THE

ONTARIO WATER RESOURCES

COMMISSION

WATER QUALITY EVALUATION

of

ROBLIN LAKE

PRINCE EDWARD COUNTY

1970

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BY

M.F.P. Michalski

and

G.J. Hopkins

BIOLOGY BRANCH

DIVISION OF LABORATORIES

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SUMMARY AND CONCLUSIONS

Limnological, bacteriological and biological data for Roblin Lake, a potential source of water supply for the village of Ameliasburgh, were collected on 5 days during the summer of 1970. Classical indications of mesotrophy and/or early eutrophy were evinced by relatively low Secchi disc readings; oxygen depletions and high phosphorus, nitrogen and iron concentrations in the lower waters; depression of pH in the deeper strata and by relatively high standing stock of phytoplankton dominated by the blue-green "water-bloom" alga *Microcystis.*

Bacteriologically, Roblin Lake is an excellent source of domestic water supply. On the other hand water taken from the euphotic zone during the summer months would be extremely warm and would contain relatively high levels of those algae which produce tastes and odours. On the other hand, water from the deeper strata, albeit slightly cooler, would contain increased concentrations of iron, nitrogen (including ammonia), phosphorus and calcium and magnesium carbonates. In addition, relatively high levels of algae periodically develop in the deeper zones of the lake.

Poor water quality would be experienced frequently by domestic users unless treatment facilities for algal removal and taste and odour control are included in the plant design. The expense of such facilities may not be justified in view of the small population to be serviced and the enriched nature of the lake.

INTRODUCTION

In May, 1970, personnel of the District Engineering Branch of the Division of Sanitary Engineering, requested that a water quality evaluation be carried out on Roblin Lake. The prime objective of the study was to assess the suitability of the lake as a potential source of potable water for the Village of Ameliasburg. Additionally, the investigation afforded an opportunity to evaluate the degree of nutrient enrichment of the lake.

GENERAL DESCRIPTION OF THE STUDY AREA

Roblin Lake is located in the Township of Ameliasburg, Prince Edward County, (Figure 1). Various physical characteristics are tabulated below:

Maximum depth	-	39 feet
Mean depth	-	10 feet
Length	-	4500 feet
Width	-	1500 feet
Volume	-	92,747,637 cubic feet
Surface area	-	0.35 square miles
Drainage area	-	1.49 square miles
Length of shoreline	-	12,406 feet

The lake is located in a drainage basin of blue, very fine crystalline to sub-lithographic limestone in excess of 100 feet in thickness which is overlain by Farmington Loam - a shallow soil of drift and weathered limestone. The lake is in a hollow, bounded on the north by a limestone escarpment rising 400 feet above sea level and on the other three sides by limestone table-lands attaining the same elevation.

An O.W.R.C. report (Coles, 1970) stated, "The location of the lake is unusual and its continued existence can only be explained by the impermeable nature of the rock in which it is situated. The topography immediately adjacent to the lake indicates that the only water available for storage must fall on the catchment area. Precipitation may reach the lake in the form of surface run-off or groundwater seepage, but it appears very unlikely that any water reaches the lake from outside the topographic drainage area, since most of the immediately surrounding land is at a lower elevation than the lake.

"An O.W.R.C. report (Yakutchik, 1963) for a survey conducted three miles northeast of Roblin Lake to determine whether sufficient ground water was available to support a subdivision of 150 - 200 people concluded - "The overall picture presented by the data indicates the bedrock (Trenton Limestone) is a poor source of water and it is unlikely that an adequate supply of water for the subdivision can be developed from it."

At present, personnel of the Hydrologic Data Branch are assessing whether sufficient water resources would be available assuming a maximum drop in summer water levels were to occur.

Roblin Lake is used almost exclusively by local residents and cottagers for swimming, boating, fishing and other water-oriented recreational activities. A number of cottages exist at either ends of the lake. A Conservation Authorities Branch report (1968) indicated that, "The large number of cottages and the absence of any large area of vegetation useful to wildfowl makes Roblin Lake quite unsuitable for breeding ducks and also unattractive to migratory birds."

Considering the fisheries of the lake, an Ontario Department of Lands and Forests study in June, 1960, concluded that the lake"is fertile and capable of supporting a heavy population of fish". Two trapnets set between June 15th and 17th, 1960, yielded 3 northern pike, 64 small mouth bass, 20 large mouth bass, 44 brown bullheads, 2 white suckers, 1 yellow perch, 422 pumpkinseed sunfish, 267 rock bass and 13 eel.

Some emergent and submergent vegetation was seen in the near-shore areas of the lake during this study while extensive tufts of the filamentous green alga, *Chara sp.*, were observed on the bottom in depths to 15 feet. This alga is notorious for imparting a "skunky" or "musty" odour to the water.

METHODS

Field Methods

Physical measurements and bacteriological, biological and chemical samplings were made on five days between June 9th and September 30th, 1970.The work was carried out at Station A, (Figure 1), a location which approximated the deepest section (42 feet) of the lake.

At Station A, temperature readings were made by immersing a standard pocket thermometer (accuracy ± 0.5°C) into the sample bottle at the time of sampling. An index of light penetration was made with a Secchi disc. Dissolved oxygen profiles were established using a Hach D.O. kit. Two samples were obtained for threshold odour determinations. The first was collected from the euphotic zone by lowering (to the 1% incident light level) and raising a weighted sampler containing a 32-ounce bottle at such a rate that the bottle filled completely just as it ascended to the surface of the water. The second sample was collected from a depth of 33 feet - a potential water intake stratum.

Chemical and biological samples were taken from six depths (1, 7, 13, 20, 26 and 33 feet) at Station A, using a Van Dorn water sampler. Samples obtained for identification and enumeration of algae were preserved with Lugol's iodine at time of sampling.

Bacteriological samples were obtained at Station A from the six aforementioned depths by means of a sterile 237 ml air syringe (Daval Rubber) mounted on a device based on a modification of the "piggy-back" sampler of Sieburth (1963). Additionally, sub-surface "grab" samples were collected at Station B and C, (Figure 1), by immersing a 6-ounce sterile bottle to arms length.

Threshold odour, chemical and bacteriological samples were kept cool during transit and were processed immediately upon arrival at the O.W.R.C. Laboratories in Toronto. The time lapse between sampling and analyzing bacteriological samples was 40-48 hours as the Roblin Lake study was carried out in connection with a second investigation at Barry's Bay necessitating an additional day of field work.

Laboratory Methods

Nutrient analyses were performed on each water sample for nitrogen (total Kjeldahl and ammonia nitrogen as N), total phosphorous (as P) and orthosilicate (as SiO_2).

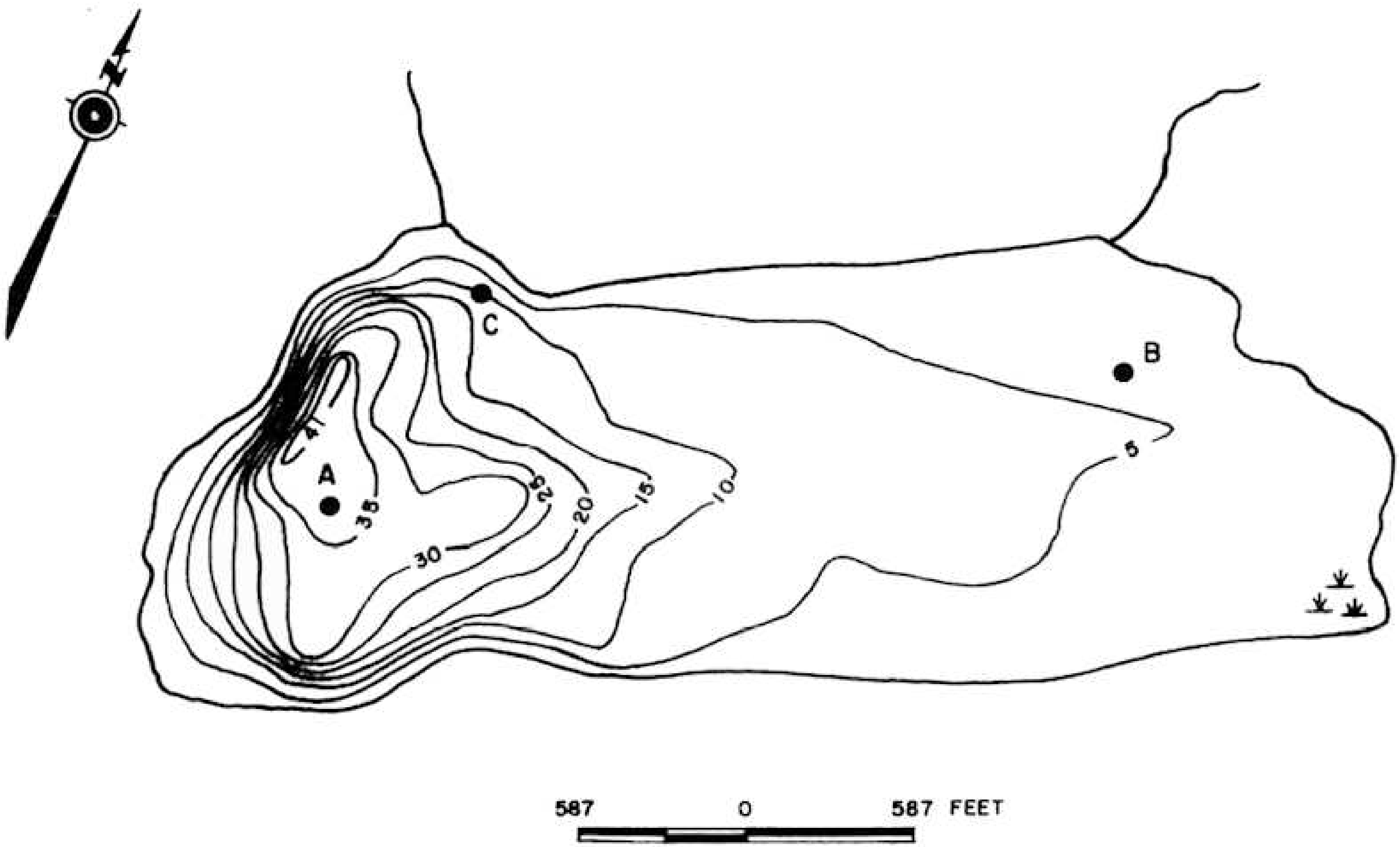

FIGURE 1: Roblin Lake - Ameliasburgh Twp. Prince Edward County Approximate Location Of Three Sampling Sites In Roblin Lake - 1970 Depth Contours Are Presented In Feet.

Also, determinations for pH, alkalinity, turbidity, colour, hardness, conductivity, chloride, sodium, potassium and iron were completed. All analyses were performed according to procedures outlined in Standard Methods (A.P.H.A. *et al.* 1965).

Threshold odour analyses were conducted at 60°C by an experienced panel of five persons. Tests followed standard procedures (A.P.H.A. *et al.* 1965), in which results were expressed as the geometric mean.

The algal samples were concentrated by allowing the cells to settle for 72 - 96 hours, and then syphoning the overlying liquid. Subsequently, the cells were re-suspended and a 1-ml aliquot was pipetted into a Sedgewick-Rafter counting cell. All of the algal forms were identified to species where possible and to genus otherwise at a magnification of 200X. Numerical results were recorded as areal standard units (a.s.u.) per millilitre.

One areal standard unit is equal to an area of 400 square microns (Whipple 1914).The areal value was employed because of its usefulness in measuring standing stocks of algae and because it is extremely useful when relating algal levels to problems associated with water treatment and supply. Depending on the density of the concentrate, strips or fields were counted. To render results statistically accurate, between 150 and 200 organisms per millilitre were identified and measured.

Bacteriological samples were analyzed by membrane filtration for total coliform (T.C.) and fecal coliform (F.C.) according to standard procedures (A.P.H.A. *et al.* 1965).

Evaluation of the data was based on the geometric mean (G.M.) of the counts. The geometric means were compared to the water quality criteria for public surface water supplies published in the O.W.R.C. "Guidelines and Criteria for Water Quality Management in Ontario" (1970).

RESULTS

Physical Aspects

Colour

In general, readings of less than 5 units for colour (expressed as True Colour Units) were recorded throughout the study period. However, on each sampling date, readings increased with depth; for example, on August 19^{th}, colour increased from less than 5 units in the upper strata to 20 units (the maximum value recorded) at 26 and 33 feet.

Turbidity

Turbidities expressed in Jackson Turbidity Units are summarized in Table 1. No definite pattern in the vertical distribution of turbidity was detected at the sampling site.

Temperature

On June 9^{th}, a temperature difference of 8°C existed between surface (22°C) and bottom (14 °C) waters (Figure 2). On this date a well-defined thermocline or zone of rapid temperature change was not apparent; in fact, throughout the entire study period a stable thermocline did not develop as waters were generally homothermous with depth. For example, on August 19^{th}, water temperatures ranged between 24°C

Table 1. Summary of turbidity values (expressed in Jackson Turbidity Units) at Station A, Roblin Lake, June 9 - September 30, 1970.

Depth (feet)	Number of Analyses	Maximum	Minimum	Mean
1	4	4.0	2.0	2.5
7	4	6.0	2.0	4.3
13	4	8.0	1.5	3.3
20	4	4.0	1.0	2.2
26	4	6.0	2.0	3.2
33	3	3.0	2.0	1.7

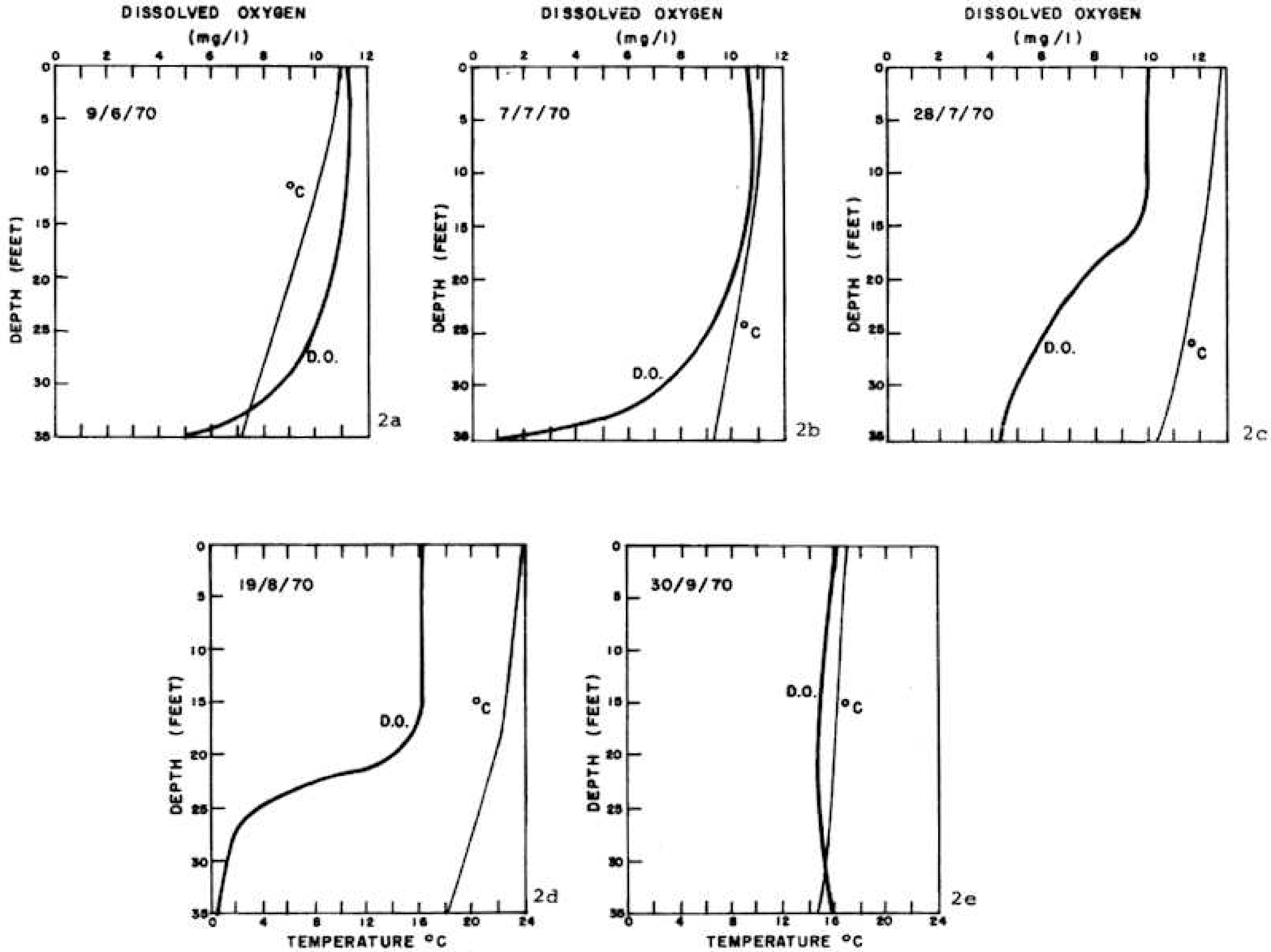

FIGURE 2: Profiles of Dissolved Oxygen (Mg/L) And Temperature °C on Five Dates in 1970 at Station "A" Roblin Lake at the surface and 18.5°C at the bottom; corresponding readings on September 30th were 17.5°C and 16.0°C (Figure 2).

Threshold Odour

Maximum and minimum Threshold Odour Numbers (expressed as a geometric mean) for samples collected through the euphotic zone were 17.3, (August 19th) and 7.9 (July 7th) respectively. Corresponding values for samples obtained from a depth of 33 feet were 14.2 (July 28) and 5.7 (September 30) respectively.

The odours were described by participating panelists as "grassy", "weedy", "algal" or "mossy-like", or more generally of a vegetative nature.

Light Penetration

Maximum, minimum and mean Secchi disc readings were 14.5, 8.3, and 10.5 feet respectively. These figures may be used to calculate (x2) a theoretical euphotic zone or zone of algal production of 29, 16.6 and 21 feet, respectively.

Chemical Considerations

General

Seasonal isopleths for hardness, alkalinity and conductivity in Roblin Lake are summarized in Figures 3a, b and c. Values for these parameters were characterized by mid-summer reductions in surface waters and corresponding accumulations in the bottom strata.

On the final day of sampling (September 30) the entire water *mass* of the lake appeared both thermally (Figure 2e) and chemically homogeneous (Figure 3) undoubtedly owing to the development of an early fall turnover.

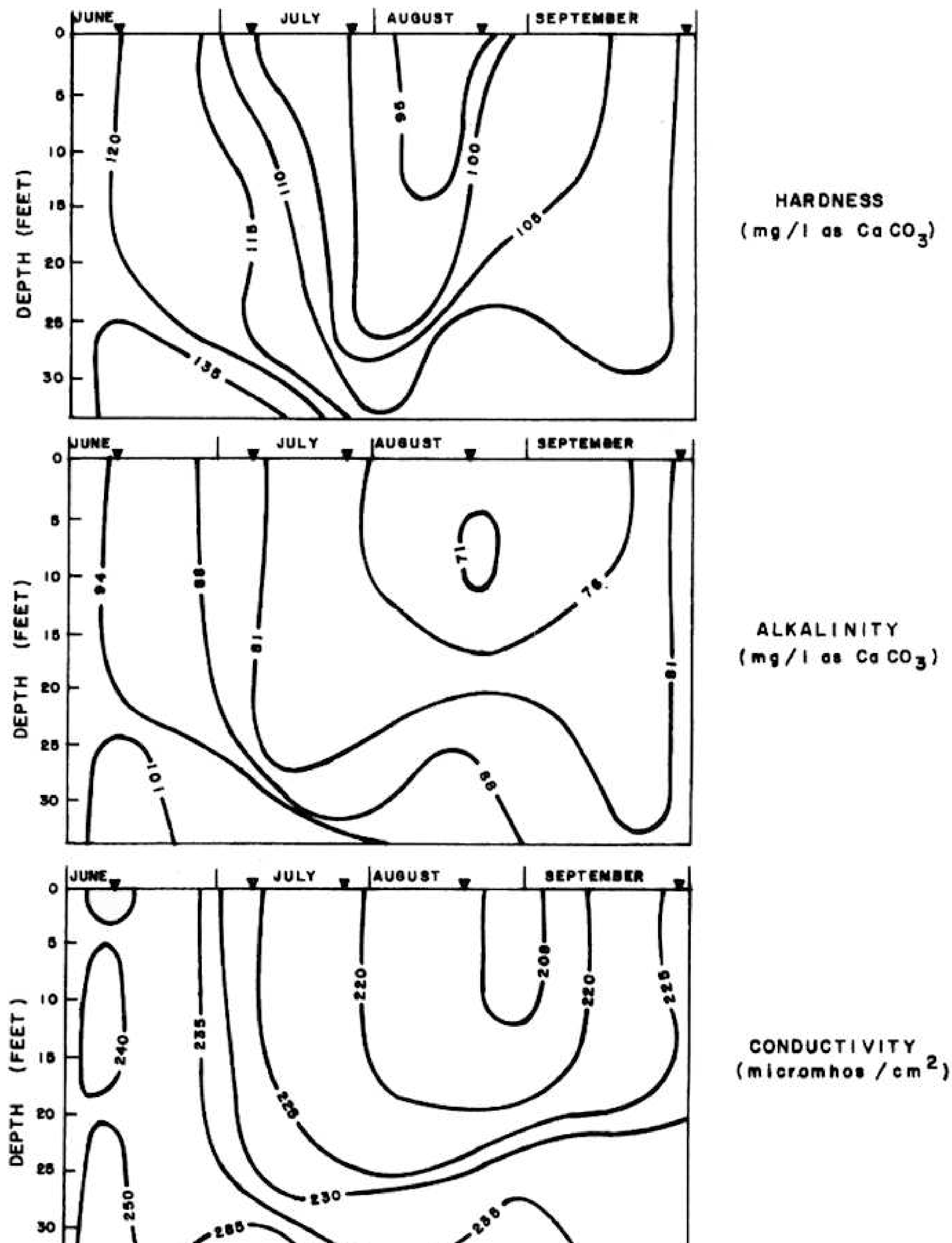

FIGURE 3: Isopleths of Hardness Alkalinity and Conductivity at Station "A" Roblin Lake June 9th - Sept. 30th, 1970.

Sodium, potassium and chloride determinations are described in Table 2. Definite seasonal or vertical variations were not evident for these parameters.

Dissolved Oxygen

Clinograde oxygen distributions or reductions in oxygen concentrations in the deeper layers of the water were quite distinct at Station A on each sampling date, with one exception (Figure 2).The exception occurred on September 30th when the distribution was orthograde or non-diminishing (Figure 2e).

On June 9th, the oxygen concentration at the surface was 11 mg/L (125% saturation) while a value of 4 mg/L (30% saturation) was measured at 33 feet. A similar profile characterized the water column on July 7th. On July 28th, some re-oxygenation in the lower strata had occurred as concentrations below 5 mg/L (54% saturation) were not detected. However, by August 19th an oxygen deficit was apparent in the deeper water as concentrations of only 1.2 mg/L (13% saturation) and 0.8 mg/L (8% saturation) were measured at depths of 26 and 33 feet, respectively. The orthograde regime of September 30th reflected the effect of an early fall lake turnover.

pH

Without exception, the pH was higher in the surface waters than in the deeper strata at Station A, (Figure 4). Considering the entire study period, pH values ranged between 8.5 (surface) and 7.5 (33 feet).

Nutrient Considerations

A summary of the nutrient data is provided in Table 3With the exception of data collected on September 30th, total phosphorous, total Kjeldahl and free ammonia

Table 2. Summary of sodium, potassium and chloride values (mg/L) at Station A, Roblin Lake, June 9 - September 30, 1970.

Depth (feet)	Sodium		Potassium		Conductivity	
	Range	Mean	Range	Mean	Range	Mean
1	2-3	2.2	2.2 - 2.4	2.3	6-8	7.0
5	2-3	2.4	2.2 - 2.4	2.3	6-7	6.6
10	2-3	2.2	2.2 - 2.5	2.3	6-7	6.7
18	-	2.0	2.2 - 2.4	2.3	6-7	6.4
30	-	2.0	2.3 - 2.4	2.3	6-7	6.4
36	-	2.0	2.1 - 2.4	2.2	6-7	6.6

Table 3. Summary of nutrient determinations (expressed in mg/L) made on samples collected from Station A, Roblin Lake on five dates between June 6 and September 30, 1970.

Depth (feet)	Total Phosphorus (as P)		Orthosilicate (as SiO_2)		Total Kjeldahl Nitrogen (as N)		Free Ammonia (as N)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
1	0.014	0.011 - 0.020	1.45	0.39 - 2.30	0.63	0.50 - 0.76	0.04	0.02 - 0.11
7	0.013	0.010 - 0.016	1.44	0.38 - 2.40	0.69	0.47 - 0.87	0.04	0.02 - 0.05
13	0.014	0.009 - 0.020	1.39	0.35 - 2.30	0.60	0.45 - 0.72	0.03	0.02 - 0.08
20	0.013	0.010 - 0.019	l.30	0.23 - 2.40	0.66	0.57 - 0.80	0.05	0.02 - 0.10
26	0.015	0.010 - 0.020	1.23	0.21 - 2.10	0.68	0.59 - 0.76	0.08	0.04 - 0.16
33	0.025	0.012 - 0.043	1.58	0.30 - 2.30	1.12	0.62 - 1.80	0.27	0.07 - 0.75

Table 4. Individual bacteriological analyses completed (Total Coliform/100 ml and Fecal Coliform/100 ml) on samples from three locations in Roblin Lake and summary of the data (Geometric Mean).

Depth	June 9		July 8		July 28*		August 19*		September 30*		G.M.	
	TC	FC	TC	FC	TC	FC	TC	FC	TC	FC	TC	FC
					Station A							
1	4	1	20	1	48	1	1	1	1	1	5.2	1.0
7	16	1	-		64	1			1	1	10.1	1.0
13			1300	1	20	1			1	1	29.6	1.0
20	8	1	1	1	16	1			12	1	6.3	1.0
26			200	1	36	1			1	1	19.3	1.0
33	1	1	12	1	144	2			1	4	6.4	1.7
					Station B							
Surface	1	1	36	1	28	20	8	4	8	1	9.2	2.4
					Station C							
Surface	1	1	36	4	42	6	20	4	8	1	11.9	2.5

* analyzed within 48 hours of sampling, otherwise analyses within 24 hours of sampling.

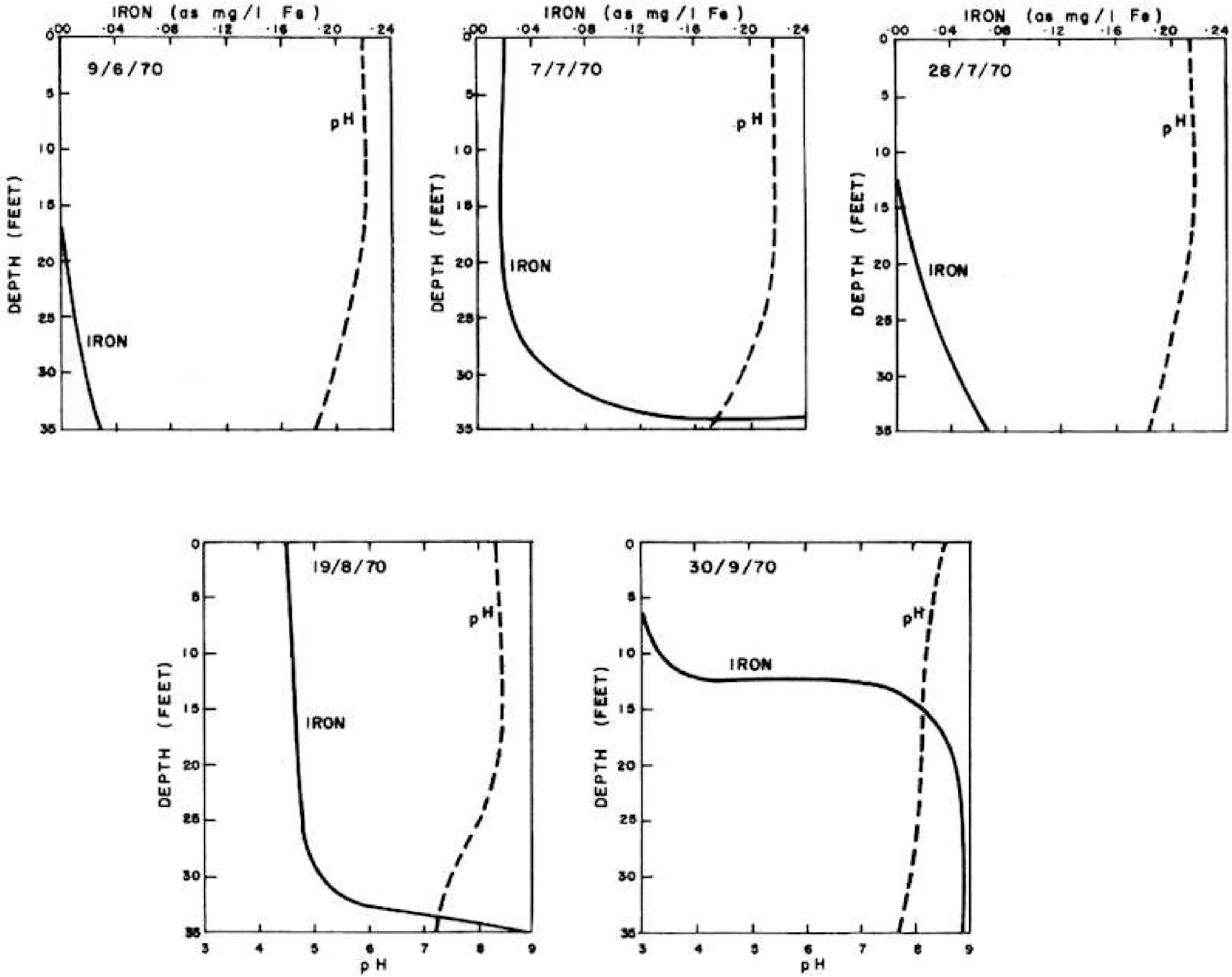

FIGURE 4: Profile Of Iron (as mg /L Fe) and pH on five dates in 1970 at Station "A" Roblin Lake.

nitrogen values were considerably higher in the deeper waters than in the upper, warmer strata. It is significant to note that iron concentrations (as Fe) generally increased with depth (Figure 4). Orthosilica levels were normally uniform with depth except for July 7th when concentrations increased from 0.8 mg/L at 26 feet to 2.3 mg/L at 33 feet. Additionally, orthosilicate levels increased during the sampling period.

Bacteriological Conditions

The station locations and their corresponding geometric means are presented in Table 4. Throughout the sampling period, all stations were characterized by low total and fecal coliforms. At Station A, no definite pattern in the vertical distribution of bacteria was detected.

Phytoplankton Populations

Figure 5 depicts the vertical distribution of standing stocks of phytoplankton at Station A on each sampling date for the period June 9th to September 30th. Considering the entire investigation, standing stocks of phytoplankton were moderate to moderately high. Algal levels increased from June 9th to August 19th, but declined between the latter date and the final sampling run. Maximum and minimum total areal standard unit values were 2,540 (7 feet) and 447 (7 feet) on August 19th and June 9th respectively. During June and early July, standing stocks were highest in the deeper waters. However, in late July and during August, highest numbers were recorded from samples collected in the surface waters owing to the development of one or more species of blue-green algae.

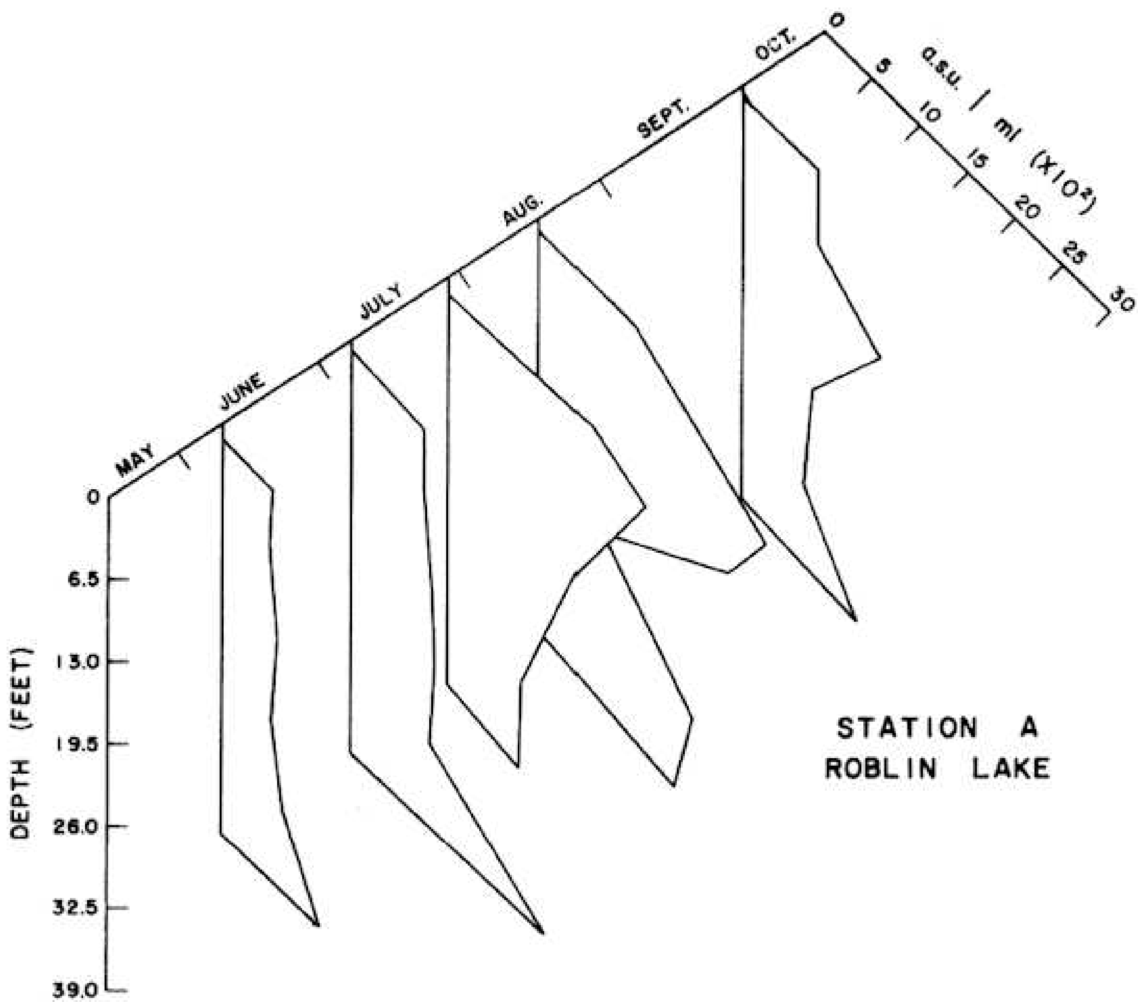

FIGURE 5: Standing Stocks of Total Phytoplankton at Station A, Roblin Lake, on Five Days Between June 9 and Sept. 30, 1970. All Results are Expressed in Areal Standard Units Per Millilitre.

In June, the flagellated alga *Dinobryon sertularia* was the most important species in the euphotic zone attaining a maximum of 300 a.s.u. per ml at the 1-foot depth, whereas representatives of the class Chroococcales (i.e. *Aphanothece* spp., *Aphanocapsa* spp., and *Chroococcus* spp.), predominated in the colder waters of the lake. ByJuly 7th, *Dinobryon sertularia* was replaced by the diatom *Rhizosolenia eriensis* and the flagellates *Ceratium hirundinella* and *Cryptomonas erosa.* A single blue-greenform (*Merismopedia* spp.) predominated in the deeper sections of the lake. On July 28th and August 19th, *Microcystis* spp. was the most abundant alga throughout the water column reaching a maximum of 1,849 a.s.u. per ml at 7 feet on the latter date. On these summer dates relatively high numbers of the diatoms *Rhizosolenia eriensis* and *Cyclotella* spp. and *Cryptomonas erosa* were present especially in the deeper waters. By September 30th, algal numbers had declined although samples were still dominated by blue-green species.

DISCUSSION

<u>Status of enrichment of Roblin Lake</u>

Depending upon the degree of plant nutrient enrichment and resulting biological productivity, lakes of north temperate regions as well as many tropical lakes have been classified into three intergrading types: oligotrophic, mestrophic and eutrophic. Oligotrophic lakes are poorly supplied with plant nutrients and support little plant growth. As a result, these lakes are generally deep, clear and unproductive with the deeper water well supplied with oxygen throughout the year. Such lakes can support cold-water species of fish such as trout, whitefish and herring. Eutrophic lakes on the other hand, are richly supplied with plant nutrients and support heavy plant growths. These lakes are turbid, warm, productive and contain warm-water game fish species such as walleye, pike, perch and other less valued species, such as catfish, carp and eel. The deeper waters become depleted in oxygen in the summer owing to decomposition of the abundant organic material produced. Lakes of intermediate types are termed mesotrophic; that is, they have a moderate supply of nutrients, plant growths and biological production.

Secchi disc values are governed by the quantity of particulate suspended material (i.e. microscopic plants or phytoplankton, zooplankton, silt, etc.) and coloured matter (i.e. humus, tannins, etc.) in the water. A Secchi disc average of 10.5 feet in Roblin Lake was substantially lower than that for oligotrophic Lake Joseph (25.0 feet, unpublished OWRC data) and slightly lower than oligotrophic Lake Bernard (13.5 feet, Michalski and Robinson, 1969) and mesotrophic Silver Lake (12.5 feet, Michalski and Robinson, 1969).

Nonetheless, Secchi disc readings were greater than those obtained for Gravenhurst Bay (3.0 feet, unpublished OWRC data) and Riley Lake (5.2 feet, Michalski and Robinson, 1970), both of which are considered to be in a state of eutrophication. The primary factor contributing to differences in light penetration between these lakes undoubtedly is related to differences in phytoplankton abundance. On the basis of Secchi disc readings Roblin Lake can be classified as "early eutrophic".

The higher pH values in the surface water (when compared with those in the deep water) resulted from the reduction of free CO_2 and $Ca(HCO_3)_2$ during photosynthesis. The decreases in pH in the deep water strata were related to conditions of decomposition with corresponding CO_2 and $Ca(HCO_3)_2$ increases. High pH values in the surface water of Roblin Lake are likely instrumental in precipitating calcium and magnesium carbonates (detected as hardness, alkalinity and conductivity), (see Figure 3).

Although the bottom waters of the lake are characterized by accumulations of salts of calcium and magnesium, the net effect throughout the summer is a decrease of these compounds in the water column (Table 2). In addition, the crusty deposits on stems and leaves of the common stonewort (*Chara* sp.) indicates that biological precipitation of calcium carbonate is occurring. In summary, the reductions of calcium and magnesium salts from solution in Roblin Lake are biologically-induced processes.

The clinograde oxygen distribution curves detected at Station A in Roblin Lake are typically characteristic of eutrophic lakes. This deep-water oxygen deficit in Roblin Lake is partially related to decomposition of the current year's production of algae following settling to the bottom and to the oxidation of previous years' suspended and/or sedimented particulate matter.

Vertical distributions of phosphorus are quite different in nutrient-poor and productive lakes. In the page missing from source document

thereby available to provide a potential stimulus for late summer and fall "algal-blooms."

As described earlier, oxygen depletions as well as accumulations of nutrients materialize in the deeper waters of Roblin Lake. However, the lake is weakly stratified and re-distribution of "bottom nutrient accumulations" throughout the entire water mass, as well as re-oxygenation of bottom waters, will occur during the summer, especially following short periods of windy weather. Thus, Roblin Lake is susceptible to periodic "pulses" of algae during the warm summer months. In fact, local residents and cottagers indicate that intermittent "water-blooms" frequently characterize the waters of Roblin Lake during the months of July, August and September.

Vertical distributions of orthosilicate were uniform with depth, with the exception of two samples collected on July 7th (Table 3). Increases in silica levels in the deeper waters of a lake reflect mesotrophy or eutrophy. The fact that the vertical distribution of silica was not stable undoubtedly relates to the effects of wind and wave action in the poorly stratified condition.

Generally, phytoplankton levels in Roblin Lake were moderate to moderately high. The most abundant phytoplankters which developed in the lake were represented by numerous species of blue-green algae, including *Microcystis* spp., *Chroococcus* spp., *Merismopedia* spp., *Aphanothece* spp., and *Aphanocapsa* spp. Of the afore-mentioned, *Microcystis* spp. was by far the most important alga attaining a maximum of 1,849 a.s.u. per ml. Prescott (1962) best describes the ecological habitat for *Microcystis*."

This species is a frequent component of water blooms, especially in lakes with eutrophic characteristics, although it is common to a great variety of aquatic habitats. The tendency to float high in the water results in the formation of large, microscopic clots and floating crusts which develop as the plants push each other above the surface. Like *Aphanizomenon flos-aquae*, this species is notorious as a spoiler of water for domestic uses, swimming and recreation and often causes the death of fish in heavily infested lakes. *Chroococcus, Aphanothece* and *Aphanocapsa* are three algal forms which have been reported in abundance from Dunlop Lake (Johnson, Michalski and Christie, 1970) and Silver Lake (Michalski and Robinson, 1969), two distinctly mesotrophic lakes located in pre-Cambrian bedrock areas of Northern Ontario.

Considering the composition of phytoplanktonic communities, it is apparent, therefore, that Roblin Lake can be classified as mesotrophic to early eutrophic.

Evaluation of Roblin Lake as a potential source of domestic supply

General

Water for domestic use must be free from pathogenic organisms, chemical substances and microscopic organisms which would otherwise impair the quality of the water. Other conditions such as corrosiveness, tendency to form incrustations, excessive soap consumption and effects of local pollutional sources are important in evaluating the quality of water intended for domestic use.

Colour

From an aesthetic point of view and as an agent which may impart stains to clothes, foods and household fixtures, colour is important. In addition, high amounts of colour reflect the presence of undesirable organic substances. The OWRC has established Desirable and Permissible Criteria of <5 and 75 True Colour Units (Platinum - Cobalt Scale), respectively. The upper strata of Roblin Lake were always characterized by readings of <5 T.C.U. However, individual samples collected from near-bottom waters on June 6, July 7, July 28 and August 19 exceeded the Desirable Criteria but were well within the limits for Permissible Criteria.

Temperature

Water temperatures should be cool enough to be refreshing; therefore, an objective of 10°C or less has been established by the Department of National Health and Welfare (C.D.W.S.O. 1968) with an acceptable limit of 15°C. The latter figure was selected as organic growths tend to develop especially well at higher temperatures in low flow portions and dead ends in a distribution system. Additionally, tastes and odours are intensified at temperatures exceeding 15°C. A Permissible Criteria of 29°C has been established by the OWRC (1970).

Considering the entire study period, June 9 was the only date when lake temperatures were below an acceptable limit of 15°C (established by the Department of National Health and Welfare). Although deep-water temperatures were always below the OWRC's Permissible Criteria it is evident that an intake located in the vicinity of Station A, the deepest section of the lake, would provide relatively warm water

(18-21°C) during the summer months. It is questionable whether such warm waters would conform with the OWRC's Desirable Criteria described as "pleasant tasting."

Turbidity

Turbidity should be minimal to ensure clarity and a pleasing appearance of the finished water. Also, high levels of turbidity may affect disinfection processes by overloading treatment facilities. The use of customary methods for measuring turbidity (including the Jackson Turbidity Unit), especially as it relates to problems associated with public water supply and treatment processing, has been seriously criticized (Water Quality Criteria, 1968).The report states, "The criterion for too much turbidity in water must relate to the capacity of the water treatment plant to remove turbidity adequately and continuously at reasonable cost.

Water treatment plants are designed to remove the kind and quantity of turbidity to be expected in each water supply source. Therefore, any increase in turbidity and any fluctuating turbidity load over that normal to a water must be considered in excess of that permissible."Turbidity levels in Roblin Lake did not conform with the OWRC's Desirable Criteria during the study period. Nonetheless, levels should be low enough to be "readily removable by defined treatment."

Taste and Odours

Problems of odours and taste are very complex because the senses of smell and taste are intimately related, and their responses are often difficult to differentiate clearly. Since taste and odour are inseparable, limits on odour should also reflect the palatability of the finished water."The Guidelines and Criteria for Water Quality Management in Ontario" indicate that odours should be absent or readily removable by defined treatment while the "Canadian Drinking Water Standards and Objectives" points out that, "when the T.O.N. approaches an acceptable limit of 4, it may be desirable to investigate the cause and nature of such odour."On all occasions Threshold Odour Numbers in Robin Lake exceeded both the federal and OWRC limits. The fact that odour values were higher on samples collected from the euphotic zone than from near-bottom strata and were characteristically vegetative-like suggest that troublesome algal-caused tastes and odours develop periodically in Roblin Lake.

pH

The maintenance of a proper pH range is essential as the effectiveness (rate and percent kill of organisms) of chlorine disinfection processes decreases as the pH increases and scaling and corrosion tendencies increase if the pH is too low. Water having pH characteristics ranging between 6.5 and 8.5 is permissible provided other conditions are satisfactory. Deep-water pH values were within this range in Roblin Lake but approximated the higher extreme of this spectrum in surface waters.

Hardness

Hardness in water is largely the result of geological formations with which the water comes in contact and should not be present in concentrations that will cause excessive soap consumption, or which will cause objectionable scaling in heating vessels and pipes. The "Water Quality Criteria - 1968" states varying water hardness is objectionable to both domestic and industrial water consumers. With varying hardness, the soap required for laundry, the effect on manufactured products, and the damage to process equipment (such as boilers and cooling coils) cannot be anticipated and compensated without facilities which are not available to most water users. A water hardness criterion must relate to the hardness which is normal to the supply and exclude hardness additions which will cause variations." Roblin Lake is moderately hard and is susceptible to seasonal "biologically-induced" variations in hardness, alkalinity and conductivity. The effects of such changes, especially as they relate to soap consumption, incrustations on service pipes and kitchen utensils and consumer sensitivity and acceptance should be duly considered when assessing the suitability of Roblin Lake as a potential source of potable water.

Dissolved Oxygen

For any individual sample, the Permissible and Desirable Criteria for dissolved oxygen is 23 mg/L and near saturation, respectively. On July 7 (33 feet) and August 19 (26 and 33 feet) the dissolved oxygen content was below 3 mg/L while levels below saturation occurred on all sampling dates in the lower waters of the lake. It should be pointed out that criteria for dissolved oxygen are included, not because of their significance to water treatment processing, but because of their importance as an indicator or organic enrichment. As described earlier, the shape of the vertical dissolved oxygen curve reflects the enriched nature of Roblin Lake.

Phosphorus

It is difficult to establish judicious criteria for evaluating levels of inorganic phosphorus in surface waters owing to the rather complex role this element has in the aquatic ecosystem. It is generally agreed, however, that phosphorus is critical in stimulating plant and algal growths in the presence of other essential growth factors. Additionally, phosphates have been known to interfere with water coagulation processes through the formation of insoluble complex phosphate compounds at concentrations as low as 0.01 mg/L (as P). It is obvious that sufficient concentrations of phosphorus were available in the euphotic zone of Roblin Lake to support the development of troublesome levels of algae.

Iron

Troublesome levels of iron are especially objectionable in waters used for domestic purposes. For example, excessive levels of iron may impart an orange or brownish colour to laundered goods, stain or cause a deposition of a slimy coating on fixtures, and promote the development of filamentous iron bacteria such as *Leptothrix* in the distribution system. Finally, tastes of finished water and beverages may be decidedly impaired page missing from source document

exclusively an underground source of supply. Maximum levels in Roblin Lake were never greater than 0.024 mg/L (NO_3 and NO_2 nitrogen).

Silica

Silica (measured as SiO_2) is present naturally in all surface waters and is an important constituent of the skeletal structure of diatoms. In waters where high levels of silica occur, water treatment problems related to filter-clogging and taste and odour production may develop. In Roblin Lake, orthosilicate concentrations increased during the course of the study (Table 3). The gradual increases which undoubtedly reflect a continuous re-cycling mechanism imply that a short-lived early spring diatom pulse may have materialized. In comparing silica concentrations of Roblin Lake with levels of other lakes (for example, Lakes Ontario and Erie) where abundant diatom levels prevail, it is apparent that sufficient orthosilicate is available to promote the development of troublesome numbers of diatoms, assuming all other chemical, physical and biological prerequisites are satisfactory.

Bacteriological considerations

The water of Roblin Lake is acceptable as a source of domestic supply, as assessed on the basis of geometric means for total and fecal coliforms. If the lake is utilized as a source of potable water further shoreline development should not be permitted. Since the lake is merely a "catch basin" with a small flow, development would cause pollution and negate the lake's usefulness as a water supply.

Biological aspects of water supply

Excessive algal populations lead to clogging of filters and to the development of obnoxious tastes and odours in the water. In all instances, problems stem from an over-abundance of algae; however, the numbers required to create difficulties will vary from species to species and from one specific problem to the other. High diatom stocks are related to reduced filter runs where pre-filtration facilities are inadequate and to taste and odour problems. Although levels as low as600 a.s.u. per ml have been reported to reduce filter runs, generally it is only when such levels exceed 1,500 a.s.u. per ml that difficulties in maintaining normal filter runs may be anticipated. These levels never materialized in Roblin Lake. However, it should be cautioned that nutrient concentrations (particularly orthosilicate) are sufficient to promote troublesome diatom numbers, assuming other factors are satisfactory.

A number of samples contained the odour-producing flagellates *Dinobryon sertularia, Peridinium, Ceratium hirundinella, Trachelomonas* and *Cryptomonas erosa.* Only small numbers of these organisms (i.e. 25-250 a.s.u. per ml) need be present in a municipal supply system to produce undesirable tastes and odours. On June 9, unpalatable conditions probably existed in Roblin Lake when levels of *Dinobryon sertularia* ranged between 170-300 a.s.u. per ml. Destruction of some of the flagellated forms such as *Dinobryon sertularia* by bacteriological dosages of chlorine may change or intensify the nature of the odour. It should be emphasized that over the past few years, a number of small Ontario lakes (Apsey Lake near Bancroft, Turner Lake near Cache Bay, Gull Lake near Kirkland Lake and Ruhl Lake near Hanover) have supported one or more species of odour-producing flagellates including *Trachelomonas, Synura, Dinobryon, Peridinium* and Ceratium. These lakes do not appear to be enriched either on the basis of their chemical and physical attributes or their levels of primary productivity. Nonetheless, the lakes have been rendered periodically unpalatable because of the presence of small numbers of one or more flagellated species. In addition, Roblin Lake contained relatively high numbers of odour-producing blue-green algae (especially *Microcystis*) throughout the summer. Significantly, the highest Threshold Odour Number (17.3) occurred on August 19 when *Microcystis* attained its maximum a.s.u. value (1849).

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Report prepared by:

M.F.P. Michalski
Biologist

G.J. Hopkins
Senior Laboratory Technician

Report approved by:

C.F.Schenk - Supervisor
Biology Branch

GLOSSARY OF TERMS

ACCEPTABLE LIMITS - the limits should not be exceeded whenever more suitable supplies are, or can be made, available within the technological and economic resources of the community. Substances in this category, when present in concentrations above the indicated limits, are either objectionable to a significant number of people or capable of producing deleterious health or other effects. When periodic evaluations of the quality confirm that the water as supplied falls between the objective and acceptable limits, a more frequent and comprehensive surveillance programme should be instituted. Any water supply, when exceeding the acceptable limits in one or more of the quality characteristics, should be assessed on its individual merits as to its suitability and safety from health, aesthetic, and other viewpoints (C.D.W.S.O. 1968).

ALGAE - an assemblage of simple, mostly microscopic non-vascular plants containing photosynthetic pigments such as chlorophyll. Algae occur suspended in water (phytoplankton) and as filaments attached to rocks and other substrates (periphyton). Some algae may produce nuisance conditions when environmental conditions are suitable for prolific growth.

AREAL STANDARD UNIT - One areal standard unit is equal to an area of 400 square microns. (WHIPPLE 1914).

BLUE-GREEN ALGAE - A group of algae with a blue pigment (phycocyanin), in addition to the green pigment - chlorophyll. A foul odour is often associated with the decomposition of dense 'water-blooms' of blue-green algae in fertile lakes.

DESIRABLE CRITERIA - Those characteristics and concentrations of substances in the raw surface waters which represent high quality water in all respects for use as public water supplies. Water meeting these criteria can be treated in the defined plants with greater factors of safety or at less cost than is possible with waters meeting permissible criteria (Water Quality Criteria. 1968).

DIATOMS - One of the most important groups of microscopic algae found in freshwater. Diatoms are distinguished by their silica cell walls (consisting of two halves, one fitting into the other like a box and its lid) and by their yellow or brown colour.

DISSOLVED OXYGEN - Atmospheric oxygen which is dissolved in water and can be expressed as parts per million or percent saturation.

EPILIMNION - The uniformly warmer and turbulent upper layer of a lake when it is thermally stratified during the summer. The layer above the thermocline.

EUPHOTIC ZONE - The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur because of ineffective light penetration.

EUTROPHICATION - The natural or accelerated process of becoming progressively older with increased enrichment in the supply of plant nutrients. It refers to the whole complex of changes which accompanies increasing enrichment with plant nutrients. The end result is always the same; the production of dense nuisance growths of algae and aquatic weeds which generally degrade water quality and render the lake useless for many purposes. Eventually the accumulations of this productivity will cause the lake to become extinct.

FECAL COLIFORM BACTERIA - A member of the group of coliform organisms, an of Fecal origin (i.e. from the intestines of warm-blooded animals including man). These organisms may be considered indicators of recent fecal pollution.

FLAGELLATED ALGAE - A group of algae which have one or more whip-like appendages (flagella) per cell that are used for mobility. This group is noted for its ability to produce odours in low numbers.

GEOMETRIC MEAN - the 'n^{th}' root of the product of ' n' observations.

GREEN ALGAE - A group of algae which have pigments (including chlorophyll; similar in colour to those of the higher green plants.

HYPOLIMNION - The uniformly cold and deep layer of a lake when it is thermally stratified during the summer. The hypolimnion is below the thermocline and is generally removed from surface influence (i.e. does not receive oxygen from the atmosphere).

LUGOL'S IODINE SOLUTION - A preservative for algae containing potassium iodide. iodine and water.

METHAEMOGLOBINEMIA - A disease (usually in infants) caused by the presence of methaeglobin in the blood. Methaeglobin is the modified oxyhaemoglobin or an oxidized heme containing ferric iron combined with the normal globin.

MESOTROPHIC - On the trophic scale which indicates the status of enrichment of a lake a mesotrophic lake will have a moderate supply of nutrients, plant growths and biological productivity lying somewhere between the oligotrophic and eutrophic types.

MICRON - A unit of measurement equal to 0.001 millimetres. One thousand microns equal 1 millimetre.

OBJECTIVE LIMITS - These limits should be interpreted as the long-term quality goal to be reached.It is impliedthat water supplies, which meet these requirements, are of very good and safe quality from health, aesthetic and other viewpoints (C.D.W.S.O. 1968).

OLIGOTROPHIC - On the trophic scale which indicates the status of enrichment of a lake an oligotrophic lake is poorly supplied with plant nutrients and support little plant growth. These lakes are generally deep, clear and unproductive with the deeper waters well supplied with oxygen throughout the year.

PERMISSIBLE CRITERIA - Those characteristics and concentrations of substances in raw surface waters which will allow the production of a safe, clear, potable, aesthetically pleasing, and acceptable public water supply which meets the limits of Drinking Water Standards after treatment (Water Quality Criteria 1968).

PHOTOSYNTHESIS - A biochemical process by which an organism manufactures sugar or other carbohydrates from inorganic raw materials (carbon dioxide, water, other nutrients) with the aid of chlorophyll in the presence of sunlight.

PHYTOPLANKTON - unattached chlorophyll-bearing microorganisms (algae) that drift with the surrounding water, some of which have slight locomotory power.

PLANKTON - An assemblage of unattached microorganisms both plant (phyto-) and animal (zoo-), that either have relatively small powers of locomotion or drift in the water subject to the action of waves and currents.

PULSE - An algal pulse is an arbitrary description for any population which is twice or more as great as the mean annual population.

SECCHI DISC - A circular metal plate, 20 centimetres in diameter, the upper surface of which is divided into four equal quadrants and so painted that the two quadrants directly opposite each other are black and the intervening ones are white. The Secchi disc is used to estimate the depth of the euphotic zone.

SEDGWICK-RAFTER COUNTING CELL - A plankton-counting cell consisting of a glass receptacle 50 x 20 x 1 millimetre sealed to a microscope slide. The cell has a capacity of exactly 1 millilitre and is used to examine plankton at magnifications up to 200 x power.

STANDING STOCK - The biota present in an environment at a selected point in time.

THERMAL STRATIFICATION - in the spring, vertical temperatures in a lake or reservoir are homogenous from top to bottom. As summer advances, the surface (epilimnetic) waters become warmer and lighter than the underlying (hypolimnetic) colder, denser waters. A thermal gradient or stratification is established in which various water layers can be defined.

THERMOCLINE - The narrow transition layer of water exhibiting a rapid temperature change lying below the warm epilimnetic waters and above the colder deeper hypolimnetic waters. It is usually defined by a change in temperature of 1°C for each metre of water depth.

THRESHOLD ODOUR NUMBER - A numerical figure designating the intensity of odour in a water as determined by its perception in a series of dilutions with "odour-free" water. It is calculated from the amount of the water sample in the most diluted portion giving perceptible odour, with the straight undiluted water being designated as having a threshold odour number (T.O.N.) of 1.

TOTAL COLIFORM BACTERIA - The coliform group of bacteria is defined in Standard Methods (A.P.H.A., 1965).This heterogeneous group of bacteriological organisms vary in taxonomic characteristics and can be found in many natural environments including soil, water and vegetation. An attempt to devise a more specific test for coliforms of intestinal origin resulted in the fecal coliform group of bacteria. This group of bacteria is more useful as an indication of recent fecal pollution and therefore an increasing chance of the presence of human disease-causing organisms.

TROPHIC STATUS - Depending on the degree of plant nutrient enrichment and resulting biological productivity, lakes are generally classified into three intergrading types: oligotrophic, mesotrophic and eutrophic. If the supply of plant nutrients to an extremely oligotrophic lakes is progressively increased, the lake will become more mesotrophic in character; with further enrichment it will eventually become eutrophic.

WATERBLOOM - An excessive growth of algae which is dense enough to be seen with the naked eye as a suspension in the water or as matted clumps floating at the surface. This excessive quantity of algae may prevent the use of the water for domestic, recreational or swimming purposes and make it aesthetically unpleasant.