levels. Diversion of surface and groundwater from sites around the lake is not recommended until surface and groundwater interactions within the watershed are better understood.

Due to the morphology of Skeleton Lake (shallow shores and deep middle), continued water level decline will cause extensive loss of littoral zones. At the current rate of loss, the Narrows may dry up entirely, separating the two bays of the lake. The loss of the shallow water around the edge of lake will ultimately lead to extensive loss of riparian habitat. Loss of riparian habitat will compound any water quality problems as there will no longer be a buffer (the riparian vegetation) to will remove sediments, nutrients and other compounds (i.e. pesticides) from surface runoff. Additionally, there may be a further decline in fish populations due to loss of spawning and/or feeding habitat.

The threat of riparian habitat loss or degradation gives a sense of urgency for further steps to be taken to protect and maintain riparian areas. Riparian health assessments should be considered along the shoreline of the lake to determine if any critical riparian areas have been degraded or lost due to dropping water levels, and if any areas need to be restored due to removal of vegetation or other land use practices.

The loss of the wetland areas and the subsequent change in hydrology to the west of the lake should also be studied to determine what effect this has on the lake. A drained wetland inventory may also help identify critical wetland areas around the lake that need to be restored or protected in order to preserve the hydrology and water levels in the lake. Land Use Bylaws should be modified to ensure preservation of these areas and also be used to limit development around the Narrows and the south basin in order to limit excess nutrient loading, and sewage management practices should be examined and improved.

It will be necessary to monitor the potential recovery and recruitment of walleye populations until the population has recovered from its collapsed state. It is advisable to keep zero bag limits until the populations have recovered. A Qualified Aquatic Environment Specialist (QAES) should assess fish habitat including spawning areas to help determine why walleye recruitment has failed. This problem may be compounded by additional loss of riparian fish habitat into the future.

The Skeleton Lake Stewardship Association should continue towards the completion of a Watershed Management Plan for Skeleton Lake. This process may include grant writing, public education and outreach, and forming partnerships with agencies such as Alberta Environment, Alberta Sustainable Resource Development - Public Lands, the Alberta Conservation Association (ACA), Ducks Unlimited Canada, Living by Water, and others. A water conservation objective should be established, and other issues within the watershed will need to be prioritized and dealt with in order of importance, starting with declining water levels.

Table 6. Priority Areas of Concern and Responsibilities.

Priority Areas (Highest to Lowest Concern)	Lead Role	Contributors
Water Quantity and Quality	Provincial and Federal Governments	SLSA and Municipalities
Assessment of land use practices	Municipal Government, Industry and General Public	All Municipalities
Zoning and infrastructure, land use bylaws	Municipal Government	All Municipalities
Riparian and Wetland Health	Cows and Fish, Ducks Unlimited	Alberta Environment, SLSA
Fish Habitat and Population Assessment	Alberta Environment	SLSA and ACA
Watershed Management Plan / Water Conservation Objective	SLSA	All Municipalities, Alberta Environment, First Nations and other stakeholders

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Appendix A

Lake Vegetation and Fish Habitat Original Data

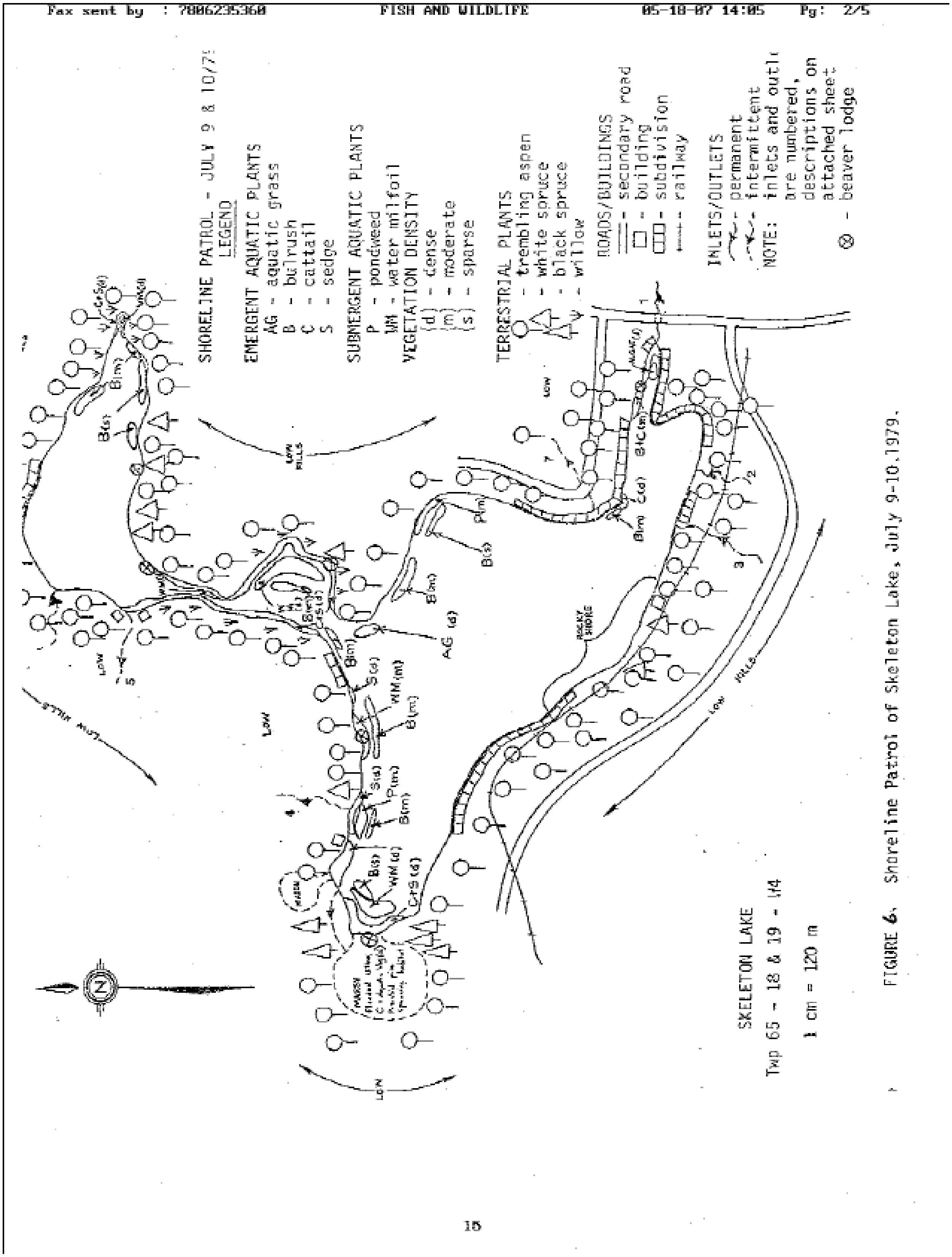

FIGURE 6. Shoreline Patrol of Skeleton Lake, July 9-10,1979.

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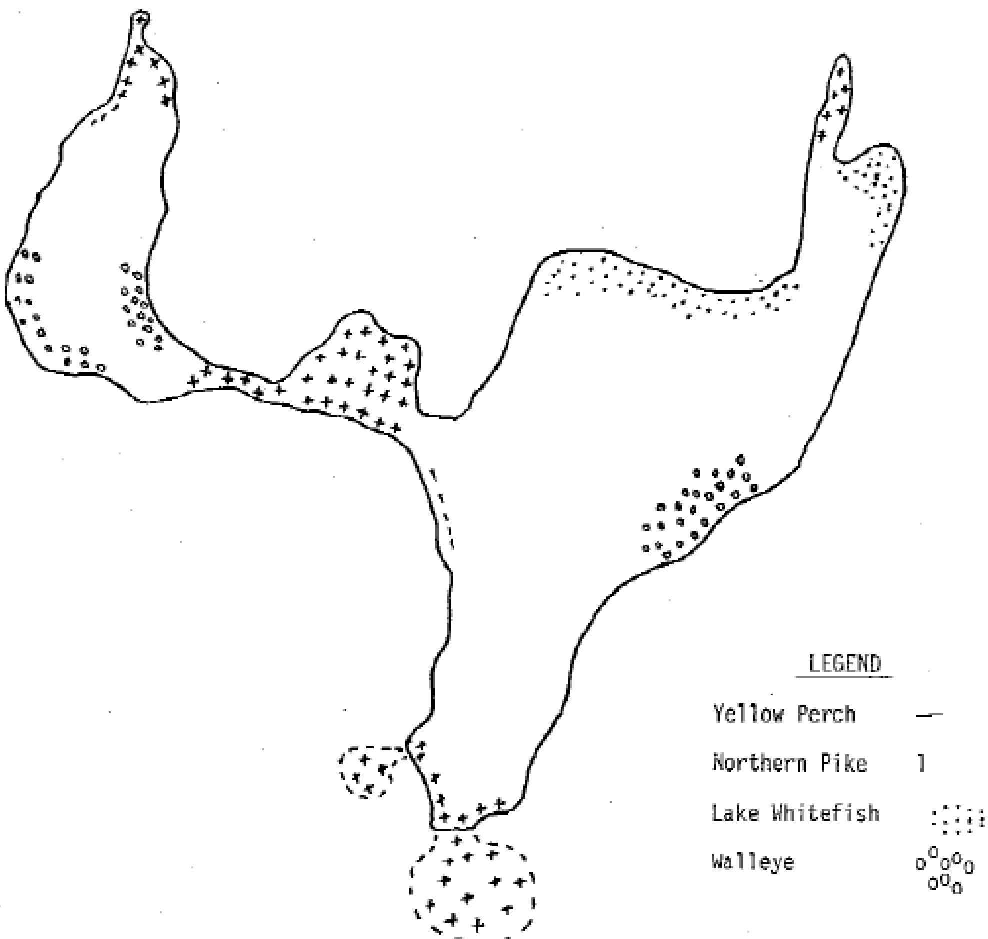

Figure 7 Potential Fish Spawning Areas in Skeleton Lake July, 1979.

16

SHORELINE PATROL - JULY 9 & 10, 1979

Description of Inlets and Outlets

1. - permanent outlet; approximately 3 km to Amisk Lake
   - at mouth approximately 3 m wide and 0.5 m deep
   - sand and rock bottom; willow along edges
   - moderate water flow; several large pools near mouth; dense algae
   - evidence of beaver activity; possible dams downstream (none seen near mouth)
   - capable of fish passage

2 & 3
   - intermittent inlets
   - at mouth approximately 3 m wide and 0.25 m deep
   - sand and rock bottom; willow along edges
   - minimal flow at present
   - capable of fish passage

4. - intermittent outlet
   - at mouth approximately 2m wide and 0.25 m deep
   - soft bottom; willow and cattail along edges
   - no flow at present
   - capable of fish passage

5. - intermittent outlet; seepage to low marshy area
   - nearly dry at present
   - incapable of fish passage

6. - intermittent inlet; run-off
   - at mouth approximately 3 m wide and 0.25 m deep; narrows to approximately 0.25 m wide within 10 m of mouth
   - sand bottom; no flow (appears to be drying up)
   - incapable of fish passage

7. - intermittent outlet
   - near mouth approximately 1 m wide and 0.25 m deep
   - sand and gravel bottom; sand bar across mouth
   - no flow at present
   - incapable of fish passage

Appendix B

Skeleton Lake Biological Assessment

Skeleton Lake
Biological Assessment

Prepared for:
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August 2007

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Table of Contents

ACKNOWLEDGEMENTS **1**
1.0 EXECUTIVE SUMMARY **3**
2.0 INTRODUCTION **4**
3.0 METHODS **5**
4.0 RESULTS **7**
4.1 Water Quality 7
4.2 Algae and Zooplankton 17
5.0 DISCUSSION **23**
5.1 Water Quality 23
5.2 Algae and Zooplankton 23
6.0 CONCLUSIONS **23**
7.0 REFERENCES **24**
8.0 GLOSSARY **25**
APPENDIX A **27**

1.0 Executive Summary

The recent decline in the water level of Skeleton Lake has caused great concern among local residents. Decreasing the lake's volume by half will effectively double the nutrient concen-trations in the lake. Therefore, continued decreases in lake water level will increase water quality problems within the lake through increased concentrations of solutes and nutrients. Algal blooms will become more frequent and persistent and aquatic plant growth may increase due to increased light penetration into the water column.

2.0 Introduction

Skeleton Lake water levels have dropped dramatically in the last 10 years, which has caused great concern to area residents and visitors. Members of the Skeleton Lake Stewardship Association have requested that a biological assessment be completed to examine water quality, phytoplankton, and zooplankton. The results of this study will provide a benchmark to which future conservation efforts can be compared.

Common water quality parameters of concern that have been examined in this assessment include nutrient levels (such as total phosphorus, nitrogen, nitrate-nitrite), salinity, pH, sulphate, iron, and others. An assessment and identification of all phytoplankton and zooplankton has also been completed.

3.0 Methods

Skeleton Lake was sampled on October 9, 2006 by a professional biologist from Aquality Environmental Consulting Ltd. Composite water samples representative of the entire euphotic zone were taken from the north and south bays of the lake. Six locations were sampled in the north bay of Skeleton Lake and twelve sites were sampled in the south bay. This resulted in two sample bottles from the northern bay and three sample bottles from the south bay being collected. The GPS coordinates and euphotic depths for the sites appear in Table 1.

Water samples were taken using a 3 m clear plastic euphotic tube with a one-way foot valve, and collected in a sterile 20L polyethylene bottle. Once the 20L bottle was full, the water was thoroughly mixed and subsamples were poured into 1L brown high density polyethylene (HDPE) sample bottles. Algal subsamples were collected from deepest spots in the two bays of the lake using the euphotic tube and 20L plastic bottle and stored in 250mL white HDPE bottles and preserved with Lugol's solution.

Zooplankton samples were collected from the deepest locations at twice the euphotic depth, using a plankton tow net with a diameter of approximately 25cm and a netting size of 64 microns. Three tows were taken at each sample location, and the net was then rinsed out with lake water. Zooplankton samples were stored in 250mL white HDPE bottles and preserved with 7% formalin solution.

Water samples were analyzed for the following parameters:

- Total nitrogen
- Total phosphorus
- Total Kjeldahl nitrogen
- Nitrate-nitrite
- Ammonium
- Chloride
- Sulphate
- Alkalinity
- Bicarbonate
- Carbonate
- Conductivity
- pH
- Colour
- Turbidity
- Non filterable residue
- Chlorophyll *a*

Phytoplankton and zooplankton samples were identified to species level; biomass and density were determined for each individual species and the total sample.

Water quality analysis was performed by the University of Alberta Limnology Laboratory, and algal and zooplankton identification was performed by Bio-Limno Research & Consulting, Inc.

Table 1. GPS coordinates and euphotic depth for all sample locations.

Location	N	W	Euphotic Depth (m)
Skeleton Lake North Bay Site 1	54 38.498'	112 42.011'	3
Skeleton Lake North Bay Site 2	54 38.449'	112 41.837'	3
Skeleton Lake North Bay Site 3	54 38.545'	112 42.414'	2.6
Skeleton Lake North Bay Site 4	54 38.545'	112 42.414'	2.6
Skeleton Lake North Bay Site 5	54 38.584'	112 42.914'	3
Skeleton Lake North Bay Site 6	54 38.764'	112 42.513'	3
Skeleton Lake South Bay Site 1	54 36.973'	112 44.009'	3
Skeleton Lake South Bay Site 2	54 36.852'	112 43.792'	2.6
Skeleton Lake South Bay Site 3	54 37.001'	112 43.645'	2.6
Skeleton Lake South Bay Site 4	54 37.034'	112 43.183'	2.6
Skeleton Lake South Bay Site 5	54 36.534'	112 42.966'	2.2
Skeleton Lake South Bay Site 6	54 36.424'	112 43.157'	3.2
Skeleton Lake South Bay Site 7	54 36.367'	112 43.292'	2.8
Skeleton Lake South Bay Site 8	54 36.178'	112 43.433'	2.8
Skeleton Lake South Bay Site 9	54 36.097'	112 42.563'	2.4
Skeleton Lake South Bay Site 10	54 36.028'	112 42.351'	2.6
Skeleton Lake South Bay Site 11	54 35.968'	112 42.510'	2.8
Skeleton Lake South Bay Site 12	54 36.028'	112 42.715'	3

4.0 Results

4.1 Water Quality

Phosphorus is usually the limiting nutrient in aquatic environments and is an essential nutrient for most organisms. However, too much phosphorus can lead to eutrophication of water bodies, which means an excessive growth of phytoplankton and plants. When plant growth becomes excessive, resultant die-off can lead to large amounts of decaying organic matter which depletes the water of dissolved oxygen and can suffocate fish populations. Decaying matter can also leave the water with an undesirable taste, odour and colour, leaving it potentially unsafe for recreation or human consumption. The water can become filled with large mats of algae, some of which produce toxins which are harmful to humans and other aquatic organisms (i.e. *Microcystis*). The Alberta Surface Water Quality Guideline for the protection of freshwater aquatic life is 0.05 mg/L (50 µg/L) of phosphorus.

As observed in Figure 1, Skeleton Lake north bay had higher average total phosphorus levels (46.89 µg/L) than the south bay (41.66 µg/L).

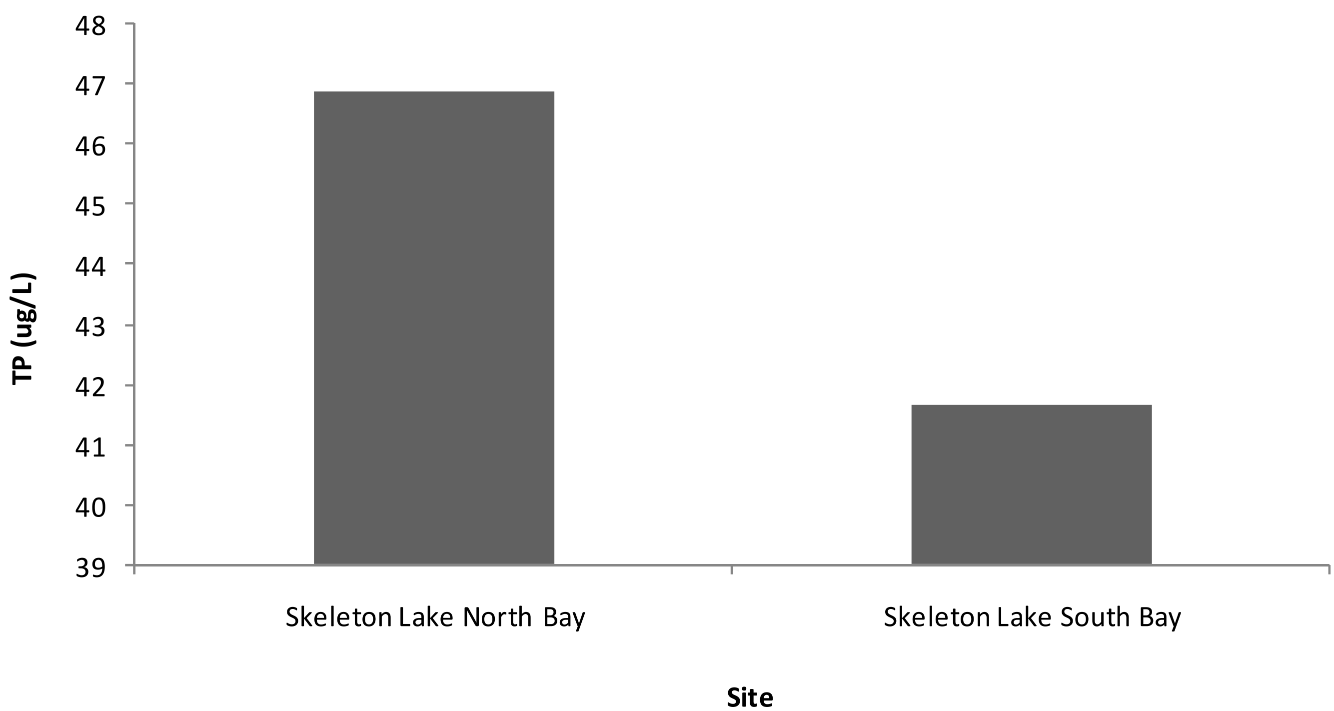

Figure 1. Total phosphorus (TP) levels in both bays of Skeleton Lake on October 9, 2006.

Chlorophyll *a* is used as a measure of phytoplankton productivity. Therefore, a large chlorophyll *a* concentration indicates a large amount of phytoplankton. The amount of chlorophyll *a* is generally correlated with phosphorus concentrations.

Chlorophyll *a* levels were similar between the north and south bays with values of 16.24 µg/L and 16.95 µg/L respectively.

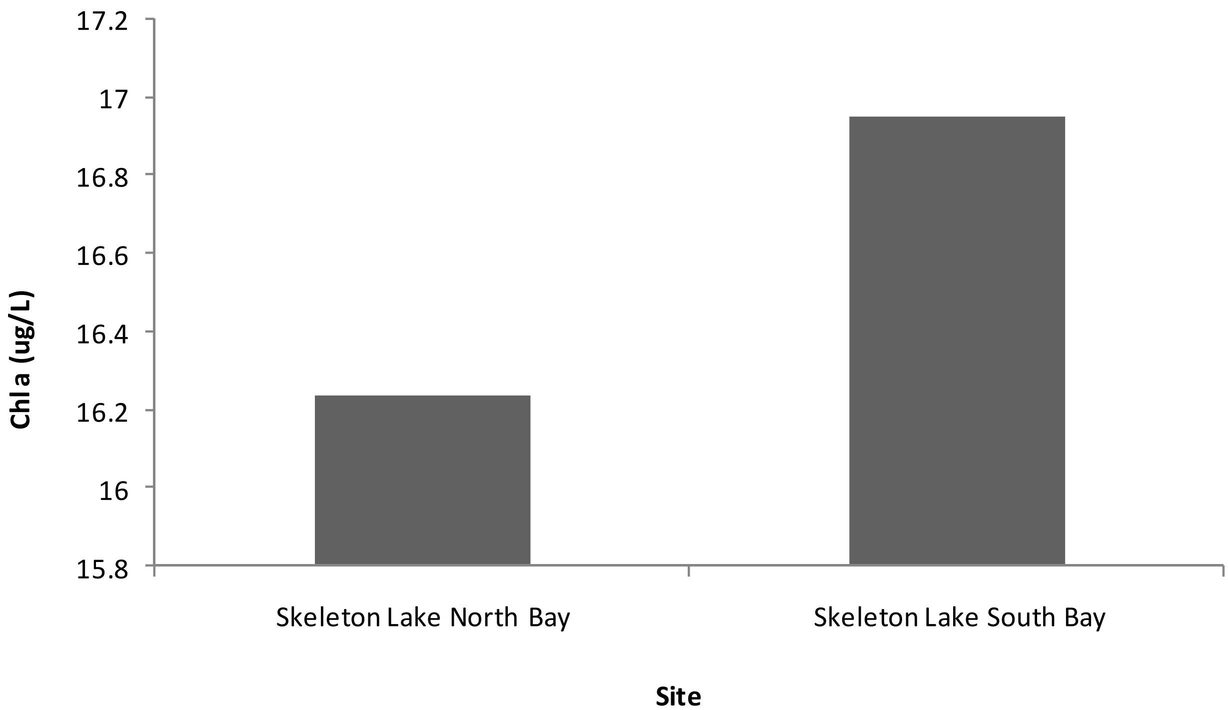

Figure 2. Chlorophyll *a* (Chl *a*) levels in both bays of Skeleton Lake on October 9, 2006.

Nitrogen is a nutrient that is essential to most organisms and can be limiting in some environments. Like excess phosphorus, excess nitrogen can contribute to increased phytoplankton growth. The Alberta Surface Water Quality Guideline for the protection of freshwater aquatic life is 1.0 mg/L (1000 µg/L) of nitrogen.

Total nitrogen was higher in Skeleton Lake north bay, averaging 1470 µg/L, (Figure 3).

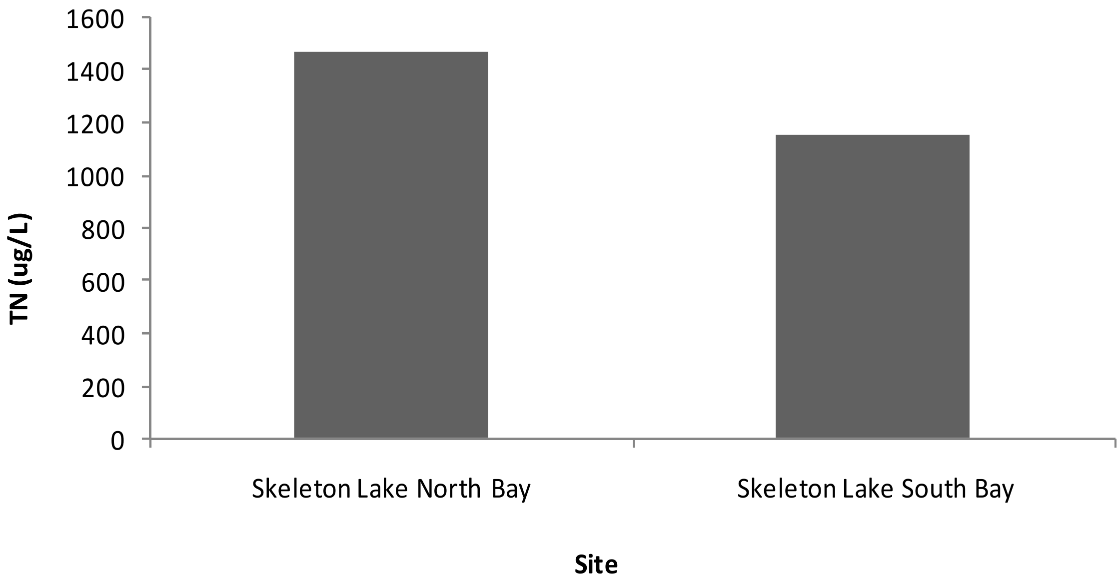

Figure 3. Total nitrogen (TN) levels in both bays of Skeleton Lake on October 9, 2006.

Total kjeldahl nitrogen is the combination of organically bound nitrogen and ammonia. Organic nitrogen is nitrogen that originated in living material (i.e. nitrogen in wastes from organisms). Ammonia is an inorganic form of nitrogen that is transformed to ammonium by bacteria.

Total kjeldahl nitrogen (TKN) levels were higher in Skeleton Lake north bay, averaging 1464.65 µg/L, (Figure 4).

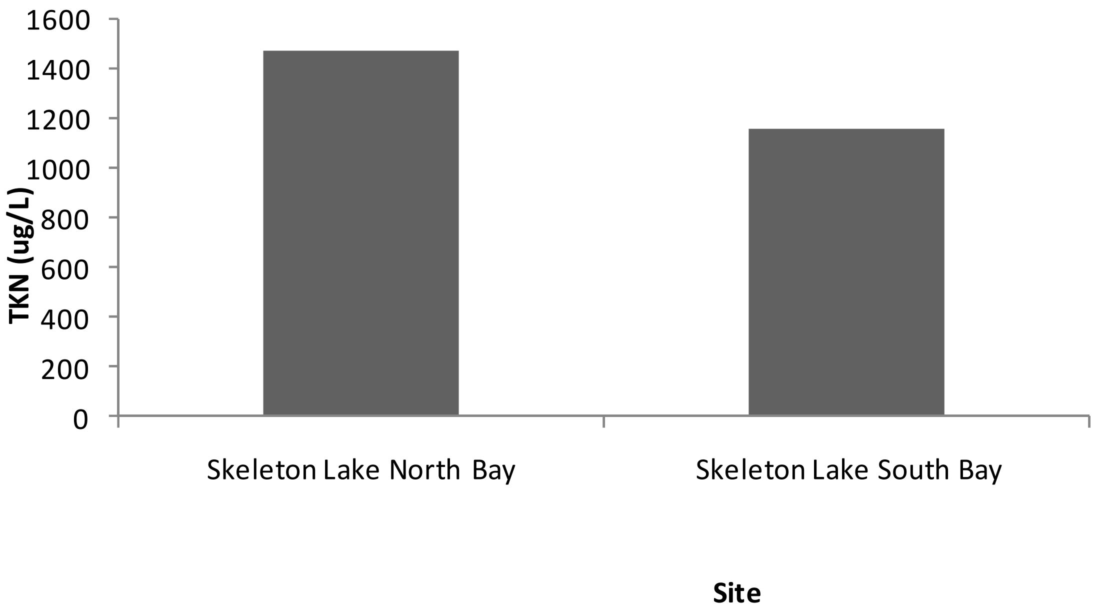

Figure 4. Total Kjeldahl nitrogen (TKN) levels in both bays of Skeleton Lake on October 9, 2006.

Nitrate and nitrite are both inorganic forms of nitrogen. As ammonia (NH_3) is broken down by bacterial action, nitrite is formed and is then converted to the more stable form, which is nitrate. Nitrate is also readily available for phytoplankton uptake. High nitrate levels in drinking water can contribute to methemoglobinemia ("blue baby" syndrome). This condition, usually affects infants and impairs the ability of blood to carry oxygen (CCME, 2002). The Canadian Council of Ministers of the Environment (CCME) Guideline for Agriculture (Livestock) for nitrate-nitrite is 100 mg/L. The CCME Guideline for nitrite for the Protection of Aquatic Life is 0.06 mg/L (60 µg/L) and there is currently no guideline for nitrate.

Nitrate-nitrite levels were lower in Skeleton Lake south bay at 4.15 µg/L (Figure 5).

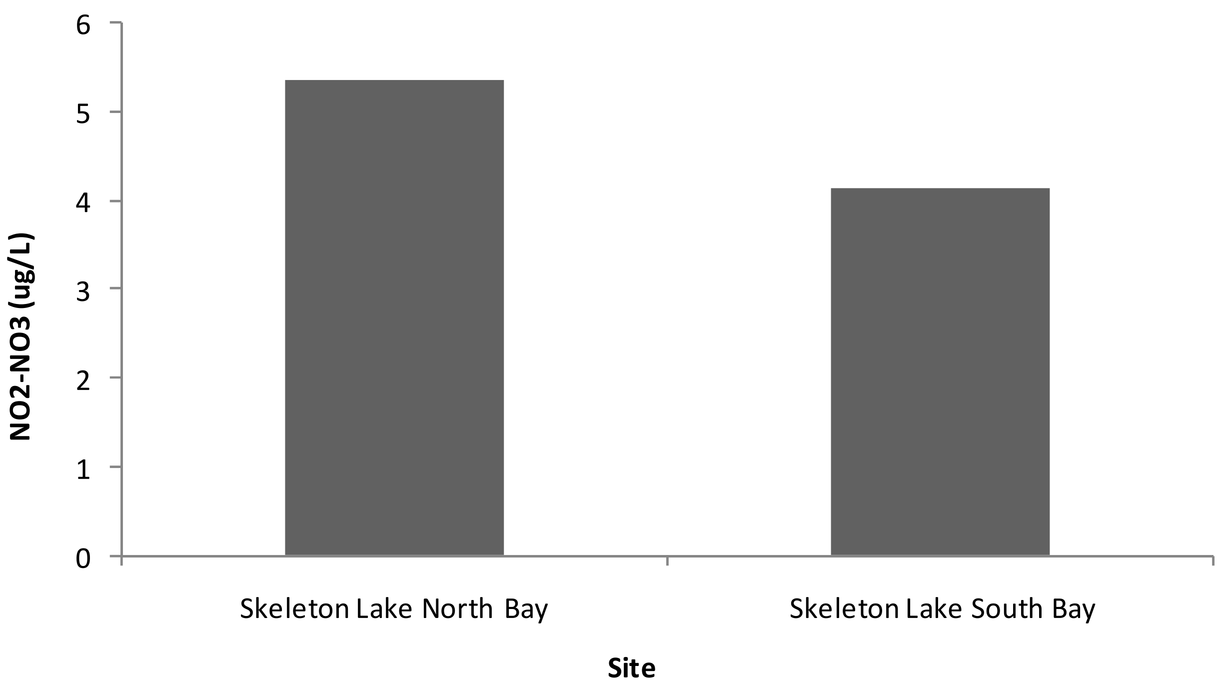

Figure 5. Nitrate-nitrite (NO_2-NO_3) levels in both bays of Skeleton Lake on October 9, 2006.

Ammonium is another inorganic form of nitrogen that is readily available for phytoplankton use. Ammonium levels were higher in Skeleton Lake north bay, averaging 152.5 µg/L, and lowest in Skeleton Lake south bay, averaging 10.14 µg/L (Figure 6).

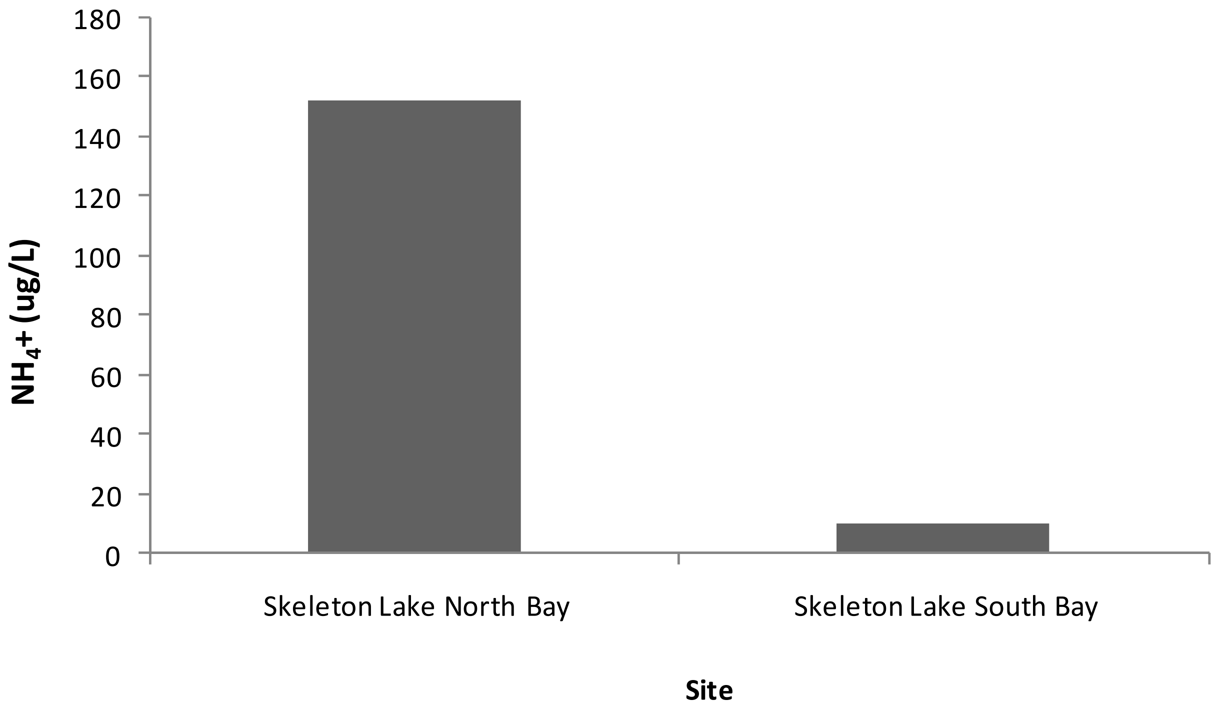

Figure 6. Ammonium (NH_4^+) levels in both bays of Skeleton Lake on October 9, 2006.

Conductivity is the measure of the ability of an aqueous solution to carry an electrical current. It is affected by the presence of dissolved and suspended solids and can be used as an indicator of general lake health. A change in conductivity may indicate the presence of pollution (i.e. sewage, stormwater runoff, oil/gas, etc.). Conductivity was lower in the northern bay of Skeleton Lake, averaging 362.5 µS/cm (Figure 7).

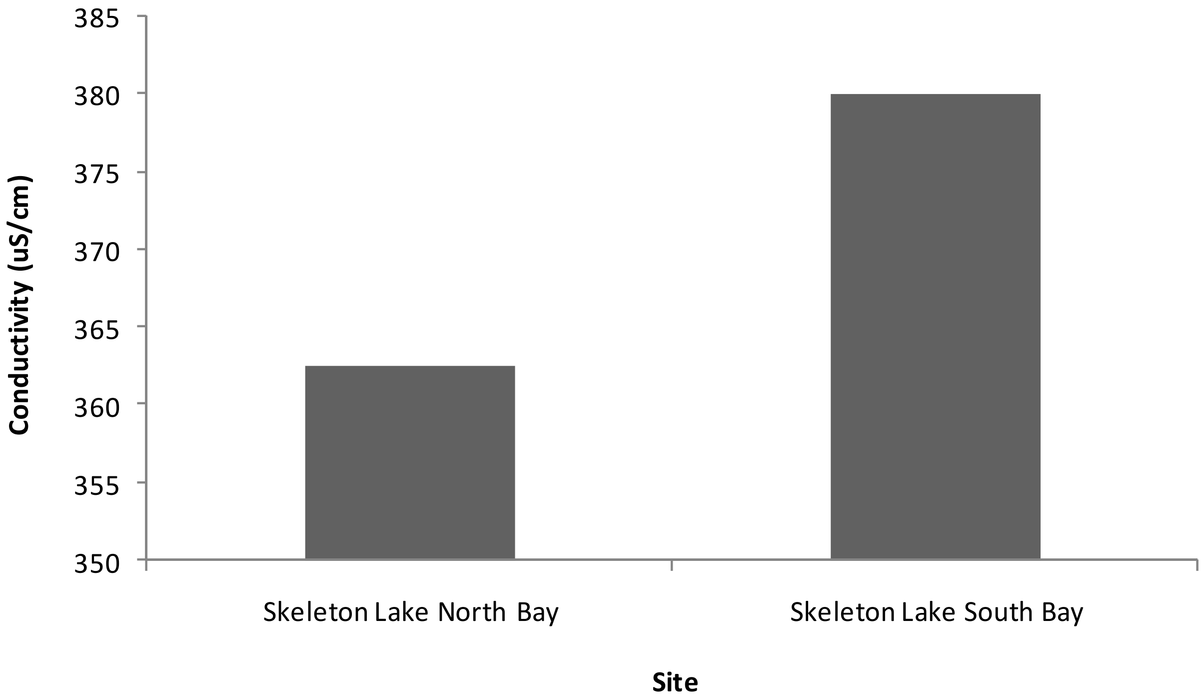

Figure 7. Conductivity levels in both bays of Skeleton Lake on October 9, 2006.

Carbonate can be used as a measure of water hardness or buffering capacity (the ability of the water to resist a change in pH). A greater carbonate concentration in surface waters means that there is a large buffering capacity. A lake with a larger buffering capacity would be more resistant to changes in pH and would remain more stable than a lake with a lower buffering capacity when facing acidification.

Carbonate levels were much higher in Skeleton Lake south bay, averaging 6.01 mg/L, (Figure 8).

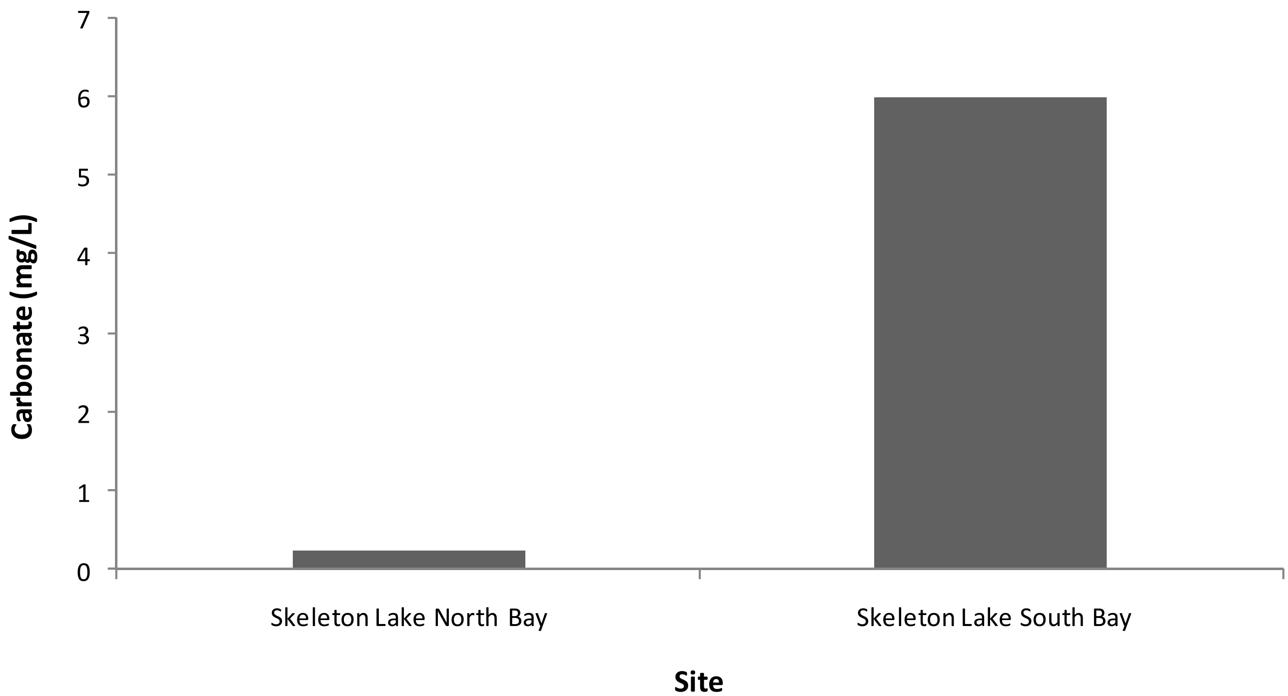

Figure 8. Carbonate levels in Skeleton Lake on October 9, 2006.

Sulphate is a naturally occurring substance that contains sulphur and oxygen. It is present in various mineral salts that are found in soil. Sulphate forms salts with a variety of elements including barium, calcium, magnesium, potassium and sodium (Government of Saskatchewan, 2003). Sulphate may be leached from the soil and is commonly found in most water supplies. There are several other sources of sulphate in water including decaying plant and animal matter, numerous chemical products including ammonium sulphate fertilizers, treatment of water with aluminum sulphate (alum) or copper sulphate. Human activities such as the combustion of fossil fuels and sour gas processing can also be a source of sulphate.

Sulphate is generally considered to be non-toxic. High amounts of various sulphate salts may give drinking water an offensive taste. Depending upon the type of sulphate salt(s) present in the water, most people begin to notice an offensive taste at concentrations ranging from 250 to 1,000 mg/L.

Sulphate levels in the lake were 2.01 mg/L on average (Figure 9).

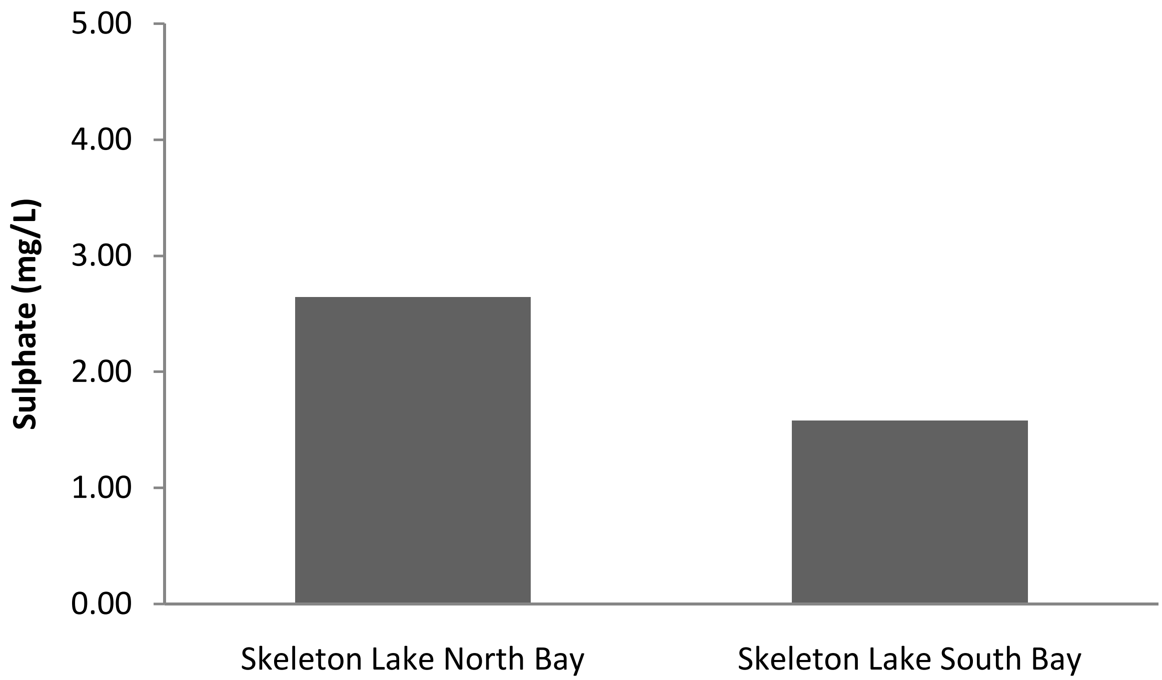

Figure 9. Sulphate levels in Skeleton Lake, 2006.

Iron is a trace element required by both plants and animals. It is a vital part of the oxygen transport mechanism in the blood (haemoglobin) of all vertebrates, macrophytes (aquatic plants) and some invertebrate animals. Iron is a natural component of water and soils and water bodies contain variable amounts of iron depending on the geological area and other chemical components of the waterway. Like sulphate, iron is generally considered to be non-toxic. However, when iron concentrations reach 0.3 mg/L there can be negative effects on freshwater aquatic life (CCME Guideline for the Protection of Aquatic Life, 1999).

Iron levels averaged 0.5 mg/L and 0.2 mg/L in the north bay and south bay of the lake, respectively (Figure 10).

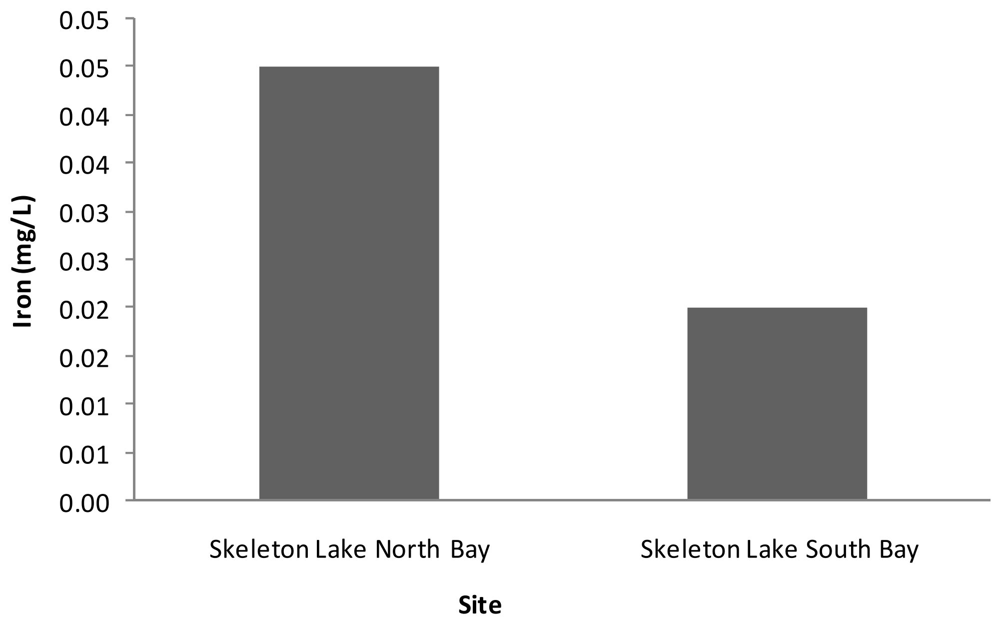

Figure 10. Iron levels in Skeleton Lake, 2006.

4.2 Algae and Zooplankton

Algal density was higher in Skeleton Lake north bay, as seen in Figure 11. Table 2 lists all the species found in the samples, as well as the density numbers and biomass.

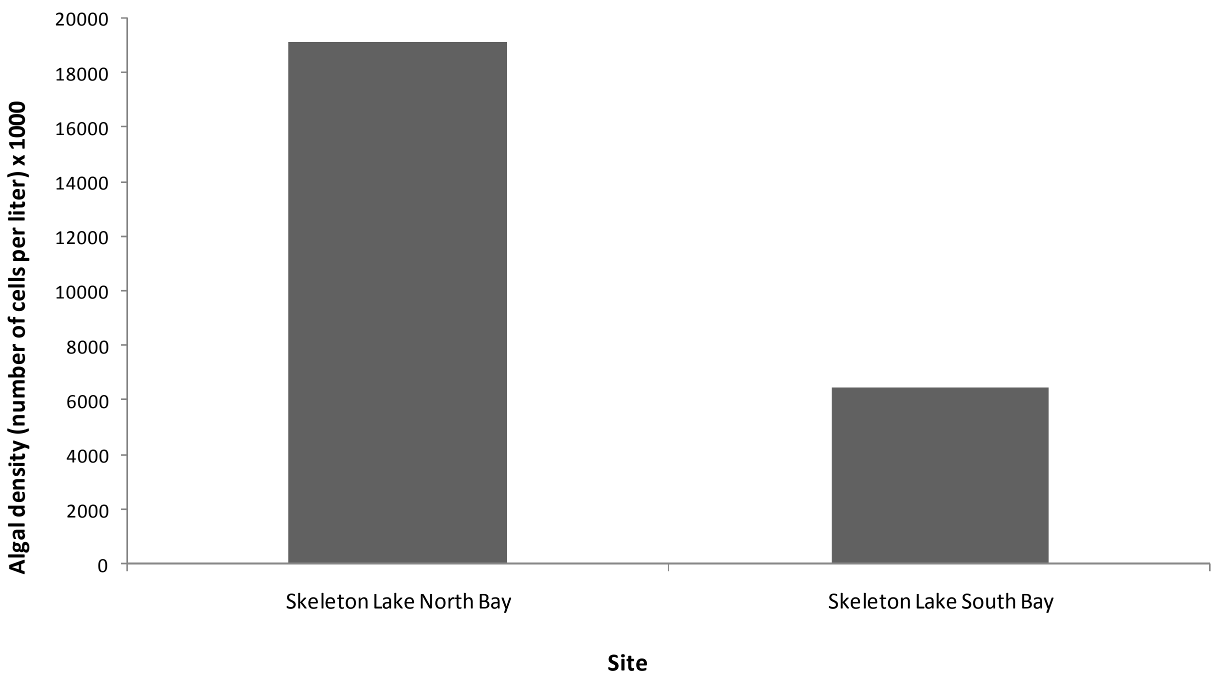

Figure 11. Algal density in both bays of Skeleton Lake on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Algal biomass was higher in Skeleton Lake south bay (Figure 12).

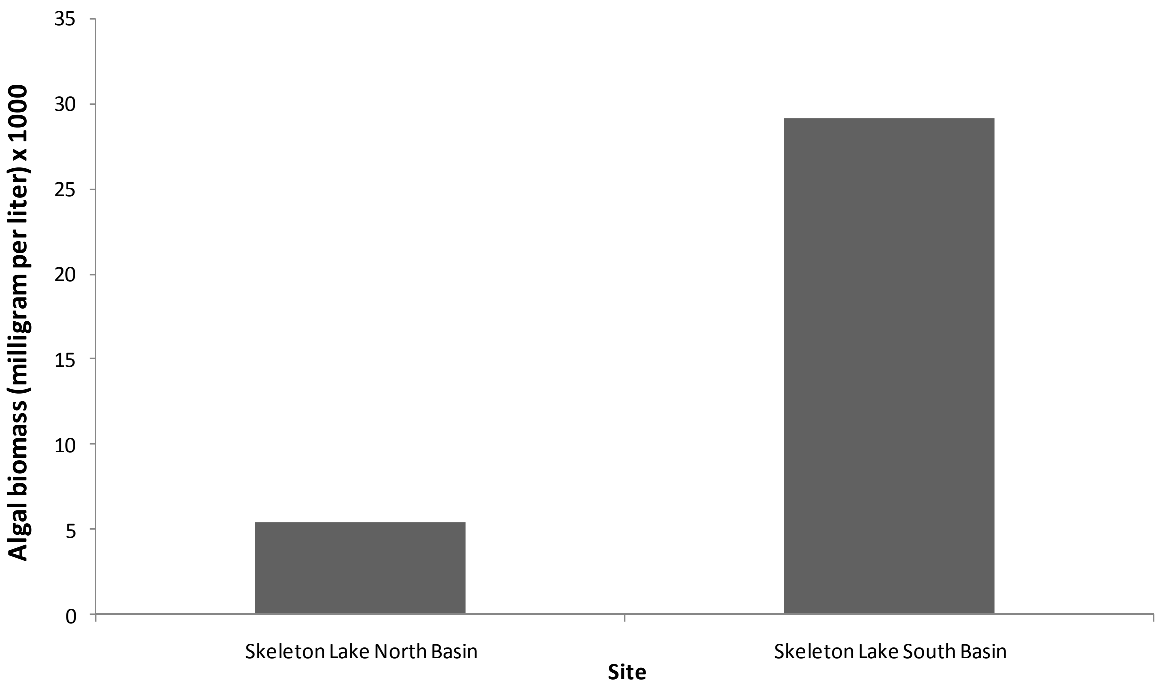

Figure 12. Algal biomass in both bays of Skeleton Lake on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Table 2. Phytoplankton density (number of units/L) and biomass (mg/m^3) in the North and South Bays of Skeleton Lake. Table courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Phytoplankton	**Skeleton Lake North Bay**		**Skeleton Lake South Bay**	
	Density units/L	**Biomass** mg/m^3	**Density** units/L	**Biomass** mg/m^3
CYANOBACTERIA (Blue-green Algae)				
Anabaena sp 1	136135	112.908	0	0
Anabaena sp 2	0	0	85084	38.491
Aphanocapsa delicatissima West & West	17016	10.692	187186	77.696
Aphanizomenon flos-aquae (Linne) Ralfs	1123119	3972.104	884881	2496.598
Aphanocapsa rivularis (Carm.) Rabenhorst	0	0	17016	171.073
Aphanocapsa sp	34033	654.355	0	0
Limnothrix sp	340339	108.631	0	0
Microcystis ichthyoblabe Kuetzing	0	0	17016	21.384
Gomphosphaeria aponina Kuetzing	0	0	34033	85.537
Oscillatoria limnetica Lemmerman	0	0	119118	71.423
Phormidium sp Kuetzing ex. Gormont	17016	38.491	0	0
Planktolyngbya contorta Lemmermann	17016	6.415	17016	8.554
Planktolyngya limnetica Lemmermann	782780	218.118	119118	43.624
Pseudanabaena limnetica Komarek	850848	77.411	136135	48.97
Snowella lacustris (Chodat) Komarek et Hindak	0	0	136135	163.589
CHLOROPHYCEAE (Green Algae)				
Ankyra judayi (G.M. Smith) Fott	17016	0.249	17016	1.426
Ankistrodesmus spiralis (Turner) Lemmermann	17016	2.281	0	0
Chlamydomonas sp 1	0	0	0	0
Chlamydomonas sp 2	0	0	17016	4.562
Choricytis (colonial)	170169	68.429	0	0
Choricytis (solitary)	15349300	128.59	3267256	23.371
Elakatothrix genevensis (Reverdin) Hindak	34033	1.443	85084	4.21
DIATOMS				
Aulacoseira granulata (Ehrenberg) Simonsen	0	0	17016	72.171
Aulacoseira spp	0	0	187186	9753.735
Centric diatom (6-10 um)	17016	6.683	119118	46.778
Fragilaria crotonensis Kitton	0	0	17016	5.445
Rhizosolenia longiseta Ehrenberg	34033	7.698	17016	1.711
Synedra spp	0	0	51049	5.973
CRYPTOPHYCEAE				
Cryptomonas marsonii Skuja	0	0	51050	53.46
Rhodomonas minuta Skuja	68067	15.397	527525	119.324
Rhodomonas minuta var. nanoplanctonica Skuja	0	0	102101	5.132
EUGLENOPHYCEAE				
Phacus sp	17016	14.256	85084	250.907
TOTAL	**19110033**	**5471.104**	**6432384**	**2913881**

Skeleton Lake north bay demonstrated a higher zooplankton biomass than the south bay, as seen in Figure 13. Table 3 lists all the zooplankton species identified in the samples, as well as their associated biomass and density.

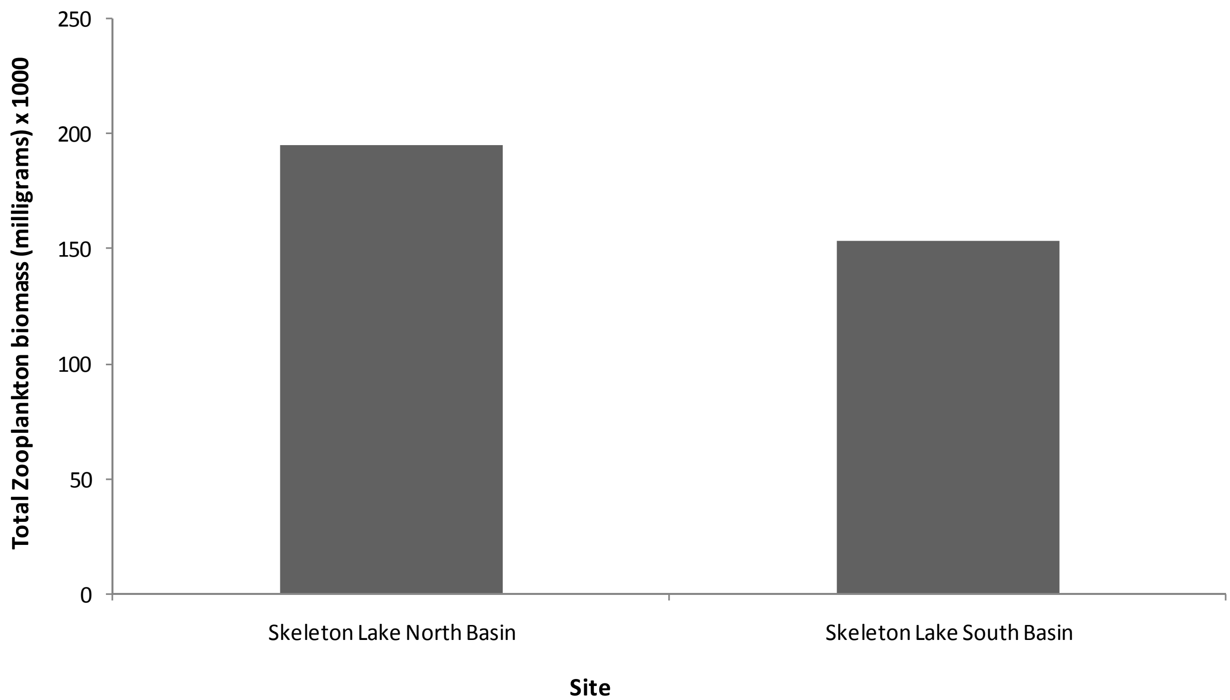

Figure 13. Zooplankton biomass in both bays of Skeleton Lake on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Zooplankton density was higher in Skeleton Lake south bay than in the north bay (Figure 14).

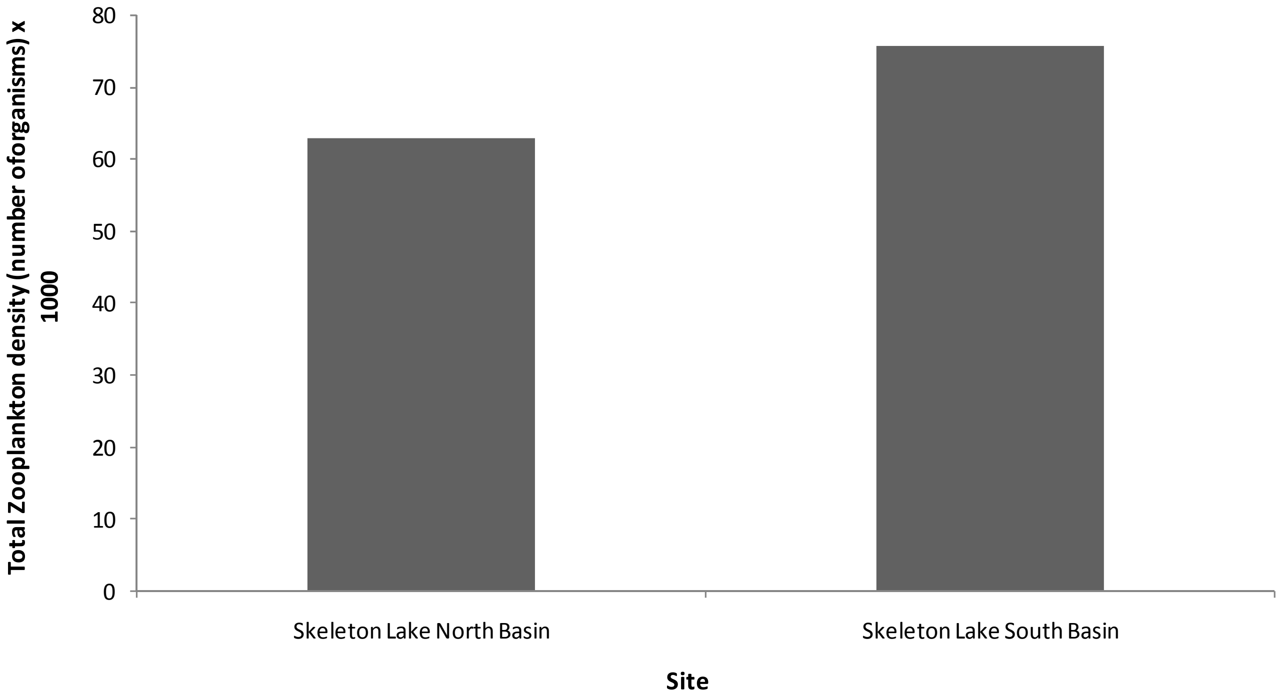

Figure 14. Zooplankton density in both bays of Skeleton Lake on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Table 3. Zooplankton density (number of organisms/m^3) and biomass (micrograms/m^3) in the North and South Bays of Skeleton Lake Table courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Zooplankton	**Skeleton Lake North Bay**		**Skeleton Lake South Bay**	
	Density no./m^3	**Biomass** mg/m^3	**Density** no./m^3	**Biomass** mg/m^3
ROTIFERA				
Conochilus unicornis	0	0	2654.40	1452.10
Collotheca mutabils	853.20	381.68	0	0
Kellicotia longispina	1706.40	1243.78	884.80	644.92
Keratella cochlearis	6399.00	3229.09	23889.60	12055.26
Polyathra vulgaris	4692.60	2855.58	4424.00	2692.13
Polyathra dolicoptera	0	0	0	0
Pompholyx sulcata	0	0	3539.20	2185.47
Calanoid (nauplii)	426.60	537.99	0	0
Cyclopoid (nauplii)	853.20	1218.72	884.80	1263.86
OTHERS (CILIOPHORA)				
Opercularia sp	23463.00	33514.86	11060.00	15798.25
CALANOIDA				
Acanthodiaptomus denticornis				
Leptodiaptomus sicilis	8885.3	83365.7	6696.0	62824.5
Calanoid copepodid	74.7	282.3	0	0
CYCLOPOIDA				
Dicyclops bicuspidatus	9109.3	48211.0	1426.0	7547.1
Acanthocyclops vernalis	0	0	0	0
Mesocyclops edax	373.3	4974.9	0	0
Cyclopoid copepodid	1717.3	2926.1	682.0	1162.0
CLADOCERA				
Daphnia galatea mendotae	597.3	4901.9	3596.0	29509.8
Daphnia rosea	0	0	0	0
Daphnia pulex	0	0	0	0
Diaphanosoma brachyurum	672.0	5437.1	620.0	5016.4
Chydorus sphericus	3061.3	2327.0	15190.0	11546.2
Cladocera (immature)	0	0	0	0
TOTAL	**62884.67**	**195407.69**	**75546.80**	**153698.02**

5.0 Discussion

5.1 Water Quality

Due to the eutrophic (nutrient-rich) nature of Skeleton Lake, one of the most critical considerations when considering changes in water quantity and quality is nutrients. Increased nutrient concentrations caused by loss of water could push the lake into a hypereutrophic state, causing excessive algal growth. Using the averaged values for total phosphorus and total nitrogen in Skeleton Lake, we can see that the Redfield ratio for the lake is roughly 30:1, meaning it is a phosphorus limited system, so an increased concentration of phosphorus would greatly increase the productivity of the lake.

The north and south basins are quite similar chemically, but the south basin appears to be slightly more productive, as indicated by the higher chlorophyll *a* concentration.

5.2 Algae and Zooplankton

Algal densities in the north bay of Skeleton Lake are higher than that of the south bay (Figures 10 and 11; Table 2). However, the algal biomass is lower in the north bay when compared to the south bay. This is likely due to the larger sized species of phytoplankton found in the south bay (i.e. there are fewer individual phytoplankton in the south bay, but they are larger). Cyanobacteria, which include toxic bloom-forming forms, were also present in Skeleton Lake. Several of the algal taxa recorded are indicators of eutrophic conditions. For example, both *Aphanizomenon-flos-aquae* (recorded in both bays of Skeleton Lake), and *Aulacoseira granulata* (found in the south bay only) are indicative of eutrophic conditions (Wetzel 1983, Reynolds, 1984). Zooplankton species richness in the two bays of Skeleton Lake did not differ substantially. (Figures 12 and 13; Table 3).

6.0 Conclusions

Decreased in water levels, if they continue at rates currently seen in the lake, will increase water quality problems within the lake through concentration of solutes and nutrients. Algal blooms will become more problematic and aquatic plant growth would likely increase due to increased light penetration into the water column. Halving the lake's volume will effectively double the nutrient concentrations seen in the lake.

7.0 References

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8.0 Glossary

Aerobic: In freshwater systems, an environment that contains oxygen.

Alkalinity: A measure of the hydroxyl ion concentration in a solution expressed as a pH value between 7 and 14. Alkalinity is a capacity factor that represents the acid-neutralizing capacity of a system (CCME 1999).

Algae: Plant or plantlike organisms, usually aquatic, capable of synthesizing their own food by photosynthesis. They occur in relative proportion to the amount of nutrients available. They are food for some fish and small aquatic animals (i.e. zooplankton). Includes the green, yellow-green, brown, red and cyanobacteria.

Anaerobic: In freshwater systems, an environment that is devoid of oxygen.

Anoxic: In freshwater systems, anoxic refers to a lack of dissolved oxygen. Bacterial decomposition of excessive organic matter under winter ice cover frequently causes anoxia.

Anthropogenic: Literally, "human origin", such as sewage inputs into a freshwater system.

Bioavailable: Refers to nutrients and compounds that are available for use by living things.

Biomass: The total mass of living organisms of one or more species per unit area or of all the species in a community.

Buffering Capacity: The ability of the water to resist changes in pH (i.e. changes in acidity or alkalinity).

Chlorophyll *a*: A measure of phytoplankton productivity in freshwaters, which is empirically positively correlated with phosphorus concentrations.

Colour: A measure of the degree to which water is stained by dissolved organic compounds (such as humic acids). Lakes with high colour are less transparent to light penetration.

Composite Sample: A series of water samples taken at a given time from several locations combined into a single sample.

Conductivity: An indication of the ionic strength of freshwater, determined by measuring its ability to conduct electricity.

Cyanobacteria: Also known as blue-green algae, cyanobacteria are a group of aquatic bacteria that obtain their energy through photosynthesis. These are part of the phytoplankton assemblage and are capable of fixing carbon dioxide and nitrogen. Some produce toxic compounds.

Euphotic Tube: A clear polyethylene (plastic) tube with a one-way foot valve used to sample a column of water from the euphotic zone.

Euphotic zone: The euphotic zone is defined as the upper layer of water into which sufficient light penetrates to allow phytoplankton growth.

Eutrophic: Refers to aquatic environments that have abundant nutrients and high rates of productivity. In eutrophic water bodies such as lakes, ponds and slow-moving rivers, oxygen levels below the surface layer may be depleted. Opposite of oligotrophic (CCME 1999).

Eutrophication: The natural and/or anthropogenic processes by which the nutrient content of natural waters is increased, generally resulting in an increase of biotic productivity and biomass (CCME 1999).

Guidelines: Generic numerical concentrations or narrative statements that are recommended as upper limits to protect and maintain the specified uses of air, water, sediment, soil or wildlife. These values are not legally binding (CCME 1999).

Hardness: The concentration of all metallic cations, except those of the alkali metals, present in water. In general, hardness is a measure of the concentration of calcium and magnesium ions in water and is frequently expressed as mg/L calcium carbonate equivalent (CCME 1999).

Hypereutrophic: Refers to aquatic environments that have very high nutrients and very high rates of productivity. Algal blooms are common in these lakes, often lasting throughout the summer and well into autumn. Oxygen depletion can occur throughout the year and may extend to the surface, leading to fish kills.(Hyper = over, above, excessive).

Mesotrophic: Refers to aquatic environments with moderate nutrient concentrations and sufficient rates of productivity to sustain aquatic life. (Meso = "middle").

Morphometry: The measurement of the shape of a lake, usually with depth contours.

Nitrogen: A nutrient necessary for the growth and development of animals and plants.

Oligotrophic: An aquatic environment that has a low nutrient concentration (phosphorus and nitrogen) and low productivity (i.e. low chlorophyll *a* concentrations). These water bodies tend to have clear water and sufficient oxygen throughout the year to support fish and other aquatic organisms

pH: A logarithmic scale used to measure the acidity of water.

Phosphorus: A nutrient necessary for the growth and development of animals and plants. Typically the limiting nutrient in aquatic systems.

Phytoplankton: Photosynthetic aquatic organisms. Includes algae, diatoms and crysophytes.

Redfield Ratio: The molecular ratio between carbon, nitrogen and phosphorus in phytoplankton (C:N:P).

Salinity: In inland fresh waters, the salinity is the sum of the ionic composition of the four major cations (calcium, magnesium, sodium and potassium) four and anions (carbonate, sulfate, chloride and nitrate) in mass or milliequivalents per liter (Wetzel and Likens, 2000).

Secchi disk: An 8-inch (20 cm) disk with 2 alternating black and white quadrants used to measure water transparency to light penetration. Transparency decreases as color, suspended sediments, or algal abundance increases.

Species Richness: The total number of species found at a given time in a given area.

Taxa: A name designating an organism or group of organisms. A taxon is assigned a rank and can be placed at a particular level in a systematic hierarchy reflecting evolutionary relationships.

Total Kjeldahl Nitrogen (TKN): A measure of the sum of organic nitrogen and ammonia nitrogen.

Trophic: Refers to the nutrient availability and productivity status of a waterbody.

Zooplankton: Aquatic heterotrophic (animal like) organisms that prey on phytoplankton and other zooplankton. Includes *Daphina, Rotifera* and Copepods, etc.

Appendix A

Raw Water Chemistry Data

Sample ID	Date	Site	NH_4^+ (µg/L)	NO_2+NO_3 (µg/L)	TN (µg/L)	TKN (µg/L)	TP (µg/L)	Cl (mg/L)	SO_4 (mg/L)	Fe (mg/L)
75306	10-Oct-06	Skeleton Lake North Bay	156.00	3.91	1,480.00	1,476.09	51.49	4.16	2.94	0.06
75307	10-Oct-06	Skeleton Lake North Bay	149.00	6.80	1,460.00	1,453.20	42.29	3.94	2.35	0.03
75308	10-Oct-06	Skeleton Lake South Bay	9.52	3.85	1,140.00	1,136.15	44.39	3.82	1.56	0.02
75309	10-Oct-06	Skeleton Lake South Bay	10.70	4.17	1,160.00	1,155.83	39.77	3.79	1.56	0.02
75310	10-Oct-06	Skeleton Lake South Bay	10.20	4.44	1,170.00	1,165.56	40.84	3.94	1.62	0.02
		Mean North	152.50	5.36	1,470.00	1,464.65	46.89	4.05	2.65	0.05
		Mean South	10.14	4.15	1,156.67	1,152.51	41.66	3.85	1.58	0.02

Sample ID	Date	Site	Alk (mg/L as $CaCO_3$)	Bicarb (mg/L)	Carb (mg/L)	Cond (µS/cm)	pH	Color (mg/L Pt)	Turb (NTU)	NFR (mg/L)	Chl-*a* (µg/L)
75306	10-Oct-06	Skeleton Lake North Bay	185.60	225.69	0.30	361.00	8.30	12.40	2.40	5.00	18.22
75307	10-Oct-06	Skeleton Lake North Bay	187.21	227.91	0.17	364.00	8.30	12.10	2.50	7.00	14.25
75308	10-Oct-06	Skeleton Lake South Bay	198.29	230.11	5.73	380.00	8.45	10.40	2.80	14.50	17.85
75309	10-Oct-06	Skeleton Lake South Bay	200.43	232.29	5.95	379.00	8.45	10.80	2.60	11.50	16.44
75310	10-Oct-06	Skeleton Lake South Bay	200.67	231.75	6.35	381.00	8.47	10.10	2.60	<MDL	16.57
		Mean North	186.41	226.80	0.24	362.50	8.30	12.25	2.45	6.00	16.24
		Mean South	199.80	231.38	6.01	380.00	8.45	10.43	2.67	13.00	16.95

MDL – method detection limit