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Nutrients in Lake Huron 1968-72

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NUTRIENTS IN LAKE HURON 1968 - 1972

by

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Introduction:

In 1968 the first survey was completed on Lake Huron. One survey was completed in each of years 1968 and 1969. Two surveys were completed in 1970. In 1971 eight extensive monthly surveys were carried out, beginning in April and ending in December. In 1972 three more surveys were completed, one in each of spring, summer and fall.

The data collected were critically analysed. A data summary will be presented on a parameter by parameter basis for each year. The dates and survey numbers are provided in Table I. This report is to be regarded as a data presentation.

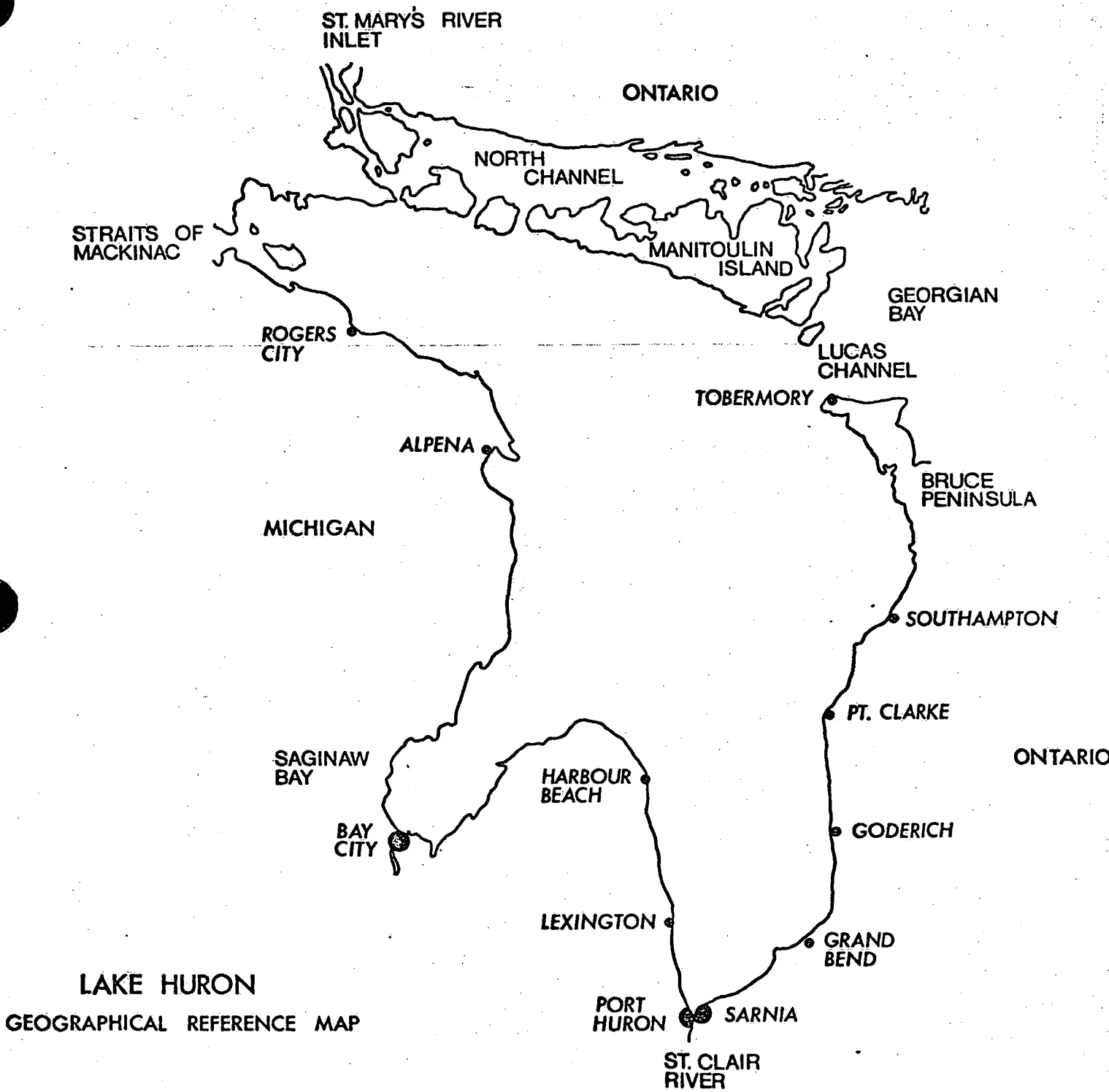
The contour maps contained in this report were produced by means of a simple computer program which plotted weighted values of the selected parameters on a grid of the lake. The station locations and the lake boundaries were defined by a set of indecis on the grid.

The data for each station were then read into the computer and a power function was used to weight the effect of each station on each grid cell. The three closest stations were used to weight each grid cell. This gave us a grid with 936 grid cells of which 372 existed within the boundaries of the lake. This number of grid cells made the countouring much easier and since the weighting was always done the same way the contouring was reproducable.

TABLE I

LAKE HURON SURVEYS

YEAR	SURVEY NUMBER	DATE
1968	68-2-01	August 5 - 13
1969	69-2-02	September 22 - 29
1970	70-2-02	May 11 - 21
	70-2-05	September 29 - October 9
1971	71-2-01	April 19 - 28
	71-2-03	May 17 - 25
	71-2-04	June 15 - 28
	71-2-05	July 19 - 27
	71-2-06	August 23 - 30
	71-2-09	September 27 - October 4
	71-2-11	October 27 - November 3
	71-2-12	November 29 - December 6
1972	72-2-01	May 1 - 9
	72-2-02	August 8 - 16
	72-2-03	November 2 - 10



LAKE HURON

GEOGRAPHICAL REFERENCE MAP

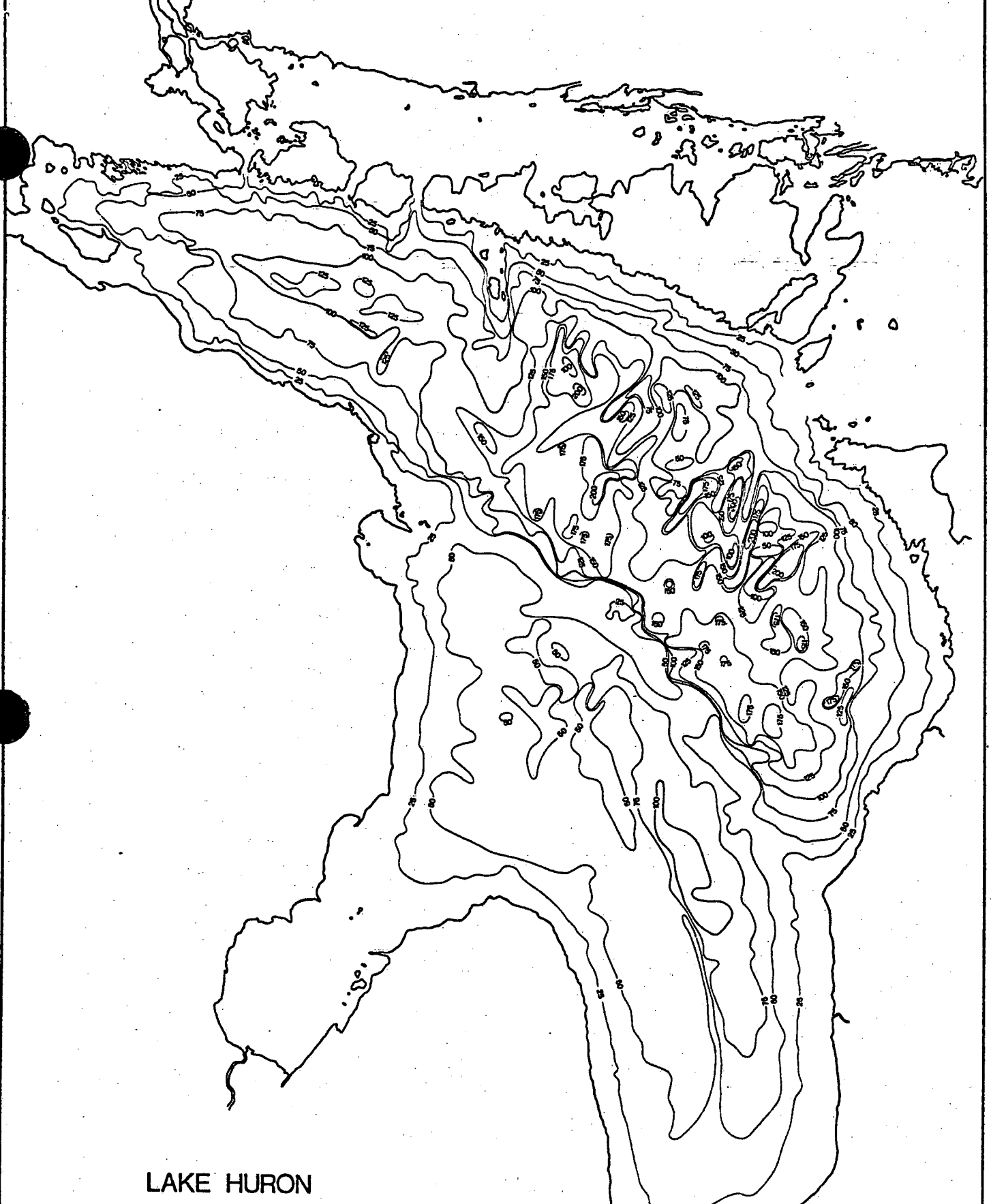
LIST OF FIGURES

LAKE HURON MORPHOLOGY:

Lake Huron is the second largest of the chain of four Great Lakes on the Canada - U.S. border. Lying between 43^{o} and 46^{o} North latitude and 81^{o} and 85^{o} West longitude it has a main basin surface area of $4.21 \times 10^{10} m^2$, a volume of $2.66 \times 10^{12} m^3$, a maximum depth of 245 m and a mean depth of 85 m.

The bottom topography of the lake is shown in fig. I. The northern section of the lake has a complex topography with sharp contours. Saginaw Bay is less than 25 meters deep and the southern part of the lake is much shallower than the northern part. Also the contours of the southern part are much smoother.

These two sections of the lake are separated by a ridge running from just north of Alpena on the Michigan shore to Point Clark on the Ontario shore. This ridge effectively divides the lake into two main basins and probably blocks exchange between the bottom waters of the two basins, especially under summer stratified conditions.



LAKE HURON

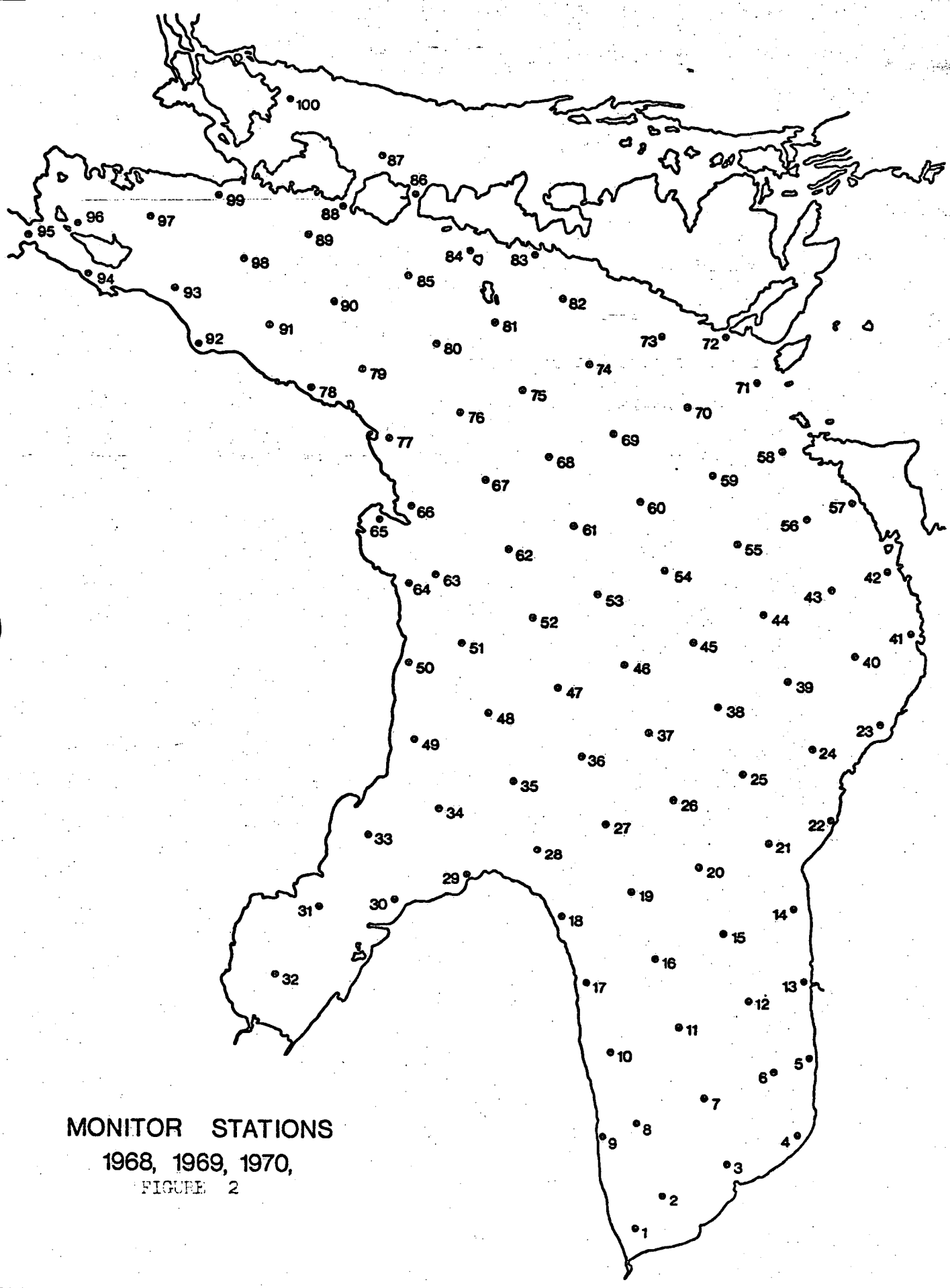
CONTOURS IN METRES

FIGURE 1

Illustrations and Discussion:

1968 DATA: Figs. 2, 3, & 4

In 1968 one extensive survey of Lake Huron was completed between August 5 and 13. During this survey; temperature, dissolved oxygen, nitrate-nitrite nitrogen, soluble reactive phosphate and reactive silicate were measured at 97 stations. Figure 2 shows the location of each of the stations.



MONITOR STATIONS
1968, 1969, 1970,
FIGURE 2

Temperature: Figure 3

The 1m. temperature was quite homogeneous with the mid-lake values ranging from 14 - 20°C. There was an apparent north-south increase in temperature. This is probably due to the cold imput from Lake Superior, the natural north-south increase in heat due to latitude and also the bathymetry of the lake (figure 1) which is deeper in the northern part of the lake.

The bottom temperature showed the typical summer cold 4° C water mass in the deep central waters and warmer waters in the nearshore areas.

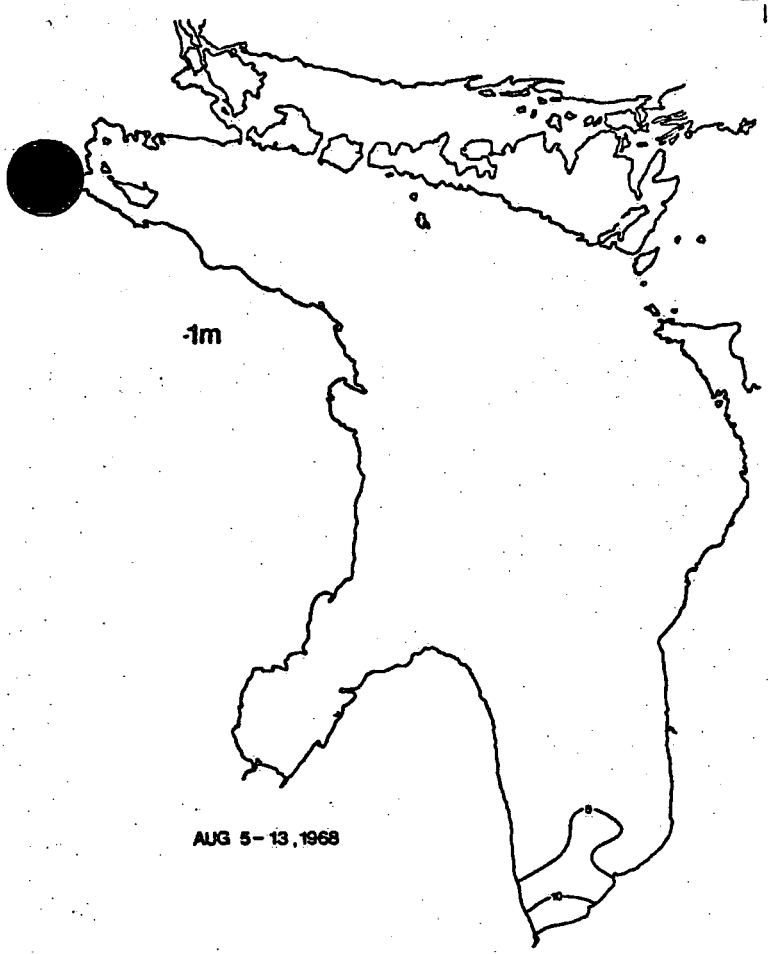
Bottom Dissolved Oxygen Saturation: Figure 3

The lake waters are normally saturated with O_2 in the surface and bottom waters. However, a small area of oxygen depletion was evident in the southern part of the lake where a minimum of 85% saturation was observed during the August survey.

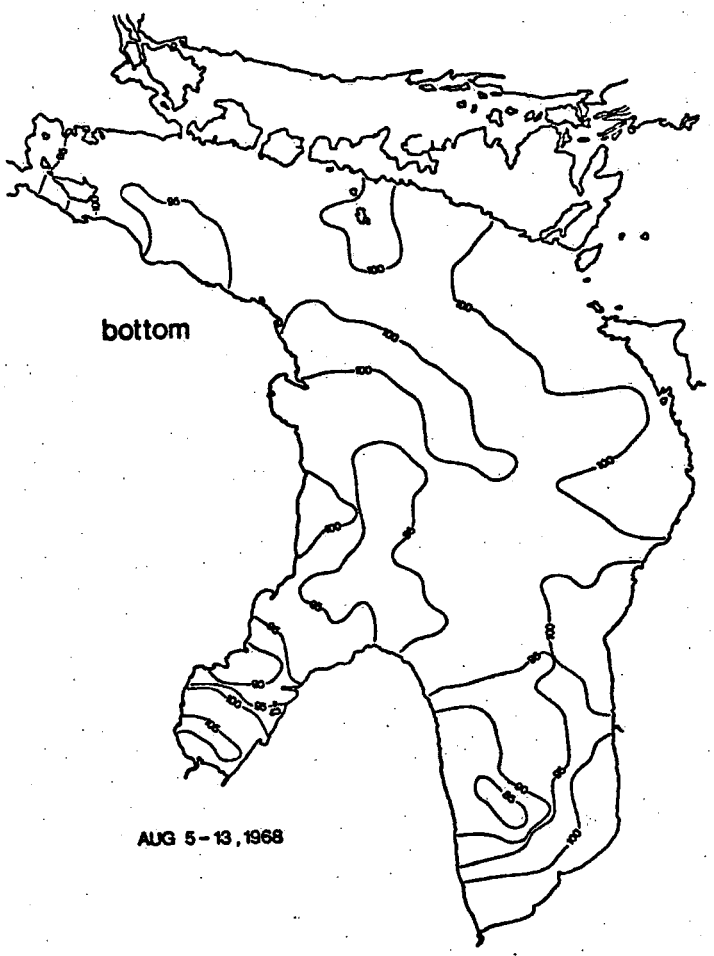
Soluble Reactive Phosphate: Figure 3

The concentration of soluble reactive phosphate in the lake was always at or near the detection limit. The range is generally 0 - 1 µg/l - PO4 with some infrequent higher areas ranging up to 10 µg/l-PO4.

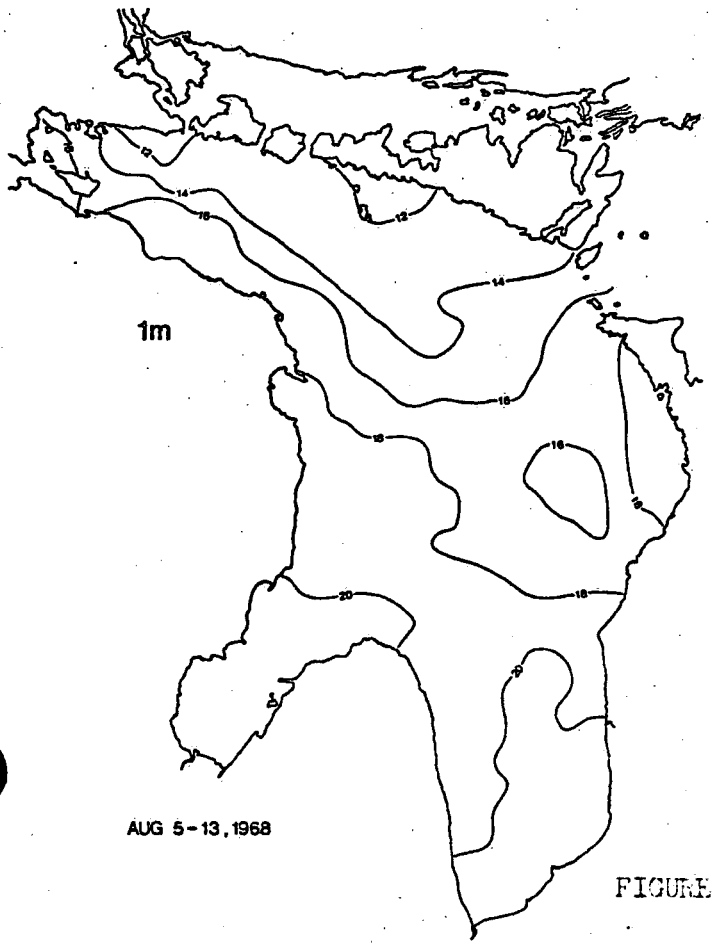
SOLUBLE REACTIVE PHOSPHATE µg/l-PO_4



DISSOLVED OXYGEN-PERCENT SATURATION



TEMPERATURE °C



TEMPERATURE °C

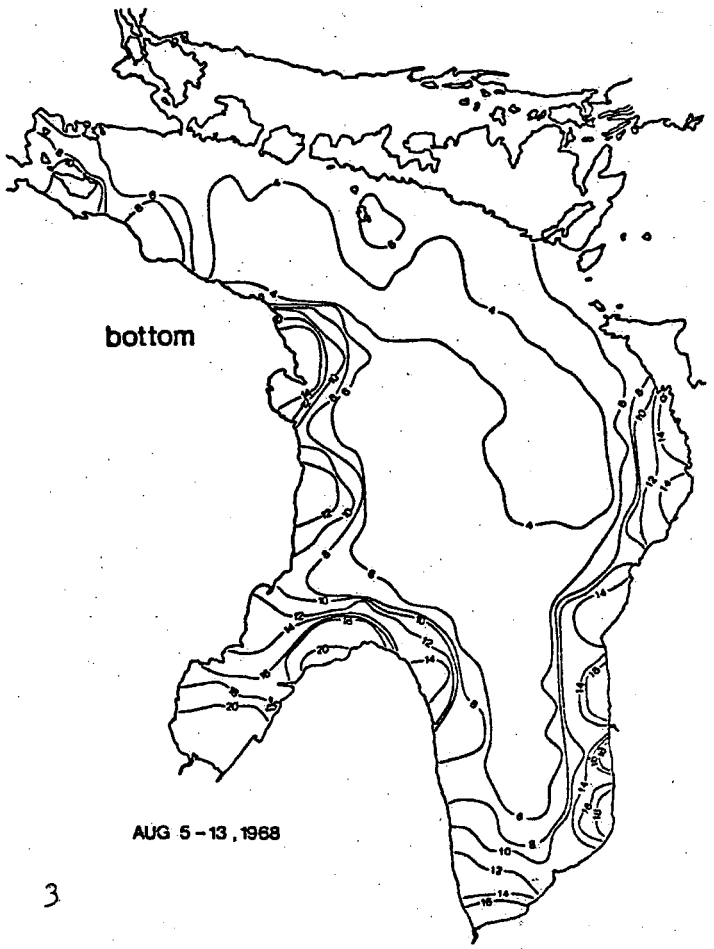


FIGURE 3

Nitrate - Nitrite Nitrogen: Figure 4

Some surface to bottom depletion of nitrate was noticed in the main lake. Generally the mid-lake surface values ranged from 175 - 200 µg/l - N wheras the bottom waters ranged from 225 - 250 µg/l - N. However in Saginaw Bay the surface nitrate concentration has been depleted down to 25 µg/l - N with the bottom values about 50 µg/l - N. Another area of obvious nitrate depletion was in Thunder Bay off Alpena where values of 125 µg/l - N were found in the surface water.

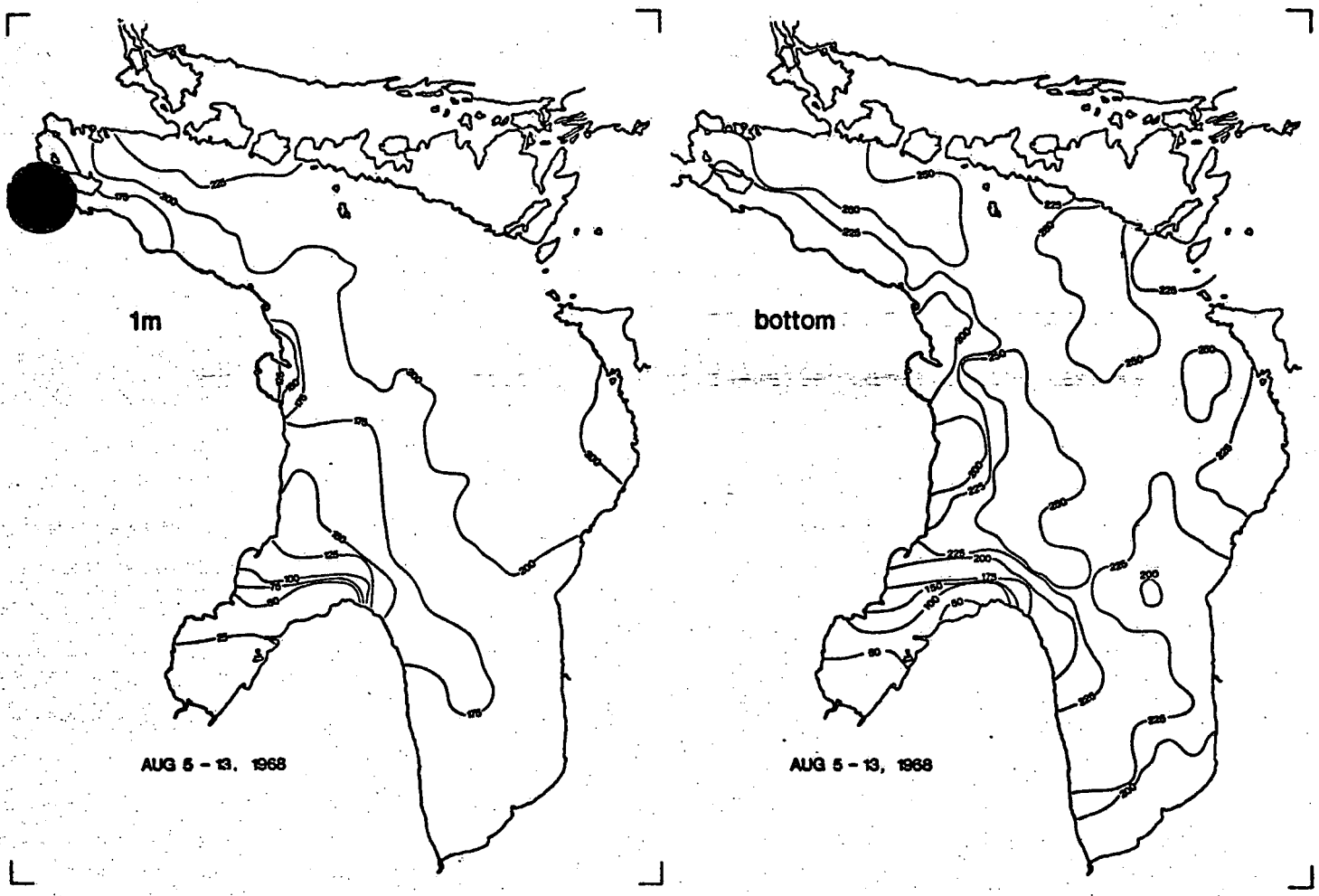
The inflow of Lake Michigan water can be observed in the northern section of the lake, particularly in the surface water. It is lower in nitrate concentration due to increased algal uptake.

Reactive Silicate: Figure 4

Some surface to bottom depletion of reactive silicate was observed. The mid-lake surface concentrations ranged from 1000 -1200 µg/l - SiO2 wheras the mid-lake bottom concentrations ranged from 1400 - 1600 µg/l -SiO2. An apparent decrease in silicate concentration was observed from north to south, particularly in the surface waters. This decrease probably occurred because the algal uptake in the south is probably greater than in the north due to increased algal growth. Also the northern highs were at least in part caused by the Lake Superior input which is significantly higher than the Lake Huron water.

The respective areas of influence of the Lake Michigan and Lake Superior inputs in the north-western area of the lake were observed easily. Lake Michigan surface water flowing into this area was lower in silicate than the Lake Huron water. The Lake Superior water flowing into this area was higher in silicate than the Lake Huron water.

NITRATE - NITRITE NITROGEN µg/l - N



REACTIVE SILICATE µg/l - SiO_2

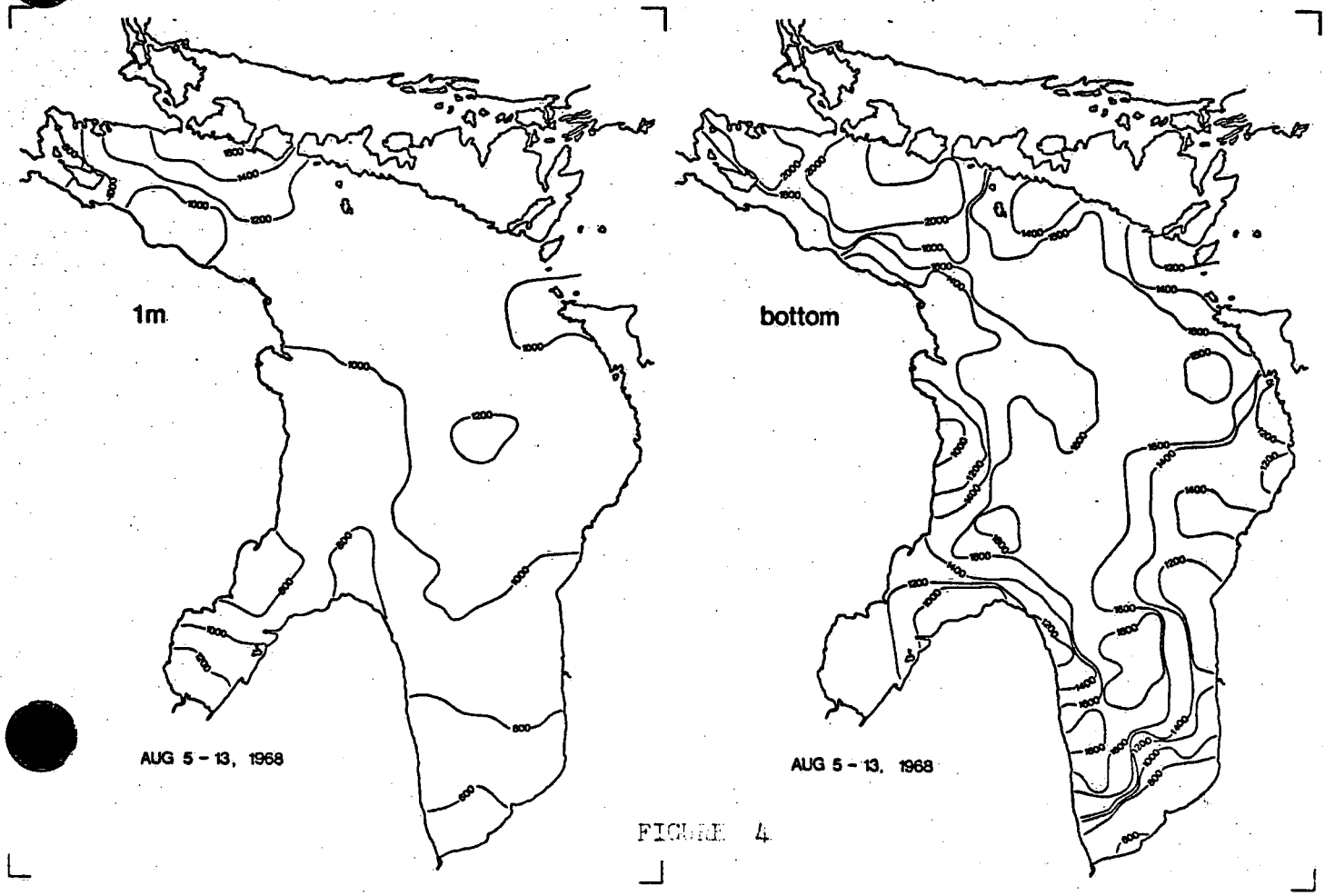


FIGURE 4

1969 DATA:

In 1969 one survey was completed in late September. Extensive temperature data was collected and samples for nitrate were analysed at 30 selected stations. These data are presented only for comparison to former and later years.

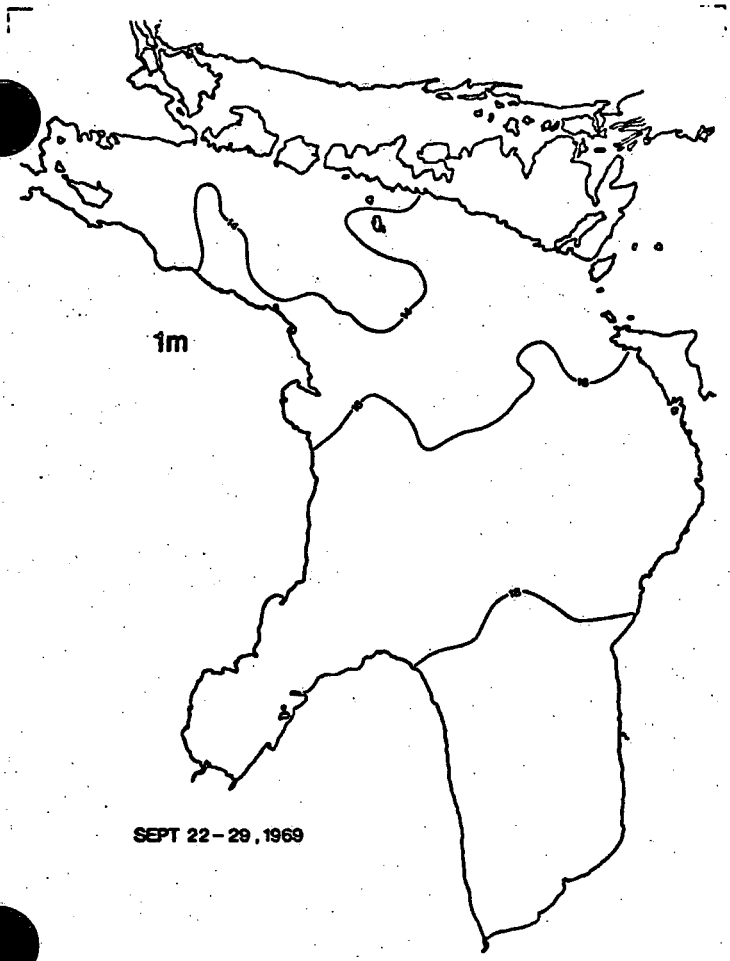
Temperature: Figure 5

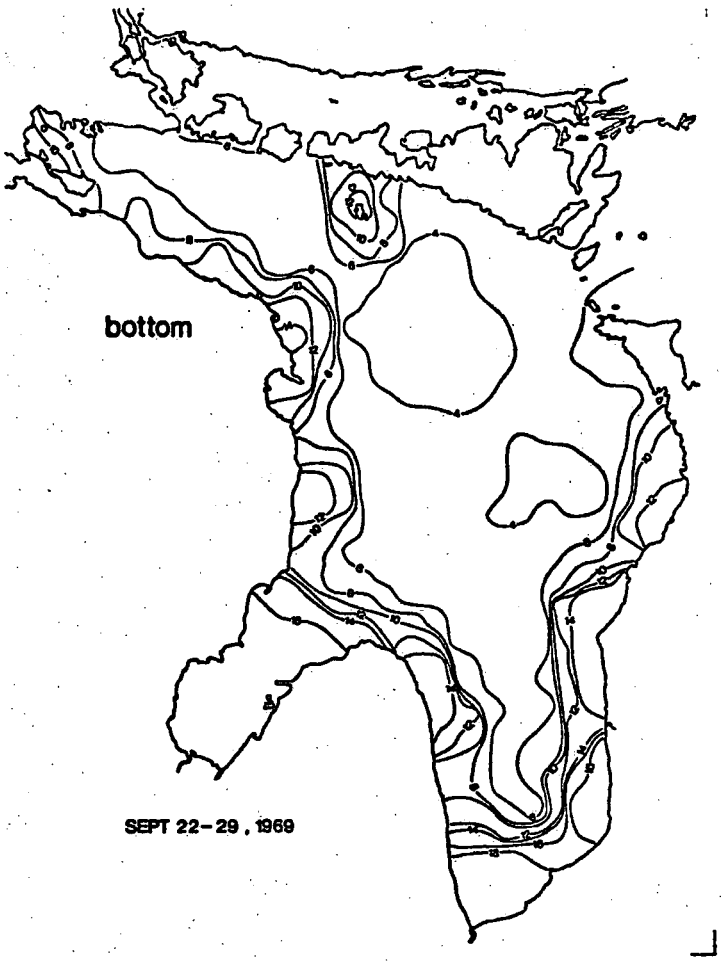
As in 1968, the surface and bottom temperatures showed an increase from north to south. The typical nearshore to mid-lake decrease in temperature was noticed in the bottom waters. A large volume of $4^{o}C$ water existed in the hypolimnion during this late September survey.

Nitrate - Nitrite Nitrogen: Figure 5

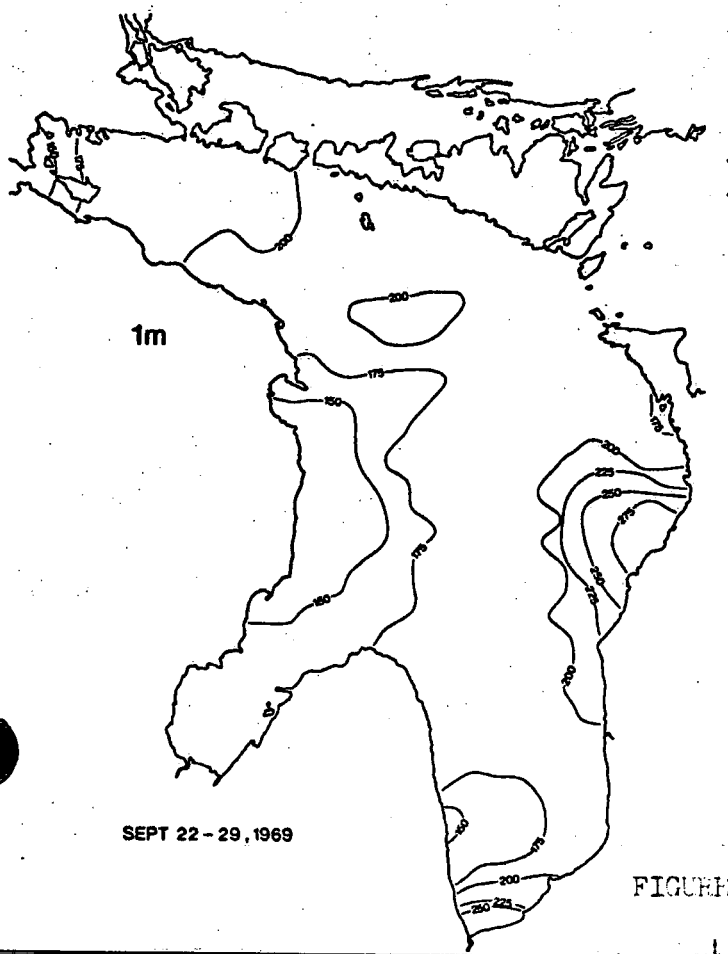
Since only 30 stations were analysed for this parameter it is difficult to compare it to the 1968 data. However the mid-lake surface concentrations were in the same range from 175 - 200 µg/l - N. Once again the decrease from surface to bottom was evident with the bottom mid-lake values in the range from 225 -250 µg/l - N. Also a few probably biologically active nearshore areas were noticed where the surface nitrate concentration was depleted to less than the mid-lake values. These were Saginaw Bay, Thunder Bay just off Alpena and also in the nearshore area just off Lexington. Two areas where there appeared to be a source of nitrate were just off Port Huron and also slightly South of Southampton.

TEMPERATURE °C





NITRATE-NITRITE NITROGEN µg/l-N



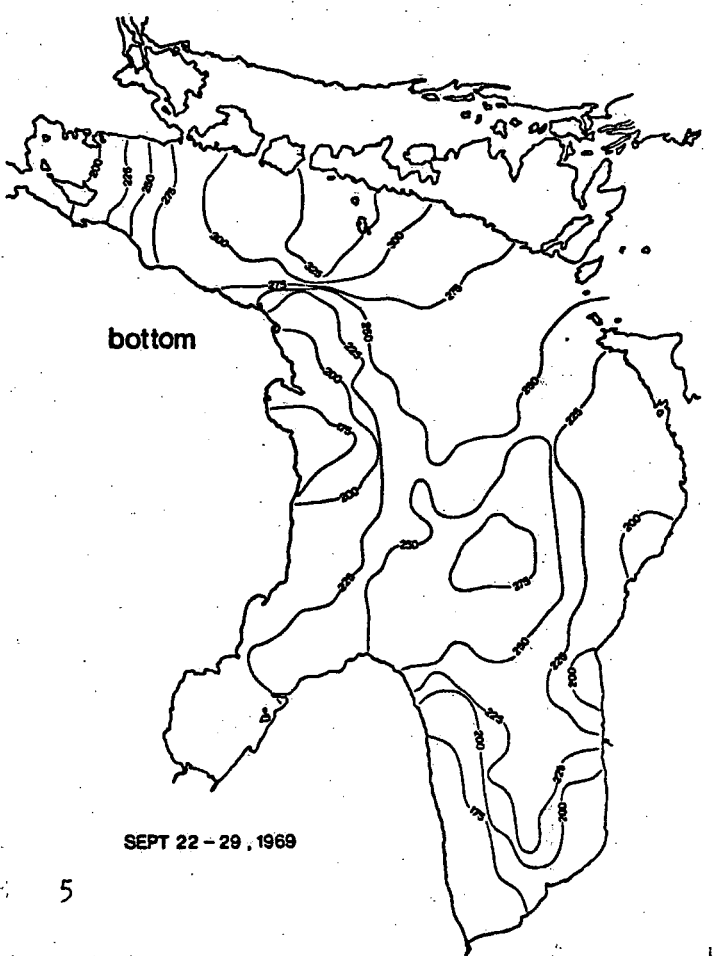


FIGURE 5

1970 DATA: Figure 6

In 1970 very little data was collected on Lake Huron. Only two cruises were completed, one in early May and the other in late September and on these no nutrient chemistry samples were collected. Hence only surface and bottom temperatures and bottom dissolved oxygen percent saturation are presented.

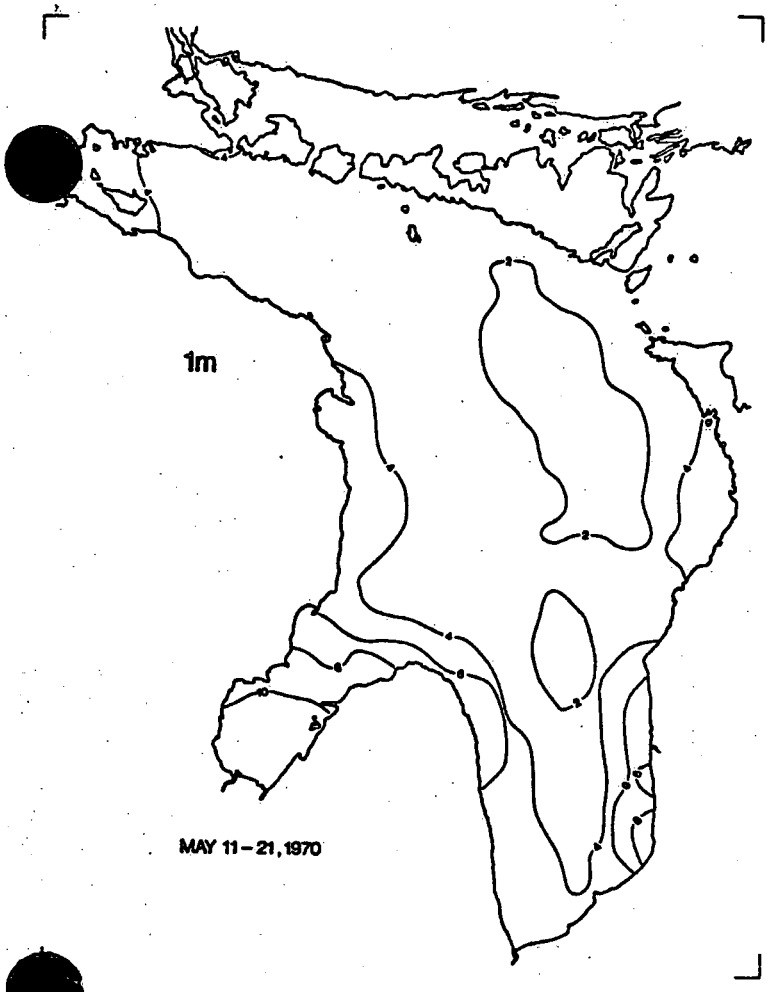
Temperature: Figure 6

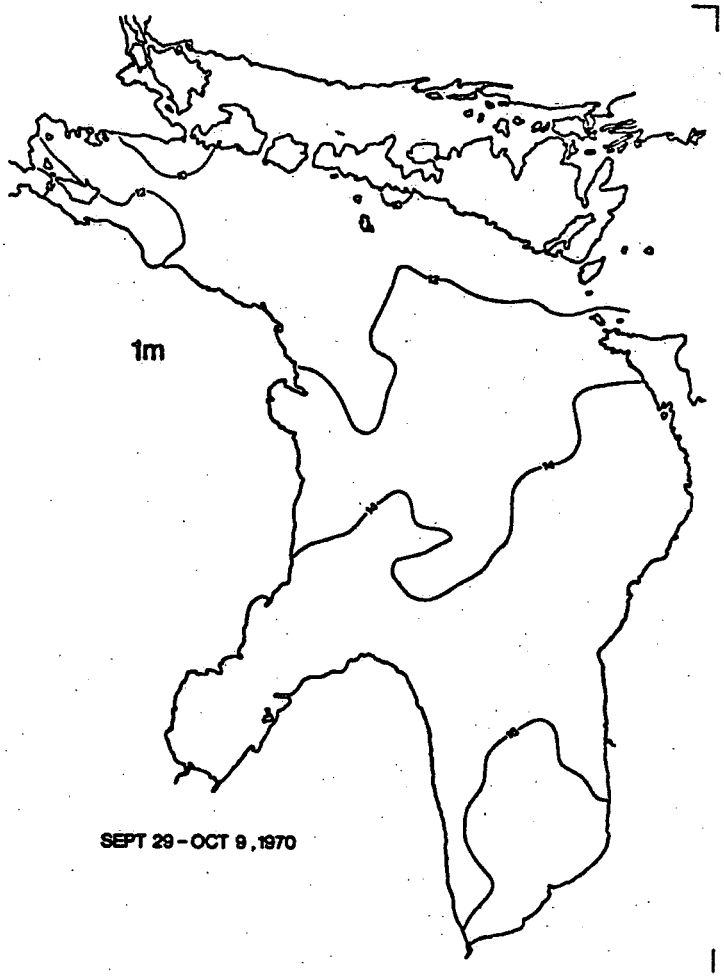
The spring surface temperature showed a thermal bar set up around the shoreline with nearly the whole lake less than $4^{o}C$ and also no significant surface to bottom differences. The late September survey once again showed the north-south increase of temperature values in the surface waters and a strong thermocline development with large volumes of cold water below $6^{o}C$ in the hypolimnion in the mid-lake areas.

Dissolved Oxygen: Figure 6

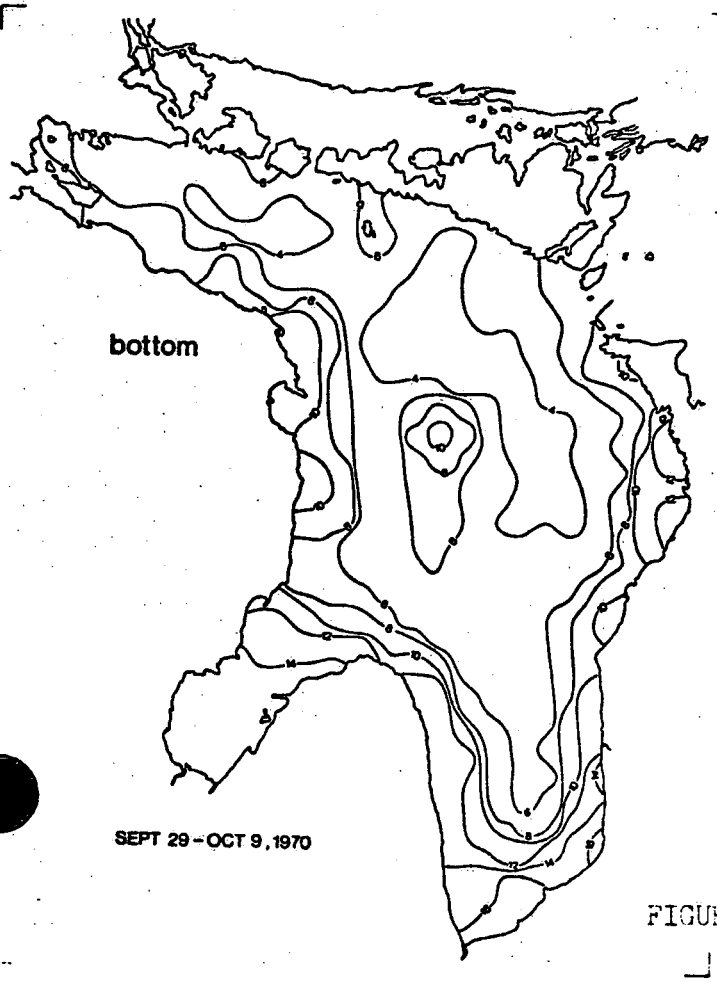
The bottom waters are generally saturated or nearly saturated. However, one area in the south-central basin was observed to be depleted to about 85% saturation and also one area was observed in the north-central region of the lake to be depleted to about 75% saturation.

TEMPERATURE °C





TEMPERATURE °C



DISSOLVED OXYGEN – PERCENT SATURATION

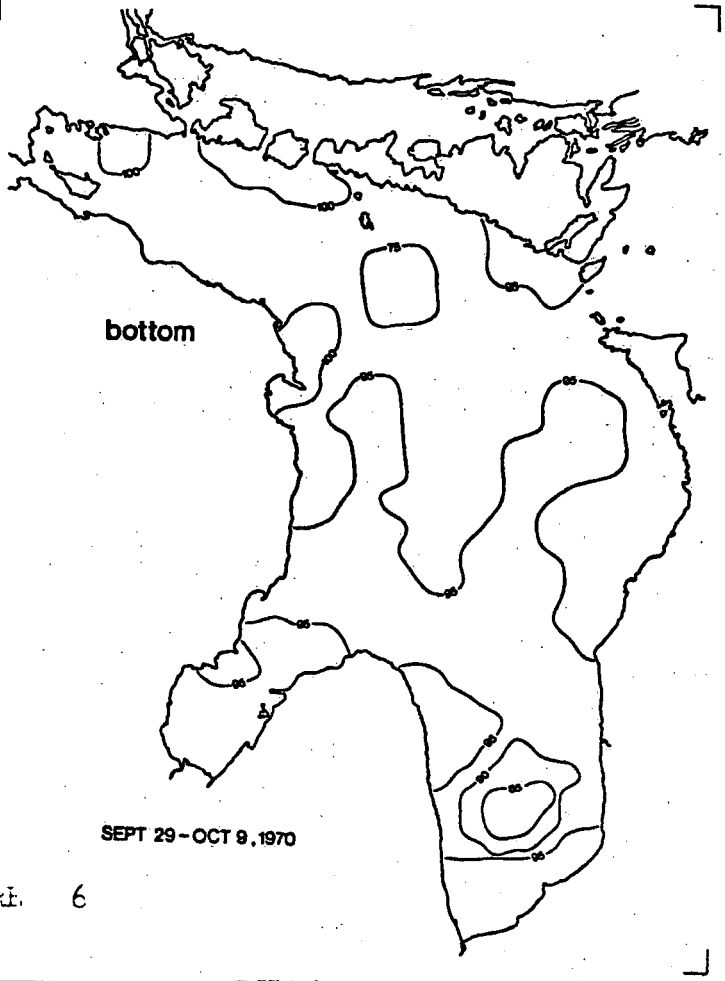


FIGURE 6

1971 DATA:

During 1971, eight monthly surveys were completed, beginning in mid-April and ending in early December. Temperature, dissolved oxygen and most of the nutrient parameters were measured at 58 selected stations throughout the year. All station locations are shown in figure 7 with the selected nutrient stations also indicated.

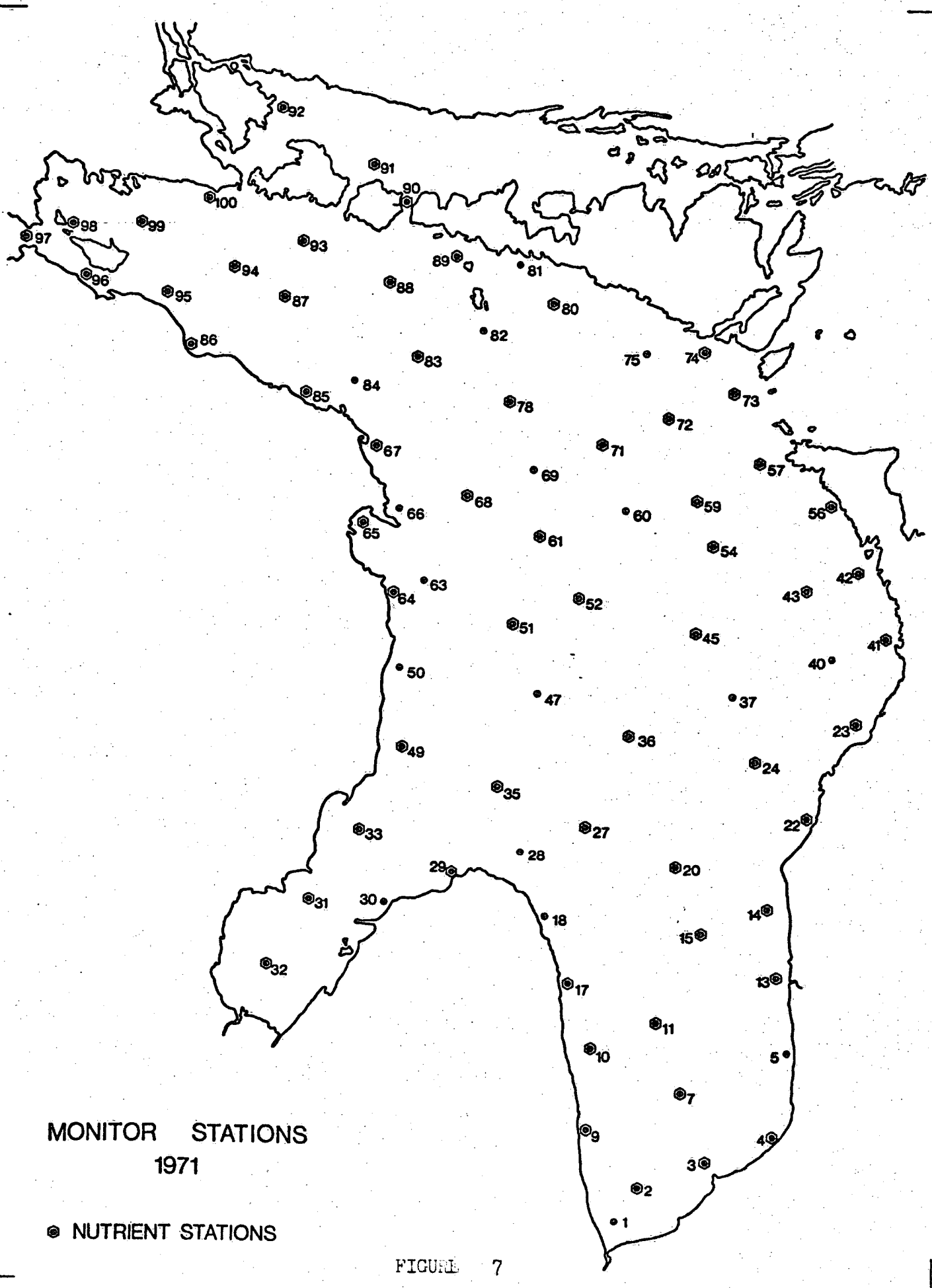


FIGURE 7

Temperature: Figures 8, 9 & 10

During the earliest survey, in mid-April; a very homogeneous temperature distribution was observed. Most of the lake was less than 2^{o}C on the surface with only Saginaw Bay and the western shore of the southern basin beginning to warm up to 4 - 6^{o} C.

By mid-May the nearshore surface waters of the lake have warmed up to about 6 - 8^{o} C with Saginaw Bay up to 10 - 12^{o} C. The typical thermal bar effect is quite visible with a large volume of the mid-lake still less than 4^{o} C. This warming up continues through August when maximum surface temperatures reached 16 - 18^{o} C. Since this is a deep lake, a strong thermocline is set up and the bottom water over a large area remains at 4^{o} C. Once again the north-south increase in temperature values was quite evident, particularly during the August, September and October surveys. After the September survey the lake began to cool down, with late October mid-lake observations in the range 10 - 14^{o} C. During this late October survey, considerable upwelling was observed along the western shore of the southern basin. By late November the lake had cooled down even further to a mid-lake surface temperature of about 6^{o} C. The distribution was nearly homogeneous both vertically and horizontally during the late November survey.

TEMPERATURE °C , 1m

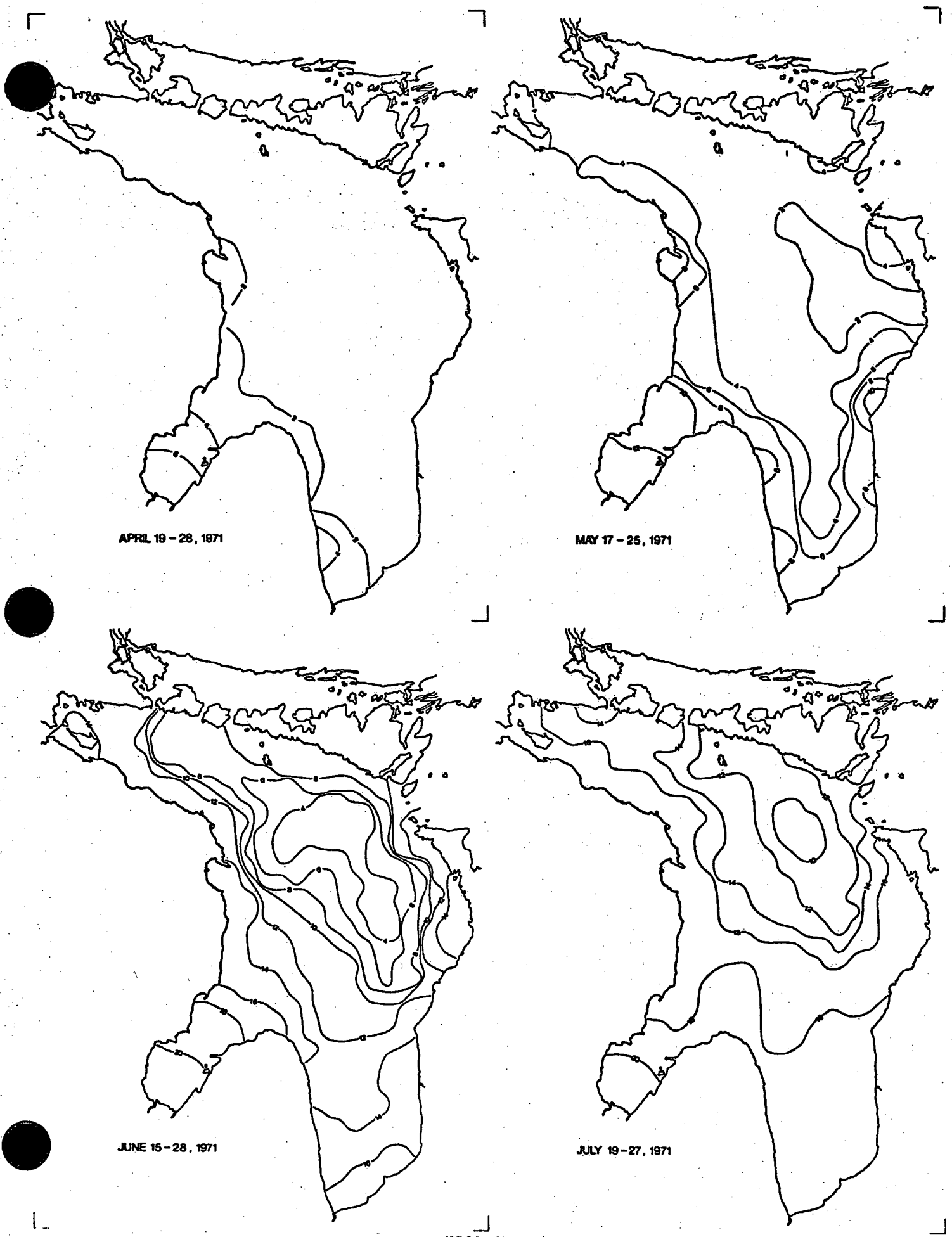
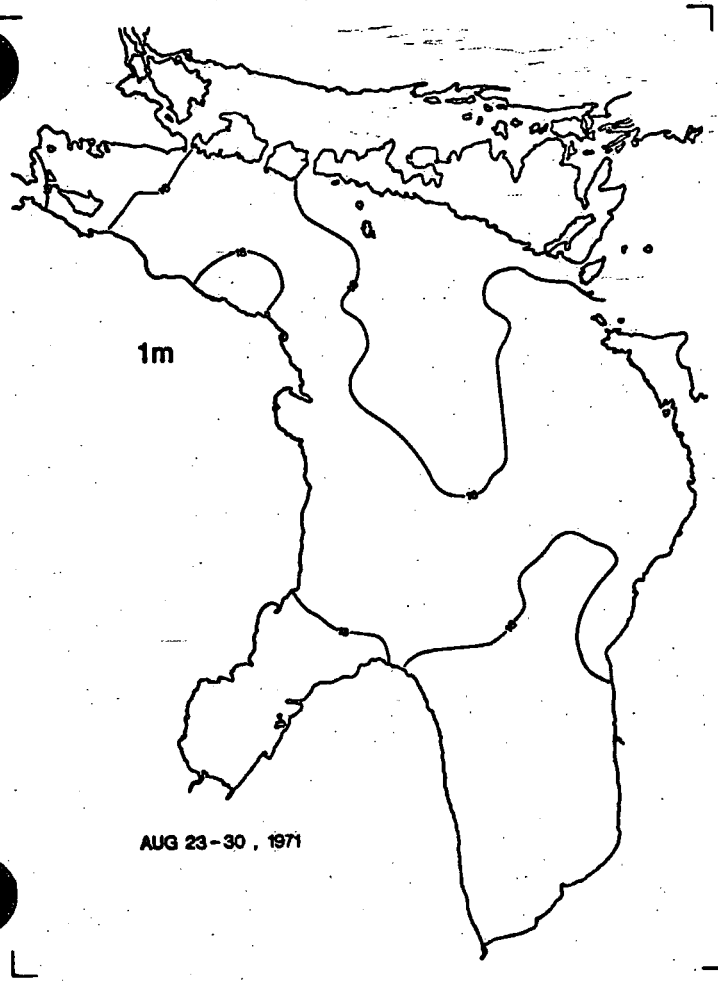
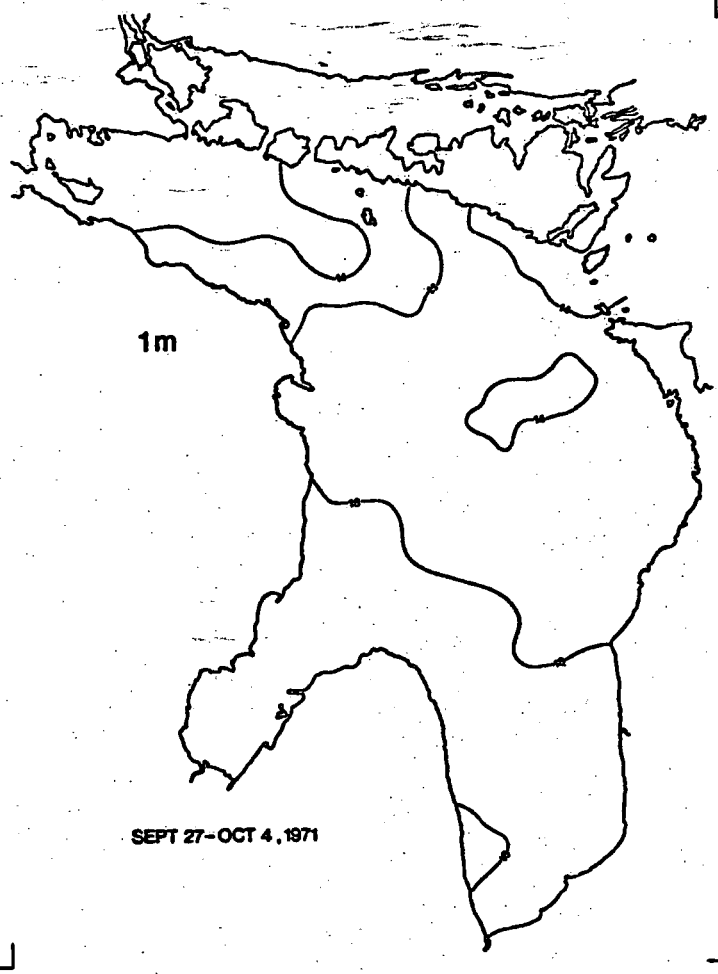


FIGURE 8

TEMPERATURE °C





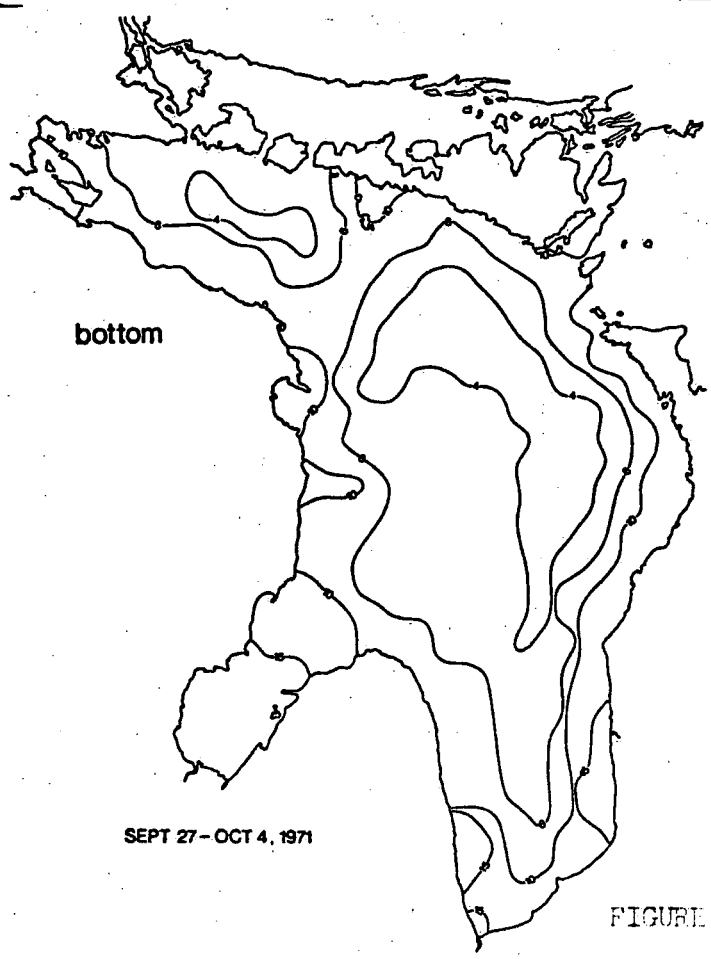
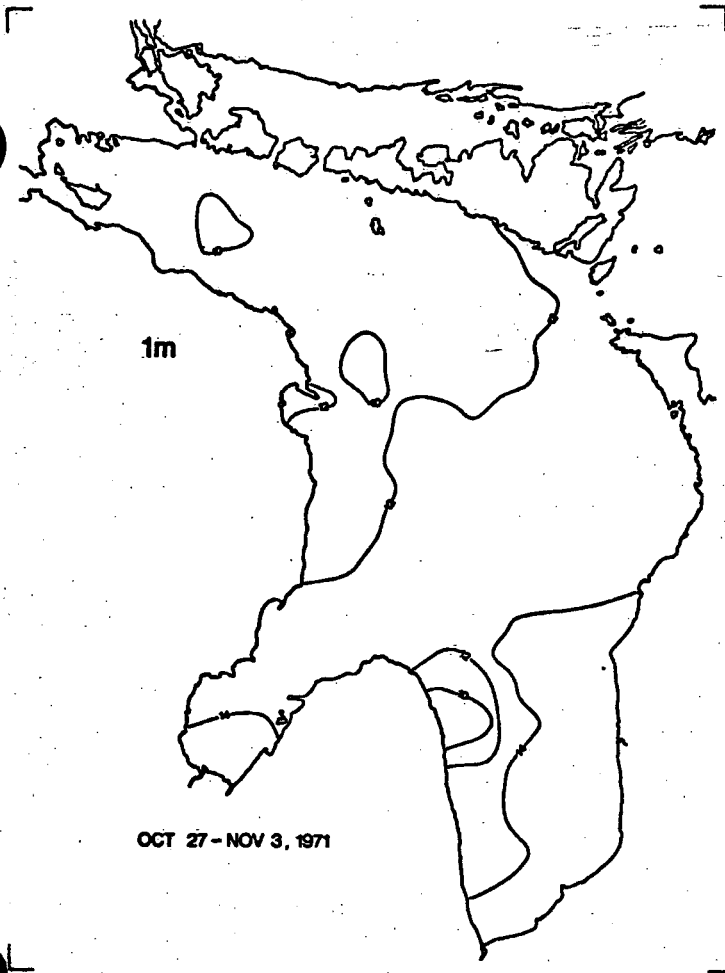
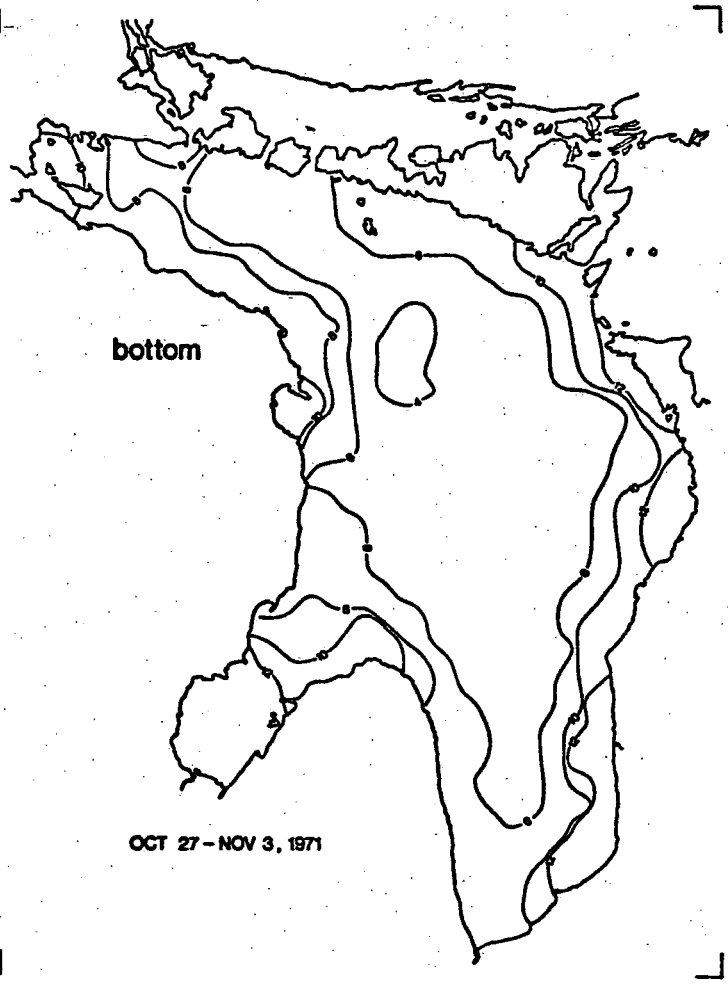
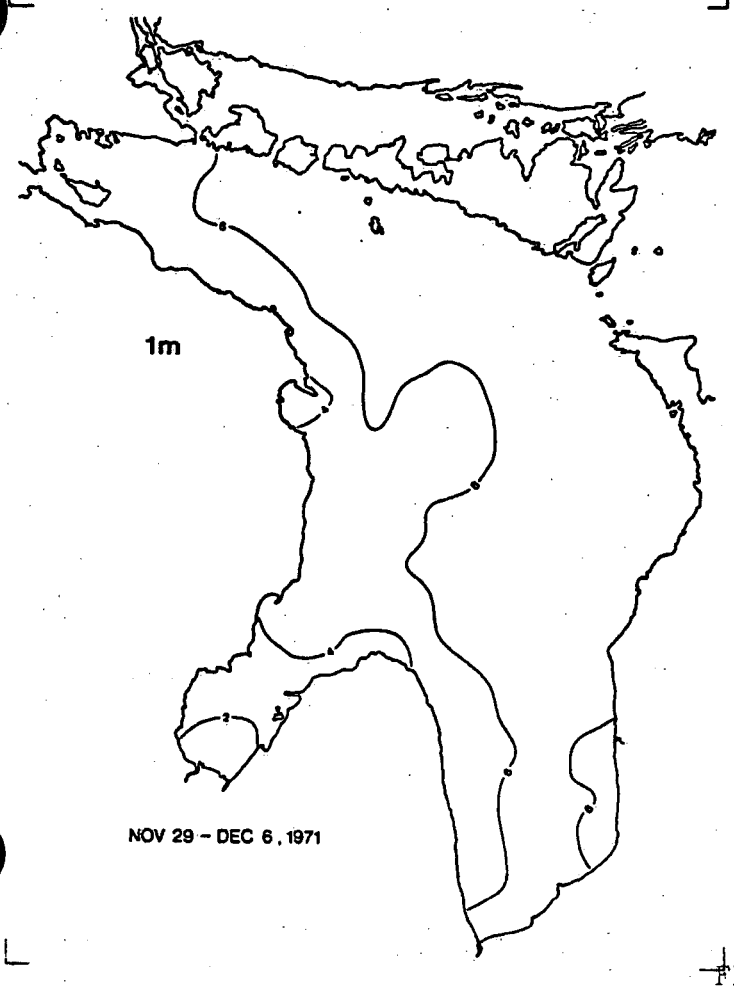


FIGURE 9

TEMPERATURE °C







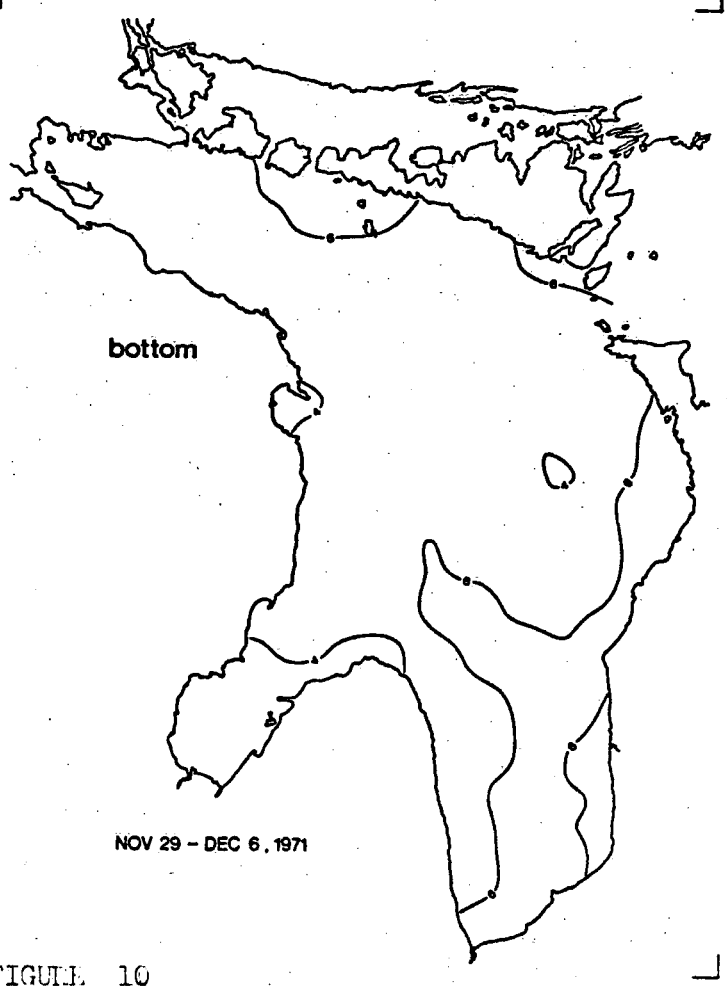


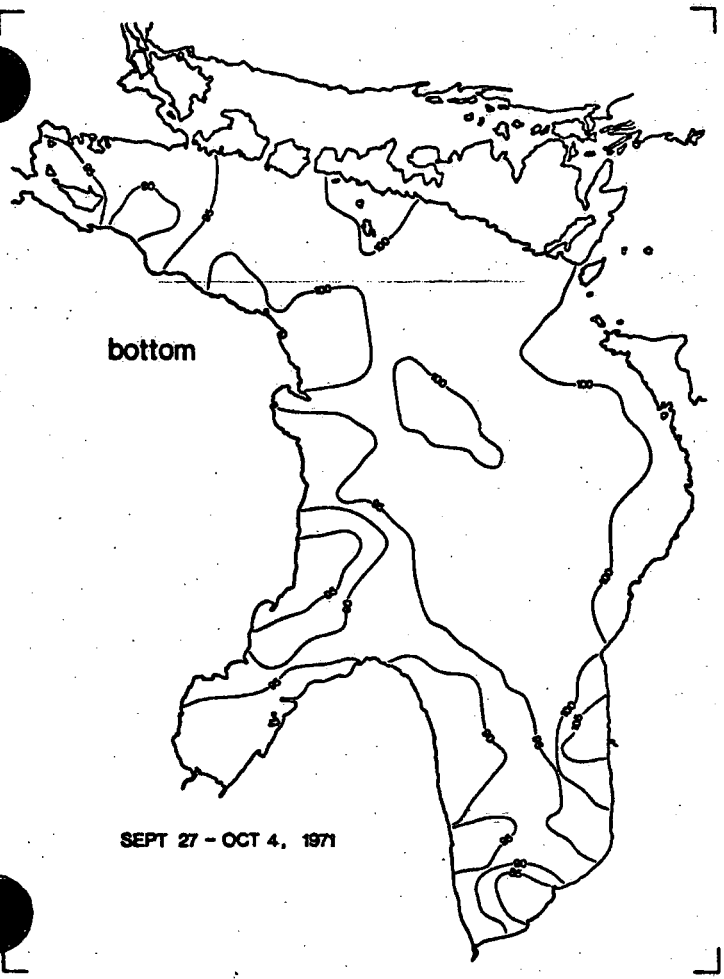
FIGURE 10

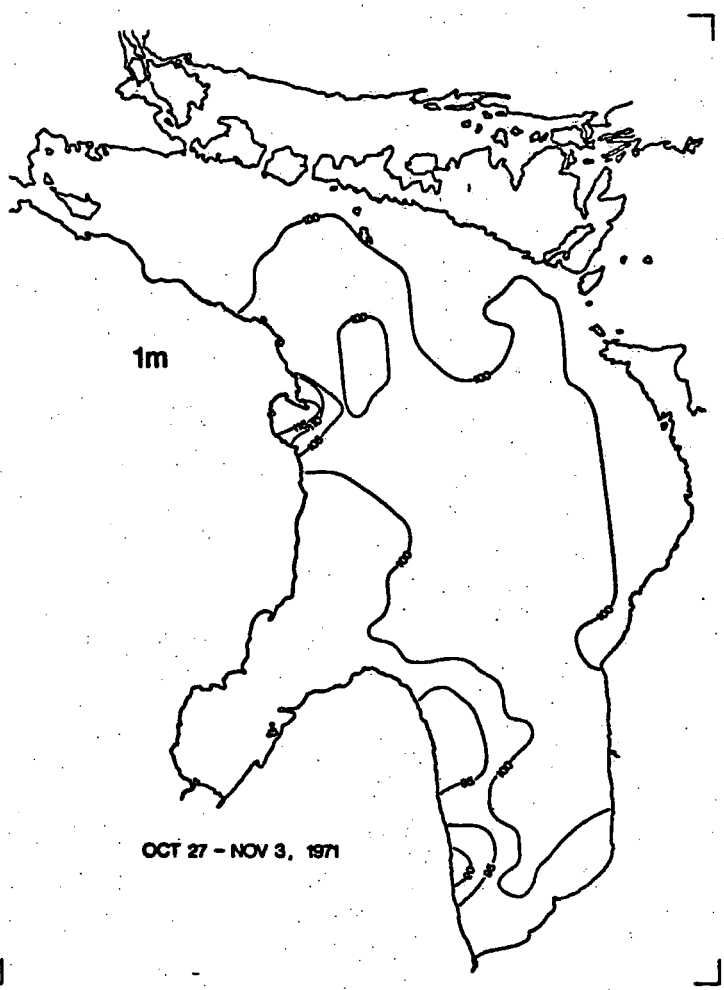
Dissolved Oxygen: Figure 11

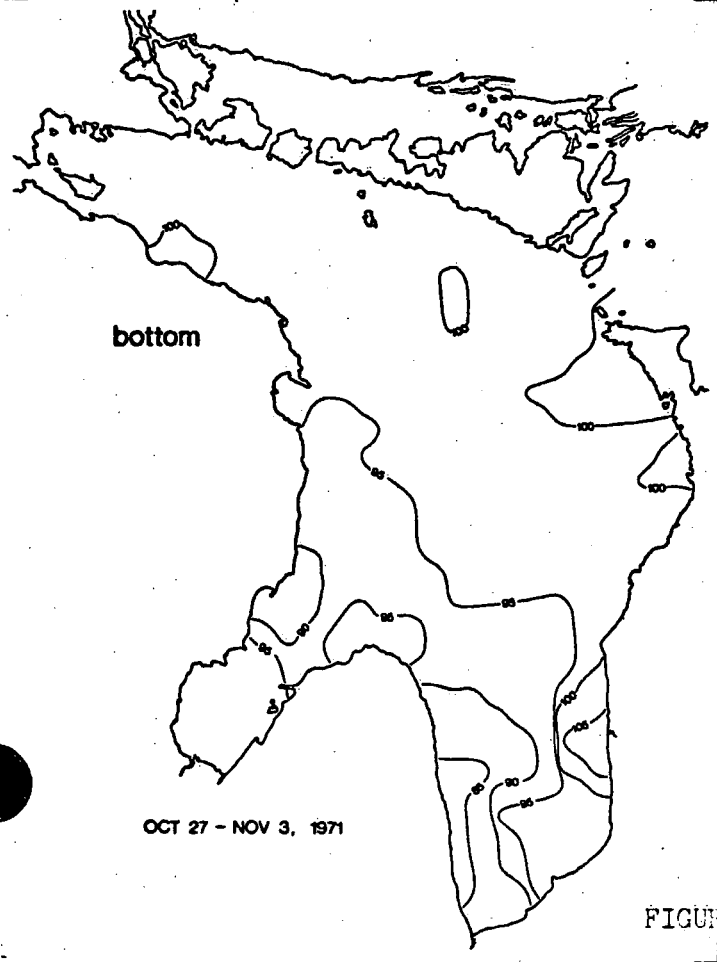
Generally Lake Huron was 90 - 100% saturated with dissolved oxygen. However in late summer a measurable depletion in oxygen occurred.

The minimum % saturation found was in late October in the bottom waters of the southern basin where it was 85% saturated.

DISSOLVED OXYGEN - PERCENT SATURATION







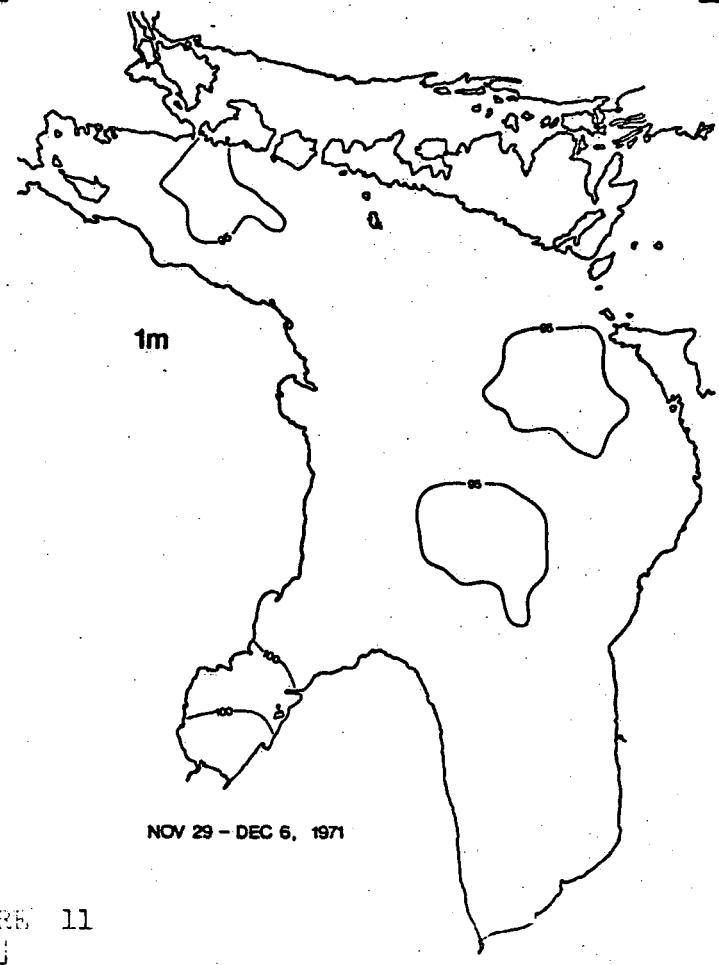


FIGURE 11

Reactive Silicate: Figures 12, 13 & 14

The yearly silicate cycle in Saginaw Bay was quite different from the main lake; hence Saginaw Bay will be discussed separately.

MAIN LAKE:

During the mid-April survey a fairly homogeneous horizontal and vertical distribution of reactive silicate was observed with values in the range 1200 - 1400 µg/l - SiO_2.

However, by mid-May, as the lake warmed up the nearshore depletion of silicate in surface waters became apparent. Mid-lake surface values ranged from 1000 - 1400 µg/l - SiO_2 with nearshore areas ranging from 600 - 1000 µg/l - SiO_2.

As the yearly cycle progressed, the mid lake surface values continued to decrease until a minimum of 600 - 800 µg/l - SiO_2 was observed in late September. Throughout the summer a strong thermocline existed and hence bottom waters were not depleted and remained at 1400 - 1800 µg/l - SiO_2.

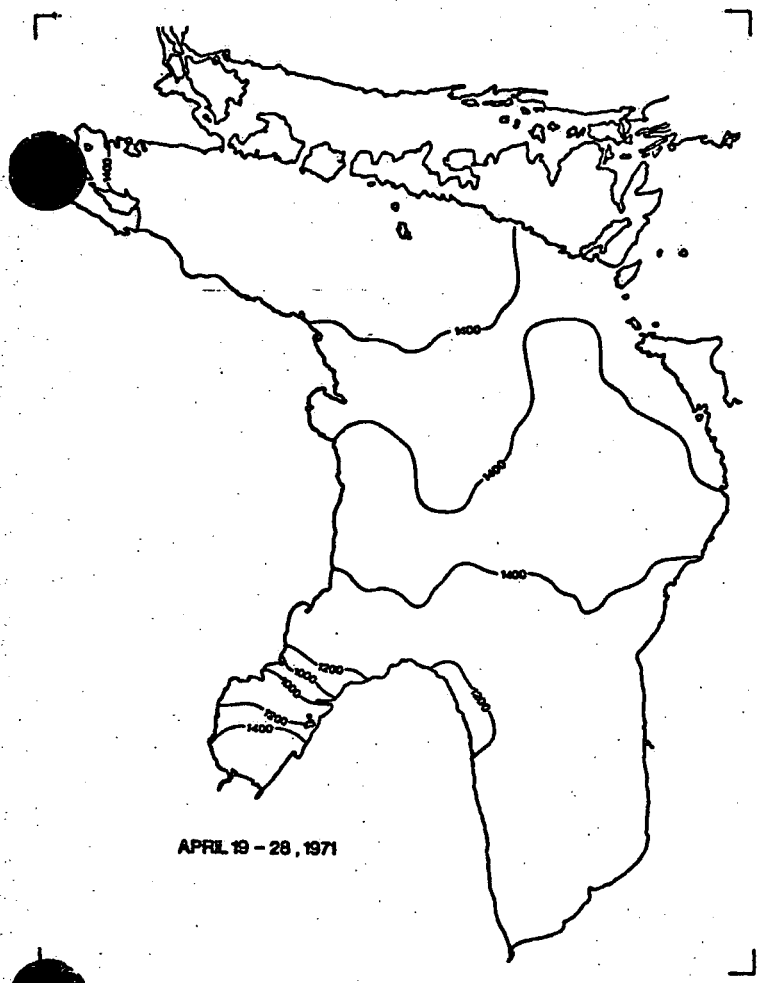
By late October, as the lake began to cool down;the mid-lake surface and bottom waters began to increase in silicate. The surface waters increased to 800 - 1000 µg/l - SiO_2 and the bottom waters increased to 1600 - 2000 µg/l - SiO_2.

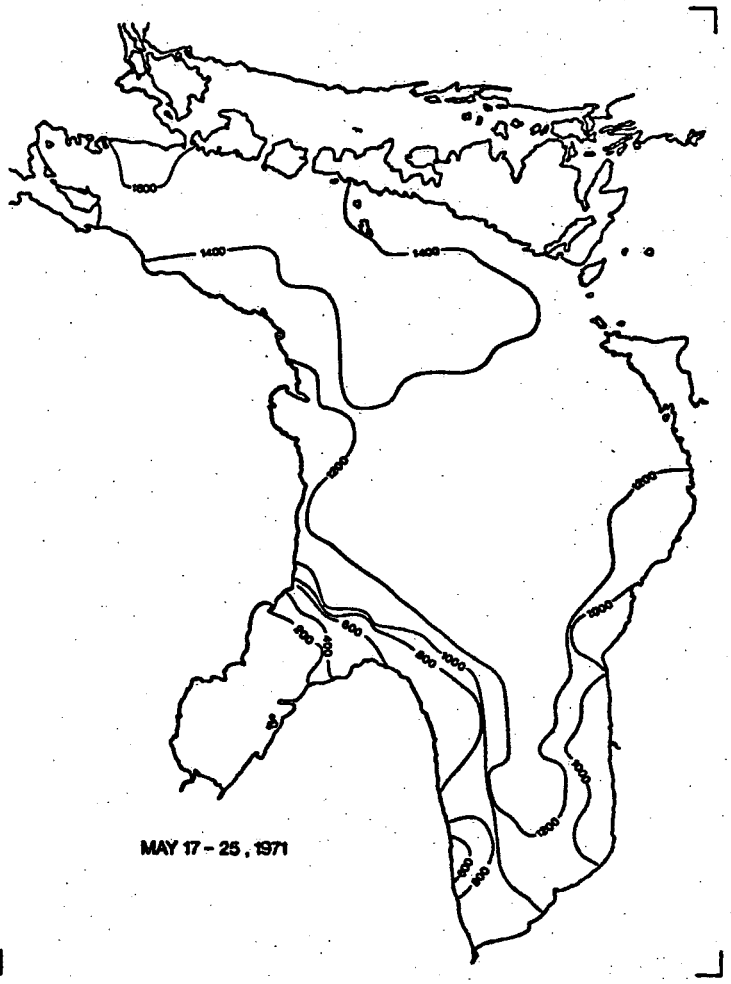
By late November the mid-lake surface values had increased to 1200 - 1400 µg/l - SiO_2 and the bottom waters had decreased slightly to 1400 - 1800 µg/l - SiO_2.

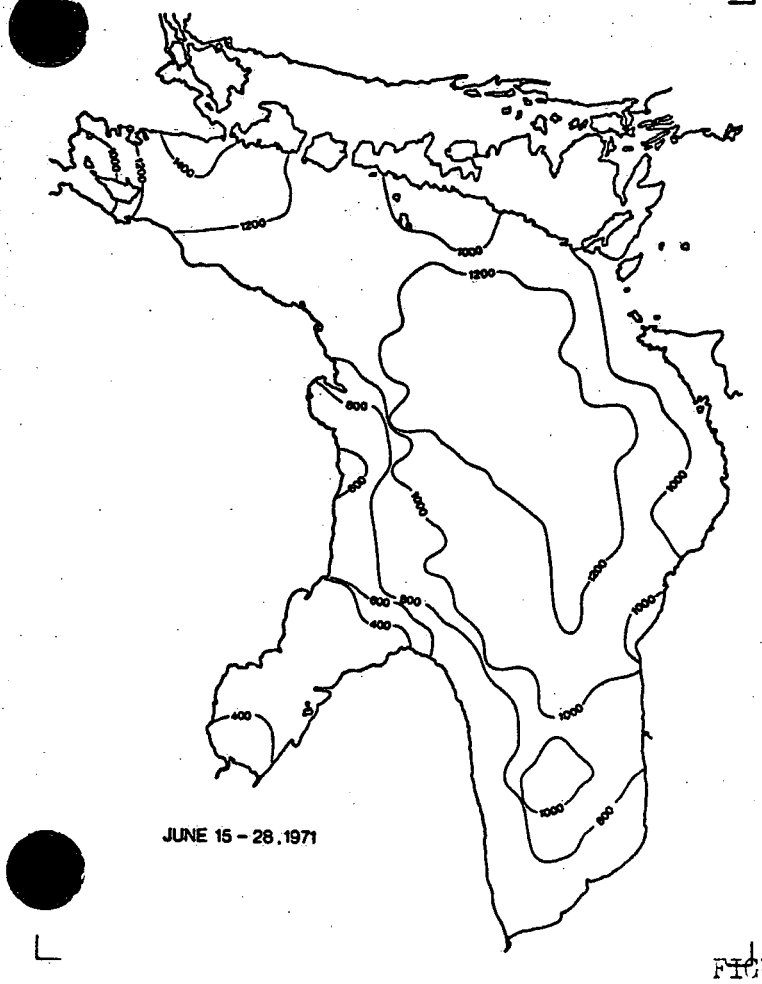
SAGINAW BAY:

In mid-April silicate values observed were nearly the same as mid-lake. However, by mid-May the silicate was nearly completely depleted to less than 200 µg/l - SiO2. Apparently a large diatom bloom has taken place between these surveys. By mid-June the silicate began to return and reached about 400 µg/l - SiO2. By mid-July Saginaw Bay silicate values ranged from 1200 - 1800 µg/l - SiO2 and continued higher than the main body of the lake throughout August, September and October. The maximum was reached in August at 2000 - 2500 µg/l - SiO2. By late November Saginaw Bay values observed were nearly the same as mid-lake values again.

REACTIVE SILICATE µg/l-SiO_2 , 1m







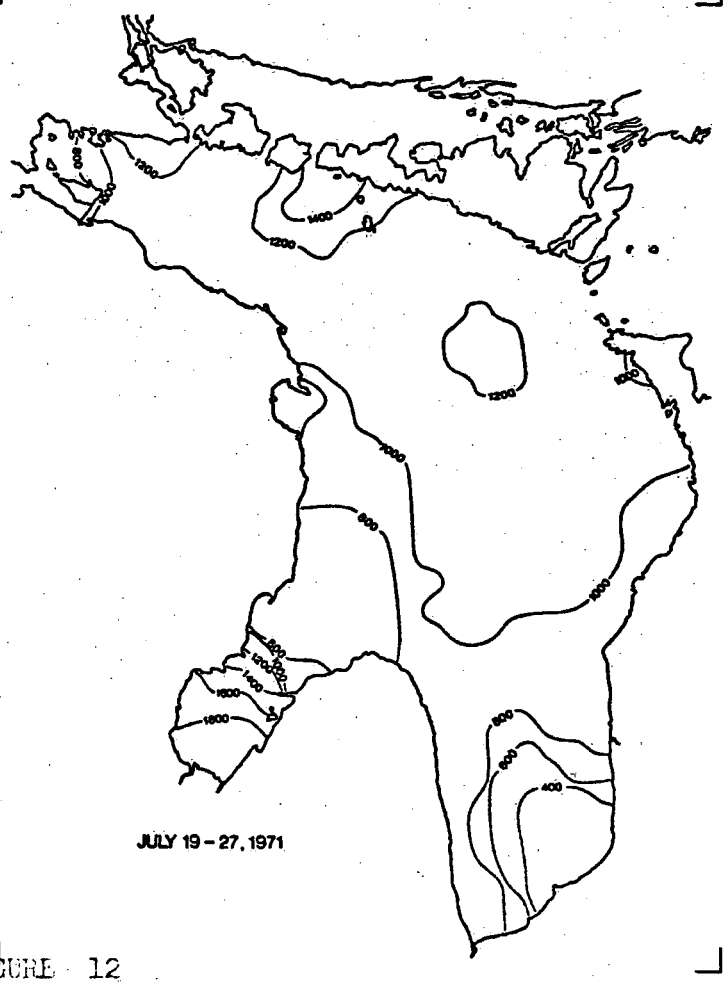
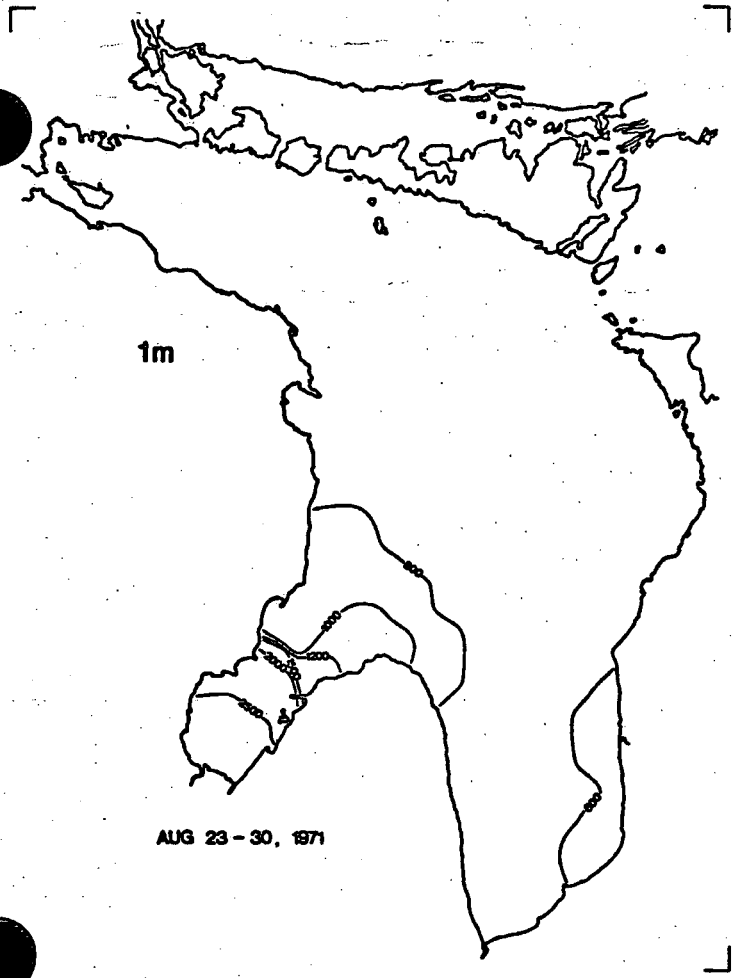
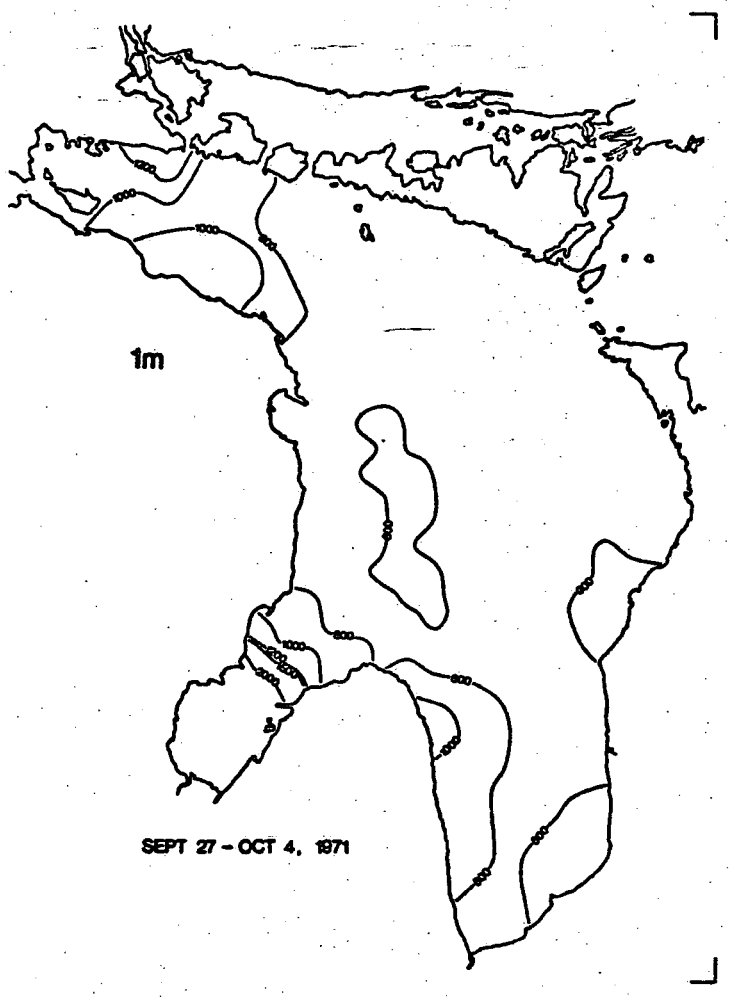


FIGURE 12

REACTIVE SILICATE µg/l - SiO_2





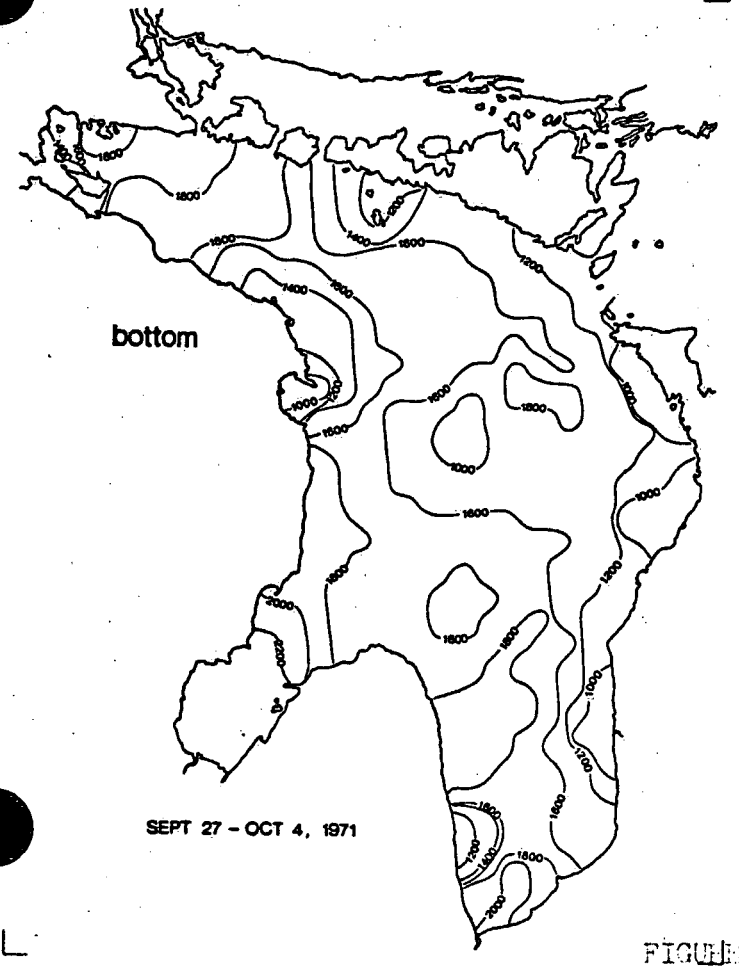
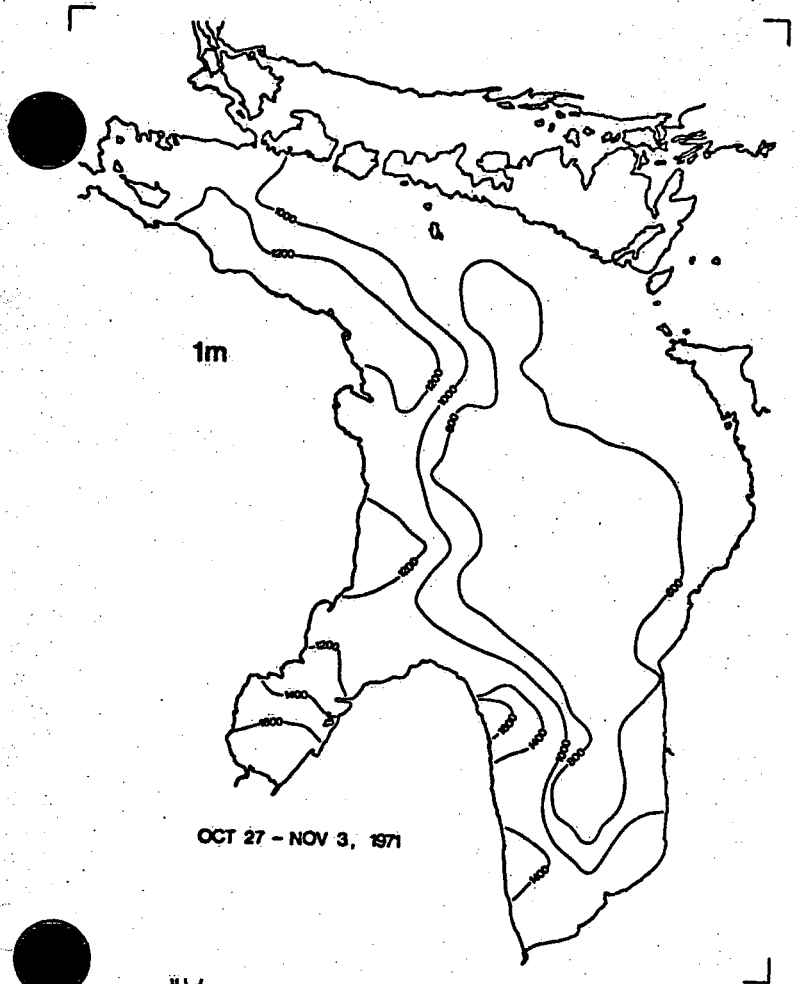
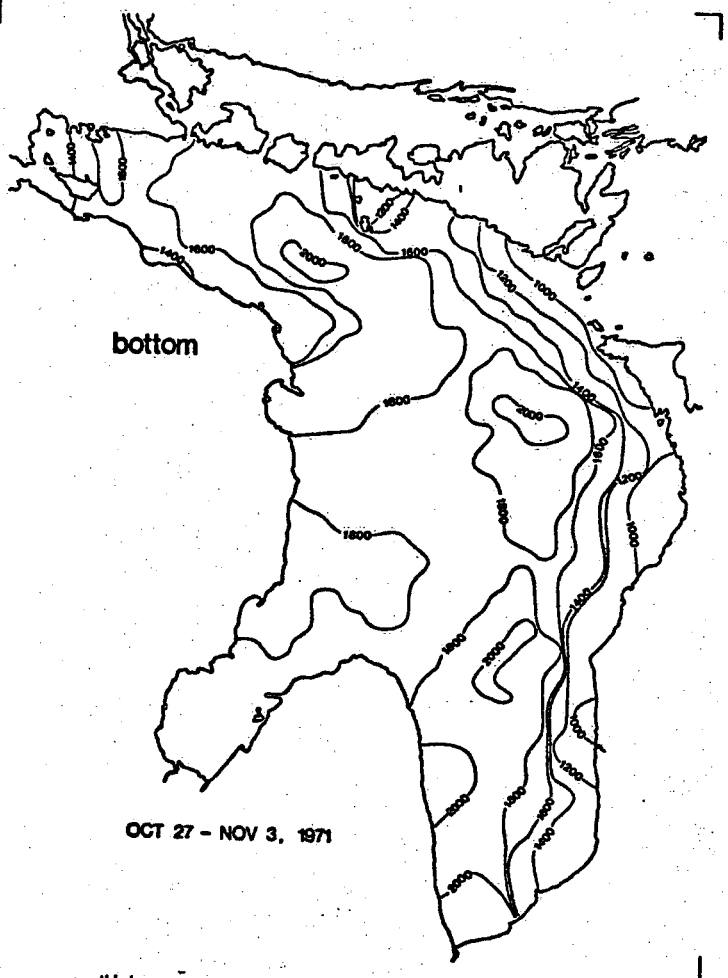
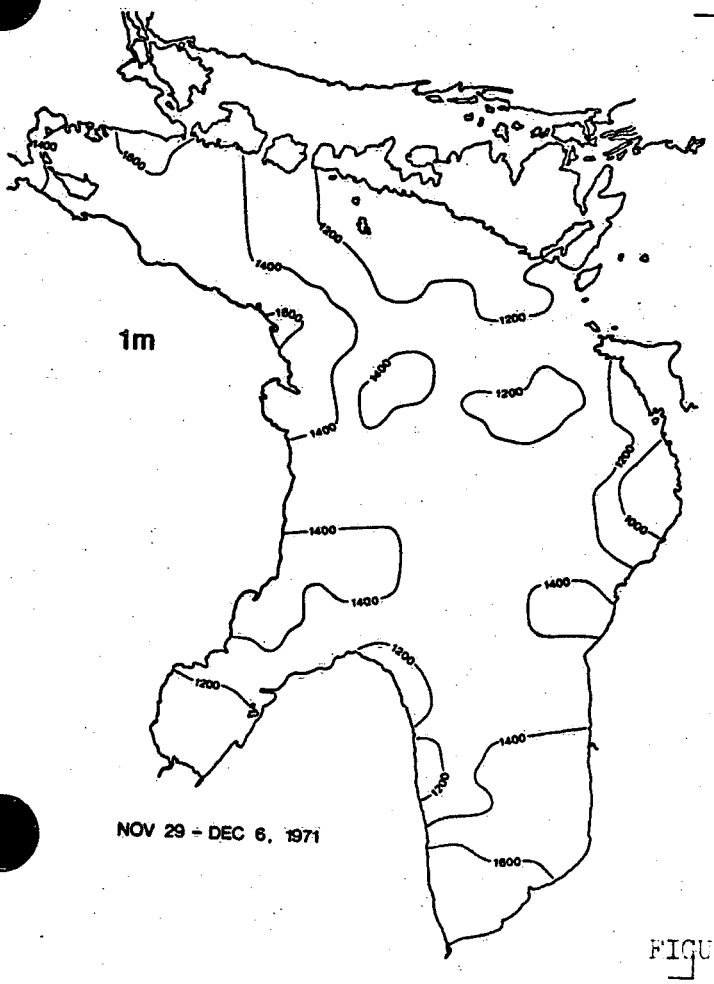


FIGURE 13

REACTIVE SILICATE µg/l - SiO_2







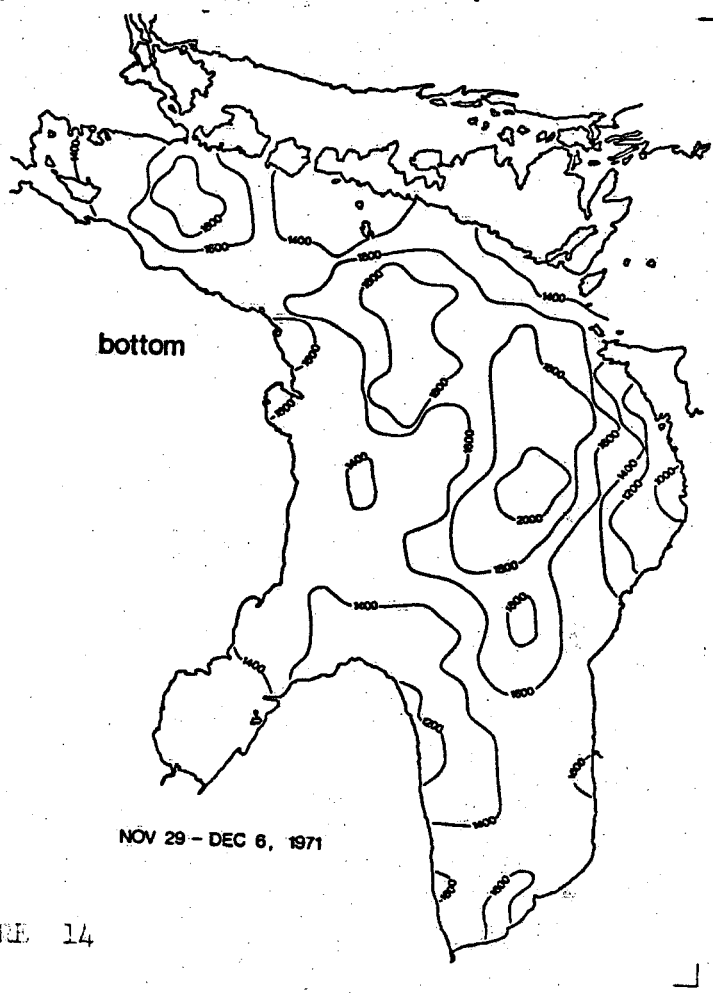


FIGURE 14

Nitrate - Nitrite Nitrogen: Figures 15, 16 & 17

During the earliest survey in mid-April a very homogeneous horizontal and vertical distribution of nitrate - nitrite nitrogen was observed at a level of about 250 µg/l - NO_3. Only Saginaw Bay with values from 250 - 700 µg/l - NO_3 and an area off Grand Bend with values to 400 µg/l - NO_3 showed much variation from mid-lake values.

By mid-May the nearshore to mid-lake pattern of nitrate - nitrite nitrogen increase was not yet very visible. However, in Saginaw Bay the nitrate - nitrite nitrogen concentration in surface waters had been depleted to 250 - 400 µg/l - NO_3. An apparent source of nitrate was observed off Goderich where values increased to a maximum of 400 µg/l - NO_3.

By mid-June the nearshore to mid-lake pattern became more evident with mid-lake surface values ranging from 200 - 250 µg/l - NO_3 and the nearshore surface values ranging from 150 - 200 µg/l - NO_3. Saginaw Bay was further depleted to 75 - 150 µg/l - NO_3.

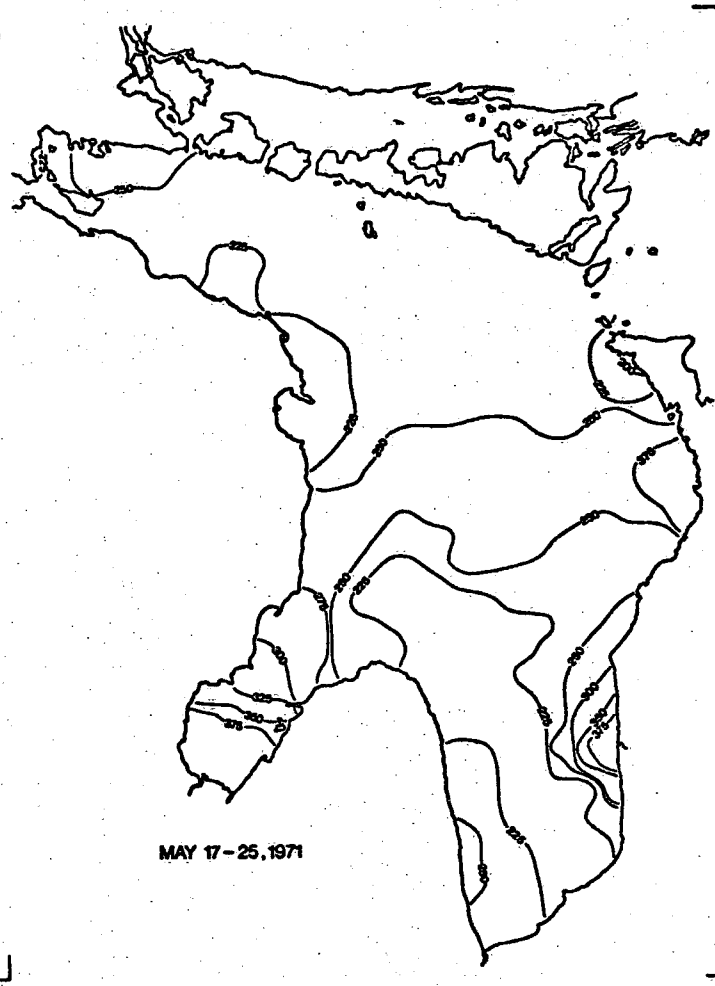
By mid-July the nearshore to mid-lake variations continued to increase. Saginaw Bay was depleted down to a minimum of about 25 µg/l - NO_3. The mid-lake surface values reached their minimum of about 175 µg/l - NO_3 in late September and the bottom water remained at about 200 - 250 µg/l - NO_3. Saginaw Bay remained lower than 100 µg/l - NO_3 until after the late October survey. By late October the surface waters increased to about 200 - 225 µg/l - NO_3. Extensive upwelling

was observed along the western shore of the southern basin. The bottom waters had increased to about 250 - 300 µg/l - NO_3 since the September survey.

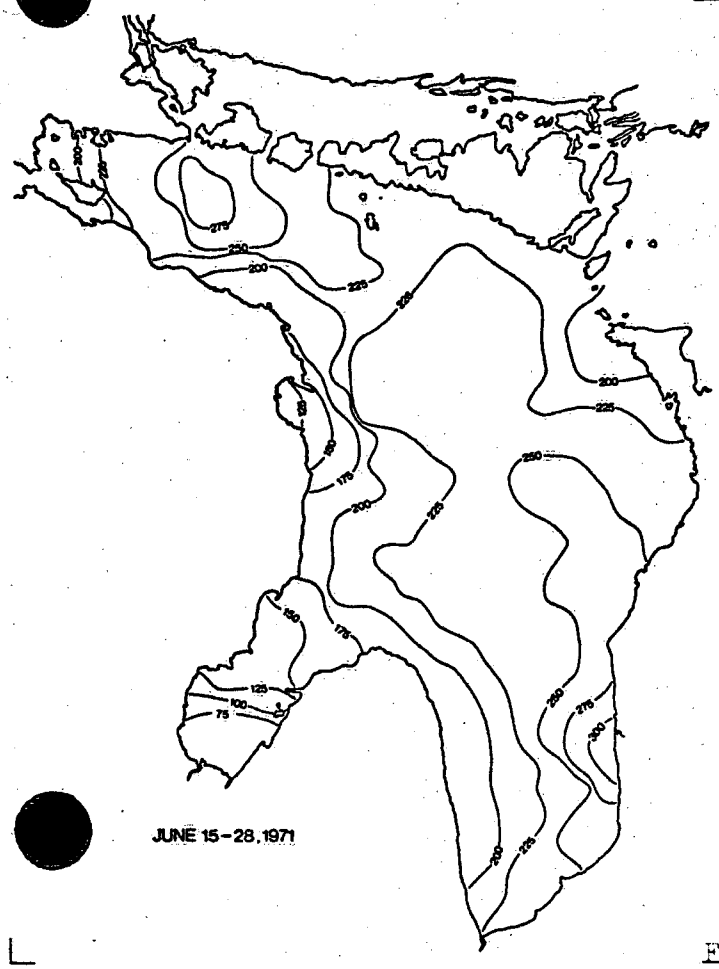
Most of the surface water had returned to its spring value of about 250 µg/l - NO_3 by late November. Bottom waters were still higher than surface waters with values ranging from 250 - 300 µg/l - NO_3. Saginaw Bay remained lower than mid-lake values at about 175 µg/l - NO_3.

NITRATE-NITRITE NITROGEN µg/l-N, 1m

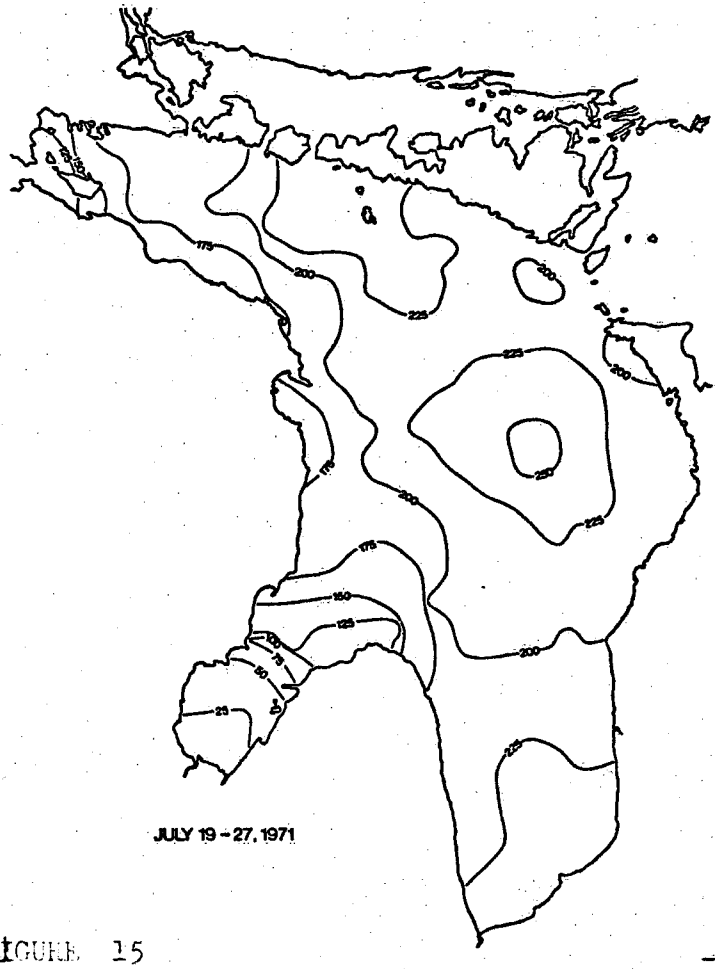
APRIL 19 - 28, 1971



MAY 17 - 25, 1971



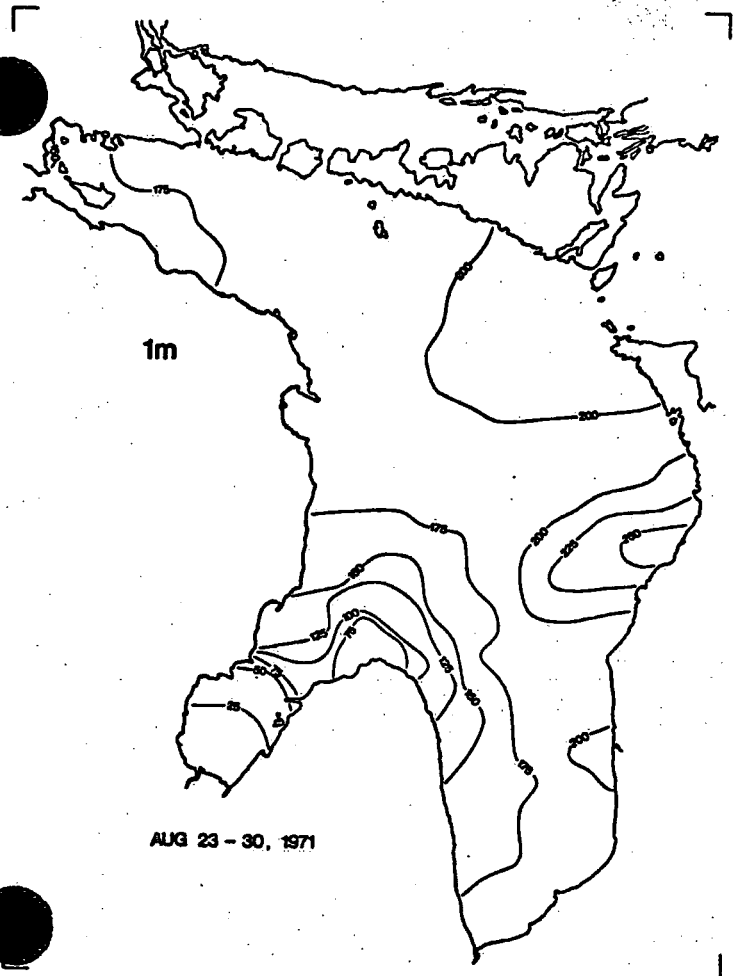
JUNE 15 - 28, 1971

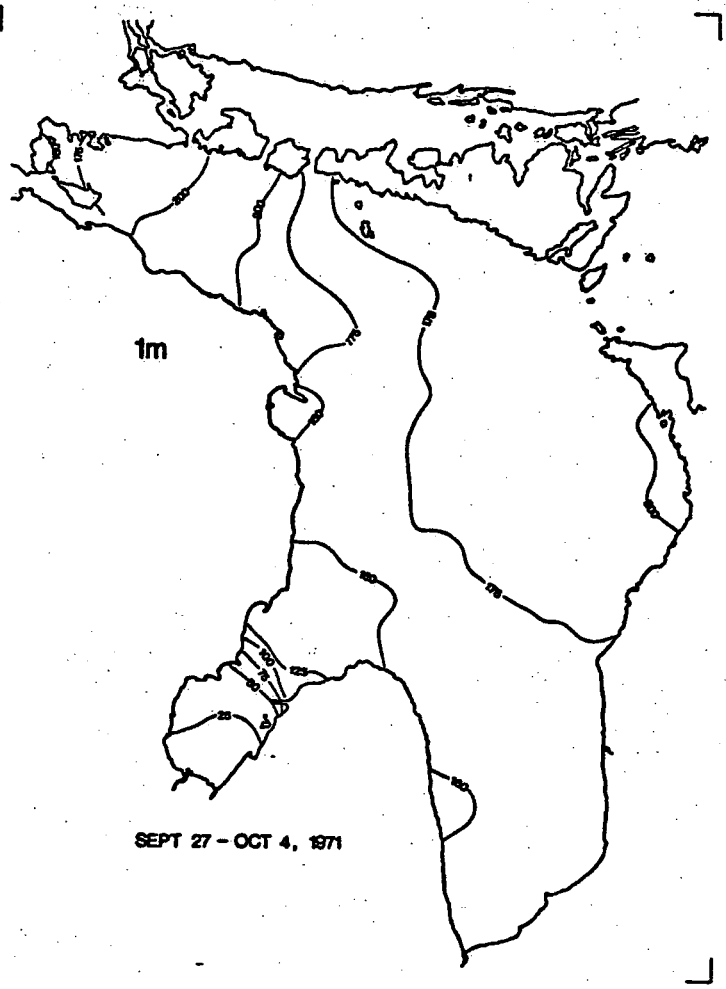


JULY 19 - 27, 1971

FIGURE 15

NITRATE – NITRITE NITROGEN µg/l – N





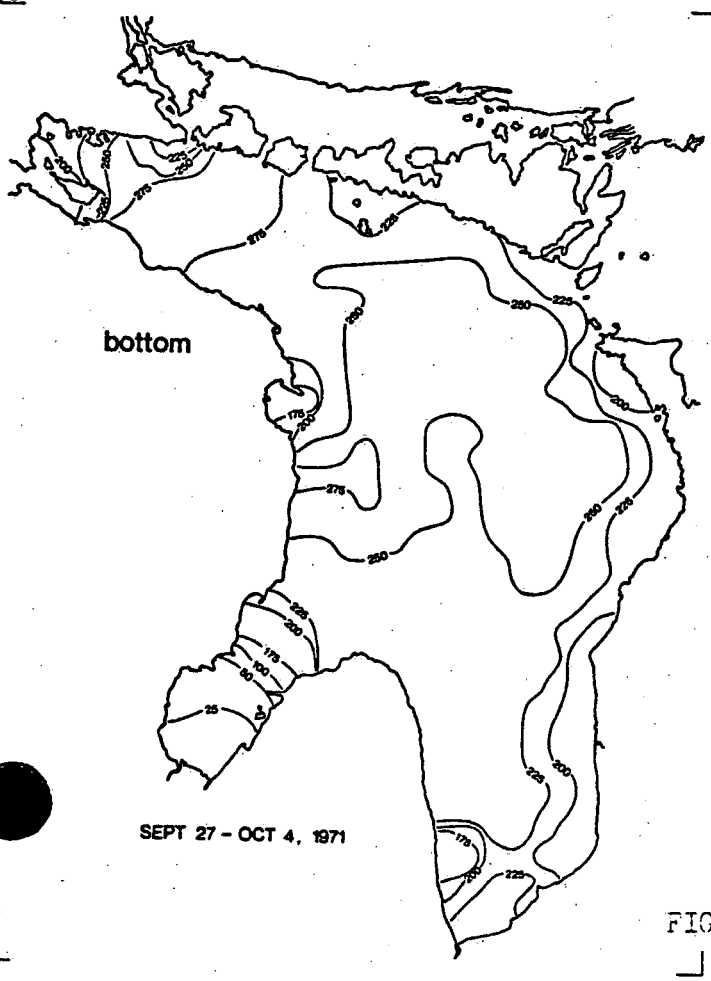
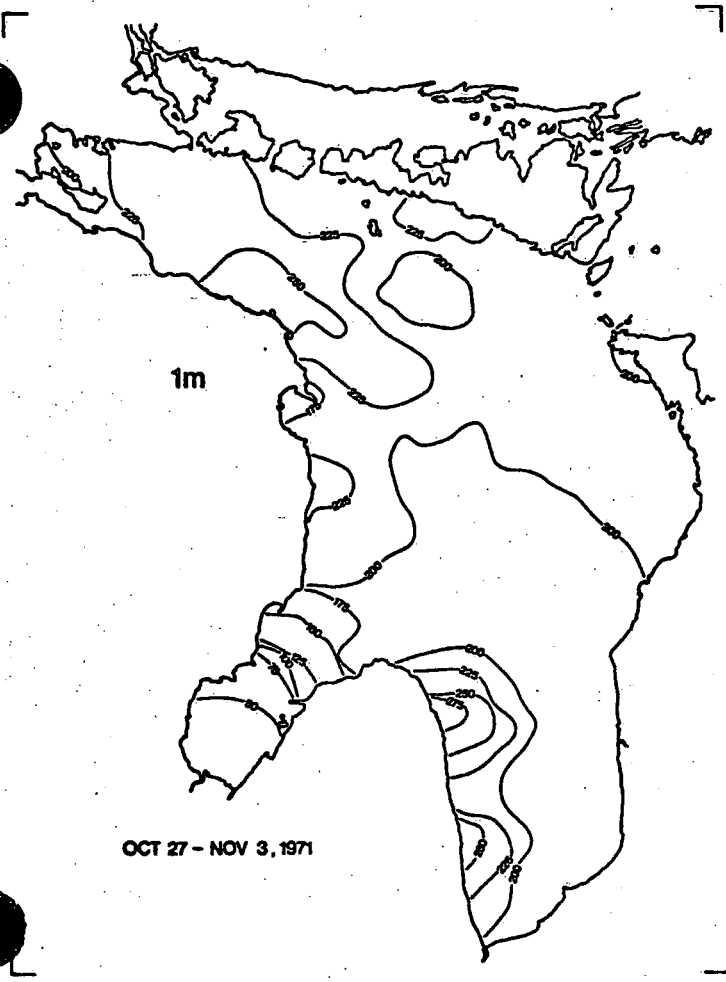
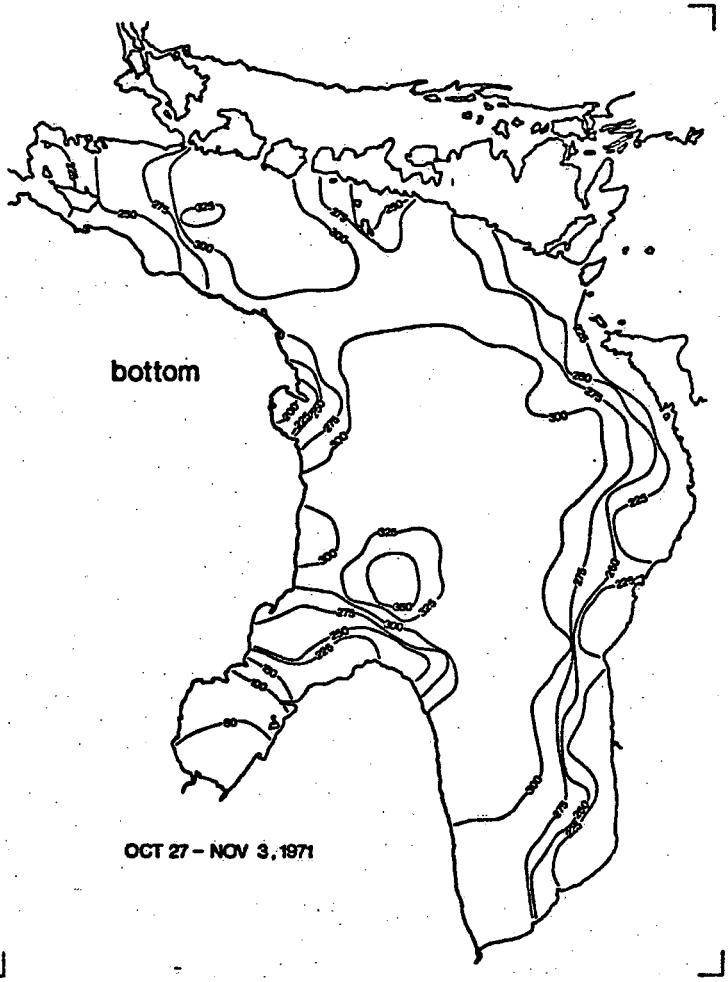
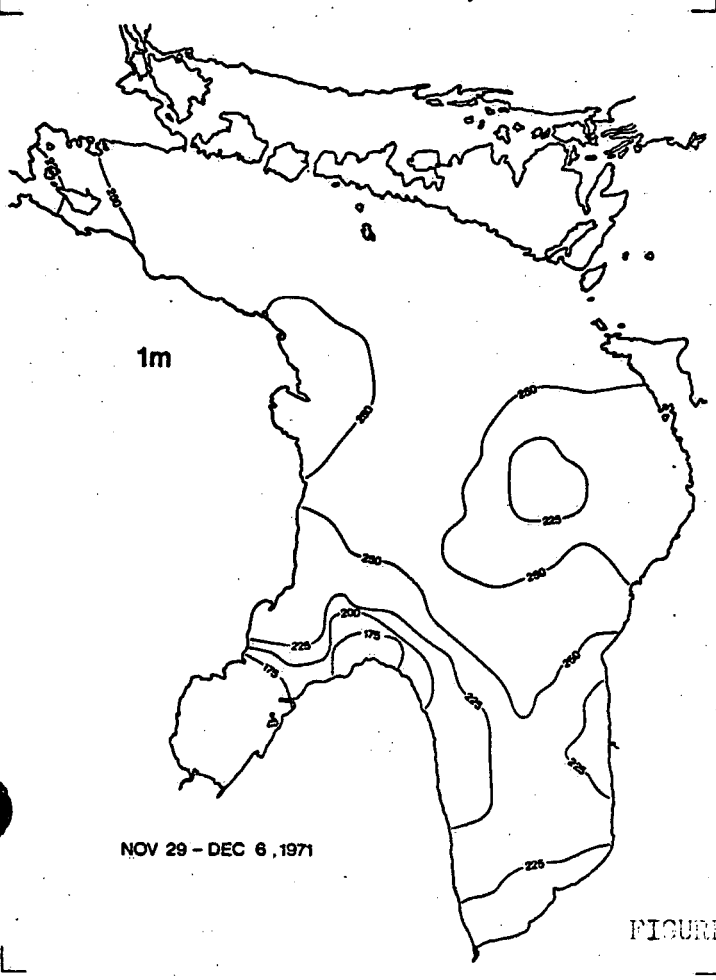


FIGURE 16

NITRATE-NITRITE NITROGEN µg/l-N







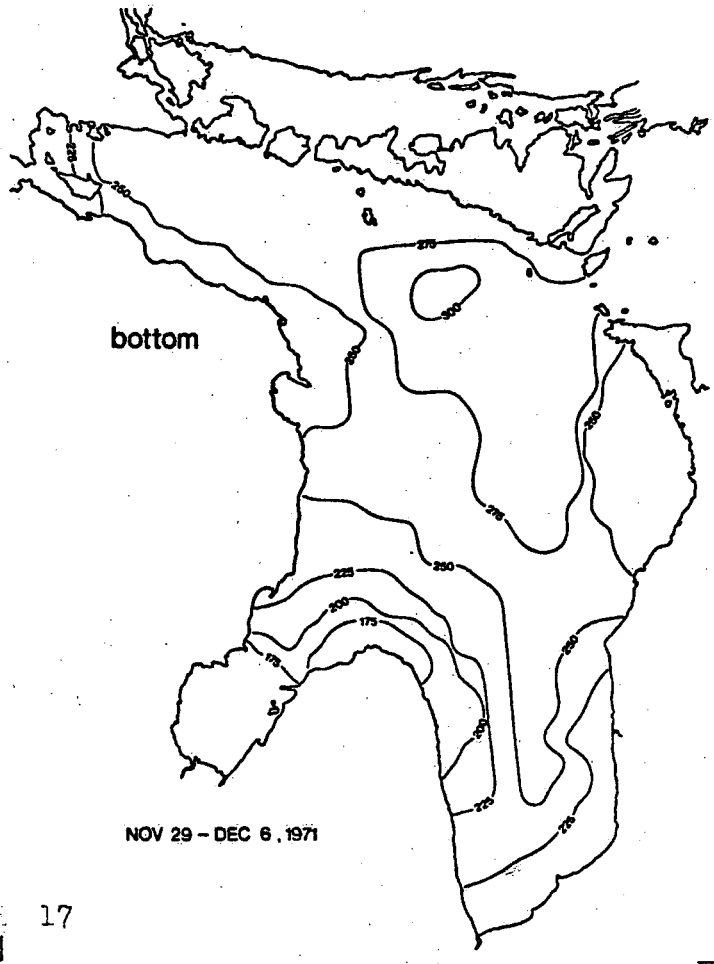
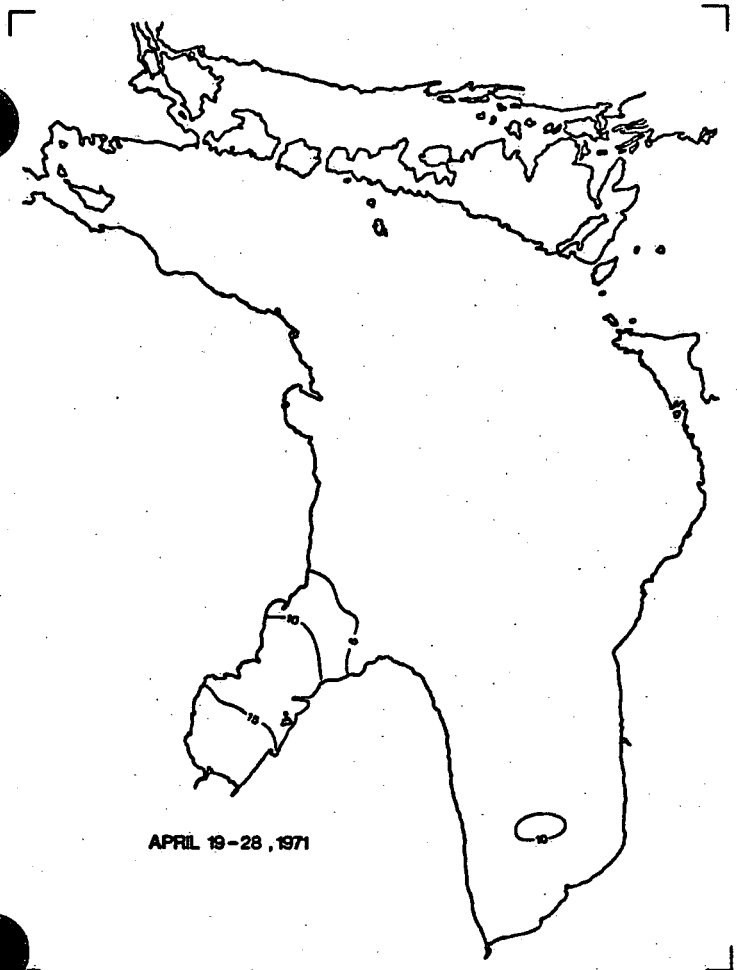


FIGURE 17

Ammonia Nitrogen: Figures 18 and 19

Ammonia nitrogen is included in this report because it is an important part of the nitrogen budget of the lake. The ammonia nitrogen values were generally quite homogeneous throughout the lake. Observed values usually ranged between 5 and 10 µg/l - N. Saginaw Bay was usually higher in ammonia nitrogen than the main lake. Two distinct peaks in ammonia nitrogen concentration were observed in Saginaw Bay. The first one occurred in mid-June when up to 40 µg/l - NH_3 - N were observed and the second occurred in late September when values up to 50 µg/l - NH_3 - N were encountered. The area immediately north of Sarnia in the southern basin also had two distinctly higher occurrences. The first occurred in late May and the second was observed in late September.

AMMONIA NITROGEN µg/l-N, 1m



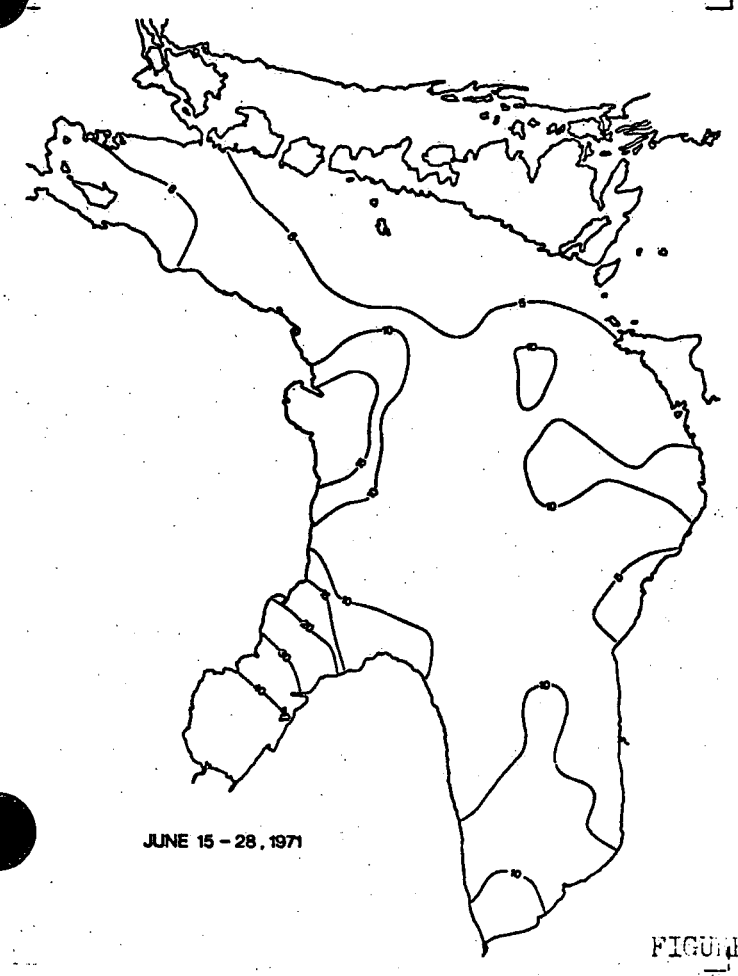


FIGURE 18

AMMONIA NITROGEN µg/l-N, 1m

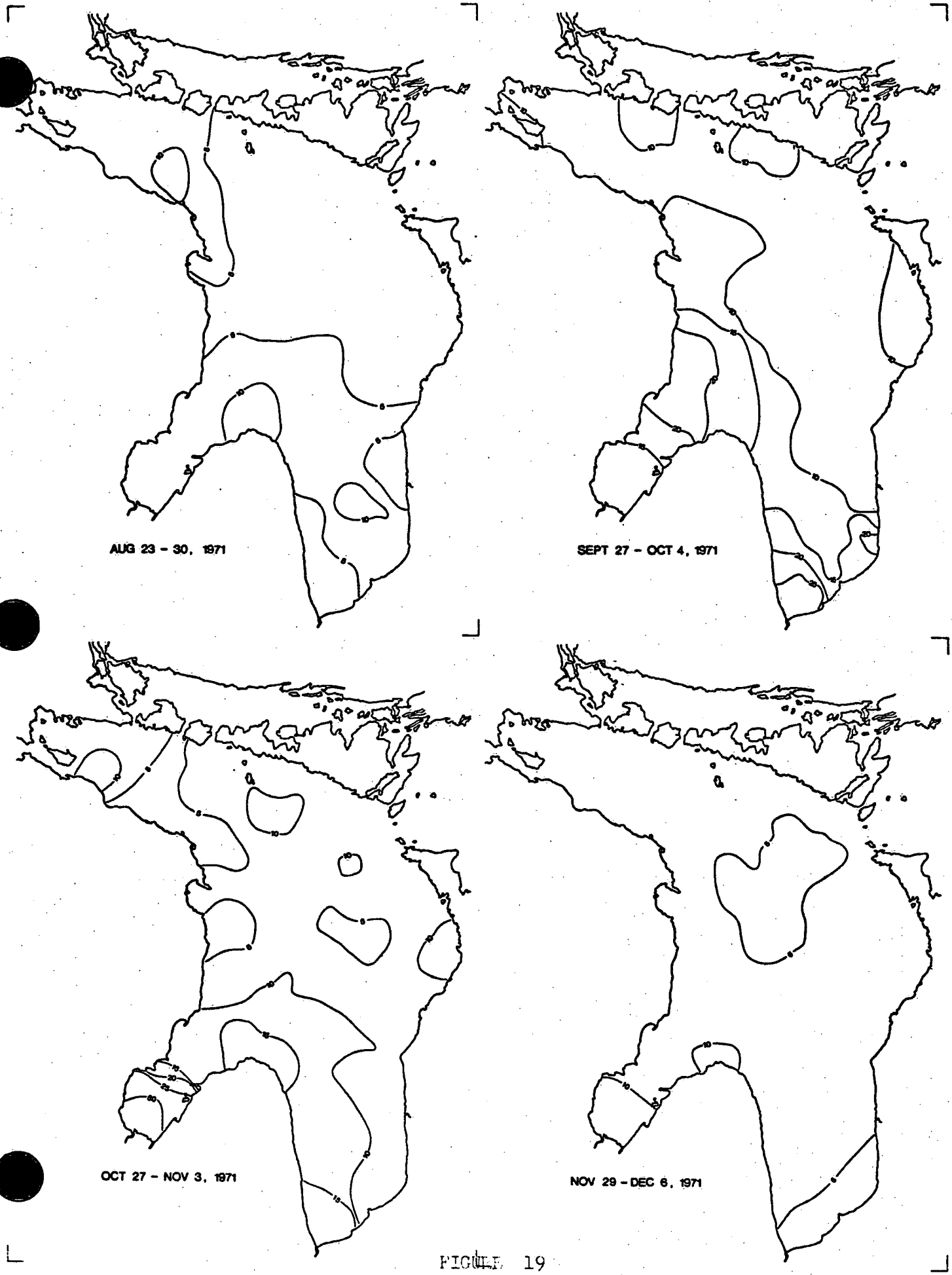


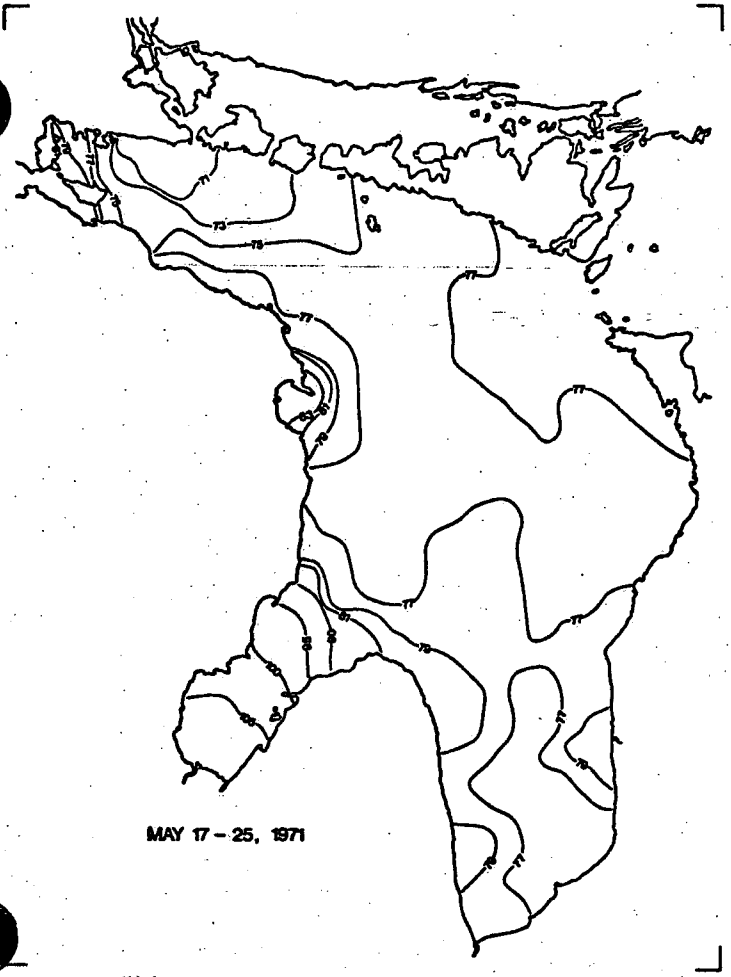
FIGURE 19

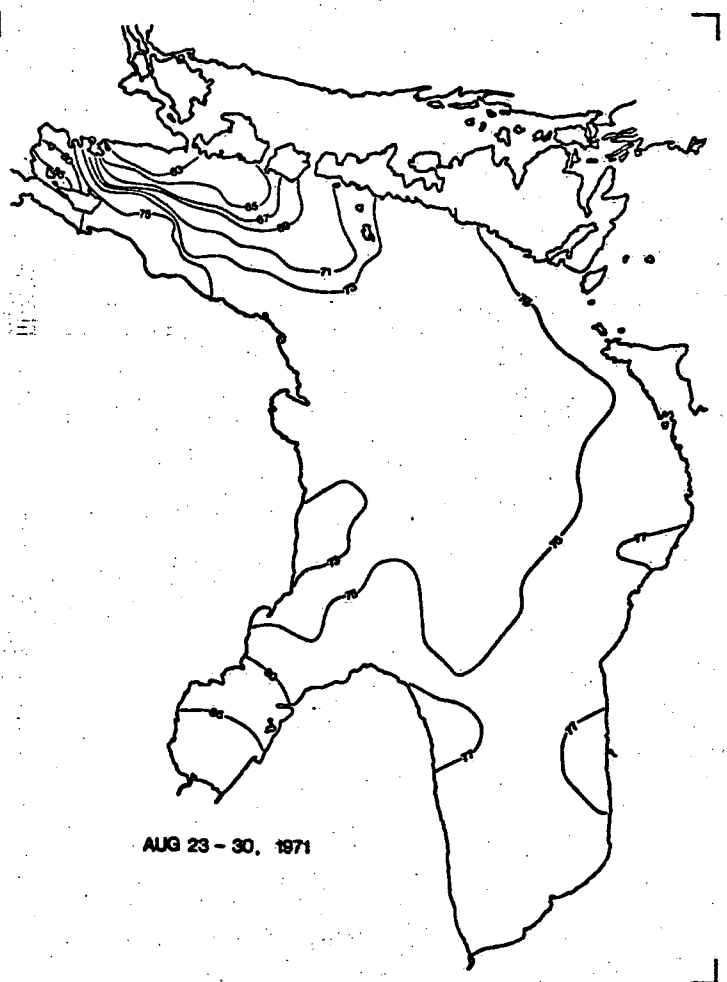
Alkalinity: Figures 20 & 21

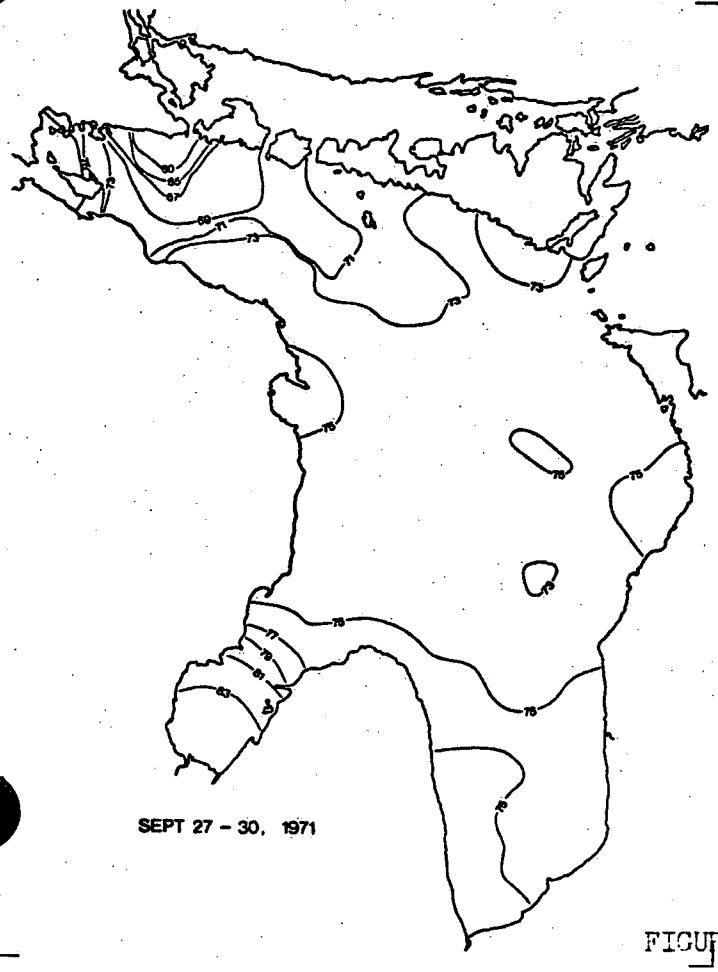
A small but measurable depletion in alkalinity occurred in the surface waters in the summer. During the rest of the year the alkalinity values were quite homogeneous.

The main reason for including the alkalinity values in this report was that they show the Lake Superior - Lake Michigan mixing zone in north-western Lake Huron. Lake Huron alkalinity values generally ranged from 73 - 75 µg/l - Ca CO_3. Alkalinity values of the Lake Michigan water entering Lake Huron through the Straits of Mackinac were in the range 75 - 80 µg/l - Ca CO_3. Alkalinity values of the Lake Superior water entering Lake Huron via the St. Marys River were generally below 60 µg/l - Ca CO_3. These large differences in alkalinity illustrated the areas of influence of each water mass.

ALKALINITY, TOTAL FILTERED mg/l - $CaCO_3$, 1m







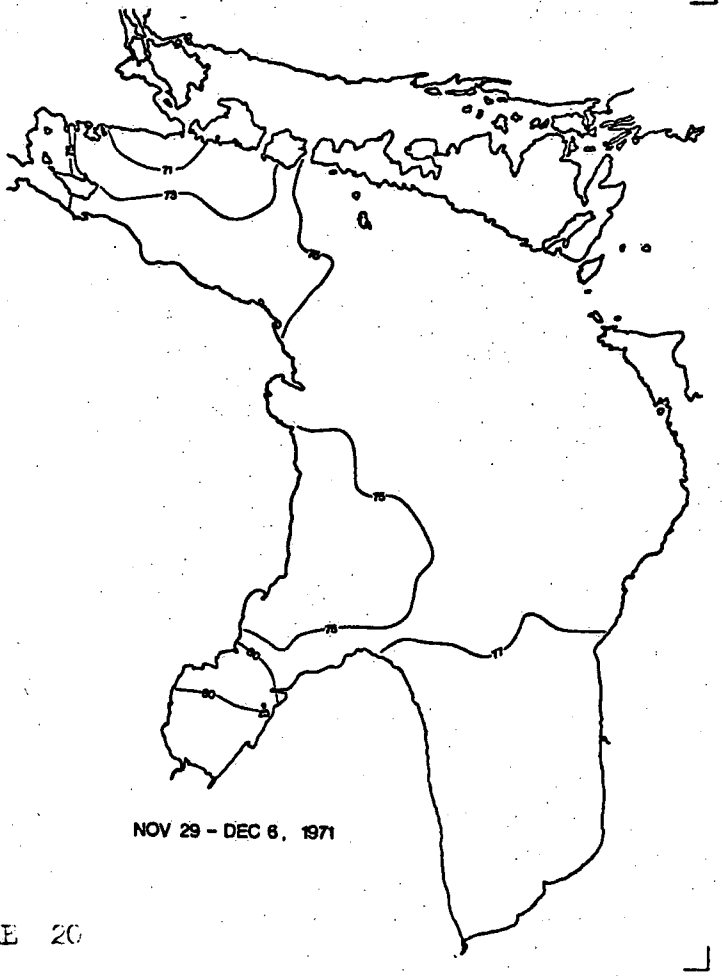
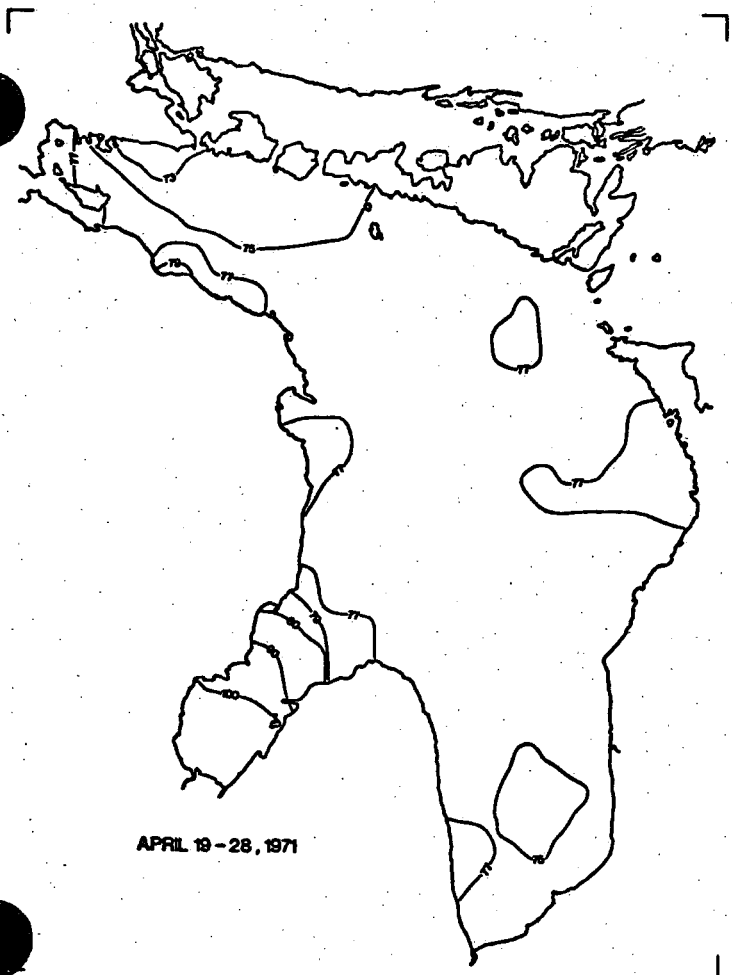
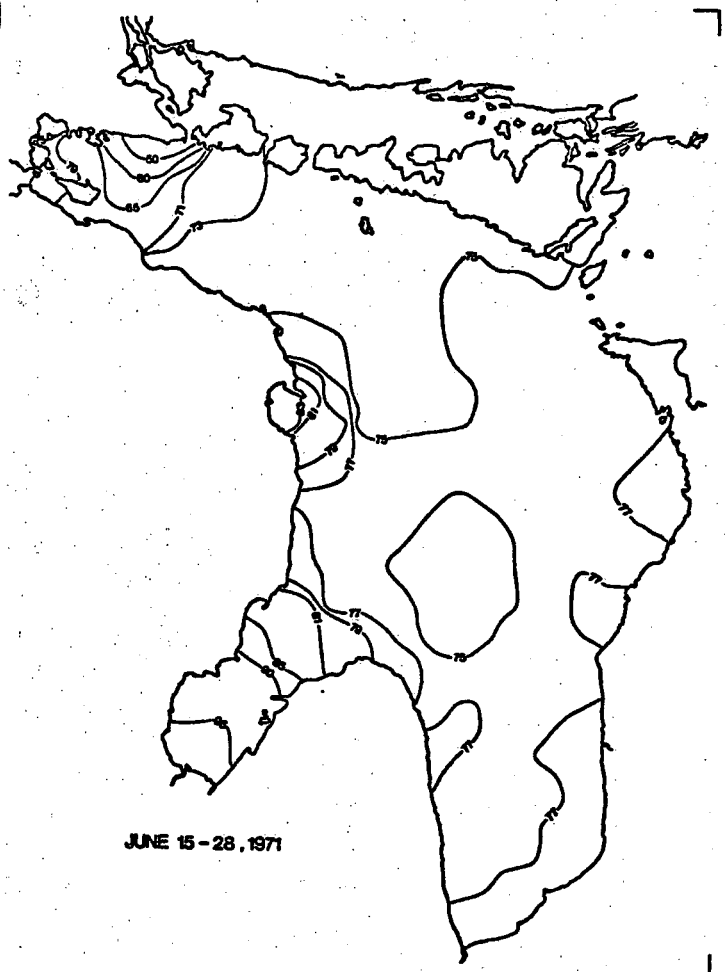
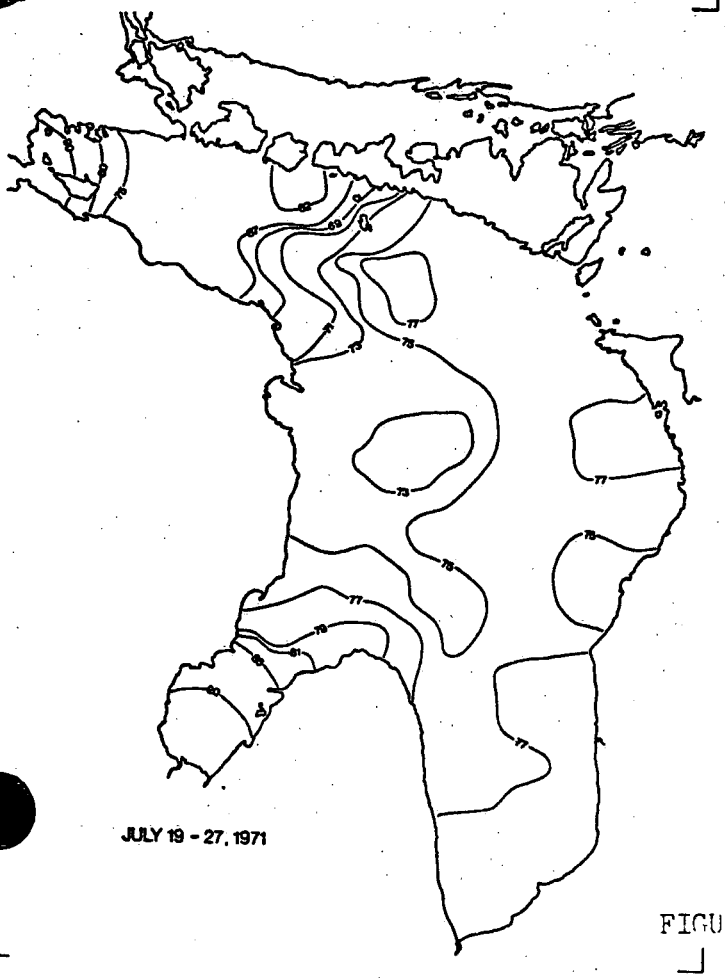


FIGURE 20

ALKALINITY, TOTAL FILTERED mg/l - $CaCO_3$, 1m







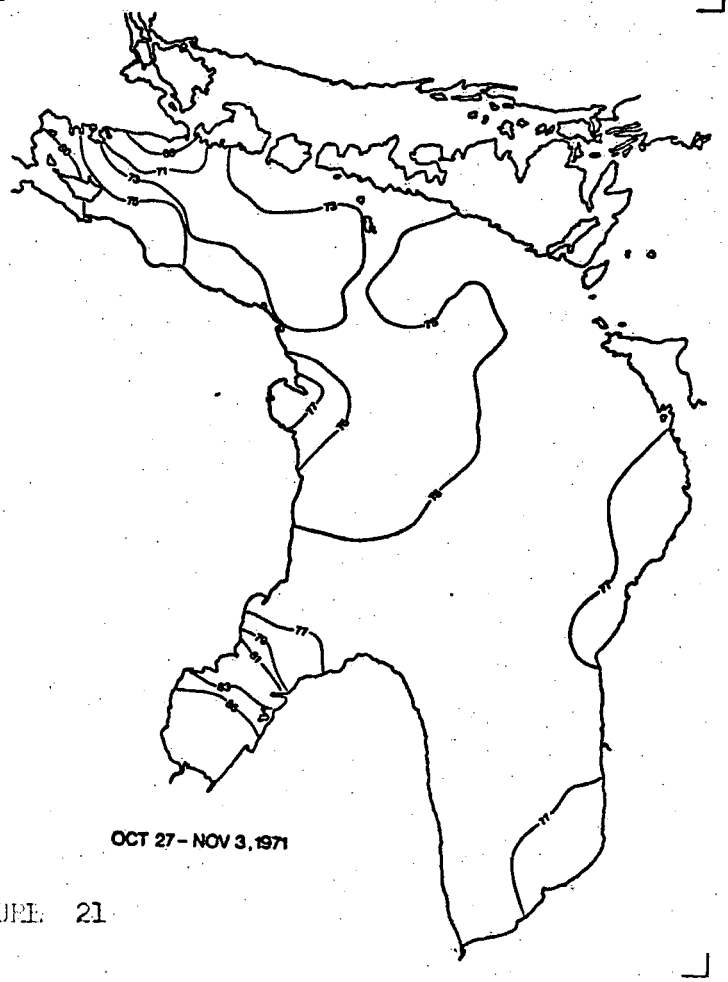


FIGURE 21

Total Phosphorus: Figures 22 and 23

A fairly homogeneous horizontal and vertical distribution of total phosphorus was observed in the main-lake throughout the year. Values for the main lake generally ranged from 5 - 15 μg/l - PO_4 throughout the year. The mid-June survey values were all quite high. There does not seem to be any reasonable explanation of this observation other than some type of analytical error.

Throughout the year values observed in Saginaw Bay were much higher than in the mid-lake. They ranged from a low of 35 μg/l - PO_4 in early December to a high of 175 μg/l - PO_4 in late September. Spill-out from Saginaw Bay into the southern part of the main lake was observed particularly during the late August and early December surveys.

A few possible municipal sources of phosphate were observed in addition to inputs to Saginaw Bay. These were Alpena and Lexington on the Michigan shore and the Grand Bend - Goderich and Southampton areas on the Ontario shore.

Since no obvious vertical distribution pattern was observed, a volume weighted average concentration was plotted for the late September survey. This included all values from surface to bottom.

TOTAL PHOSPHORUS µg/l - PO_4 , 1m

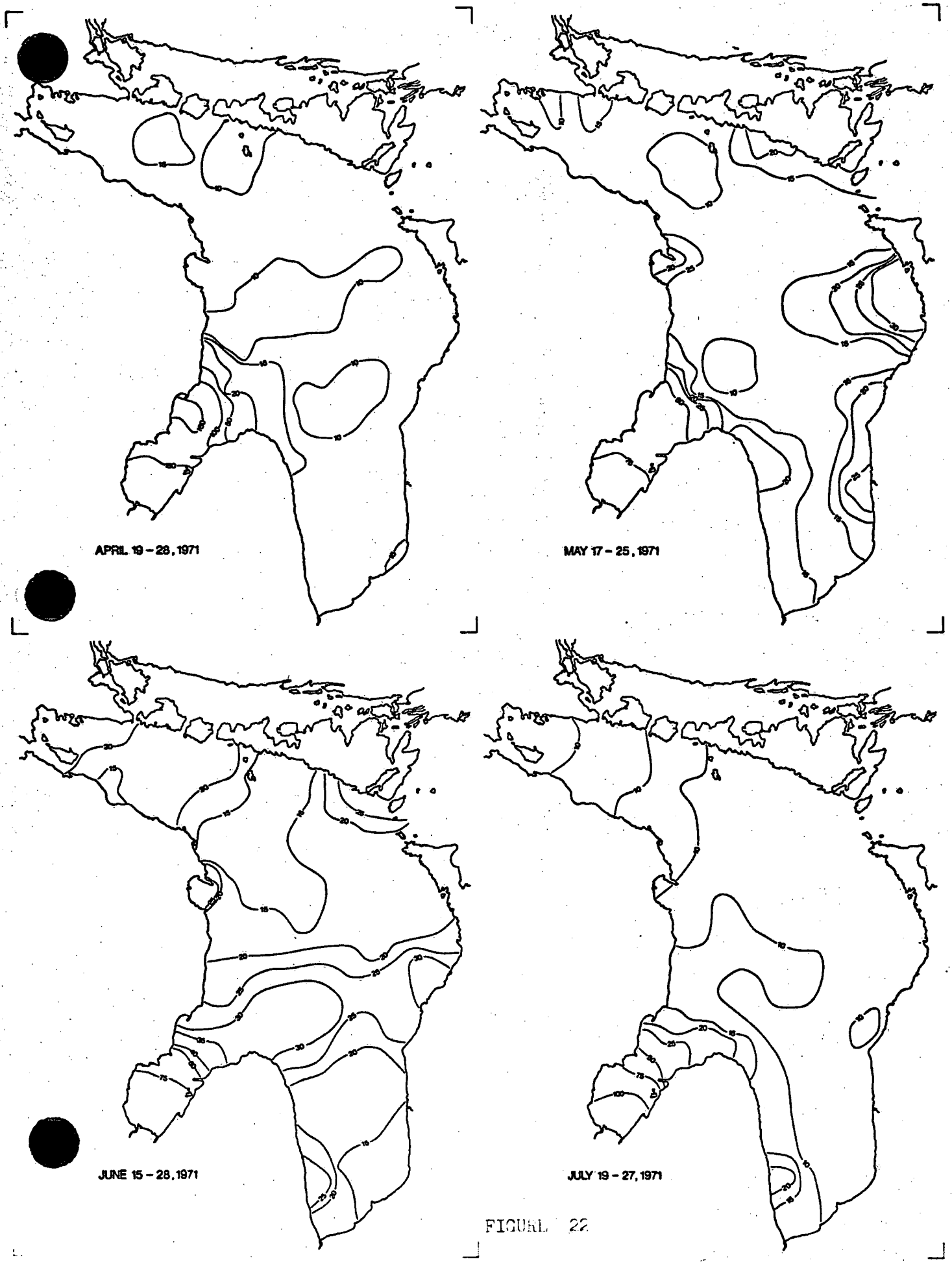
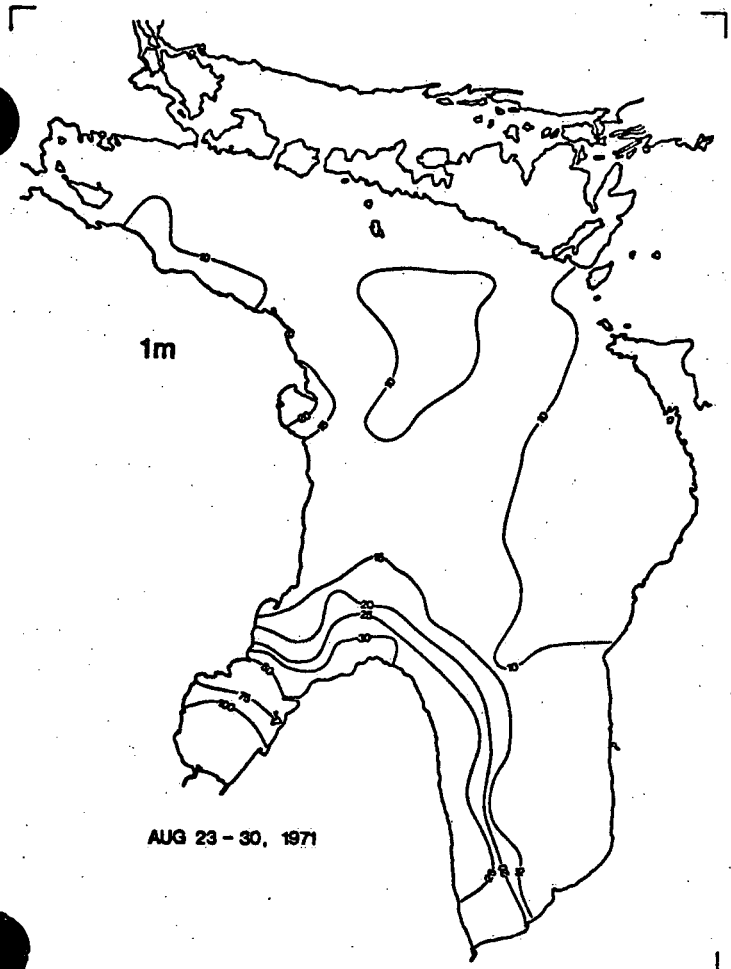


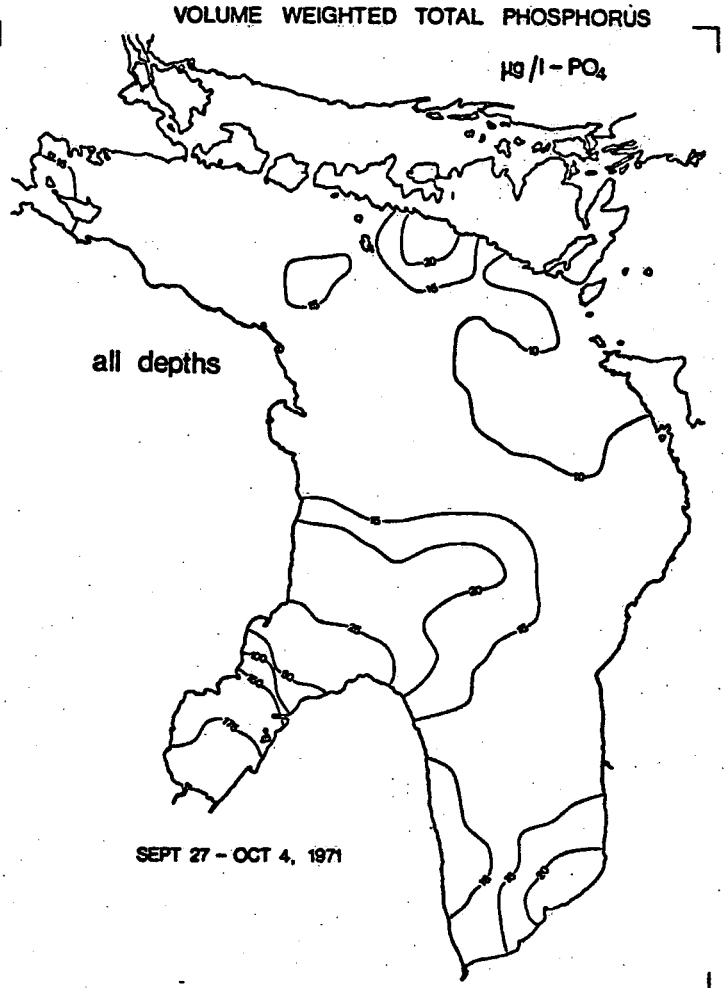
FIGURE 22

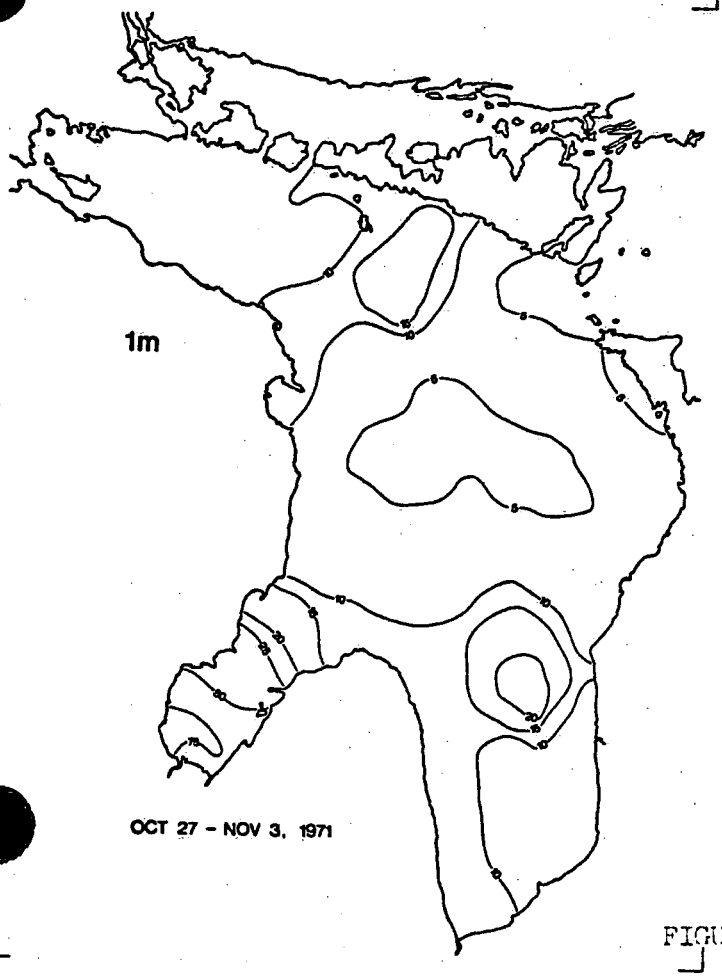
TOTAL PHOSPHORUS $\mu g/l - PO_4$



VOLUME WEIGHTED TOTAL PHOSPHORUS

$\mu g/l - PO_4$





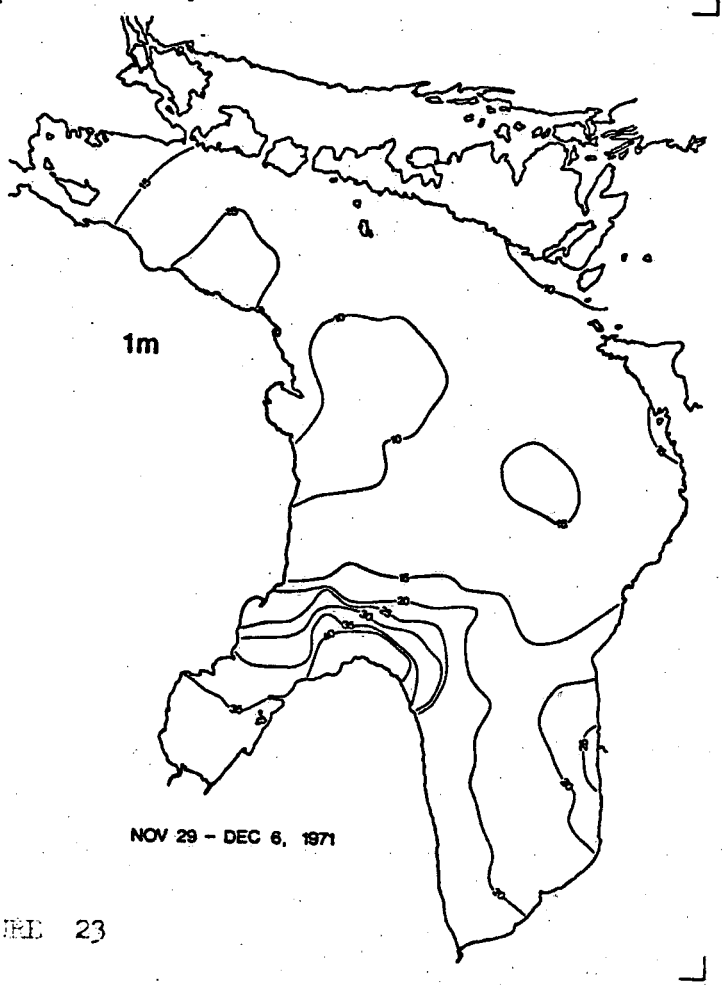


FIGURE 23

Total Filtered Phosphorus: Figures 24 and 25

Total filtered phosphorus values observed in the main body of Lake Huron were quite homogeneous throughout the year. Observed values were generally around 5 µg/l - PO_4 in the main lake. As for total phosphorus values, the total filtered phosphorus values for the June survey are all high. Once again analytical error is suspected.

Values observed in Saginaw Bay were much higher than the main body of the lake. Concentrations ranged from 10 to 50 µg/l - PO_4.

Soluble Reactive Phosphate:

The soluble reactive phosphate was always at or near the detection limit of the analytical method. Main lake values were usually around 1 µg/l - PO_4. Saginaw Bay values were slightly higher but were never above 5 µg/l - PO_4.

TOTAL FILTERED PHOSPHORUS µg/l-PO_4 ,1m

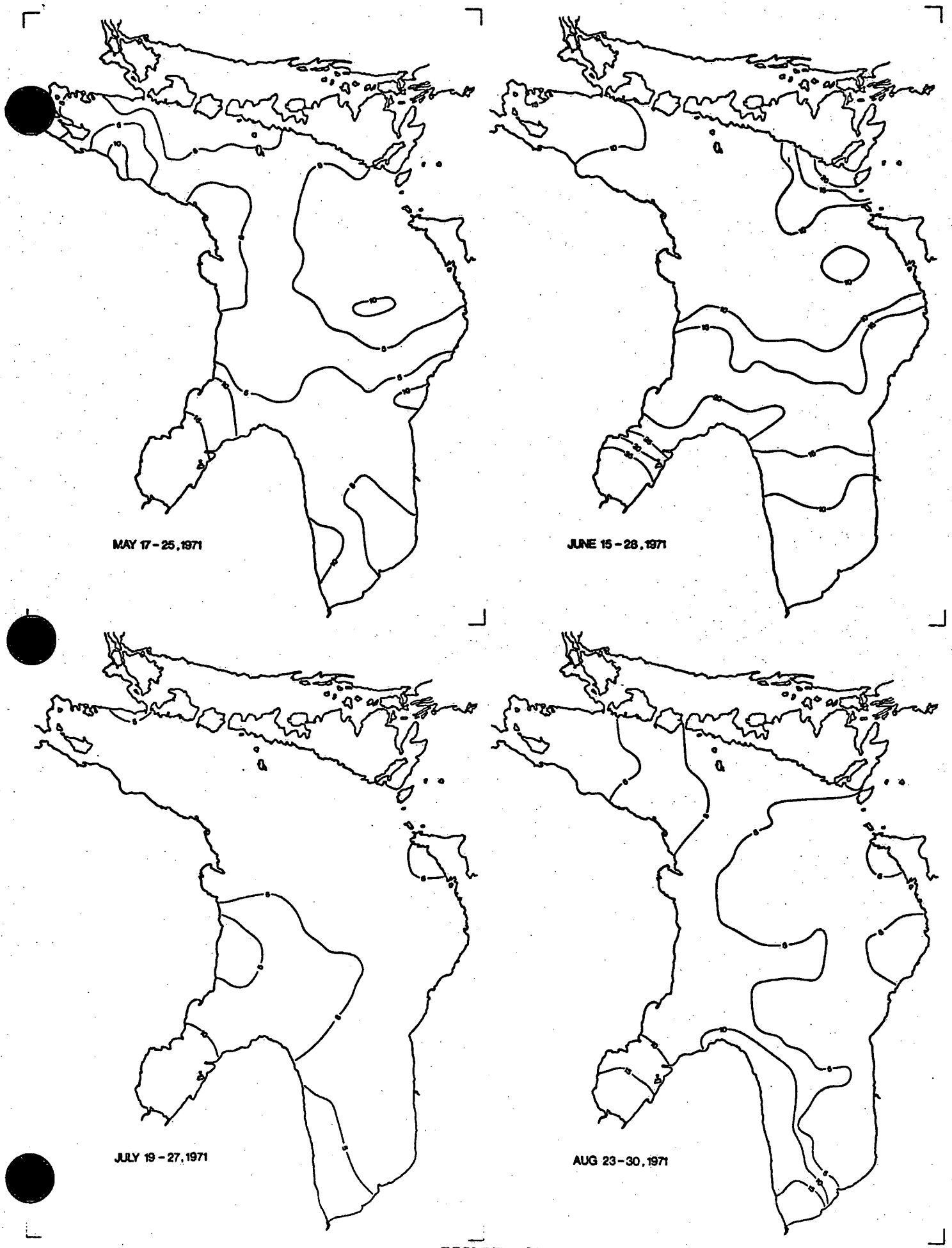
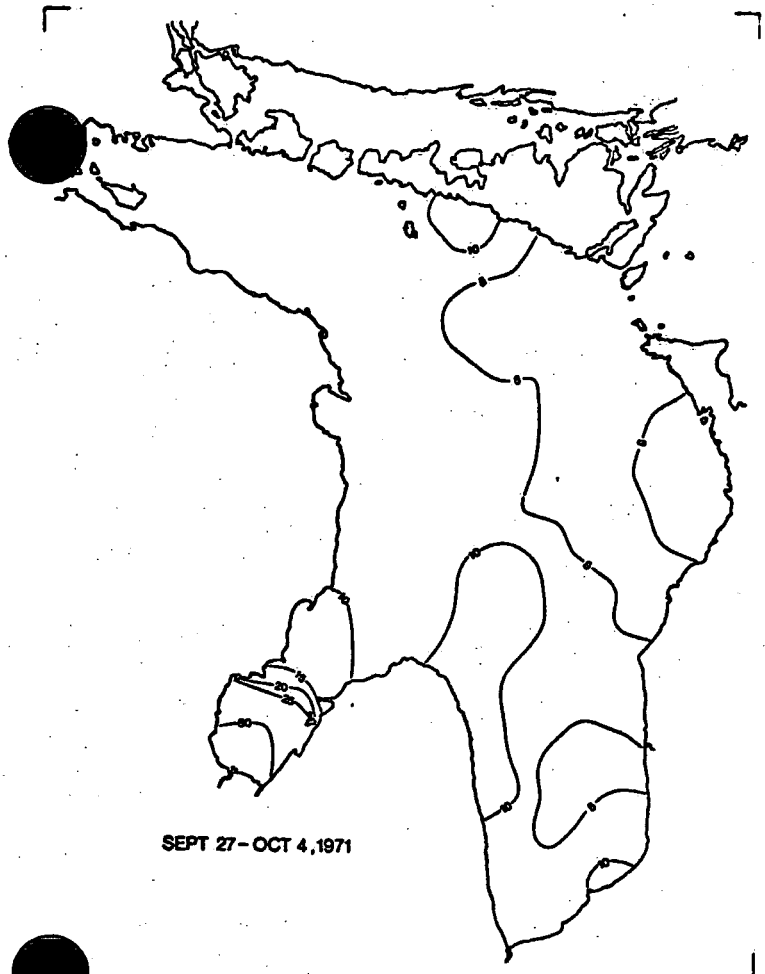
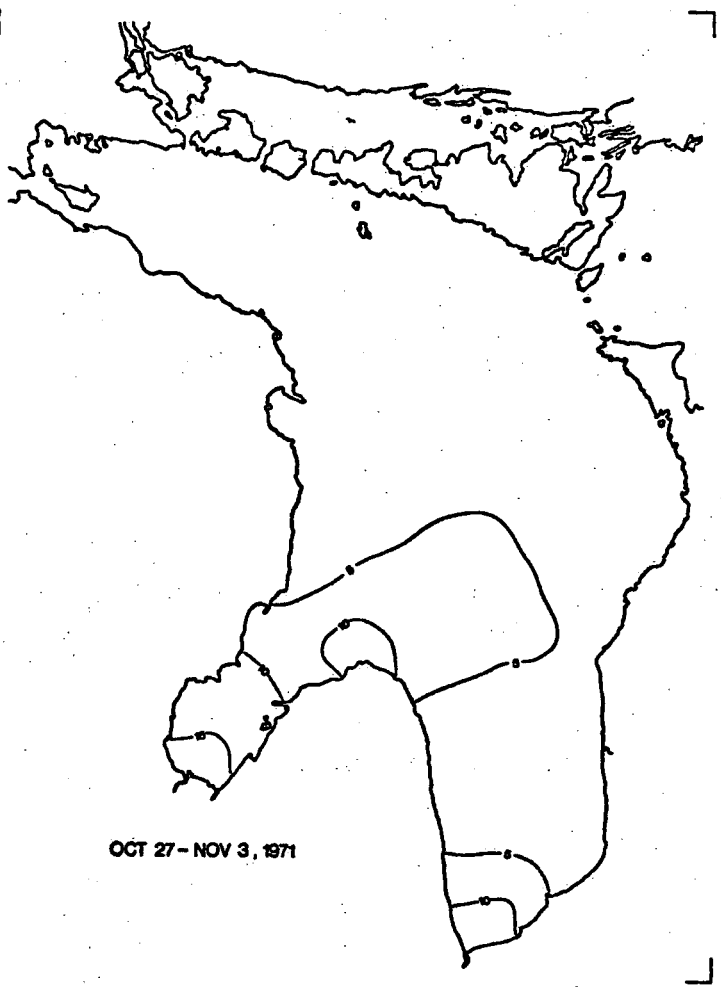


FIGURE 24

TOTAL FILTERED PHOSPHORUS µg/l-PO_4, 1m





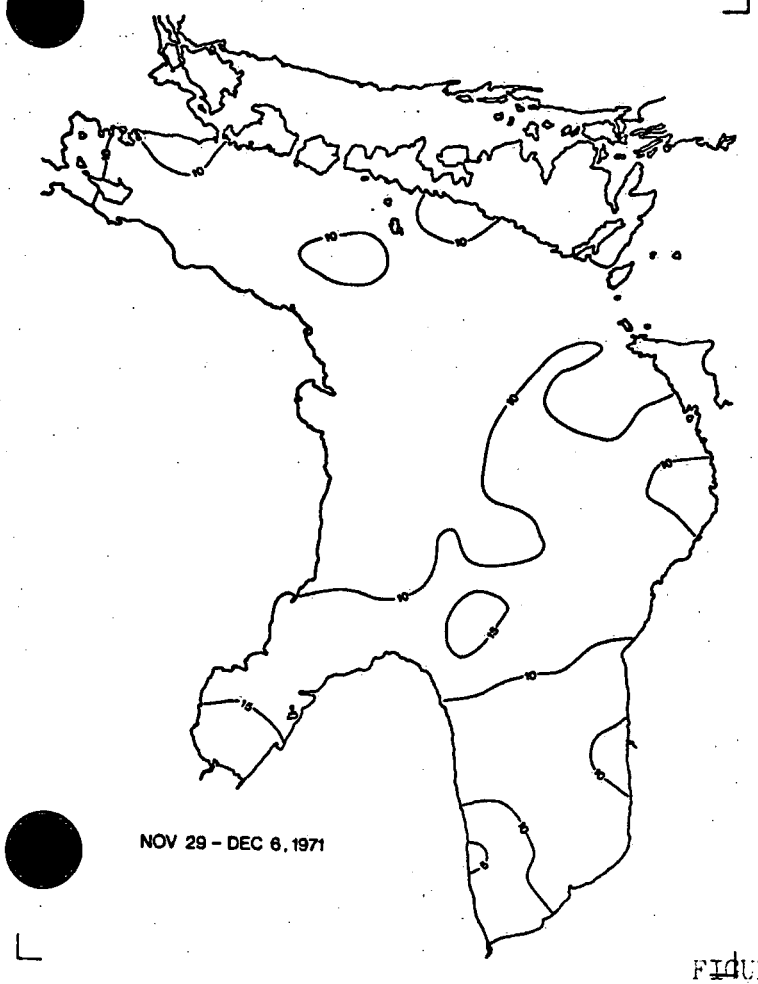


FIGURE 25

Particulate Phosphorus: Figures 26 & 27

Generally mid-lake particulate phosphorus values ranged from 5 - 10 µg/l - PO_4. However, Saginaw Bay values ranged from 20 - 100 µg/l - PO_4. In Saginaw Bay the particulate phosphorus concentration increased during the year until it reached its maximum during the August and September surveys and then decreased again by the later surveys.

Since this is a calculated rather than directly measured value, the data should be interpreted with care because a double error is involved. Also sampling for total phosphorus is more susceptable to error due to the presence of particulates in the sample.

PARTICULATE PHOSPHORUS $\mu g/l - PO_4$, 1m

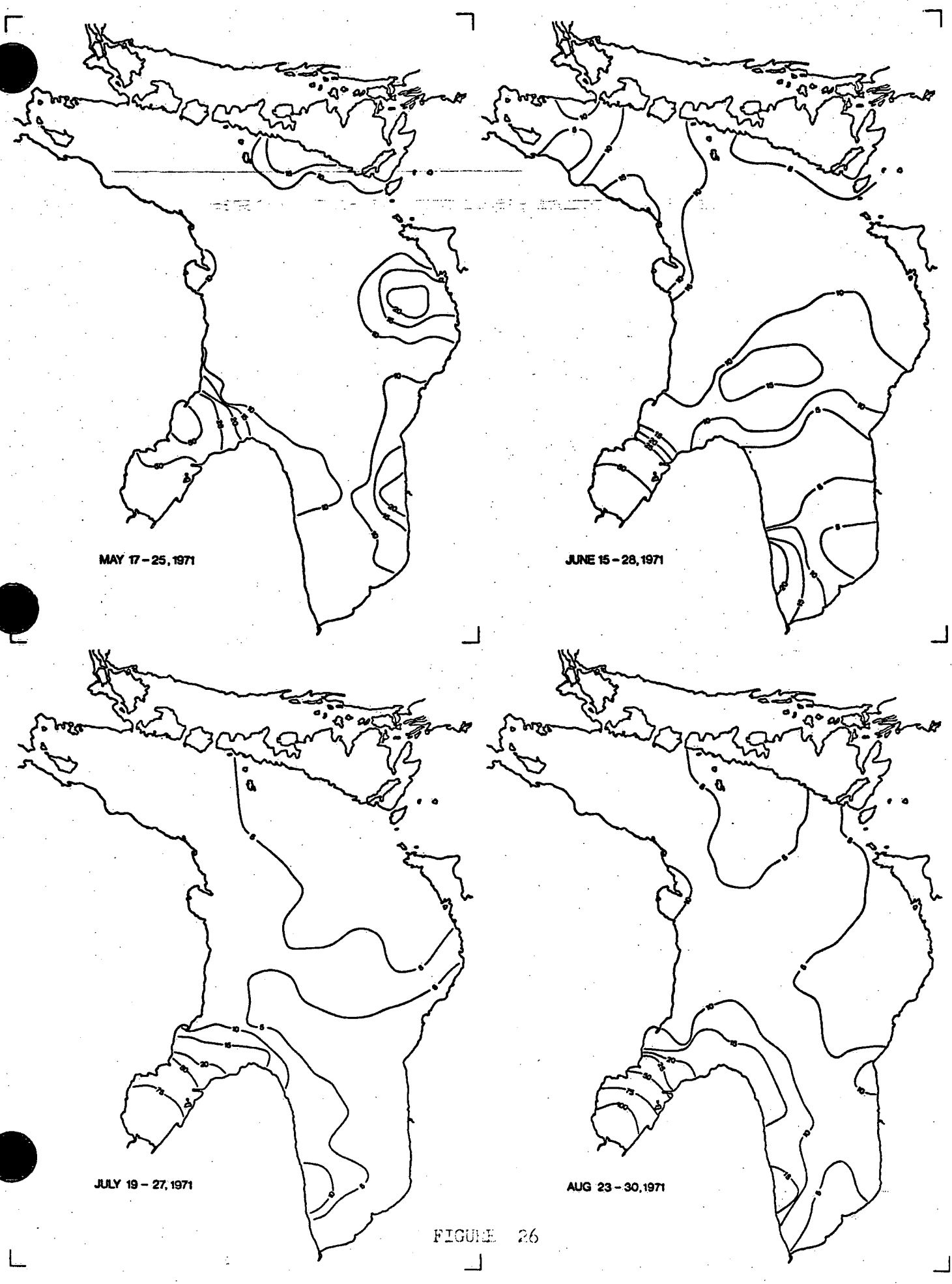
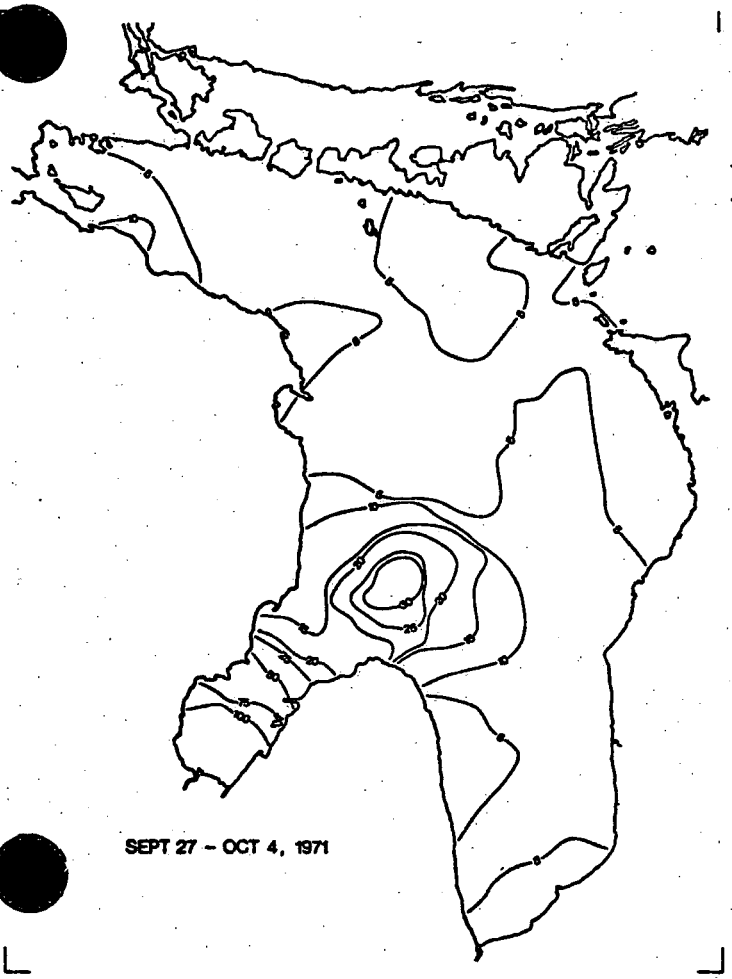
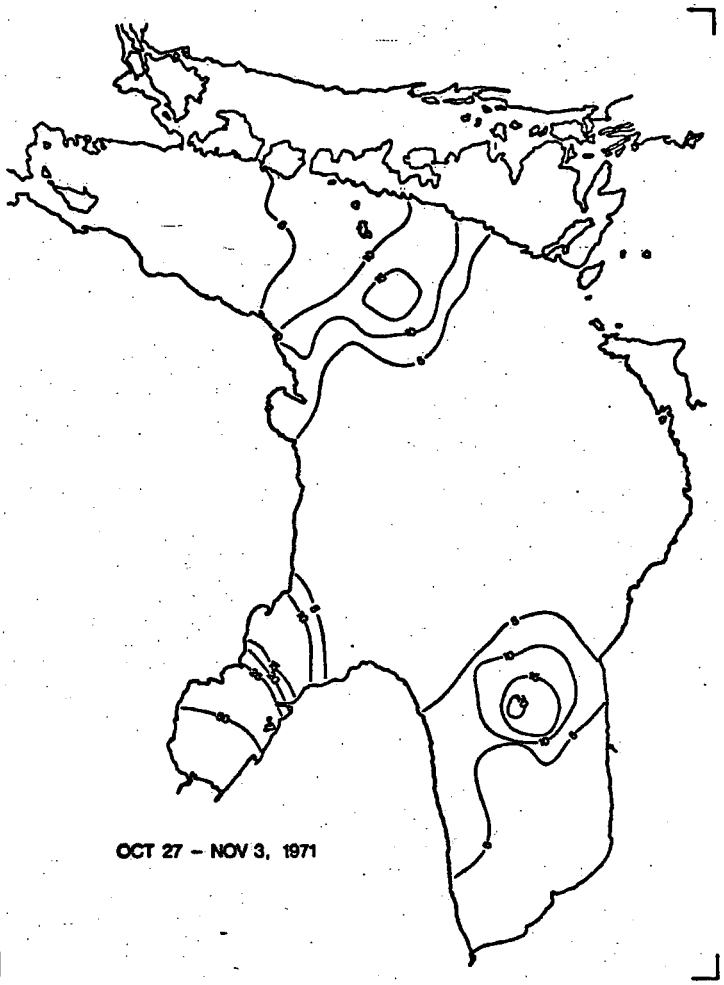


FIGURE 26

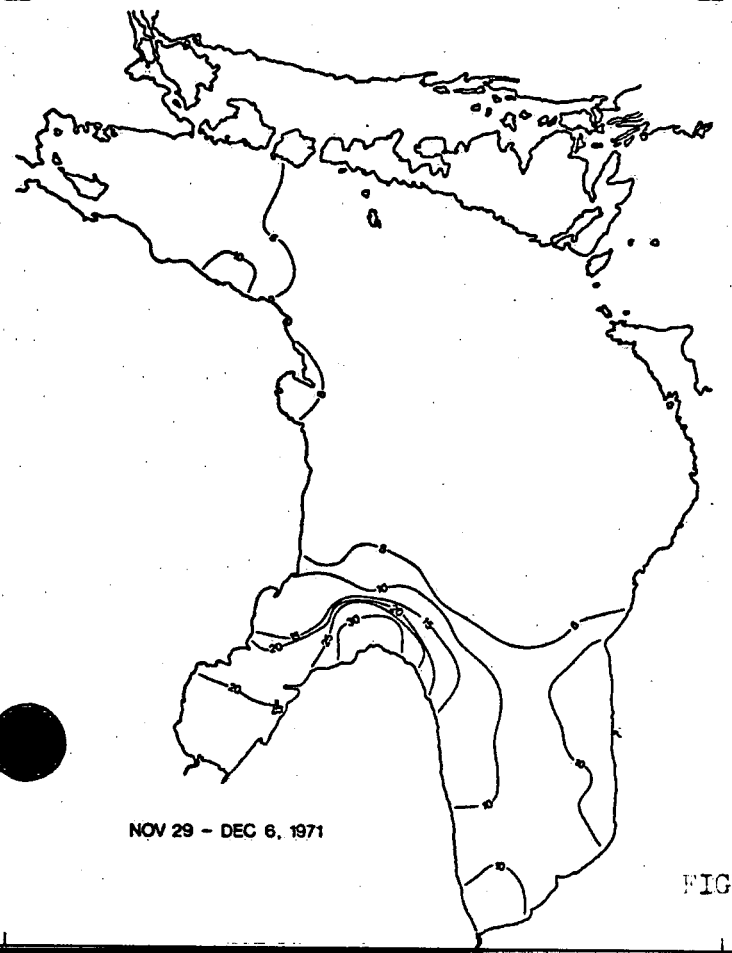
PARTICULATE PHOSPHORUS µg/l-PO_4 , 1m



SEPT 27 – OCT 4, 1971



OCT 27 – NOV 3, 1971

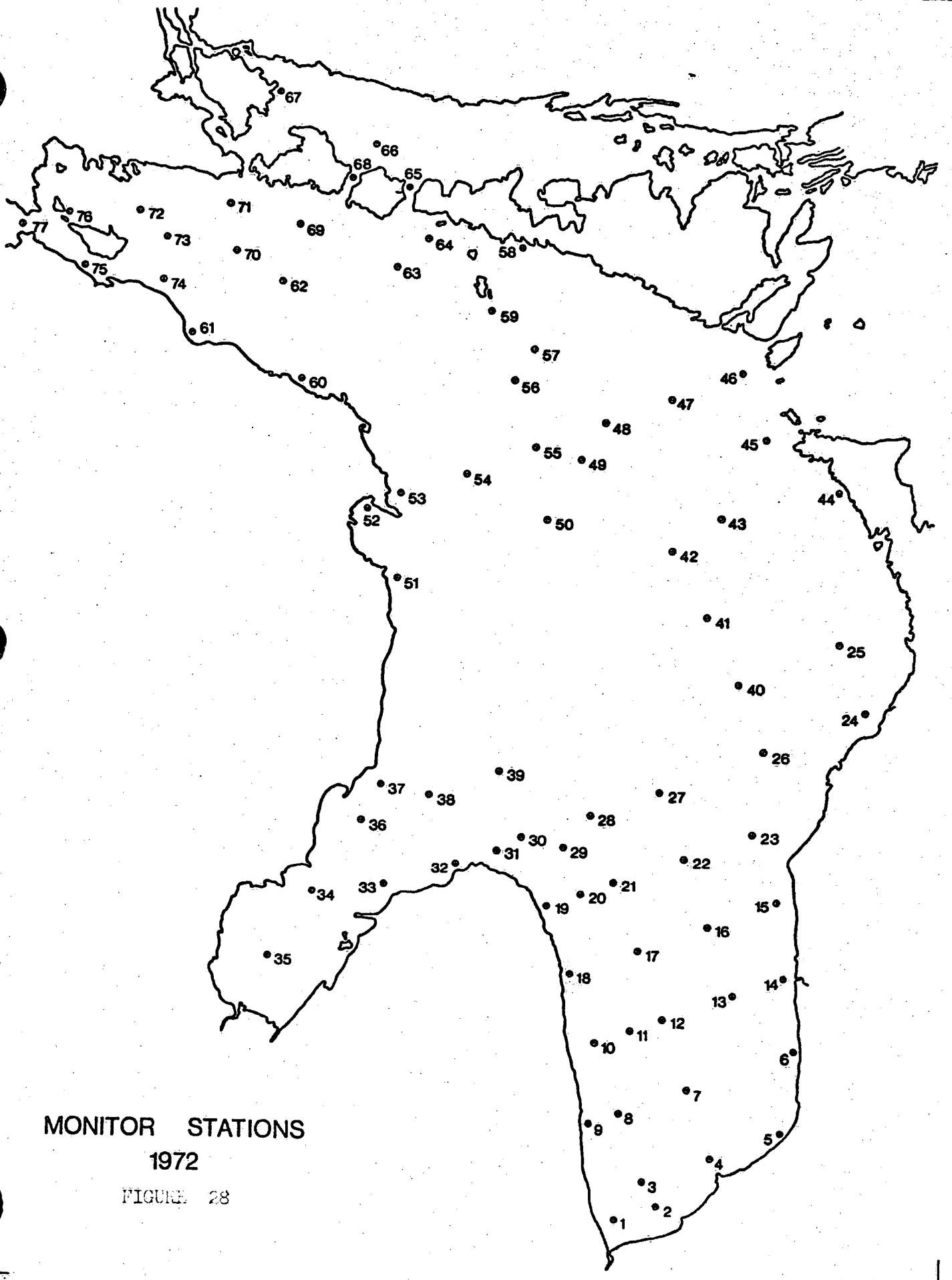


NOV 29 – DEC 6, 1971

FIGURE 27

1972 DATA

During 1972 three surveys were completed, one in each of May, August and November. The station pattern as shown in Figure 28 was designed to illustrate the Saginaw Bay spill-out into the southern part of the main lake and also the Lake Superior - Lake Michigan mixing zone in the north-western part of the lake. Temperature, dissolved oxygen and most of the nutrient parameters were measured at about 70 stations throughout the year.



MONITOR STATIONS

1972

FIGURE 28

1972

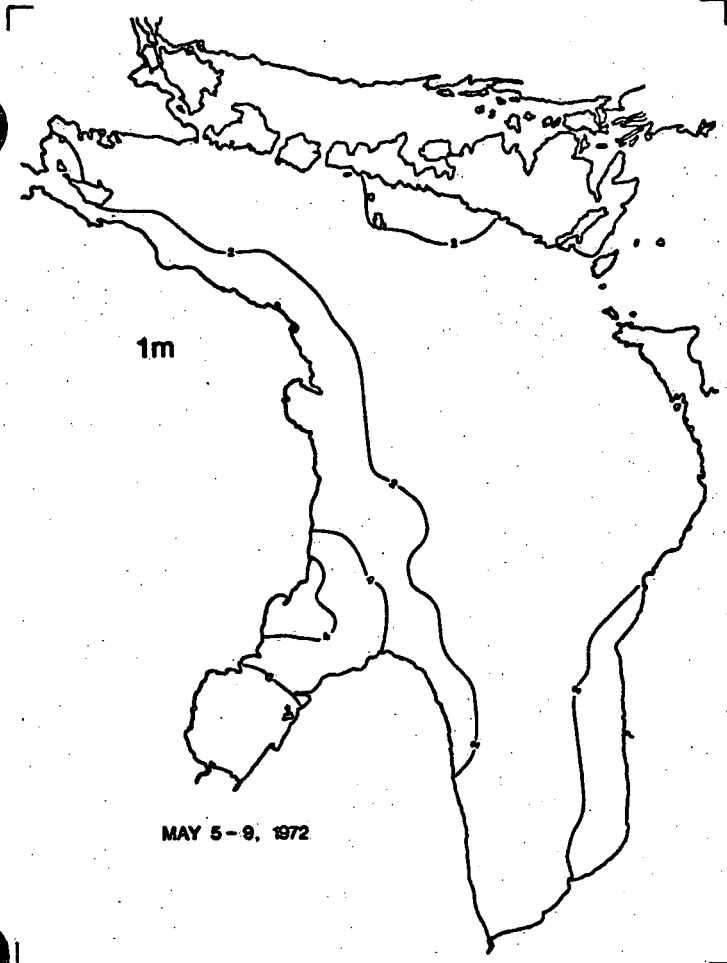
Temperature: Figure 29

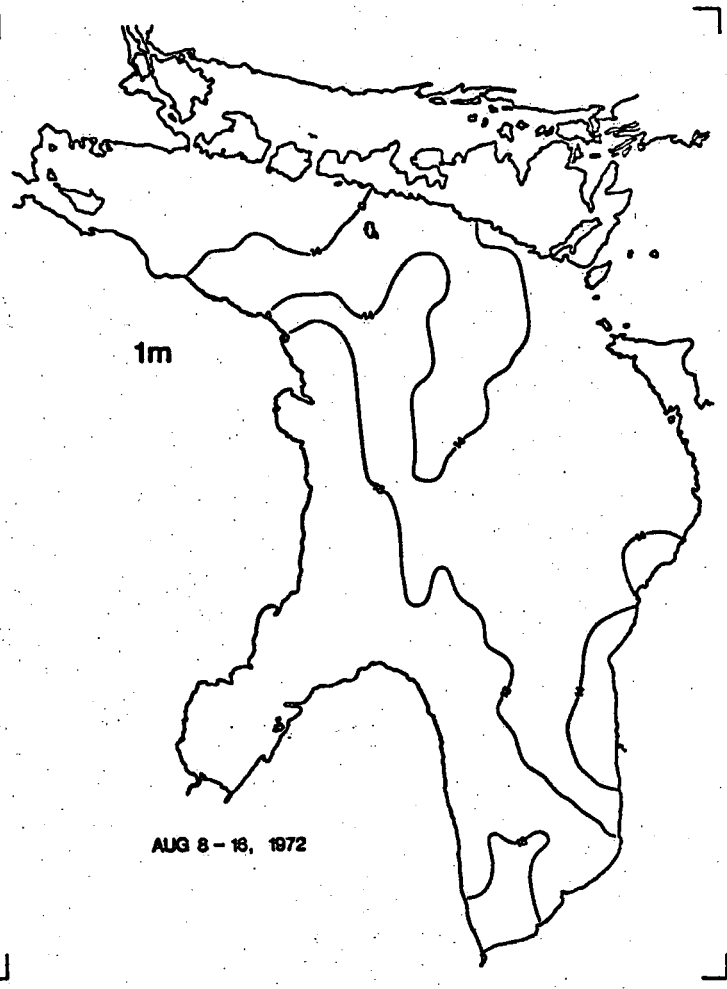
During the spring survey the temperature distribution was fairly homogeneous with surface temperatures generally 2 - 4° C with only Saginaw Bay up to 6° C.

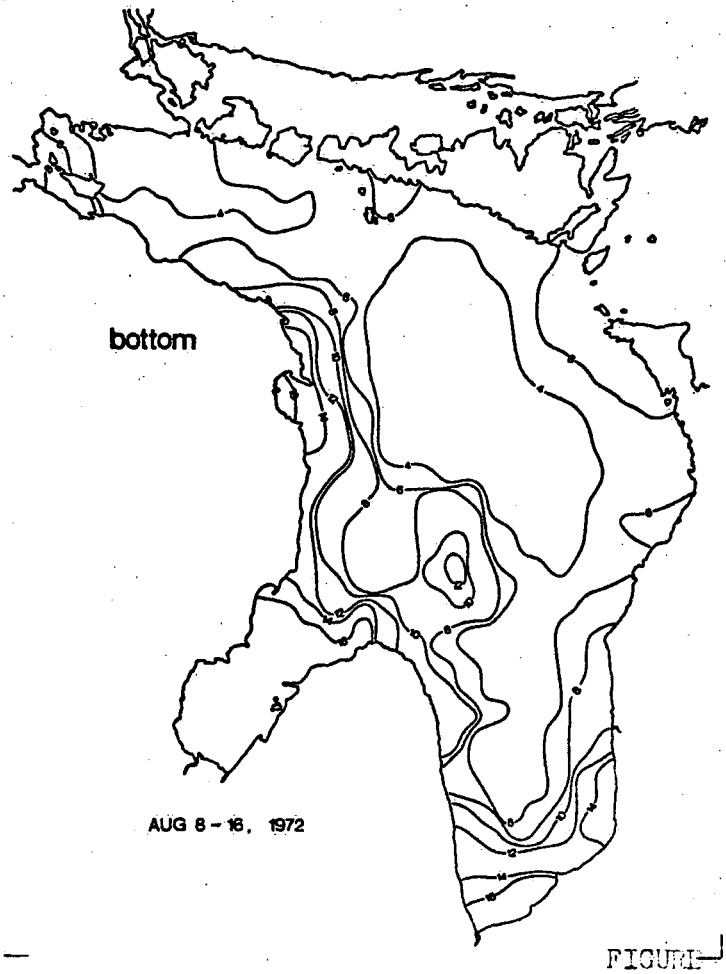
By August the mid-lake surface temperatures had nearly reached their maximum and ranged from 14 - 18° C. As in previous years a continuous north-south increase was observed in surface temperatures. The northern part of the lake had temperatures of 14° C while the southern part of the lake had temperatures of 18° C. A strong thermocline existed at this time of year and hence bottom waters were much colder with a large volume of water remaining at 4° C.

By November the lake had overturned and surface and bottom waters had cooled down.

TEMPERATURE °C







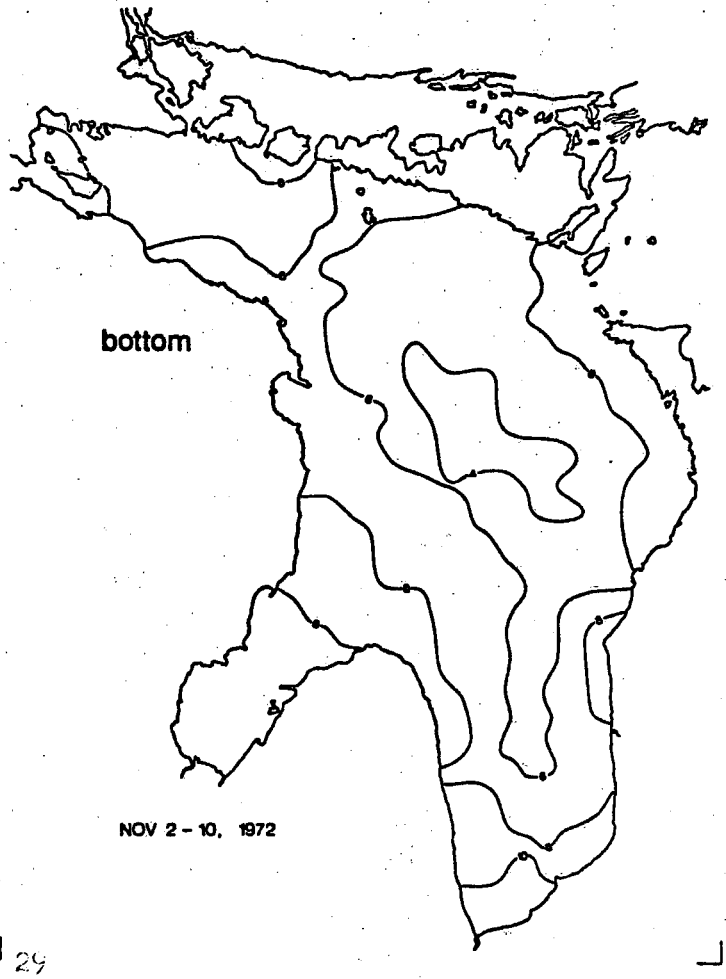


FIGURE 29

Dissolved Oxygen: Figure 30

Surface and bottom waters of this lake were nearly always saturated with O_2. However some depletion was observed in Saginaw Bay and in the southern basin with minimum values of 85% saturation reached in November.

DISSOLVED OXYGEN – PERCENT SATURATION, bottom

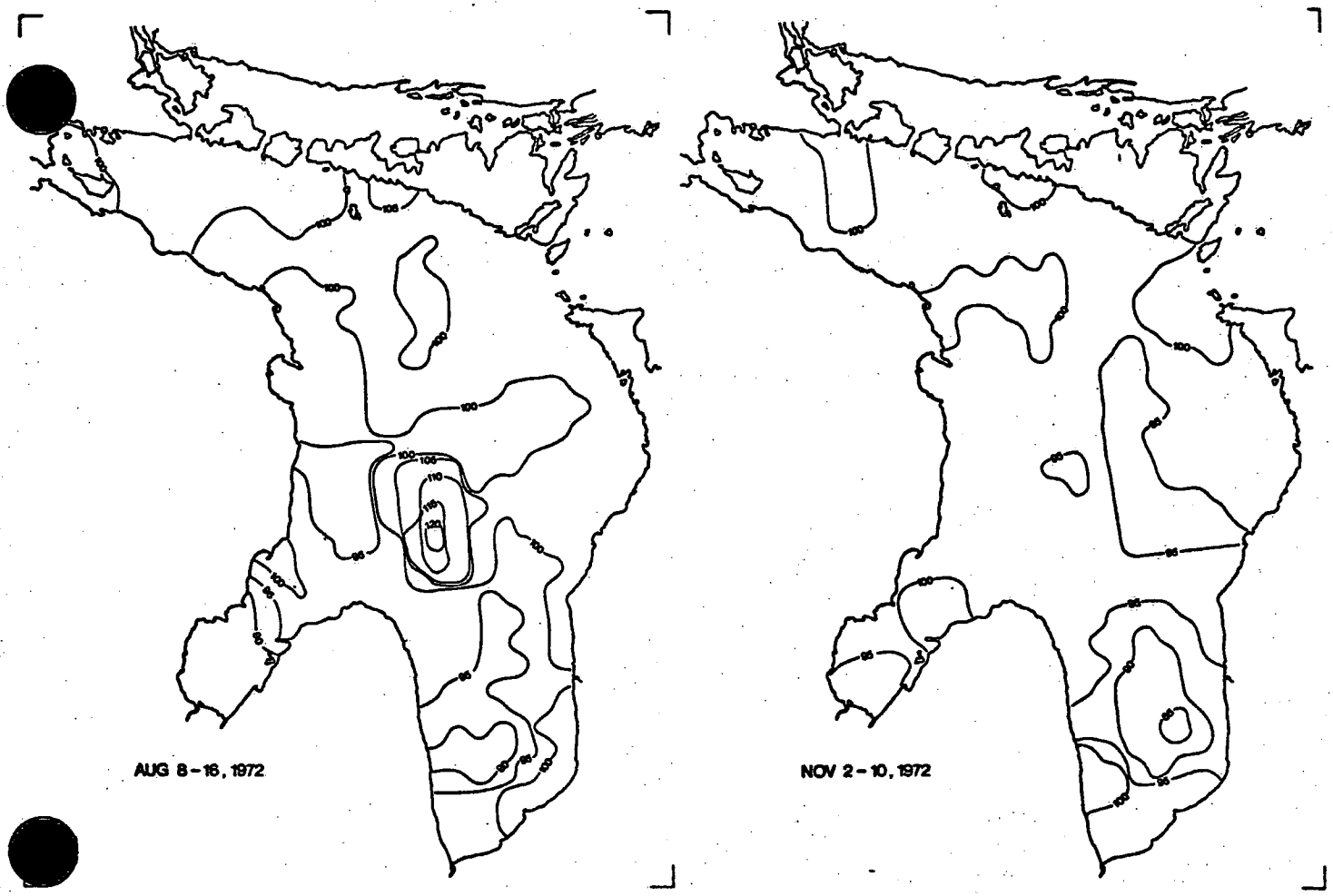


FIGURE 30

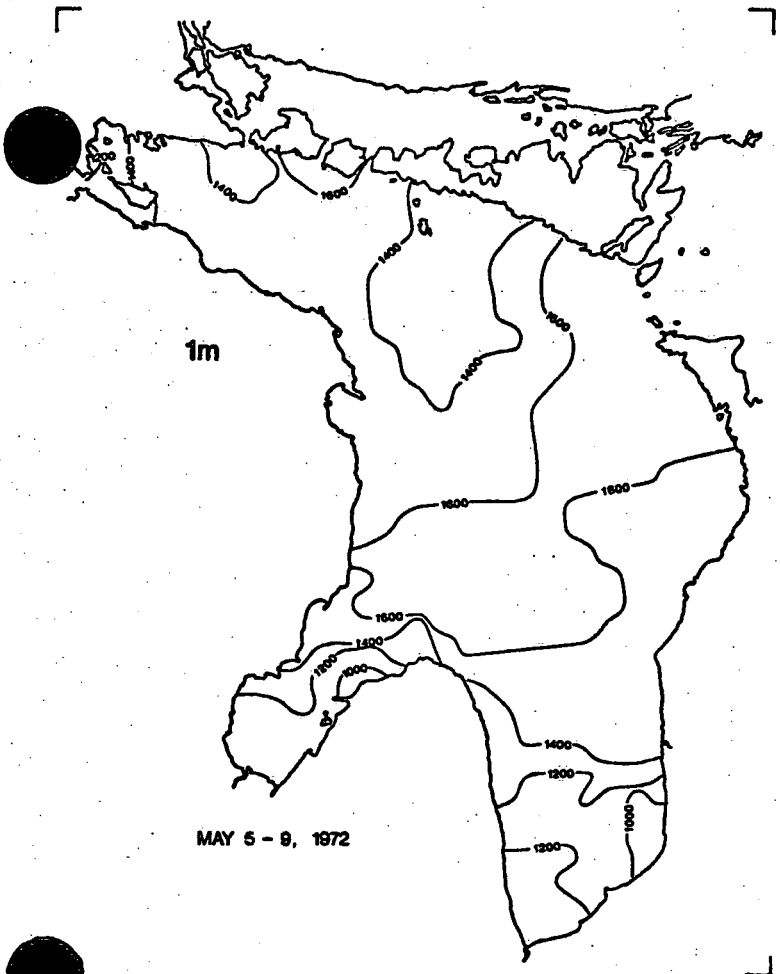
Reactive Silicate: Figures 31 & 32

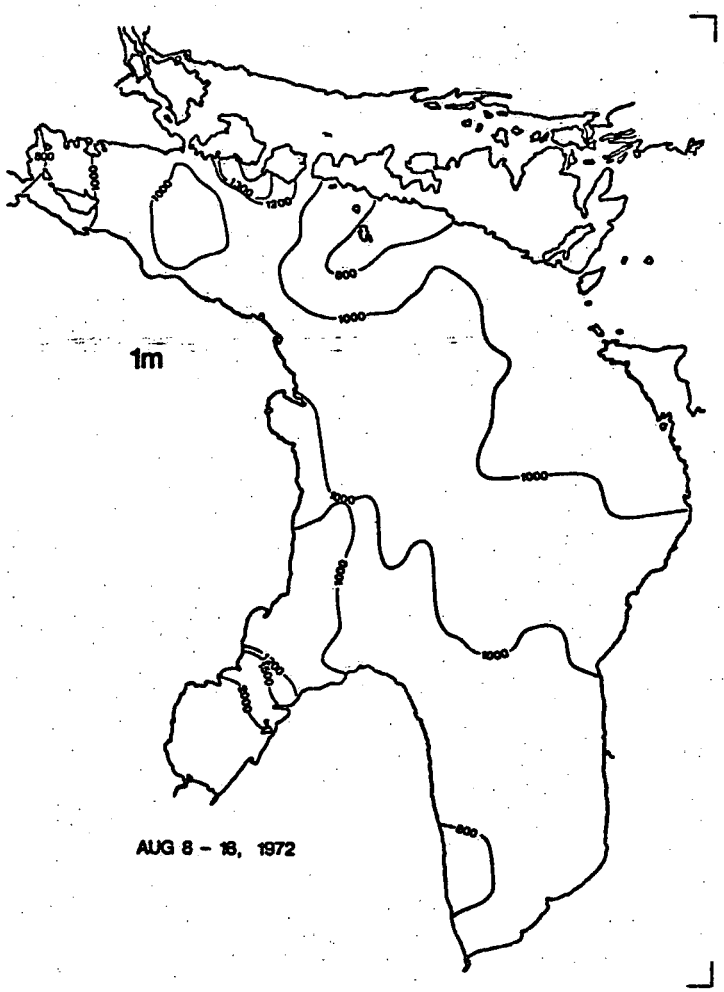
During the early May survey a homogeneous horizontal and vertical distribution of reactive silicate was observed. Silicate concentrations in the range 1400 - 1600 µg/l - SiO2 were observed in the main lake; with slightly lower values observed in Saginaw Bay, in the southern basin and also at the Lake Michigan inflow to the lake.

By August the surface waters of the lake had been depleted down to about 1000 µg/l - SiO2 wheras the bottom waters had increased to 1400 - 2000 µg/l - SiO2. Saginaw Bay, with values to 2000 µg/l - SiO2 in the surface and up to 2400 µg/l - SiO2 in the bottom waters was higher than the main lake. Once again slightly lower values were observed in the southern basin of the lake and also at the Lake Michigan input to the lake.

By November the surface silicate values except for Saginaw Bay had increased again to about 1200 µg/l - SiO2. However, the bottom waters remained much higher at from 1400 - 2000 µg/l - SiO2. Saginaw Bay also remained higher with from 1600 - 2500 µg/l - SiO2 in surface and bottom waters.

REACTIVE SILICATE µg/l - SiO_2





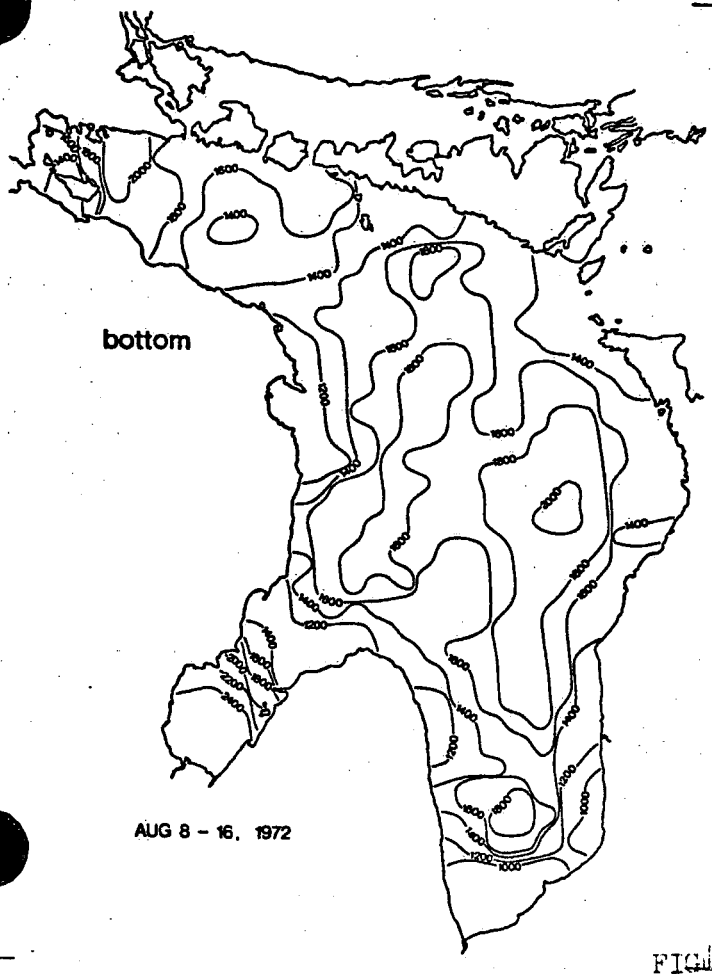


FIGURE 31

REACTIVE SILICATE µg/l – SiO_2

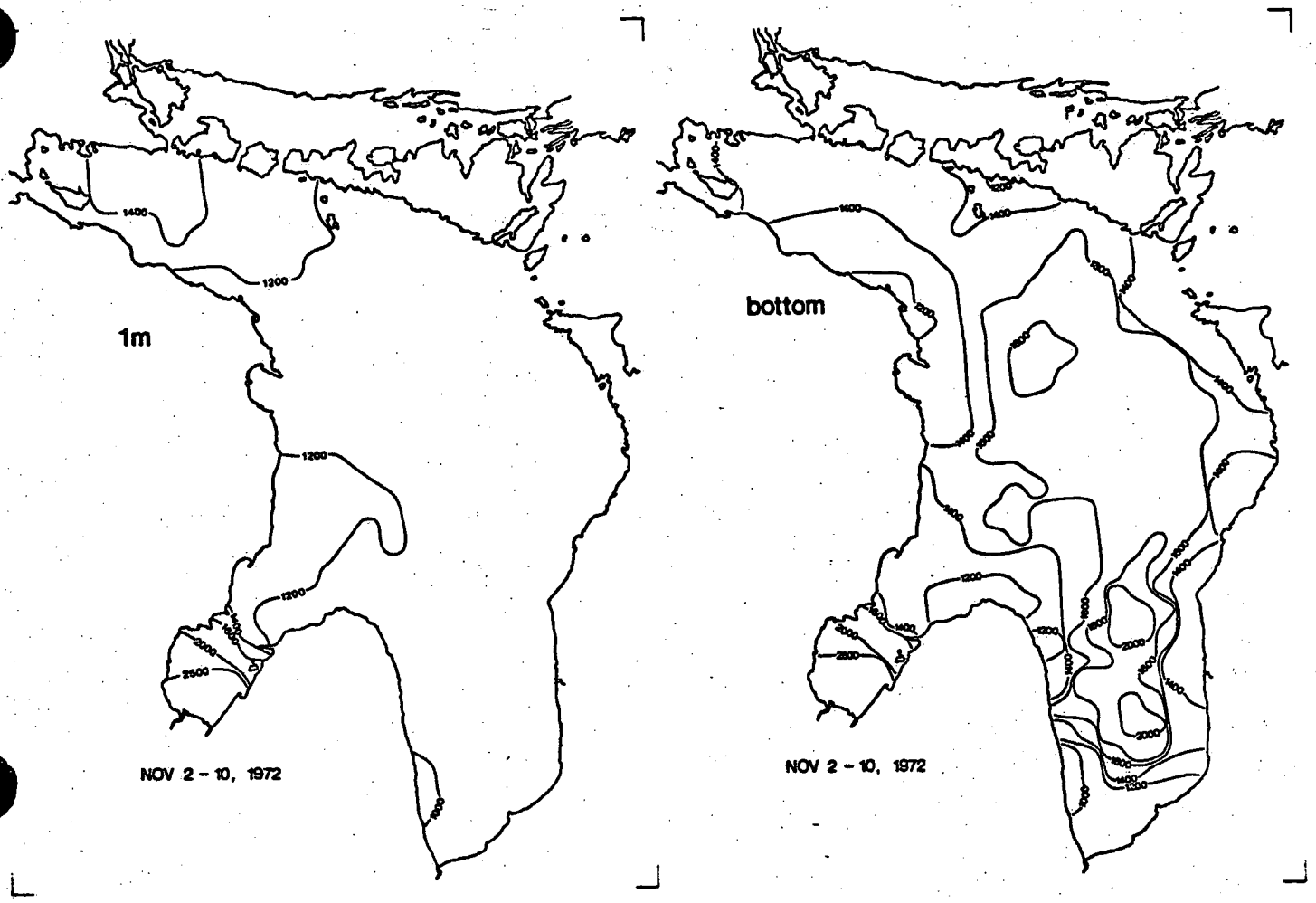


FIGURE 32

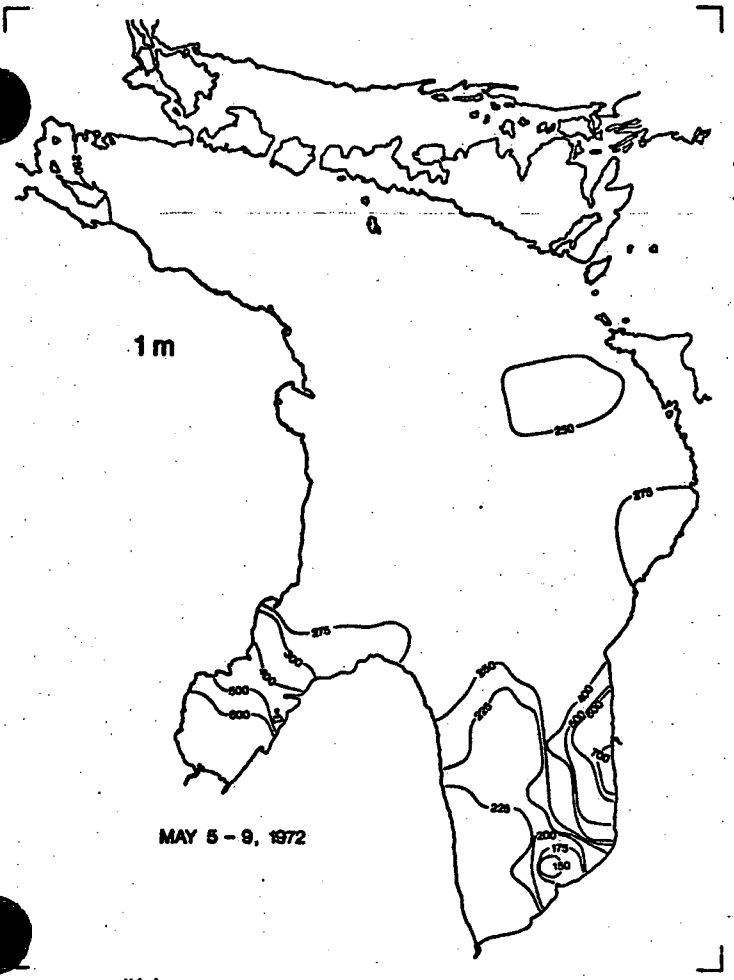
Nitrate - Nitrite Nitrogen: Figures 33 & 34

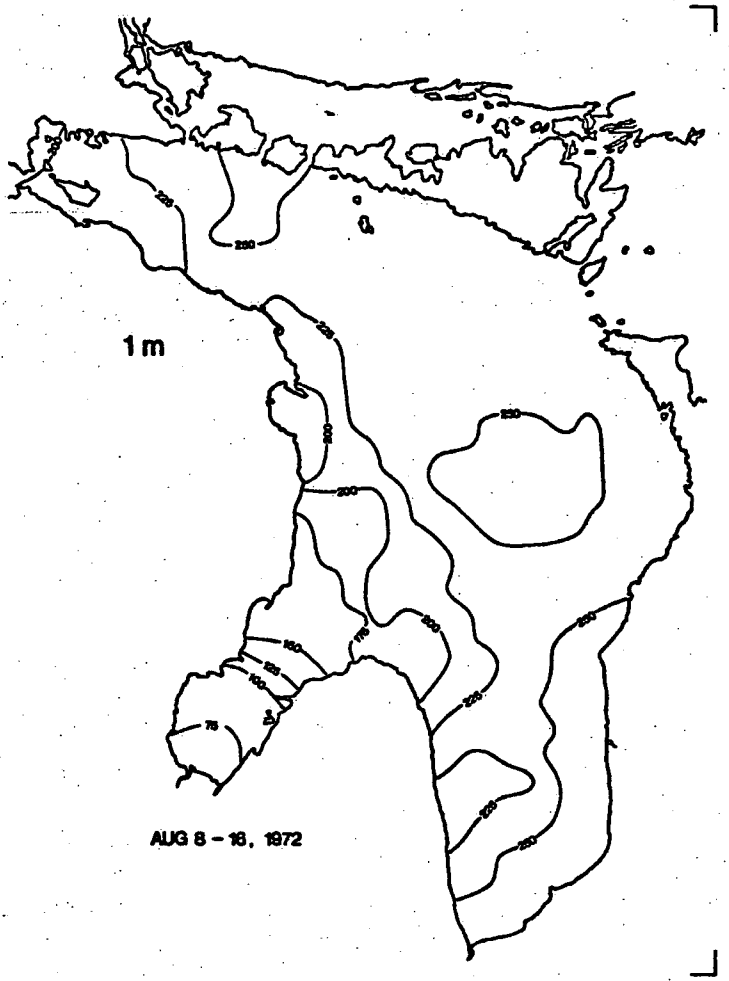
In early May the nitrate - nitrite nitrogen distribution was fairly homogeneous throughout the main body of the lake. Values ranged from 225 - 275 µg/l - N. Saginaw Bay values were much higher and ranged from 300 - 600 µg/l - N. Also in an area off Goderich very high values up to 700 µg/l - N were observed in the nearshore area. At the same time, an area in the south-western part of the lake was being depleted and surface values down to 150 µg/l - N were observed.

By August, the surface values had decreased slightly to about 200 - 250 µg/l - N in the main lake and Saginaw Bay values were below 150 µg/l - N. Vertical stratification had increased since May and the bottom waters now had increased to 250 - 300 µg/l - N.

By November the surface and bottom concentration of nitrate - nitrite nitrogen were nearly equal. Values ranged from 225 - 275 µg/l - N in the main lake with values in Saginaw Bay from 175 - 600 µg/l - N.

NITRATE – NITRITE NITROGEN µg/l – N





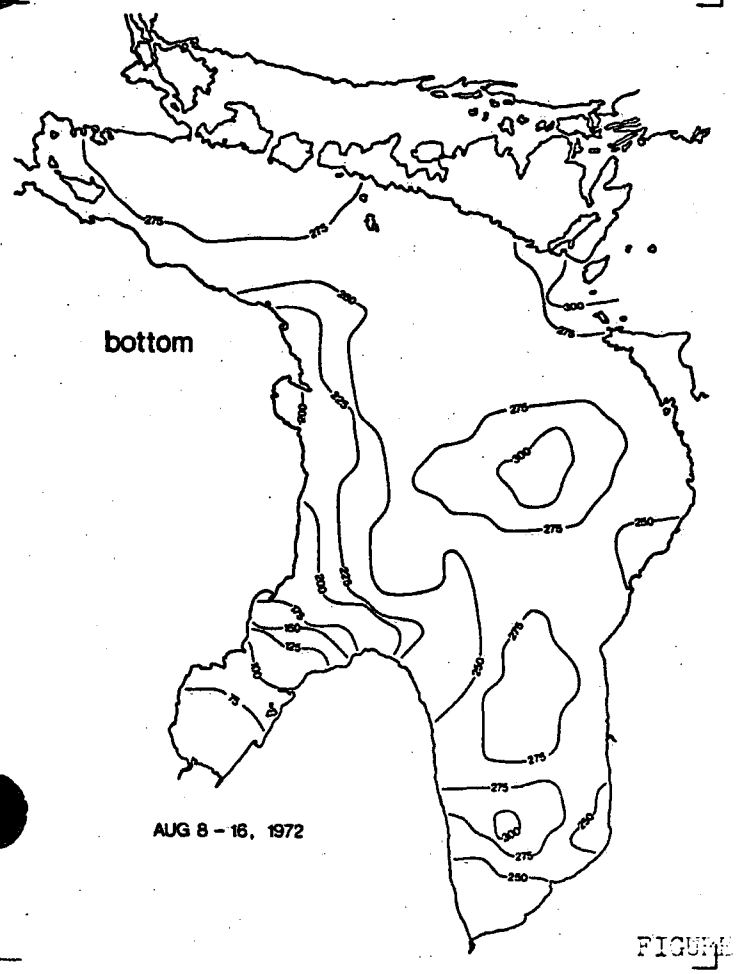


FIGURE 33

NITRATE-NITRITE NITROGEN µg/l-N,

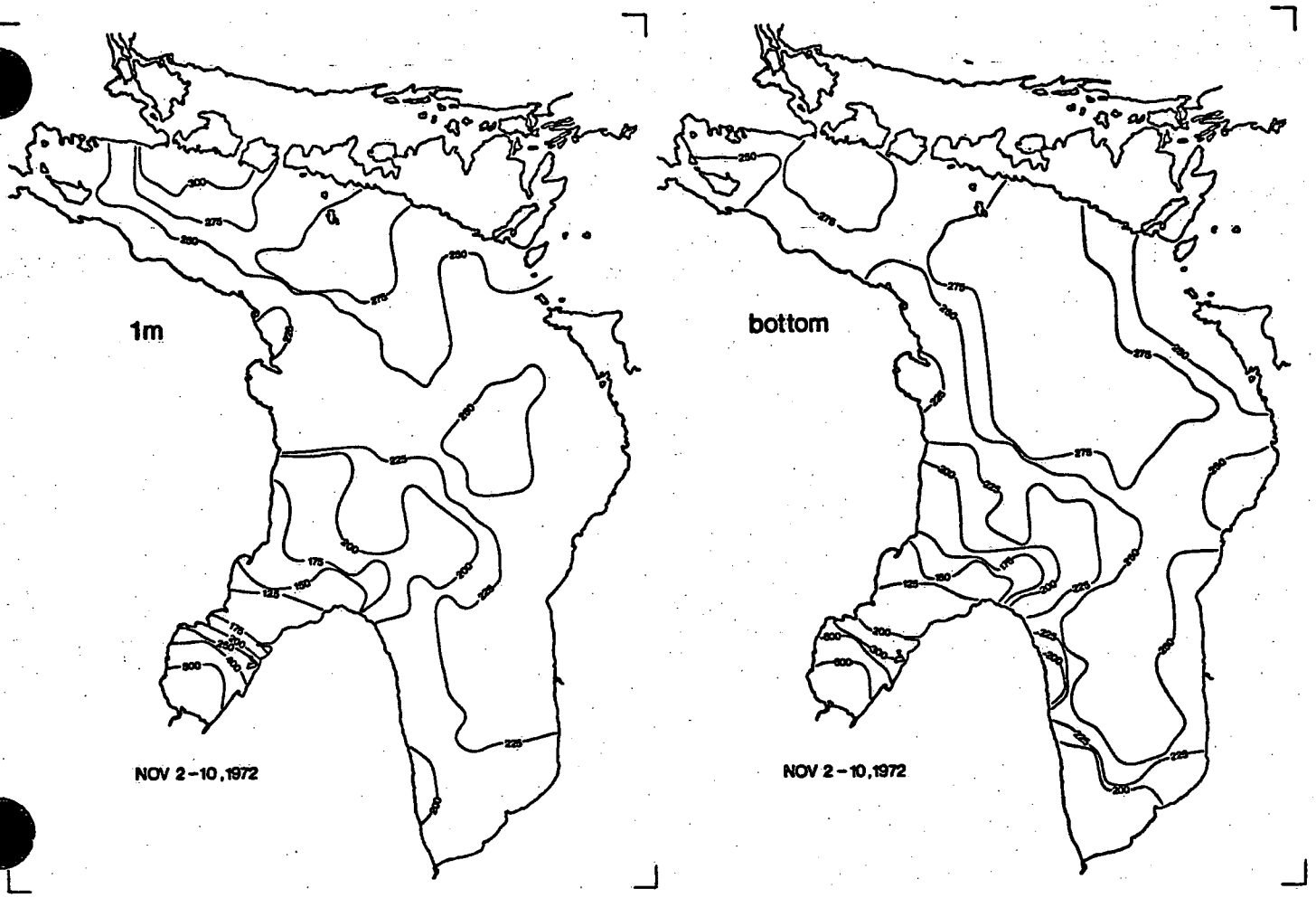
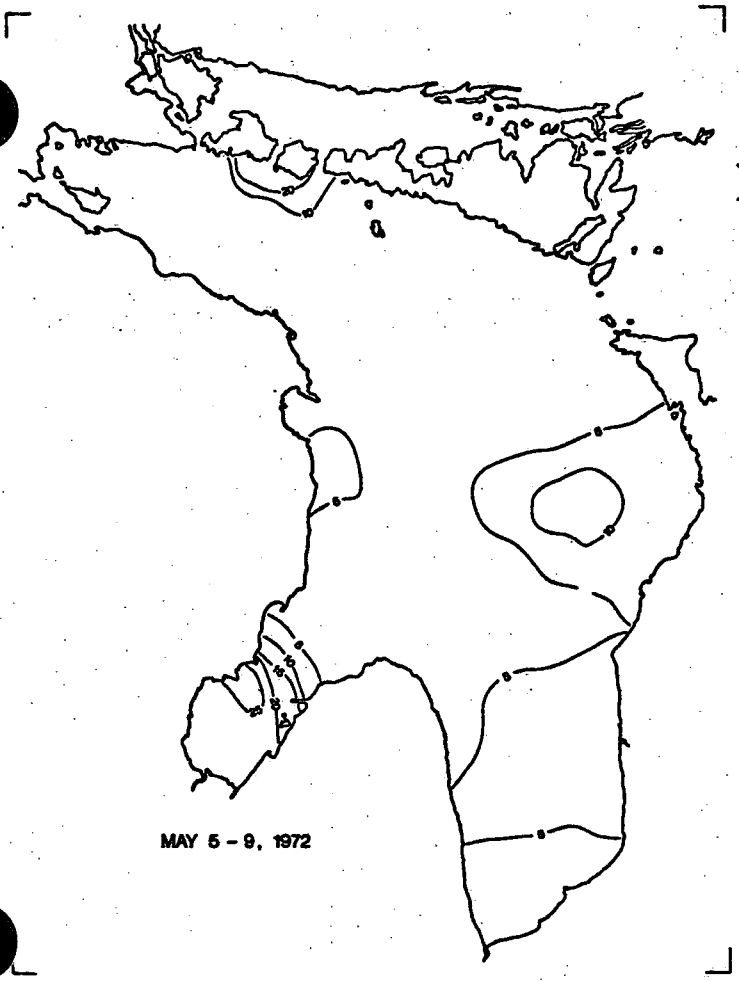


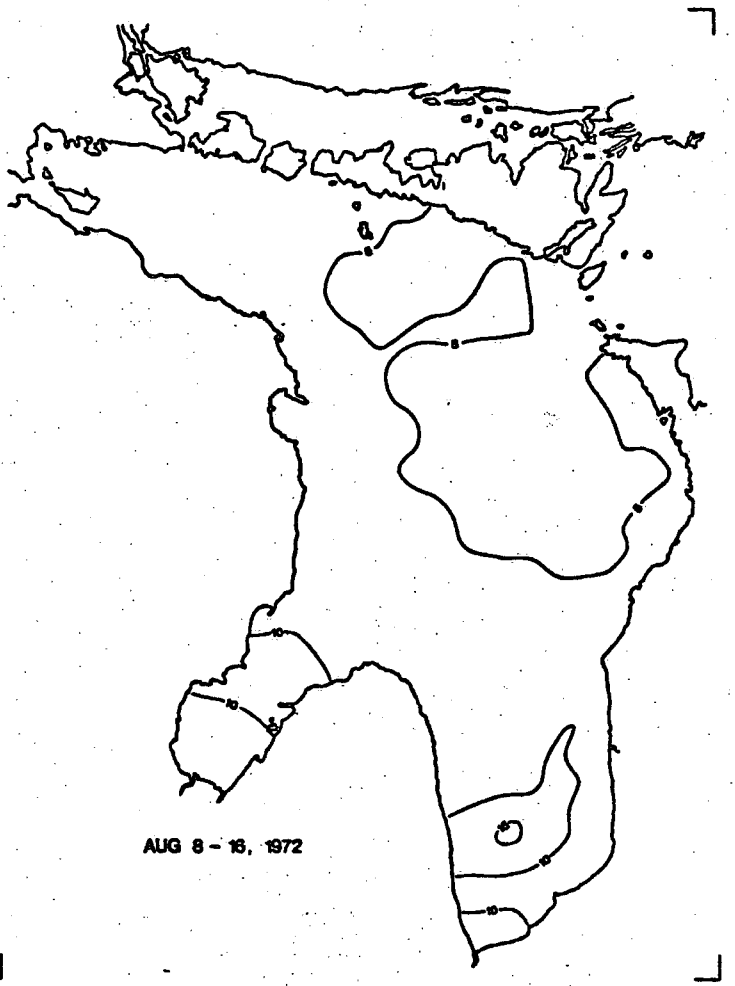
FIGURE 34

Ammonia Nitrogen: Figure 35

Ammonia Nitrogen values were generally quite homogeneous with values from 5 - 10 µg/l - N throughout the main body of the lake. Saginaw Bay values were considerably higher than those observed in the main lake. Maximum values up to 50 µg/l-N were observed in November in Saginaw Bay.

AMMONIA NITROGEN µg/l-N, 1m





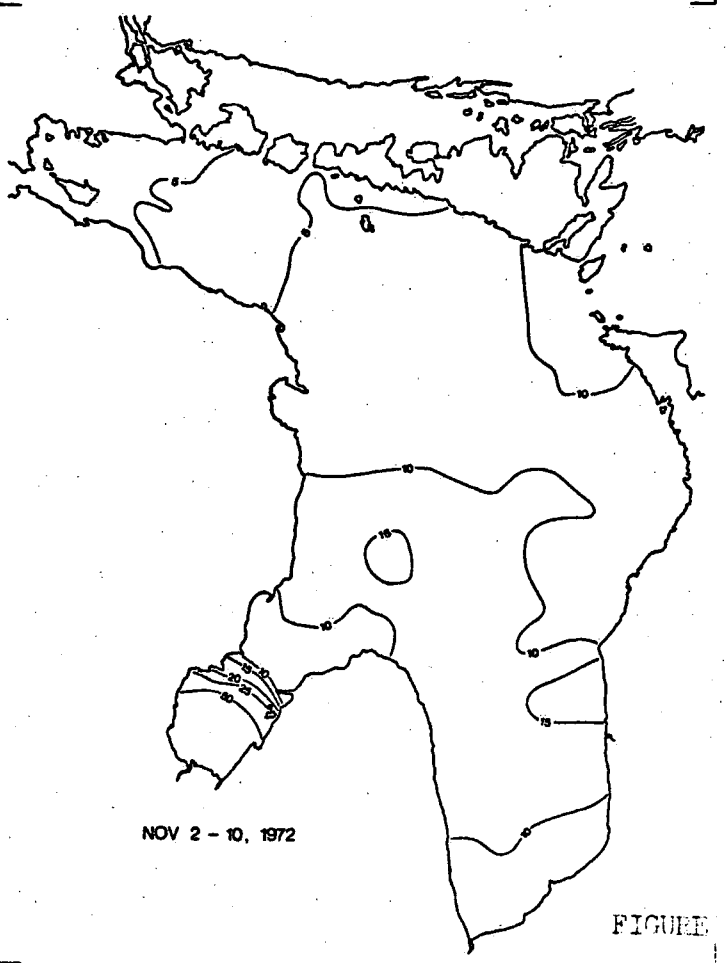
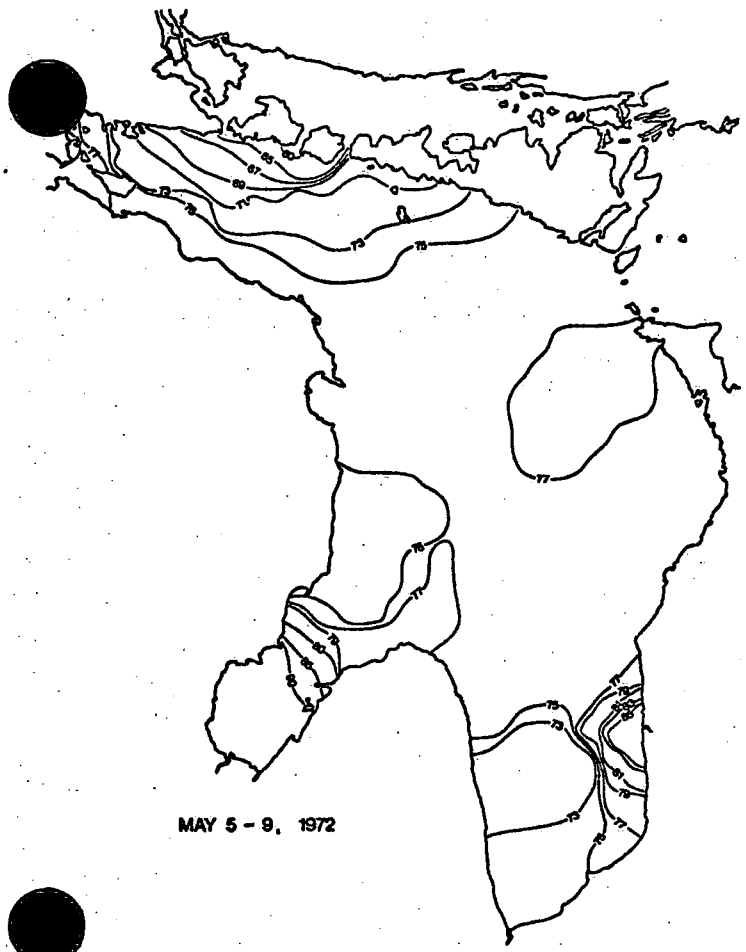


FIGURE 35

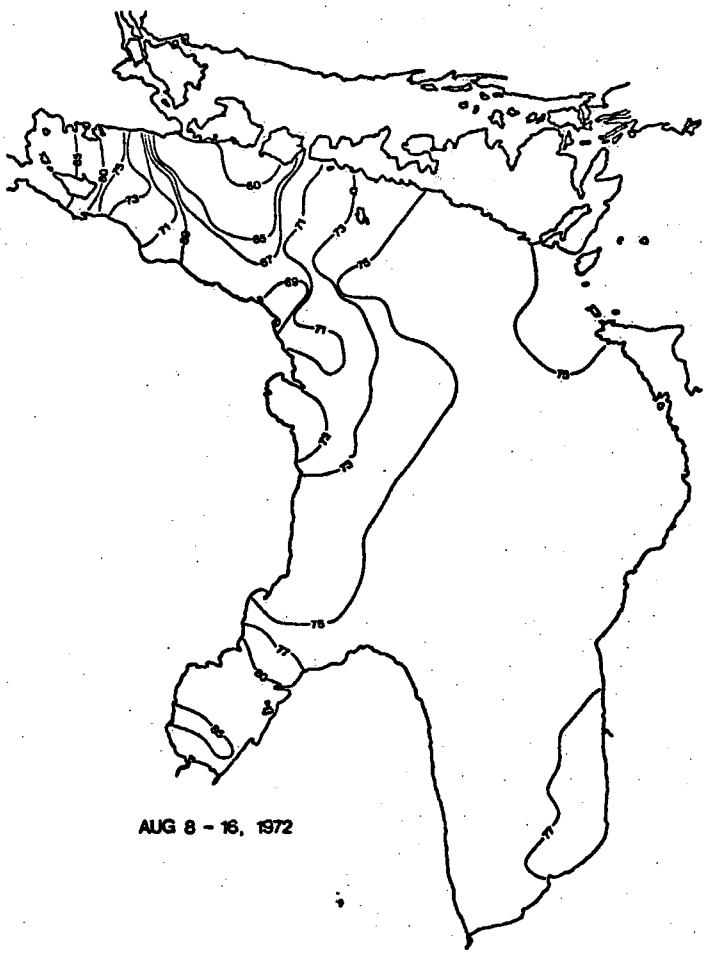
Alkalinity, Total Filtered: Figure 36

Alkalinity values showed very little surface to bottom depletion during the year. Main lake values ranged from 75 - 77 µg/l - $CaCO_3$ with Saginaw Bay values considerably higher from 75 - 100 µg/l - $CaCO_3$. The Lake Michigan - Lake Superior mixing zone in the north - western section of the lake is illustrated very well by this data. Lake Michigan inflows are considerably higher than Lake Huron water with values from 79 - 85 µg/l - $CaCO_3$ while Lake Superior inflows ranged from 60 - 69 µg/l - $CaCO_3$. In addition a probable municipal input was observed off Goderich during the May survey.

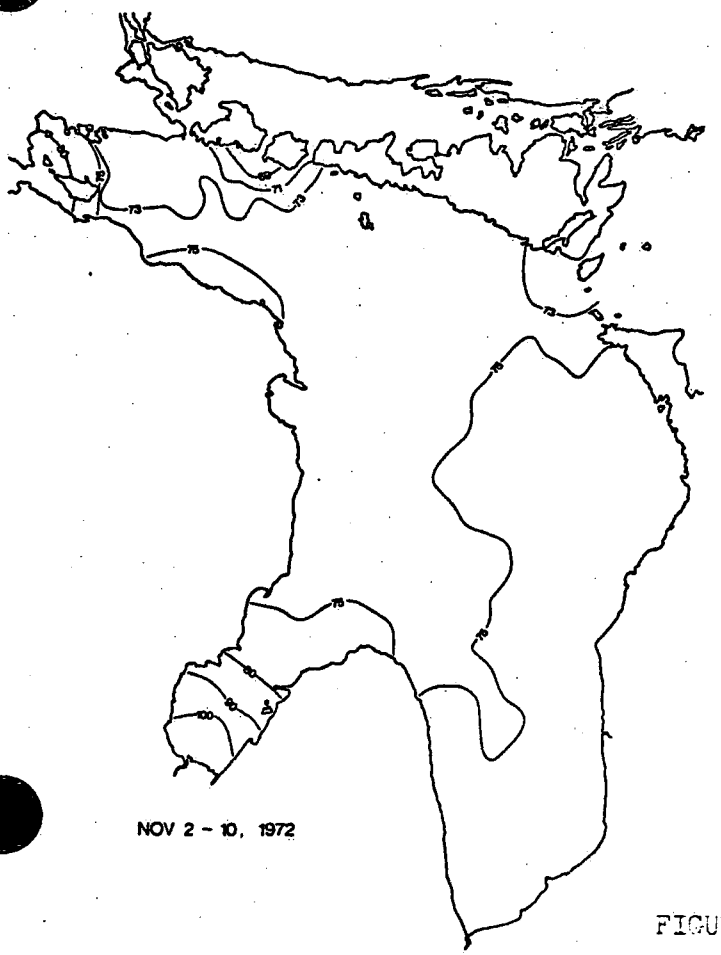
ALKALINITY, TOTAL FILTERED mg/l - $CaCO_3$ 1m



MAY 5 - 9, 1972



AUG 8 - 16, 1972



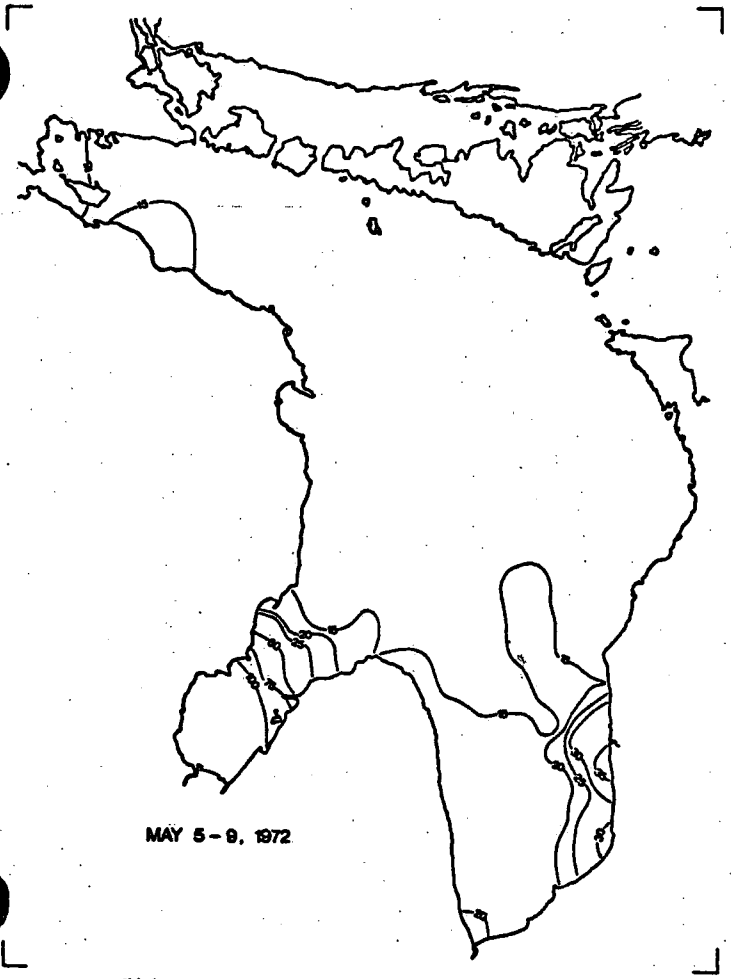
NOV 2 - 10, 1972

FIGURE 36

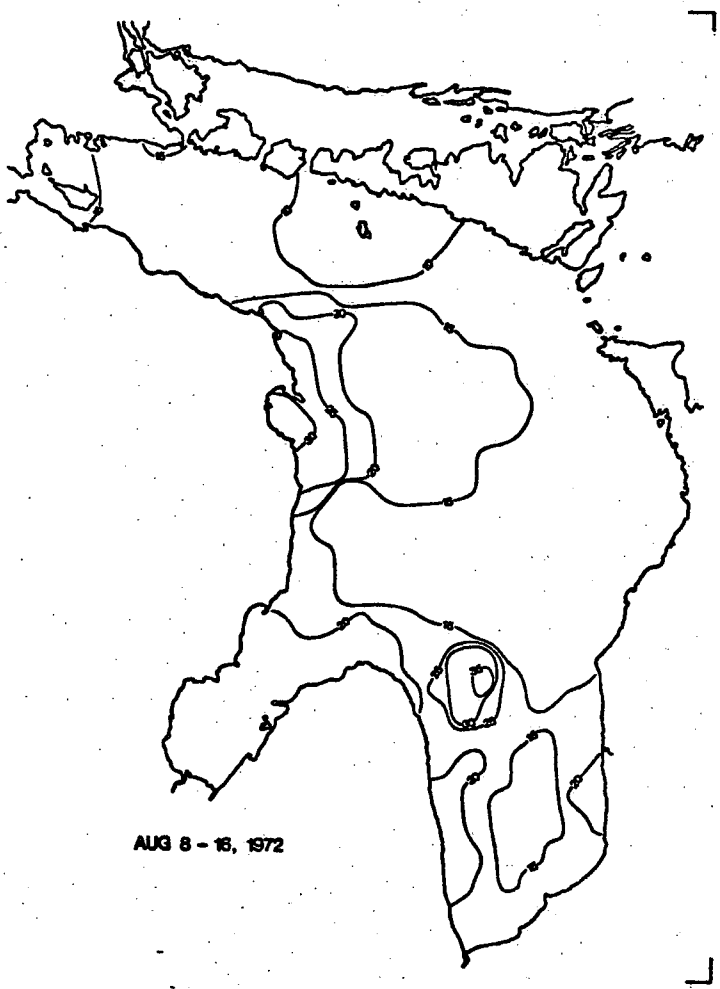
Total Phosphorus: Figure 37

As in 1971, a fairly homogeneous horizontal and vertical distribution of total phosphorus was observed in the main body of the lake throughout the year. Values for the surface waters of the main lake ranged from 5 - 15 µg/l - PO_4 throughout the year. Values in Saginaw Bay ranged from a low of 20 µg/l - PO_4 in August to a high of 100 µg/l - PO_4 in May. A few possible municipal sources of phosphorus were observed in Thunder Bay off Alpena in August and off Goderich in May. Also higher total phosphate values were observed to be coming from Lake Michigan, particularly in November.

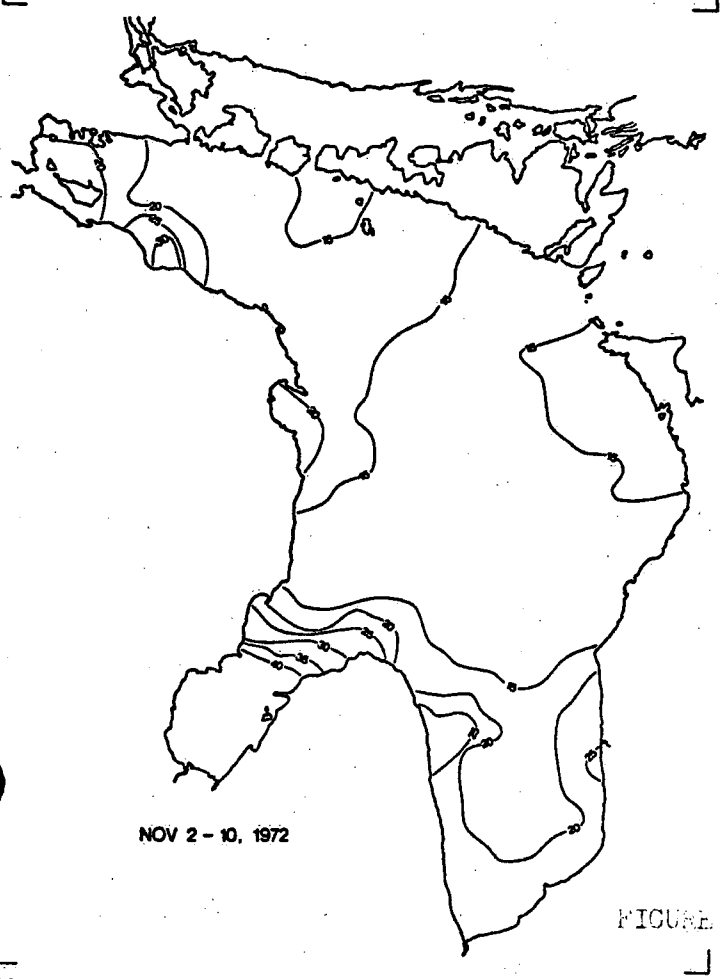
TOTAL PHOSPHORUS $\mu g/l - PO_4$, 1m



MAY 5 - 9, 1972



AUG 8 - 16, 1972



NOV 2 - 10, 1972

FIGURE 37

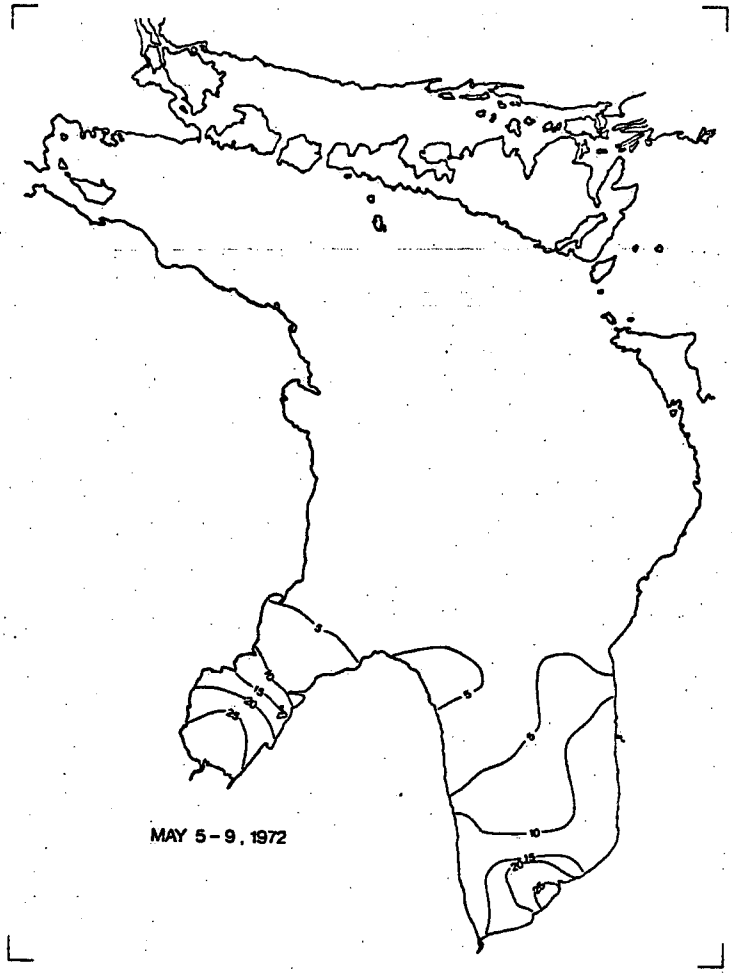
Total Filtered Phosphorus: Figure 38

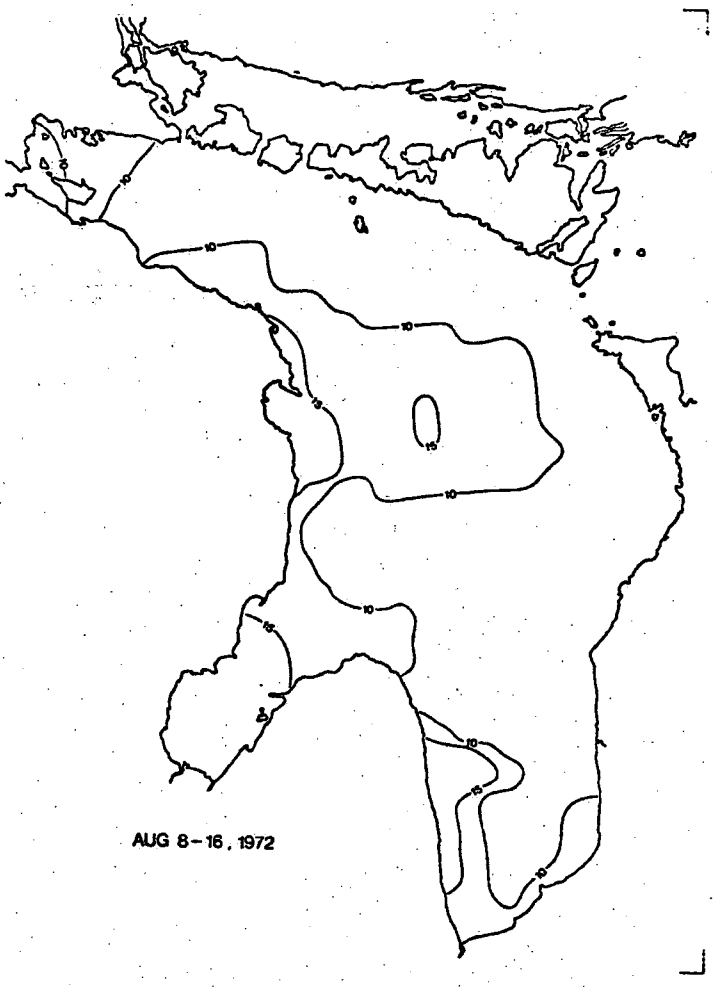
Total filtered phosphorus values ranged from 5 - 10 µg/l - PO_4 in the main lake. Not much variation was observed during the year. Maximum values of 25 µg/l - PO_4 were observed in Saginaw Bay in May. Also an area off Grand Bend had concentrations up to 25 µg/l - PO_4 in May.

Soluble Reactive Phosphate:

Soluble reactive phosphate concentrations were always at or near the detection limit of the analytical method. Main lake values ranged from 0 - 5 µg/l - PO_4 with most values below 2 µg/l - PO_4.

TOTAL FILTERED PHOSPHORUS µg/l-PO_4 ,1m





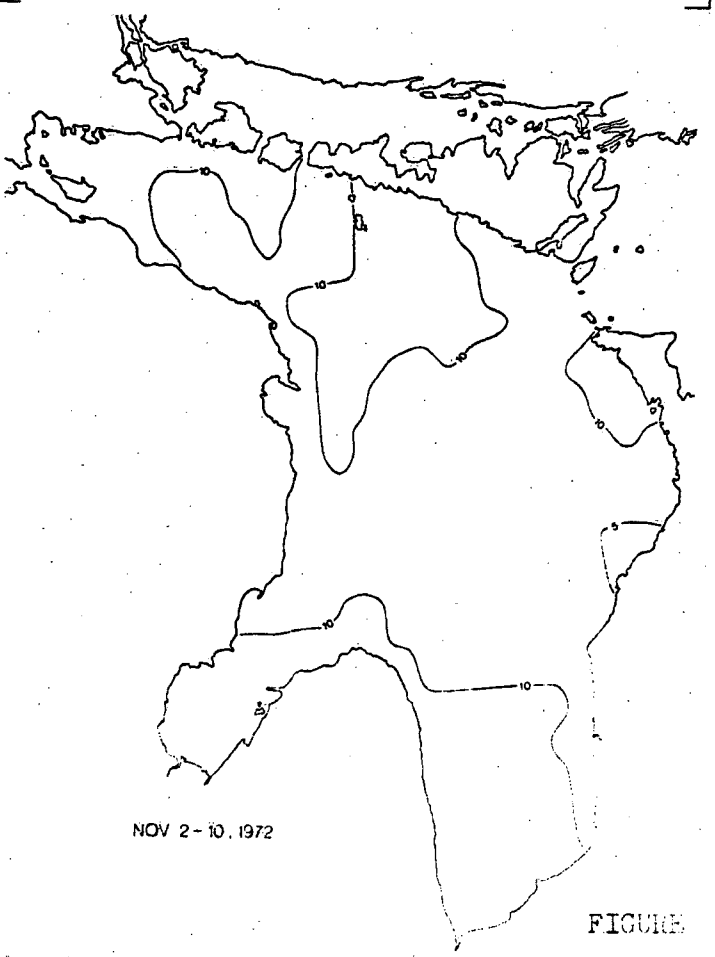
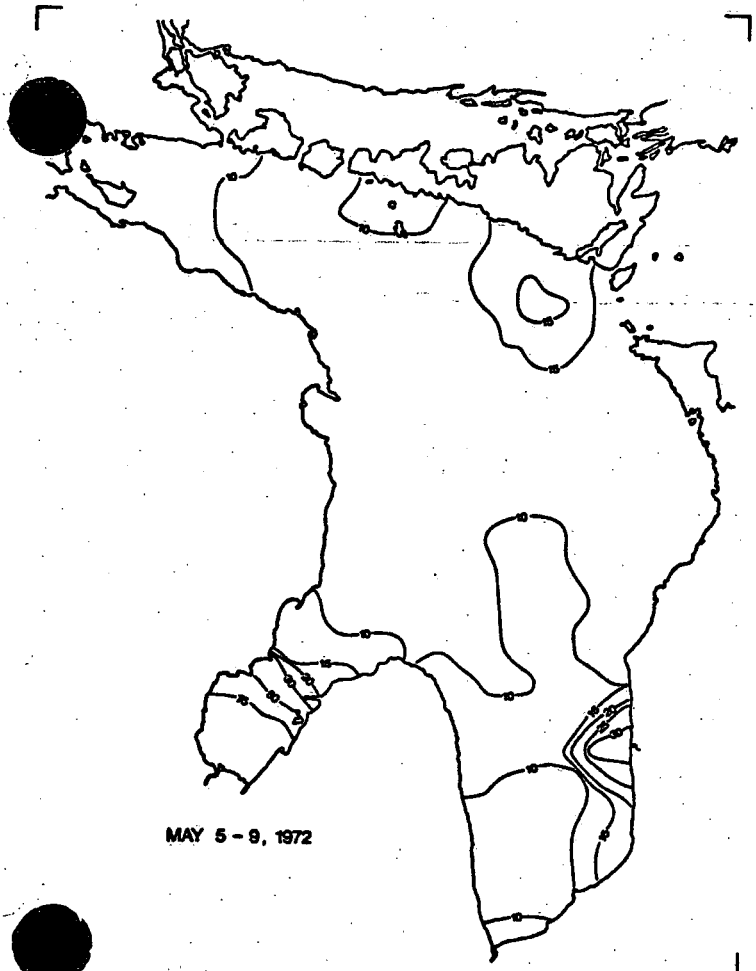


FIGURE 38

Particulate Phosphorus: Figure 39

Mid-lake particulate phosphorus concentrations ranged from 5 - 10 µg/l - PO_4. However, Saginaw Bay concentrations ranged from 10 - 75 µg/l - PO_4. As for total phosphorus, a possible source of phosphorus is observed off Goderich during the May survey.

PARTICULATE PHOSPHORUS µg/l - PO_4 , 1m



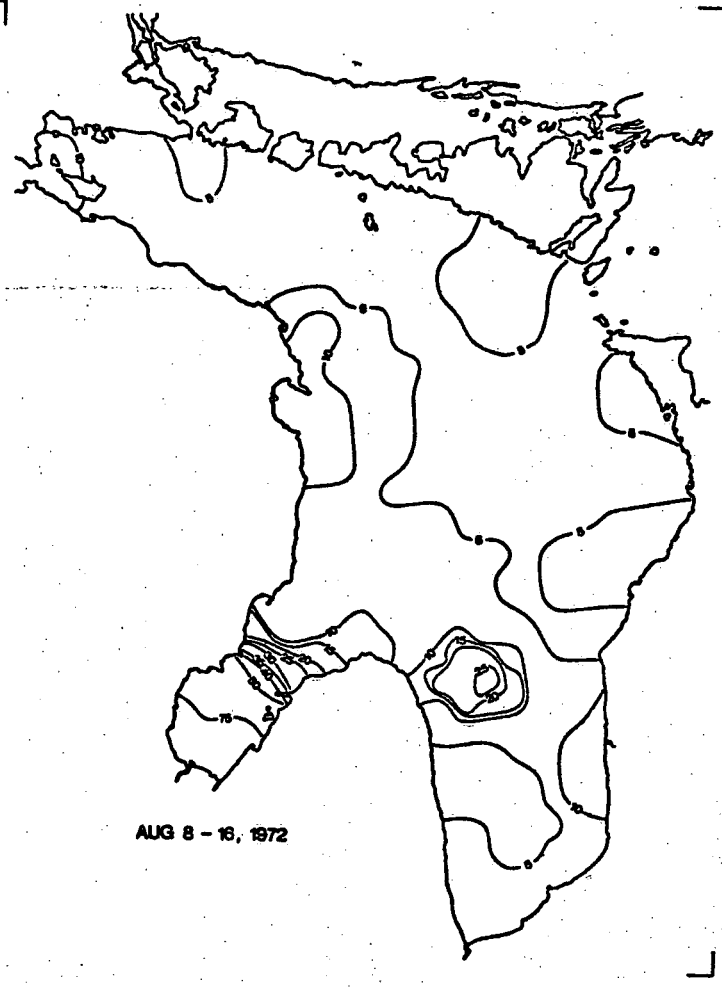


FIGURE 39