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1. INTRODUCTION

Charlie Lake is one of 7 priority sub-basins in the Peace River area (Figure 1) that have been selected for water quality assessment and the development of water quality objectives. The other priority sub-basins are shown in Figure 2.

Charlie Lake (Figure 3) is located approximately 8 km north west of Fort St. John. It is a medium-sized lake (31.2 km^2) with a very shallow mean depth (approximately 5 m) and a maximum depth of 12 m (Figure 4). The watershed is, in proportion, relatively large (298 km^2), consisting of rolling terrain with seasonally flowing streams in most of the valleys. The forest cover is largely aspen poplar, and has been cleared in many areas for agricultural development. The soils of the area[7] are heavy clay textured, developed on tills with rock outcrops at higher elevations. Some aspects of the geology of the area have been described[9][10][11].

Settlement in the watershed has been in two strips northward from the south end of the lake along the east and west shores. A major concern has been the effect of this development on the area and on the very poor water quality of Charlie Lake[4][17][18]. The lake is very important for recreation because of its proximity to Fort St. John, and it serves as the water supply for the city. The suitability for both these purposes would be adversely affected if further deterioration in water quality were to occur.

Soils are a relevant consideration in the assessment of water quality since a major problem of the watershed is the disposal of sewage to ground from domestic residences, and the effect of this effluent on the lake water quality. The soils of the area are generally heavy clay textured, developed on tills which are not well suited to accept septic tank effluent. Efforts have been made to utilize evaporation mounds and lagoon systems, but these methods have some limitations. Lagoon systems, for example, are dependable if they are adequately sized.

2. HYDROLOGY

The major inflow and outflow streams are both called Stoddart Creek. A gravel dam regulated the lake level from 1968-1980. A new earth fill dam was constructed in 1981 including an improved flow regulation structure and a fish ladder. In 1983, year-round flows from the lake to Stoddart Creek were negotiated between the City of Fort St. John and the Water Management Branch, Ministry of Environment. Flow data were collected for the outflow stream for the years 1968-1977 (station no. 07FC004). As the values were obtained by correlating a gauge on the outlet to the lake level, it should be noted that these values are estimates rather than accurate flow measurements. Peak flows for the outlet generally occur in May (mean May flow 2.6 m^3/s), and minimum flows occur in December (0.031 m^3/s). No information is available on the inflow streams. For Stoddart Creek inflow (drainage area 171 km^2), there is generally little flow after spring freshet. Low flow estimates made for Stoddart Cr. inflow indicate that the mean October to April minimum 7-day average discharge would be zero. As well, the mean August discharge is zero.

The mean annual discharge from the lake (1968-1977) was 19 000 dam^3. The calculated inflow (Table 2) was 23 400 dam^2. These two values result in mean lake water residence times of 7.4 and 5.9 years based on a lake volume of 139 653 dam^3. However, year to year variation appears to be substantial. For the eight years of outflow record, the water residence times range from 276 years (1969) to 3.7 years (1972). Outlet water flows via Stoddart Creek into the Beatton River and then into the Peace River.

Lake level was also recorded (station no. 07FC005), and the level generally fluctuates within a one metre range, with the maximum level in April, May or June and the minimum in late fall or winter. This reflects both the inflow timing (spring freshet) and the summer evaporation (~54 cm /yr). The locations of flow and level gauges are shown in Figure 4.

3. WASTE DISCHARGES

In the Charlie Lake watershed, there are no point source discharges which affect water quality. The major contributors of pollutants are all diffuse, non-point sources. These non-point sources include agriculture, residential development and oil and gas exploration. From agriculture, there could be losses of fertilizers and pesticides to water courses, and generation of suspended sediments. Residential development would be expected to increase nutrient loading to the streams and to Charlie Lake, and perhaps increase the concentration of fecal coliform bacteria in the lake. The oil and gas exploration activity could generate suspended sediments, and perhaps some drilling chemicals could enter the water systems from spills.

As with most diffuse sources, quantification of the amounts of materials which reach Charlie Lake is extremely difficult. Some effort should be made to quantify phosphorus inputs, in light of the high levels of algal growth in the lake, and the importance of Charlie Lake as a multiple-use water resource. For other variables such as pesticides, a preliminary monitoring program would appear to be appropriate to determine if pesticides reach the lake. Initial sampling has been done by the Peace River Health Unit, but further sampling, particularly during freshet would seem advisable.

4. WATER USES

4.1 WITHDRAWALS - IRRIGATION AND WATER SUPPLY

There are several water licences on the lake and the inflow and outflow (Table 1). The locations of the licenced water withdrawals are shown in Figure 5. The largest licence is to the city of Fort St. John for domestic water works. Other data pertaining to water withdrawals and lake levels are included in Table 2.

4.2 RECREATION

Charlie Lake is well utilized by the public for water-based recreation: water skiing, boating, fishing and swimming. There are also shoreline-based activities such as picnicking, hiking and camping.

There are four public parks: Fort St. John Park (semi-developed, owned by the City of Fort St. John) at the south end of the lake, Montney Centennial Park at the north end of the lake, Beatton River Provincial Park and Charlie Lake Provincial Park. There are numerous public access points along the lakeshore, particularly on the west side off the Alaska Highway. There is also a private beach (Sunnyside) on the east shore of the lake. Figure 6 shows the park areas, the roads adjacent to the lake, and major blocks of private and publicly owned land, and land use.

4.3 FISHERY

Charlie Lake provides an extremely important recreational fishing resource for the area. Northern pike were introduced into the lake in 1952 or 1953 by a local rod and gun association. Pike adapted very well and have been the focus of the sport fishery, providing good numbers of fish and large fish up to 12 kg. In recent years the pike population has declined significantly. Walleye were introduced into the lake in the late 1950's in an attempt to add an additional species for angling. Walleye were present in only small numbers for many years, but have recently (since 1980) increased greatly and presently provide an excellent fishery. The Charlie Lake fishery presently is centered around Walleye. Yellow perch were introduced to the lake in 1981, have now established a population and are successfully reproducing. Stoddart Creek inflow provides a spawning and rearing habitat for yellow perch.

Stoddart Creek inflow, in the lower reaches, provides rearing habitat for pike and walleye, as well as spawning area for pike. Stoddart Creek outflow (also known as "Fish Creek") has its flow controlled by a dam at the outlet of the lake. Flow records show that from 1968-1982 there was little or no flow to Stoddart Creek in the later summer, fall and winter. Since the construction of a fish ladder around the dam, year round flows to the creek have been negotiated with the City of Fort St. John. The creek is used for spawning by suckers, and it will be desirable for these fish to have access to Charlie Lake as they are food for sport fish. Stoddart Creek outflow is used as a rearing habitat for pike, perch and some walleye (pers. com. Jay Hammond, Fish and Wildlife Branch, Fort St. John).

5. WATER QUALITY

5.1 INFLOW - STODDART CREEK

Water quality sampling has been carried out at a number of sites on the lake and on Stoddart Creek (Figure 7). Samples taken in 1974-75 indicate that values in Stoddart Creek were higher than in the lake for a number of variables. These include specific conductance, turbidity, organic carbon, ammonia and phosphorus. Mean concentrations in comparison to lake concentrations are shown in Table 3. The samples were obtained outside the spring freshet period. Values were relatively high even though freshet is the period when the highest flow, and likely the highest amounts of suspended and dissolved solids, nutrients and other materials would be expected to enter the lake. These materials would originate largely from agriculture.

5.2 OUTFLOW - STODDART CREEK

Relatively few samples have been taken on the outflow creek. In general, their quality was very similar to the lake water quality (as would be expected).

5.3 CHARLIE LAKE

The data for Charlie Lake were collected in 1974-76 by the Waste Management Branch. A preliminary report[1] reviewed the data collected and made a number of recommendations. Since then, only limited data have been collected. The Peace River Health Unit sampled the water from the Fort St. John water intake in 1982 and analysed for a variety of variables related to drinking water standards.

5.3.1 GENERAL WATER QUALITY

The overall water quality of Charlie Lake was very poor. In terms of biological productivity and nutrient concentrations, it is one of the most eutrophic lakes in British Columbia. Key water quality variables are summarized in Table 4. Particularly notable are the high overall mean values for: colour (true colour 27.5 units, TAC colour 21.9 units), turbidity (4.6 NTU), ammonia nitrogen (0.078 mg/L), organic nitrogen (1.09 mg/L), total phosphorus (0.096 mg/L), and chlorophyll a (31.4 μg/L), and the low water clarity (Secchi disc depth of 1.5 m).

The water did not always meet standards for drinking water[2] for a number of variables, particularly colour (15 TCU), temperature (15°C) (Figure 9) and turbidity (acceptable 5 NTU, objective ≤1 NTU). The standards for these variables are primarily based on aesthetic considerations. Dissolved oxygen concentrations below guidelines (3 mg/L) suggested by at least two authorities[13][14] may have occurred. No standards exist for amounts of algal growth in drinking water, but Charlie Lake in summer would appear to have far in excess of any acceptable amount. The algae present are typically blue-green algae which are particularly noxious. Reports in the scientific literature are numerous of blue-green algae being toxic to cattle and wildlife, and causing extreme difficulty with water treatment, as well as being the source of taste and odour problems. One other concern which has been raised in other areas where drinking water has large amounts of algal growth and must be chlorinated, is that compounds like trihalomethanes can be formed, and these compounds may pose a serious health risk. One sample has been taken for trihalomethanes by the Peace River Health Unit in May 1983. The sample showed concentrations to be an order of magnitude below the maximum acceptable concentration (0.35 mg/L) given by Environment Canada[6].

Few attempts have been made to establish criteria for recreational use of lake water. In Ontario[5], it was suggested that lakes used for body contact recreation should have chlorophyll a levels of less than 5 µg/L and water clarity (Secchi) greater than two meters. These contrast with Charlie Lake where the mean chlorophyll a was 31.4 µg/L and mean water clarity was 1.5 meters.

Most water quality variables show some change through the year. Key variables are nitrogen and phosphorus since a major factor in Charlie Lake's present poor condition is the excessive algal blooms which occur throughout the summer period. Abelson's[1] review of the water quality data estimated the spring phosphorus concentration to be 0.066 mg/L (May 1974). The concentration at spring overturn is generally considered to represent the supply of phosphorus to the lake. Generally, concentrations decrease through the summer, but in Charlie Lake they generally increase in midsummer, then decrease in fall (Figure 8). The reason for this unusual pattern is unclear.

The total nitrogen concentration for spring overturn was 1.03 mg/L, indicating that phosphorus is likely the more important of these two major nutrients, since the N:P ratio is slightly greater than 15 to 1 (i.e. phosphorus is likely the growth limiting nutrient).

5.3.2 PHOSPHORUS LOADING

Since phosphorus does assume a primary role, it is useful to examine the relationships between land use (particularly agriculture and sewage disposal) and water quality. Using relationships described in the literature (3)(19)(21) to relate spring phosphorus concentration and flushing rate (known) to phosphorus loading (unknown), it can be estimated that the annual loading to Charlie Lake is approximately 0.82 $g/m^2/yr$ or 25.7 tonnes/yr of phosphorus. To determine the significance of the contributions from various sources, estimates from these sources (each stream, groundwater, aerial loading, sewage, agriculture, etc.) are a necessity. However, no data of this type exist for Charlie Lake. Along with the other indicators of trophic status which were noted previously (chlorophyll a, water clarity), the level of phosphorus loading places the lake clearly into the eutrophic category. For a lake of mean depth 5 m, Vollenweider(22) cites a "permissible" loading of 0.07 $g/m^2/yr$ and a "dangerous" loading of 0.13 $g/m^2/yr$. Therefore it can be noted that the loading to Charlie lake is about twelve times the permissible and six times the dangerous loading.

5.3.3 PHYSICAL LIMNOLOGY

Charlie Lake generally shows little or no temperature stratification (Figure 9). The shallow depth and strong winds in the area are the two major forces which bring about this situation. The 1974-75 data indicate at most a three to four degree difference between top and bottom waters. Many summer sampling periods indicate isothermal conditions. However stratification could occur if periods of little or no wind mixing occurred. Lake survey data from Fish and Wildlife Branch in July 1968 showed a vertical temperature differential of more than 12°. If such stratification persisted for more than a few days, a significant oxygen depletion could occur. Since no thermocline is usually formed, the lack of thermal barriers implies reasonable vertical mixing and absence of low bottom water oxygen concentrations. However, because of the extremely high productivity and consequent high oxygen demand, it appears that even with vertical mixing, and particularly with restricted mixing oxygen concentrations can be depressed in bottom water. Values of less than 5 mg/L were not uncommon. However, bottom water concentrations near saturation (8-12 mg/L) were more usual, and the occurrence of high or low concentration in the deeper water seems to be dependent on the amount of wind mixing. The 1974 to 1976 temperature and dissolved oxygen profiles are shown in Figure 9 and Figure 10, respectively.

5.3.4 COLIFORM BACTERIA

Surveys were carried out by the Peace River Health Unit and results reported in 1973(15) and 1979(16). In the 1973 report, the Peace River Health Unit reported a coliform median value of 452/100 mL for 1971, 135/100 mL in 1972, and for 1973, 95/100 mL (at the lake outlet) and 48/100 mL (at the city water intake). No indication was made of whether the analyses were for total or fecal coliforms in any pre-1980 data. Any assessment of trends is difficult to make since sites and methods differed from year to year.

The Peace River Health Unit(16) report gave data for 1974-1979 for the beach area and water intakes, with values 1.9-8.0/100 mL with no trend over time. Data collected in summer of 1980 were for both total and fecal coliforms. This unpublished information (file data from Peace River Health Unit) showed that most samples had very low values (<2/100 mL) with a geometric mean for total coliforms of 20.9/100 mL and for fecal coliforms of 3.0/100 mL, with some samples very high (>2400/100 mL) for fecal coliform bacteria. The samples were collected in July and August at nine sites around the south shore of the lake.

These values should be viewed in relation to fecal coliform criteria which are available for several water uses. For domestic water supply, the B.C. Ministry of Health(2) indicates that with 0-10 MPN/100 mL (90th percentile) disinfection would be required, and for values of 10-100 MPN/100 mL partial water treatment plus disinfection would be required. The criteria for body contact recreation used by the B.C. Ministry of Health (20) are a geometric mean of 200 MPN/100 mL and a 90th percentile value of 400 MPN/100 mL. Charlie Lake water is within the range acceptable for recreation use, but any water withdrawn for domestic consumption would require disinfection and some treatment. At present the waterworks provide filtration and chlorination of the raw water.

5.4 WATER QUALITY OBJECTIVES

It is proposed that the designated water uses for Charlie Lake and Stoddart Creek should be:

Stoddart Creek upstream from Charlie Lake	Irrigation Fisheries
Charlie Lake	Domestic water supply Recreation Fisheries Industrial
Stoddart Creek downstream from Charlie Lake	Domestic water supply Fisheries Irrigation Recreation

The main water quality concerns for Charlie Lake and Stoddart Creek are eutrophication, fecal contamination, and possibly insecticides and herbicides.

5.4.1 EUTROPHICATION

Eutrophication can be manifested by changes in the following variables:

- algal standing crop (biomass, chlorophyll a)
- water clarity (turbidity, Secchi depth)
- abundance of blue-green algae
- taste and odour
- hypolimnetic dissolved oxygen depletion
- nitrogen and phosphorus concentrations and loadings

The water quality assessment in this report has shown that Charlie Lake is very eutrophic, and that several of the above variables are at undesirable levels. The causes of the eutrophic condition are probably a combination of agricultural activities and residential development as well as a naturally productive lake. Action can usually be taken to improve this type of situation, by reducing the phosphorus loading.

A simple way of monitoring the response of the lake to improvement measures or long term changes in general is to use the total phosphorus concentration as an index of biological productivity. The following provisional water quality objectives for Charlie Lake are proposed as an initial goal for upgrading water quality.

- total phosphorus at spring overturn: 0.050 mg/L
- total phosphorus at all other times: 0.075 mg/L

Objectives to protect water quality from the effects of eutrophication have been proposed elsewhere. For drinking water and fisheries, criteria have been based on hypolimnetic oxygen depletion. However in Charlie Lake, there would only appear to be uncommon occurrences of summer stratification so these criteria would not appear to be applicable. The Province of Ontario(24) and the International Joint Commission(25) both use 0.010 mg/L phosphorus as a criterion to protect lakes from hypolimnetic oxygen depletion. The 0.010 mg/L phosphorus criterion appears to be below any practical goal for Charlie Lake since it would require an order of magnitude reduction in phosphorus loading as well as being inapplicable. The B.C. drinking water standards suggest a concentration of 0.065 mg/L, however even this would appear to be too high to protect lakes from algal blooms. Very heavy algal growth can be supported by 0.065 mg/L and our suggested criteria are not based on the drinking water criterion. For protection of fisheries (and aquatic life), no criteria have been suggested which would provide for good fisheries production in a polymictic lake. Such a criterion would require information regarding lake characteristics, fish species production rates and feeding habits and a variety of other data which are not available nor likely to be in the near future.

Criteria for phosphorus have been suggested for recreation and aesthetics. Ontario (24) specified 0.010 mg/L for a high level of protection and 0.020 mg/L as a general level of protection. Both of these values would not appear to be practically attainable for Charlie Lake.

The objectives are very optimistic considering that the 1974-75 data suggested a spring overturn phosphorus concentration of 0.066 mg/L and an overall mean concentration of 0.096 mg/L. The objectives of 0.050 mg/L (average at spring overturn) and 0.075 mg/L (water column average at other times) are based (a) on the assumption that a decrease in phosphorus would be beneficial (less algae to interfere with water treatment or recreation, better water clarity, less risk of an oxygen depletion) and (b) that a reduction of this amount would appear to be an achievable goal. However in the absence of information on the relative contribution of phosphorus from various sources, no lower concentration could be suggested. A 25% reduction from whatever source or combination of sources seems a reasonable goal.

These are long-term objectives that will only be achieved when the sources of phosphorus to the lake have been quantified, and appropriate measures have been implemented to reduce phosphorus input.

These objectives would apply to the average of at least three discrete samples taken at different locations or depths. The problems associated with eutrophication are expected to be reduced when the quality of the lake water is upgraded to meet these objectives. The situation should then be reassessed to decide whether more stringent objectives and further corrective action are required.

5.4.2 FECAL CONTAMINATION

Fecal contamination in the Charlie Lake watershed may be caused by human sewage disposal, birds or livestock. Fecal coliform bacteria can be used as general indicators of recent fecal contamination. The most sensitive water use with regard to fecal coliforms is domestic water supply, followed by water-contact recreation, irrigation, and livestock watering.

Water quality presently appears to meet or be close to meeting, criteria for raw domestic water supply that receives disinfection only. However because of the heavy algal growth in the lake, filtration is required and presently used at the water treatment plant. In periods of heavy algal growth, the filter is bypassed. The following provisional water quality objective is proposed to assure that this most sensitive use is protected. The assumption is that all water withdrawn for domestic use receives disinfection, as the Ministry of Health recommends.

The fecal coliform density shall not exceed 10 MPN per 100 mL in 90 percent of samples taken in any consecutive 30-day period. The objective applies year-round to discrete samples taken in or near water intakes in the lake and Stoddart Creek downstream from the lake. A minimum of 5 samples should be taken to determine if the objective is being met.

To protect recreation the following provisional objectives are proposed: the fecal coliform density shall not exceed 400 MPN per 100 mL in 90 percent of samples taken in any consecutive 30-day period, nor shall the running log mean for 30 days be greater than 200 MPN per 100 mL. The objectives apply to bathing beaches during the recreation season. A minimum of 5 weekly samples should be taken over 30 days to determine if the objectives are being met.

5.4.3 INSECTICIDES AND HERBICIDES

Water quality criteria are available for certain insecticides and herbicides for various water uses. It is recommended that the study outlined in section 6.2 be conducted to determine if insecticides and herbicides are a problem in Charlie Lake and Stoddart Creek. This study would indicate if there is a need for water quality objectives for certain insecticides and herbicides to protect the designated water uses.

6. CONCLUSIONS AND MONITORING RECOMMENDATIONS

6.1 CONCLUSIONS

Charlie Lake has a number of key water uses including domestic water supply, recreation, fisheries and industrial use. Stoddart Creek (inflow) is used for irrigation and fisheries and the outflow is used as domestic water supply, and for irrigation and fisheries.

There are no point source waste discharges in the watershed, however, diffuse sources are very important and originate from two major land uses, namely agriculture and residential development.

The overall water quality of Charlie Lake is very poor. The lake is in a state of advanced eutrophication. Parameters which reflect this are high nutrients (nitrogen and phosphorus), high chlorophyll a, noticeable blooms of blue-green algae, high colour, low water clarity and periods of low dissolved oxygen. These characteristics affect all of the major uses noted above. The eutrophic condition is caused by high loadings of phosphorus, but the sources of this phosphorus input are unclear. Some sampling for fecal contamination has been done, and there appears to be the possibility of contamination from sewage, birds or agriculture.

Designated water uses have been proposed for both Charlie Lake and Stoddart Creek. Provisional water quality objectives for fecal coliform bacteria and phosphorus have been set to protect the main water uses. The possibility of contamination from agricultural chemicals also exists, but in the absence of any data, some sampling is required to determine the magnitude of such contamination, if any.

Overall, an effort should be made to improve the water quality of Charlie Lake to a level which would allow improved recreational values (better water clarity, less algal growth as a consequence of reduced phosphorus loading) and improved water for bulk domestic water supply.

6.2 MONITORING RECOMMENDATIONS

The monitoring recommendations in this section have been made from a technical perspective, and the extent to which the recommended monitoring is conducted on any one waterbody will depend on the overall priorities and monitoring resources available for the province. Three types of study are recommended. Each would be carried out once and would not involve routine monitoring.

6.2.1 FECAL COLIFORM SURVEY

A systematic survey of fecal coliform bacteria should be undertaken to determine densities in recreation areas, inflow streams and at domestic water intakes.

This program requires sampling 5 times per month at each site, for at least one month during the open water period, at approximately ten sites. This sampling could probably be coordinated with the monitoring of stream inflows and the lake sampling which would be part of the nutrient monitoring and in that case should add to the expenditure of manpower by two weeks. If the coliform monitoring program were done independently, at least four man-weeks would be required. Data analysis and report preparation would require four man-weeks.

The possibility that birds, particularly waterfowl, might make a significant contribution to the fecal coliform bacteria contamination of Charlie Lake should also be investigated. The scarcity of open water and the population of waterfowl resident in the general area may be conducive to congregations of waterfowl on the lake. A preliminary estimate of the frequency of waterfowl congregations and their approximate numbers on each occasion would assist in evaluating the need for further investigation of this factor. Some comparative bacterial sampling before and after congregations have occurred, or in congregation areas and in control areas might be possible.

6.2.2 WATERSHED STUDY

A watershed study should be undertaken to establish the sources of nutrients, particularly phosphorus, which maintain the present eutrophic condition of Charlie Lake. This should include quantification of phosphorus from:

1. ground disposal of sewage
2. agriculture
3. inflow streams
4. ground water
5. dustfall and precipitation
6. internal lake processes

This study is a prerequisite to finding sources contributing the most phosphorus to the lake, and determining where the most effort should be directed to reduce phosphorus loading and improve lake water quality. There is considerable concern expressed by different agencies about the effects of sewage disposal on the lake water quality. However, it must first be established whether sewage, agriculture, or other sources are major contributors, since if these are not major inputs, efforts to reduce loadings from these sources would be without benefit.

To carry out this investigation, the following sampling would be required:

a. Inventory of sewage disposal in the watershed. Included would be the number of permanent dwellings and population, seasonal residents, distance of sewage disposal systems from the lake, soil types which sewage is being disposed to, slopes of terrain etc., which would affect transmission of nutrients to the lake. For examples of phosphorus inflow estimation using these variables see Wiens (23).

A certain amount of this type of information has already been gathered by the Charlie Lake Planning Committee and Urban Systems Limited in their work on the Fort St. John area Official Settlement Plan amendment and sewage disposal pilot study. Additional information was also gathered by the Regional District and the Health Unit as part of the Charlie Lake Sanitary Survey Report of December 1980.

b. Inventory of agricultural losses of nutrients to the lake and to streams. Included here would be an inventory of the amount and type of land in agricultural use, numbers of livestock, the amount of fertilizer applied and estimation of transmission between the cultivated area and the water courses.

c. Estimation of input from streams. The streams of the watershed have significant flows for only two to three months each year and it would be expected that the greatest amount of nutrient loading would occur in this period. Intensive sampling during this period at one week intervals for the following variables would be appropriate: total, total dissolved, and ortho phosphorus; total, nitrate and ammonia nitrogen; total and suspended solids, colour, fecal coliform bacteria and flow. From this, an estimate of the relative contributions to the lake from these streams could be made.

d. Groundwater input could be estimated by having a water balance calculated for the lake to estimate quantity. Groundwater quality could be measured by analysis of water from wells close to the lake and from groundwater flowing into the lake by utilizing samplers such as described by Lee [(8)]. There may be sufficient data to estimate this input if two wells and three in-lake samplers were used to collect monthly samples over a six-month period, from March or April, and analysing for: total, ammonia and nitrate nitrogen and total, total dissolved and ortho phosphorus.

e. Dustfall and precipitation can be significant contributors to lake nutrient budgets. To determine this input, an ambient air quality station can be established and samples for total phosphorus and total nitrogen obtained monthly.

f. Internal lake loading (return of phosphorus from lake sediments) may be a factor. Sampling should be carried out to determine more precisely if the total amount of phosphorus in the lake changes over the year, and if gradients exist in the lake water column. Combined with information on inputs and outputs, the possibility of internal loading can be evaluated. Samples of phosphorus (total, total dissolved and ortho) at two stations and three depths (surface, mid depth and near bottom) should be carried out at three to four week intervals through the year, particularly under ice cover. Temperature and dissolved oxygen profiles should accompany the water sampling.

The sampling should be carried out over a one year interval. The program as outlined would require approximately 10 man-weeks to collect the data.

6.2.3 INSECTICIDE/HERBICIDE SURVEY

A survey should be conducted to determine the type, quantity and location of insecticides and herbicides used in the Charlie Lake watershed.

A sampling program could then be undertaken to monitor agricultural chemicals (insecticides and herbicides) in lake sediments, particularly in periods when these chemicals are being used, or in the heaviest runoff period (freshet). Design of the program would be dependent on documentation of the types of chemicals, the areas of the watershed in which they were used and the timing of their application.

REFERENCES

(1) Abelson, D.H.G. 1980. Water Quality in Charlie Lake. Unpublished report. B.C. Ministry of Environment. Prince George, B.C. 11 p.

(2) B.C. Ministry of Health, British Columbia Drinking Water Quality Standards 1982.

(3) Canfield, D.E. and R.W. Bachmann. 1981. Prediction of Total Phosphorus Concentrations, Chlorophyll a, and Secchi Depths in Natural and Artificial Lakes. Can. J. Fish. Aquat. Sci. 38:414-423.

(4) Charlie Lake Advisory Planning Commission. 1981. Charlie Lake at the Crossroads. Prepared for the Peace River Liard Regional District. 28 p.

(5) Dillon, P.J. 1975. A manual for calculating the capacity of a lake for development. Ontario Ministry of the Environment. 57 p.

(6) Environment Canada, Guidelines for Surface Water Quality, Vol. 1, Inorganic Chemical Substances, Preamble, Ottawa, Canada, 1979.

(7) Farstad, L, T.M. Lord, A.J. Green, and H.J. Hortie. 1965. Soil Survey of the Peace River area in B.C. Report No. 8 of the B.C. Soil survey. 114 p. and maps.

(8) Lee, D.R. 1977. A device for measuring seepage flux in lakes and estuaries. Limnol. Oceanog. 22:140-147.

(9) Mathews, W.H. 1973. Quaternary Geology, Charlie Lake, British Columbia. Geological Survey of Canada. Paper 73-1, part A, p. 110-111. Report of Activities April-October 1972.

(10) Mathews, W.H. 1972. Quaternary Geology, Charlie Lake, British Columbia). (94A).Geological Survey of Canada. Paper 72-1. part A. p. 89-90. Report of Activities. April-October 1971.

(11) Mathews, W.H. 1963. Quaternary stratigraphy and geomorphology of the Fort St. John area, northeastern B.C. B.C. Dept. Mines and Petroleum Resources, 22 p.

(12) National Academy of Sciences, Water Quality Criteria 1972, Washington, D.C., 1972.

(13) Nemerow, N.L. 1974. Scientific Stream Pollution Analysis. Syracuse University, New York. 1974.

(14) Ontario Ministry of the Environment, 1973. Guidelines and Criteria for Water Quality Management in Ontario. Ministry of the Environment, Toronto, Ontario.

(15) Peace River Health Unit. 1973. Sanitary Survey Charlie Lake Watershed Summary 1973. Mimeo Report 8 p.

(16) Peace River Health Unit. 1979. Bacteriological Test Results. Mimeo Report. 2 p.

(17) Peace River-Liard Regional District. 1980. Charlie Lake Study. Charlie Lake Subcommittee of the Technical Planning Committee.

(18) Peace River-Liard Regional District. 1972. Charlie Lake and Watershed Lands, a planning strategy. 44 p. and appendix.

(19) Reckhow, K.H. and J.T. Simpson. 1980. A Procedure Using Modelling and Error Analysis for the Prediction of Lake Phosphorus Concentration from Land Use Information. Can. J. Fish. Aquat. Sci. 37:1439-1448.

(20) Richards, H.M., Provincial Health Officer, Ministry of Health, Memorandum to R.J. Buchanan, Water Management Branch, May 20, 1983.

(21) Vollenweider, R.A. 1969. Moglichkeiten und Grenzen elementares Modelle der Stoffbilanz von Seen. Arch. Hydrobiol. 66:1-36.

(22) Vollenweider, R.A. 1968. Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication. Paris, Rep. Organisation for Economic Co-operation and Development, DAS/CSI/68.27, 192 p.; Annex, 21 p.; Bibliography, 61 p.

(23) Wiens, J.H. 1983. Phosphorus loading from domestic and livestock waste - Tie Lake. Surveys and Resource Mapping Branch, B.C. Ministry of Environment.

(24) Province of Ontario. 1979. Rationale for the establishment of Ontario's Provincial Water Quality Objectives. Ministry of Environment.

(25) International Joint Commission. 1980. Report of the aquatic ecosystems objectives committee. Great Lakes Science Advisory Board, I.J.C. Windsor, Ontario.

TABLE 1
SUMMARY OF WATER LICENCES IN THE CHARLIE LAKE WATERSHED

STODDART CREEK UPSTREAM FROM CHARLIE LAKE

Licensee	Quantity	Purpose	Annual Quantity
T.W. Duncan	93.71 dam³	Irrigation	93.71 dam³

ROPER CREEK

Licensee	Quantity	Purpose	Annual Quantity
Creighton, H&G	4.5 m³/d	Domestic	1642.5 m³

CROWN SPRING

Licensee	Quantity	Purpose	Annual Quantity
Snider, W.L.	2.3 m³/d	Domestic	839.5 m³

CHARLIE LAKE

Licensee	Quantity	Purpose	Annual Quantity
1. City of FSJ	18181 m³/d	Waterworks	7048 dam³
2. City of FSJ	7401 dam³	Storage (lake)	-
3. Golf Club	55.5 dam³	Irrigation	55.5 dam³
4. BCBC (Mines)	45.5 m³/d	Domestic	16.5 dam³
5. Charlie Lake Ent	114 m³/d	Waterworks	41.5 dam³
6. Scurry Rainbow	870 dam³	Oil Field injection	8.4 dam³
Application			0
7. Charlie Lake Ent	7.4 dam³	Storage	-
8. Charlie Lake	2.5 dam³	Irrigation	2.5 dam³
Portabilt	2.3 m³/d	Domestic	0.8 dam³

STODDART CREEK DOWNSTREAM FROM CHARLIE LAKE

J.E.D. Woolley	246.7 dam³+ 9.1 m³/d	Irrigation & Domestic	250 dam³
J.E.D. Woolley	49.3 dam³	Storage (Reservoir)	----
J&L Sodergren	8 dam³	Irrigation	8.0 dam³

The above licences are not being utilized to their fullest extent. It was estimated that the City of Fort Saint John used 2002 dam³ during 1978. This use will increase as the population increases which is the reason there is water available for Scurry Rainbow for a 10 year period. After 1990, Scurry Rainbow's requirements will decrease to zero by 2010. Mr. Woolley is not utilizing all of his licence because he has not constructed his storage reservoir. Figure 5 shows the approximate location of the authorized points of diversion.

TABLE 2

SUMMARY OF HYDROMETRIC AND WATER LICENCE DATA FOR CHARLIE LAKE

Assumed zero elevation for Charlie Lake	691.9 m
Maximum level to be maintained for storage	692.5 m
Estimated 100 year recurrence interval flood elevation	693.3 m
Maximum recorded instantaneous level, May 6, 1972	693.3 m
Estimated that flooding of farmland may occur at	692.8 m
To convert gauge readings to geodetic add	691.5 m
Drainage (Watershed) area	297.7 km^2

Effect on lake levels by current licences and applications (as of 1980):

Scurry Rainbow Oil Ltd. application	869 dam^3 = 6.1 cm
Fort Saint John 1978 water use	2002 dam^3 = 12.2 cm
Fort Saint John total licenced quantity	7151 dam^3 = 42.7 cm
Fort Saint John Storage licence	7398 dam^3 = 45.8 cm

Sixteen years of direct and correlated records have been assembled:

Estimated median annual inflow	23427 dam^3 = 1.43 m
Estimated minimum 100 year inflow (annual)	4685 dam^3 = 0.27 m
1978 inflow = 8500 ac.ft. = 10 480 dam^3	= 0.65 m

(17) The above information was supplied as part of the Charlie Lake Study (Peace River - Liard Regional District, 1980) submitted by D. Roberts of the B.C. Ministry of Environment, Water Management Branch.

TABLE 3
WATER QUALITY SUMMARY FOR STODDART CREEK INFLOW - COMPARISON TO CHARLIE LAKE*

		STODDART CREEK (INFLOW)		CHARLIE LAKE
SITE NUMBER YEARS		0400397 1974-75	0410026 1982	ALL SITES 1974-1976
pH		7.3 ± 0.29 (n=6)	7.8 ±0.11 (n=3)	7.9
total solids	mg/L	224.4 ± 65.3 (n=5)	269.0 ±8.4 (n=3)	121.4
suspended solids	mg/L	35.2 ± 28.0 (n=6)	5.0 ±1.7 (n=3)	7.9
specific conductance	µS/cm	199.0 ± 97.5 (n=6)	358.3 ±29.5 (n=3)	145.1
turbidity	NTU	29.5 ± 23.5 (n=6)		4.6
alkalinity	mg/L	82.5 ± 52.3 (n=6)		62.2
organic carbon	mg/L	28.3 ± 8.5 (n=6)		15.3
hardness	mg/L	82.7 ± 39.6 (n=6)		61.1
ammonia N	mg/L	0.58 ± 0.79 (n=6)	0.072±0.045 (n=3)	0.078
organic N	mg/L	1.3 ± 0.7 (n=6)	1.05 ±0.44 (n=3)	1.09
total phosphorus	mg/L	0.32 ± 0.26 (n=6)	0.086±0.033 (n=3)	0.096
ortho phosphorus	mg/L	0.226± 0.225 (n=2)	0.02 ±0.017 (n=3)	0.038
calcium	mg/L	21.4 ± 10.0 (n=6)		16.1
magnesium	mg/L	7.1 ± 3.5 (n=6)		5.1

* Average values ± standard deviation.
All data from Ministry of Environment Data Base, EQUIS.

TABLE 4
SUMMARY OF CHARLIE LAKE WATER QUALITY 1974-1976 (from EQUIS)

VARIABLE	STATION												
	MEAN VALUES (ALL DEPTHS)												
	0400241	0400242	0400388 #1	0400389 #2	0400390 #3	0400391 #4	0400392 #5	0400393 #6	0400394 #7	0400395 #8	overall mean (all stations)	range (all stations)	n*
colour, true (colour units)			25	23.8	25	28.2	28	31.1	31.1	27.8	27.5	16-60	70
pH	7.5	7.8	7.77	7.87	7.75	7.95	8.01	7.84	7.96	7.99	7.9	7.1-9.3	203
total solids			122	122	120.9	121.1	118.2	122.7	116.9	127.2	121.4	108-180	109
total dissolved solids			108	108	109.2	110	109.4	110.9	111.1	113.2	110	100-124	70
suspended solids			9.0	6.5	9	6.5	5.4	7.2	8.4	11.4	7.9	1-47	181
Specific Conductance µS/cm	131	147	150	151	149	148	148.9	149.9	114.5	149.7	145.1	132-183	203
turbidity (NTU)	16	7.9	4.2	3.25	4.5	4.2	3.8	4.4	5.3	6.8	4.6	0.5-26	184
Secchi depth (m)			1.6	1.5	1.5	1.2	1.3	1.5	1.5	1.2	1.5	0.5-8.0	22
color,TAC(colour units)			19.6	20	19	18	19.6	28.1	28	22.7	21.9	12-56	70
total alkalinity			63.1	62.8	62.7	62.1	62.6	62.2	60.2	61.8	62.2	53-79	203
organic carbon	22	19.5	14.5	14.3	14.7	14.7	15.0	14.7	17.4	17.2	15.3	10-45	202
hardness			62.3	61.9	61.3	60.9	61.6	61.3	59.1	60.9	61.1	55-75	187
ammonia N			0.076	0.067	0.083	0.086	0.071	0.077	0.081	0.082	0.078	<0.005-0.304	203
nitrate/nitrite N	0.04	0.02	0.05	0.046	0.048	0.047	0.040	0.058	0.052	0.054	0.056	0.02 -0.190	95
nitrate N			0.081	0.080	0.089	0.067	0.072	0.089	0.058	0.100	0.080	0.02 -0.400	125
organic nitrogen			0.949	1.03	0.859	1.17	1.1	1.0	1.1	1.53	1.09	0.21 -4.97	187
Kjeldahl nitrogen	0.78	0.63	1.01	1.08	0.931	1.26	1.16	1.07	1.18	1.56	1.15	0.270-5.0	185
total nitrogen	0.82	0.63	1.07	0.91	0.967	1.32	1.47	1.13	1.19	2.56	1.33	0.63 -5.0	76
orthophosphorus	0.027	0.015	0.038	0.039	0.041	0.091	0.091	0.037	0.033	0.037	0.038	0.005-0.097	68
total dissolved phosphorus	0.043	0.027	0.059	0.062	0.060	0.076	0.081	0.055		0.059	0.056	0.026-0.105	14
total phosphorus	0.106	0.086	0.097	0.091	0.107	0.104	0.095	0.094	0.102	0.080	0.096	0.030-0.497	203
inorganic carbon	14	15	14.7	14.5	14.7	14.14	14.5	14.2	12.3	13.2	14.0	10-24	90
chlorophyll _a_ (µg/L)			28.8	16.1	12.1	27.7	25.3	26.8	66.8	47.1	31.4	2-412	163
calcium	14	16	16.4	16.3	16.1	16.0	16.2	16.1	13.3	16.0	16.1	14-20	203
magnesium	4.7	5.4	5.2	5.2	5.2	5.1	5.2	5.2	5.0	5.1	5.1	4.7-6.0	203
volatile solids					56						56		1

All values in mg/L unless noted
* n = Number of values
See Figure 7 for site location.

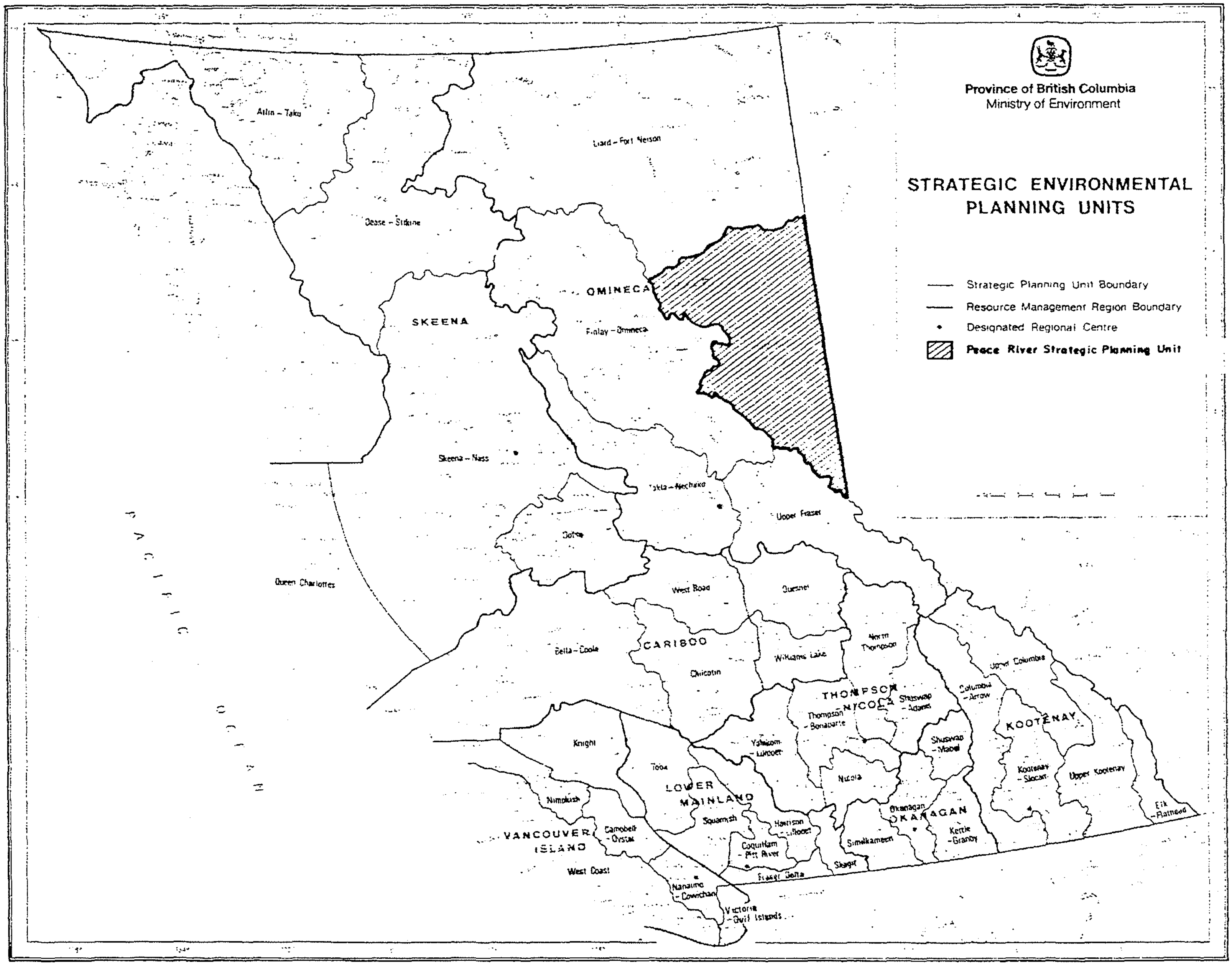

FIGURE 1 Peace River Planning Unit

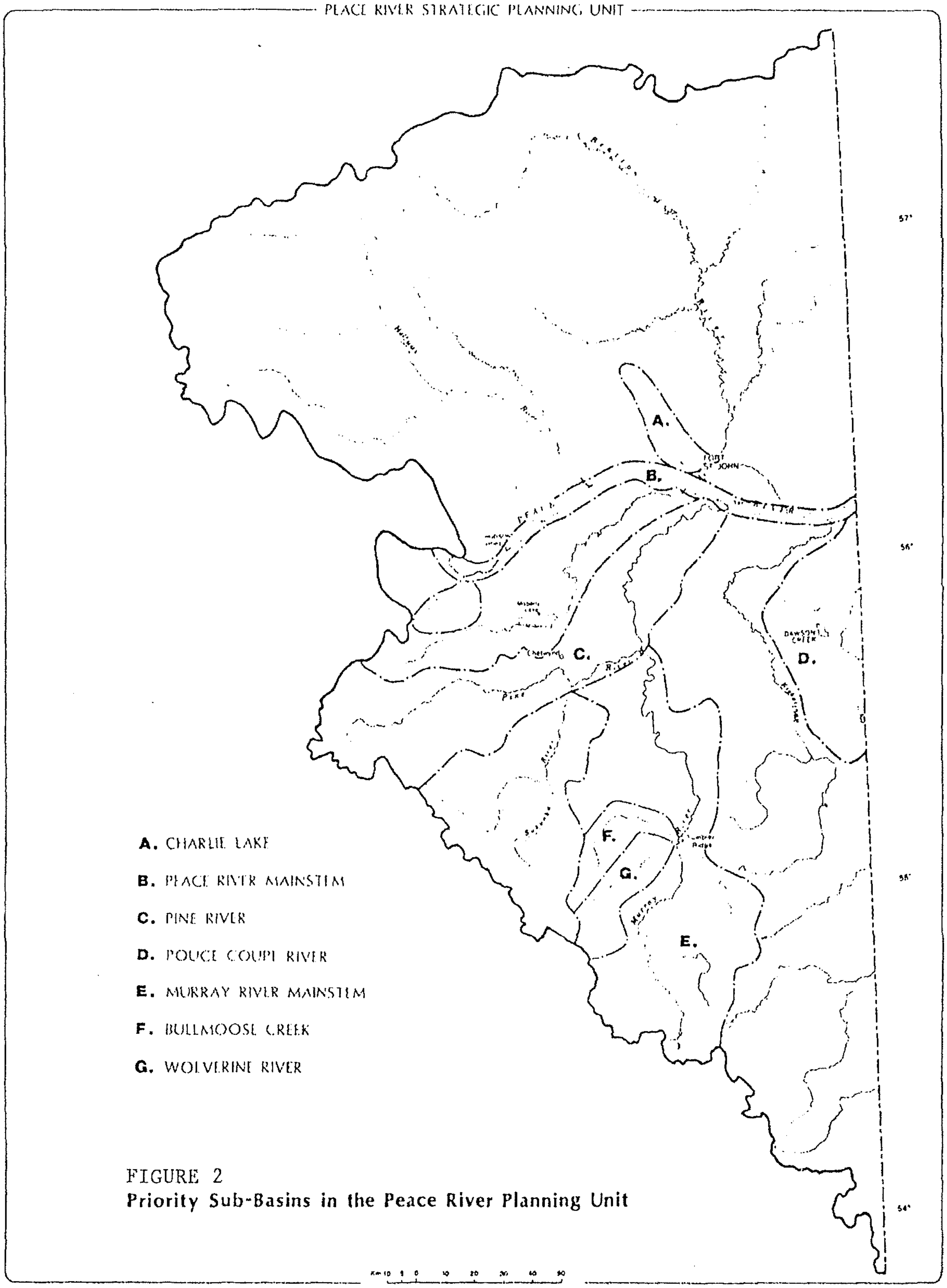

FIGURE 2
Priority Sub-Basins in the Peace River Planning Unit

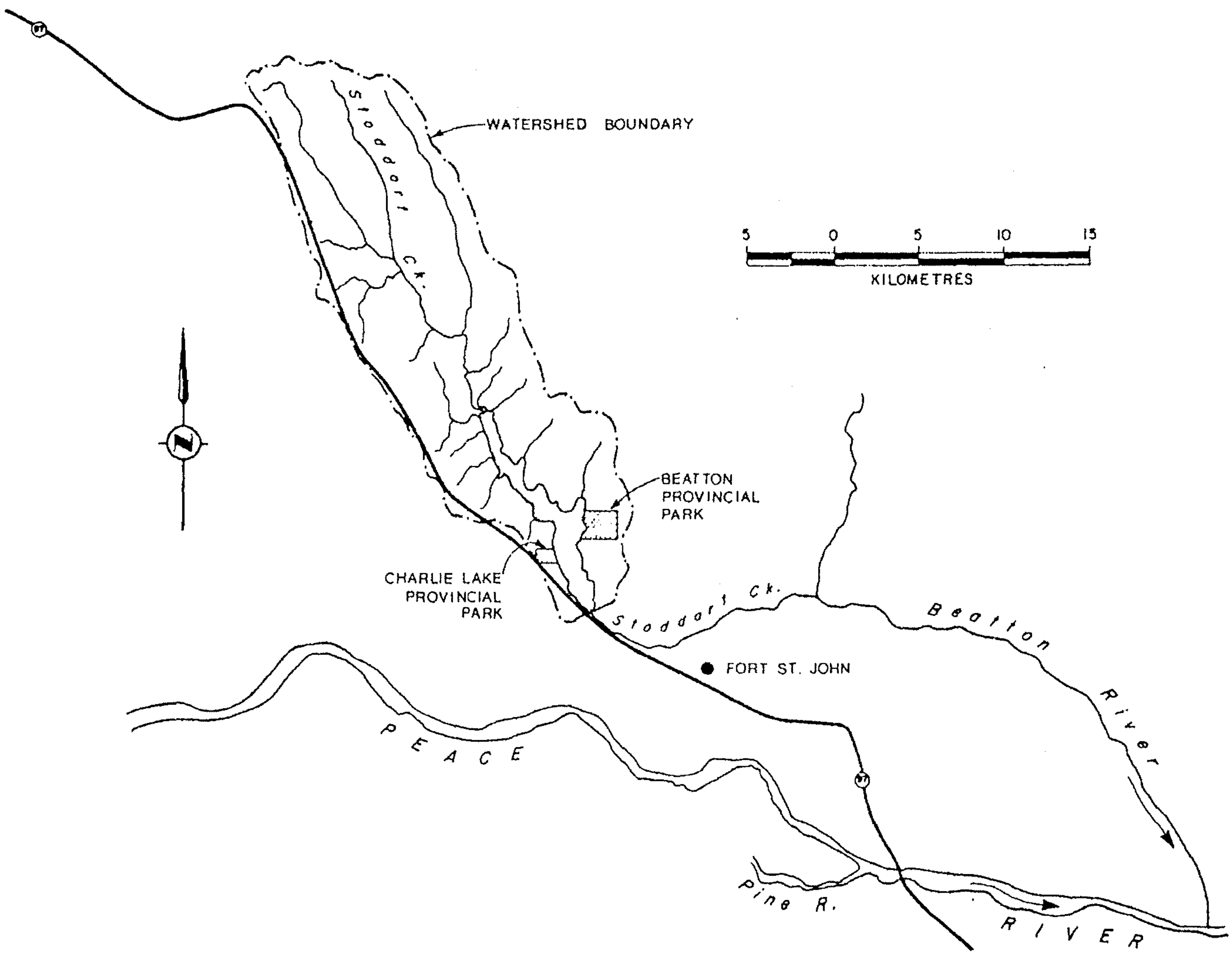

FIGURE 3 Charlie Lake: Watershed, Location Map

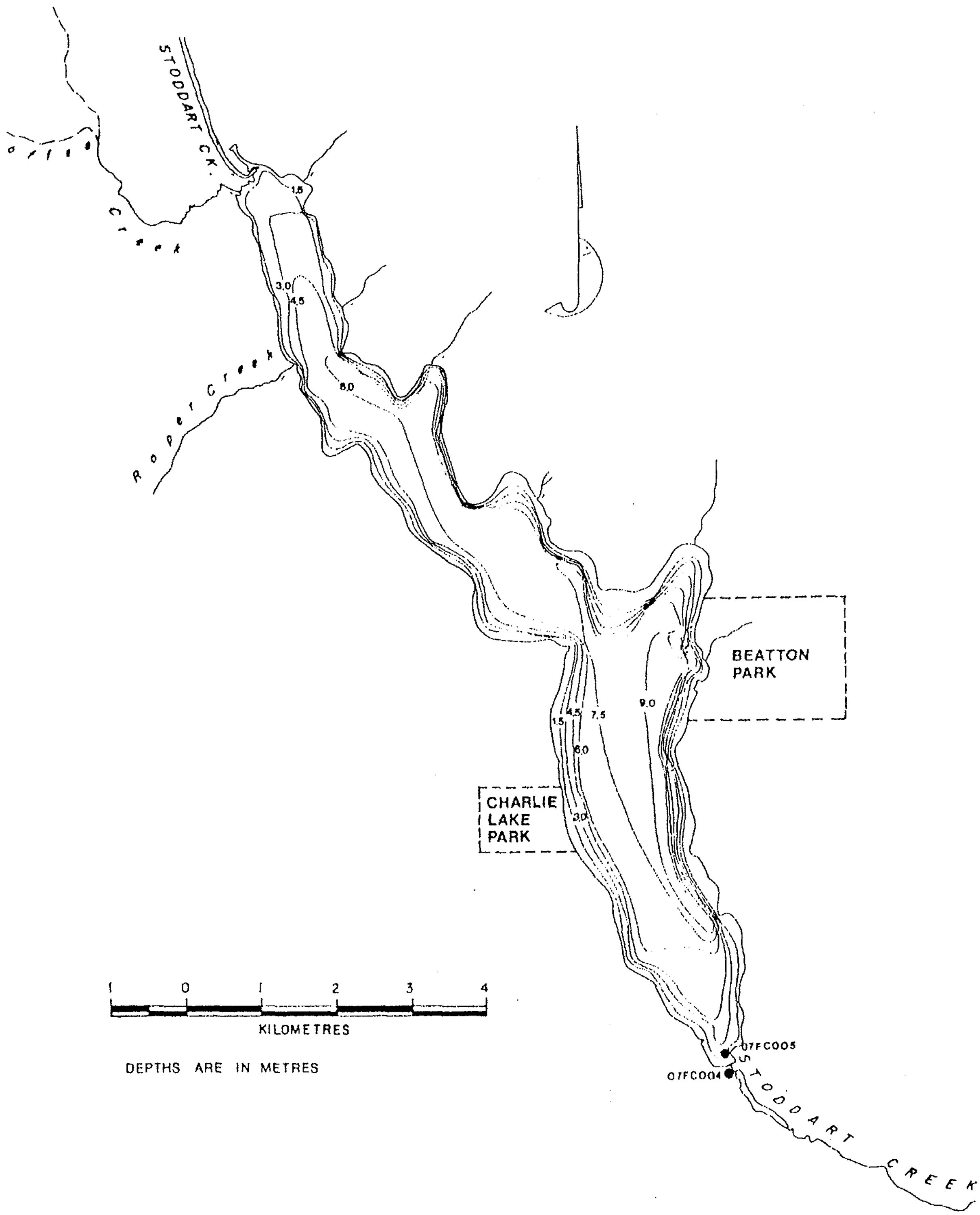

FIGURE 4 Charlie Lake Bathymetry

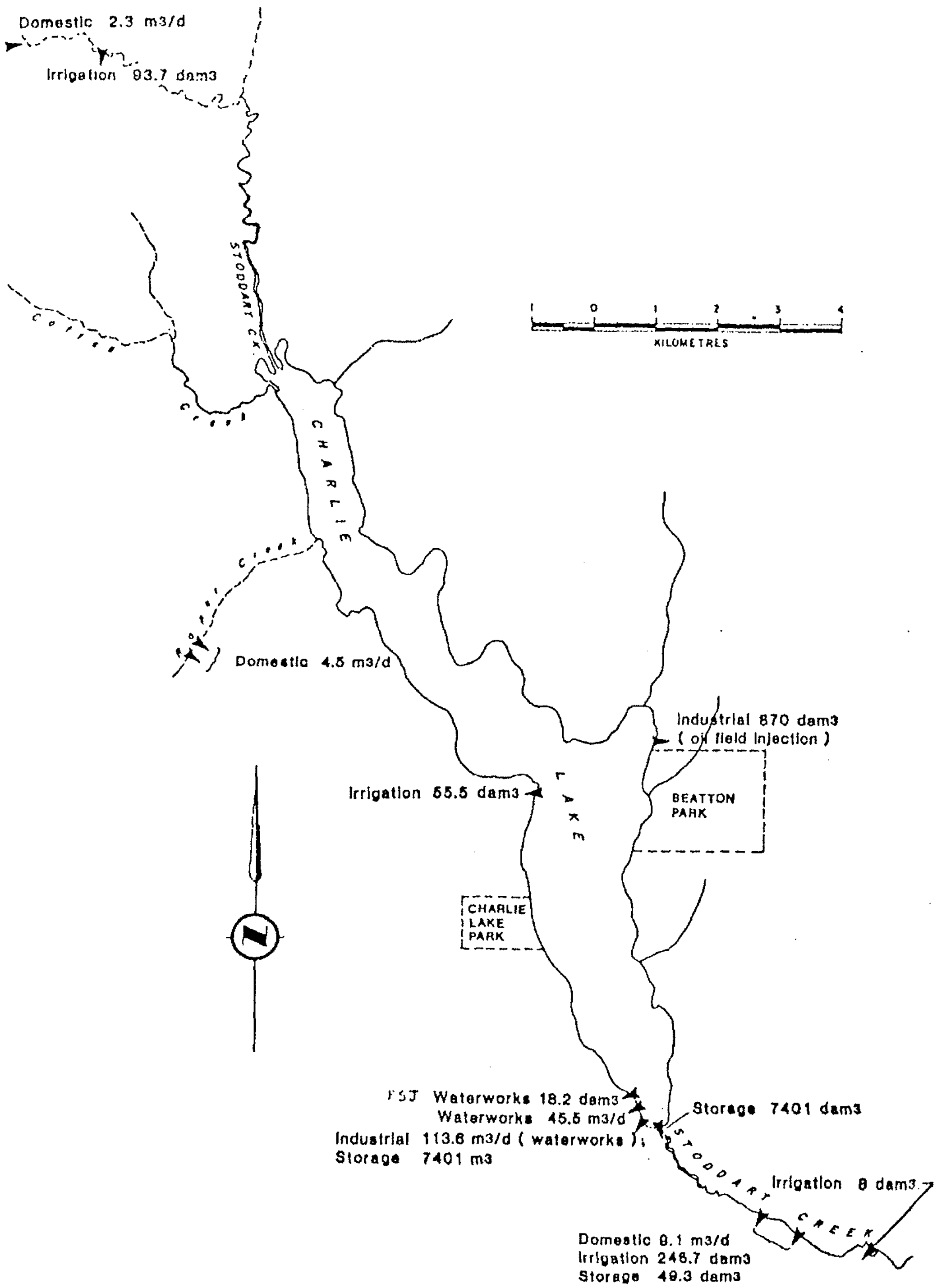

FIGURE 5 Water Licences - points of diversion

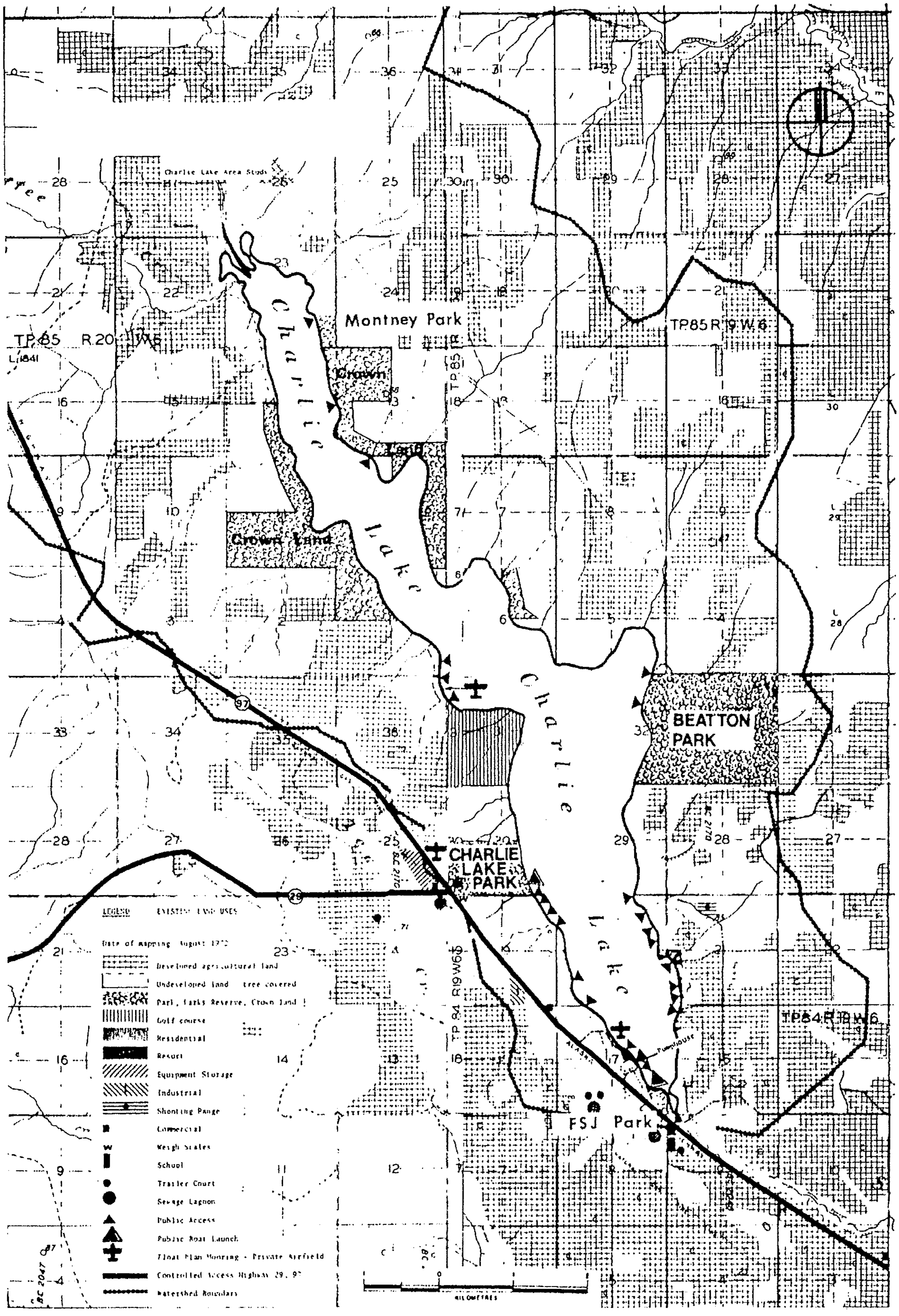

FIGURE 6 Land use, Park Areas and Access to Charlie Lake
(Adapted from reference 18)

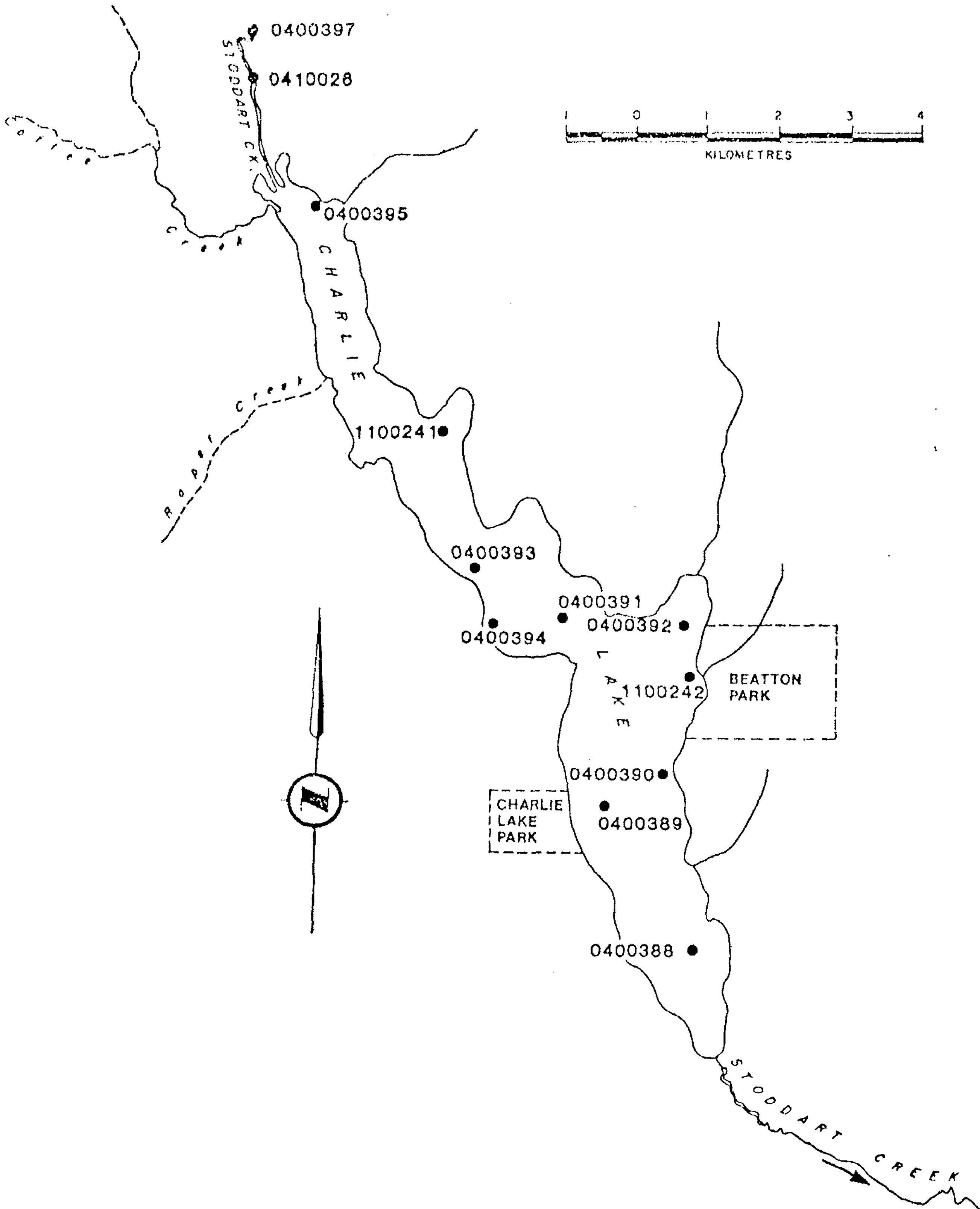

FIGURE 7 Water Quality Sites

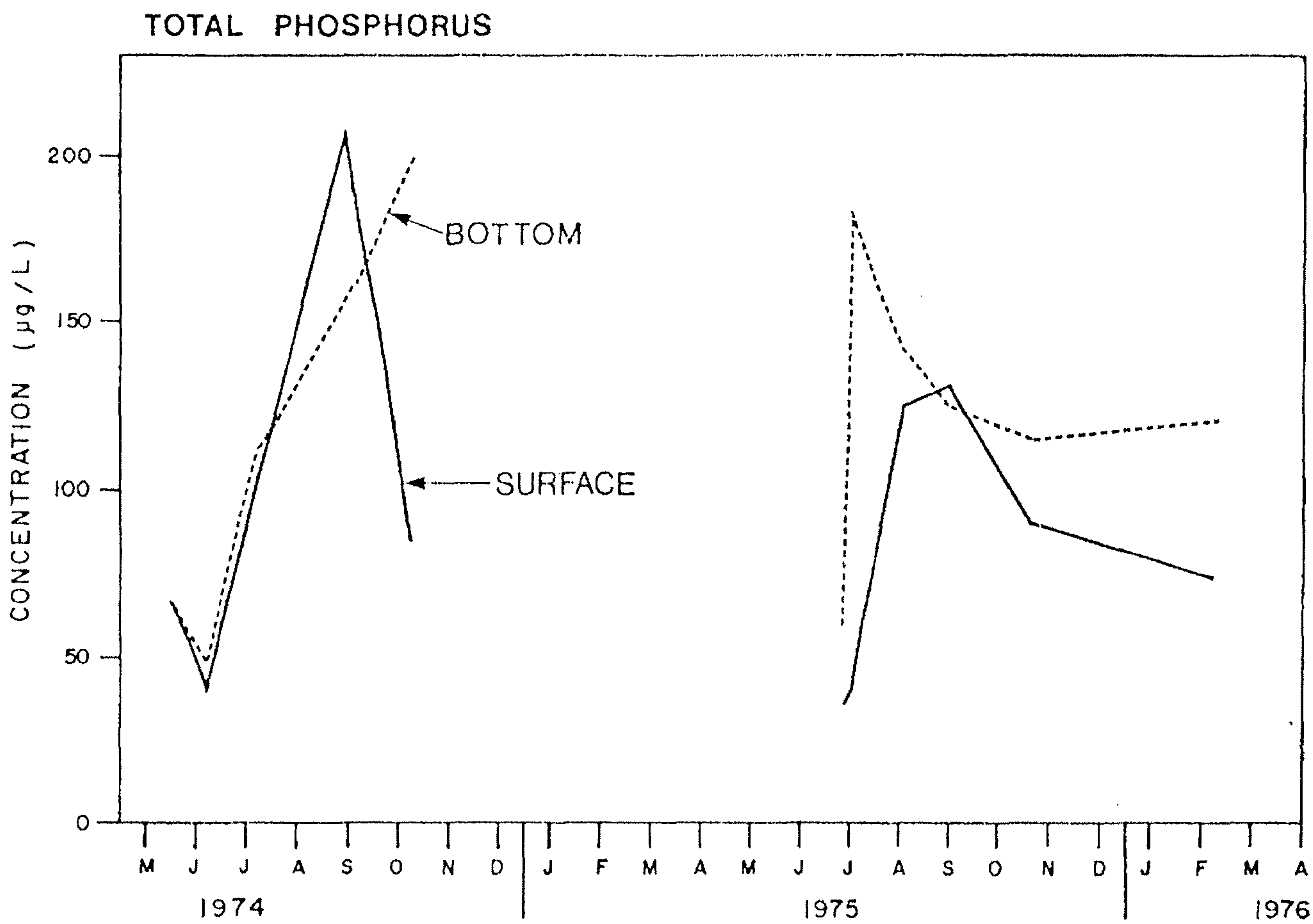

FIGURE 8 CHARLIE LAKE TOTAL PHOSPHORUS 1974-76

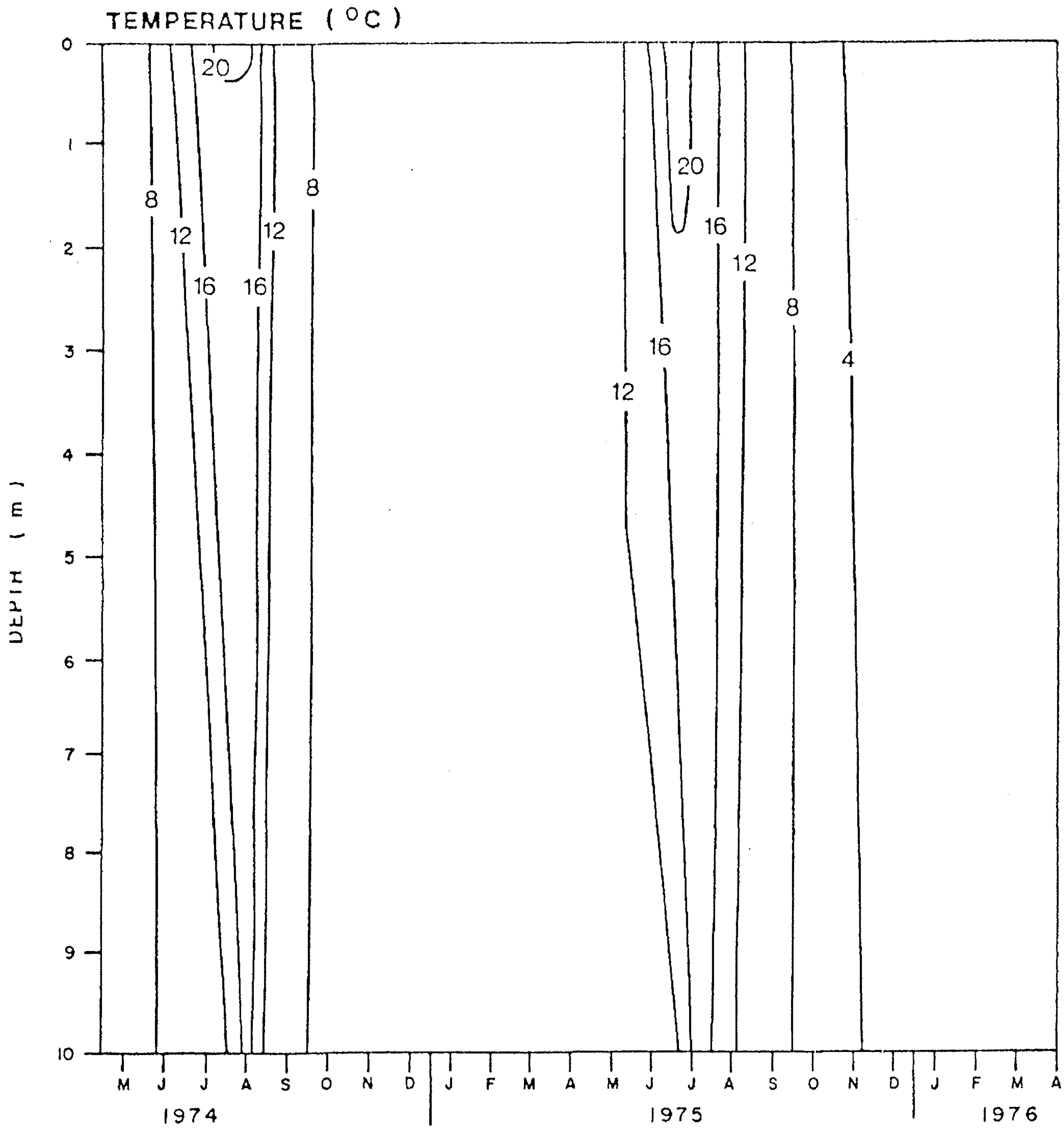

FIGURE 9 Charlie Lake Temperature: Time/Depth

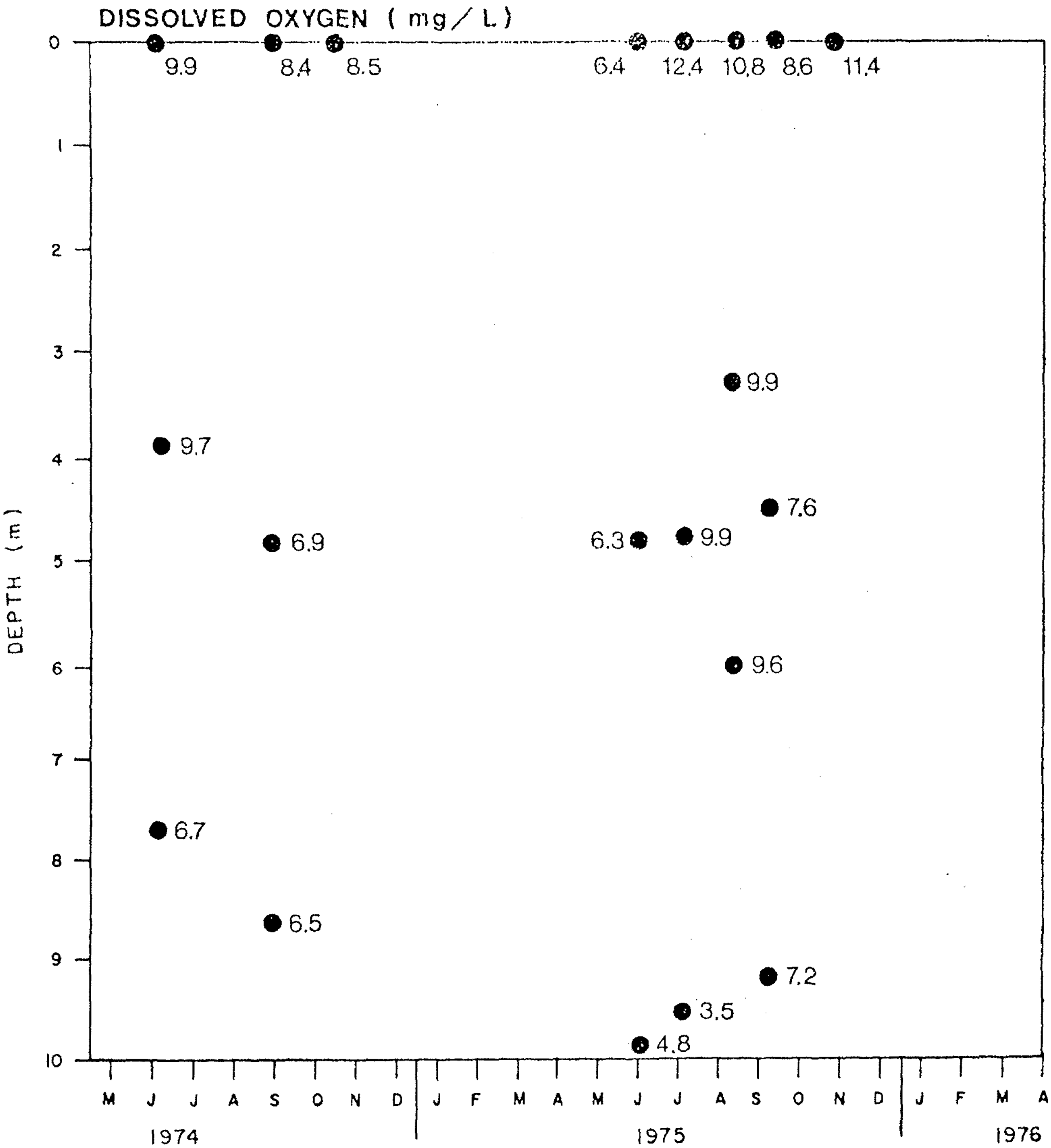

FIGURE 10 Charlie Lake Dissolved Oxygen (mg/L): Time/Depth