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WATER QUALITY ISSUES

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WATER QUALITY ISSUES IN THE CLEAR LAKE BASIN RIDING MOUNTAIN NATIONAL PARK

by

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Prepared for Riding Mountain National Park and the Canadian Parks Service

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PREFACE

Water quality is essential not only to the long-term maintenance of aquatic ecosystems but also to sustainable tourist industries based on water resources. The original attraction of Riding Mountain National Park was the clean clear water of Clear Lake. The tourist industry developed around summer cottaging, fishing, swimming, boating and related recreational activities. Continued attractiveness of the Lake, therefore, is fundamental to viable tourism. Paradoxically, the very attractiveness of the resource is what created potential threats to its sustainability. As the number of people visiting the Clear Lake Basin increased, their real and potential impact also increased. Human activities create both organic and inorganic byproducts. These in turn may enter the surface or ground water systems and accumulate in the lakes, marshes and streams of the Basin. National Parks' mandate clearly includes preservation of existing ecosystems. Management, therefore, becomes a balancing act that allows human use of resources, but prevents or mitigates potentially negative activities.

This is one of a series of inter-related reports that are meant to review human intervention in the Clear Lake Basin. Emphasis here lies with the quality of water in the Basin, with both natural and human chemical and physical impacts reviewed. The intent is to provide information for future decisions regarding protection and management of water quality.

ACKNOWLEDGEMENTS

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INTRODUCTION

Riding Mountain National Park (RMNP) in western Manitoba is a popular vacation area, with recreational opportunities associated with the cold, clear waters of Clear Lake being the principal attraction for Park visitors. Prior to and following establishment of the Park, recreation demand has lead to changes in land use and development of the surrounding area. Use has increased to the point where human activities now impact on the water quality of the Clear Lake Basin. This is contrary to the basic management goal of RMNP, and the preservation goal of the Canadian Park Service, for continuation of the natural state of Clear Lake waters in terms of both physical and chemical properties. The purpose of this report is to review available documents to qualitatively and, when possible, quantitatively record the human impact on the water quality of the Clear Lake Basin.

Physical and Biological Characteristics of the Clear Lake Basin

Clear Lake is the largest (2947 ha) and deepest (34.2 m) lake in RMNP, forming a significant part of the Clear Lake watershed, which is some 11,648 ha in area (De L Can, 1982). The other major hydrological components of the drainage basin include the Octopus Lake, Octopus Creek, Ominnik Marsh and South Lake complex on the south, and Pudge Lake and Creek to the east (Figures 1 and 2). Along with Bogey Creek at the Wasagaming Golf course (Figure 1) and three to six small unnamed intermittent streams along the north shore of Clear Lake, these components provide the only surface inflow for maintenance of Clear Lake water levels. Wasamin Creek, located at the west end of Clear Lake (Figure 1) is the single outlet for the basin. This stream flows slowly year-round, eventually joining the Little Saskatchewan River, and is a controlling factor in the level of Clear Lake (Rousseau, 1990). The Park has records for Clear Lake water levels for the open-water periods of 1960-1976 and 1978, taken by the Water Survey of Canada and the RMNP Warden Service, respectively. The flushing time of Clear Lake is suspected to be approximately 150 years (Rousseau, 1990).

Clear Lake is of glacial origin, probably formed as a result of a combination of land subsidense and meltwater outlet channel blockage, and was at one time part of the Glacial Lake Agassiz complex (Kooyman and Hutchison, 1979). Clear Lake is cooler than other Manitoba prairie lakes and was considered by Bajkov (1932) as almost alpine or sub-alpine in character because of its glacial origin and comparatively high elevation. Clear Lake freezes in late November - early December and break-up usually commences in early to late May. Complete turn-over or mixing occurs each spring and fall (Wickstrom, 1983). The lake develops a definite thermal stratification with a thermocline established by early July. Surface temperatures of approximately 20^0 C, with deep water temperature of approximately 10^0 C, are typical for the summer months (Bajkov, 1932). The midsummer thermal stability is vulnerable to strong gale force winds that may cause wind mixing and a homothermic condition throughout the entire depth of the lake (Rousseau, 1991).

The water in Clear Lake is slightly alkaline (pH 8.4-8.7) with a tendency for the deeper waters to have lower pH values (Table 1). Dissolved oxygen concentrations at all levels are reported to be fairly constant at or near saturation values in most studies. Magnesium and sulphate are in greater abundance than calcium. This is indicative of spring water intrusions into Clear Lake and is unique in comparison to most other lakes in the Park (Kooyman and Hutchison, 1979). Clear Lake is considered to be less productive that other lakes in the Park, a fact that is reflected in its name and supported by Secchi Disc readings (Table 1). However, it supports the greatest diversity of phytoplankton, zooplankton, benthic fauna, aquatic vegetation and fishes of all the lakes in the Park. Clear Lake is unique in Riding Mountain National Park.

FIGURE 1

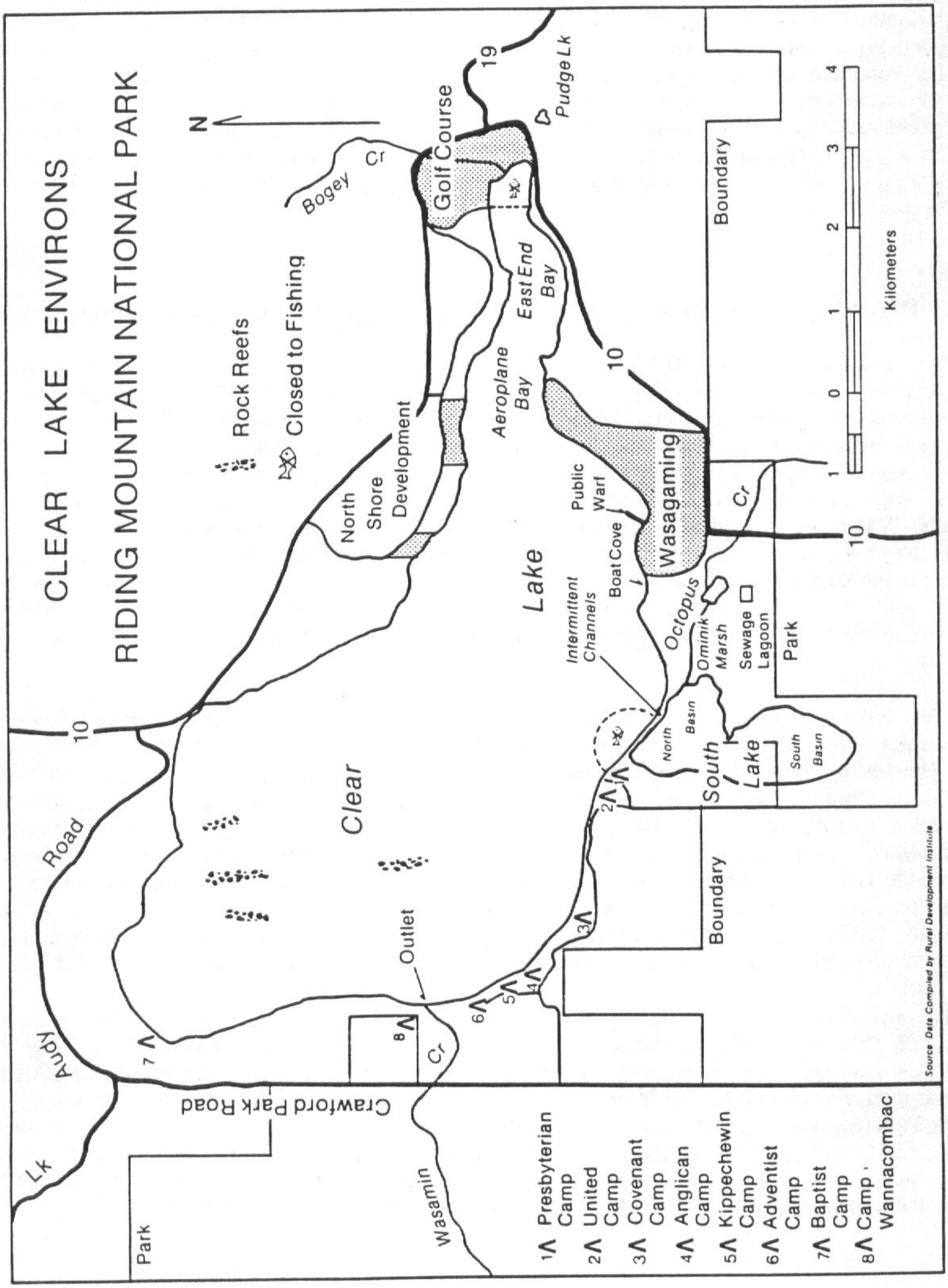

CLEAR LAKE ENVIRONS
RIDING MOUNTAIN NATIONAL PARK
N
Rock Reefs
Closed to Fishing
Bogey Cr
Golf Course
19
Pudge Lk
East End Bay
Aeroplane Bay
North Shore Development
10
Public Warf
Wasagaming
Boat Cove
Boundary
Cr
Kilometers
0
1
2
3
4
Clear
Lake
Intermittent Channels
Octopus
Ominik Marsh
Sewage Lagoon
Park
North Basin
South Lake
South Basin
Road
Audy
Lk
Outlet
Cr
Crawford Park Road
Wasamin
Park
Boundary
1 Presbyterian Camp
2 United Camp
3 Covenant Camp
4 Anglican Camp
5 Kippechewin Camp
6 Adventist Camp
7 Baptist Camp
8 Camp Wannacombac
Source Data Compiled by Rural Development Institute

FIGURE 2

THE WASAGAMING - ONANOLE CORRIDOR

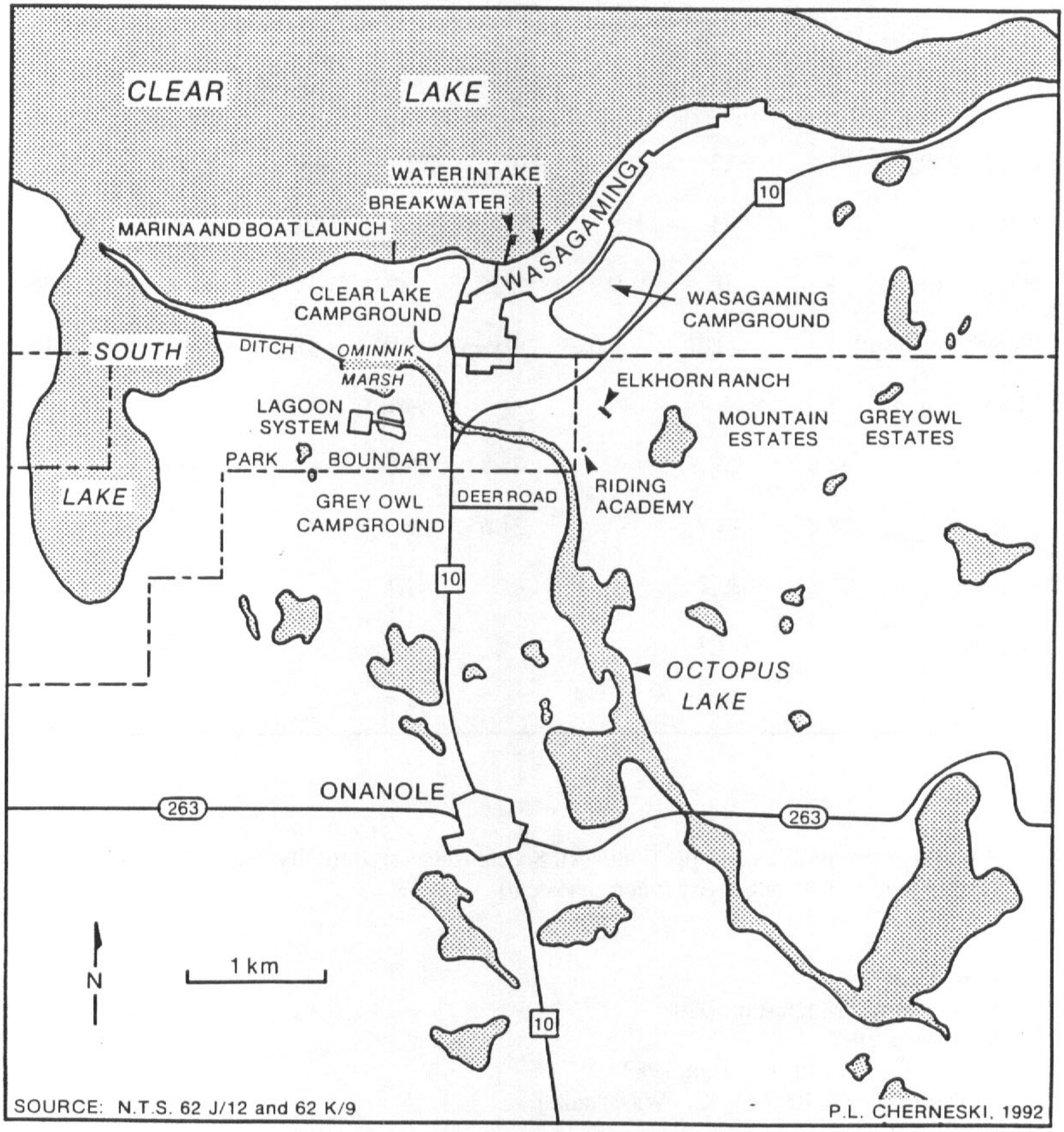


Table 1. A summary of available chemical data for Clear Lake and South Lake*

Parameter	Clear Lake 1932[1]	Clear Lake 1973[2]	Clear Lake 1976[3]	Clear Lake 1982[4]	Clear Lake 1989[5]	Clear Lake 1991[6]	South Lake 1973[2]	South Lake 1982[4]
pH	8.4	8.5-8.7	8.5	8.5	8.7	8.6	>9.0	8.8
Secchi	6	4.27	-	-	-	-	-	-
Turbidity	-	<2.0	0.5	-	-	-	20	-
Colour	-	<5.0	-	-	-	-	-	-
Conductivity	-	352	-	416	421	448	2266	430
Alkalinity	-	194	184	181	-	191	292	203
Nitrogen (as N)	-	0.28	0.65	0.45	0.71	0.42	-	2.35
Phosphorus (as P)	-	0.01	0.02	0.04	0.01	<0.01	-	0.1
Chlorine	3.0	5.2	-	-	4.1	-	7.4	-
Calcium	32.6	20	-	28.8	29.3	-	17.8	-
Magnesium	28.3	43.7	-	31.6	32.3	-	35.3	-
Sulphate	35.8	39.7	-	-	41.1	-	27.8	-
Potassium	-	3.2	-	-	-	-	6.8	-
Sodium	-	8.2	-	-	14.7	-	8.2	-

* All values are mg/L except pH (unitless), Secchi (meters), turbidity (Jackson turbidity units), colour (Hazen units) and conductivity (micromhos/cm).

1 Bajkov, 1932
2 Kooyman and Hutchison, 1979
3 MacLaren, 1976
4 Bergman, 1987 and De L Can, 1982
5 Stauch, 1989 and RMNP files - Wasagaming
6 Pratt, 1991

South Lake, with an area of 202.3 ha, is the second largest component of the Clear Lake Basin. It has a maximum depth of 1.8 m and is considered to be a recently cut off shallow bay of Clear Lake formed as a result of wave action building up an isthmus of sand and gravel which has effectively isolated the two bodies of water. An outlet from South Lake to Clear Lake forms intermittently during spring run-off (Figure 1). South Lake is known to freeze well before Clear Lake, usually by early November, and ice thickness is known to reach the bottom over much of the lake area (Wickstrom, 1983). The ice is completely off South Lake considerably sooner than that on Clear Lake each year.

South Lake develops no thermal stratification because of its shallowness and rapidly acquires the mean daily temperature by late May - early June. Kooyman and Hutchison (1979) describe South Lake as a "moderately large shallow, turbid, coloured lake." Nutrient rich inflows from Octopus Creek make South Lake eutrophic with dense weed and algal growths in the summer months and year round vegetative decay. South Lake is different from Clear Lake chemically (Table 1). Secchi disc transparencies can be less than 0.3 m with pH values greater than 9 (Kooyman and Hutchison, 1979). The level of dissolved oxygen in South Lake usually is less than that of Clear Lake because of its greater biological activity, and it regularly becomes depleted of oxygen during winter months (Collingwood, 1976; Heap, 1988). Winter killing is thought to make South Lake less diverse biologically than is Clear Lake. [The physical and biological characteristics of both Clear and South Lakes and the significance of their relationship, are discussed in greater detail in a report on fisheries in this series.]

Use of the Clear Lake Basin

Pre-European use of the Clear Lake Basin was limited to wandering bands of Plains Indians who carried out traditional hunting, gathering, and fishing activities. With the advent of settlement of western Canada, the forests surrounding the Basin became an important source of lumber and meat animals to sustain settlement activities. Prior to the establishment of the Park in 1935, logging and forest fires are thought to have had drastic and permanent effects on most existing watersheds in the area. This may be reflected in decreased historical levels of inflow and outflow for Clear Lake (Rousseau, 1990). Also, prior to 1912, the Minnedosa Power Company built a dam on Wasamin Creek, the outlet for Clear Lake. Flooding resulted throughout the Lake basin, and was recorded by a settlement with Indian Reserve GIA in 1913 for 30 acres of land flooded by high water levels.

As early as 1910, Clear Lake was known as an excellent area for camping and fishing, although development did not occur until the late 1920's and 1930's. With the coming of the Depression years and the establishment of the Park, work camps of up to 1,000 men were located in the Wasagaming area. Domestic use of Clear Lake water began with the advent of cottage and business development, construction of a break-water/public wharf at the main beach, and building for the Wasagaming Golf Course at the East End Bay (Figure 1). Initial sewage and water facilities were installed by 1937, with upgrading occurring in the 1950's, 1960's and 1970's.

The Clear Lake Basin currently receives the greatest direct pressure from recreational use, including swimming, power boating, sailing and angling. The number of people in the Wasagaming - Clear Lake area ranges between 5,000 and 15,000 on any given day during June, July and August. There are 246 cottages, 39 commercial establishments, the Wasagaming Campground (which can accommodate in excess of 500 people), the seasonal Clear Lake Campground with a peak population of 525, and a marina in the town site (Figure 2). All of these facilities are open from about May to September and discharge their waste waters into the Wasagaming Lagoon (Figure 2). There are other cottage developments along the north shore of Clear Lake (Figure 1) with septic tanks to accommodate wastes. Four remaining "church" camps are located in the southwest corner of Clear Lake, and are used mostly during summer. They have individual water and septic systems.

Numerous private developments are located south of the Park in the LGD of Park (Figure 2). These include the Elkhorn Ranch Resort complex, a riding academy, a group of approximately 75 residences along Deer Road, a group of smaller commercial areas and an amusement park south of Deer Road, the village of Onanole with a population of 200, three private development areas southeast of the Park (Mountain Estates, Grey Owl Estates, and Parkview Estates), and Grey Owl Campground west of Highway 10. Drainage of this area is through the Octopus Lake system (Bergman, 1987). Clear Lake is the only source of domestic water for Wasagaming and the Elkhorn Resort. [Land use patterns, subdivision and development for the Clear Lake Basin are discussed in greater detail in another paper in this series].

WATER QUALITY CONCERNS FOR THE CLEAR LAKE BASIN

The above uses of the Clear Lake Basin provide a variety of sources of pollution that do, or potentially could effect water quality. These include the Grey Owl Landfill sight north of the Golf Course (Figure 1), the Wasagaming Sewage Lagoon, septic fields, the town site sewage line system, underground and above ground gasoline storage units, power boat exhaust emissions, contaminated surface water run-off from cottage developments, leaching of agricultural chemicals from the surrounding countryside, run-off of chemicals from the golf course, acid rain, and heavy metal fallout. Any or all of these sources of pollutants may have an individual effect, accumulative effects, or, in combination, an overall significant effect on water quality in the Clear Lake Basin.

Unrelated and project specific studies, many of them to do with fishery management, have documented certain Clear Lake Basin water quality issues from prior to the establishment of the Park to the present. A complete study of the "Aquatic Resources of Riding Mountain National Park" was produced by Kooyman and Hutchison (1979) in which the historical aspects of aquatic research for the Clear Lake Basin were listed back to the early 1920's. More recent water quality information is available in both reports and memos from the RMNP files and the library at Wasagaming, and from the Natural Resources Conservation library at the Prairie and Northern Regional Office of the Canadian Parks Service in Winnipeg. The remainder of this report will be a summary of information on Clear Lake Basin water quality from these sources.

Wasagaming Beach

One of the most popular visitor facilities in the Clear Lake Basin is the public beach and dock area at Wasagaming on the southeastern shore of Clear Lake (Figures 1 and 2). The beach and dock are protected by an artificial breakwater which extends about 200 m from shore. This area has been experiencing a gradual deterioration in quality that has reduced the attractiveness of bathing and water sport activities. Deterioration is evidenced by the following conditions; loss of sand, deposition of mud, growth of aquatic vegetation, poor water circulation, deterioration of water quality, and the persistence of "swimmer's itch" in the public beach area. As a consequence, Parks Canada commissioned De L Can, a private consulting firm, to investigate the causes of and possible solution for the problem in 1982.

As part of De L Can's study a water quality assessment was carried out to determine the severity of water quality deterioration, if any, in the Wasagaming beach area. Water samples were taken inside and outside the breakwater/bathing area at different depths and analyzed for various standard parameters. No significant differences in parameters were found among samples from various locations and depths. The water quality data obtained also were compared to earlier data recorded by Kooyman and Hutchison (1979) in 1973, and found to be consistent. Therefore, it was concluded that water quality had not deteriorated, and that water quality in the bathing area and behind the breakwater was about the same as quality elsewhere in the lake (De L Can, 1982)

De L Can reported that beach deterioration could be attributed primarily to the presence of the artificial breakwater which interferred with the natural current and processes that had originally formed Wasagaming beach. Recommendations to restore natural conditions included opening up of the breakwater to restore beach building water circulation patterns.

A recent water quality issue associated with Clear Lake is the use of fireworks on Wasagaming Beach during special Park celebrations. In 1990 this practise was stopped by the Park administration because of the unknown potential effects of residue fall-out on Clear Lake. Potential effects include nutrient loading from nitrates and poisoning from heavy metals present in fireworks residue.

Swimmers Itch

Swimmers itch is a problem that occurs regularly in Clear Lake, reducing Wasagaming Beach's attractiveness for water-based recreational activities. The earliest known report on swimmers itch in Clear Lake is McLeod's 1934 report which is believed to be the first description of this problem in a Canadian lake. Swimmers itch (Schistosome dermatitis) is an allergic reaction of the skin stimulated by penetration of minute parasitic larvae into the hair follicles, and usually manifests itself as an itchy red rash. The larvae, called cercariae, belong to a group of parasites called schistosomes which live as adults in aquatic birds.

Swimmers itch becomes a problem when great numbers of cercariae are emitted from snails which are secondary hosts to the schistosomes. The cercariae must penetrate a host bird in order for the life cycle of the schistosome to be completed. The cercariae may, however, mistakenly penetrate human skin on contact, causing swimmers itch. Outbreaks of swimmers itch usually occur throughout Clear Lake and in many surrounding lakes, in July and early August. Bathers using the beaches at the church camps on the west shore of Clear Lake and those at Wasagaming are especially vulnerable during certain wind conditions. The schistosome cercariae are found in several species of snails common along popular swimming areas of Clear Lake (De L Can, 1982).

Control of swimmers itch involves interruption of the normal life cycle of the schistosome, with the host snail populations usually being targeted. Historically, control methods for cercaria snails in Clear Lake has been accomplished by application of the biocide bluestone (copper sulphate) and removal of the submergent vegetation that forms the snail's habitat.

The use of bluestone in controlling swimmers itch at Wasagaming Beach is mentioned by various investigators (McLeod, 1934; Cuerrier, 1949; Atkinson, 1958 and Kooyman and Hutchison, 1978). Varying degrees of success were achieved. In 1949, Cuerrier reported an early August Clear Lake fish kill which was suspected to be due to an accidental overdose of bluestone applied by an inexperienced Park employee about a month perviously. It is questionable whether the bluestone overdose was the cause of this occurrence as a heavy fish kill also could have been caused by an upset of normal temperature stratification by high winds .

The use of bluestone to eliminate the itch at Wasagaming beach was discontinued sometime during the late 70's or early 80's as it was considered an inappropriate practice in a National Park. Also, its effectiveness was questioned (De L Can, 1982). Whatever its potential long term effect on water quality, bluestone has been used extensively in Clear Lake. Atkinson (1958) mentions the use of the herbicide 2,4-D on aquatic weed concentrations at the east end of Clear Lake with no clear results as to effectiveness.

Mercury Pollution

Mercury pollution from human or natural sources is another water quality concern in the Clear Lake Basin. In 1970 dead suckers were observed in Bogey Creek (Figure 1) and an analysis of the fish showed high levels of mercury. Their death, however, could not be attributed to the presence of mercury (Kooyman and Hutchison, 1979). This finding raised the question of possible mercury contamination in game fish in Clear Lake, and in the following year a fish sampling program was undertaken to confirm this possibility. Results of analysis of the sampled fish confirmed levels of mercury above the 0.5 parts per million (ppm) which is the established safe level for human consumption (Briscoe, 1979).

It was initially suspected that the source of mercury contamination was mercury-based fungicide used to control snow mould on the greens on Wasagaming Golf Course prior to 1968. Use of such compounds was discontinued in 1969. Soil samples from one of the greens adjacent to Bogey Creek contained high levels of mercury but samples from Bogey Creek itself contained low levels. The source of mercury was left in doubt. In 1971, Clear Lake was posted to warn the public of the potential health hazards of eating game fish angled from the lake.

In 1973 scientists conducted surveys to check for mercury contamination in Clear Lake, but only normal background levels of mercury were found. South Lake and Pudge Lake (Figure 1) samples, however, had high levels of mercury, which made these lakes potential sources for mercury contaminations of Clear Lake. The origin of mercury in South and Pudge Lakes could not be explained, although Pudge Lake receives some run-off from the golf course, which renewed the suspicion that the fungicide may be a source of contamination. It was concluded that since the use of fungicides containing mercury had been discontinued, concentrations in fish tissue should decrease with time if the fungicide was indeed the source of contaminations (Kooyman and Hutchison, 1979).

Further testing for mercury in fish taken from Clear Lake has occurred in subsequent years by various researchers. Lockhart et. al. (1986) assembled mercury data for fish samples taken in 1973, 1980, and 1986. Data also are available in the Park files for fish taken in 1989. All available data are summarized in Table 2, and show that mercury contamination remains high in Clear Lake game fish. Data, however, do not account for weight and age differentials of the fish samples.

It is apparent that either residual fungicide is still present in the lake, or other sources are causing mercury contamination. The Wasagaming sewage lagoons and the Grey Owl landfill also are potential unnatural sources of mercury (Kooyman and Hutchison, 1979). At present it is believed that the mercury contamination comes from a natural source, for it is not uncommon to find elevated mercury levels in fish and in waters remote from any source of human contamination. Long Lake, to the west of Clear Lake in the Park, is an example (Wickstrom, 1982).

The East End Wasagaming Golf course - Grey Owl Landfill

Wasagaming Golf Course is a potential source of pollution that could degrade Clear Lake water quality. Golf course development mirrored that of Wasagaming with increased use of fertilizers, pesticides, and herbicides until controls were established in the late 1960's and early 1970's. A number of harmful chemicals may have, and still may be leaching through the golf course into Clear Lake. The possible role of a fungicide of golf course origin in mercury contamination is an example already mentioned.

Table 2. A summary of mercury testing in Clear Lake fishes

Species	1973[1]	1980[1]	1986[1]	1989[2]
Northern pike	0/1*	9/21	3/9	4/4
Walleye	23/66	18/21	25/27	3/4
Lake Trout	12/14	-	-	5/6
Lake whitefish	-	-	0/1	0/4
White sucker	-	-	0/10	0/4
Perch	0/12	-	-	-

* The value given is the number of fish with muscle mercury levels of more than the allowable 0.50 ppm over the number of fish sampled for a given species.

1 Lockhart et. al., 1986

2 RMNP files - Wasagaming

Only one other documented record of pollution from golf course origin could be found in Park files. In August 1991, it was noticed that the Wishing Well visitor facility, located near the golf course, had a cloudy or milky water flow which could be traced back to a spring originating from the golf course (McKillop, personal conversation, 1991). Water samples were taken for analysis with the possible contaminants being algae, fertilizer, lime for marking boundaries, pesticides, or grey water from washing. No biological organism was observed in the sample and nothing could be determined with regards to the cloudy material. However, chemical analysis of the water revealed the presence of the pesticides 2,4-D; 2,4,5-T; BROMOXYNIL, DICAMBA DINOSEB; MCPA; 2,4-DB; 2,4-DP; SILVEX and TRICLOPYR in levels which did not exceed Health and Welfare Canada's guidelines for drinking water. The total concentration of pesticide analyzed (0.02 mg/l) was below the maximum allowable for drinking water (0.1 mg/l). The Wishing Well drains directly into Clear Lake and the possible long-term effects of this level of pesticide contamination on Clear Lake water quality is yet to be determined. The incident, however, demonstrates that pesticides are leaching from the golf course.

The Grey Owl landfill is a potential source of contamination of Clear Lake water. Only one cursory study has been done by Park staff to determine the potential of the landfill as a source of pollution. In May 1990 three sites were sampled along Bogey Creek which runs adjacent to the landfill and drains into Clear Lake at the Wishing Well: a site upstream of the landfill, a site that passes near the landfill and a site downstream of the landfill near the outlet. These samples were analyzed using standard tests for landfill leachate (heavy metals, nitrogen, salts, etc.). Analysis showed no significant difference in chemical composition between water samples from the different sites. No conclusion about surface water contamination of landfill origin could be made from this initial study. However, the Park will be carrying out a ground water investigation for the Grey Owl Landfill site this year.

Octopus Lake - South Lake Complex

The water quality of the Octopus Lake - South Lake complex has the potential to be impacted severely by human activities not only because it receives drainage from both seasonal and permanent facilities located outside the Park, but also because of proximity to the Wasagaming sewage lagoon located within Park boundaries (Figure 2). The 3-celled sewage lagoon is located southwest of Wasagaming and originally was built as a single-celled system in the late 1950's and early 1960's from in-situ soils. The two additional cells were added in the early 1970's. At the time of lagoon construction, it had to be known that there would be excessive leakage, but it was not unusual at that time to build lagoons that leaked (Pratt, 1991). In addition to the possibility of effluent leakage, there also is the possibility of the release of effluent directly into Ominnik Marsh during times of peak lagoon use during summer months. At the time of lagoon construction a ditch also was dug to connect Ominnik Marsh to South Lake. Prior to ditch construction Octopus Lake and Ominnik Marsh discharged directly into Clear Lake at a site that is now used as a boat launch (Figure 2). This change in drainage could have had a pronounced effect on both the hydrology and ecology of the Clear Lake Basin (Pratt, 1991). Concern for the water quality of the Octopus Lake - South Lake complex has been the focus of recent in-depth studies .

In 1977, a ground water investigation was completed at the Wasagaming lagoon site (MacLaren, 1978). Test wells were drilled around the lagoon and a series of chemical and bacteriological tests were conducted on ground water samples. The study showed that the direction of ground water flow from the lagoon was westwards towards South Lake. There also was some indication of degradation of ground water in proximity to the lagoon, but contamination was not considered to be serious as the water quality of South Lake, the ultimate receptor of the ground water was of poorer quality than that measured in the most westerly located test well (MacLaren, 1978).

In 1982, Parks Canada enlisted their in-house Environmental Protection Service (EPS) to study the production of uncharacteristic odours which occurred periodically in Ominnik Marsh in the vicinity of the area where Octopus Lake drained into the marsh near the sewage lagoon (Bergman, 1987). Water samples were collected during the summer of 1982 from sites along the Octopus Lake - Ominnik Marsh - South Lake drainage, and from Clear Lake, with standard chemical and bacteriological tests applied to the samples. The study concluded that Octopus Lake was eutrophic and was being impacted by anthropogenic activities in the immediate area. Particular note was made of run-off from the Riding Academy (Figure 2) and contamination from septic fields. Higher than normal phosphorous values in Ominnik Marsh adjacent to the sewage lagoon also were noted. This indicated that seepage was occurring from the lagoon system, raising nutrient levels in the area of the marsh. No downstream effects from this seepage were noted as no significant change in water quality was observed between Ominnik Marsh and South Lake. EPS believed that surface run-off from adjacent agricultural lands was the major source for nutrients entering South Lake. Clear Lake water quality was good, with no indication of eutrophic conditions (Table 1).

In 1991 G.A. Pratt and associates conducted a study of the utilities capacity of the Wasagaming town site with specifications to the sewage lagoon. Essentially, they repeated the work of MacLaren and the EPS with essentially the same results and conclusions (Pratt, 1991). They also concluded that discharge of effluent from the lagoon directly into Ominnik Marsh would not leave the wetland owing to the size and character of the marsh. Clear Lake water quality would not be impaired if such an event occurred. A more sophisticated study, tracing the flow of nutrients through the Octopus Lake - South Lake complex, was recommended to ensure maintenance of Clear Lake water quality.

Faecal Bacterial Contamination

Faecal coliform bacterial contamination in water is a public safety concern wherever there is human activity. A summary of available bacteriological data for Clear Lake suggests great variability (Table 3). Coliform counts can be wide ranging in lakes and rivers because of the presence of bird faeces, algal growth, dead fish, and other organic material. The general conclusion made from values presented in Table 3 is that the bacterial water quality of Clear Lake generally is good. There is, however, a prevalence of coliform in areas of the lake experiencing significant human activity. Most notable is the Wasagaming beach area west of the breakwater.

Surface Water Contamination

Surface water contamination and run-off from the seasonal Clear Lake Campground and the Wasagaming town site is another Clear Lake Basin water quality issue. Contamination may consist of lawn fertilizers and herbicides, pet faeces, petroleum products from poorly maintained engines and crankcases, and many other sources. Two problems result. First, direct pollution of chemicals can build up over time in the water and food chain, and second, increased nutrient levels may result in algae blooms at extreme levels, or increased turbidity of lake water at minor levels. De L Can (1982) analyzed a water sample collected at a storm water outfall near the east end of Wasagaming Beach. The sample was markedly higher in suspended solids and turbidity then lake samples. They concluded that summer storms could cause significant discharges of low quality storm water into the beach area causing temporary reductions in water quality and increased nutrient levels. Pratt (1982) related higher than expected coliform bacteria values from mid-June tó mid-July for Clear Lake water samples (Table 3) to storm water drainage from developed areas of the town site.

Petroleum

Only one report (Lockhart et. al., 1986) investigated petroleum pollution in the Clear Lake Basin. A Clear Lake water sample was analyzed for the presence of petroleum hydrocarbons, and alkane and xylene were detected. Petroleum pollution is generally suggested when there is a consistent pattern of alkane with both even and odd numbers of carbon atoms, but this was not detected in the Clear Lake sample. Lockhart et. al. (1986), however, believed that detection of xylenes, even though concentrations were low, must represent pollution, since they are among the most abundant of the water-soluble materials in gasoline. A more definitive statement regarding petroleum pollution in Clear Lake requires more sampling.

Chemical Composition

Chemical data from several studies for the waters of Clear and South Lakes are summarized in Table 1. Sample collection was not standardized, and it is difficult to draw conclusions with regards to changes in Clear Lake Basin water quality. The pH and alkalinity values of Clear Lake appear to have changed little over time, and readings for concentrations of most cations show little variation. The only measurement which may show a trend is that for conductivity.

A recent comprehensive study of Clear Lake provides more accurate data on changes in the chemical composition of Clear Lake. Starting in 1978 and for the following 10 years, Patalas et. al. (1992) regularly sampled Clear Lake as part of a long-term zooplankton study. In the first two years, only mid-summer sampling was carried out, but, beginning in 1980, a two-week sampling interval was implemented during the open water season from May to October. Water samples taken at about 0.2m below the surface were analyzed for conductivity, chlorophyll-a concentration, and a number of different ions. The chemical characterization of the water was intended to serve as background for interpreting zooplankton changes.

Table 3. A summary of bacteriological testing of Clear Lake

Date	Location	Coliform/100ml Total	Faecal
1973[1]	G stations	4-1100	0-93
May 18/76[2]	Near South Lake outlet	0	0
Oct 18/76	At boat launch	28	<4
Oct 18/76	Near South Lake outlet	120	8
Oct 18/76	At east end	8	<4
June 24/82[3]	West of breakwater	240	240
July 26/82	West of breakwater	460	93
Aug 17/82	West of breakwater	1500	1500
May 28/91[4]	Adjacent to water pumphouse	0	0
June 18/91	Adjacent to water pumphouse	39	39
July 1/91	Adjacent to water pumphouse	430	23
July 1/91	Near South Lake outlet	150	23
July 10/91	Adjacent to water pumphouse	230	7
July 10/91	At boat launch	0	0
July 19/91	Adjacent to water pumphouse	93	43
July 19/91	At boat launch	75	20
July 25/91	Adjacent to water pumphouse	9	0
July 25/91	At boat launch	9	0
July 25/91	Observation point, east of townsite	240	-
July 25/91	At east end	0	-
Aug 15/91	Adjacent to water pumphouse	9	-
Aug 15/91	At boat launch	15	-
Sept 4/91	Adjacent to water pumphouse	4	0
Sept 4/91	At boat launch	0	0

1 1973 data from Kooyman and Hutchison (1979)
2 1976 data from MacLaren (1976)
3 1982 data from Bergman (1987)
4 1991 data from Pratt (1991)

Palatas et. al. (1992) present data for the chemical composition of Clear Lake (Figures 3 and 4). Of the six lakes analyzed, Clear Lake has the highest levels of chloride, potassium and sulphate ions, confirming the earlier work of Kooyman and Hutchison (1979). An increase in calcium, magnesium, and potassium levels, as well as in conductivity was noted for Clear Lake over the period of the study. Magnesium concentration was up 5 percent to 7 percent in the last three years of the sampling period and potassium levels had increased by 100 percent following 1984. Increases in chlorophyll-a values, indicative of algal growth, paralleled decreases in Secchi disc transparencies in Clear Lake over the sampling period (Figure 4). Its not known whether the above phenomena were the result of human intervention, and the authors do not interpret the results.

The Future

A Water Quality Monitoring Plan was written for Clear Lake by the Warden Service of RMNP in 1990 (Rousseau, 1990). The plan calls for establishment of a yearly monitoring program to collect basic data, as well as indicator information, to be used to assess current pollution levels and potential problems. The plan calls for the collection of three basic sets of data on a regular basis: 1) pH and alkalinity to monitor buffering capacity, 2) total phosphate, kjedahl nitrogen, coliform and faecal coliform levels to monitor nutrient loads, and 3) heavy metal (aluminum, zinc, cadmium and mercury) levels in fish. Other water parameters, such as dissolved hydrocarbons and any other elements related to a specific concern, would be monitored on a need-to-know basis. The Plan calls for establishment of both short and long range water quality standards that translate qualitative goals into quantitative maximum levels allowed in water and aquatic organisms (Rousseau, 1990)

Summary

1. Clear Lake is unique in Riding Mountain National Park and Southwestern Manitoba and forms part of a small watershed that has been impacted by human activities for the last 100 years. The quality of the water of Clear Lake, which had originally attracted visitors to the region, apparently has been degraded by a variety of pollution sources from anthropogenic activities occurring in the basin.

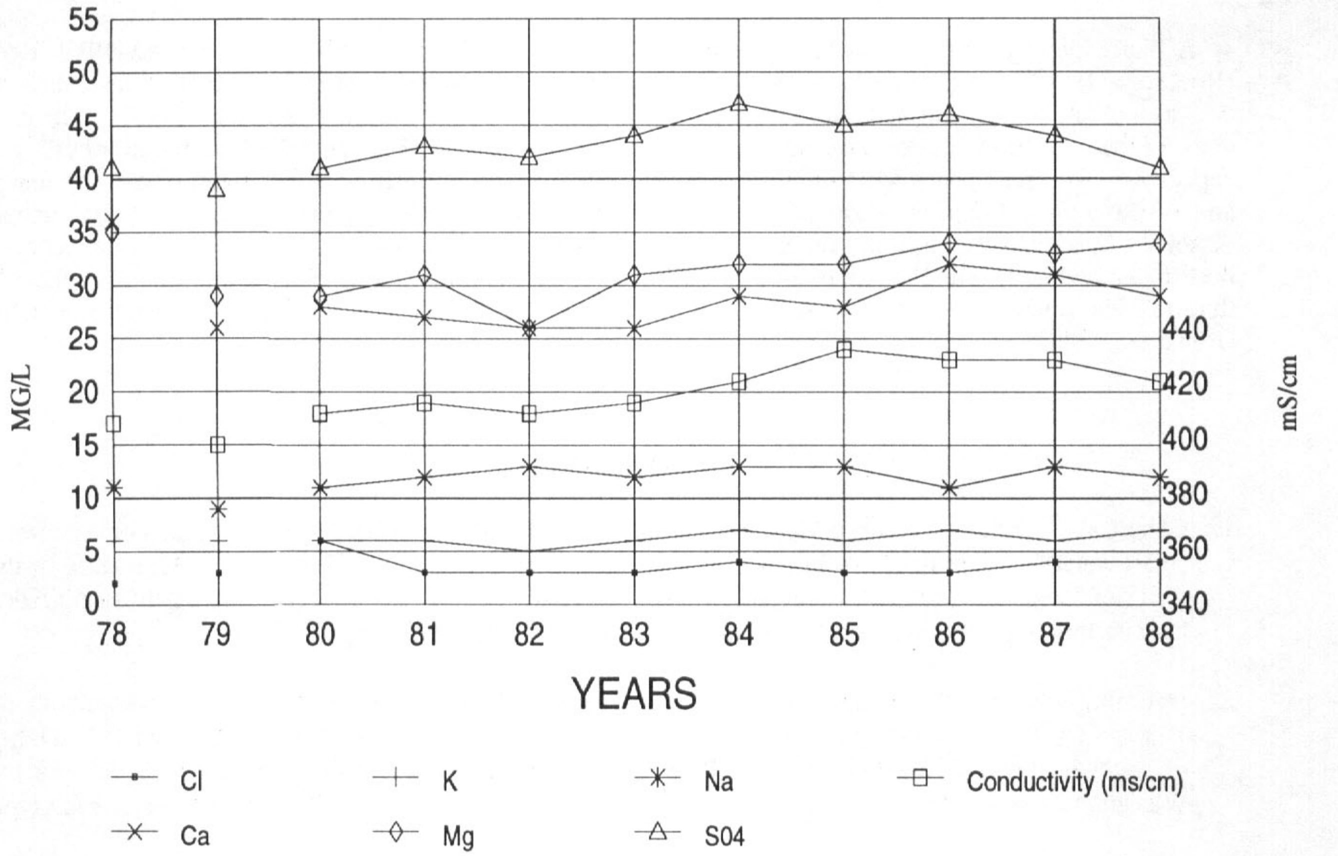
2. Deterioration of the Wasagaming Beach occurred since the construction of an artificial breakwater in the 1930's. The breakwater disrupted the natural processes which had originally built the beach. The quality of water in the area, however, has not been impacted by this disruption. Fireworks displays on the Wasagaming Beach have been discontinued because of the potential of pollution from residue fall out.

3. Swimmers itch (Schistosome dermatitis) continues to be a concern for recreational users of Clear Lake waters. Discontinued historical methods used to control the host of the causative parasite (copper sulphate or "bluestone", and aquatic weed control by herbicide application) may have residual effects on Clear Lake water quality.

4. Mercury pollution from human or natural sources is another water quality concern for the basin. After the initial detection of mercury contamination in Clear Lake fish in 1970, the levels of mercury in fish, sampled as recently as 1989 have remained high, especially in the larger fish of the game species. The source of mercury pollution has not been located, but early suspicions of a fungicide used on the greens of the Wasagaming Golf Course has not been ruled out. High mercury levels also have been found in Pudge and South Lake. It is possible that high mercury levels are natural, as they also were found in Long Lake fish. Long Lake is remote from any non-natural source of contamination.

Figure 3

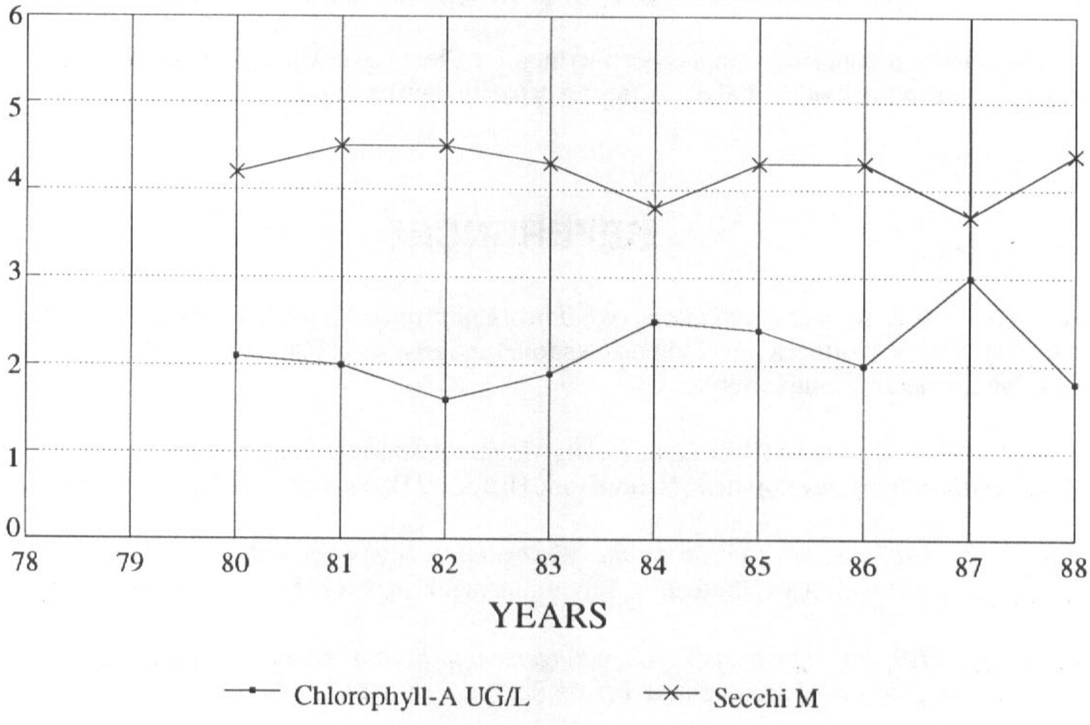
Ion Composition and Conductivity of Clear Lake Ice Free Season Means 1978-1988[1]



[1] Source : Patalas et. al., 1992

Figure 4

Secchi Disc and Chlorophyll-A in Clear Lake Ice Free Season Means 1978-1988[1]



[1] Source: Patalas et. al., 1992

5. Park facilities located at the East End Bay of Clear Lake may be impacting on water quality via contaminate leaching and run-off. The Wasagaming Golf Course is leaching pesticides and the Grey Owl landfill is a potential source of pollution for the watershed. Preliminary testing, however, did not indicate contamination from the landfill

6. The Octopus Lake - South Lake complex is being impacted by surface run-off from adjacent developments, and from seepage of effluent from the Wasagaming lagoon. Changes in drainage patterns in the area may have had a pronounced effect on the relationship between Clear Lake and South Lake. No impact on Clear Lake water quality has been detected from the above system.

7. Surface water run-off from the Wasagaming town site may be affecting Clear Lake water quality, including faecal bacteria contamination and residual petroleum pollution.

8. Changes in the chemical compostion of the water of Clear Lake are noted in a 10-year study carried out between 1978 and 1988 by Patalas et. al. (1992). Changes are reported, but interpretations are not given.

9. A water quality monitoring plan has been written for Clear Lake which calls for an annual monitoring program to keep track of the Lake's buffering capacity, nutrient load and the level of heavy metals.

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