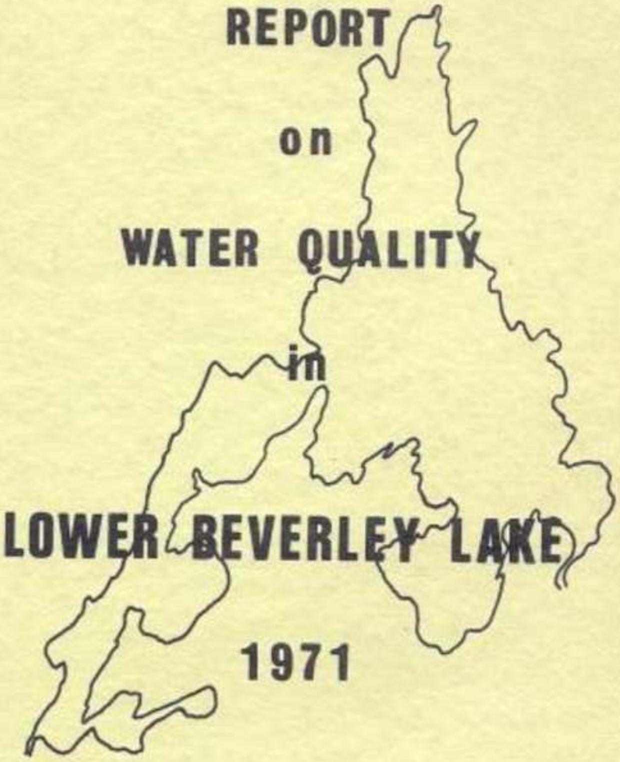
ONTARIO WATER RESOURCES COMMISSION

REPORT on WATER QUALITY in LOWER BEVERLEY LAKE 1971



RECREATIONAL LAKES PROGRAM

GENERAL TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

A study to evaluate the status of water quality in Lower Beverley Lake was carried out during the summer of 1971.

Lower Beverley Lake lies in the Smith Falls Limestone Plain which is characterized by a relatively flat terrain with shallow overburden and poor local drainage. Most of the soil belongs to the Farmington series which is characterized by a shallow layer of loam or sandy loam covering limestone bedrock. Both the nature of the soils and topography surrounding the lake can be considered as unsuitable for cottage development utilizing standard subsurface septic tank systems.

During May, relatively uniform temperature and dissolved oxygen profiles were apparent throughout Lower Beverley Lake. Three distinct temperature zones with respect to depth characterized the deep-water stations during the July and October surveys. During this period, depressed deep-water concentrations of dissolved oxygen and elevated carbon dioxide levels resulting from the decomposition of organic matter were observed. Dissolved oxygen values in the deeper strata were not sufficient to maintain cold-water species of fish.

The water is relatively hard but has no unusual mineral characteristics. Relatively high surface pH values, resulting from photosynthetic activities of algae, exceeded the criteria for recreational use, during the July and October surveys.

Kjeldahl nitrogen and total phosphorus reached concentrations which could be expected to support nuisance levels of algae.

Algal levels as measured by chlorophyll a concentrations were moderately high during the May and July surveys and high during the October survey. Such high algal densities are capable of severly reducing water-oriented recreational activities and diminishing the aesthetic quality of the lake.

Generally, the lake had good bacteriological water quality, well within the OWRC recreational use criteria.

Delta Creek during the 1970 and 1971 surveys appeared to be contributing a continuing bacterial input accordingly. The District Engineer's Section of the Ministry of the Environment will be conducting a water pollution survey of Delta Creek in 1973.

In view of the high nutrient concentrations and chlorophyll a levels, every effort should be made to prevent any direct flow or leachate from domestic waste disposal systems or other potential sources of pollution from gaining access to Lower Beverley Lake.

INTRODUCTION

Maintenance of good water quality in recreational lakes in the Province of Ontario is of vital concern to the Ontario Ministry of the Environment and other governmental agencies involved in tourism and the control and management of shoreline development of cottages and resorts. In 1970 an interdepartmental program was established to survey a number of recreational lakes in order to detect and correct sources of water pollution and ensure that our lakes would be well managed to protect water quality. The Ontario Department of Health, whose jurisdiction in the program was transferred to the Ministry of the Environment would carry out on-shore inspection and correction of faulty private waste disposal systems, whereas the Ontario Water Resources Commission (now within the Ministry of the Environment) would evaluate the existing water quality of the respective lakes. A record of the present status of the private waste disposal systems and the lake water quality would also be documented for comparative use in any future studies.

Recreational lakes are subjected to two major types of water quality impairment; bacteriological contamination and excessive growths of algae and aquatic weeds (eutrophication). The two problems may result from a common source of wastes but the consequences of each are quite different. Bacteriological contamination by raw or inadequately treated sewage poses an immediate public health hazard if the water is used for bathing. In order for this to occur, raw wastes or septic tank effluents must gain entry to the lake although it may not be obvious upon visual inspection of the site. It must be noted that no surface water is considered safe for human consumption withour prior treatment including disinfection. The algae and weed growths impair aesthetic values and recreational use of a lake but seldom pose a health hazard. There are nutrient sources other than sewage wastes which do not create serious bacterial hazards but do support nuisance plant growths such as agricultural fertilizer losses and normal nutrient runoff from forest and field.

In order to carry out its responsibility of evaluating the status of water quality in recreational lakes, the Ontario Water Resources Commission undertook a study on Lower Beverley Lake in the summer of 1971. A preliminary survey of the lake was carried out in July, 1970 (OWRC 1970).

Three surveys were conducted in 1971; a spring survey from May 15 to 19, a mid-summer survey from July 9 to 13 and a fall survey on October 18, 19, 20 and 22. These studies included the assessment of bacteriological, physical, chemical and biological conditions of the lake with stress being placed on the bacteriological and nutrient enrichment problems.

Sampling surveys were conducted on an intensive basis (sampling each day for a minimum of five days) which is required for a reliable assessment of bacteriological conditions. However, due to technical difficulties, Lower Beverley Lake was sampled on only four days during the fall survey.

In addition to the results obtained from these studies, information from other governmental agencies has been incorporated in this report which is the Ontario Water Resources Commission's contribution to the Interdepartmental Task Force Report which will deal with the overall cottage pollution control program in Ontario.

AREA DESCRIPTION

Geography and Topography

Lower Beverley Lake is located in the Townships of Bastard, South Crosby and Rear of Leeds and Lansdowne, County of Leeds, approximately 48 kilometers (30 miles) north-east of the City of Kingston.

Lower Beverley Lake has a surface area of 8 square kilometers (3 square miles) and a shoreline length of 44 kilometers (27 miles). It is a relatively flat-bottomed lake with a maximum depth of 26 meters (85 feet) and a mean depth of 9 meters (30 feet). Its total volume is approximately 70 cubic hectometers (56,900 acre feet).

The immediate watershed of the lake excluding the waters flowing into it from Upper Beverley Lake, consists of 168 square kilometers (65 square miles) of land characterized by a flat to gently sloping terrain, lying within the Smith Falls Limestone Plain. This plain is characterized by relatively flat terrain with shallow overburden and poor local drainage. The surrounding area consists mostly of loam type soils and rock outcrop. The area surrounding the north half of Lower Beverley Lake belongs to the Farmington series of soil which is a thin, stone-free glacial till overlying a limestone bedrock. Generally, there is several inches of overburden. The peninsula between Wellys Bay and Kendricks Bay has a gently sloping topography and belongs to the Hinchinbrooke soil series which is a poorly drained, stone-free, fine sandy loam. It is generally found in long narrow channels, bordered by **Precambrian rock, which were inlets of a former past glacial lake.** The soil usually has a high water table for most of the year. Most of the west shoreline of the west branch of Lower Beverley Lake and the area between the east shore of Kendricks and Halladay bays belongs to the Rockland series. This series is comprised of 50 to 90 per cent granite and granite gneiss thinly covered with a mixture of humus and sand overburden, with small deposits of deeper soil materials in crevices. The southern portion of the west arm of Lower Beverley Lake consists of the Muck soil series which is made up of organic deposits found in old glacial spillway channels and other depressional areas. Normally there is 46 centimeters (18 inches) or more of organic material overlying the mineral soil. The organic matter is comprised primarily of partially decomposed remains of sedges and trees. In most of the area surrounding the lake, the overburden is less than the minimum of five feet required by the Ministry of the Environment for installation of standard subsurface septic tank systems.

Climate Range

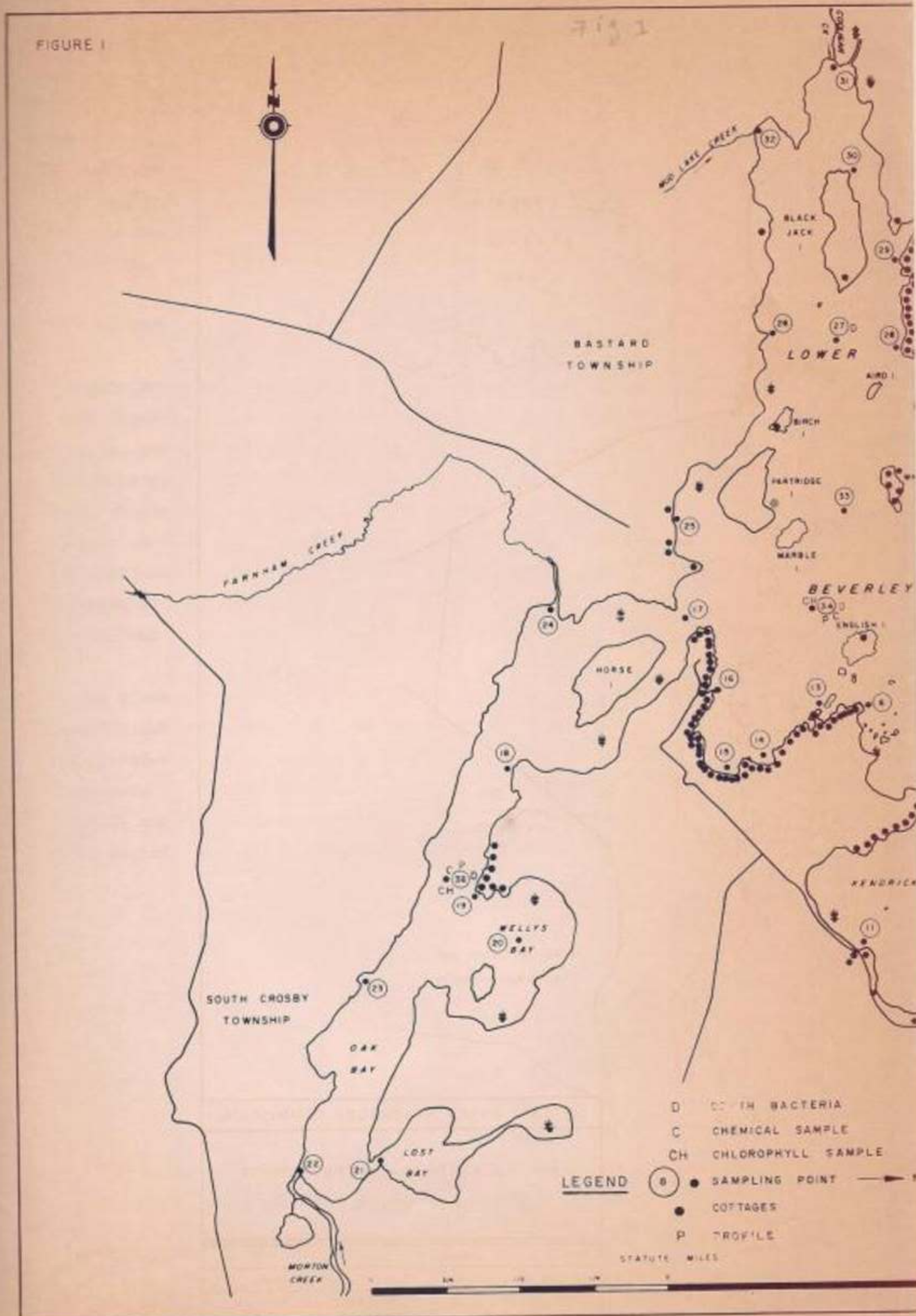
The area has a mean daily temperature of $-8^{\circ}C$ ($17^{\circ}F$) in January and a mean daily temperature of $21^{\circ}C$ ($69^{\circ}F$) in July. The mean annual precipitation is 89 centimeters (35 inches) including 200 centimeters (80 inches) of snow. According to meteorological reports, the area enjoys over 200 days yearly with no measurable precipitation. The summer climate is conducive to most recreational activities and the winter with its abundance of snow provides for participation in most winter sports.

Water Movement

Lower Beverley Lake is part of the St. Lawrence River Terminal Drainage Basin and is fed by four tributaries; Morton Creek, located at the south end of Oak Bay; Farnham Creek, located at the north end of the west branch of the lake; Cooligan Creek, located at the north end of the lake; and Delta Creek the main inlet which flows from Upper Beverley Lake and enters the lake via Lower Beverley Lake Park. The only outlet is Lyndhurst Creek, which flows out of the south-east end of Halladay Bay (Figure 1). Lyndhurst Creek eventually reaches the St. Lawrence River via the Gananoque River. There are dams on both Lyndhurst and Delta Creeks located in the communities of Lyndhurst and Delta respectively which are owned and operated by the Ministry of Natural Resources. The water level of the lake fluctuates 76 centimeters (2.5 feet) seasonally.

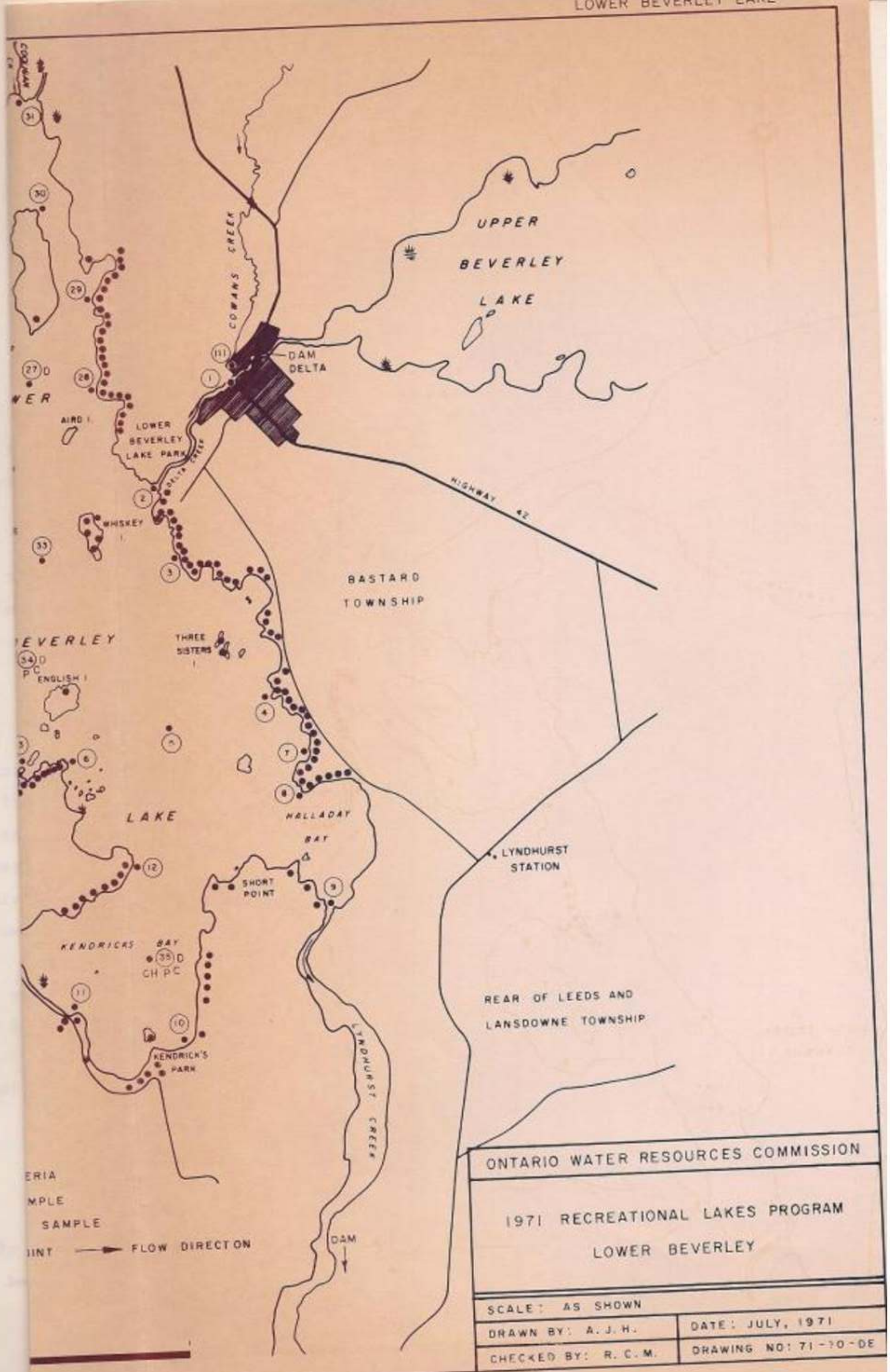
Shoreline Development

The east and south-west shoreline, with the exception of the east shore of Halladay Bay and the south-west shore of Kendricks Bay, is well developed



BASTARD TOWNSHIP
SOUTH CROSBY TOWNSHIP
LOWER
BEVERLEY
KENDRICK
BLACK JACK I
AIRD I
BIRCH I
PARTRIDGE I
MARBLE I
ENGLISH I
HORSE I
WELLYS BAY
OAK BAY
LOST BAY
MUD LAKE CREEK
FARNHAM CREEK
MORTON CREEK
LEGEND
D BACTERIA
C CHEMICAL SAMPLE
CH CHLOROPHYLL SAMPLE
SAMPLING POINT
COTTAGES
P PROFILE
STATUTE MILES

FIGURE 1


UPPER
BEVERLEY
LAKE
COWANS CREEK
DAM
DELTA
LOWER
BEVERLEY
LAKE PARK
DELTA CREEK
AIRD I.
WHISKEY I.
HIGHWAY 42
BASTARD
TOWNSHIP
THREE SISTERS I.
ENGLISH I.
LAKE
HALLADAY
BAY
LYNDHURST
STATION
SHORT
POINT
KENDRICKS BAY
KENDRICK'S
PARK
LYNDHURST CREEK
REAR OF LEEDS AND
LANSDOWNE TOWNSHIP
DAM
FLOW DIRECTON
ONTARIO WATER RESOURCES COMMISSION
1971 RECREATIONAL LAKES PROGRAM
LOWER BEVERLEY
SCALE: AS SHOWN
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DATE: JULY, 1971
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DRAWING NO: 71-10-DE

with 90 per cent of the lake's 200 cottages. There are two public swimming areas on the lake; Kendrick's Park and Lower Beverley Park (Figure 1). The latter can facilitate 40 to 50 tents and trailers. The central wash room facilities are provided with cold and hot running water and sewage disposal facilities consisting of a septic tank system. There are no marinas located on the lake.

Water Usage

The majority of cottage owners use the lake water as their source of domestic water supply. The lake supports recreational water sports such as fishing, boating, water skiing and swimming. According to information available from the Ministry of Natural Resources, the lake offers a sport fishery of northern pike, smallmouth bass and largemouth bass. The coarse fish in the lake are pumpkin seed, bluegill, rock bass, brown bullhead, yellow perch, white sucker and american eel. The sport fish have good spawning facilities in the lake. Stocking of fry and fingerlings of smallmouth and largemouth bass has been carried out since 1951.

At the present time there are no direct discharges of wastes into Lower Beverley Lake from municipal sewage treatment facilities. The area residents are provided with two municipal solid waste disposal sites within 1.6 kilometers (1 mile) of the lake, located on Lot 25, Concession VII, Bastard Township and Lot 5, Concession I, South Crosby Township. Both sites appear to be satisfactory and are not posing any pollution hazards to the lake.

FIELD AND LABORATORY METHODS

Physical, Chemical and Biological Field Methods

Water quality surveys were conducted from May 15 to 19, from July 9 to 13 and from October 19 to 22. Four near-shore stations (2, 9, 22 and 37), as well as three mid-lake stations (34, 35 and 36) were selected for physical, chemical and biological sampling. Near-shore stations were adjacent to inlets and outlets.

Dissolved oxygen and temperature profiles were determined daily in the field using a combination dissolved oxygen-telethermometer unit. Total alkalinity and free carbon dioxide were measured daily titrimetrically and pH was measured with a portable pH meter. Daily chlorophyll samples were collected in 32-ounce bottle, at each station, utilizing a composite sampler lowered through the euphotic zone (2X Secchi disc) and immediately preserved with 10-15 drops of a 2% $MgCO_3$ suspension.

At least once per year, a 32-ounce sample for hardness, alkalinity, chloride, total phosphorus, total Kjeldahl nitrogen, iron and conductivity was collected at mid-lake stations as well as at the major inlets and outlets. The mid-lake stations were sampled using a composite sampler through the euphotic zone. At inlets and outlets, samples were collected from 1 meter of depth using a Kemmerer samplet.

At stations 34 and 35 one sample for total phosphorus, total Kjeldahl nitrogen and iron was obtained by means of a Kemmerer sampler from a depth of 1 meter above the bottom on October 22.

Physical, Chemical and Biological Laboratory Methods

All analyses were carried out using routine OWRC methods based on Standard Methods 13th Edition.

Iron was measured after the sample had been digested with acid to dissolve all forms of iron present.

Kjeldahl nitrogen and total phosphorus were determined after the sample was digested with acid and an oxidizing agent to destroy organic matters.

For chlorophyll determinations, 1 liter samples were filtered through a 1.2 u membrane filter which was then extracted with 90% acetone for 24 hours. Absorbance of the extract was determined at wavelengths 600 to 750 mu using a Unicam SP1800 ultra violet spectrophotometer. The concentrat of chlorophyll a were calculated using the equation given by Richards and Thompson (1952).

Bacteriological Field and Laboratory Methods

Five-day intensive bacteriological surveys in May and July and a 4-day survey in October were completed on Lower Beverley Lake. Thirty- seven surface samples were taken daily as well as four depth samples at Stations 27D, 34D, 35D and 36D.

Surface samples were collected at a depth of one metre below the surface using sterile, autoclavable polycarbonate 250 ml bottles. Depth samples were collected one metre above the bottom using a modified "piggy back" sampler and sterile 237 ml evacuated rubber air syringes.

All samples were stored on ice and delivered to the mobile laboratory within two to six hours and analyzed for total coliforms, fecal coliforms and fecal streptococcus using the membrane filtration technique (MF) (Standard Methods, 13th Edition) except that m-Endo Agar Les (Difco) was used for total coliform and MacConkey membrane broth (Oxoid) was used for fecal coliform determinations. The total coliforms (TC), fecal coliforms (FC) and fecal streptococcus (FS) were used as "indicators" of fecal pollution. The "indicators" are the normal flora of the large intentine, and are present in large numbers in the feces of man and animals. When water is polluted with fecal material, there is a potential danger that pathogens or disease causing microorganisms may also be present.

The coliform group is defined, according to Standard Methods, 13th Edition, as "all of the aerobic and facultative anaerobic, gram-negative, non-sporeforming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C and, or "all organisms which produce a colony with a golden-green metallic sheen within 24 hours of incubation" using the MF technique. This definition includes, in addition to the intestinal forms of the Escherichia coli group, closely related bacteria of the genera Citrobacter and Enterobacter. The Enterobacter - Citrobacter groups are common in soil, but are also recovered in feces in small numbers are their presence in water may indicate soil runoff or, more important, less recent fecal pollution since these organisms tend to survive longer in water than do members of the Escherichia group, and even to multiply when suitable environmental conditions exist. A more specific test for coliforms of intestinal origin is the fecal coliform test, with incubation of the organisms at 44.5°C. Though by no means completely selective for Escherichia coli, this test has proved useful as an indicator of recent fecal pollution.

Fecal streptococci (or enterococci) are also valuable indicators of recent fecal pollution. These organisms are large, ovoid, gram-positive bacteria, occurring in chains. They are normal inhabitants of the large intestine of man and animals, and they generally do not multiply outside the body. In waters polluted with fecal material, fecal streptococci are usually found along with coliform bacteria, but in smaller numbers, although in some waters they may be found alone. Their presence, along with coliforms, indicates that at least a portion of the coliforms in the sample are of fecal origin.

Bacteriological Statistical Methods

Fluctuations in bacterial concentrations due to changing environmental conditions require that a great number of samples be taken to arrive at a mean value which is representative of a specific sample location or sampling area. The most appropriate mean for bacterial levels and this type of data is the geometric mean. The vast quantities of bacteriological data generated from these samples necessitated the development of additional statistical methods to summarize the mean results into a more concise presentation. The statistical methods used are based on the analysis of variance. The stations on the lake can be grouped, by this method, into areas or groups of stations within the same statistical bacterial level, without the bias normally associated with manual interpretation.

The analysis of variance is particularly effective where bacterial concentrations vary slightly throughout the lake. Areas or stations with slight differences in bacterial concentration may be isolated. Areas or stations with statistically higher bacterial numbers reliably indicate an input.

The results from all the analyses were organized as replicates representing the stations during the survey period. All data were transformed to logarithms (base 10) and all further analyses were done using these transformed data. A geometric mean (the antilogarithm of the average of the logarithm) was calculated on each stations and for each parameter. The validity of the analysis of variance program (ANOVA-CRE; Burger 1972), was based on the assumptions that the variances of all the stations were similar (Bartlett's test of Homogeneity) and that the data were normally distributed.

Both of these assumptions were checked on Lower Beverley Lake. The Bartlett's test was found to be non-significant and the data followed a normal distribution, hence the analysis of variance (F-test, Sokal, 1969) was calculated on all stations.

If the F was significant, then the multiple-t test was used to help determine the stations which should be deleted from the overall group to yield a homogeneous group of stations. The withdrawn stations were regrouped with respect to geographic proximity and similar means. The calculations on all groups were repeated using the analysis of variance program until each discrete group was homogeneous. The homogeneous groups that were geographically isolated were compared by means of the Student-t test (using the log GM and S.E.) which indicated the statistical difference between these groups. The Student-t test was also used to compare the grouped bacteriological data from the three surveys.

Temperature and Dissolved Oxygen

During the survey conducted in May, only minor temperature differences were apparent between surface and bottom waters (Figure 2). Dissolved oxygen concentrations, which differed up to 50% saturation between surface and bottom strata, were sufficient to maintain aquatic life.

In July, a well-defined thermocline or zone of rapid temperature decline was apparent between 5 and 7m (Figure 2b). This temperature zone serves as a physical barrier to mixing between the warmer upper waters (epilimnion) and the cool bottom waters (hypolimnion). Depending on the station, the epilimnion, thermocline and hypolimnion were characterized by dissolved oxygen concentrations ranging from 73 to 129% saturation, 5 to 80% saturation, and 1 to 34% saturation respectively. The deep-water oxygen depletion resulted from bacterial oxidation of organic matter, biological respiration and chemical oxidation.

During the October survey, the zone of rapid temperature decline at Station 35 (Figure 3a) was located 6m deeper than during the preceding survey. This phenomenon was in keeping with the expected seasonal change and is characteristic of small inland recreational lakes. Uniform temperatures, with respect to depth, were present at the shallow Station 36 (Figure 3b). At Station 35 a rapid dissolved oxygen decline, from 72 to 1% saturation (Figure 3a), occurred in the thermocline. In fact, dissolved oxygen concentrations below 10m were extremely low or absent. For the period July 12 through to October 22, dissolved oxygen concentrations in the thermocline and hypolimnion were not sufficient to maintain cold-water species of fish such as lake trout, white fish and herring. Additionally, concentrations were below the criteria established for public surface water supplies.

pH, Free Carbon Dioxide and Total Alkalinity

Mean surface pH values for the mid-lake stations were 7.9, 8.7 and 8.6 for the May, July and October surveys respectively. As a result of the relatively high photosynthetic activity by algae, pH values were generally higher in the surface waters than the deeper strata. For example, on July 10, 1971, at Station 35, values at 1 and 19m were 8.7 and 7.2 respectively. The surface pH during the latter two surveys was in excess of the limit (8.3) considered to be suitable for most water oriented recreational activities.

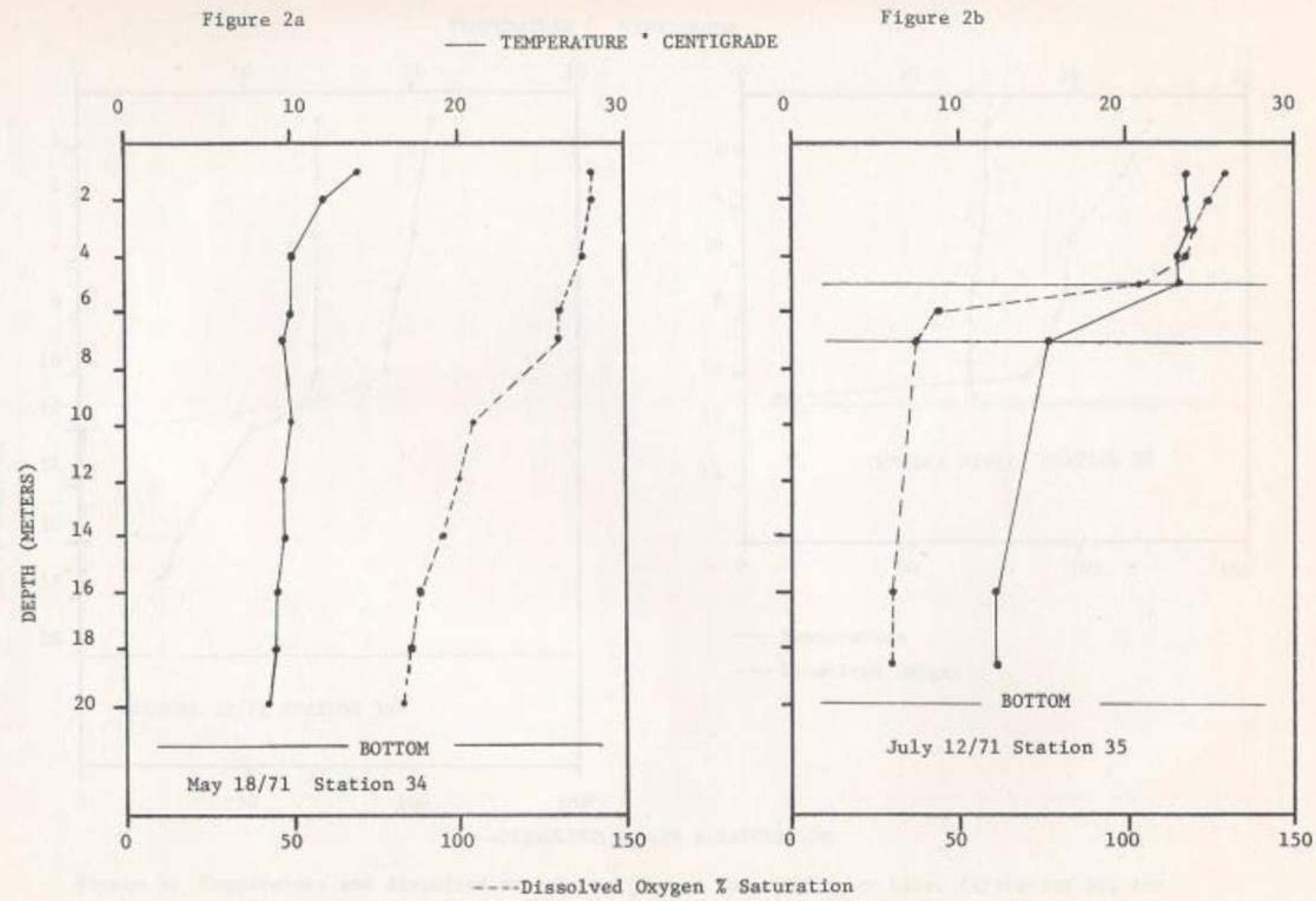

Figure 2: Temperature and dissolved oxygen profiles in Lower Beverley Lake, (a) Station 34 for May 18, 1971 and (b) Station 35 for July 12, 1971. The shaded area approximates the position of the Thermocline.

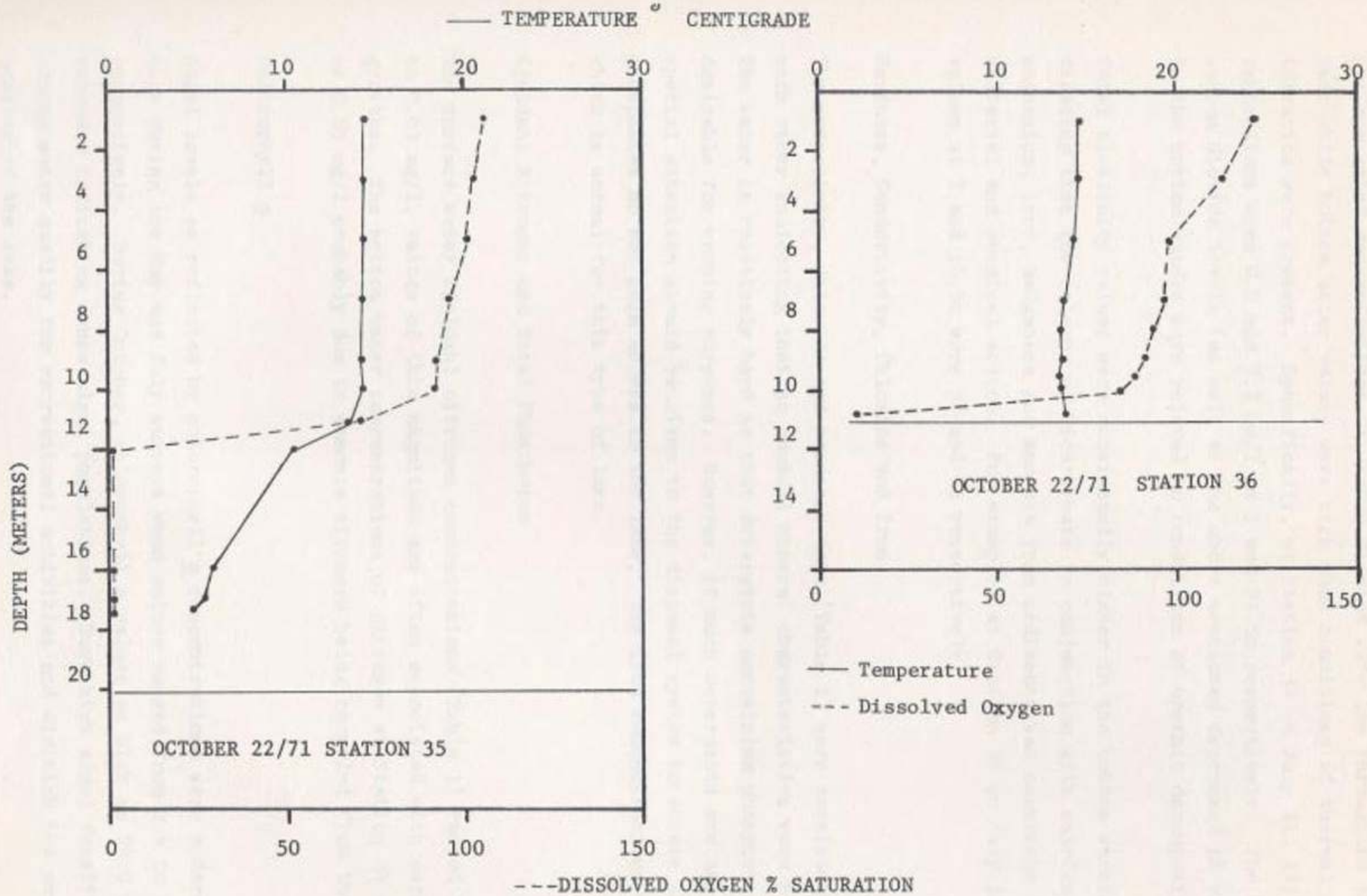

Figure 3: Temperature and dissolved oxygen profiles in Lower Beverley Lake, (a) station 35, for October 22, 1971, and (b) station 36, for October 22, 1971. The shaded area approximates the position of the thermocline.

Surface water concentrations of carbon dioxide were low throughout the year while bottom water values were high when conditions of thermal stratification were present. Specifically, at Station 34 on July 11, 1971, concentrations were 0.0 and 9.7 mg/l at 1 and 21.5m respectively. The high carbon dioxide levels (as well as the above mentioned depressed pH values) in the bottom waters were related to conditions of organic decomposition.

Total alkalinity values were consistently higher in the bottom waters indicating that the release of bicarbonate in conjunction with calcium, magnesium, iron, manganese and ammonia from sediments was occurring through bacterial and chemical action. For example, at Station 36 on July 12, 1971, values at 1 and 10.5m were 38 and 41 respectively.

Hardness, Conductivity, Chloride and Iron

The conductivity, chloride and hardness data (Table 1) were consistent with each other indicating that no unusual mineral characteristics were present. The water is relatively hard so that detergents containing phosphates will be desirable for washing purposes. However, if such detergents are used by cottagers special attention should be given to the disposal system to ensure that the phosphates do not gain access to the lake. The iron concentrations were low which is normal for this type of lake.

Kjeldahl Nitrogen and Total Phosphorus

The surface water Kjeldahl nitrogen concentrations (Table 1) ranged from 0.55 to 0.63 mg/l; values of this magnitude are often associated with excessive algal growths. The bottom water concentrations of nitrogen at Station 34 were as high as 0.85 mg/l probably due to ammonia nitrogen being recycled from the sediments.

Chlorophyll a

Algal levels as reflected by chlorophyll a concentrations were moderately high during the May and July surveys when values ranged from 2.4 to 9.1 ug/l respectively. During October, chlorophyll a values as high as 24.0 ug/l were recorded indicating dense algal populations. Such high algal densities severely reduce water quality for recreational activities and diminish the aesthetic quality of the lake.

Water clarity, which is one of the more important parameters used in defining water quality, can be measured using a Secchi disc. Figure 4 presents a chlorophyll a -Secchi disc relationship for a number of surface waters and clarifies the trophic status of Lower Beverley Lake relative to numerous other well-known recreational lakes in the province (See Brown 1972 for derivation of chlorophyll a - Secchi disc relationship). The moderately enriched status of Lower Beverley Lake is indicated (Figure 4) by its location midway between values computed for the bay of Quinte, the Western Basin of Lake Erie and Gravenhurst Bay - three enriched or eutrophic bodies of water, and the oligotrophic to mesotrophic Lake Ontario and Lake Erie, East Basin.

FIGURE 4

CHLOROPHYLL a - SECCHI DISC RELATIONSHIP

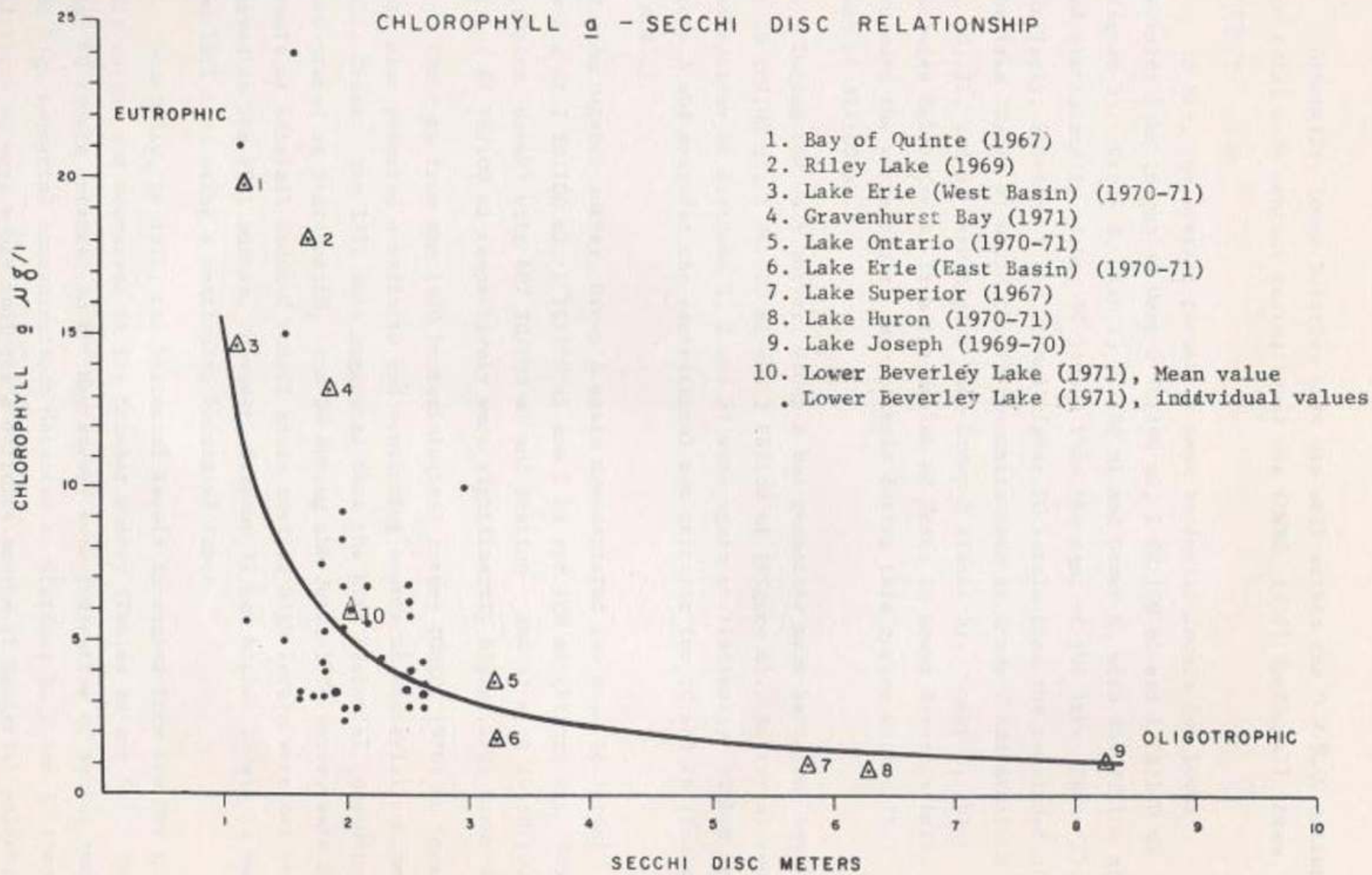

Figure 4: The relationship between chlorophyll a and Secchi disc as determined from the recreational lake survey in 1971 as well as the individual and overall mean values of chlorophyll 2 - Secchi disc for Lower Beverley Lake. The values for the Great Lakes were added for comparitive purposes.

Bacteriology

Generally, Lower Beverley Lake was well within the O.W.R.C. criteria for total body contact recreational use (OWRC, 1970) during all three surveys.

In May, the overall geometric mean bacterial levels for Lower Beverley Lake (Group A) were 3 TC/100 ml, 1 FC/100 ml and 1 FS/100 ml (Figure 5). Group B, with 13 TC/100 ml and Group C, with 864 TC/100 ml, had statistically higher TC levels than the rest of the lake (Table 3). Similarly, Stations 1 and 31 had higher FC levels than the remainder of the lake (Table 4) while the FS concentrations at Group C and Stations 3, 10, 31, and 32 were higher than Group A (Table 5). Group C, which includes Delta Creek, from the Hamlet of Delta to Lower Beverley Lake, exceeded the recreational use criteria during this survey with a FS mean of 39/100 ml.

During the July survey, Group A had geometric mean bacterial levels of 29 TC/100 ml, 1 FC/100 ml and 3 FS/100 ml (Figure 6). Bacterial concentrations at Stations 1, 2 and 37 were again statistically higher than Group A and exceeded the recreational use criteria for TC and FS (Tables 3 and 5).

In the October survey, Group A again demonstrated low mean bacterial levels of 5 TC/100 ml, 1 FC/100 ml and 1 FS per 100 ml (Figure 7). Group B (Delta Creek) with 407 TC/100 ml and Station and 37 with 10 FS/100 ml and 67 FS/100 ml respectively were significantly higher than Group A.

The data from the 1970 bacteriological survey (OWRC, 1970) on Lower Beverley Lake also revealed a definite and continuing source of bacterial contamination from Delta Creek. The 1971 data suggested that the high bacterial concentrations encountered at Stations 18, and 24 during the June, 1970 survey were a result of rainfall induced runoff since similar high levels were not observed in the 1971 survey. However, Station 31 had higher levels in both 1970 and 1971 indicating a continuing bacterial input.

Generally, in 1971, the bacterial levels increased from the May to the July survey and decreased in the October survey (Tables 6a and 6b). The high FS levels detected in the May survey were indicative of spring runoff. The high bacterial concentrations detected at Stations 1, 2 and 37 throughout all three surveys would indicate a definite source of bacterial pollution from Delta Creek. A water pollution survey of the community of Delta will be carried out by the District Engineer's Section of the Ministry of the Environment to determine the nature and the source of this bacterial pollution.

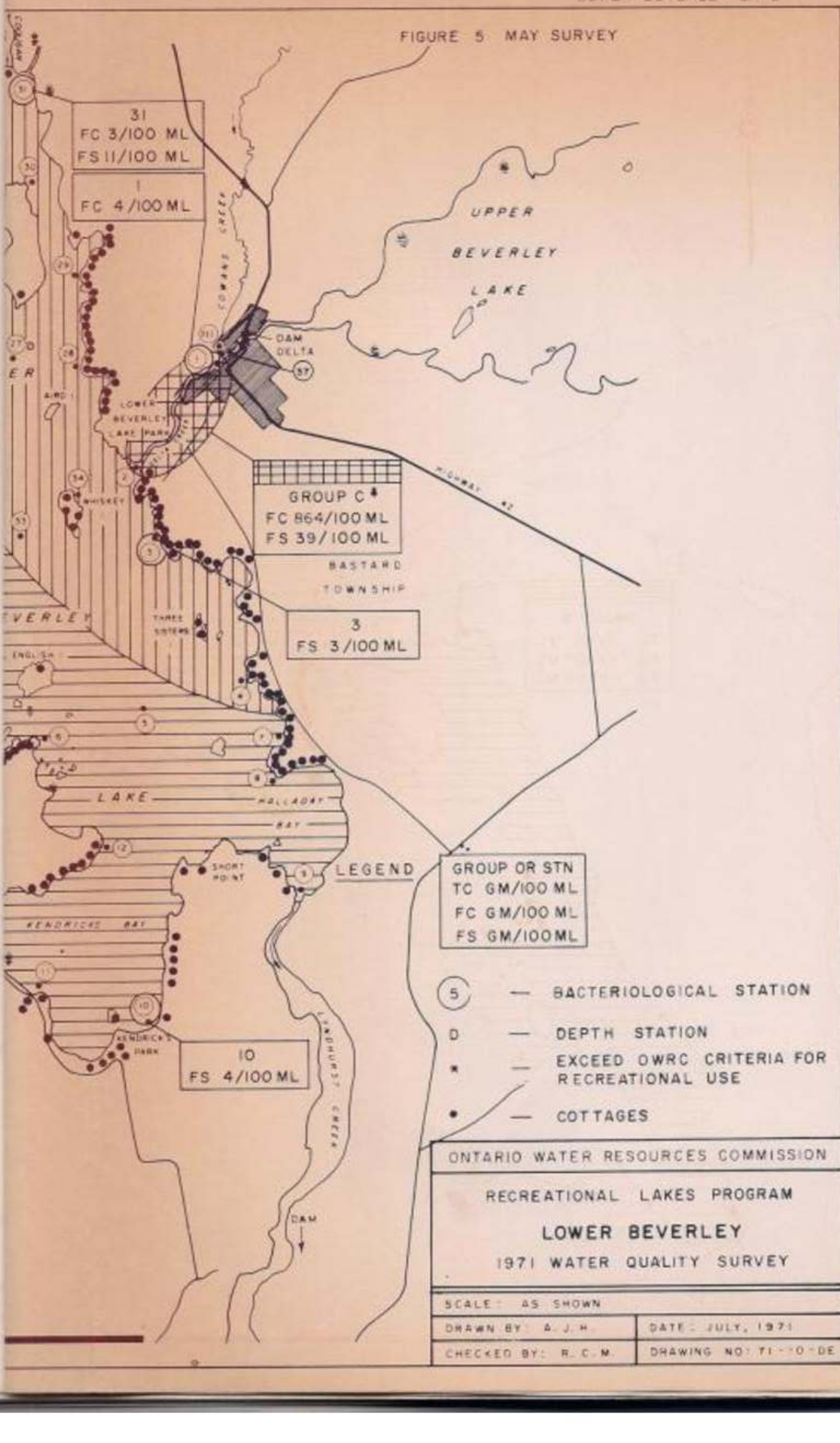
FIGURE 5 MAY SURVEY
31
FC 3/100 ML
FS 11/100 ML
1
FC 4/100 ML
UPPER
BEVERLEY
LAKE
DAM
DELTA
GROUP C
FC 864/100 ML
FS 39/100 ML
BASTARD
TOWNSHIP
3
FS 3/100 ML
LAKE
SHORT POINT
LEGEND
GROUP OR STN
TC GM/100 ML
FC GM/100 ML
FS GM/100 ML
10
FS 4/100 ML
DAM
5 — BACTERIOLOGICAL STATION
D — DEPTH STATION
* — EXCEED OWRC CRITERIA FOR RECREATIONAL USE
• — COTTAGES
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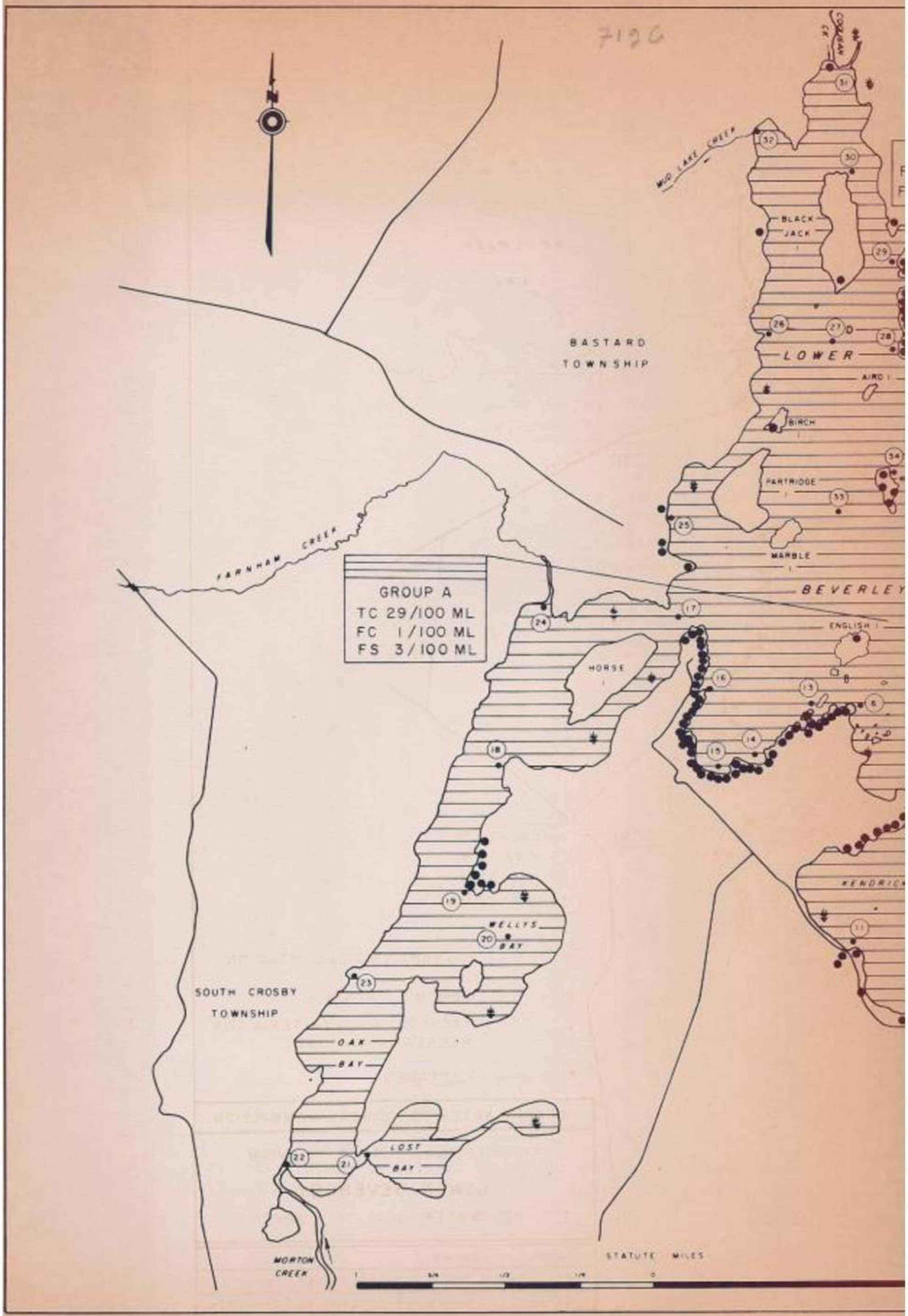
BASTARD
TOWNSHIP
SOUTH CROSBY
TOWNSHIP
GROUP A
TC 29/100 ML
FC 1/100 ML
FS 3/100 ML
FARNHAM CREEK
MUD LAKE CREEK
BLACK JACK I
LOWER
AIRD I
BIRCH
PARTRIDGE I
MARBLE I
BEVERLEY
ENGLISH I
HORSE I
WELLYS BAY
OAK BAY
LOST BAY
MORTON CREEK
STATUTE MILES

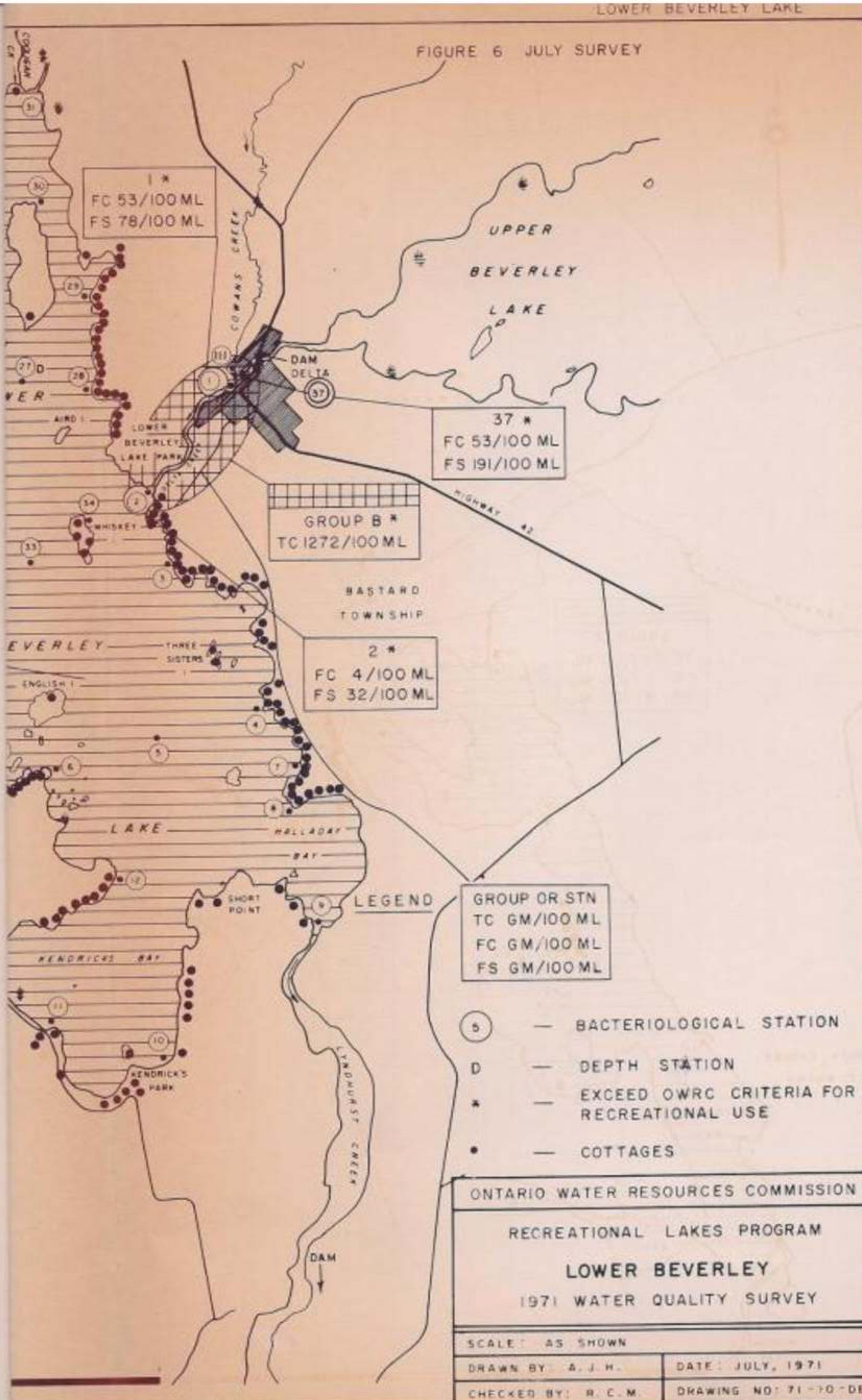
FIGURE 6 JULY SURVEY
1 *
FC 53/100 ML
FS 78/100 ML
UPPER
BEVERLEY
LAKE
COWANS CREEK
DAM
DELTA
37 *
FC 53/100 ML
FS 191/100 ML
LOWER BEVERLEY LAKE PARK
HIGHWAY 42
WHISKEY
GROUP B *
TC 1272/100 ML
BASTARD
TOWNSHIP
EVERLEY
THREE SISTERS
2 *
FC 4/100 ML
FS 32/100 ML
ENGLISH I.
LAKE
HALLADAY
BAY
SHORT POINT
LEGEND
GROUP OR STN
TC GM/100 ML
FC GM/100 ML
FS GM/100 ML
KENDRICKS BAY
KENDRICK'S PARK
LYNDHURST CREEK
DAM
5 — BACTERIOLOGICAL STATION
D — DEPTH STATION
* — EXCEED OWRC CRITERIA FOR RECREATIONAL USE
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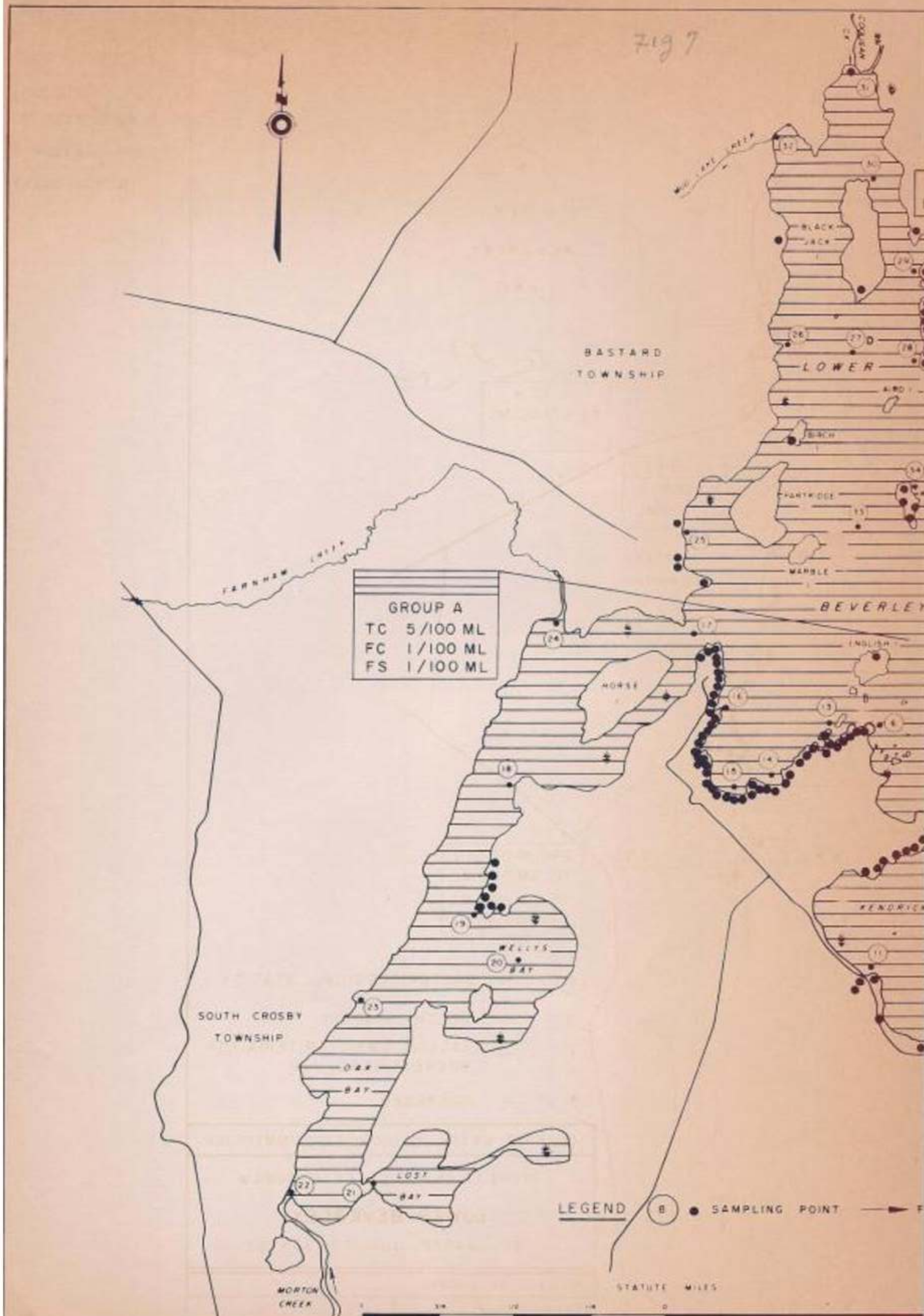
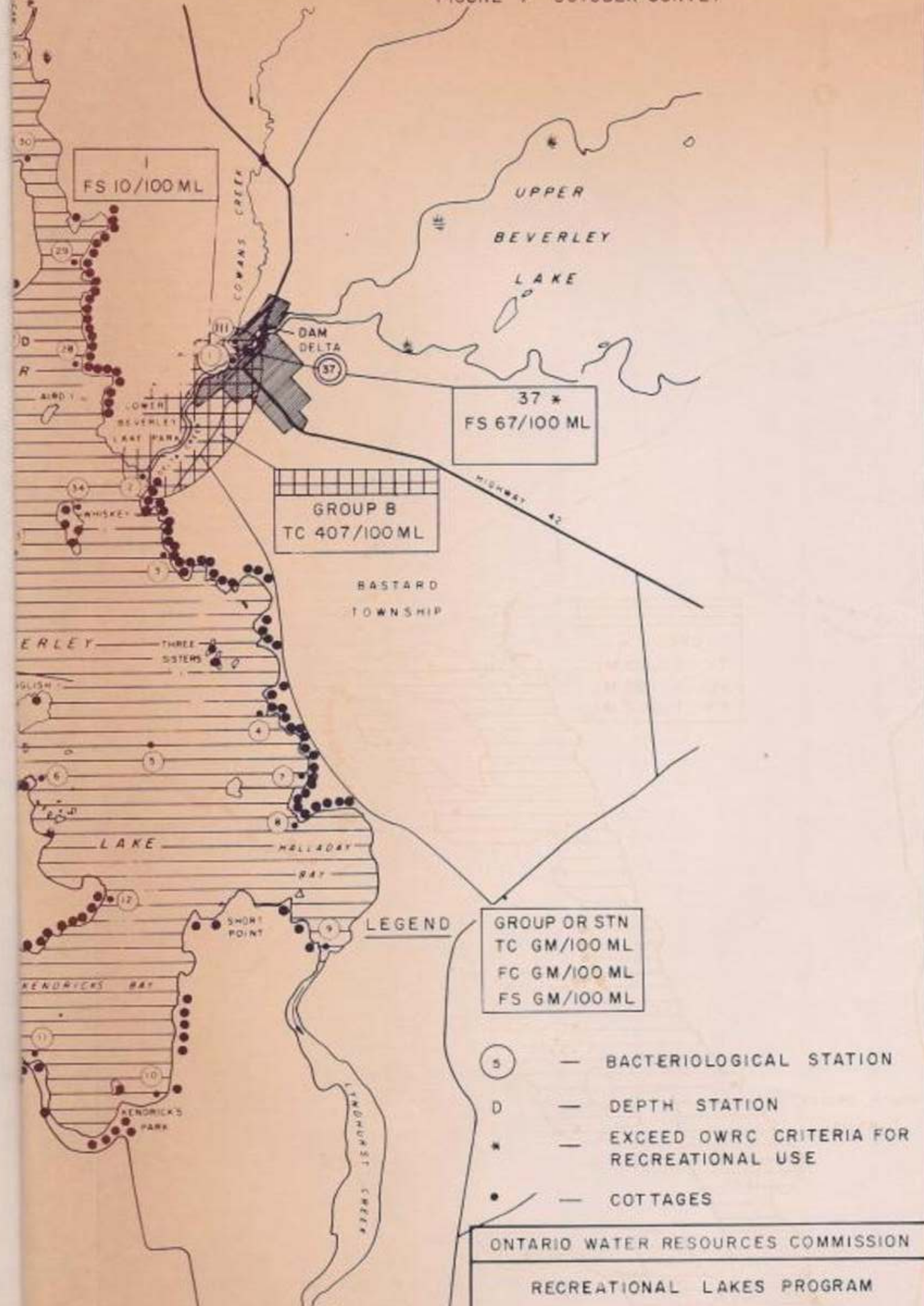
Fig 7



BASTARD
TOWNSHIP
LOWER
BLACK
JACK
BIRCH
PARTRIDGE
MARBLE
BEVERLEY
ENGLISH
HORSE
FARNHAM CREEK
GROUP A
TC 5/100 ML
FC 1/100 ML
FS 1/100 ML
WELLYS
BAY
SOUTH CROSBY
TOWNSHIP
OAK
BAY
LOST
BAY
MORTON
CREEK
KENDRICK
LEGEND
SAMPLING POINT
STATUTE MILES

FIGURE 7 OCTOBER SURVEY



Although Lower Beverley Lake was within the recreational use criteria, no surface water is considered potable without prior treatment including disinfection.

EXPLANATION OF TERMS IN BACTERIOLOGICAL TABLES

F - the calculated analysis of variance statistic on F ratio.

df - degrees of freedom of the F ratio for "between group" and "within group" variation.

F(5%) - the F ratio from a statistics table (Rohlf 1969). If the calculated F is greater than the F(5%), a significant difference (SD) occurred between the groups in the analysis. If the F is less than F(5%), no significant difference (NSD) occurred.

log GM - the logarithm (base 10) of the geometric mean.

S.E. - the standard error of the log GM where

$$S.E. = \frac{s}{\sqrt{n}} \quad \text{and } s = \text{standard deviation}$$

N - the number of values in the mean.

GM - the geometric mean of the bacterial level. See opp P. 9

t - the calculated test of significance or student t-test used to compare stations, groups and a survey.

If t for the number of degrees of freedom shown is greater than the critical t value, a significant difference (SD) occurs.

SD refers to a significant difference at the .05 level but no significant difference at the .01 level.

SD* refers to a significant difference at the .01 level but no significant difference at the .001 level.

SD** refers to a significant difference at the .001 level.

Table 1

Iron, Hardness (Hard), Total Phosphorus (P), Kjeldahl Nitrogen (N), Chloride (CI) and Conductivity (Cond) for Lower Beverley Lake 1971. The results are expressed as mg/l except conductivity which is µmhos/cm^3.

Station	Depth	Date	Iron	Hard	P	N	CI	Cond.
2	1m	19/5	0.20	168	0.032	0.36	5	-
2	1m	22/10	<0.05	140	0.066	0.67	7	269
9	1m comp	10/7	0.05	140	0.028	0.55	6	267
9	1m	22/10	0.05	138	0.020	0.57	7	268
22	1m	22/10	0.05	110	0.028	0.65	6	218
34	1m	15/5	0.10	122	0.031	0.78	7	-
34	1m	16/5	0.05	152	0.035	0.61	5	-
34	1m	17/5	0.10	150	0.024	0.52	6	-
34	1m	19/5	0.05	156	0.022	0.40	5	-
34	5m comp	9/7	0.05	150	0.030	0.52	6	288
34	3m comp	22/10	0.05	138	0.020	0.63	7	269
34	20m	22/10	0.10	-	0.14	0.85	-	-
35	4m comp	15/5	0.10	154	0.022	0.69	6	-
35	4.2m comp	19/5	0.05	156	0.024	0.44	6	-
35	3.4m comp	9/7	0.05	148	0.032	0.54	6	281
35	6m comp	22/10	0.05	138	0.018	0.64	6	272
35	16m	22/10	0.10	-	0.032	0.48	-	-
36	4m comp	15/5	0.10	154	0.025	0.68	6	-
36	3.6m comp	16/5	0.05	122	0.032	0.84	6	-
36	4m comp	17/5	0.10	120	0.036	0.64	6	-
36	4m comp	18/5	0.05	124	0.042	0.63	7	-

(cont.)

Table 1 (continued)

Station	Depth	Date	Iron	Hard	P	N	CI	Cond.
36	3.6m comp	19/5	0.05	134	0.032	0.52	6	-
36	3.6m comp	9/7	0.05	124	0.026	0.45	6	246
36	3.2m comp	22/10	0.05	126	0.040	0.98	7	239
37	1m	10/7	0.25	156	0.13	0.68	6	296

< means "less than"

"comp" means a composite sample taken through the depth indicated.

TABLE 2

DATE	STATION #34 CHLOR a	S.D.	STATION #35 CHLOR a	S.D.	STATION #36 CHLOR a	S.D.
May 15	6.7 µg/l	2.2 m	5.2 µg/l	2.0 m	8.1 µg/l	2.0 m
May 16	9.1	2.0	5.5	2.2	7.5	1.8
May 17	3.1	1.6	3.2	1.6	2.8	2.0
May 18	-	-	-	-	2.4	2.0
May 19	2.8	2.1	3.2	1.9	4.1	1.8
July 9	2.9	2.6	3.1	1.7	3.1	1.8
July 10	3.2	2.6	4.0	2.5	2.7	1.8
July 11	3.4	2.5	5.8	2.5	5.1	1.8
July 12	3.5	2.6	2.8	2.5	4.0	1.8
July 13	4.3	2.6	4.3	2.3	5.0	1.5
October 19	6.8	2.5	6.2	2.5	5.6	1.2
October 20	6.6	2.0	6.6	2.0	21.0	1.2
October 22	15.0	1.5	10.0	3.0	24.0	1.6
Mean	5.62	2.23	4.99	2.23	7.34	1.72
Overall means	Chlorophyll a 6.02 µg/l S.D. 2.05 m					

Chlorphyll a and Secchi disc values for Lower Beverley Lake, Stations 34, 35 and 36, during 1971.

TABLE 3

SUMMARY OF THE ANALYSIS OF VARIANCE GROUPING OF STATIONS

PARAMETER: TOTAL COLIFORM (T.C.)

Survey	May 15 - May 19	July 9 - July 13	October 18 - October 22
Group	All Stations	All Stations	All Stations
F	8.225	1.413	3.861
df	39,153	40.160	31.95
F(.05)	1.492	1,485	1,578
	S.D.	N.S.D.	S.D.
Group	A.	A.	A.
	Stations 5-17, 25 34D, 35, 35D, 36, 36D	All Stations Except 1, 2, 37.	All Stations Except 1, 2, 37.
F	1.1504	0.650	1.389
df	19,75	37.151	28,86
F(.05)	1.96	1.503	1.97
	N.S.D.	N.S.D.	N.S.D.
Log GM	0.04612	1.4617	1.6523
S.E.	0.0457	0.0738	0.0458
N	95	189	11
GM	3	29	5

(cont.)

TABLE 3 (Continued)

PARAMETER: TOTAL COLIFORM

Survey	May 15 - May 19	July 9 - July 13	October 18 - October 22
Group	B	B	B
	Stations 3, 4, 26-33, 27D	Stations 1, 2, 37.	Stations 1, 2, 37
F	1.712	1.159	0.722
df	10,42	2,9	2,9
F(05.)	2.072	4.260	4.260
	N.S.D.	N.S.D.	N.S.D.
Log GM	1.1232	3.1043	2.6100
S.E.	0.0745	0.1684	0.4589
N	53	12	12
G.M.	13	1272	407
Group	C		
	Station 1 & 2		
t	0.082		
df	8		
t(.05)	2.306		
Log GM	2.9366		
S.E.	0.1917		
N	10		
G.M.	864		

TABLE 4

SUMMARY OF THE ANALYSIS OF VARIANCE GROUPING OF STATIONS

PARAMETER: FECAL COLIFORM (F.C.)

Survey	May 15 - May 19	July 9 - July 13	October 18 - October 22
Group	All Stations	All Stations	All Stations
F	1.486	12.238	0.0
df	39,152	40,163	31,95
F(.05)	1.493	1.484	1.578
	S.D.	S.D.	N.S.D.
Group	A	A	A
	All Stations Except 1, 31	All Stations Except 1, 2, 37	All Stations
F	0.793	1.235	0.0
df	37,144	37,152	31,95
F(.05)	1.506	1.502	1.578
	N.S.D.	N.S.D.	N.S.D.
Log GM	0.0390	0.0317	0.0
S.E.	0.0127	0.0093	0.0
N	182	190	127
GM	1	1	1

(cont.)

TABLE 4 (Continued)

Survey	May 15 - May 19	July 9 - July 13	October 18 - October 22
Group	C		
	Stations 1, 37		
F	1.068		
df	7		
F(.05)	2.365		
	N.S.D.		
Log GM	1.7202		
S.E.	0.25386		
N	9		
G.M.	53		

TABLE 5

SUMMARY OF THE ANALYSIS OF VARIANCE GROUPING OF STATIONS

PARAMETER: FECAL STREPTOCOCCUS (F.S.) (ENTEROCOCCUS)

Survey	May 15 - May 19	July 9 - July 13	October 18 - October 22
Group	All Stations	All Stations	All Stations
F	9.683	4.757	12.066
df	39,152	40,163	31,95
F(.05)	1.493	1.484	1.578
	S.D.	S.D.	S.D.
	A	A	A
	All Stations Except 1, 2, 3, 10, 31, 32.	All Stations Except 1, 2, 37	All Stations Except 1, 37
F	1.202	0.875	0.8164
df	33,128	37,152	29,90
F(.05)	1.537	1.502	1.710
	N.S.D.	N.S.D.	N.S.D.
Log G.M.	0.0354	0.5084	0.0584
S.E.	0.0114	0.0300	0.0187
N	162	190	120
G.M.	1	3	1

(cont.)

TABLE 5 (Continued)

Survey	May 15 - May 19	July 9 - July 13	October 18 - October 22
Group	C		
	Stations 1 & 2		
t	0;3140		
df	8		
t(.05)	2.306		
	N.S.D.		
Log G.M.	1.5915		
S.E.	0.1660		
N	10		
G.M.	39		

TABLE 6a

SUMMARY OF TESTS OF SIGNIFICANCE BETWEEN ANALYSIS

OF VARIANCE GROUPS

PARAMETER: FECAL STREPTOCOCCUS

MAY SURVEY

Group or Station	Group A	Group B	Station 3	Station 10	Station 31	Station 32
Station A	t=13.848 df=350	t=7,963 df=198	t=0.272 df=193	t=0.572 df=193	t=2.812 df=193	t=0.789 df-193
Station 37	t=30.588 df=164	t=2.532 df=12	t=5.458 df=7	t=3.788 df=7	t=3.723 df=7	t=10.761 df=7
Station 1	t=27.798 df-165	t=1.205 df=13	t=4.714 df=8	t=3.225 df=8	t=1.663 df=8.0	t=8.783 df=8
Station 2	t=22.248 df=165	t=0.309 df=13	t=3.501 df=8	t=2.282 df=8.0	t=1.570 df=8	t=6.736 df=8
Group A	t=1.104 df=280	t=19.277 df=128	t=3.747 df=123	t=4.840 df=123	t=9.273 df=123	t=3.107 df=123
Station 37	t=24.373 df=164	t=1.805 df=12	t=4.088 df=7.0	t=2.749 df 7	t 2.351 df 7	t 8.122 df 7
Station 1	t=5.697 df=164	t=1.122 df=12	t=1.203 df=7	t 712 df 7	t .099 df 7	t 1.789 df 7

TABLE 6 b
SUMMARY OF TESTS OF SIGNIFICANCE BETWEEN ANALYSIS
OF VARIANCE GROUPS
PARAMETER: FECAL STREPTOCOCCUS

July Survey

	Group or Station	Group A	Station 37	Station 1	Station 2
	Group A	t 11.087 df 308	t 21.483 df 122	t 19.578 df 123	t 15.601 df 123
Survey October	Station 37	t 6.357 df 192	t 4.325 df 6	t .4951 df 7	t 2.601 df 7
	Station 1	t 2.311 df 192	t 3.583 df 6	t 2.738 df 7	t 1.597 df 7

ALKALINITY :The alkalinity of a water sample is a measure of its capacity to neutralize acids. This capacity is due to carbonate, bicarbonate and hydrozide ions and is arbitrarily expressed as if all of the neutralizing capacity was due to calcium carbonate alone.

ANOXIC :Refers to conditions when no oxygen is present.

BACKGROUND COLONIES :Background colonies are other lake water bacteria capable of growing on the total coliform plate, in spite of the inherent restrictive conditions.

CHLORIDE :Chloride is simply a measure of the chloride ion concentration and is not a measure of chlorination.

CHLOROPHYLL a :A green pigment in plants.

CONDUCTIVITY :Conductivity is a measure of the waters ability to conduct an electric current and is due to the presence of dissolved salts.

DIATOMS :Unicellular plants found on all continents and in all types of water where light and nutrients are sufficient to support photosynthesis. They are comprised of two siliceous frustules (cell walls) which have an outer valve (epitheca) fitting over the inner valve (hypotheca) like the lid on a box. The siliceous deposits comprising the frustules vary in regular patterns according to the individual species.

EPILIMNION :Is the thermally uniform layer of a lake lying above the thermocline. Diagram 1.

EUPHOTIC ZONE :The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur due to insufficient light penetration.

EUTROPHIC :Waters containing advanced nutrient enrichment and characterized by a high rate of organic production.

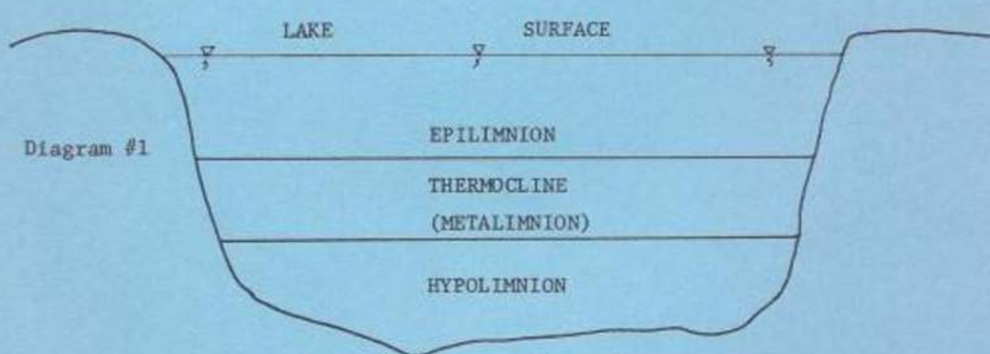
EUTROPHICATION	:The process of becoming increasingly enriched in nutrients. It refers to the entire complex of changes which accompanies increasing nutrient enrichment. The result is the increased production of dense biological growths such as algae and aquatic weeds which generally degrade water quality and render the lake unsuitable for many recreational activities.
FECAL COLIFORMS (FC)	:Fecal coliforms are bacteria associated with recent fecal pollution from man and animals.
FECAL STREPTOCOCCUS (FS)	:Fecal streptococcus are bacteria associated with fecal pollution from animals and to a lesser extent man.
HARDNESS	:Hardness of water is a measure of the total concentration of calcium and magnesium ions expressed as if all of the ions were calcium carbonate.
HYPOLIMNION	:The uniformly cold and deep layer of a lake lying below the thermocline, when the lake is thermally stratified. Diagram #1
KJELDAHL NITROGEN	:Sum of nitrogen present in the ammonia and organic forms (it does not include nitrite or nitrate).
MESOTROPHIC	:Waters characterized by a moderate nutrient supply and organic production (i.e. midway between eutrophic and oligotrophic).
METALIMNION	:See thermocline.
OLIGOTROPHIC	:Waters containing a small nutrient supply and consequently characterized by a low rate of organic production.
pH	:Is the measure of the hydrogen ion concentration expressed as the negative logarithm of the molar concentration.
PHOSPHORUS (TOTAL)	:Sum of all forms of phosphorus present in the sample.

SECCHI DISC :A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal quadrants. Two quadrants directly opposite each other are painted black and the intervening ones white. The secchi disc is used to estimate the turbidity of the lake water.

THERMAL STRATIFICATION :During the spring, vertical temperatures in a lake are homogeneous from top to bottom. As summer advances, the surface waters become warmer and less dense than the underlying cooler waters. A strong thermal gradient (Thermocline) occurs giving rise to three distinct water layers. The variation in density between layers retards mixing by wind action and water currents. Diagram #1.

THERMOCLINE (metalimnion) :The layer of water located between the epilimnion and hypolimnion in which the temperature exhibits a decline equal to or exceeding $1^{\circ}C$ increase per meter.

Diagram #1



TOTAL COLIFORMS (TC) :Total coliforms are bacteria commonly associated with fecal pollution but may also be present naturally in the environment.

TROPHIC STATUS :Depending upon the degree of nutrient enrichment and resulting biological productivity, lakes are classified into three intergrading types:

TROPHIC STATUS
(continued)

:oligotrophic, mesotrophic and eutrophic. If the supply of nutrients to an oligotrophic lake is progressively increased, the lake will become more mesotrophic in character and with continued enrichment it will become eutrophic.

BIBLIOGRAPHY

BENNETT, E.A. Taken from the Great Lakes as an Environment, Edited by D.V. Anderson, Great Lakes Institute Report PR 39, University of Toronto, October 1969.

BROWN, D.J. 1972 Chlorophyll a - Secchi disc relationship in Ontario Recreational Lakes (In Preparation).

BURGER, A. Statistical Bacterial Data Summarization and Interpretation Internal OWRC Report (Unpublished).

Guidelines and Criteria for Water Quality Management in Ontario OWRC, June 1970.

Microbiological Criteria

Water used for body contact recreational activities should be free from pathogens including any bacteria, fungi or viruses that may produce enteric disorders or eye, ear nose, throat and skin infections. Where ingestion is probable, recreational waters can be considered impaired when the coliform fecal coliform, and/or enterococcus geometric mean density exceeds 1000, 100 and/or 20 per 100 ml respectively, in a series of at least 10 samples per month, including samples collected during weekend periods.

RICHARDS, F.A. and THOMPSON, T.G. 1952 The estimation and characterization of plankton populations by pigment analysis 11. The spectrophotometric method for the estimation of plankton pigments. J. Marine Res., 11:156.

ROHLF, F.M. and SOKAL, R.R. 1969 Statistical Tables, W.H. Freeman and Company, San Francisco.

SOKAL, R.R. and ROHLF, F.J. 1969 Biometry, the principals and practices of statistics in biological research, W.H. Freeman and Company, San Francisco.

Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971. APHA, AWWA, WPCF.

Water Quality Report on Lower Beverley Lake, OWRC 1972.