WSD #920-0475-203-000
JF 92-09-03

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A HALF YEAR STUDY OF THE LIMNOLOGY OF FLORENCE LAKE, VANCOUVER ISLAND.

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BIOLOGY 426

DR. HAGMEIER

APRIL 1973.

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INTRODUCTION

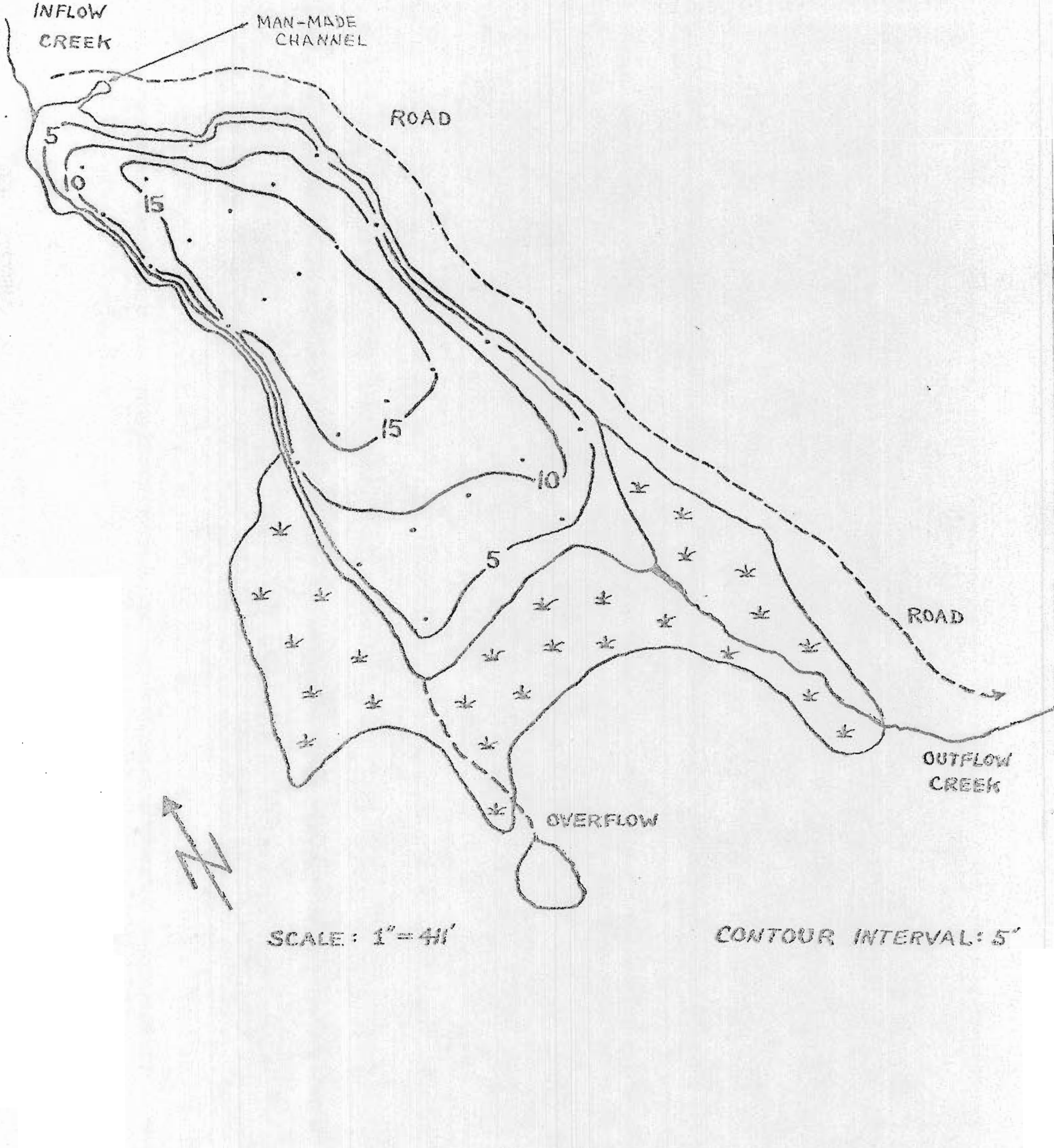
As far back as the last week of September, 1972, a group was assembled and a lake of study was chosen. The five members, myself, Midge Lambert, Evan Martin, Rob Sweet, and Tom Webber decided on Florence Lake. It is a lake close to Victoria (approx. 7 miles) and has had little previous work done on it.

It is a small lake of about 29 acres and located in the Esquimalt Land District at an elevation of 248 feet above sea-level. It can be found at a latitude of 48° 27' 30" North and at a longitude of 123° 30' 45" West on any map of southern Vancouver Island. Florence Lake has a grid reference of 6762 on map number 92 B/5 H: GOLDSTREAM.

Access to the warm monomictic lake was provided at the north end by the Hidden Valley Mobile Home Park located at 2500 Florence Lake Road. Storage for a pair of oars was provided and a launching site for the small wooden boat was available.

The lake is situated in the Insular Lowland Limnological Region based on its elevation and various physical factors. According to Northcote & Larkin (1963), the Insular Lowland region is characterized by elevations less than 400 feet, moderate precipitation (25"-40"), warm dry summers, mild moist winters, and moderate plankton and bottom fauna crops, but low fish crops. The same authors (1956) also suggest the following conditions: lake areas less than 5 $km.^2$ (1235 Acres), a mean depth of less than 10 metres, total dissolved solids of 100 p.p.m. or greater, high summer surface temperatures, and severe oxygen depletion in the deep layers during summer stratification. More will be discussed, in regards to these aspects, in following sections.


1:25,000
Millstream
MOUNT
FINLAYSON
GOLDSTREAM
PROVINCIAL
PARK
Niagara
River
WOLF
HILL
GOLDSTREAM DIST
HIGHLAND DIST
SKI
MOUNTAIN
HIGHLAND DIST
GOLDSTREAM DIST
ESQUIMALT DIST
CANADIAN
PACIFIC
Goldstream
Pipeline
MOUNT
WELLS


INFLOW
CREEK
MAN-MADE
CHANNEL
ROAD
5
10
15
15
10
5
ROAD
OUTFLOW
CREEK
OVERFLOW
N
SCALE: 1" = 41'
CONTOUR INTERVAL: 5'

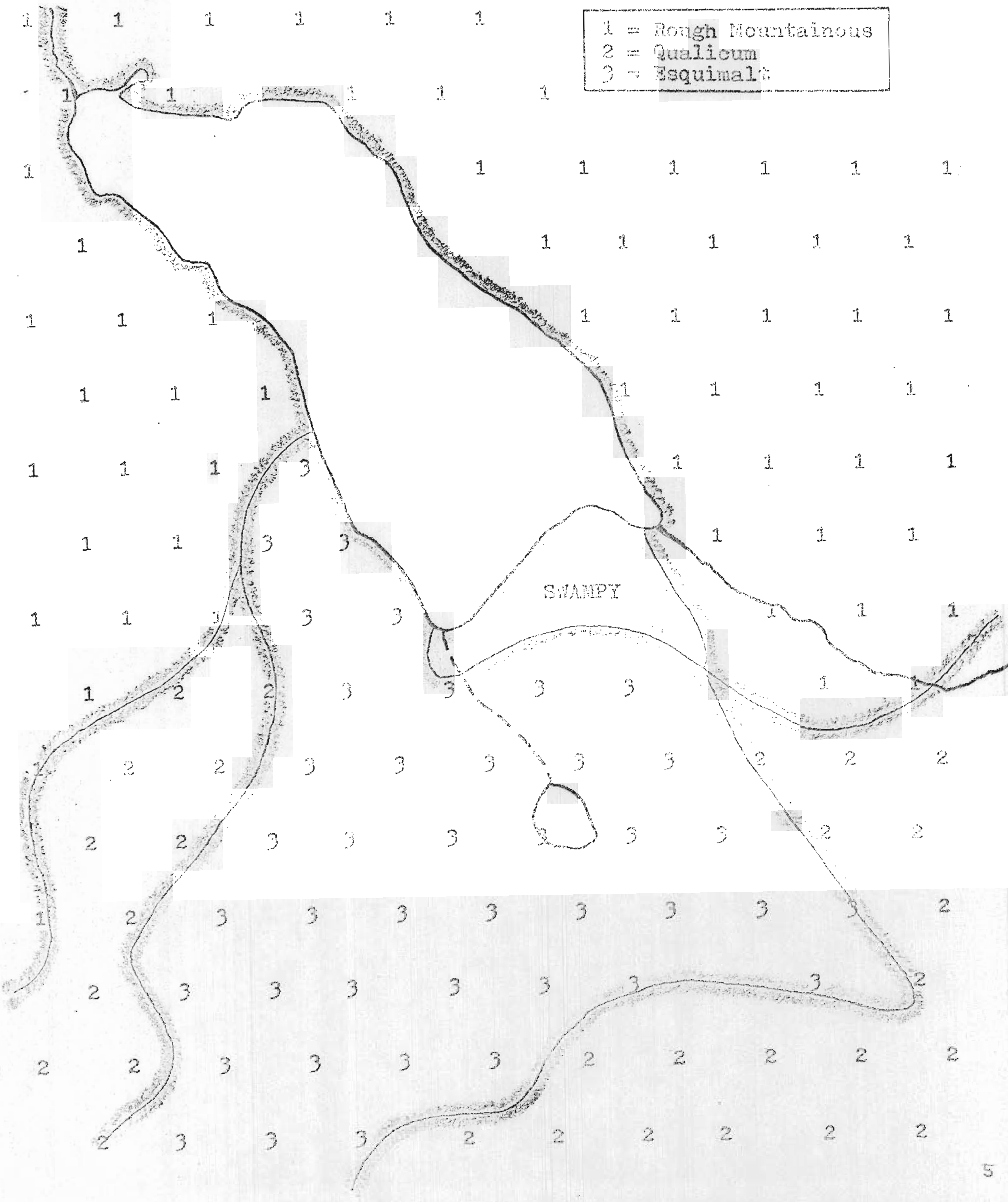
GEOLOGY - SOILS - LAND USE

The geology of the area closely follows that of the soil groups. The northern part, denoted as Rough Mountainous on the soil map, is composed of Jurassic and Cretaceous Coast Intrusion rock types. These include quartz diorite, diorite, granite, and their gneissic equivalents. Skirt Mountain, with a summit of 1125 feet, is the highest point in the drainage basin. ~~This~~ There is a difference of about 875 feet from the summit to lake level. This region is characterized by rough, mountainous land with thinly mantled bedrock (Day et al. 1956 Report #6).

The southern regions of the land drainage area, watershed lake are dominated by drift-covered areas composed of sands and gravels. These are course or medium textured fluvial glacio-fluvial aeolins and marine materials (Forward - 1969 Land Use Booklet). The soils of this region are those of the Qualicum and Esquimalt types. The Qualicum soils, designated as type 2 on the soil map, are on both sides of the medial Esquimalt group. The Qualicum soils are loamy sand or gravelly loamy sands and are members of the brown podzolic group (Day et al. Report #6). These soils are rapidly drained on the level to gently sloping topography. A typical soil profile is described as having 36-44" of yellowish-brown grading to pale brown, loose, and very permeable loamy sand or gravelly loamy sand (the B horizon). This overlies a pale brown or grey, loose sand or gravel (the C horizon) according to Day et al.

The Esquimalt soils, designated as type 3 on the soil map, are the rich black, stone free, rapidly drained soils characteristic of wet, and level to gently sloping areas. A typical profile may be described as follows: a layer of 8-10" of dark grey-brown granular, gravel-

GREAT SOIL GROUPS



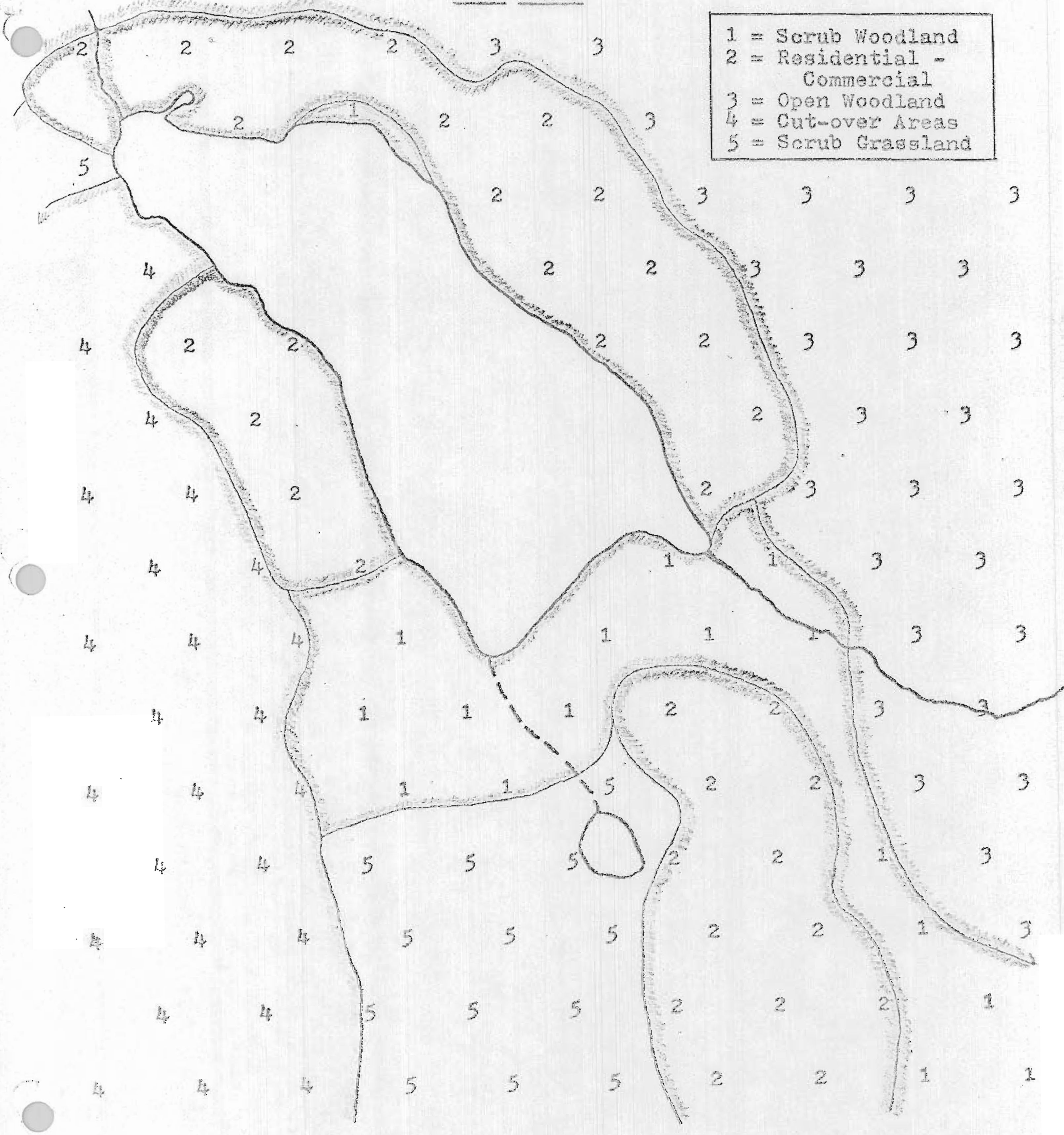
ly sandy loam or sandy loam (horizon A_1), over 8" of brown to yellowish-brown, very permeable, loamy sand (horizon B). This overlies a layer of grey, loose, gravelly loamy sand (the C horizon).

There are two possibilities as to the origin of the lake. It may be either an ice-scoured lake or a kettle lake. Because of the apparent glacial deposits at the south end of the lake, I would conclude that it was a kettle lake formed by ice blockage, glacial depositing, and subsequent ice melt.

The land use is dominated largely by open woodland, scrub woodland, and burnt or cut-over areas. The area away from the lake on the east side is open woodland and that on the western side is cut-over area. Scrub grassland is dominant at the south end of the lake on either side of the highway. The over-flow pond is located in this region fairly close to a residential area. Scrub woodland is present along the shores of the lake at the south end and extending in a narrow belt towards Langford Lake.

There are three main residential areas. The largest is located along the entire east side of the lake and extending into the northern basin in recent years. Another, more sub-division like, residential area occurs in the south-central region of the lake. This is the most densely populated of the three residential zones. The third zone is situated at the mid-western side of the lake and involves only a few residences. Road access is available along both sides of the lake, although one cannot circum-navigate the lake by road.

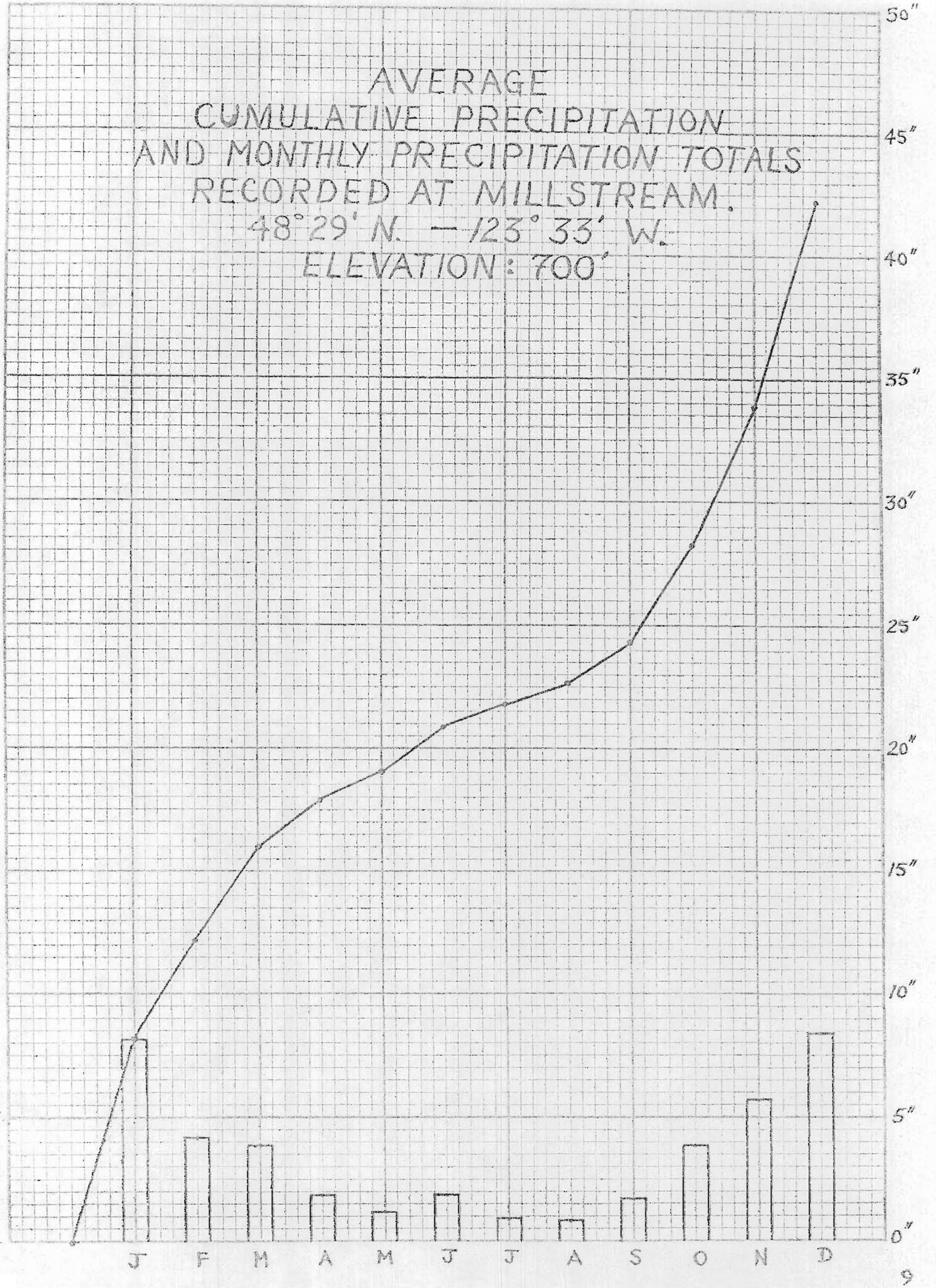
LAND USAGE


1 = Scrub Woodland
2 = Residential - Commercial
3 = Open Woodland
4 = Cut-over Areas
5 = Scrub Grassland

CLIMATE

According to Department of Transport Tables (Toronto, 1967), for the Millstream station located at an elevation of 700 feet and at 48 29' North latitude and 123 33' West longitude, the average annual precipitation amounts to 42.26 inches. This has been compiled over a 10 to 24 year period between 1931 and 1960. Significant snowfall was recorded, on the average, during five months of the year. The months involved include November, December, January, February, and March. The mean annual snowfall over this period between 1931 and 1960 amounts to some 21.6 inches - or a water equivalent of 2.16 inches. During the summer months of April through to September, a total of only 8.37 inches of rainfall generally occurs. The remaining 33.89 inches fall between October and March of each year.

The Department of Agriculture report for 1969 lists the 30 year average (1931-1960) for hours of bright sunshine at Gonzales Heights as 2216 hours. Chapman (1952) lists 65 year averages for a station 228 feet above sea-level and at a latitude of 48 25' North. The average number of hours with bright sunshine is 2207 and the average number of days with precipitation is 144. For Florence Lake, the sunshine would probably be slightly less and the days with precipitation, slightly more. Chapman (1952) also notes that during January there is a 30 % frequency of North winds and 18 % of Northeast winds. For July, a 40 % frequency of Southwest winds and 29 % West winds were compiled. According to Chapman (1952), the highest mean monthly temperatures are recorded in July and August with a 60 degree average. The lowest mean monthly temperatures are recorded in January with a 39 degree average.


AVERAGE
CUMULATIVE PRECIPITATION
AND MONTHLY PRECIPITATION TOTALS
RECORDED AT MILLSTREAM.
48° 29' N. — 123° 33' W.
ELEVATION: 700'
50"
45"
40"
35"
30"
25"
20"
15"
10"
5"
0"
J F M A M J J A S O N D

VEGETATION

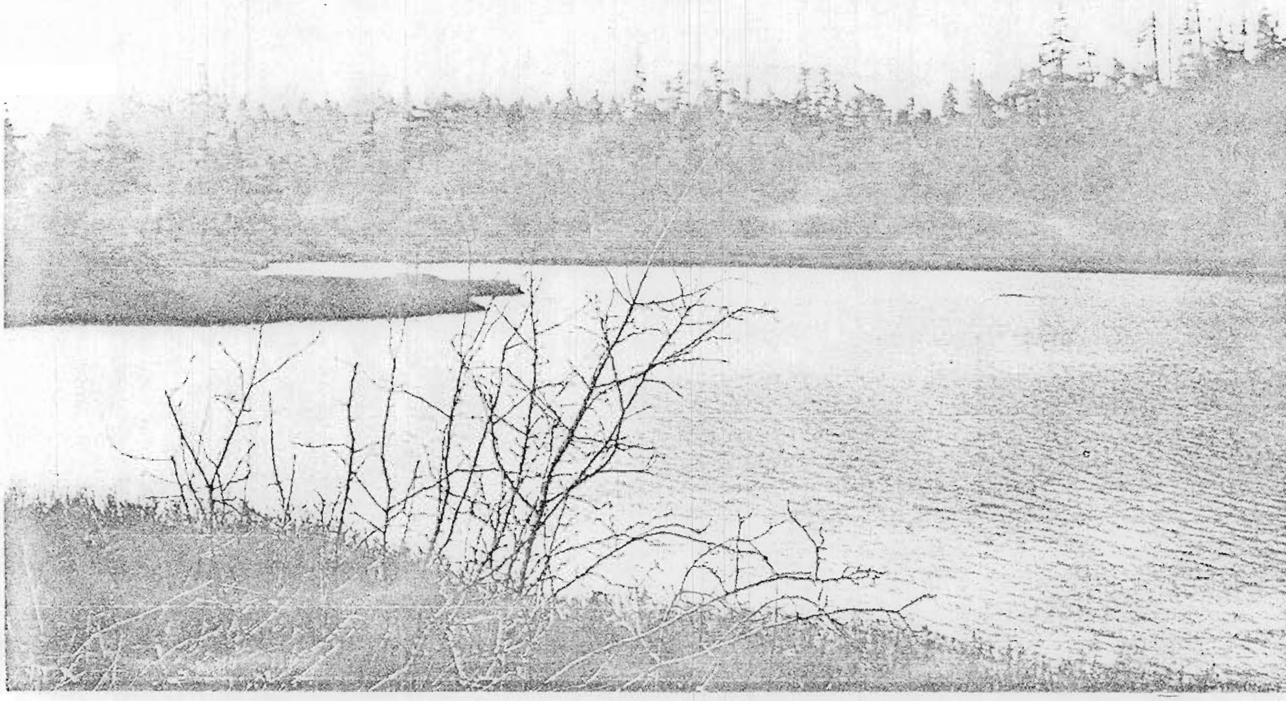
The vegetation of the area is a transitional Red Cedar: Douglas Fir: Mixed Deciduous composition. The dominant trees are *Pseudotsuga menziesii* (Douglas Fir), *Thuja plicata* (Western Red Cedar), *Pinus contorta* (Shore Pine), *Acer macrophyllum* (Broad-leafed Maple), and *Arbutus menziesii* (Arbutus). Some *Abies grandis* (Grand Fir) and *Populus tremuloides* (Trembling Aspen) were noted at the south end of the lake near the residential area.

The dominant shrubs along the water's edge are *Myrica gale* (Sweet Gale) and various *Salix* spp. (Willow). The Willow species are most abundant on the springy, peaty south shores of the lake and the Sweet Gale most abundant along the eastern shore of the lake. Other shore plants noted include *Eleocharis palustris* (Spike-rush), *Carex* spp. (Sedges), and *Scirpus* lacustris *subterminalis* (Bulrush).

On the southern scrub grassland areas, *Crataegus douglasii* (Black Hawthorn), *Quercus garryana* (Garry Oak), *Mahonia nervosa* (Oregon Grape), and *Ilex aquifolia* (English Holly) were identified.

Other commonly occurring plant species of this area include *Equisetum arvense* (Common Horsetail), *Cirsium lanceolatum* (Common Thistle), *Polystichum munitum* (Western Swordfern), *Pteridium aquilinium* (Bracken Fern), and *Polypodium vulgare* (Licorice Fern). The following shrubs were identified from the Florence Lake area: *Cytisus scoparius* (Scotch Broom), *Gaultheria shallon* (Salal), *Rubus ursinus* (Trailing Blackberry), and *Symphoricarpos albus* (Snowberry).

The following animals were seen during the winter months: Coots, Mallards, Gulls, Kingfishers, a Great Blue Heron, and a Muskrat.



Lake Outlet: (upper left) Typical Shoreline and Scrub Woodland Vegetation. -- SOUTH END OF LAKE.

Lake Inlet: (lower, extreme left) Vegetation of Upper Drainage Basin Area and Shoreline. -- NORTH END OF LAKE.

LAKE MORPHOMETRY

The lake drainage system is open with both an intermittent inlet and outlet. The inlet stream drains the upper part of the basin and the Mount Skirt area and empties into the lake at the northwest corner. The outlet leaves the lake at the southeast corner and flows in a wandering course toward Millstream where it empties into the stream. Millstream subsequently flows into the Esquimalt Harbour near Colwood.

Both the inflow and outflow streams were dry during the early part of the study from October to December. This dry period was probably lengthened by several weeks due to the particularly dry fall experienced last year. The first noted appearance of a substantial inflow occurred on December 20/72. However, a major inflow probably started around December 12 in association with the light rains of the first week of December.

No outflow was noted at this time, as the lake level was rising and the over-flow pond was being filled. The pond, which started filling around the 15th. of December, was almost full as of the 20th. Rain started again on the 15th. of December after a week of freezing weather. By December 22, the outflow had started flowing substantially and the over-flow pond was completely filled. Both the inflow and outflow streams continued to flow during the remainder of the study.

Due to the "false bottom" of the lake, it was difficult to make an accurate sounding. The maximum depth, as best as we could determine was around 18 feet. The Fisheries Branch, in an earlier survey, arrived at 19 feet as their maximum depth. The mean depth was calculated as 10.7 feet. Rawson (1952) demonstrated that, at least for large

5. Morphometry:

		Metric	
1.	Land District:		ESQUIMALT
2.	Limnological Region:		INSULAR LOWLAND
3.	Elevation:	75.6 metres	248 feet
4.	Maximum Length:	697 metres	2286 feet
5.	Max. effective length:	697 metres	2286 feet
6.	Maximum width:	282 metres	925 feet
7.	Max. effective Width:	282 metres	925 feet
8.	Mean Width: (Surface Area/ Max. Length)	171 metres	560 feet
9.	Maximum Depth:	5.5 metres	18 feet
10.	Mean Depth:	3.3 metres	10.7 feet
11.	Mean Depth/Max. Depth:	0.59	0.59
12.	Max. Depth: $\sqrt{\text{Surface Area}}$	0.016	0.016
13.	Direction of Major Axes:		N.N.W. - S.S.E.
14.	Lake Surface Area:		29.4 acres
15.	Number of Islands:	0.	0.
16.	Area of Islands:	0.	0.
17.	Shoreline Length:	1716 metres	5630 feet
	(Including Island):	1716 metres	5630 feet
18.	Shoreline Development:	1.40	1.40
	(Including Islands):	1.40	1.40
19.	Volume:		314.8 acre-feet
20.	Volume Development:	1.78	1.78
21.	Mean Slope:		0.046 feet/feet
22.	Cryptodepression:	0. percent	0. percent
23.	Shoal: % Area 20 ft deep & less:	100 %	100 %
	% Volume " " " " :	100 %	100 %

lakes, mean depth was related to plankton and bottom fauna standing crops and to long-term fish production. He noted that lakes with shallower mean depths had greater biomasses of plankton and bottom fauna and greater fish production. Northcote & Larkin (1956), state that Rawson felt mean depth to be a lake's most significant dimension.

The lake area, as determined with a polar planimeter and using the Fisheries Branch map, is 29.4 acres. The Fisheries had calculated the lake area to be 27 acres. The drainage basin area, excluding the lake area, is 411.7 acres and the ratio of drainage basin area to lake area (411.7/29.4) is equal to 15.0. Our value for lake volume is 314.8 acre-feet compared to the Fisheries 324 acre-feet.

Florence Lake has an average annual flushing rate of 2.02 years. This is fairly rapid compared to some of the larger lakes (ie. Prospect Lake: approx. 7 years). See appendix 1 for flushing rate calculations and the formulas used to calculate lake volume, mean depth, shoreline development, and mean slope. The following table summarizes area and volume by lake strata:

DEPTH	AREA (Acres)	AREA (Sq. Ft.)	% TOTAL AREA
0 - 18'	29.36	1,279,309	100.0
5 - 18'	25.23	1,099,161	85.9
10 - 18'	17.20	749,310	58.6
15 - 18'	8.21	357,684	28.0

STRATUM	VOLUME (Cu. Ft.)	VOLUME (Acre-feet)	% TOTAL
0 - 5'	5,940,482	136.33	43.3
5 - 10'	4,593,336	105.42	33.5
10 - 15'	2,707,828	62.14	19.7
15 - 18'	476,912	10.95	3.5

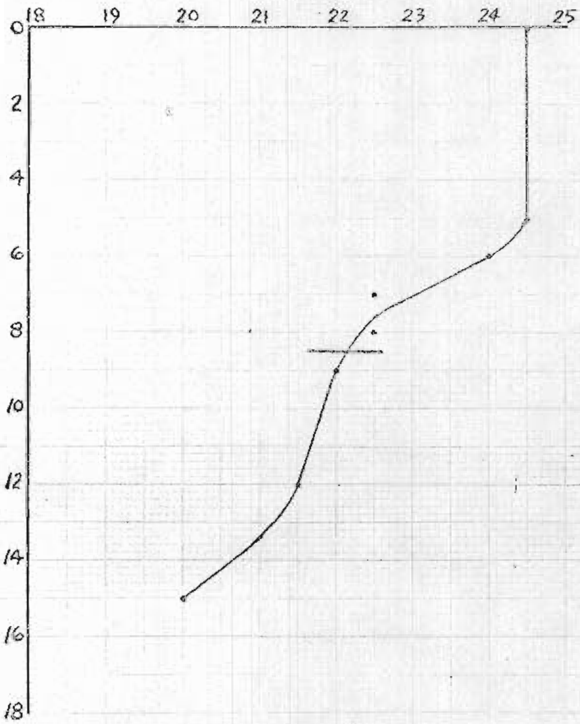
STRATUM	CUMULATIVE VOLUME	CUMULATIVE % VOLUME
0 - 5'	136.33 Ac-ft.	43.3
5 - 10'	241.75 Ac-ft.	76.8
10 - 15'	303.89 Ac-ft.	96.5
15 - 18'	314.84 Ac-ft.	100.0

TEMPERATURES & HEAT BUDGETS

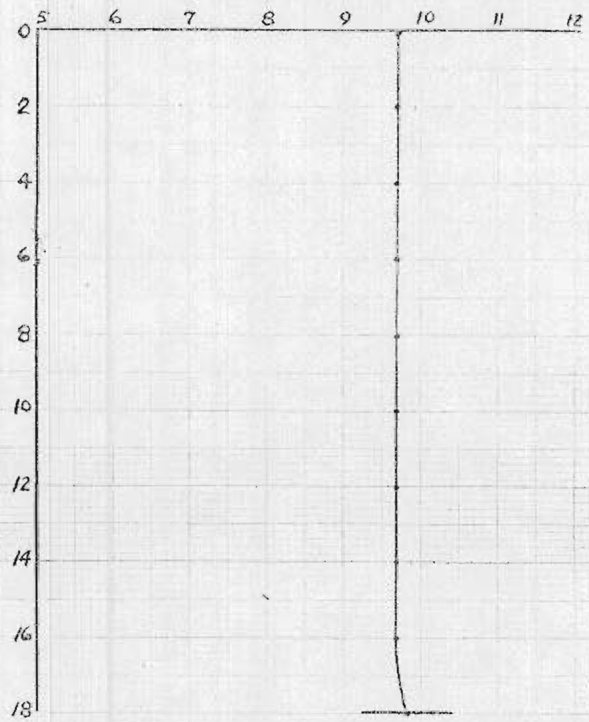
Based on July 29, 1972, temperature data (courtesy of Sharon D. Brown), the highest bottom temperature was approximately 19.0 degrees Centigrade and the highest surface temperature was 24.5 degrees. Using a percent volume factor and multiplying by the mean temperature of each stratum, a mean summer lake temperature can be calculated by summing for each stratum. The mean lake temperature on July 29/72 was thus calculated as 23.2 degrees Centigrade. The calculations are detailed in appendix 1-A.

Although the length of study was too short to determine the duration of stratification, a reasonable estimate can be made. Our first sampling on October 19, 1972, revealed an isothermal condition with a temperature of 9.7 degrees. However, at this time other local lakes (Langford, Big Maltby, and Prospect) still had remnants of a thermocline. It appears that fall turnover occurred probably around October 15 based on the above information. The start of spring stratification would likely be around May 1 (earlier in spring of 1973) and would be correlated with the increasing hours and intensity of sunshine. Assuming this period to be representative of the duration of stratification for Florence Lake, then a thermocline is present for 5½ months of the year. This probably represents a period typical of other local lakes.

Vertical temperature profiles are graphed on the following two pages. The July 29 profile is included for comparison with the isothermal conditions observed from mid-October to March. Secchi disk depths are also marked on each temperature profile.

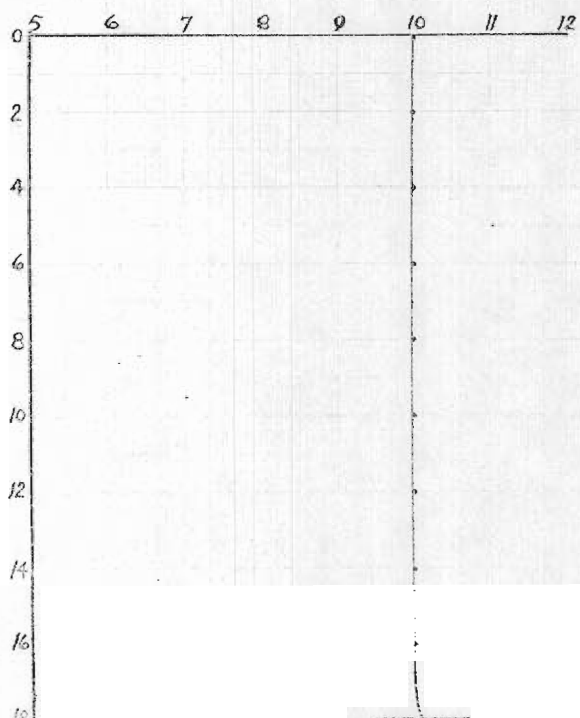


JULY 29/72.

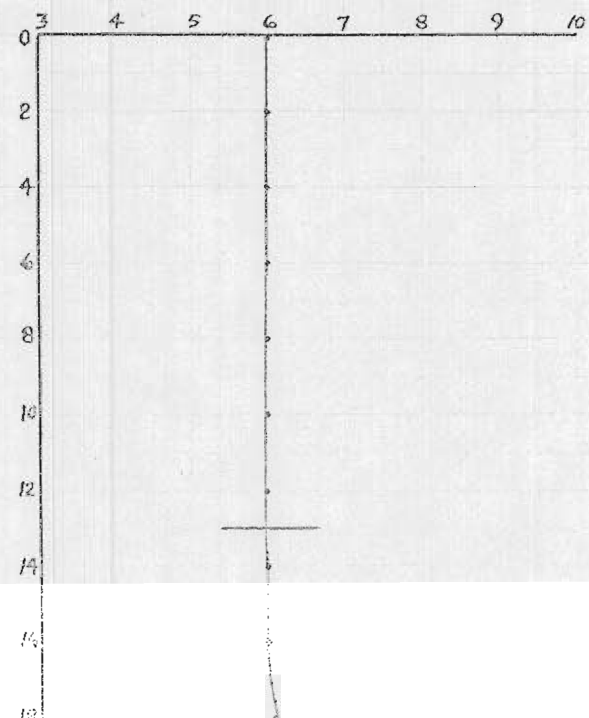


OCT. 19/72.

(DEPTH IN FEET & TEMPERATURE IN °CENTIGRADE)

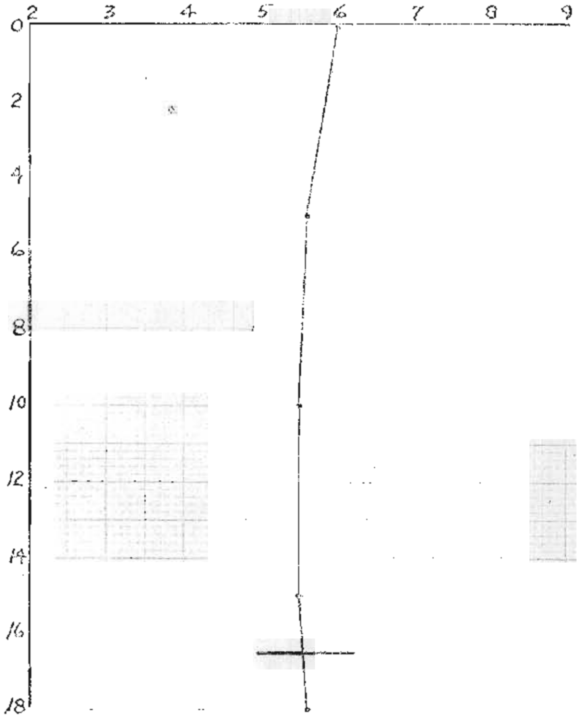


OCT. 26/72.

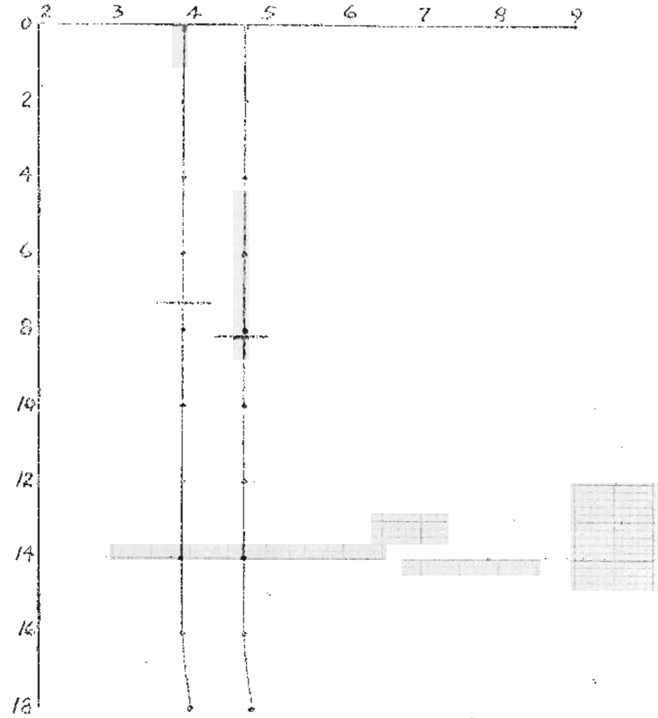


NOV. 16/72.

SECCHI DISK DEPTHS MARKED IN RED.

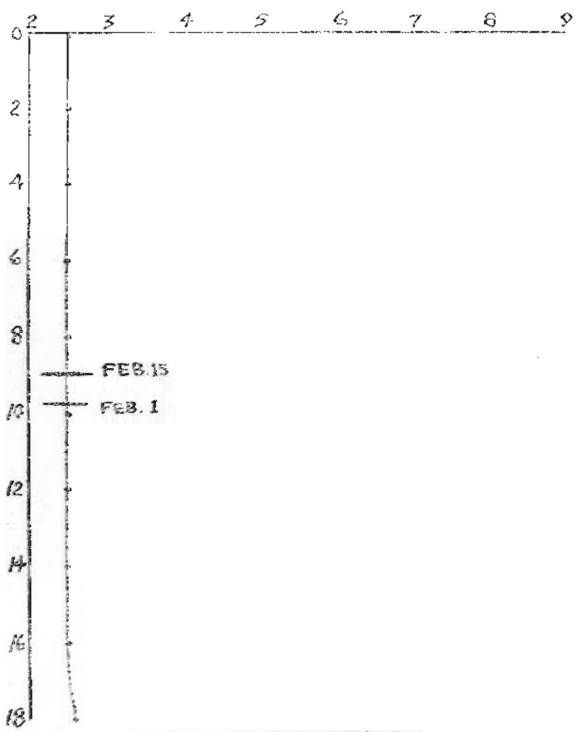


NOV. 23/72.

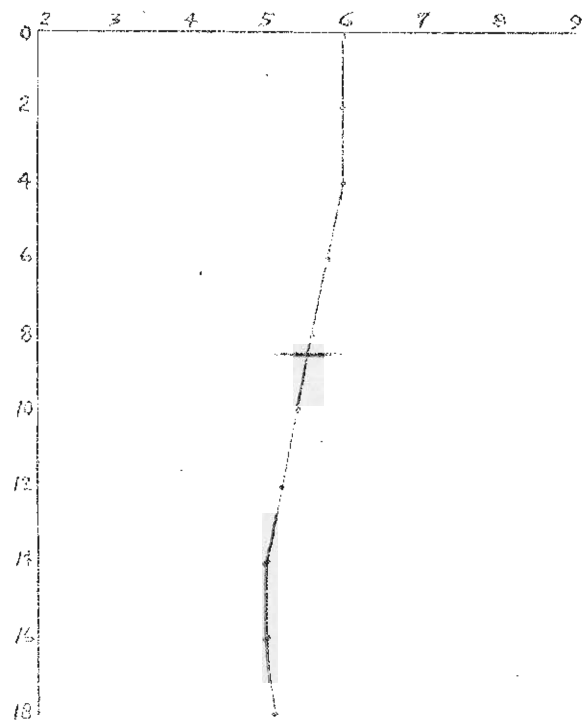


JAN. 18/73.(4.7°C.)
& JAN. 25/73.(3.9°C.)

(DEPTH IN FEET & TEMPERATURE IN °CENTIGRADE)



FEB. 1 & 15/73.



MAR. 1/73.

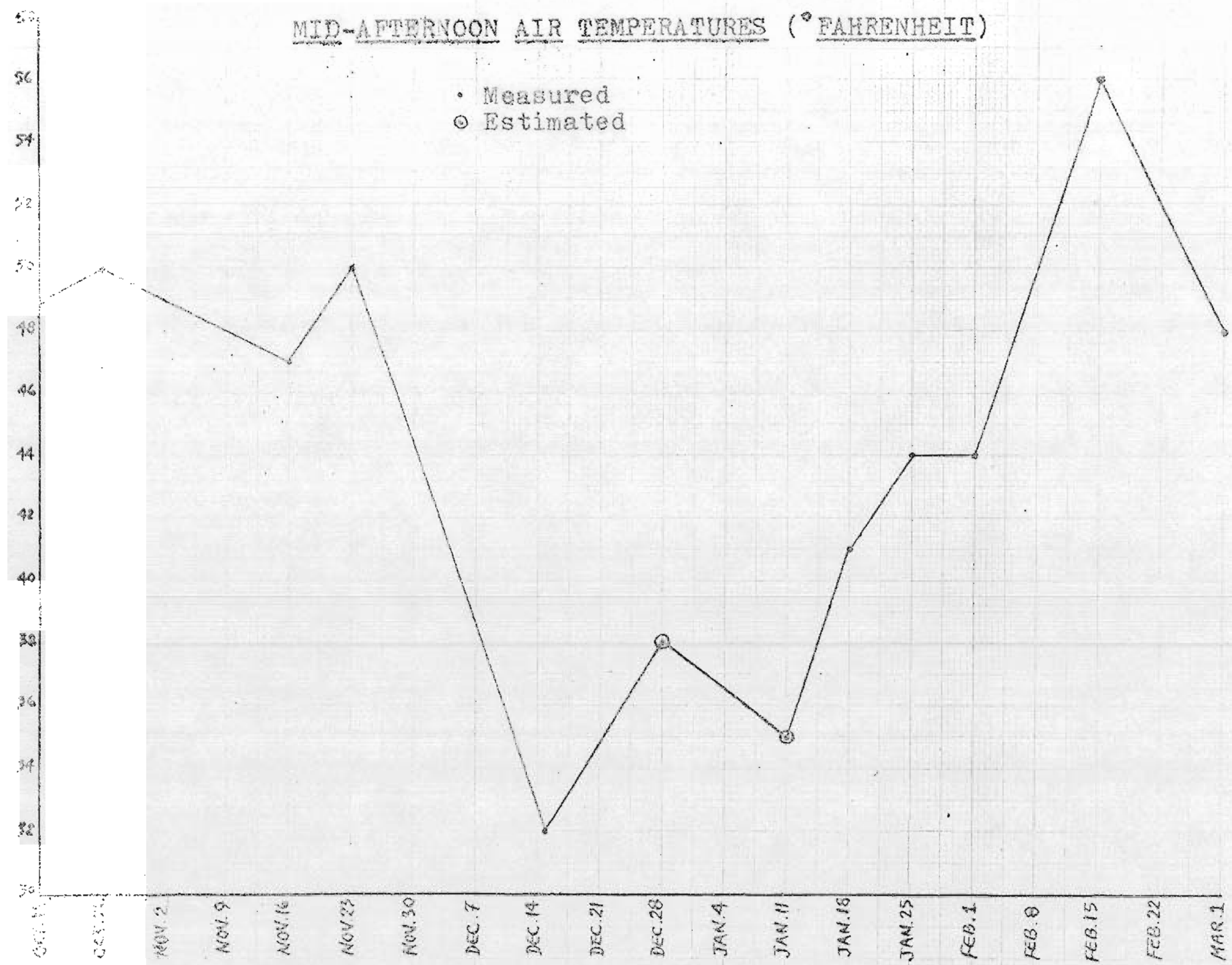
SECCHI DISK DEPTHS MARKED IN RED.

All vertical temperature profiles show completely isothermal conditions, except for November 23 and March 1 where the surface temperatures are a degree or half a degree warmer than the bottom waters. During the first half of February, the minimum temperatures of 2.5 degrees Centigrade were recorded. From November 16 till March 1, surface temperatures never exceeded 6 degrees, although during October they hovered around 10 degrees Centigrade. The graph on the next page shows the trend in air temperatures during afternoons of sampling days. There is a fairly gross correlation between water temperatures and air temperatures during the five months.

Bottom sediment temperatures were generally about 5 degrees warmer than the water. Values of 11.5 were recorded on October 19, 10.5 on November 16, and 11.0 degrees on November 23. It appears that these bottom sediments, undergoing decomposition and producing heat, supply a great amount of heat to the water column during the winter months. In shallow lakes such as Florence, they may supply enough heat to keep the lake surface free of ice during times of moderately low temperatures.

During two days in October, the Secchi disk depth was recorded as the bottom of the lake. This was associated with moderate standing crops and no lake inflow due to the extremely dry fall conditions. January and February compensation points were much shallower because of the inflow of allochthonous materials from the watershed during heavy rainfall periods. Turbidity readings of 5-6 Jackson Turbidity Units were recorded on November 16. This value would probably be low compared to those of January & February. Apparent water color was noted as 28 units on November 23/72.

MID-AFTERNOON AIR TEMPERATURES (°FAHRENHEIT)



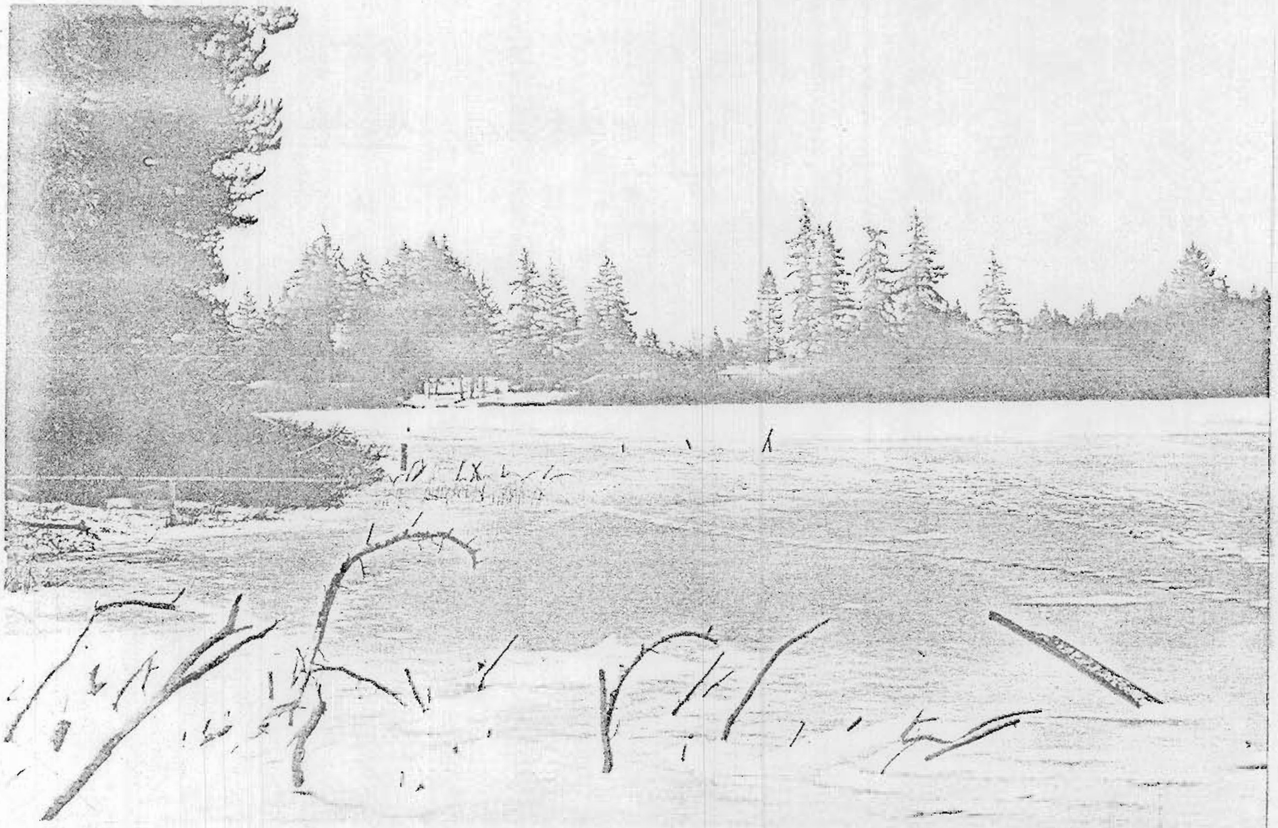
lakes of [illegible] lowlands of [illegible] which are

Although, normally warm monomictic lakes have Annual Heat Budgets equal to their Summer Heat Income, this year proved different with two periods of ice cover. On December 20/72, the ice was observed to be about 5 inches thick (however, the overflow pond was still clear of ice). The ice cover lasted for about two weeks, starting about December 8 and ending December 22. The cold spell associated with the ice started on December 4 and ended on December 14. Observations on the afternoon of December 23 revealed no ice present on the lake. The second period of ice cover was associated with a cold spell starting on the 3rd. of January and lasting until the 10th. of the month. Overnight lows of around 15 degrees Fahrenheit were recorded during this period. The ice cover probably lasted from about January 5 until January 16. The ice was of similar thickness to that of the first period of ice cover. On January 12, the overflow pond was completely frozen and the only place not frozen was the area around where the inflow creek empties into the lake.

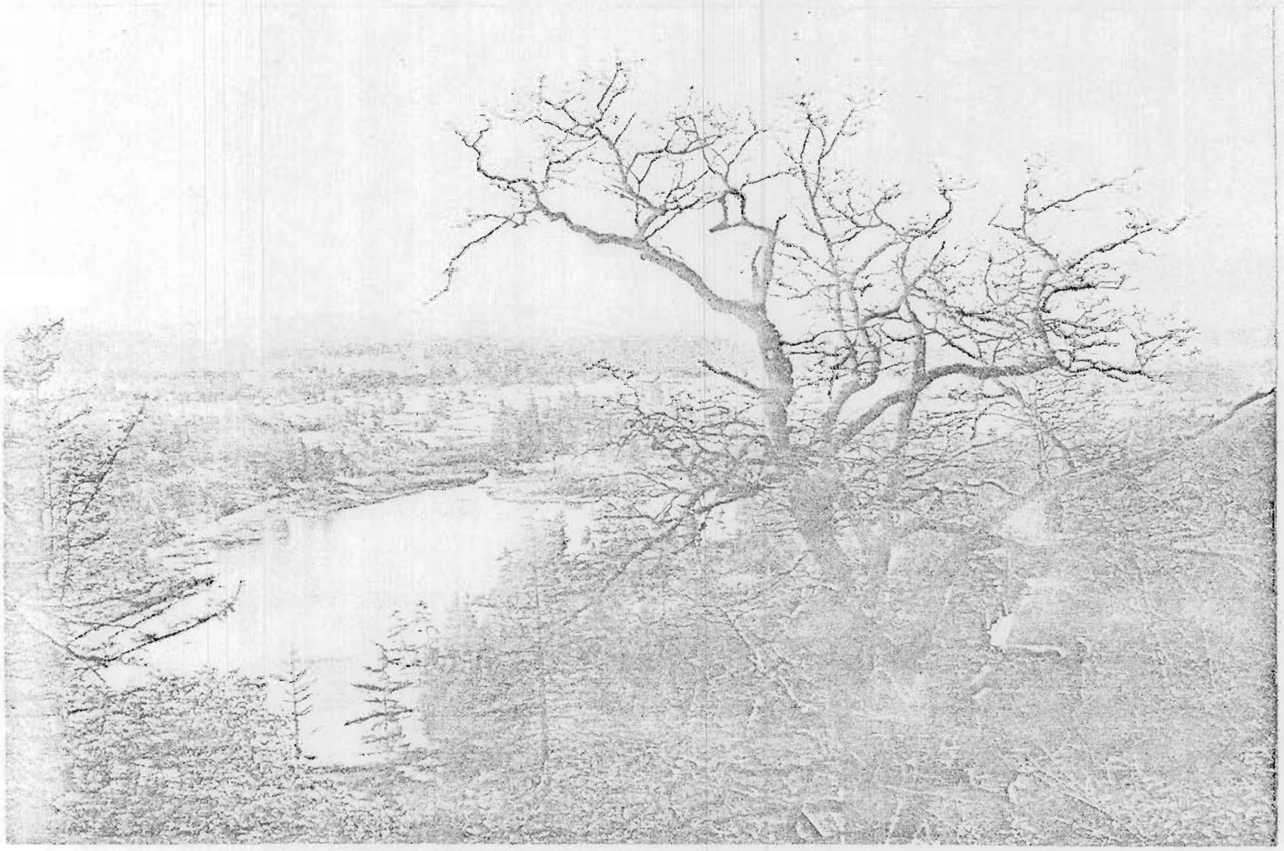
The Summer Heat Income is calculated by multiplying the mean depth (in centimetres) of the lake by the difference between the mean summer temperature and the mean winter temperature (set at 4°Centigrade). The result is expressed in gram calories per centimetre squared. Using the mean summer temperature of 23.2 degrees based on July 29/72 data, the Summer Heat Income is equal to 6261.9 gm.cal./cm.^{2} (see appendix 1-A for calculations). Other local lake Summer Heat Incomes were determined for Durrance and Lower Thetis lakes. Based on August 17/72 data, the value for Durrance is 8576.1 gm.cal./cm.^{2} and for August 28/72 data, the value for Lower Thetis is 7947.7 gm.cal./cm.^{2}

The Winter Heat Income is the amount of heat required to raise the water from its lowest (winter minimum) heat content to 4 degrees Centigrade. For the purposes of calculating, the mean summer temperature is set to 4 degrees. Assuming (conservatively) that the minimum mean winter lake temperature was equal to 2.0 degrees Centigrade, then the Winter Heat Income is equal to 652.3 gm.cal./cm.^{2}. The Annual Heat Budget, the sum of the Summer and Winter Heat Incomes, is then equal to 6914.2 gm.cal./cm.^{2}. It should be remembered that other factors such as sediments and winds serve to heat lakes and should probably be included in the Annual Heat Budget. Hutchinson (1957) also suggests that the latent heat of melting ice should be subtracted from the Winter Heat Income. This amounts to about 70 gm.cal./cm.^{2} for every centimetre of ice.

In regards to Heat Budgets, Hutchinson (1957) concludes that there is no consistent latitudinal variation within the temperate zone. According to him, a general low temperature promotes heat uptake by facilitating mixing, and leads to a higher heat budget. He also states that small, shallow lakes all have low heat budgets. This is noticeable in comparing Florence (a shallow lake) with Durrance and Lower Thetis lakes which are deeper. It would seem then, that within a given latitudinal range, lakes with a smaller heat budget have a greater potential for productivity of organic matter. This appears to be true in comparing the above three lakes.



FLORENCE LAKE - ICE & SNOW COVERED.



FLORENCE LAKE - WITHOUT ICE & SNOW COVER.

WATER CHEMISTRY

Total dissolved solids are a measure of the amount of ionizable solids (electrolytes) in solution. They have been used extensively by several authors as an index of lake production. Northcote & Larkin (1956) concluded that TDS appeared to be the most important factor in determining the general level of productivity in the 100 lakes they studied throughout the province. They found TDS to be over seven (7) times as powerful as mean depth in forecasting bio-indices of lakes. Rawson (1951) found a positive correlation between TDS and average standing crop of plankton and bottom fauna. He suggested, however, that the effect of TDS may be supressed by unfavorable climatic and morphometric parameters.

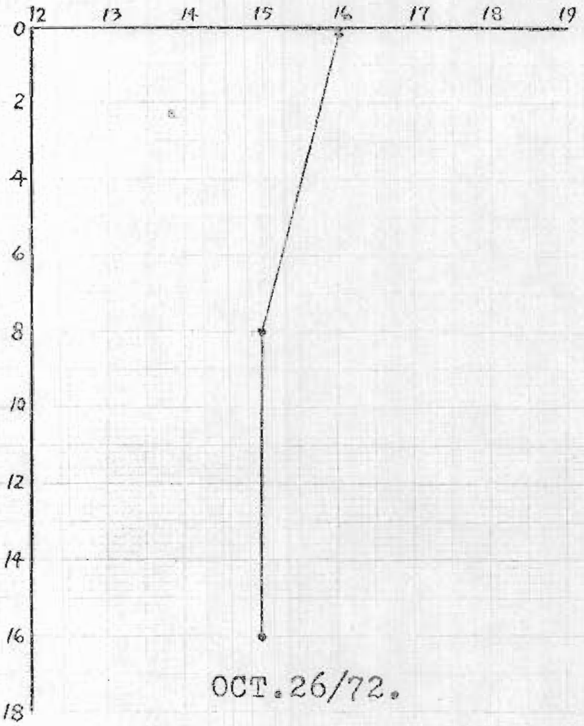
Northcote & Larkin (1956) found mainland coast lakes to have about 45 ppm. TDS, those on the lower elevations of Vancouver Island about 90 ppm., and those of the Kamloops interior area to have about 230 ppm. TDS. The conductivity measurements for Florence Lake were made by Sharon D. Brown using a Beckman RA-2A Conductivity Cell. The following table shows the results of several determinations.

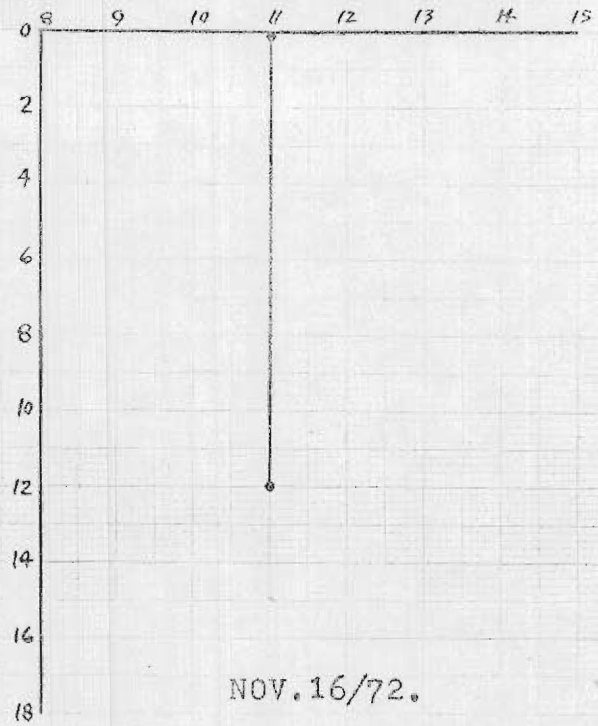
DATE	MEASUREMENT	CONDUCTIVITY AT 25 C.	TDS
July 29/72	160 umhos @ 9.6 C.	219 umhos	165
Nov. 16/72	105 umhos @ 11.4 C.	139 umhos	107
Jan. 18/73	200 umhos @ 21.0 C.	216 umhos	163
Jan. 25/73	200 umhos @ 22.5 C.	210 umhos	158
Feb. 1/73	200 umhos @ 21.3 C.	216 umhos	163
Mar. 1/73	120 umhos @ 18.4 C.	136 umhos	105
Mar. 1/73	125 umhos @ 18.7 C.	140 umhos	** 108

** TDS of outflow creek.

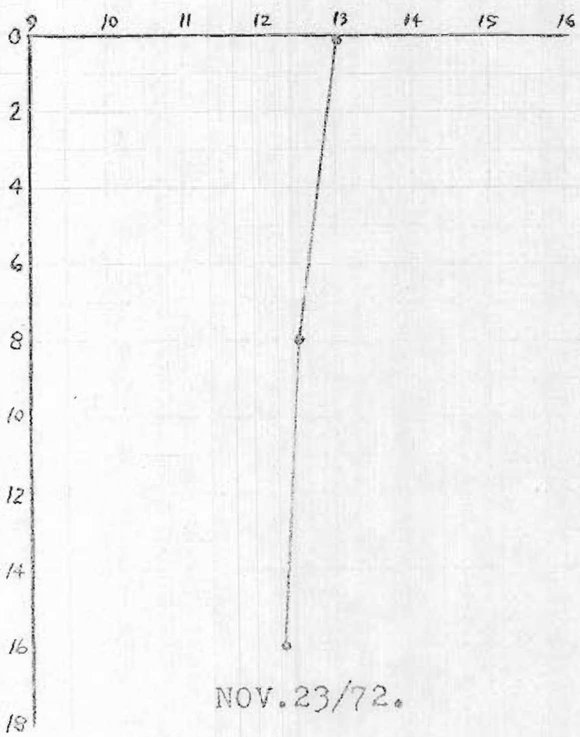
Dissolved oxygen values were high throughout the water column during the period from October to March. The minimum dissolved oxygen was recorded as 9 mg./l. at a depth of 12 feet on January 25/73. The highest values were recorded in late October and early March. A dissolved oxygen concentration of 14-16 mg./l. was noted at these times. The inflow creek water had a D.O. value of 12 mg./l. on February 15. The outflow creek had a low D.O. of only 7 mg./l. on March 1. The vertical distribution of dissolved oxygen showed slightly clinograde curves during this period. Several profiles were completely isoxy. The minimum D.O. of the bottom water during summer is probably less than 0.5 mg./l. This is typical of many of the local lakes whose bottom waters become anoxic for several months during the summer. Elk Lake was anoxic at 18 métres from July 18 to late October of 1972 (Sharon D. Brown data).

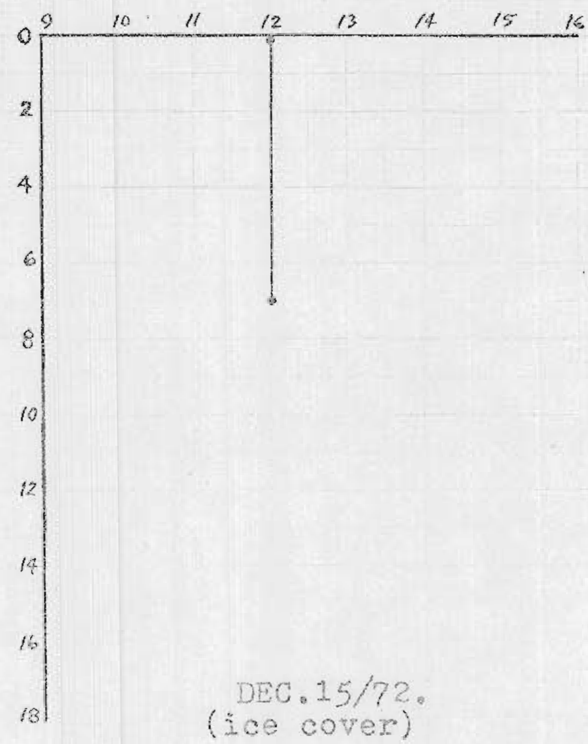
The basic relationship between temperature and dissolved oxygen is inversely proportional. As temperature decreases, dissolved oxygen increases. Percent saturation values were determined using a nomogram. The highest value was 135 % on October 26, with another maximum of 120 % on March 1. The lowest value was about 70 % on December 15 during the first period of ice cover. The higher percentages observed both early and late in the study are likely the result of reasonably high phytoplankton productivity. The period of ice and snow cover would reduce the available light and therefore decrease the productivity of the phytoplankton. Also, the effect of the wind in stirring the lake waters and of introducing oxygen into the surface layers would be negated.



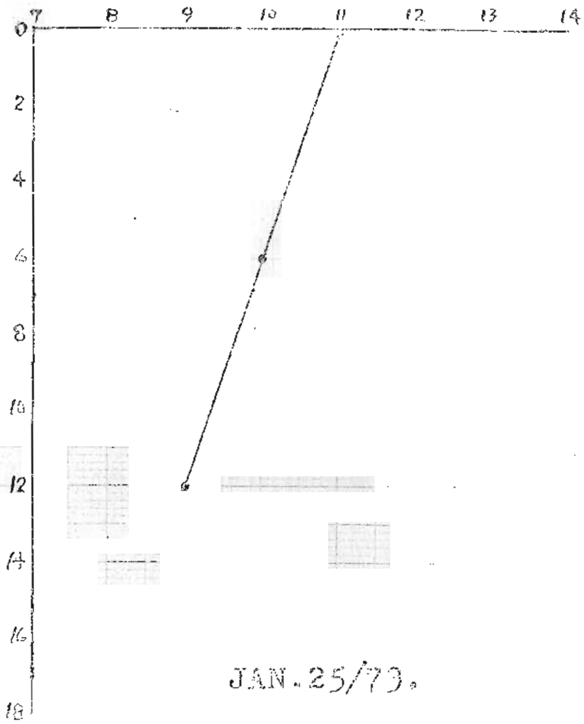


(DEPTHS IN FEET & DISSOLVED OXYGEN VALUES IN mg./l.)

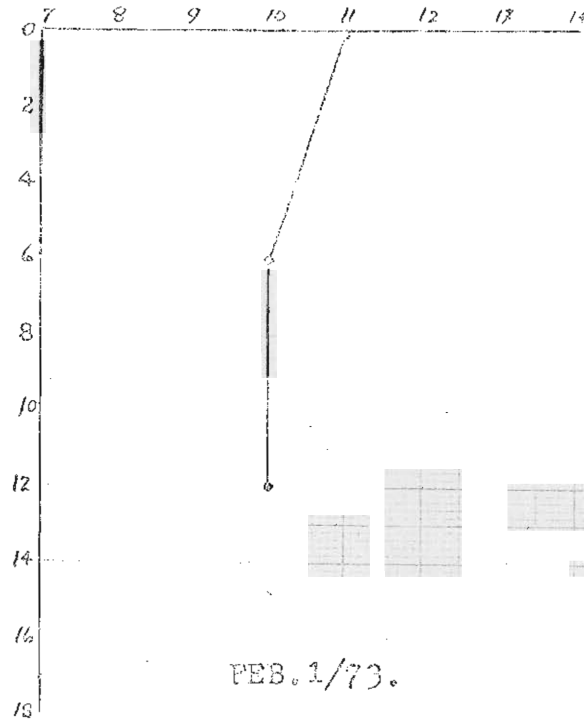




(DEPTHS IN FEET & DISSOLVED OXYGEN VALUES IN mg./l.)

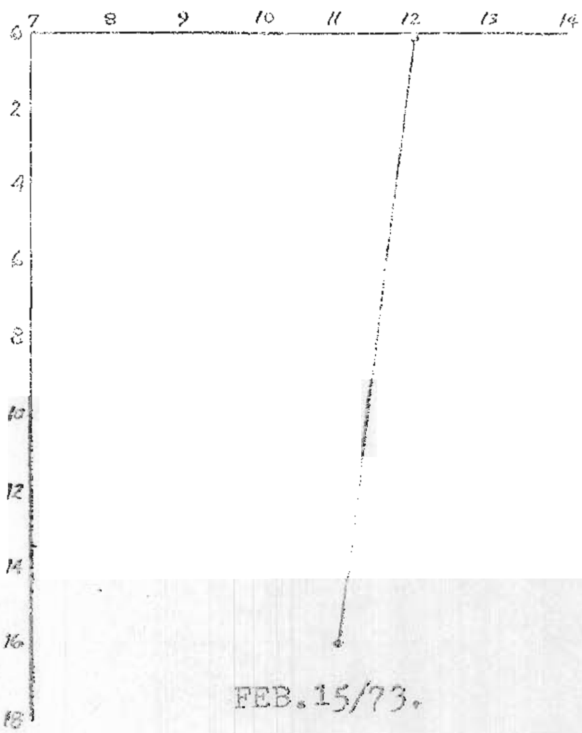


JAN.25/73.

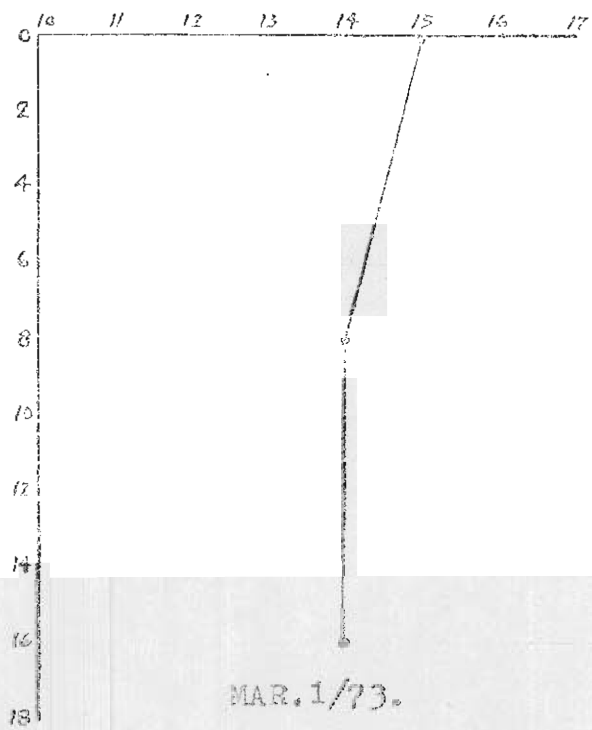


FEB.1/73.

(DEPTHS IN FEET & DISSOLVED OXYGEN VALUES IN mg./l.)



FEB.15/73.



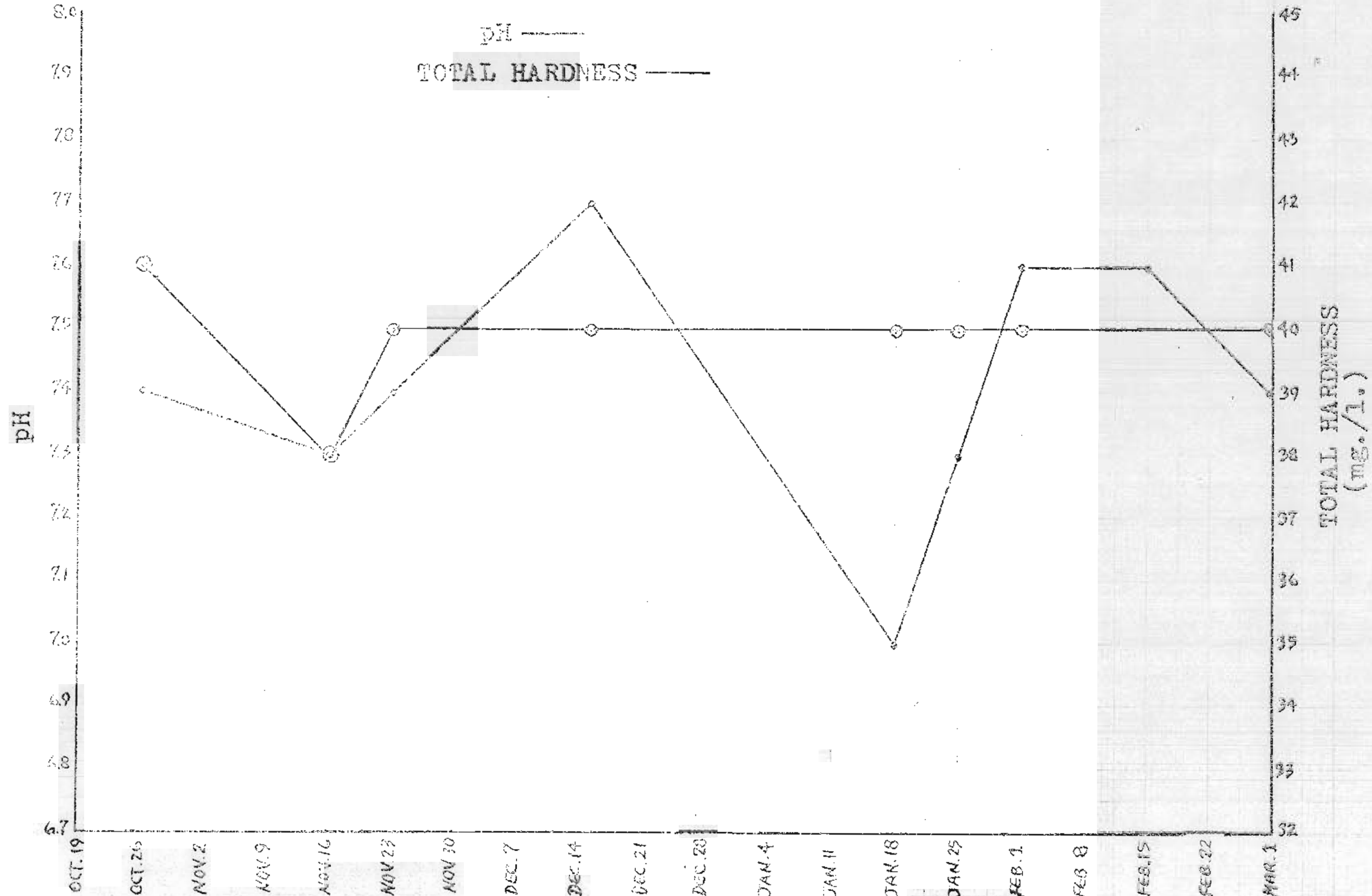
MAR.1/73.

(DEPTHS IN FEET & DISSOLVED OXYGEN VALUES IN mg./l.)

Lake pH, a measure of the degree of alkalinity or acidity, can be used to determine the relative degree of productivity as carbon fixation. This is supported by the high surface pH of 8.5 noted on July 29/72. The graph on the following page shows the seasonal changes in pH. The maximum value recorded during the study was 7.7 on December 15 and was associated with a period of ice cover. It seems that the ice cover has affected the pH balance of the lake for some unknown reason. (Another reason could be the apparent inaccuracy (at times) of the Hach DR-EL Laboratory Kit used to measure the various chemical parameters.) The lowest lake pH was 7.0 (neutral) recorded on January 18.

The graphed values are lake surface pH and are fairly typical of the pH for the whole water column. However, the bottom water usually had a slightly greater pH than the surface by some 0.1 to 0.4 units. A low pH of 5.6 was measured in the bottom water on October 26. This may be correct or it may likely be an error in procedure or reading. The inflow creek had a pH of 7.5 on February 15 and the outflow creek a pH of 6.3 on March 1. The low pH of the outlet is associated with a low dissolved oxygen of 7 mg./l.

Total hardness and Calcium hardness were very consistent during the five months. Total hardness was always near 40 mg./l. and Calcium hardness around 30 mg./l. Hardness of the bottom waters was equal to, or slightly less, than those of the surface. July 29/72 values showed a total hardness of 34 mg./l. and a Calcium hardness of 27 mg./l. It appears that the hardness of Florence Lake does not vary much during any part of the year. Increased hardness is positively correlated with productivity (Hutchinson, 1957).

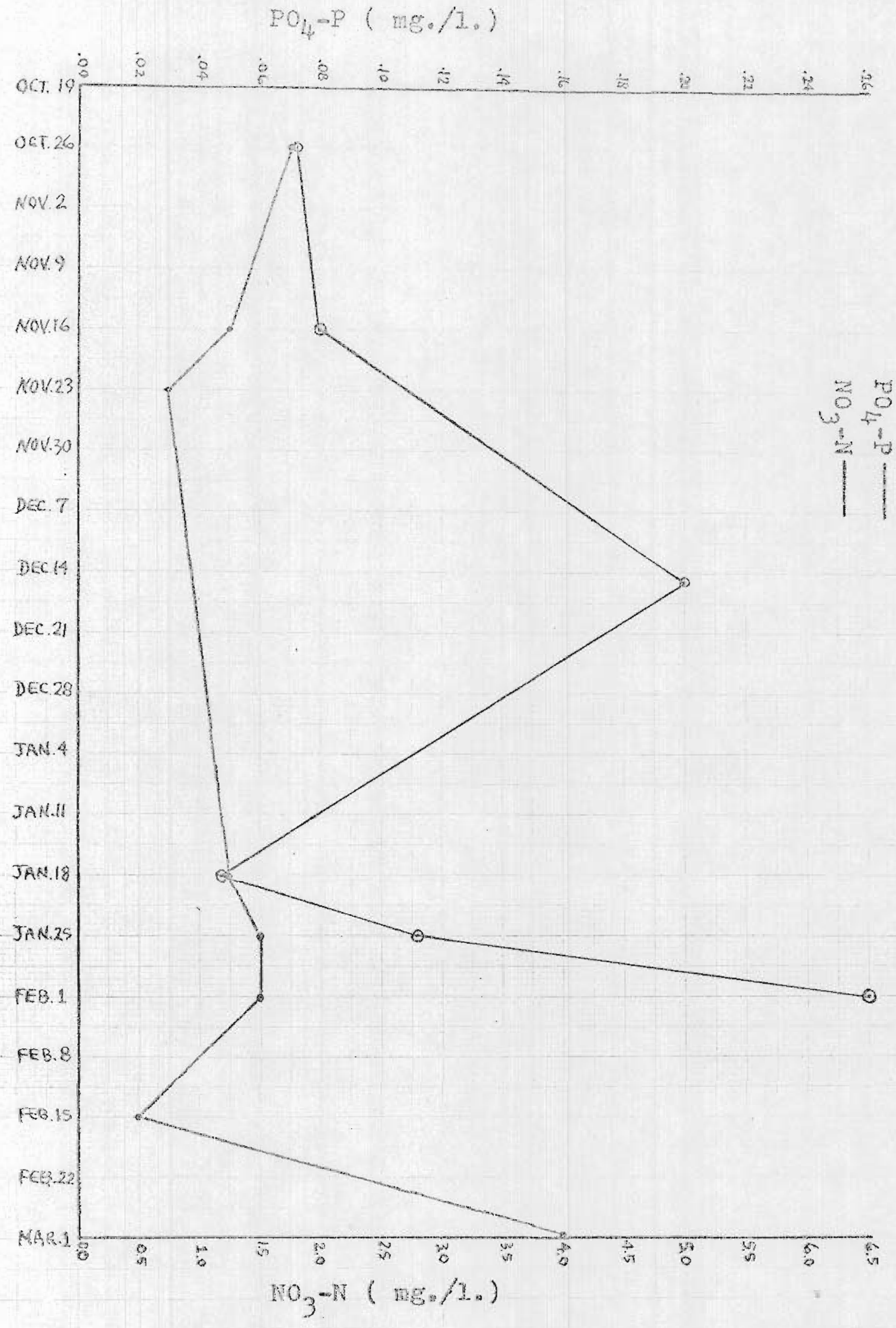

pH
TOTAL HARDNESS
pH
TOTAL HARDNESS
(mg./l.)
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
45
44
43
42
41
40
39
38
37
36
35
34
33
32
OCT. 19
OCT. 26
NOV. 2
NOV. 9
NOV. 16
NOV. 23
NOV. 30
DEC. 7
DEC. 14
DEC. 21
DEC. 28
JAN. 4
JAN. 11
JAN. 18
JAN. 25
FEB. 1
FEB. 8
FEB. 15
FEB. 22
MAR. 1

The inflow creek had a total hardness of 50 mg./l. and a Calcium hardness of 36 mg./l. on February 15. The outflow creek had hardness values close to those of the lake waters. The total hardness was 40 mg./l. and the Calcium hardness 25 mg./l.

Total alkalinity was very high in October and dropped to low values between December and March. On October 19, total alkalinity was 110 mg./l. and on October 26 it was 113 mg./l. The July 29 value was 49 mg./l. According to Russel-Hùnter (1970), the alkalinity of lake waters is increased during "blooms" and decreases when productivity is low. This explains the above differences. It is likely that the productivity was fairly low during mid-summer because of nutrient depletion and hence the lower total alkalinity. During the weeks of October, the fall "bloom" was likely near its peak and therefore a high alkalinity was observed.

By December 15, total alkalinity had decreased to only 38 mg./l. and remained close to this value throughout the succeeding months. The inflow creek had a slightly higher alkalinity (as would be expected) than the lake. A value of about 50 mg./l. was measured on February 15. The outflow creek had a total alkalinity of 32 mg./l. on March 1/73.

Phosphorus (ortho-phosphate) is probably the major limiting nutrient of lake waters and varies considerably over short periods of time (Hutchinson, 1957). Ortho-phosphate concentrations varied between 0.02 and 0.07 mg./l. during the months from October to February. A high of 0.07 mg./l. was measured on October 26 and a maximum of 0.16 mg./l. was measured on March 1. These are surface values - bottom water values were sometimes slightly more and sometimes slightly less than



PO$_4$-P (mg./1.)
.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26
OCT. 19
OCT. 26
NOV. 2
NOV. 9
NOV. 16
NOV. 23
NOV. 30
DEC. 7
DEC. 14
DEC. 21
DEC. 28
JAN. 4
JAN. 11
JAN. 18
JAN. 25
FEB. 1
FEB. 8
FEB. 15
FEB. 22
MAR. 1
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5
NO$_3$-N (mg./1.)
PO$_4$-P
NO$_3$-N

those of surface waters. The October 26 and March 1 values are both associated with similar conditions. Phosphate cycling is a bacterial decomposition process and therefore the concentrations of ortho-phosphate are dependent upon the rate of release from the sediments as well as the rate of uptake by the phytoplankton. Although the water was fairly warm on October 26, the phytoplankton probably used the greater portion of phosphate released from the sediments on turn-over. The March 1 water temperature showed a slight warming over that of the previous weeks and the rapid rise in phosphate must be associated with a release from the sediments. It is not due to surface loading because the concentrations in the inlet were very low - 0.004 mg./l. Phosphates may again be released when the bottom waters become anoxic. The removal of oxygen allowing a chemical change of insoluble ferric phosphate to soluble ferrous phosphate (Tucker, 1957).

Nitrogen, probably the second-most primary limiting nutrient (behind phosphate), showed considerable variation. Nitrate-nitrogen increased steadily during the period October 26 to December 15. This may be expected after a fall "bloom" and would be due largely to bacterial regeneration of the nitrate and its subsequent circulation throughout the lake waters. Concentrations were generally greater in the bottom waters as would be expected from the sites of regeneration. The peak of 5.0 mg./l. nitrate-nitrogen on December 15 is associated with the first period of ice cover. The ice cover, itself, may have been responsible for the high value in some manner.

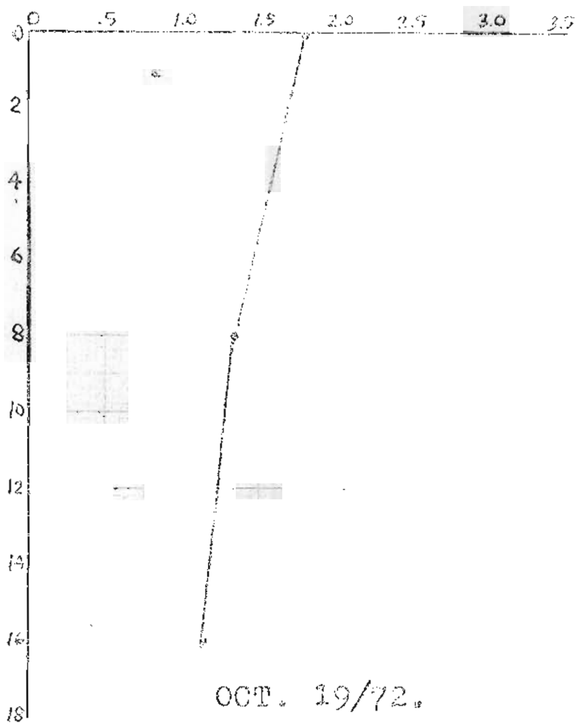
A minimum value was recorded on January 18 and the following two weeks produced steadily increasing concentrations. The maximum was 6.5 mg./l. nitrate-nitrogen recorded on February 1/73. If the decrease from December to January is significant, it may have been caused by a faster flushing rate during ice cover? during this time compared to that of October and November. It may also have been associated with a minor plankton bloom during the cold, sunny weather of this period.

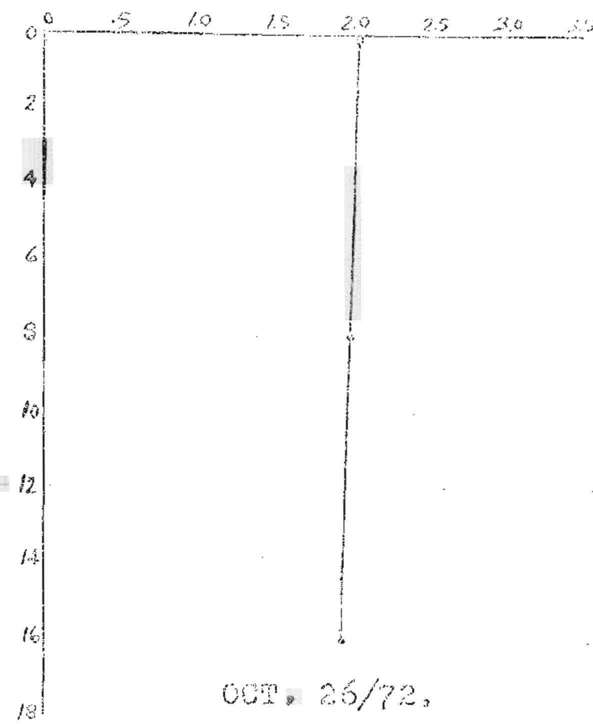
The period of increase during late January and early February may be due to the highest flushing rate of the year. Inflow creek concentrations measured on February 15 were 3.5 mg./l. Bacterial regeneration would account for the remainder of the increase.

Nitrite-nitrogen values were always low during the October to March period. The highest value measured for lake water was 0.004 mg./l. On February 15, the inflow creek had a concentration of 0.01 mg./l. nitrite-nitrogen.

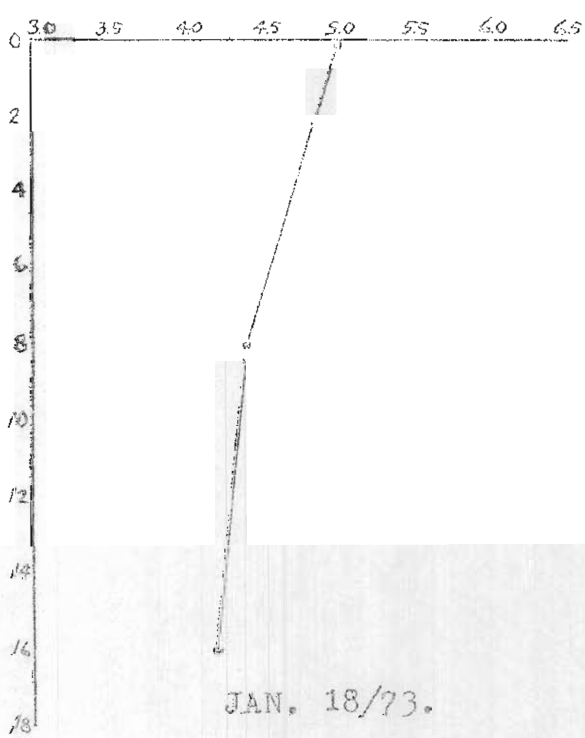
Silicate concentrations, important and even limiting in the production of diatoms, were always above the critical level. Lund (in Hutchinson, 1957) noted that Asterionella production was limited at silicate concentrations below 0.5 mg./l. The minimum value recorded in Florence Lake was 0.80 mg./l. It appears that silicate is non-limiting for diatoms during the months October to March in Florence. The inflow creek concentrations were 1.40 mg./l. on the 15th. of February and the lake waters showed a value of 0.80 mg./l. on this same day. The December 15 (under ice) silicate measured 1.60 mg./l.

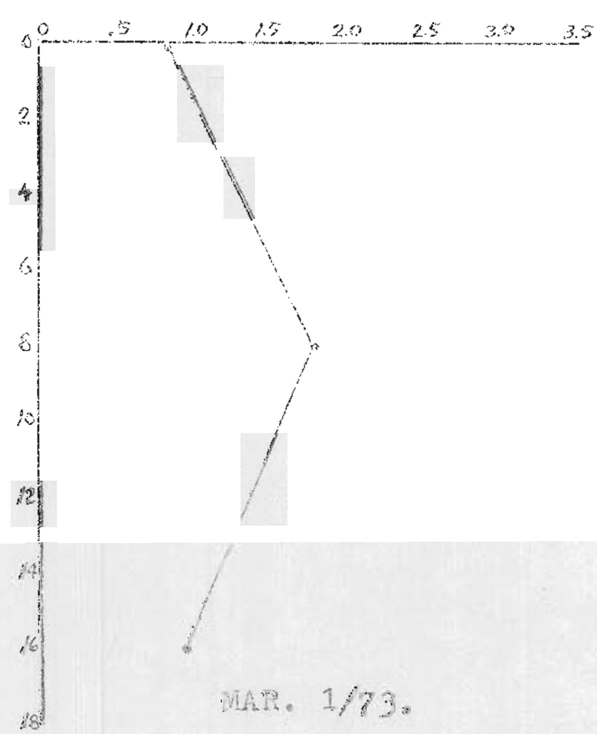
The following page shows some vertical profiles of silicate concentrations. Values were always less near the bottom and showed steadily decreasing concentrations from the surface. March 1 was a noteable exception - the highest value being recorded at mid-depths. The maximum concentration during the study was 5.0 mg./l. on January 18.





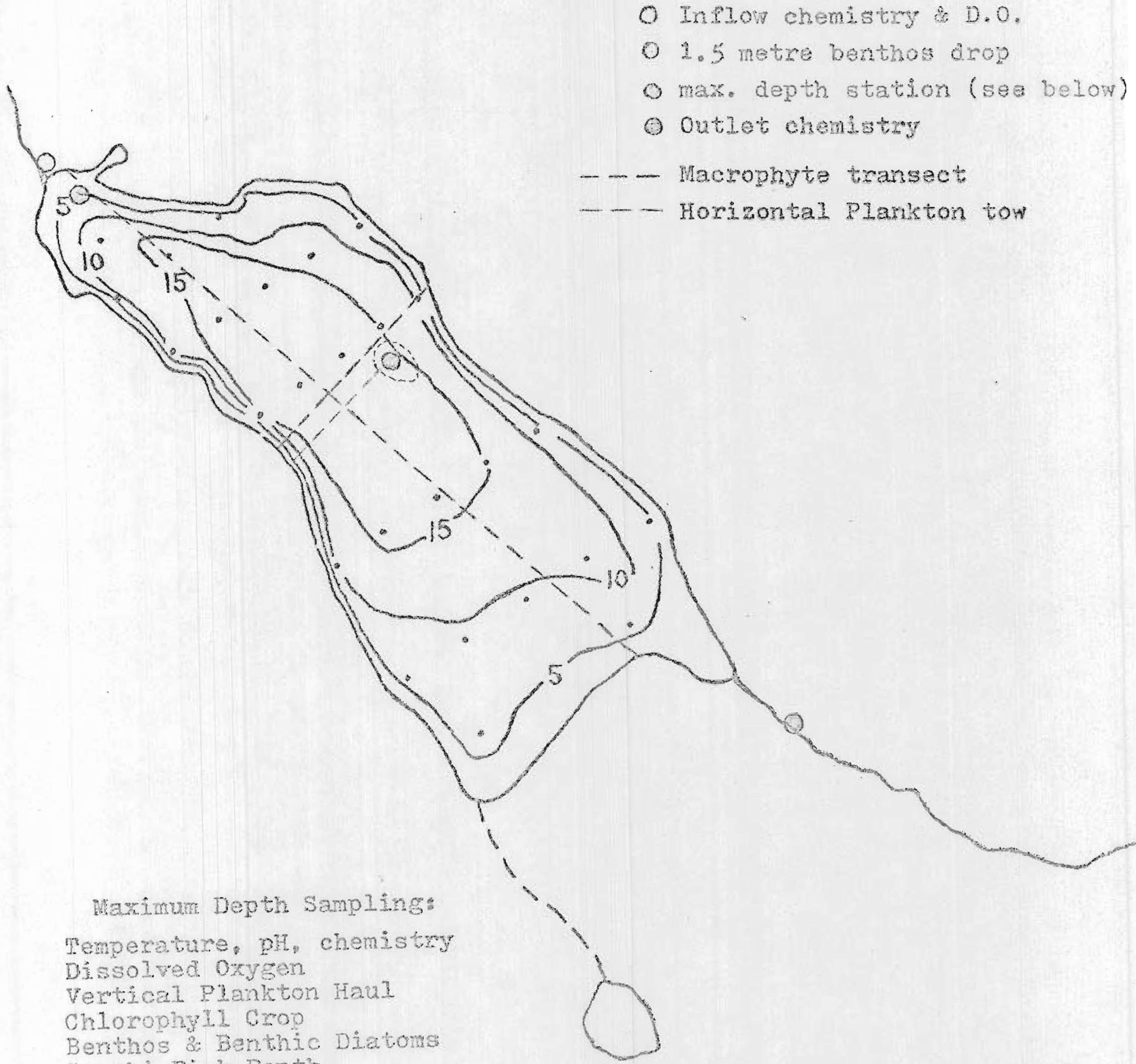
(DEPTH IN FEET & SILICATE CONCENTRATIONS IN mg./l.)





(DEPTH IN FEET & SILICATE CONCENTRATIONS IN mg./l.)

SAMPLING SITES & STATIONS



Maximum Depth Sampling:

Temperature, pH, chemistry
Dissolved Oxygen
Vertical Plankton Haul
Chlorophyll Crop
Benthos & Benthic Diatoms
Secchi Disk Depth

CHLOROPHYLL CROP & PRODUCTION

For three consecutive weeks in mid-winter (Jan.18, Jan.25, and Feb.1) water samples were taken at the surface, 3, 6, 9, and 12 feet to be analyzed for chlorophyll 'A' concentrations. Various volumes were filtered (see following table) through Millipore filters under a vaacum pressure. The filters were kept in a dark bottle in a freezer until they were used for the chlorophyll extraction on February 8/73.

Extinctions were measured at 750 mu for turbidity correction and at 663, 645, and 630 mu for determining the chlorophyll values. A 1 cm. cell-path length was used for the extinction measurements in a Spectronic 20 spectrophotometer. Only chlorophyll 'A' values are reported. This is because chlorophyll 'B' and 'C' values are much less accurate under this technique. The equation for chlorophyll 'A' from the extinction values is: Chlorophyll 'A'= $11.64\ e_{663} - 2.16\ e_{645} + 0.10\ e_{630}$. This must then be corrected for the extract volume, filtered volume, and cell length.

The chlorophyll concentrations in mg./m.^{3} were then plotted versus depth on graph paper in order to determine crop and production. Because of the low degree of chlorophyll stratification during this time of year, Vollenweider's 0.53 $P_{max.}$ method of crop calculation could not be used. Instead, a modification of the above method was employed. This involved using a polar planimeter to determine the area under the crop curve as far down as the estimated compensation depth, which was calculated as Secchi disk depth plus 10 %. Appendix #2 shows the calculations of both chlorophyll 'A' crop and production from this method.

The crop and production figures were calculated not from the

Cell-to-Cell Blank: *****

CHLOROPHYLL ANALYSIS

Lake: FLORENCE Date: FEB.8/73. -ANALYSIS. Cell Length 1 CM.

Station: MAX. DEPTH

	Filter No.	Vol. Filt.	Vol. Extr.	Depth	** 750 *	Extinction mu 663	645	630	Chlorophyll µg/l (CHL."A")
JAN.18/73.	1	500	6.90	0.5		.042	.009	.010	6.49
	2	500	7.00	3.0		.040	.004	.007	6.41
	3	500	5.00	6.0		.066	.018	.021	7.31
	4	500	5.30	9.0		.051	.009	.008	6.10
	5	500	6.50	12.0		.077	.019	.021	11.15
JAN.25/73.	6	800	6.60	0.5		.045	.006	.008	4.22
	7	800	6.40	3.0		.073	.018	.018	6.50
	8	800	6.80	6.0		.073	.013	.015	7.00
	9	800	4.70	9.0		.093	.027	.028	6.03
	10	800	4.50	12.0		.071	.018	.020	4.44
FEB.1/73.	11	850	6.50	0.5		.077	.020	.020	6.54
	12	850	6.50	3.0		.076	.016	.016	6.51
	13	850	6.60	6.0		.086	.022	.024	7.42
	14	850	6.20	9.0		.081	.019	.020	6.59
	15	850	6.90	12.0		.069	.019	.021	6.20

*** EXTINCTION VALUES HAVE BEEN CORRECTED FOR 750 mu ABSORPTIONS AS WELL AS THE CELL-TO-CELL BLANKS. (DEPTHS IN FEET AND VOLUMES IN MILLILITRES.)

Calculations:

Subtract 750 readings from all others.

$$\text{Chlorophyll A} = 11.64e_{663} - 2.16e_{645} + 0.10e_{630}$$

$$\text{Chlorophyll in } (\mu g/l) = \frac{\text{Chlorophyll A} \times \text{vol extract (ml)}}{\text{volume filtered (L)}} \div \text{Cell length (cm)}$$

observed data points, but from a least squares cubic polynomial equation fitted to the data points. The three graphs with the observed (circled data points) and expected curves follow on the next three pages. The cubic polynomial equations for the three weeks data are:

January 18/73 $Y = 5.809 + 1.087x - 0.276x^2 + 0.018x^3$

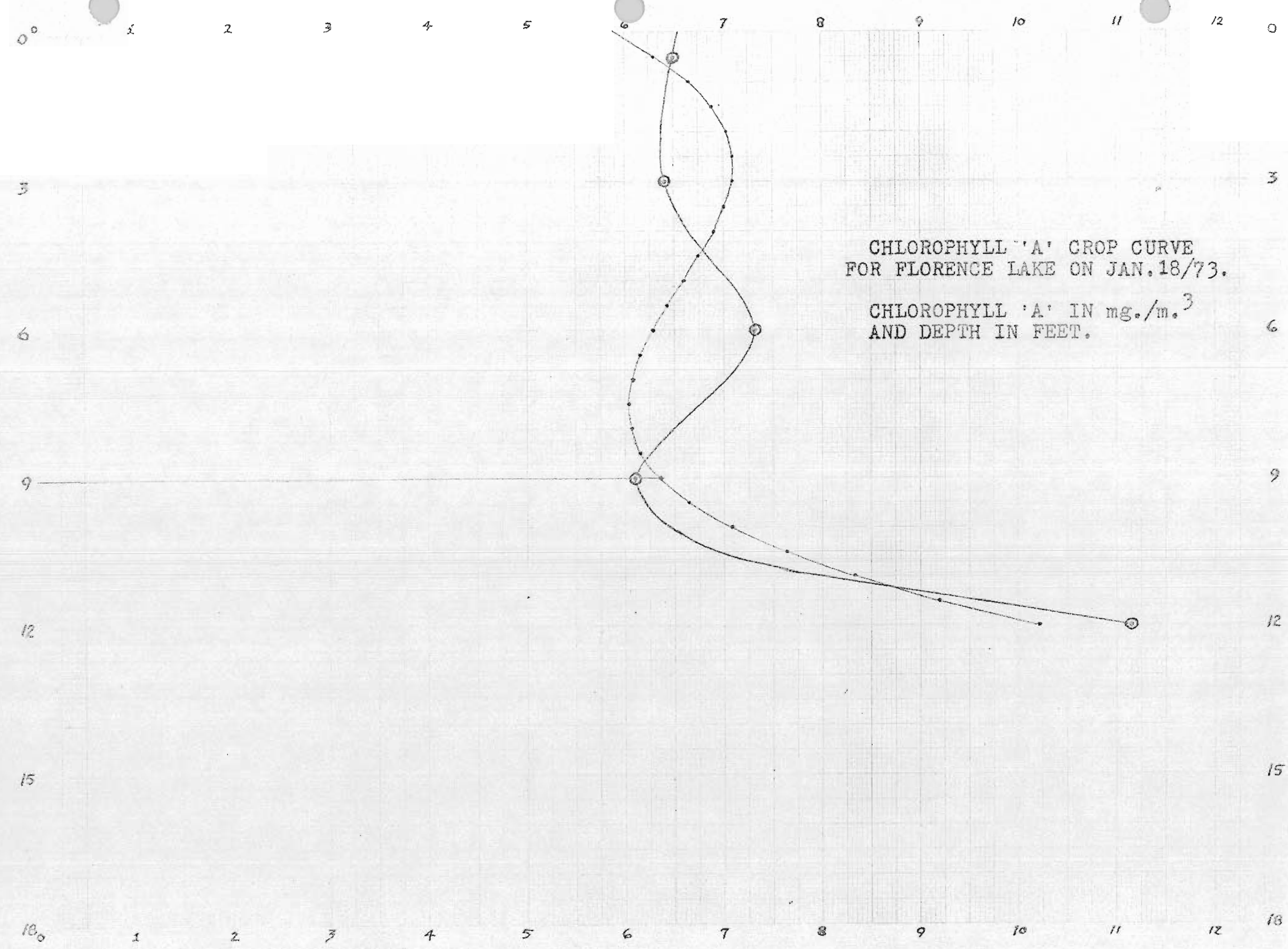
January 25/73 $Y = 3.518 + 1.502x - 0.188x^2 + 0.006x^3$

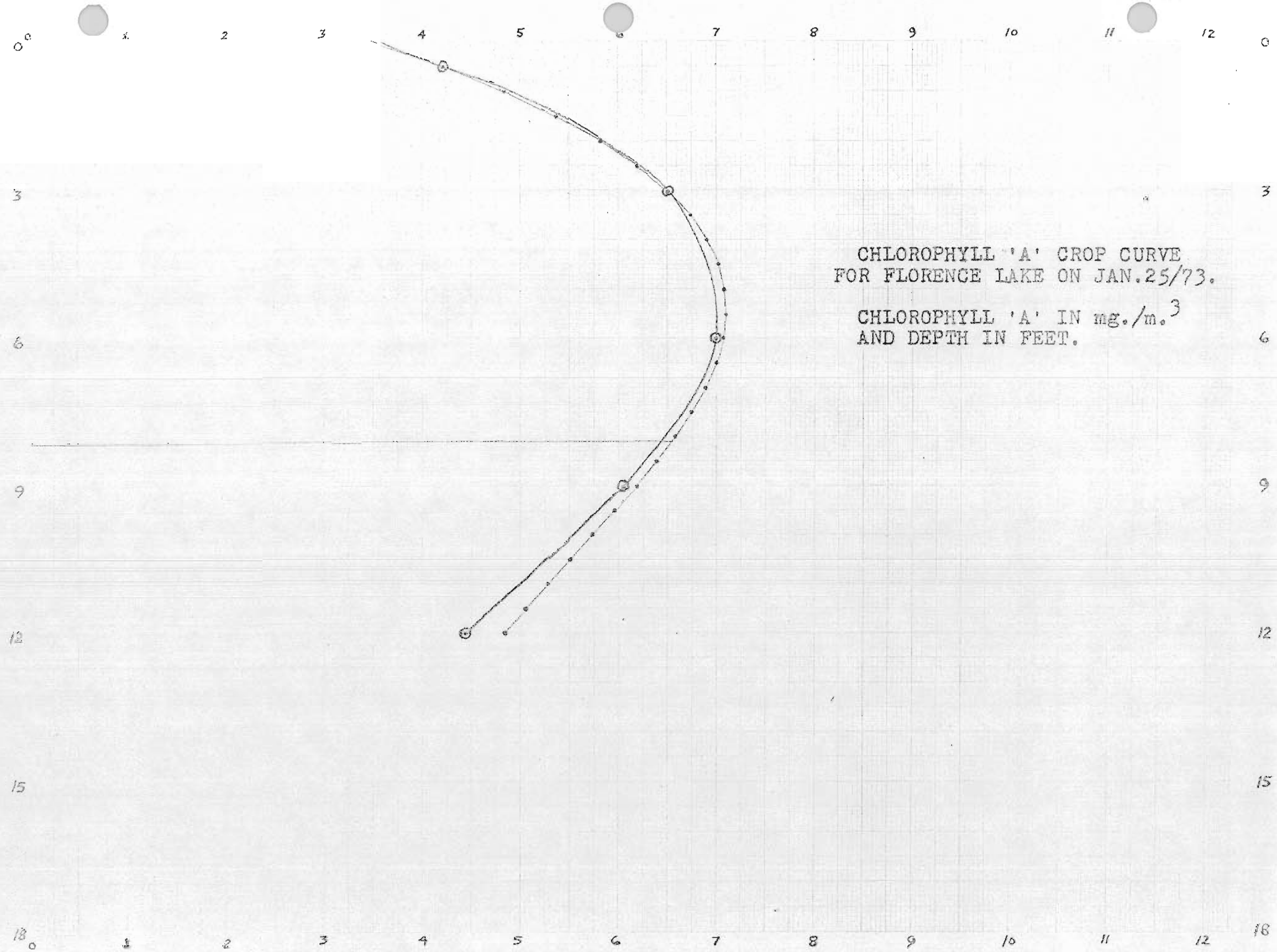
February 1/73 $Y = 6.371 + 0.163x - 0.003x^2 - 0.001x^3$

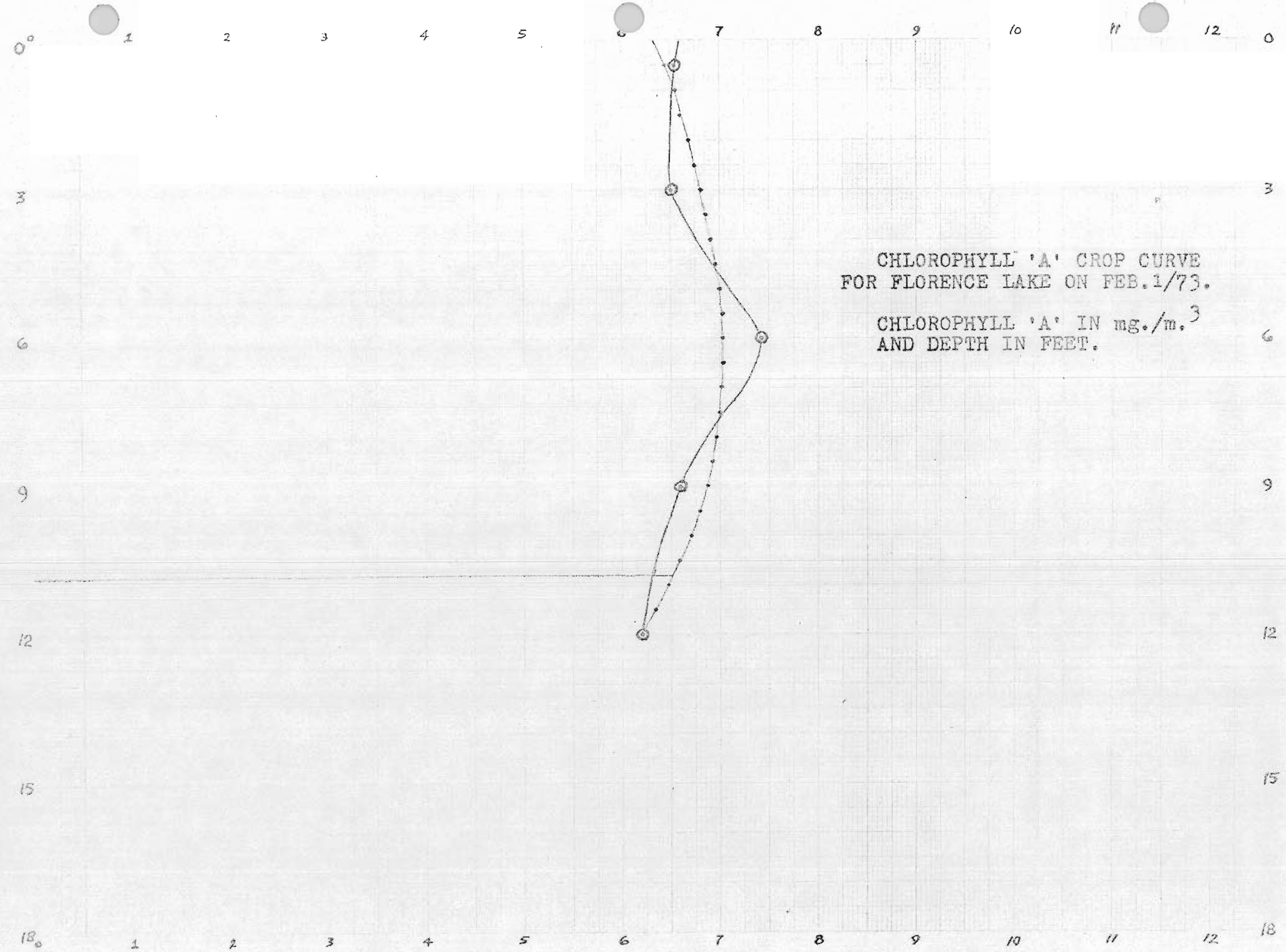
The chlorophyll 'A' crop in mg. chlorophyll 'A'/m.^{2} for the three weeks were: January 18 (17.92), January 25 (15.47), and February 1 (22.42). This works out to an average chlorophyll 'A' standing crop of 18.54 mg./m.^{2} for the three week period. It must be remembered, however, that all of these values have not been corrected for phaeophytins - the chlorophyll degradation products. According to Paul Rankin (personal communication) these accounted for at least 50 % of the extinction values he got for Prospect Lake. A similar situation probably exists for Florence Lake.

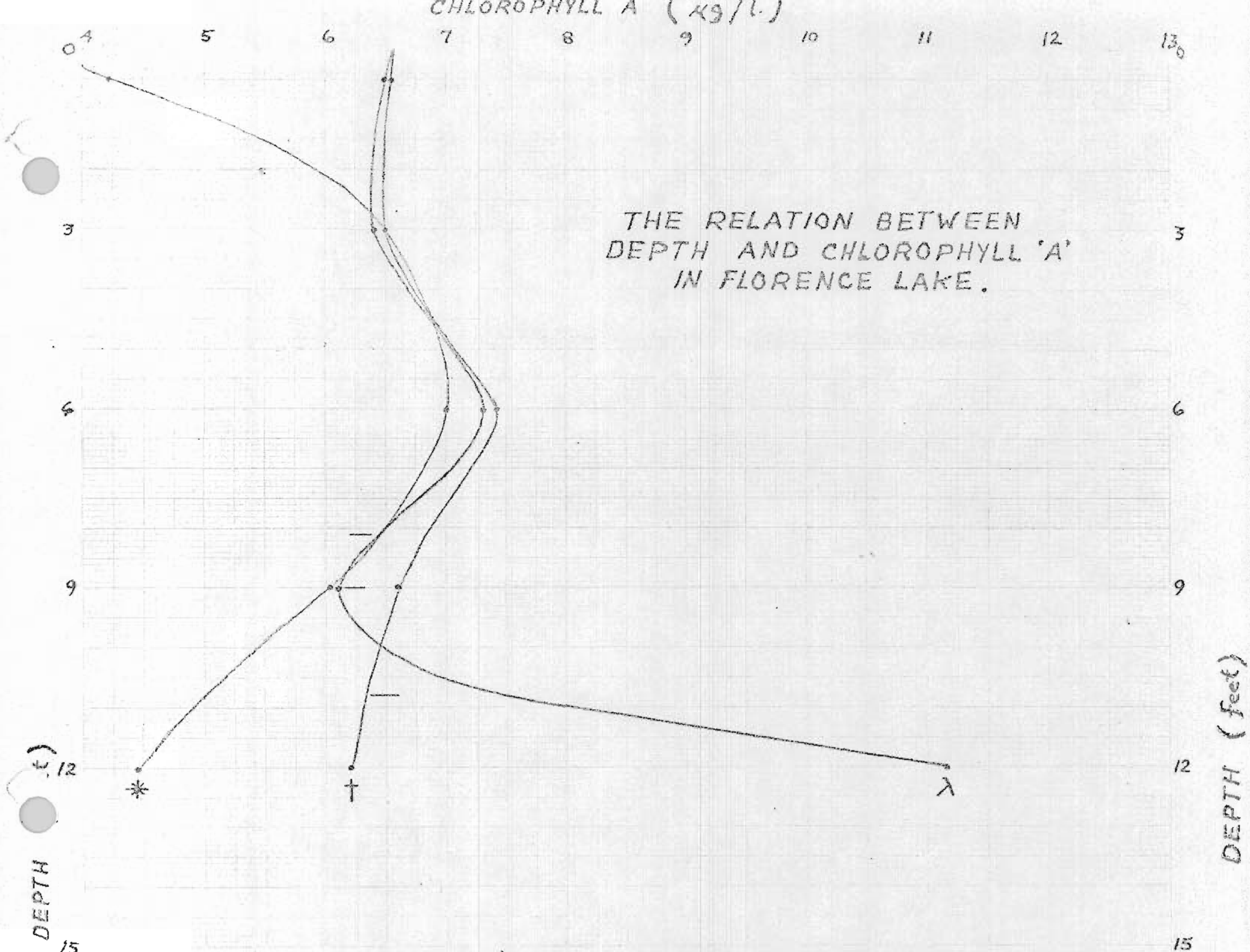
Primary production has been calculated empirically from the crop values, and not from experimental production data. It has been estimated (lab manual) that 1 mg. chlorophyll 'A' is equivalent to about 17.3 mg. carbon or 35 mg. of dry organic matter. This conversion factor is utilized in calculating the 'potential' primary production during the three weeks. The productivity in gm.C/m.^{2}/day for the three weeks was: January 18 (0.310), January 25 (0.268), and February 1 (0.388). This represents an average 'potential' production of 0.322 gm.C/m.^{2}/day for the three week period.

The above values for both crop and production are greater than


CHLOROPHYLL 'A' CROP CURVE
FOR FLORENCE LAKE ON JAN.18/73.
CHLOROPHYLL 'A' IN mg./m.3
AND DEPTH IN FEET.
0 1 2 3 4 5 6 7 8 9 10 11 12
0 3 6 9 12 15 18


CHLOROPHYLL 'A' CROP CURVE
FOR FLORENCE LAKE ON JAN.25/73.
CHLOROPHYLL 'A' IN mg./m.3
AND DEPTH IN FEET.
0
1
2
3
4
5
6
7
8
9
10
11
12
0
3
6
9
12
15
18


CHLOROPHYLL 'A' CROP CURVE
FOR FLORENCE LAKE ON FEB.1/73.
CHLOROPHYLL 'A' IN mg./m.3
AND DEPTH IN FEET.



λ	JAN. 18/73	SECCHI DISK DEPTH	8.2′
		COMPENSATION DEPTH	9.0′
*	JAN. 25/73	SECCHI DISK DEPTH	7.4′
		COMPENSATION DEPTH	8.1′
†	FEB. 1/73	SECCHI DISK DEPTH	9.8′
		COMPENSATION DEPTH	10.8′

18

those of Swan, Big Maltby, and Prospect lakes over the same time interval. Only Langford Lake had greater crop-production values. According to Hargrave (1969), Marion Lake in the Haney Research Forest has an annual phytoplankton production of 8 gm.C/m.^{2}, or an average daily production of 0.022 gm.C/m.^{2}. This low value attests to the low productivity of the lake and hence to its oligotrophic character. If one subtracts 50 % of the Florence Lake productivity value as being due to the failure to correct for phaeophytins, and assumes that the three week period is representative of average daily production, then the annual primary production of phytoplankton is approximately 58.8 gm.C/m.^{2}. This is about 7 times that of Marion Lake and would definitely be considered as representing eutrophic conditions.

Parsons et al (1972) have shown that phytoplankton productivity doubled to 12 gm.C/m.^{2} per year from 6 gm.C/m.^{2} per year in Great Central Lake, a large oligotrophic lake located northwest of Port Alberni on the west coast of the Island. It is apparent, at least in this case, that Florence Lake has a higher phytoplankton productivity than even an oligotrophic lake undergoing controlled fertilization.

PHYTOPLANKTON

PHYTOPLANKTON

Both vertical and horizontal plankton tows were taken with a #25 Rigosha net. A total of 47 species were identified from the horizontal tows. Four species were present in the vertical tows which were absent from the surface tows. These included Stauroneis phoenicentron, Pediastrum araneosum, Scenedesmus sp., and Cosmarium sp., and were all present in the October samples before being replaced by the winter species. A grand total of 51 species were sampled over the five month period.

Of the species present in both the vertical and horizontal tows, the following genera were more abundant in the vertical samples: Nitzschia, Aphanocapsa, and Spirulina. The latter two are members of the Cyanophyceae. The succeeding two pages show in tabular form, the changes in abundance of the plankton taken in the horizontal tows during the period October 19 to March 1.

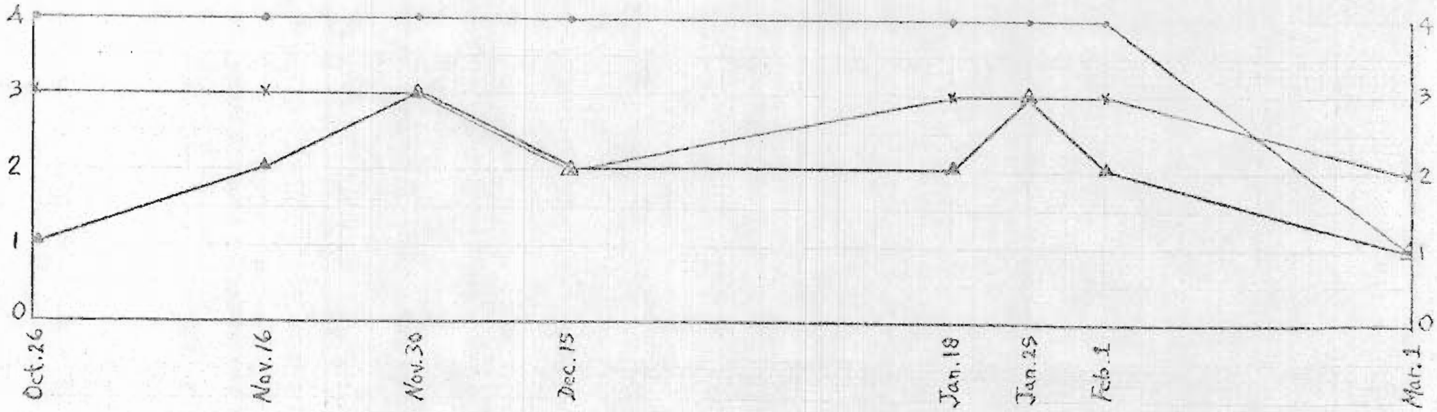
Species which were abundant or dominant for any time included Oscillatoria sp., Spirogyra sp., Tabellaria fenestrata, Tabellaria flocculosa, Ankistrodesmus falcatus, Synura uvella, and Dinobryon divergens. Over the five months, one could say that a Tabellaria - Dinobryon association existed, as these were the two dominant genera.

Oddly enough, these two genera are classified by Rawson (1956-b) as being characteristic of oligotrophic conditions. None of his species indicating eutrophy were even common at any time during the lake study. Using the ecologically dominant species of phytoplankton, a provisional classification based on community types can be formulated. Hutchinson's (1967) system is followed closely. Over the five month

PHYTOPLANKTON - HORIZONTAL TOW

	OCT.19/72	OCT.26/72	NOV.16/72	JAN.18/73	JAN.25/73	FEB. 1/73	MAR. 1/73
CYANOPHYCEAE:							
Anabaena limnetica	-	R	-	-	-	-	-
Aphanocapsa sp.	R	R	-	R	R	R	R
Coelosphaerium naegelianum	-	-	R	-	-	-	-
Oscillatoria sp.	R	C	A	C	R	C	R
Spirulina sp.	-	-	-	R	R	R	R
Tolypothrix sp.	-	-	-	R	R	R	-
CHRYSOPHYCEAE:							
Dinobryon divergens	C	D	D	D	D	D	R
Mallomonas caudata	-	-	-	-	R	-	-
Synura uvella	-	-	-	A	A	A	D
DINOPHYCEAE:							
Ceratium hirundinella	C	C	R	-	-	-	-
Gymnodinium sp.	-	-	-	C	C	C	R
Peridinium willei	-	-	-	-	R	R	R
EUGLENOPHYCEAE:							
Euglena sp.	-	-	-	R	C	R	-
'FILAMENTOUS GREENS':							
Cladophora sp.	-	-	-	-	-	R	-
Mougeotia sp.	-	-	C	-	-	-	-
Oedogonium sp.	-	-	R	R	-	-	-
Spirogyra sp.	C	R	C	C	A	C	R
BACILLARIOPHYCEAE:							
Melosira italica	-	-	-	R	-	-	-
Stephanodiscus niagarae	-	R	-	-	-	-	-
Asterionella formosa	R	-	-	-	-	-	-
Cymbella sp.	-	-	-	-	R	R	-
Fragilaria capucina	R	-	-	-	R	-	-
Fragilaria construens	-	-	-	R	-	-	-

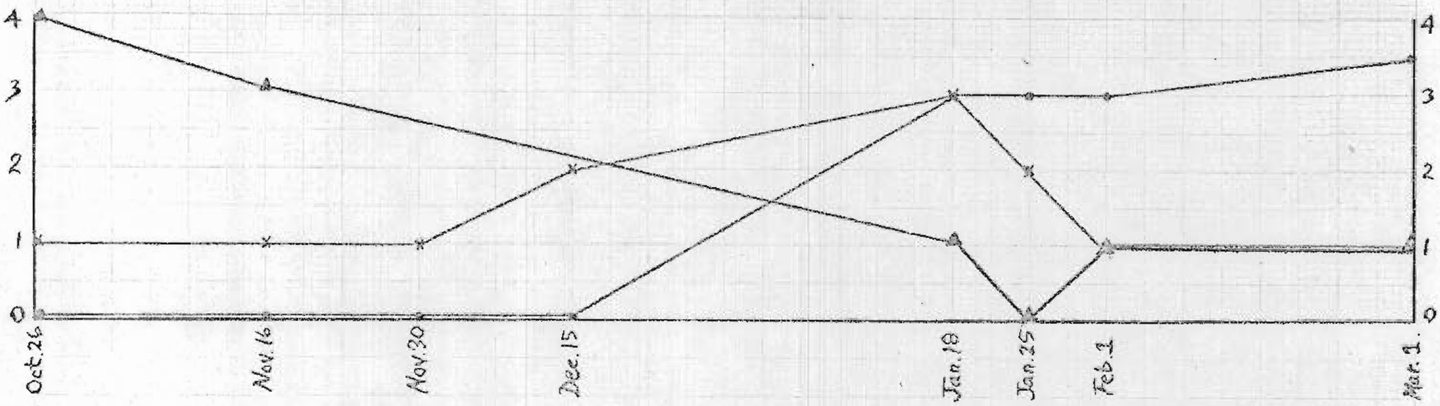
	OCT.19/72	OCT.26/72	NOV.16/72	JAN.18/73	JAN.25/73	FEB. 1/73	MAR. 1/73
BACILLARIOPHYCEAE:							
Fragilaria crotonensis	-	-	R	-	-	R	R
Fragilaria virescens	-	-	-	-	-	-	R
Gomphonema acuminatum	-	-	-	-	R	-	-
Navicula radiosa	R	R	-	R	R	-	-
Nitzschia sp.	R	R	C	R	R	R	-
Pinnularia (nobilis?)	R	-	-	-	-	-	-
Rhopalodia gibba	-	-	-	R	-	R	-
Synedra ulna	-	-	-	-	C	C	R
Tabellaria fenestrata	C	A	A	A	A	A	C
Tabellaria flocculosa	R	C	C	C	C	C	A
CHLOROPHYCEAE:							
Chlorococcales-							
Ankistrodesmus falcatus	-	R	R	A	C	R	R
Ankistrodesmus fractus	-	-	R	-	-	-	-
Crucigenia sp.	-	-	-	-	R	-	-
Micractinium? sp.	-	-	-	-	R	-	-
Volvocales-							
Eudorina elegans	-	-	-	R	-	C	R
Pandorina morum	R	R	-	-	R	-	-
Volvox aureus	-	-	-	-	R	R	R
Desmids-							
Closterium sp.	-	-	R	R	R	R	-
Hyalotheca sp.	-	-	-	-	-	R	-
Micrasterias (radiosa?)	R	-	R	-	R	R	R
Pleurotaenium trabecula	R	-	R	R	R	R	R
Staurastrum (limneticum?)	-	-	R	-	R	-	-
Staurastrum (oxyacanthum?)	R	R	-	-	-	-	-
Xanthidium sp.	-	-	-	-	-	-	R



Dinobryon divergens

Tabellaria fenestrata

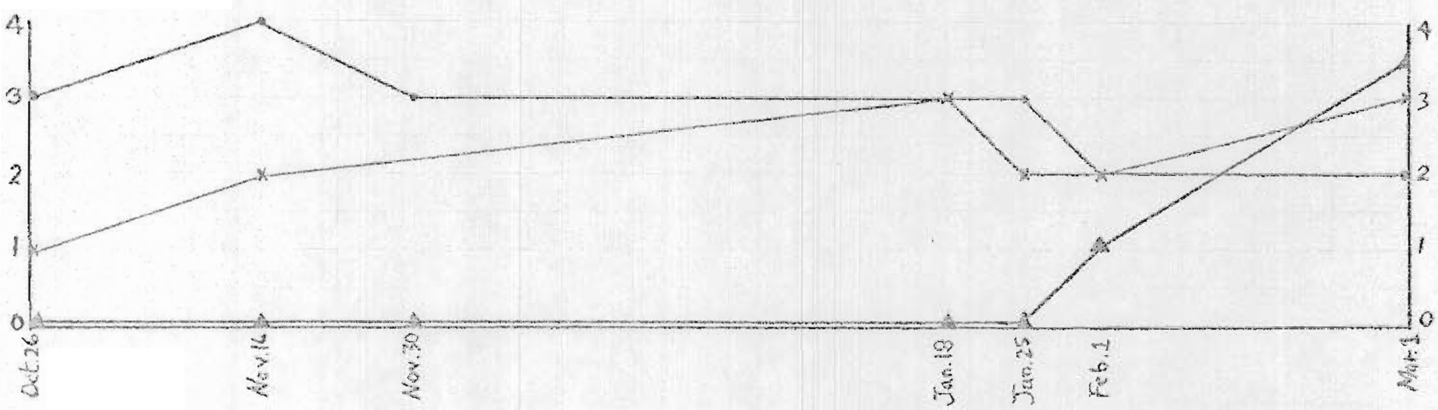
Spirogyra sp.



Synura uvella

Ankistrodesmus falcatus

Conochilus sp.



Keretella cochlearis

Cyclops sp.

Synchaeta sp.

FLORENCE: SEASONAL CHANGES IN PHYTO- AND ZOOPLANKTON DOMINANTS.

period, Florence Lake had a Chrysophycean plankton (type #4) with Dinobryon dominant, and according to Hutchinson, characteristic of nutrient-poor waters. In association with this was an Oligotrophic Diatom plankton (type #2) with Tabellaria dominant, and which Hutchinson considers usual in nutrient-poor lakes with neutral or slightly alkaline water. During this time, Florence Lake water was reasonably nutrient-poor and its pH ranged from 7.0 to 7.7.

The following page shows the seasonal changes in plankton dominance. Again, the Chrysophyceans are the most interesting. Dinobryon divergens was dominant until March 1 whereupon it had dropped to rare. Synura uvella, on the otherhand, was absent up to December 15 and subsequently increased to abundant by January 18. It remained at this level or greater through to the end of the sampling.

Nygaard's Compound Index can be applied to the number of species in various algal groups. The index is computed as the sum of the number of species of Cyanophytes, Chlorococcales, Centrales, and Euglenophyta divided by the number of species of Desmids. Values less than 1 indicate oligotrophy and values greater than 2.5 indicate eutrophy. Intermediate values are characteristic of mesotrophy or slight eutrophy. For Florence Lake, a value of $(6+4+2+1)/7$ is equal to 1.86. This is in the middle of the meso- slight eutrophic conditions. I would conclude that the index indicates Florence as slightly eutrophic.

Some physical and chemical reasons for the dominance of Tabellaria, Dinobryon, and Synura should be considered. In regards to light intensities, Edmondson (1956) noted that a large population of Dinobryon was associated with the 1 % surface light intensity at 14.5

metres in Crystal Lake, Wisconsin? Rodhe, in Hutchinson (1967) has cited the optimal range of temperature at which Dinobryon divergens is at its maximal production as between 8 and 13 degrees Centigrade. In Florence Lake, Dinobryon was present at temperatures as high as 11 degrees, but largely in the range of 4 to 6 degrees. McCombie (1953) noted a correlation of Dinobryon spring increase with rising water temperatures. He claims a range of 11 to 19 as being suitable for Dinobryon increases. It seems that no one can agree to a typical temperature range for Dinobryon species under optimal conditions.

Another correlation has been proposed (Rodhe, 1948 in Hutchinson, 1967) between Dinobryon and the concentration of ortho-phosphate in lake waters. According to Rodhe (in Hutchinson), Dinobryon divergens has an obligate low phosphorus requirement. He has produced a plankton classification based on the ortho-phosphate levels. Class I, typical of Chrysophycean plankton, has PO_4 concentrations less than 0.06 mg./l. During the majority of the five months, Florence had a PO_4 concentration of between 0.01 and 0.06 mg./l.

Hutchinson (1967) has noted that Dinobryon is inhibited by Asterionella, and that as Asterionella develops, Dinobryon declines. This seems unlikely for Florence Lake, but there is a possibility that Synura uvella may inhibit Dinobryon, based on the observed changes in abundance over the last month of sampling.

Vollenweider (1969) notes that Dinobryon has a low (2x) ratio of production at low densities to that at maximal densities. This fact may account for the lengthy period at which Dinobryon was dominant. It appears that no one hypothesis can explain the patterns observed.

BENTHIC DIATOMS

Species	# Counted	% of Total
RAPHIDIOIDINEAE:		
Eunotia pectinalis	1	0.19
MONORAPHIDINEAE:		
Achnanthes lanceolata	1	0.19
Achnanthes lapponica	5	0.95
Achnanthes (minutissima?)	4	0.76
Cocconeis placentula	5	0.95
ARAPHIDINEAE:		
Fragilaria capucina	2	0.38
Fragilaria construens	74	14.07
Fragilaria crotonensis	21	3.99
Fragilaria pinnata	13	2.47
Fragilaria vaucheriae	3	0.57
Fragilaria virescens	10	1.90
Synedra capitata *	x	x.xx
Synedra cyclopum	3	0.57
Synedra rumpens	9	1.71
Synedra (ulna?)	4	0.76
Tabellaria fenestrata	12	2.28
Tabellaria flocculosa	13	2.47
BIRAPHIDINEAE:		
Amphora libyca	1	0.19
Amphora ovalis	x	x.xx
Anomoneis vitrea	2	0.38
Caloneis limosa *	x	x.xx
Cymbella angustata	4	0.76
Cymbella caespitosa	1	0.19
Cymbella cesatii	3	0.57
Cymbella cistula	x	x.xx
Cymbella cuspidata	1	0.19
Cymbella ehrenbergii	x	x.xx
Cymbella gracilis	2	0.38

Species	# Counted	% of Total
BIRAPHIDINEAE:		
Cymbella heteropleura	1	0.19
Cymbella ventricosa	6	1.14
Diatomella balfouriana	6	1.14
Diploneis finnica *	x	x.xx
Diploneis smithii	1	0.19
Epithemia sp.1	1	0.19
Epithemia sp.2	2	0.38
Gomphonema acuminatum coronatum	2	0.38
Gomphonema constrictum	1	0.19
Gomphonema intricatum	1	0.19
Navicula bacillum	1	0.19
Navicula cryptocephala	4	0.76
Navicula cuspidata	x	x.xx
Navicula decussis	2	0.38
Navicula laevissima	4	0.76
Navicula pupula	2	0.38
Navicula radiosa	17	3.23
Navicula seminulum	8	1.52
Navicula sp.	5	0.95
Neidium iridis	1	0.19
Nitzschia (angustata?)	2	0.38
Nitzschia denticulata	3	0.57
Nitzschia (gandersheimiensis?)	6	1.14
Nitzschia linearis	2	0.38
Nitzschia palea	3	0.57
Nitzschia vermicularis	4	0.76
Pinnularia abaujensis	2	0.38
Pinnularia gentilis	1	0.19
Pinnularia nodosa	1	0.19
Pinnularia viridis	x	x.xx
Rhopalodia gibba	1	0.19
Stauroneis phoenicentron	2	0.38

Species	# Counted	% of Total
BIRAPHIDINEAE:		
Surirella (elegans?)	x	x.xx
Surirella linearis	x	x.xx
Surirella linearis constricta *	x	x.xx
Surirella splendida	x	x.xx
CENTRALES:		
Cyclotella stelligera	55	10.46
Melosira binderana	164	31.18
Melosira italica	x	x.xx
Melosira? sp.	21	3.99
Stephanodiscus niagarae *	x	x.xx

N.B. - counts made from top 2 cm. of sediment.
x = identified but not counted in random field counts.
* = observed only in deeper sediments (12-16 cm.).

Species abundance fits were applied to MacArthur's Broken Stick Model, Motomura's Geometric Series, Fisher's Log Series, and Preston's Lognormal Curve. The chi-square goodness of fit test was used to determine which of the above abundance patterns the benthic diatoms best followed. The chi-square values for all abundance models except Preston's Lognormal were greater than 150. The chi-square for Preston's Lognormal was 7.17 and the degrees of freedom were 8. The critical value for 8 degrees of freedom and P=0.01 is 21.955. Since 7.17 is less than the critical value, the diatom data is consistent with Preston's Lognormal fit at a P 0.01.

A total of 69 different diatom species were identified from the sediments in the deepest part of the lake. In the random field counts, 55 species and 526 individuals were tabulated. The breakdown by order was 240 Centrales species and 286 Pennales species. The following table shows the number of individuals per family and the percent of the total number counted:

MONORAPHIDINEAE & RAPHIDIOIDINEAE :	16	3 %
ARAPHIDINEAE:	164	31 %
BIRAPHIDINEAE:	106	20 %
CENTRALES:	240	46 %
	526	100 %

From the above table it can be seen that the Araphs and Centrales account for some 77 % of the total number of individuals counted. Of the 55 species counted, 5 were Monoraphs & Raphidioids, 11 were Araphs, 36 were Biraphs, and 3 were Centrales.

Two trophic indices have been developed and used in association with sediment diatoms. These are Nygaard's Diatom Quotient which is calculated by dividing the number of individuals of Centrales by the number of individuals of Pennales and Stockner's Diatom Quotient (or A/C Ratio) which is equal to Araphs divided by Centrales. The latter index is the more commonly used, but, as will be seen later, the former index may be more useful for local lakes.

Values greater than 0.2 for Nygaard's Quotient are indicative of eutrophic conditions. For Stockner's Quotient, values of from 0 to 1 indicate oligotrophy and greater than 2 indicate eutrophy. The A/C ratio for Florence Lake is (164/240) 0.683 ; indicating oligotrophic conditions. Because Florence is certainly not oligotrophic, this index has to be questioned - at least for warm monomictic lakes. Stockner, himself, has revised his use of the index as follows. The A/C classification does not seem applicable to shallow lakes or bogs. According to Stockner (1972), such habitats tend to be isothermal and benthic diatoms or heavily silicified Centrales usually predominate despite the trophic condition.

Other A/C values, as of February 15/73, for local lakes are: Langford (317/352) 0.90, Swan (175/238) 0.74, Big Maltby (259/357) 0.73, and Prospect (102/447) 0.23. All of these values even fail to indicate at least a mesotrophic condition. Since mere numbers of individuals did not seem to produce valid quotients, it was decided to use a relative volume basis to re-calculate the A/C ratio. The relative volumes used are those of the lab manual and of Dr. Hagmeier's interpolations. This did not appreciably raise the ratio - the new value being 0.755.

Nygaard's Diatom Quotient approximates the trophic conditions of Florence Lake much more closely than the A/C ratio. The C/P ratio is equal to (240/286) 0.839. This indicates eutrophy since the value is greater than 0.2.

Diversity of the diatom assemblages were calculated using both Brillouins and Shannon-Weiner diversity statistics. The resulting diversities were 3.88 and 4.02, respectively. These values are both indicative of a high diversity and contradict the assumption that eutrophic systems tend to have low diversities. Although diverse, the greater percentage of the diatoms were of three species. Melosira binderana, Fragilaria construens, and Cyclotella stelligera accounted for 55.71 % of the total number of individuals.

Melosira binderana was also the dominant diatom in Council and Lower Thetis lakes (Dr. Hagmeier, 1971) and Big Maltby (Feb./73).

These lakes are at the oligo-mesotrophic end of the trophic scale and it is surprising to have Melosira binderana as the dominant in Florence Lake. Cyclotella stelligera, a species Stockner (1971) found to be a dominant in the ELA lakes, was also very common in Florence. However, Asterionella formosa, a species associated with eutrophic conditions locally and elsewhere, was essentially absent - none were found in the sediments used to make the Hyrax mounts from which the species were identified and counted.

Stockner (1972) noted that numbers of Asterionella formosa were found only in those lakes with drainage basins strongly influenced by agricultural activities. The Florence watershed has little, if any, agricultural activity. He also noted that in the more oligotrophic lakes, Asterionella formosa frustules were very rarely encountered in the sediment.

A possible explanation for the above has been suggested by Hawthorn & McCormick (1972), who relate the definite competition or interactions between the macrophytes and phytoplankton. Lakes with large macrophyte crops (ie. Florence) may have reduced phytoplankton crops and they may perhaps be more oligotrophic in nature than would be expected by other variables.

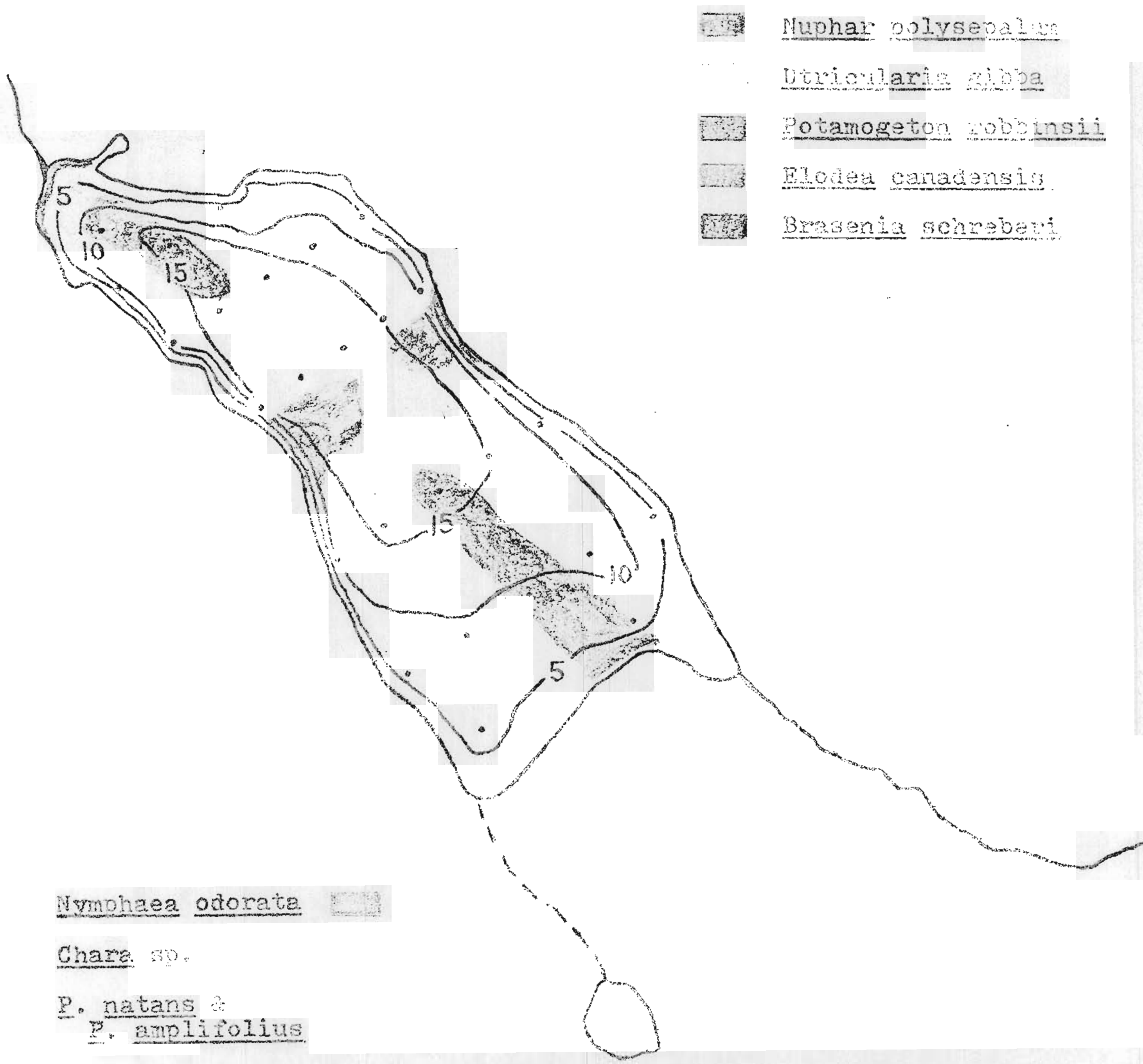
MACROPHYTES

Nine different macrophyte species were identified from Florence Lake. These include *Brasenia schreberi* (Watershield), *Elodea canadensis* (Waterweed), *Utricularia gibba* (Bladderwort), *Chara* sp., *Nuphar polysepalum* (Yellow Pond Lily), *Nymphaea odorata* (White Water Lily), *Potamogeton amplifolius* (Large-leafed Pondweed), *P. natans* (Floating-leafed Pondweed), and *P. robbinsii* (Robbins Pondweed). Sawbridge (1968) in his survey of the Florence hydrophytes, did not identify any of *Nymphaea odorata*, *Chara* sp., *Potamogeton natans*, or *Potamogeton amplifolius*. He did, however, come across some *Potamogeton lucens* in the deeper portions of the lake. These differences may have been partly due to the late date of the survey on January 25/68.

From our study we found the maximum depth of submerged hydrophytes to be about 15 feet. Sawbridge (1968) also came to the same conclusion of 15 feet. The three most abundant macrophytes were, in decreasing order, *Nuphar polysepalum*, *Potamogeton robbinsii*, and *Potamogeton natans*. *Utricularia gibba* was also quite widespread. The following table shows the approximate depth ranges of the above eight species.

Brasenia schreberi	1' - 6'
Potamogeton natans	1' - 6'
Nuphar polysepalum	1' - 8'
Chara sp.	3' - 10'
Elodea canadensis	3' - 10'
Utricularia gibba	3' - 12'
Potamogeton amplifolius	3' - 12'
Potamogeton robbinsii	5' - 15'

MACROPHYTE VEGETATION MAP



Sawbridge (1968) noted the occurrence of Potamogeton robbinsii only once in his two transects; however, it appeared to be much more abundant in our survey. He also found Elodea canadensis to be present in deeper waters (10 - 15 feet), whereas we found it be be in shallower (3 - 10 feet) water. Although we noted Potamogeton amplifolius to be essentially absent below 12 feet, a healthy individual was found at 17 feet at the maximum depth station. The freshwater sponge, Spongilla lacustris, was found on some Potamogeton robbinsii at about 12 feet depth.

From his survey, Sawbridge (1968) classified Florence Lake as 'polluted'. Semenchuk also lists Florence as 'polluted' based on redox potentials of the bottom sediments (Sawbridge, 1968).

Davies (1970) noted that in Marion Lake positive productivity occurred between April and September and for the other months respiration exceeded production. Hargrave (1969) found that the annual productivity of macrophytes was 2.25 times that of phytoplankton in Marion Lake. If one assumes a similar ratio for Florence, then the annual macrophyte productivity amounts to (2.25 x 58.8) approximately 132 $gm.C/m.^2$. One can also calculate an energy value for the summer maximum macrophyte crop by assuming one square metre of macrophytes is equivalent to 2500 kilocalories of energy:

Macrophyte Area: 21.15 acres (85,578 $m.^2$)
Lake Area: 29.36 acres (118,798 $m.^2$)
Macrophyte Energy: (85,578/118,798) x 2500
= 1800.9 kcal./square metre lake area.

This value essentially expresses the percentage of the lake's area which is in the littoral or shoal region of the lake.

ZOOPLANKTON

The zooplankton of Florence Lake was dominated by Rotifers, the copepods *Cyclops* and *Diaptomus*, and the Cladoceran *Chydorus*. Gliwicz (1969) associates *Chydorus* with eutrophic conditions along with another micro-filtrator, *Bosmina*. The zooplankton was taken with a #25 Rigosha net and hence some of the larger forms may have eluded the net and been missed.

The copepods were dominated by the genus *Cyclops* and by many copepod nauplii. The genus *Diaptomus* was always present, but in low to moderate numbers. A Harpacticoid copepod, probably *Canthocamptus*, was common from January 25 to March.

The rotifers, however, were the most diverse group of zooplankton with 8 species identified. Three species, *Polyarthra trigla*, *Trichocerca cylindrica*, and *Conochilus* sp., were at their highest densities at mid-October and steadily decreased from then through to March. Hutchinson (1967) considers the genus *Trichocerca* as a summer dominant characteristic of eutrophic waters. Mizund (1964) cites *Polyarthra trigla* and *Trichocerca cylindrica* as characteristic of meso-eutrophic conditions.

Keretella cochlearis was the most common rotifer through the five months of sampling. Rawson (1956) found the species to be the dominant in Great Slave Lake, as did Carl (1952) for Cowichan Lake. *K. cochlearis* is apparently a species with a wide trophic tolerance. The most striking increase in a rotifer species occurred from February 1 to March 1. Prior to this, the rotifer *Synchaeta* was absent. However, it rose from absent to dominant in a month or less.

ZOOPLANKTON - HORIZONTAL TOW

	OCT.19/72	OCT.26/72	NOV.16/72	JAN.18/73	JAN.25/73	FEB. 1/73	MAR. 1/73
ROTIFERA:							
Asplanchna priodonta	R	R	R	-	-	R	C
Conochilus sp.	D	D	A	R	-	R	R
Kellicottia longispina	-	R	R	R	R	R	-
Keretella cochlearis	A	A	D	A	A	C	C
Keretella quadrata	-	R	R	R	R	C	R
Polyarthra trigla	R	R	R	-	-	-	-
Synchaeta sp.	-	-	-	-	-	R	D
Trichocerca cylindrica	C	C	R	-	-	-	-
COPEPODA:							
Canthocamptus? sp.	-	-	-	R	C	C	C
Cyclops sp.	R	R	C	C	C	C	A
Diaptomus sp.	R	R	R	R	R	C	C
Copepod Nauplii	C	C	C	C	C	A	A
CLADOCERA:							
Bosmina longirostris	R	-	-	R	-	-	-
Chydorus (*sphaericus?*)	R	R	C	-	C	A	C
PROTOZOA:							
Difflugia sp.	R	R	C	R	R	-	R
GASTEROTRICHA:							
Chaetonotus sp.	-	-	R	-	-	-	-
NEMATODA:							
Nematode worm	R	-	-	-	-	-	-
DIPTERA:							
Diptera larvae	-	-	-	-	-	-	R

BENTHIC INVERTEBRATES

The Florence Lake benthos was sampled on the afternoon of February 15/73 using a 6"x6" Ekman dredge. Five drops were made at and around the maximum depth station and another in shallower (1.5 metre) water near the far end of the lake. The location of the stations is marked on the previous map which shows the sampling stations used in this lake survey. The dredged sediments were transfered into a plastic bucket along with some water. The mixture was swirled and poured off in portions into a screened bucket with a mesh size #30 (screen openings = 0.589 mm.). The screened organisms were then backflushed into wide-mouth jars before returning to the lab.

Chironomids, Chaoborids, Ostracods, Trichopterans, Insect parts, and a few Copepod exoskeletons were identified from the invertebrates in the jars. Decaying macrophytes, coniferous needles, and seed husks & seeds were also present. However, no Amphipods, Molluscs, Oligochaetes, or Hirudineans were found in the dredged sediments.

Chironomids were the most abundant with an average density of 1860 per $m.^2$. According to Hargrave (1969), Chironomids were also the most abundant benthic invertebrate in Marion Lake, having a density of 4600 per $m.^2$. Chaoborids were the next most dominant with an average density of 517 per $m.^2$. Although Chaoborids were absent from Marion Lake, there their place was taken by the more oligotrophophilic Amphipods which reached densities of 850 adults per $m.^2$. Ostracods and Trichopterans were equally abundant with 95 individuals per square metre, in Florence Lake. Insect wings, heads, and body parts accounted for almost 5400 pieces per $m.^2$.

	HAUL 1	HAUL 2	HAUL 3	HAUL 4	HAUL 5	SUM	AVERAGE
CHIRONOMIDAE	82 3531	37 1593	38 1636	25 1076	34 1464	216 9300	43 1860
CHAOBORIDAE	16 689	10 431	18 775	8 344	8 344	60 2583	12 517
MOUTH AND BODY PARTS	198 8526	170 7320	108 4651	3 129	131 5641	610 26267	122 5253
INSECT WINGS	-- ---	-- ---	8 344	2 86	5 215	15 645	3 129
OSTRACODS	-- ---	6 258	-- ---	4 172	1 43	11 473	2 95
TRICHOPTERA CASES	-- ---	3 129	3 129	1 43	4 172	11 473	2 95
SEED HUSKS & SEEDS	108 4650	-- ---	-- ---	28 1206	-- ---	136 5856	27 1171

* HAUL NUMBERS 1-5 AT 5.5 METRES AT MAXIMUM DEPTH STATION.

* FIRST VALUES ARE NUMBERS PER EKMAN DREDGE.

* SECOND VALUES ARE CONVERTED NUMBERS PER SQUARE METRE.

ETHANOL AIR-DRY WEIGHTS OF BENTHOS (FEB.15/73)

Chironomidae	15 - 6.30 mg.	@ 0.420 mg.
Chaoboridae	15 - 1.46 mg.	@ 0.097 mg.
Ostracoda	10 - 1.27 mg.	@ 0.127 mg.
Trichoptera Case	1 - 14.24 mg.	@ 14.240 mg.
Insect Wings	10 - 0.19 mg.	@ 0.019 mg.
Mouth & Body Parts	25 - 0.18 mg.	@ 0.007 mg.
Plant Fragments & Unsieved Sediments	HAUL #5	@ 969 mg.

	HAUL 1	HAUL 2	HAUL 3	HAUL 4	HAUL 5	AVERAGE
CHIRONOMIDAE	1483	669	687	452	615	781
CHAOBORIDAE	67	42	75	33	33	50
OSTRACODA	---	33	---	22	5	12
TRICHOPTERA CASES	---	1837	1837	612	2449	1347
INSECT WINGS	---	---	7	2	4	2
MOUTH & BODY PARTS	61	53	33	1	41	38

* VALUES ARE WEIGHTS IN mg./m.^{2}

A dredge haul at 1.5 metres was taken to compare with the average values of the five hauls at 5.5 metres. The shallower dredge generally showed greater densities of benthic organisms. A total of 83 Chironomids (3574 per m.^{2}) were present in the dredge, whereas a total of 1860 per m.^{2} were evident at 5.5 metres. Chaoborids showed even greater variation - 26 (1120 per m.^{2}) were counted in the shallow dredge, but the 5.5 metre average was only 517 per m.^{2}. Ostracods were also more numerous in the shallows. Eight (344 per $m.^2$) were counted compared to an average density of 95 per $m.^2$ in the deeper waters. Insect body and mouth parts did not show any significant differences between the two depths. The average density at 5.5 metres was 5253 per $m.^2$ and at 1.5 metres it was 4995 per $m.^2$.

The shallower sediment was noticeably more darker than the virtually 100 % organic (sapropel) sediments in the deeper portions of the lake. The shallower areas also possessed a greater proportion of inorganic sediment components.

If the values obtained for benthic invertebrate densities in the shallower water is representative of that of other similar shallow areas, then there are several reasons for the density discrepancy between the deep and shallow. Firstly, they may be due to a preference for a particular sediment texture or composition or it may be due to the fact that the shallow areas are much closer to the terrestrial vegetational influence. Secondly, it may be caused by some chemical or physical aspect - likely dissolved oxygen; the shallows having a greater concentration, especially during lake stratification.

BENTHOS COMPARISON OF LOCAL LAKES

All five local lakes, Swan, Florence, Big Maltby, Langford, and Prospect had similar benthic organisms. Chironomids and Chaoborids were present in all lakes, but were quite variable. Florence and Prospect lakes had the greatest densities of Chironomids, whereas Swan and Langford had the lowest densities (see following table). From the data, it appears that Chironomids are most abundant in mildly eutrophic lakes and least abundant in lake types such as Swan and Langford

	CHAOBORIDAE	CHIRONOMIDAE	INSECT WINGS	HEADS & BODIES	EPHIPPIA	PLANT FRAGMENTS	MISC.
SWAN	896	26	--	1361	5503	---	* 603 16
	617	26	--	177	62	29,280	** 887 2
FLORENCE	517	1860	120	5253	---	---	@ 95 1347
	50	781	2	38	---	41,725	@@ 95 12
BIG MALTBY	904	861	344	34	---	---	34
	291	1189	5	14	---	13,750	12
LANGFORD	86	86	1335	172	5022	---	258
	54	321	20	3	441	9,565	853
PROSPECT	388	1701	--	2218	---	---	---
	120	3951	--	100	---	---	35

SWAN: Miscellaneous - (*) WATER PENNIES
- Coleopteran beetle larvae of family Psephenidae.
- (**) APHIDS

FLORENCE: Miscellaneous - (@) TRICHOPTERAN CASES
- (@@) OSTRACODS

LANGFORD: Miscellaneous - OLIGOCHAETA

* FIRST VALUES ARE NUMBERS PER SQUARE METRE.

* SECOND VALUES ARE mg. DRY WEIGHTS PER SQUARE METRE.

which are fairly strongly eutrophic.

Chaoborids did not show any significant patterns. The greatest densities occurred in both the most and least eutrophic lakes - Swan and Big Maltby, respectively. Insect wings, heads, and body parts were numerous in all lakes, except Big Maltby.

Several lakes produced unique benthic groups. Swan had moderate concentrations of Water Pennies and Aphids, Florence - low densities of Ostracods and Trichoptera, Langford - moderate densities of Oligochaetes.

The most striking differences, however, were in the densities of Ephippia. According to Ward & Whipple (1959), in sexual female cladocerans producing haploid eggs, the carapace enclosing the brood chamber may begin to thicken and darken. A semi-elliptical (in the Daphnidae) portion of the dorsal region of each valve becomes greatly altered to form an ephippium. The carapace closes around the eggs after they are extruded into the chamber and fertilized, and at the next molt the ephippia are shed as a unit (Ward & Whipple, 1959). The early embryo lies dormant, often withstanding freezing and drying, until conditions are suitable for development.

Swan and Langford lakes were the only ones with significant densities of ephippia; having 5503 and 5022 per square metre, respectively. Because Florence had no Daphnidae species during the period studied, it seems reasonable that there would be few, if any, ephippia present. It may, however, be significant that Swan and Langford, the two most eutrophic lakes, had the greatest densities of ephippia.

FISH SPECIES

Although Florence Lake was at one time one of the better Smallmouth Bass lakes on the lower Island, it no longer supports a Bass fishery. No netting or other fish investigations were carried out during the study period from October 1972 to March 1973. The following information was received from the Fish & Wildlife Branch through a letter to Mr. John Balkwill.

Prior to Synergized Rotenone rehabilitation on October 7, 1960, Smallmouth Bass, Rainbow Trout, Sunfish, and Brown Bullheads were known to be residents of the lake. In the fall of 1961, Smallmouth Bass were reintroduced into the lake. The fish varied in size as they were netted from populations in other local lakes for transplantation.

The Fish & Wildlife Branch did some experimental netting in May of 1971 and found Sunfish and Prickly Sculphins to be present. These fish either survived the Rotenone treatment or were introduced after the treatment, illegally. There is no report of fishing success by anglers. From the above information, it appears that the Smallmouth Bass have not taken since they were reintroduced. There are several reasons for this happening. A lack or shortage of sufficient good quality spawning area or a shortage or change in the potential food of the Bass may have resulted in their not taking. Even more remote is the possibility that they were killed by an algal bloom, anoxic conditions, or a lengthy freeze-over period. Whatever the reason, no one seems to know for sure.

POLLUTION

The chief source of any pollution is from sewage and its disposal. The 150 or so residences in the Florence Lake watershed are on septic tanks. The latest, large-scale development in the area is the Hidden Valley Mobile Home Park located at the far end of the lake. According to one gentleman whom I talked to on the premises, the trailer park is apparently on a system called "Bio-Pure". It is supposed to be much more efficient than septic tanks - emitting clean water. The sewage is pumped into holding areas located in a small basin behind the park. Treatment occurs there and the effluent probably drains down through the watershed being filtered by the soil on its way to the lake.

By carrying out a coliform test on the lake waters, the degree of pollution by sewage or surface water can be determined. The coliform bacteria are a group found in the intestines of animals and humans and also in the soil. A presumptive coliform test was conducted during the first week of February. It involved the use of five tube assemblies. Results showed four tubes positive and one negative, thus indicating a minimum of 16 coliform bacteria per 100 ml. of lake water.

In regards to present standards, they are variable. The New Zealand Waters Pollution Regulations (1963) specify the standard for recreational water as 1000 coliforms per 100 ml. of water; (Loutit et al. ,1972). However, the authors recommend a national standard of 300 confirmed coliform bacteria per 100 ml. for contact recreational waters. A letter to J.L.M. Whitbread of the Greater Victoria Metropolitan Board of Health was replied to by A.G. Bouchard (Public Health Inspector).

According to him, the unofficial coliform count regarded as satisfactory for fresh water bathing areas by the Health Department is an average of 240 with no more than 10 % of the samples being over 1000 per 100 ml. water. The average coliform count for seawater shoreline areas established by the Pollution Control Board is 1000. It appears that Florence Lake has acceptable levels as far as recreational aspects are concerned, but probably not in regard to drinking water.

APPENDIX #1.

FLUSHING RATE CALCULATIONS:

Average rainfall recorded at Millstream: 42.26"
Total evapo-transpiration taken as 90% of rainfall.
One inch rainfall or ET on one acre: 27,154.17 gal.

Lake Volume: 102,577,580 gal. (314.8 Acre-feet)
Total Drainage (land + lake): 441.4 Acres
1" rainfall on 441.4 Acres: 11,985,849 gal.
Total Catchment Volume: 42.26 x 11,985,849
= 506,521,987 gal.
Total ET loss: 38.03 x 11,985,849 = 455,821,845 gal.
Total Inflow: (RF-ET) 50,700,142 gal.
Flushing Rate: 1/(50,700,142/102,577,580)
= 2.02 years.

CONTOUR LENGTHS

0' - 5630'	10' - 4050'
5' - 4890'	15' - 2650'

MORPHOMETRIC DATA FORMULAS:

Volume: $V_s = 1/3\ (A_1 + A_2 + \sqrt{A_1 A_2}) \times h$
where A_1 and A_2 are the areas of adjacent contours in square feet and h is the contour interval in feet. -- SUM ALL STRATUM VOLUMES.

Mean Depth: $\bar{d}$ = Volume/Area -- both in the same units.

Shoreline Development: $SD = SL/2\sqrt{\pi A}$

Mean Slope: $\bar{s} = 1/n(0.5L_0 + L_1 + L_2 + L_3 + \ldots + 0.5L_n)\ d_{max}/A$
where n = number of contours
L_0, L_1, L_2, L_3, L_n = length of contours in feet
d_{max} = maximum depth in feet
A = area of lake in square feet

APPENDIX #1-A:

MEAN SUMMER LAKE TEMPERATURE CALCULATIONS:

DEPTH	TEMPERATURE (°C.)	STRATUM	MEAN TEMPERATURE (°C.)
0'	24.50		
		0 - 5'	24.50
5'	24.50		
		5 - 10'	23.16
10'	21.85		
		10 - 15'	20.92
15'	20.00		
		15 - 18'	19.25
18'	18.50		

STRATUM	VOLUME FRACTION	STRATUM MEAN TEMP. (°C.)
0 - 5'	0.433	10.61
5 - 10'	0.335	7.76
10 - 15'	0.197	4.12
15 - 18'	0.035	0.67
		23.2°C.

SUMMER HEAT INCOME CALCULATIONS:

Mean depth = 10.7 feet
= 10.7 x 30.48 cm. = 326.14 cm.

Summer Heat Income = 326.14 x (23.2 - 4.0)
= 6261.9 gm.cal./cm.^{2}

WINTER HEAT INCOME CALCULATIONS:

Winter Heat Income = 326.14 x (4.0 - 2.0)
= 652.3 gm.cal./cm.^{2}

ANNUAL HEAT BUDGET (1972-1973):

Annual Heat Budget = 6261.9 + 652.3
= 6914.2 gm.cal./cm.^{2}

APPENDIX #2.

CHLOROPHYLL CROP & PRODUCTION CALCULATIONS:

Average of three planimeter readings for 10 sq. in. = 0647.
Conversion factor: 1 sq. in. = 6.42 $cm.^2$

CROP:

January 18/73
(1182/0647) x10 = 18.27 sq. in.
18.27 x 6.42 = 117.29 $cm.^2$
from graph; 1 sq. cm. = 2.5 mg. x .61 m. x 0.1
= 0.1525 mg./m. sq.
117.29 x 0.1525 = 17.92 mg./$m.^2$

January 25/73
(1023/0647) x10 = 15.81 sq. in.
15.81 x 6.42 = 101.50 $cm.^2$
from graph: 1 sq. cm. = 2.5 mg. x 0.61 m. x 0.1
= 0.1525 mg./m. sq.
101.50 x 0.1525 = 15.47 mg./$m.^2$

February 1/73
(1479/0647) x10 = 22.86 sq. in.
22.86 x 6.42 = 146.76 $cm.^2$
from graph; 1 sq. cm. = 2.5 mg. x 0.61 m. x 0.1
= 0.1525 mg./m. sq.
146.76 x 0.1525 = 22.42 mg/$m.^2$

Using a conversion factor of 17.3 for crop to production.

PRODUCTION:

January 18/73 17.92 x 0.001 x 17.3 = 0.310 gm.C/$m.^2$ per day

January 25/73 15.47 x 0.001 x 17.3 = 0.268 gm.C/$m.^2$ per day

February 1/73 22.42 x 0.001 x 17.3 = 0.388 gm.C/$m.^2$ per day

* Average Crop = 18.54 mg. chlorophyll 'A'/$m.^2$

* Average Production = 0.322 gm.C/$m.^2$/day

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