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NATIONAL PHYSICAL RESEARCH LABORATORY

ISOTOPIC INVESTIGATION OF LAKE ST LUCIA

by

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PRETORIA

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ISOTOPIC INVESTIGATION OF LAKE ST LUCIA

1. INTRODUCTION

1.1 Description of the Lake System

St Lucia lake, situated in northern Zululand, is a large shallow lake connected to the sea by a narrow channel about 20 km long. The northern part of the lake is divided into two compartments of which the western one is known as False Bay (see Figure 1). The Nyalazi, Hluhluwe and Mzinene rivers supply fresh water to False Bay; the Mkuze river enters the lake through swamps in the North. The Mkuze river is the most important river in the lake system; its catchment area is almost twice as large as that of the other three together. A small stream, the Mpate river, runs into the Narrows at Essengeni.

Rain over the area is mainly brought in with south-westerly winds. The mean annual rainfall decreases from about 1 200 mm/year along the East Coast to about 600 mm/year at the western shores of the lake. Rain isohyets are shown on the map in Figure 1.

The potential evaporation increases from east to west with an average value of 1 380 mm/year (Symons pan value). When evaporation exceeds the inflow of fresh water from precipitation and rivers the water level of the lake will drop, and seawater will enter the lake.

1.2 The Stable Isotope Method

The stable isotopes oxygen-18 (^{18}O) and deuterium (D or ^{2}H) are present in small concentrations in all natural waters as the molecules $H_2{}^{18}O$ and $HD^{16}O$. Since the physical behaviour of these molecules is slightly different from that of the normal $H_2{}^{16}O$ molecules, their concentrations vary in waters of different origin. In seawater the abundance of the isotopes is very constant and concentrations are usually expressed as δ-values which represent the permil deviation from Standard Mean Ocean Water (SMOW). Negative δ-values indicate that the sample contains less of the heavy isotope than the SMOW standard and positive values vice-versa. When ocean water evaporates the lighter isotopic molecule $H_2{}^{16}O$ evaporates faster than the heavier ones. Thus rainwater, and consequently also river- and groundwater, will be depleted in the heavy isotopes with respect to ocean water and the δ-value will be negative. Only when these waters are subject to evaporation, as is the case in lakes and to a lesser degree also in rivers, the heavy isotope concentration will increase and positive δ-values may occur. This enrichment continues to a maximum value, which is determined by the atmospheric water vapour (humidity). The oxygen-18 and deuterium concentrations vary in parallel and for natural unevaporated water (with the exception of ocean water) they follow the relation $\delta^{D} = 8\ \delta^{18}$ + const. During evaporation their relation is given approximately by $(\delta^{D} - \delta^{D}_{o}) = 5\ (\delta^{18} - \delta^{18}_{o})$ where δ^{D}_{o} and δ^{18}_{o} are the isotopic concentrations of the original unevaporated water. Thus evaporated water is identified on a $\delta^{D} - \delta^{18}$ graph by a departure from the line with slope 8(Craig, 1961). Because of the marked differences in isotope concentrations of the different kinds of water, these isotopes can be used to detect sea- and fresh water inflow and evaporation.

1.3 Radioactive Isotopes

Natural waters contain small amounts of the radioactive hydrogen isotope tritium (T or ^{3}H). The tritium content of a sample is expressed in tritium units (T.U.) where 1 T.U. represents a T/H ratio of 10^{-18}.

The surface water of the southern oceans has a low tritium content as compared with precipitation and run-off on the continent. The tritium content in the lake and estuary can thus be used to trace seawater in its passage into the lake. In the course of time the tritium content of the seawater in the lake will increase by isotopic exchange with atmospheric vapour. Therefore only a fresh inflow from the sea can be traced by tritium.

Tritium profiles of groundwater and of the water in the sediment under the lake can be measured. Recent increases in the tritium content of the rain due to nuclear weapon tests allow the infiltrated water to be dated. This provides an estimate of the recharge and infiltration rate.

The radiocarbon (^{14}C) method is used to determine the rate of sediment deposition in the lake. The carbon-14 concentrations of organic materials and shells at different depths in the sediment are measured to obtain the age of the sediment samples.

2. SURVEY OF THE LAKE SYSTEM

2.1 Stable Isotope Observations

Monthly samples of rain-, ground-, sea- and lake water in the St Lucia area were collected from June 1970 to September 1973. The sampling stations are shown in Figure 1. The oxygen-18 concentrations of all samples were determined; deuterium measurements were made for some samples to observe the effect, if any, of evaporation.

The results of the deuterium measurements are given in Table 1. The simultaneous change in ^{18}O- and D-concentrations that takes place during evaporation was shown in an earlier report (Vogel and Van Urk, 1971).

The ^{18}O-content of some seawater samples from Mission Rocks was measured. The δ^{18}-values are given in Table 2. Their average value is δ^{18} = + 0,59 ‰.

Table 3 gives the results of the ^{18}O-measurements of some riverwater samples. The low values represent the average ^{18}O-concentration of the rainfall in the catchment area, the higher ones indicate evaporation.

The δ-values of rainwater vary widely (see Table 4 and 5, and Figure 2). At Charter's Creek the difference between the highest and lowest observed δ^{18}-value is 6,3 ‰. The average δ-value, weighted with amount of rainwater over the period 1 September 1970 to 31 August 1973 was - 3,71 ‰ for oxygen-18 and - 15,2 ‰ for deuterium. At Lister's Point these values were - 2,48 ‰ (^{18}O) and - 6,5 ‰ (D).

The oxygen-18 concentration of the groundwater at Old Jetty was very constant. The δ^{18}-values fluctuated between - 3,15 ‰ and - 3,67 ‰ with an average of - 3,35 ‰ (Table 6); this compares well with the average δ^{18}-value of the precipitation in the area.

At Sengwane the oxygen-18 content of the groundwater varied considerably. The borehole from which the samples are taken is situated very near the lake edge and mixing of groundwater with lake water is suspected.

In Figure 3 the monthly δ^{18}-values of the groundwater at Sengwane are compared with the salinity of the lake water at the same station (Table 6) and the δ^{18}-values of the lake water at Lister's Point, which are taken to be representative for the ^{18}O-content of the northern lake compartment. Some of the variations in the ^{18}O-content and the salinity of the lake water are indeed reflected in the δ^{18}-value of the groundwater which supports the assumption that mixing of the two kinds of water takes place.

The results of the oxygen-18 measurements of the lake water at the three stations, Lister's Point, Charter's Creek and Essengeni are presented graphically in Figure 4. The values are given in Table 4. For the stations Charter's Creek and Lister's Point the amount of precipitation and its total oxygen-18 content, viz., amount of precipitation times the ^{18}O-concentration, for each month are included in the graph.

It must be borne in mind, however, that the rainfall samples are "spot samples", and they should only be used as an indication of the amount of rainfall and its isotopic composition in the area. The highest oxygen-18 concentrations in lake water are found at Lister's Point. Concentrations at Charter's Creek in the lower compartment were usually lower while those at Essengeni, situated near the estuary mouth, were still lower and approximately equal to that of ocean water.

Deuterium measurements confirm that the high δ^{18}-values are due to evaporation. The maximum value that can be reached appears to be approximately $\delta^{18} = + 4$ ‰. Fluctuations are caused by occasional fresh water inflow and can be observed at all the stations.

During February 1972 floods occurred in the area causing the oxygen-18 concentrations in the lake to drop considerably. The δ^{18}-value of the lake water in False Bay, where three rivers enter the lake, decreased by 4 ‰. The decrease was less pronounced at Charter's Creek. This compartment has no fresh water supply from rivers and serves as a buffer between the northern part of the lake and the estuary mouth. At Essengeni the δ^{18}-value of the lake water dropped sharply, probably as a result of fresh water inflow from the Mpate river into a relatively small area of the lake. Immediately after the floods the oxygen-18 concentrations in the lake increased again as a result of evaporation and within a year's time the maximum value had again been reached.

2.2 Salinity

The salinity measurements of the lake water samples were carried out by Mr F. Joubert of the Natal Parks Board at St Lucia. The values for the stations, Lister's Point, Charter's Creek and Essengeni are included in Figure 4, and Tables 4 and 5.

Until February 1972 the salinity in the lake increased from south to north, with values of about 35 ‰ (the salinity of the seawater) at the estuary mouth, to values between 30 ‰ and 60 ‰ in the lower lake compartment and over 80 ‰ in the upper part of the lake. At Lister's Point a salinity of 109 ‰ was measured at 1 October 1970.

During the period June 1970 to February 1972 the salinity varied more or less in parallel with the oxygen-18 concentration. Only the values of 1 May 1971 form an anomaly which remains unexplained. During January and February 1972 when flood waters entered the lake the salinity dropped sharply at Lister's Point and to a lesser degree also at Charter's Creek and Essengeni. Until August of that year the lake had a uniform salinity of about 20 ‰. After August 1972 seawater started entering the lake again, which can clearly be observed from the rise in salinity at Essengeni. This, in combination with evaporation, caused salinities to increase, especially in the upper part of the lake. In September 1973, at the start of the rainy season the salinity dropped once again to 20 ‰ to remain at that value during the rest of the season. It is noticed that although Charter's Creek received more rain than Lister's Point at several occasions, the drop in salinity after heavy rainfall is much sharper at Lister's Point than at Charter's Creek. This is caused by the facts that -

(a) the rainfall figures are only "spot samples"; and

(b) the four main rivers, representing a catchment area of more than 7 000 km^2, all enter the lake in the northern part while only one small river (catchment area less than 50 km^2) feeds into the narrows. Therefore, when a large amount of fresh water enters the lake the saline water is flushed down from the north to the south and if the salinity in the upper part was very high, the salinity in the lower parts will rise temporarily.

2.3 Salinity and Oxygen-18 Distribution Over the Lake

On a few occasions, i.e. during, immediately after, one month and six months after the flood of February 1972, an extensive series of lake water samples was taken to obtain a more complete picture of the oxygen-18 distribution in the lake. The samples of the series taken on 29 February 1972 were also analysed for their chemical composition. It appeared that 98 % of the salt present in the lake was derived from seawater (Vogel, 1972). The sampling stations are indicated on the map in Figure 5. Table 7 gives the names of these stations and their salinity- and δ^{18}-values. The results are presented graphically in Figures 6 and 7. Before the flood the salinity amounted to 60 ‰ in the northern part of the lake. The fresh water from the Mkuze river entering the lake during February can clearly be observed on the graphs. By the end of February the fresh water had penetrated a bit further south and False Bay had also received fresh water.

After two months equilibrium had been reached and the lake had a fairly uniform salinity and oxygen-18 concentration. The influence of evaporation can already be seen in the δ^{18}-values : on the average it had risen by 0,5 ‰ in the southern compartment. Fresh water inflow could still be observed in the northern compartment, and to a lesser degree also in False Bay.

By the end of August, after the dry winter season, the oxygen-18 content had increased even more as a result of evaporation. The salinity had remained the same with a very uniform distribution over the lake. Only at the Narrows, near the estuary mouth, the salinity had increased, indicating seawater inflow. The oxygen-18 concentration at the mouth had decreased as a result of this.

The changes in salinity and oxygen-18 concentration are shown simultaneously in Figure 8. On 1 February 1972 Lister's Point still showed a high salinity and a high δ^{18}-value. The values for Charter's Creek lie in between those of Lister's Point and sea water. The values for Essengeni are already very low, probably as a result of fresh water supply from the Mpate river. During the February flood a range of values between those of fresh water and those of the original lake water is found.

On 1 May 1972 it is found that the lake water is well mixed with salinity values between 15 ‰ and 25 ‰. The increase of the δ^{18}-values show that evaporation had become noticeable. There is still some fresh water supply and no evidence of seawater inflow.

After the winter, at 1 September 1972, the lake water had evaporated to such a degree that its δ^{18}-value had risen to more than + 1,0 ‰ and sea water has started entering the lake again.

2.4 Tritium Concentrations

Tritium measurements were carried out on a few samples; the results are shown in Table 8. No concentrations of rain- and riverwater samples from the St Lucia area were measured but values for two successive seasons were available for precipitation at Durban and Estcourt and for riverwater from the Tugela. The tritium content of the groundwater at Old Jetty and other boreholes at the eastern shore are also an indication of the tritium concentration of the fresh water supply of St Lucia lake. Although the concentration in fresh water varies, it differs markedly from that of sea water; the two kinds of water can thus easily be distinguished.

In the lake the lowest tritium concentrations are expected and observed at Essengeni, while the highest concentration is found at Lister's Point. The low values reflect sea water inflow, the high ones fresh water supply.

Generally, the tritium concentration in the lake does not vary very much and a value of 12 ± 1,5 T.U. can be taken as the average equilibrium concentration in the lake.

3. SEDIMENT INVESTIGATION

3.1 Sampling Method

During October 1973 seven boreholes were sunk through the sediment at various points in the lake. Drilling was continued until hard rock was struck and sediment samples were taken at different depths. The locations of the boreholes and their total depths are shown in Figure 9. The core samples that contained sufficient organic material were dated by the radiocarbon method. In some samples enough shell was present to determine the age of the sediment and the age of the deposited shells separately.

When the first three boreholes were drilled, no special precaution was taken to preserve the water contained in the sediment. The core samples of the last four boreholes, however, were kept in closed bottles so that the water could later be extracted for determination of the tritium content, the salinity and the oxygen-18 concentration.

The composition of the sediment (sand, clay, shells) of the different boreholes and the depths at which the samples were taken, are given in Figure 10.

The water was extracted by complete distillation of the core samples. The water samples thus obtained were used for oxygen-18 and tritium determinations. After the distillation a known amount of distilled water was added to the residue. This was then stirred to dissolve the salt in the sample and the water was separated by centrifugation. A conductivity cell was used to measure the salinity.

Other methods to extract the water from the core samples proved to be unsuitable. When filtrated under vacuum the water evaporated visibly. Centrifugation of the samples, if necessary after dilution with a known amount of distilled water, also caused the water to evaporate. By measuring the loss of weight during centrifugation the salinity values could be corrected for evaporation. However, the increase in the δ^{18}-value was so large (up to 2 ‰) that this method could not be applied for isotope determination and complete distillation remained the only solution.

A list of results of the measurements and descriptions of the samples appears in Table 9.

3.2 Oxygen-18 Determinations

The results of the oxygen-18 measurements of the distilled water samples are presented graphically in Figure 11 where the δ^{18}-value is shown as a function of the depth for the different boreholes. For comparison the δ^{18}-value of seawater is indicated and the δ^{18}-value of the lakewater near borehole No. 5 at the time of drilling is inserted as that of a sample at depth zero.

It is observed that most of the values for the boreholes Nos. 4, 5 and 6 are positive. This indicates that the lakewater had been subject to evaporation before infiltration into the sediment. However, all the values are lower than the maximum δ^{18}-value of + 4 ‰. This can mean either that the lakewater had a high O^{18}-concentration before infiltration and was subsequently diluted by fresh groundwater in the sediment, or that the δ^{18}-value represents the average composition of the lake water at the time of infiltration.

Borehole No. 7 shows a completely different picture. This borehole is situated near the estuary mouth, where the lakewater usually has the composition of seawater. One would therefore expect the O^{18}-concentrations of the sediment water to be about the same as that of seawater, but no such high concentrations are found. The low values that are observed, especially those between 7,5 and 13,5 m depth where the isotope content is as low as that of the local groundwater, indicate lateral groundwater seepage into the sediment.

3.3 Salinity Distribution

In Figure 12 the results of the salinity measurements are presented in the same manner as those of the oxygen-18 concentrations.

In contrast with the findings for oxygen-18, the four boreholes show distinct differences in salinity. Borehole No.7 is the least saline, the low concentrations support the conclusion made in 3.2 that groundwater flows into the sediment. Of the three remaining boreholes No. 4 is the least saline.

In order to establish whether fresh water seepage had occurred in these three boreholes the δ^{18}-values are plotted against the salinity (Figure 13). When mixing takes place the points will be scattered around a straight line between the fresh- and lakewater values. This is clearly demonstrated for borehole No. 7.

As far as the other boreholes are concerned, there are indications, but no obvious evidence that fresh water infiltration into the sediment has taken place. An attempt was made to determine the salinity variations for borehole No. 3. The samples from this borehole consisted mainly of clay, with little shell. From measurements on the clay samples of the last four boreholes it was established that the proportion dry clay/water in the sediment had an average value of 0,6. After drying and weighing the samples of borehole No. 3, distilled water was added to obtain ratio clay/water of 0,6. The samples were then stirred and centrifuged and the salinity was determined. The results of these measurements are given in the table below. The average salinity was 19 ‰. This value compares well with the salinity values observed at borehole No. 4. Borehole No. 5 which is situated between Nos. 3 and 4, however, is much more saline. A possible explanation for this is that the lakewater at boreholes Nos. 3 and 4, both situated near the edge of the lake, receives fresh run-off from the shore.

borehole No. 3	
depth in m	salinity in ‰
4,5	16
9	19
11	18
19	18
23	21
26	16
32	14

3.4 Tritium Profiles

The tritium content was measured of some representative samples. The results are given in Table 9.

It appears that even the deepest water still contains some tritium which means that it is relatively young (20 - 40 years). The δ^{18} - and salinity values discussed above can thus be taken to represent variations in the lakewater over the last 40 years.

Nuclear weapon tests caused the tritium content of atmospheric vapour to rise considerably during 1962-1963. This sudden increase can be observed when the tritium concentrations are plotted against depth for each of the boreholes (Figure 14). Water which infiltrated during the five years before the nuclear tests shows tritium concentrations between 3 and 5 T.U.; the water which infiltrated after the tests has a concentration of more than about 11 T.U. Concentrations of less than 3 T.U. represent water which infiltrated before 1957.

The dating can be improved by comparing the salinity variations in the boreholes to the salinity variations of the lakewater during the last few decades (Figure 15). This method was applied for the boreholes Nos. 4, 5 and 6. The estimated infiltration rates are 1,5, 0,7 and 0,5 m/year, respectively.

In borehole No. 7 tritium concentrations as low as 1,6 and 1,7 T.U. were found at depths of 7,5 and 12 m. At the depth of 15 m, however, the concentration had risen again to 4,5 T.U. The explanation for this phenomena is that the groundwater, the presence of which was shown in the previous section, infiltrates the sediment from below. The data, however, are not sufficient to determine either the infiltration rate of the groundwater or that of the lakewater.

3.5 Radiocarbon Age Determinations

Some carbon-14 measurements on sediment samples were carried out in November 1964 (Report of the Commission of Inquiry, 1964-1966). Two samples were taken, at depths of 3 and 9 meters, at Hell's Gates in the vicinity of borehole No. 3. Two further samples were obtained at Picnic Point, just south of Lister's Point in False Bay (depths 4 and 8 m). The carbon-14 concentration of the organic material was determined. Five samples taken in October 1973 were used for age determinations. From borehole Nos. 1 and 3 the carbon-14 concentration of the shells found at depths of 31 m and 32 m, respectively, was measured. The sample at depth 10,5 m of borehole No. 4 contained sufficient organic material and shell to make it possible to perform two separate age determinations. In the samples of borehole No. 7 no shells were found and the age of the organic material at depths 7,5 m and 15 m was determined.

The results of the measurements are given in Table 10. Those obtained in November 1964 are included in the table, where boreholes Nos. 2 and 3 refer to Picnic Point and Hell's Gates, respectively.

From the two separate analyses of the sample from borehole No. 4 it appears that the age of the calceous material (shells) is less than that of the organic material. The age of the shells should be taken as representative for the age of the sediment, because the organic material might have been retained in the rivers for a long time before being deposited in the lake.

In Figure 16 the results are presented graphically.

The ages of the sediment at boreholes Nos. 1, 2, 3 and 4 are of the same order of magnitude. Sedimentation appears to have started at No. 1. For borehole No. 2 the graph can be extrapolated to its total depth (14 m) to obtain an age comparable to that of borehole No. 3. From the age of the sample from borehole No. 4 it can be deducted that the sediment in the eastern part of the lake is certainly not older than that in False Bay. Borehole No. 7 shows once more, a completely different picture. This suggests that in earlier times the southern part of the lake did not belong to the lake system as it exists today.

SUMMARY

Although the stable isotope method by itself does not seem to provide more information than other methods to describe a hydrological system like St Lucia, it proved to be of great importance in combination with other methods.

* At Sengwane, mixing of the lakewater with the groundwater was detected.
* The movement of the water masses in the lake was described, during and after floods and during dry periods.
* Where the increase in salinity was too small to be significant, the stable isotope oxygen-18 served as an excellent indicator for evaporation.
* In the sediment under the lake, infiltration of fresh groundwater could be demonstrated.

The tritium method provided the rates of infiltration of the lakewater into the sediment, and also confirmed the infiltration of groundwater which had been detected by means of the oxygen-18 method.

Sedimentation rates can be computed from the age of the sediment as determined by the carbon-14 method. A significant difference between the age of the sediment in the northern and that in the southern part of the lake was found.

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Report of the Commission of Inquiry into the alleged threat to animal and plant life in St Lucia Lake, 1964-1966. Government Printers.

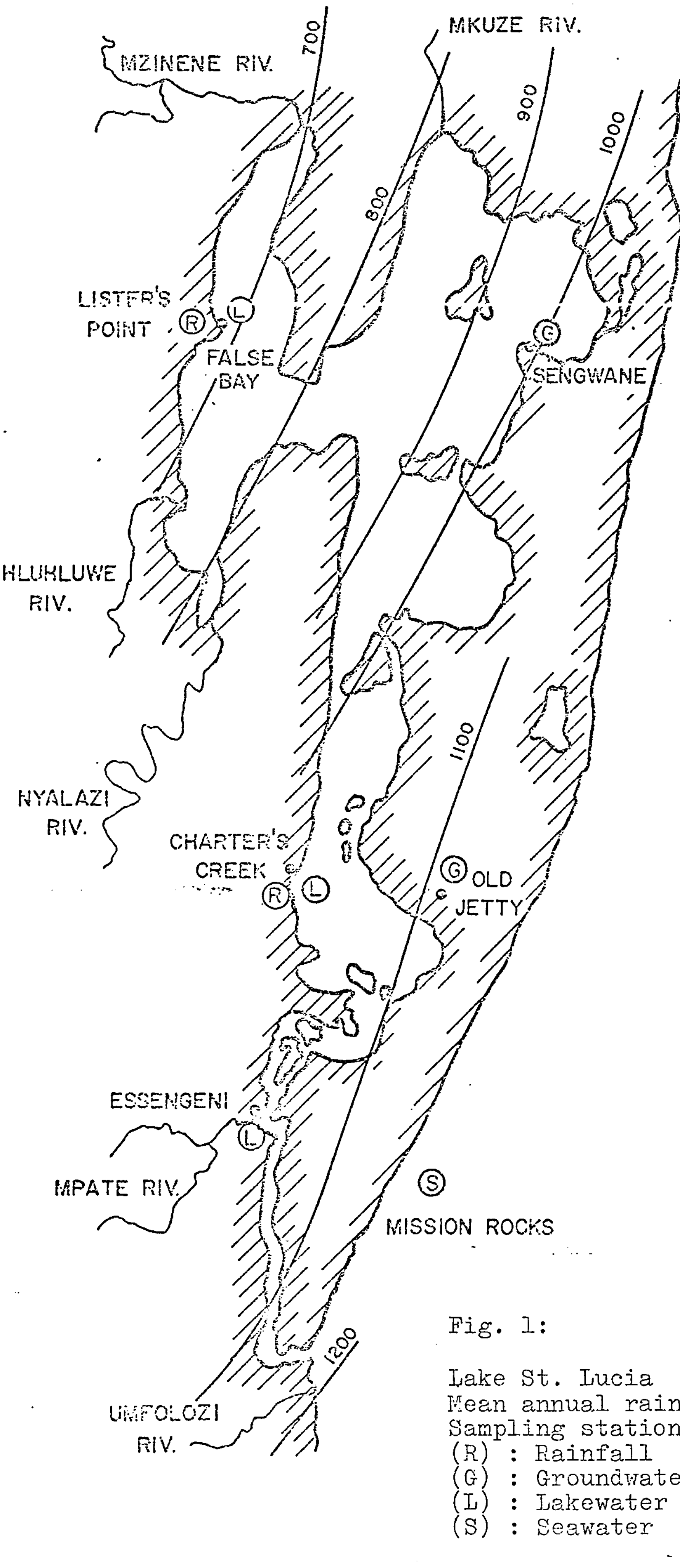

Fig. 1:

Lake St. Lucia
Mean annual rainfall in mm.
Sampling stations:
(R) : Rainfall
(G) : Groundwater
(L) : Lakewater
(S) : Seawater

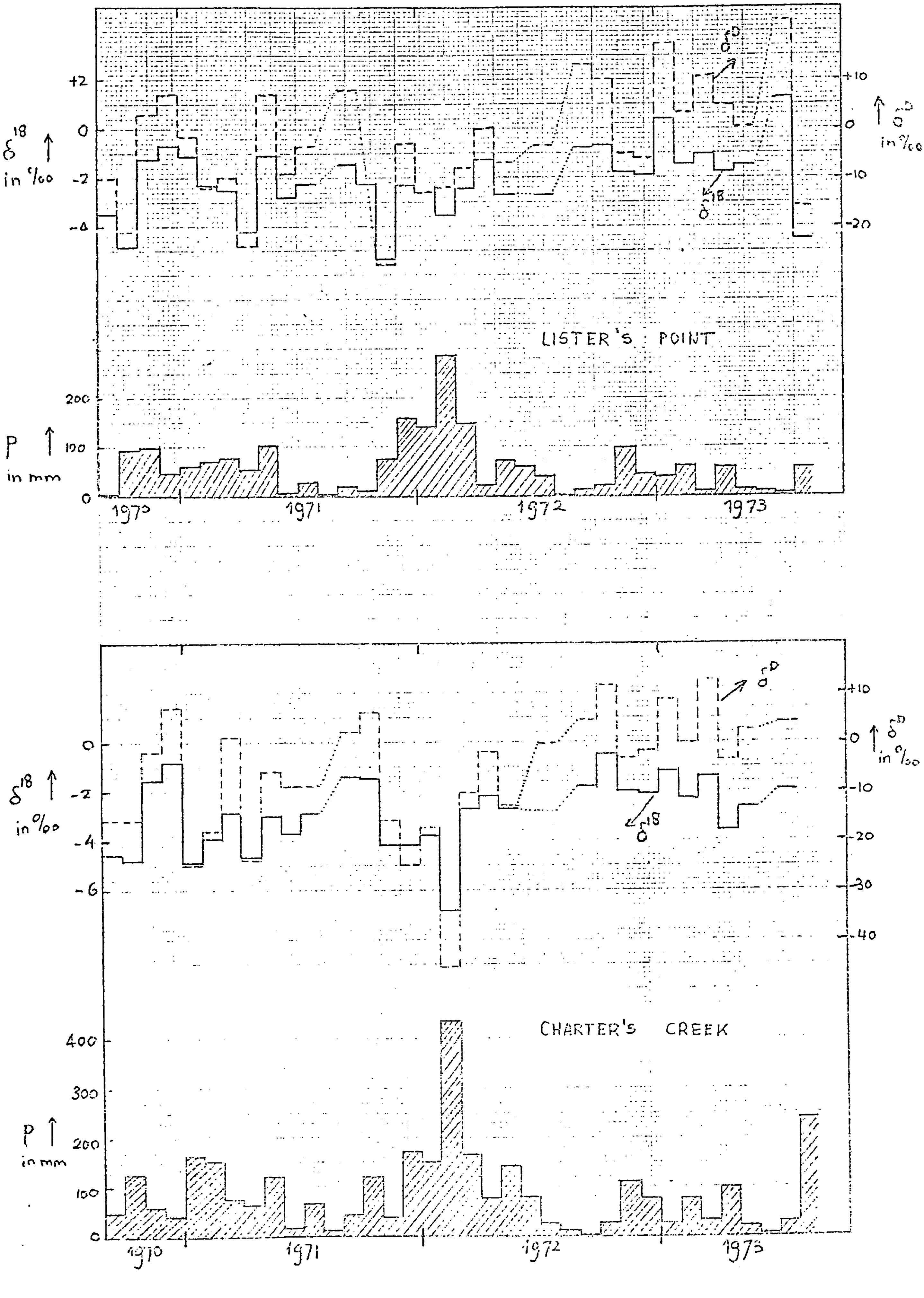

FIG. 2 MONTHLY VALUES FOR RAINFALL AND OXYGEN-18 - AND DEUTERIUM CONCENTRATIONS IN PRECIPITATION AT LISTER'S POINT AND CHARTER'S CREEK

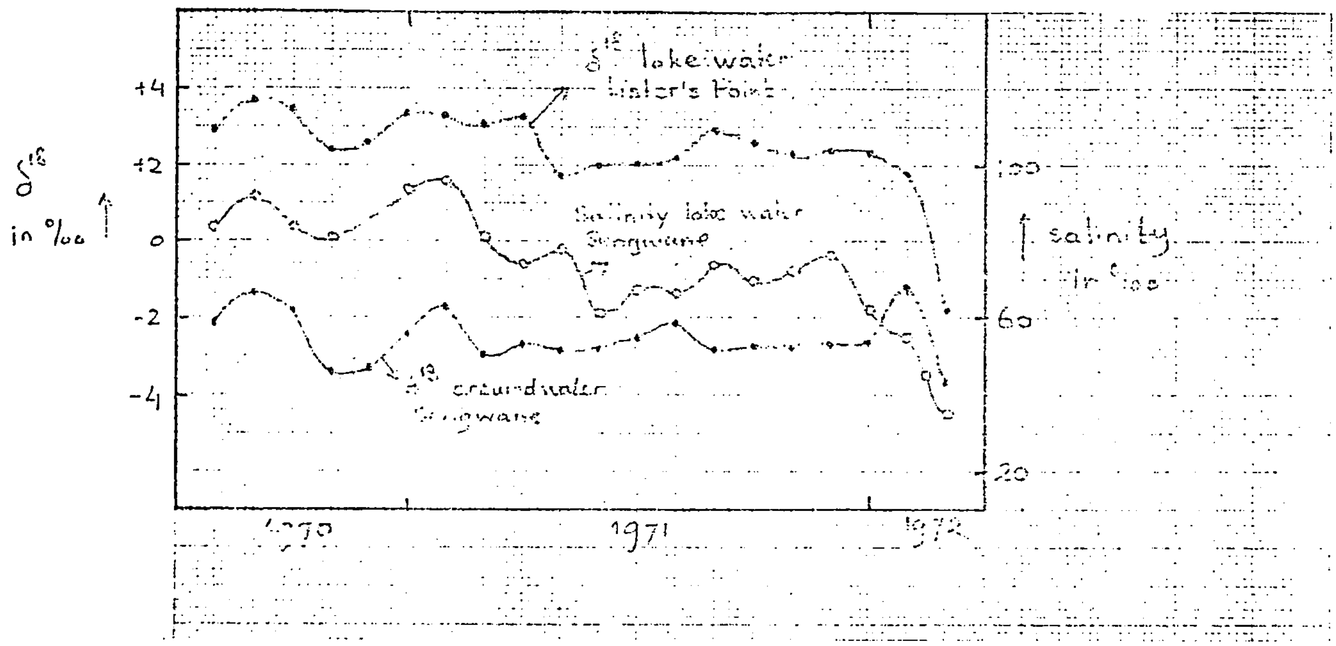

FIG. 3 VARIATIONS IN THE OXYGEN-18 CONCENTRATION OF THE GROUND WATER AT SENGWANE COMPARED TO THOSE OF THE LAKE WATER AT LISTER'S POINT AND TO THE CHANGES IN SALINITY OF THE LAKE WATER AT SENGWANE

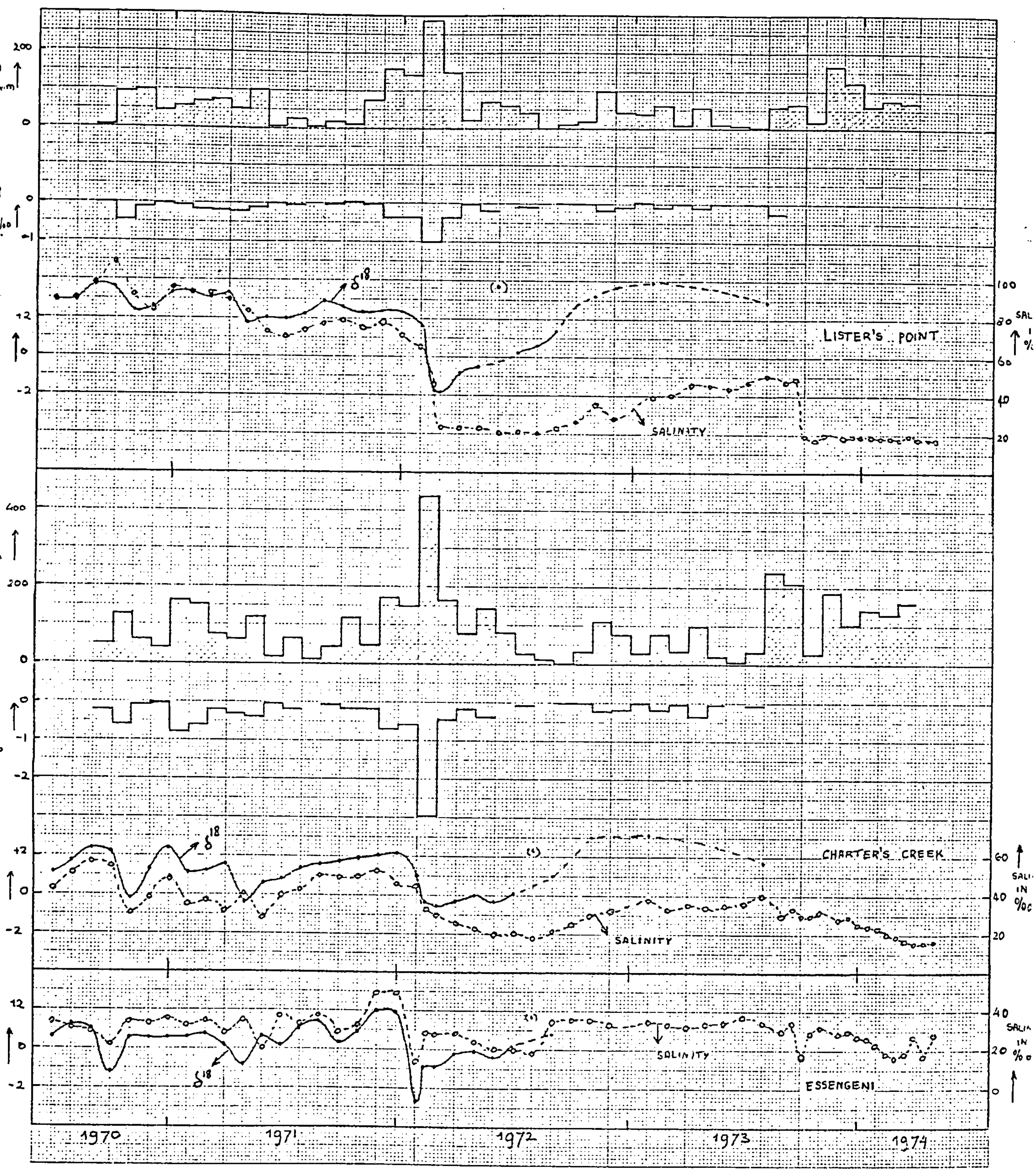

FIG.4. MONTHLY VALUES FOR RAINFALL AND OXYGEN-18 CONTENT OF THE RAIN AT LISTER'S POINT AND CHARTER'S CREEK, AND MONTHLY VALUES FOR OXYGEN-18 CONCENTRATION AND SALINITY OF THE LAKE WATER AT LISTER'S POINT, CHARTER'S CREEK AND ESSENGENI.

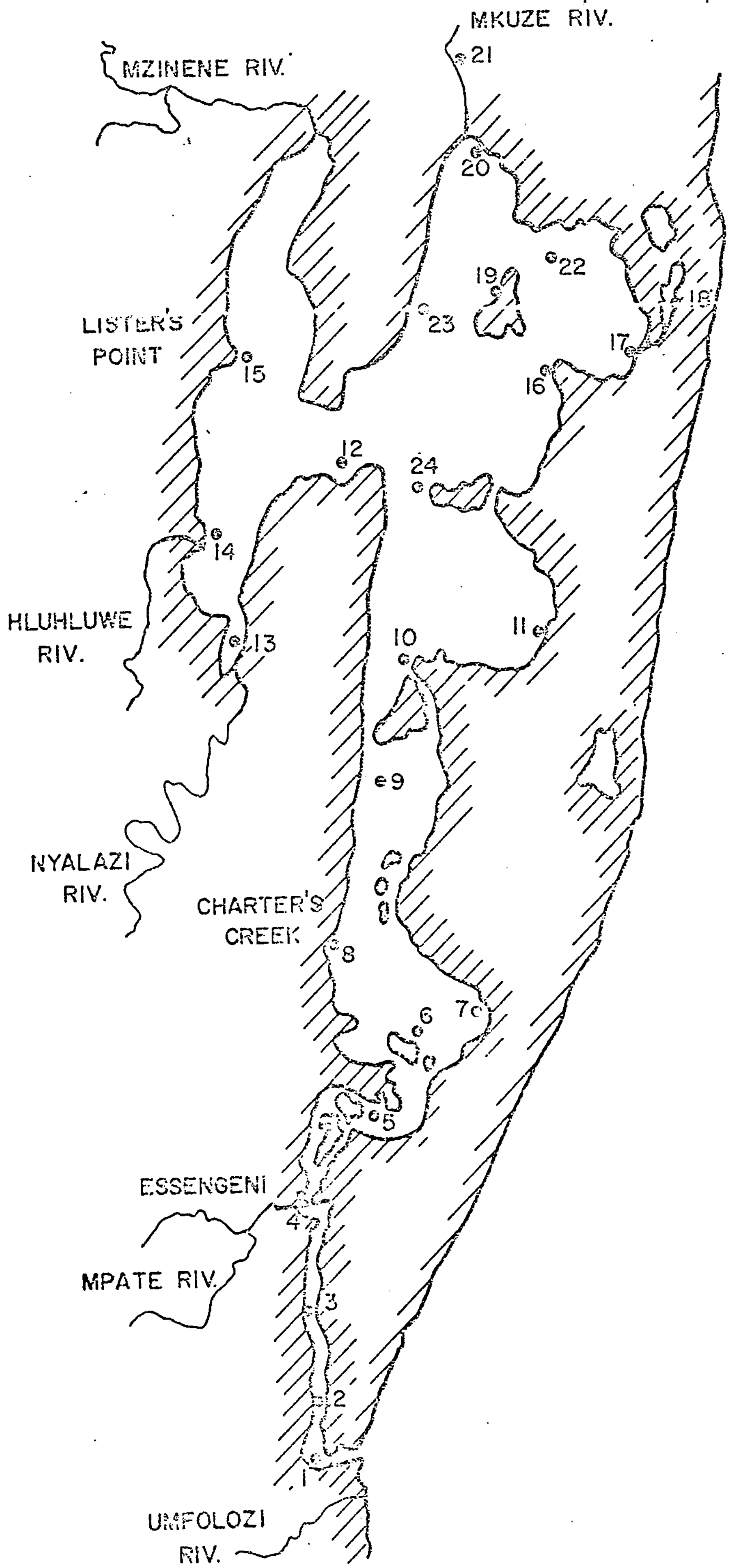

Fig. 5: Locations of lakewater sampling stations. (Cf. table 7)

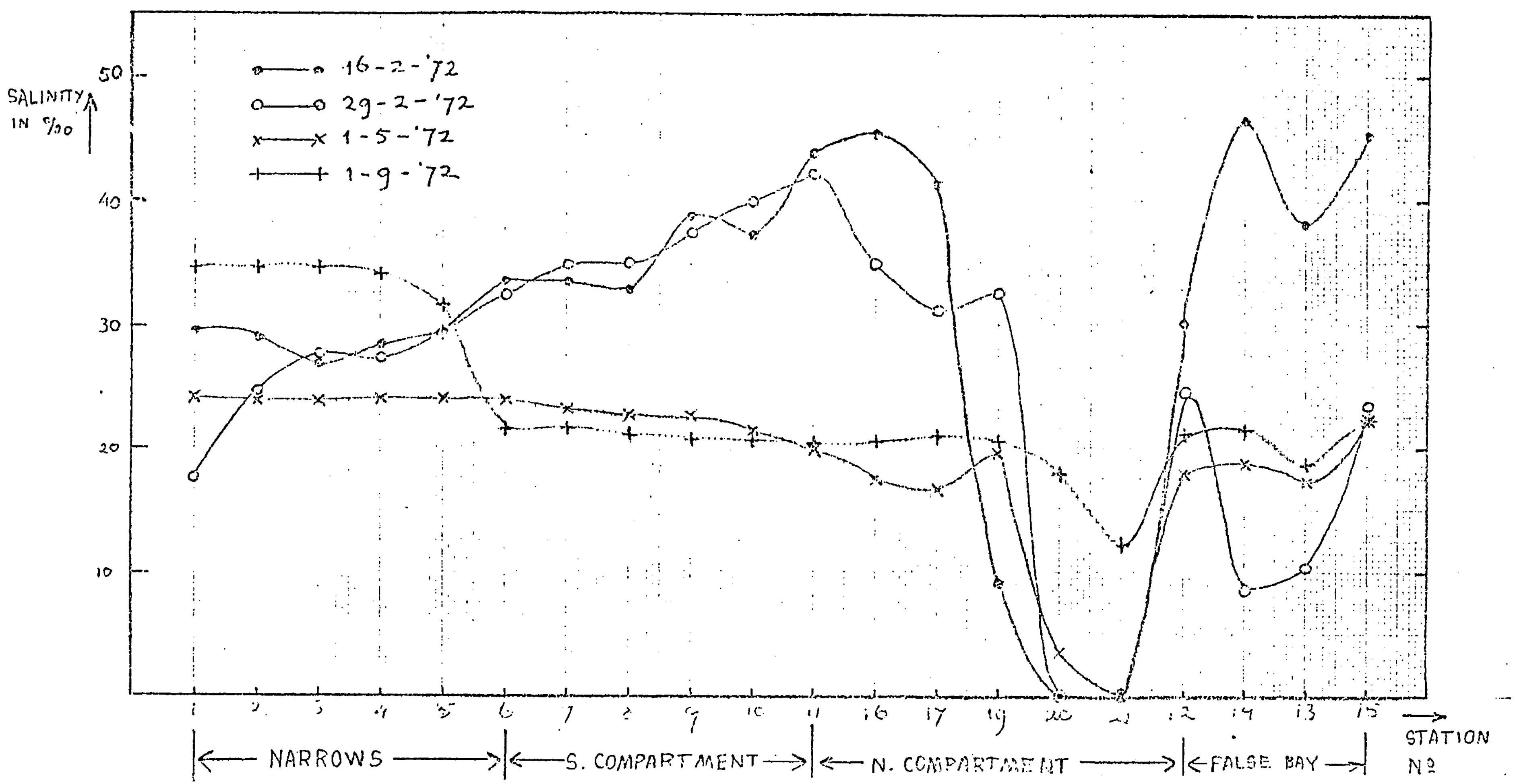

FIG. 6 SALINITY DISTRIBUTION IN THE LAKE DURING FLOODS, IMMEDIATELY AFTER, TWO MONTHS AND SIX MONTHS AFTER THE FLOODS. STATION NUMBERS REFER TO THE NUMBERS OF FIG. 5.

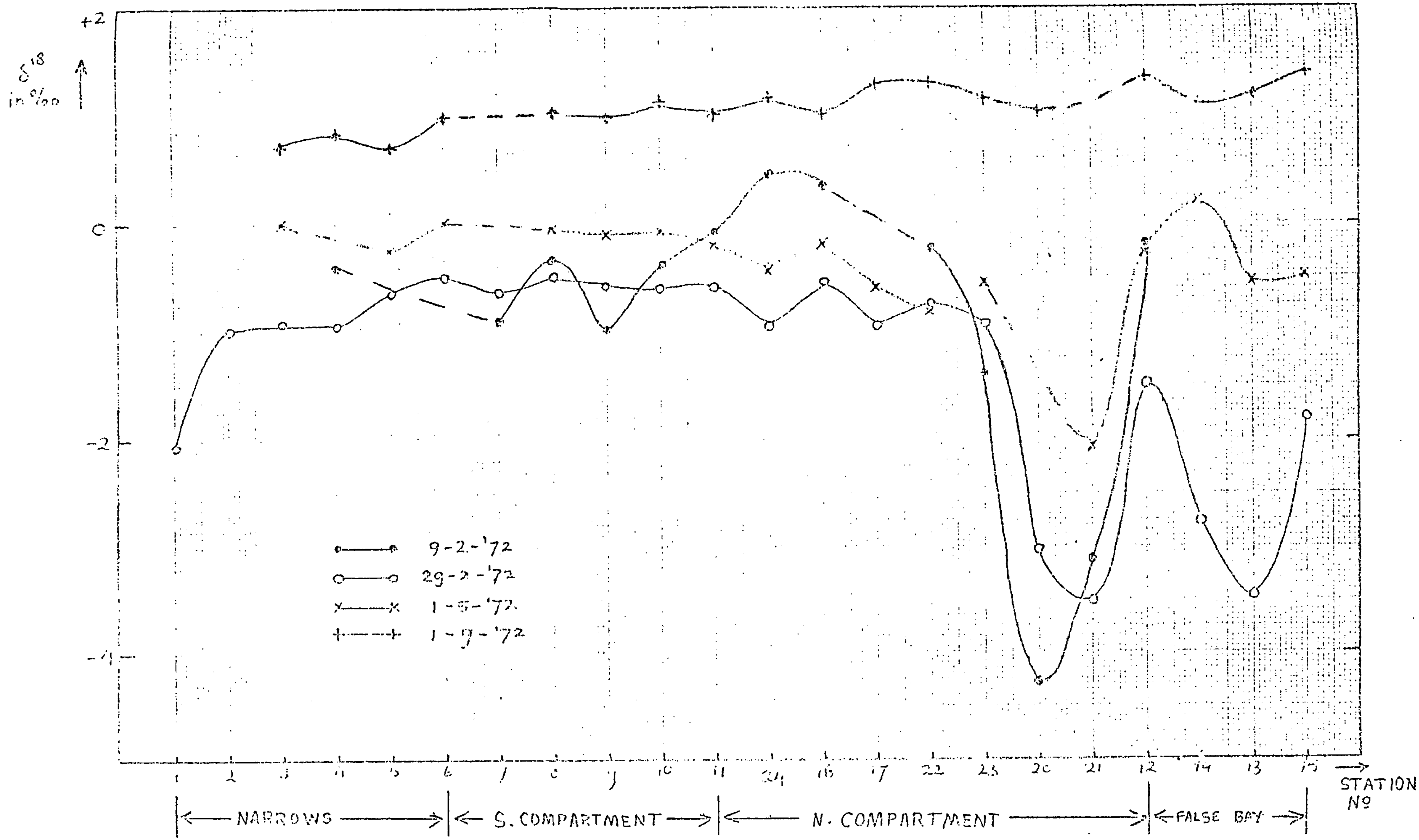

FIG. 7 OXYGEN-18 DISTRIBUTION IN THE LAKE DURING FLOODS, IMMEDIATELY AFTER, TWO MONTHS AND SIX MONTHS AFTER THE FLOODS. STATION NUMBERS REFER TO THE NUMBERS OF FIG. 5.

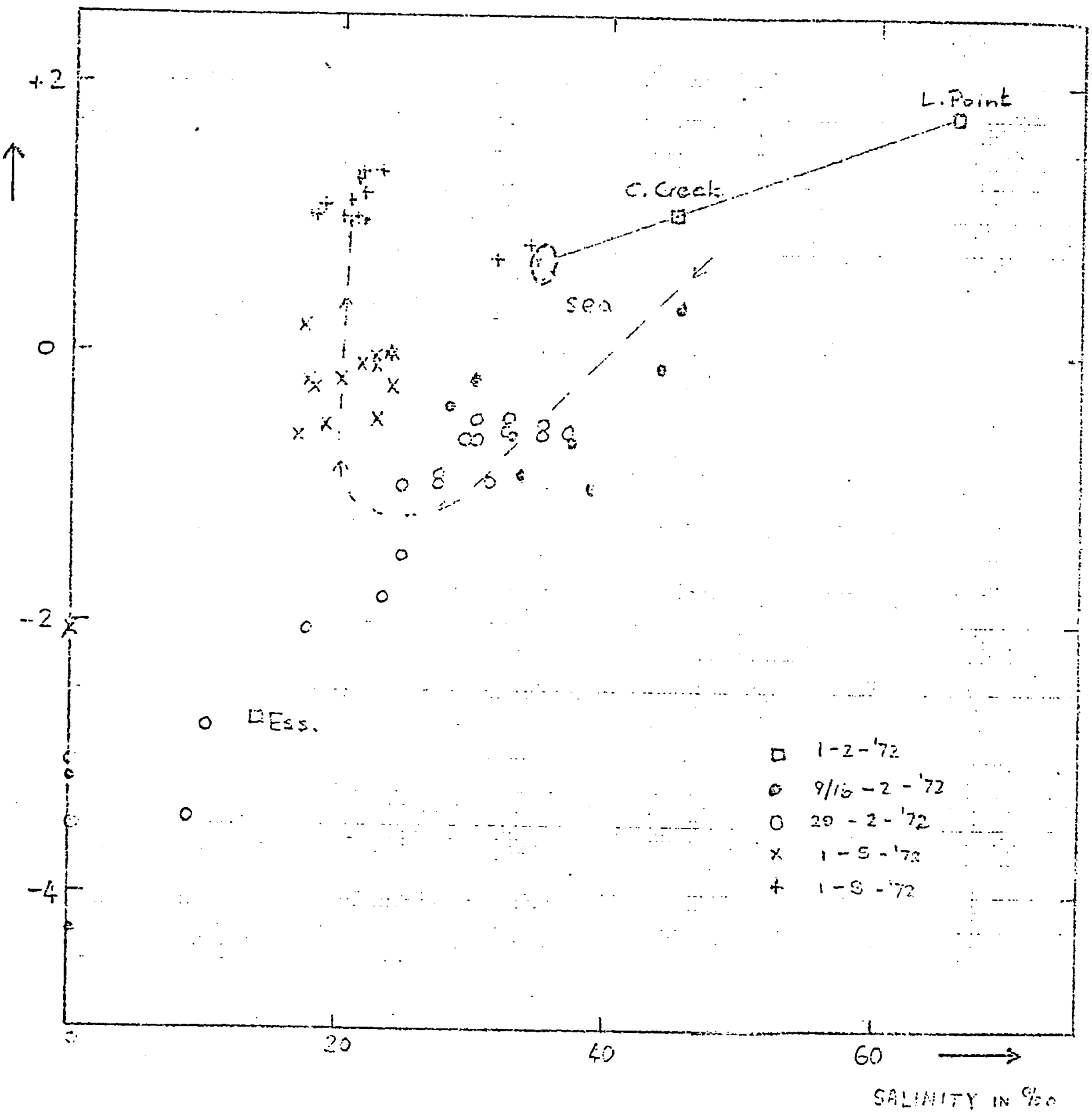

FIG. 8 OXYGEN-18 CONCENTRATIONS OF FIG. 7 PLOTTED VS. THE CORRESPONDING SALINITY VALUES OF FIG. 6.

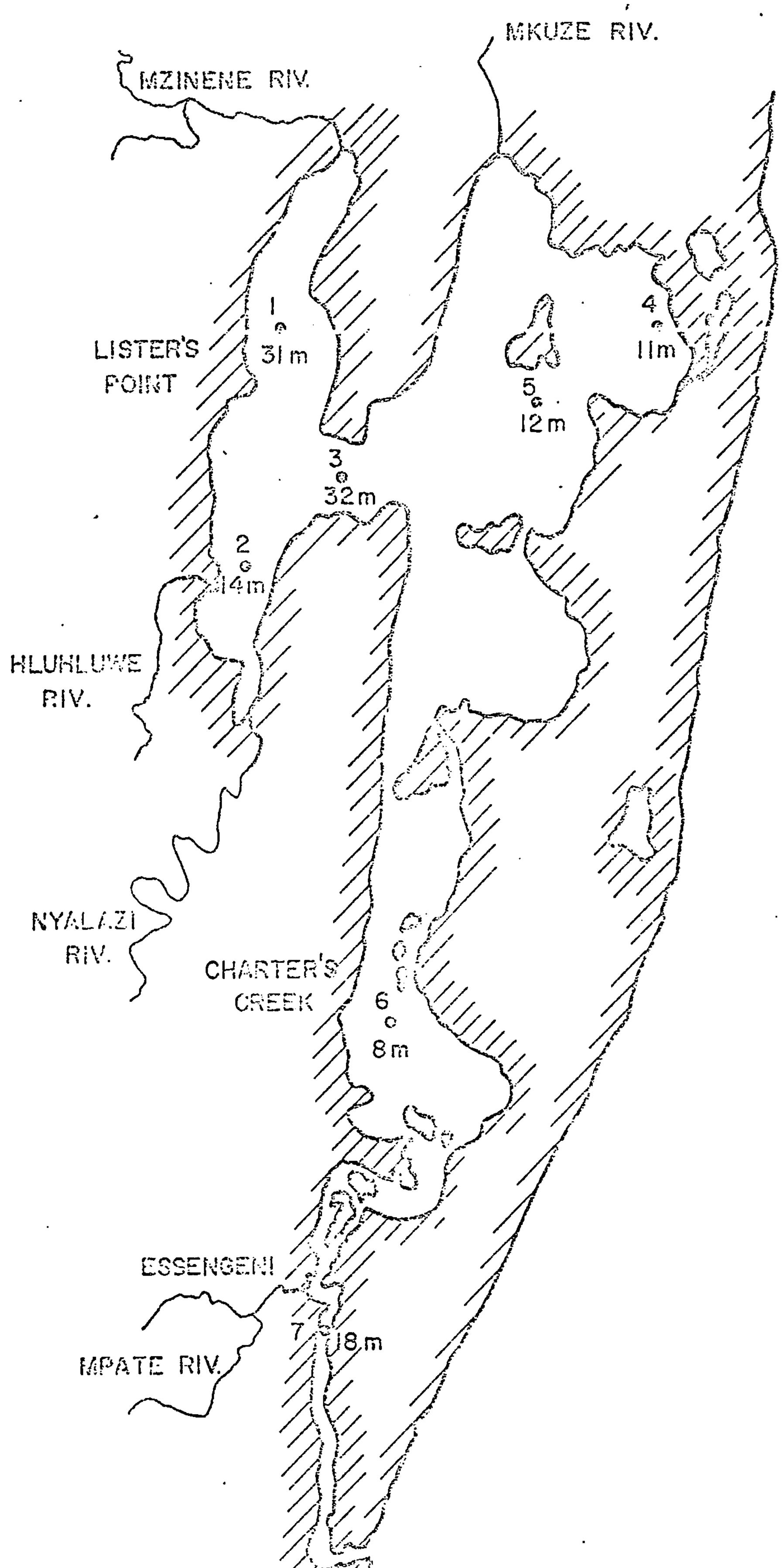

Fig. 9: Positions and depths of the boreholes drilled during October 1973.

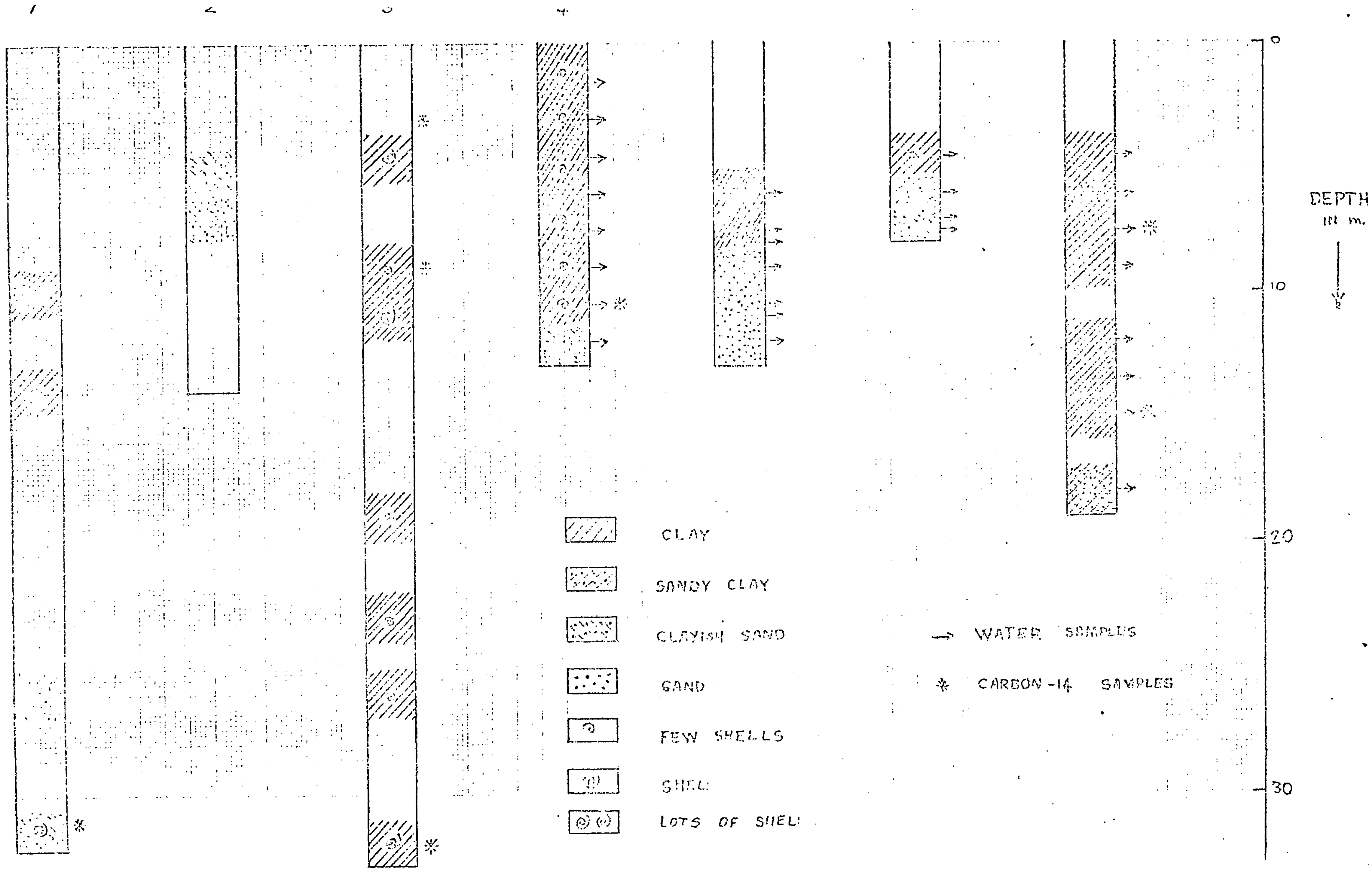

FIG. 10. SEDIMENT COMPOSITION OF THE BOREHOLES AT DIFFERENT DEPTHS; THE DEPTHS AT WHICH WATER AND/OR CARBON-14 SAMPLES ARE TAKEN, ARE MARKED.

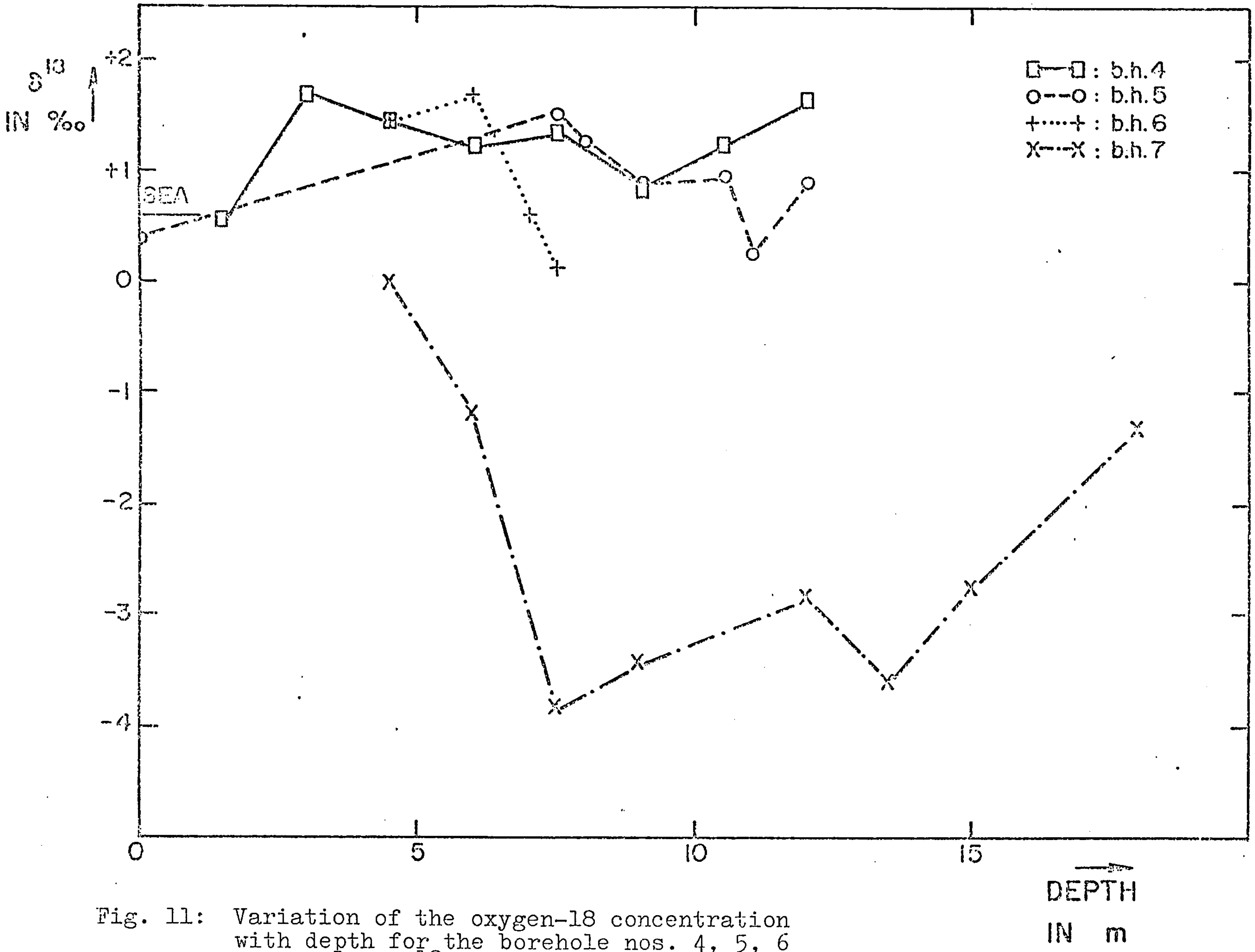

Fig. 11: Variation of the oxygen-18 concentration with depth for the borehole nos. 4, 5, 6 and 7. The δ^{18} value of seawater is shown, as is that of the lakewater at borehole no. 5 (both indicated at depth zero).

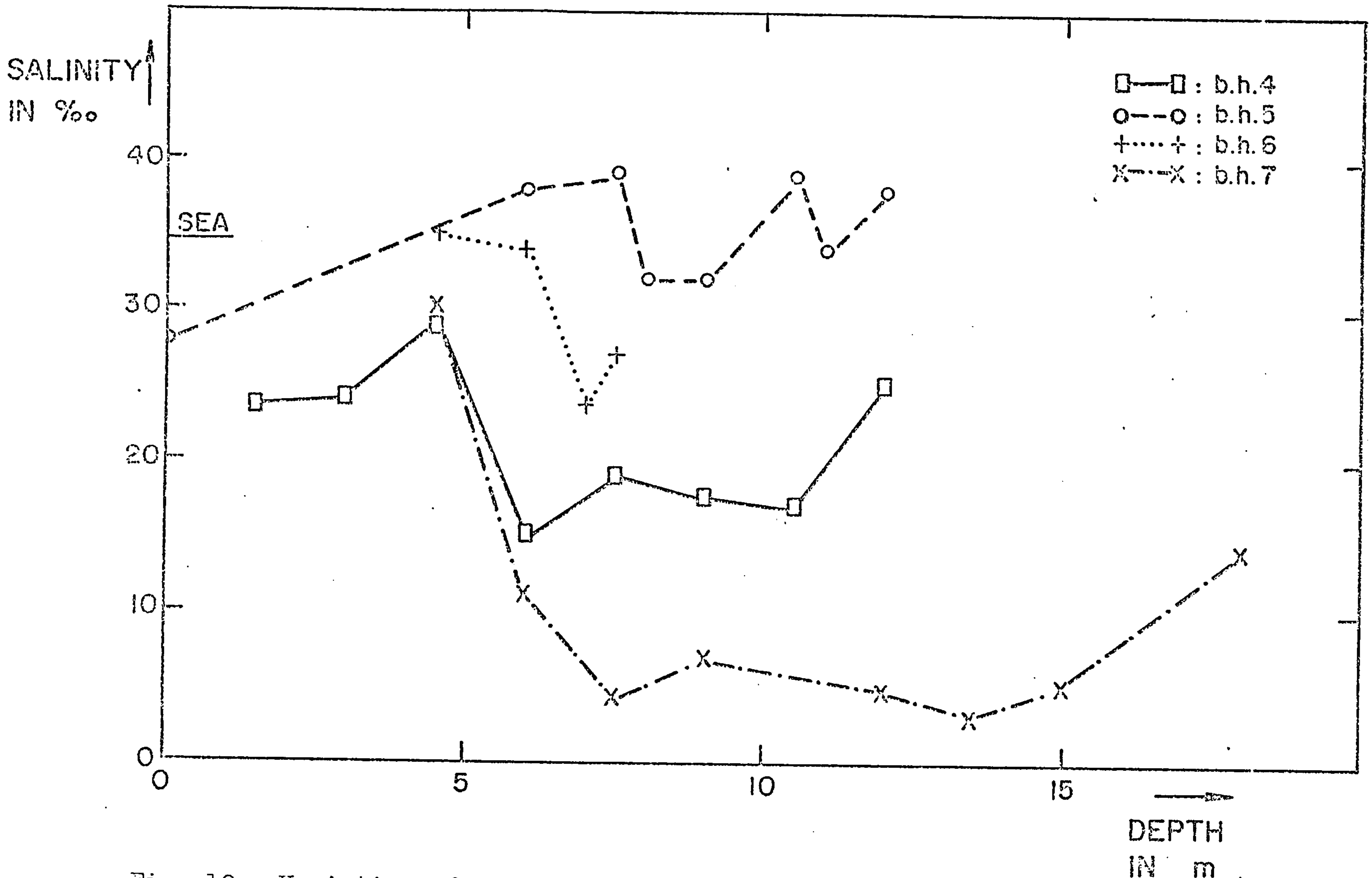

Fig. 12: Variation of the salinity with depth for the boreholes nos. 4, 5, 6 and 7. Values for seawater and the lakewater at borehole no. 5 are included.

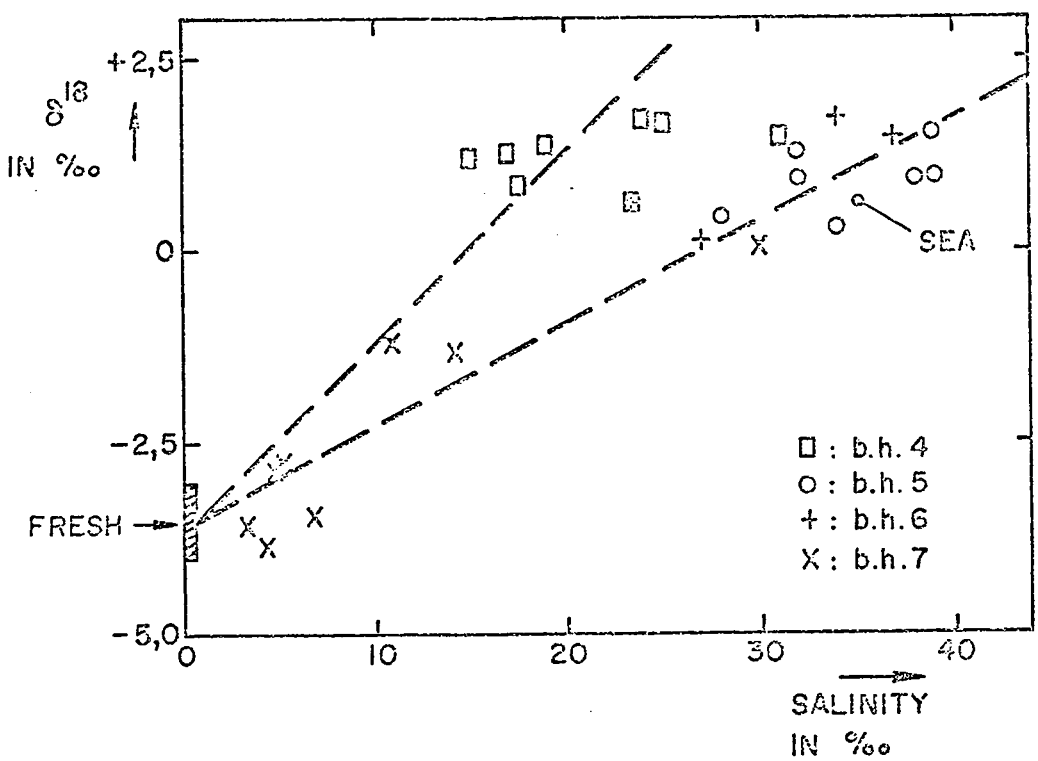

Fig. 13: Oxygen-18 concentration of the water in the sediment plotted versus its salinity. The values for sea- and fresh water are included for comparison.

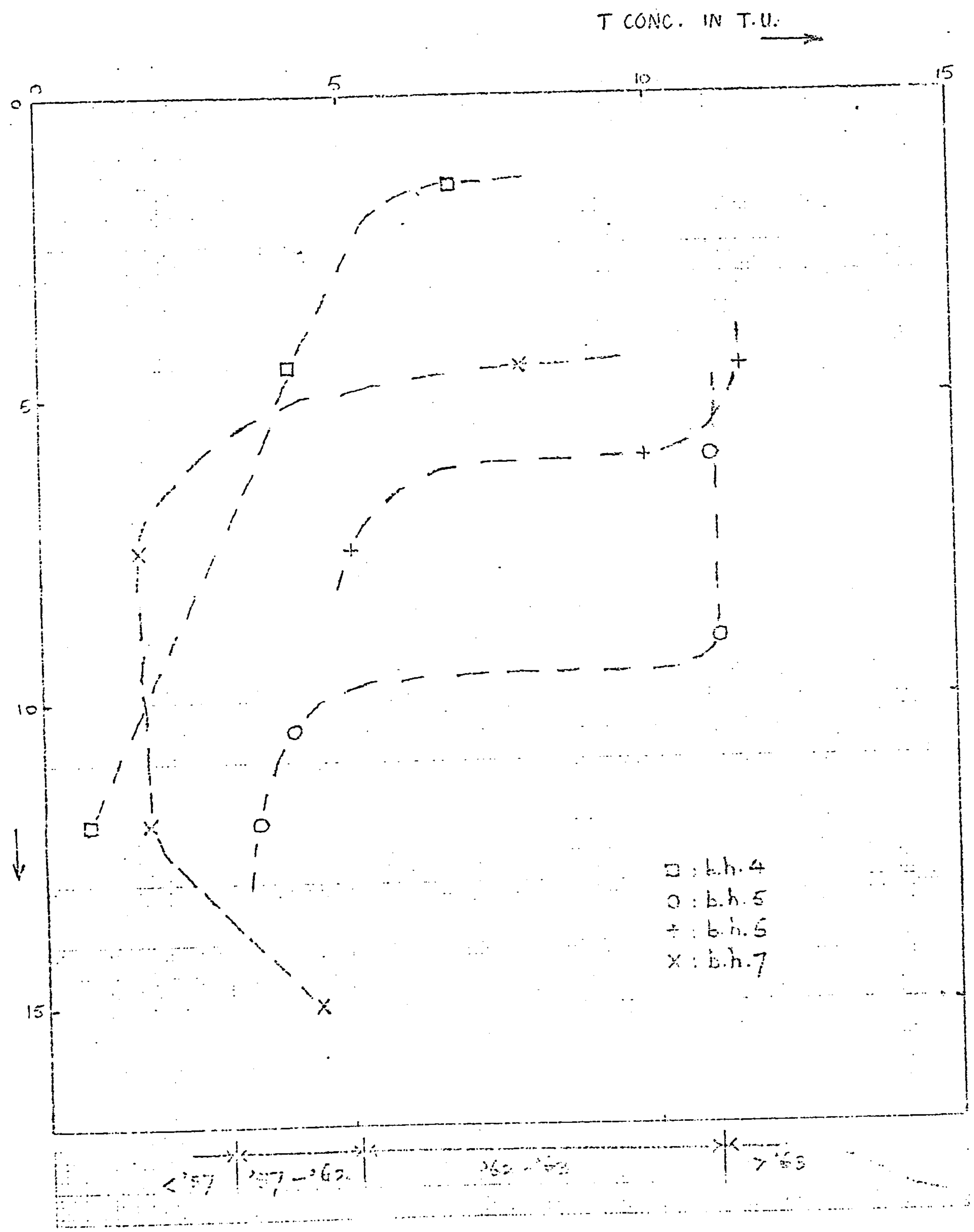

FIG. 14 VARIATION OF TRITIUM CONCENTRATION WITH DEPTH. THE REPRESENTED TIME-PERIOD IS INDICATED FOR EACH GROUP OF VALUES.

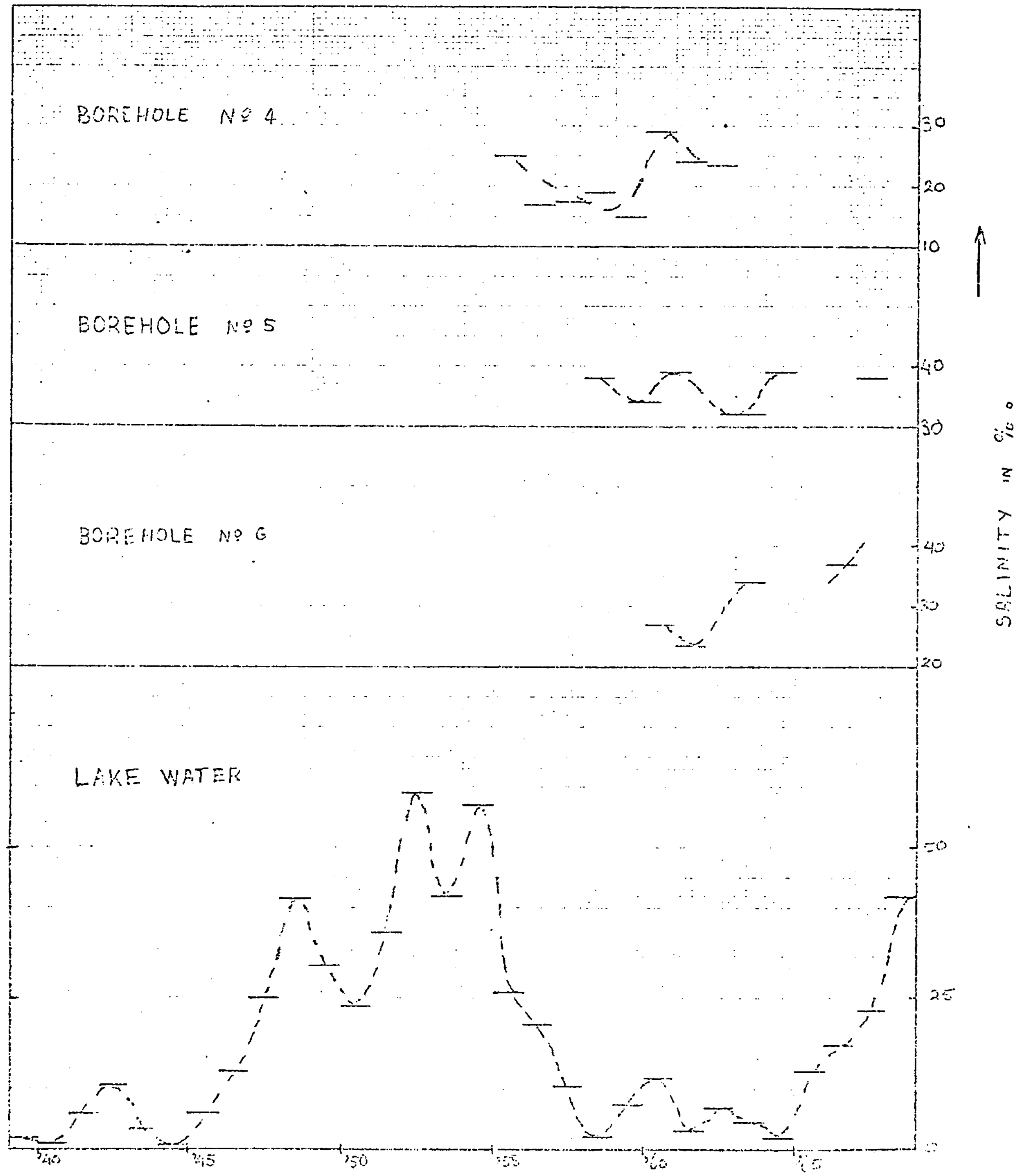

FIG. 15. VARIATION OF THE SALINITY IN THE BOREHOLES Nos 4, 5 AND 6, AS COMPARED TO THE VARIATION WITH TIME OF THE SALINITY OF THE LAKE WATER.

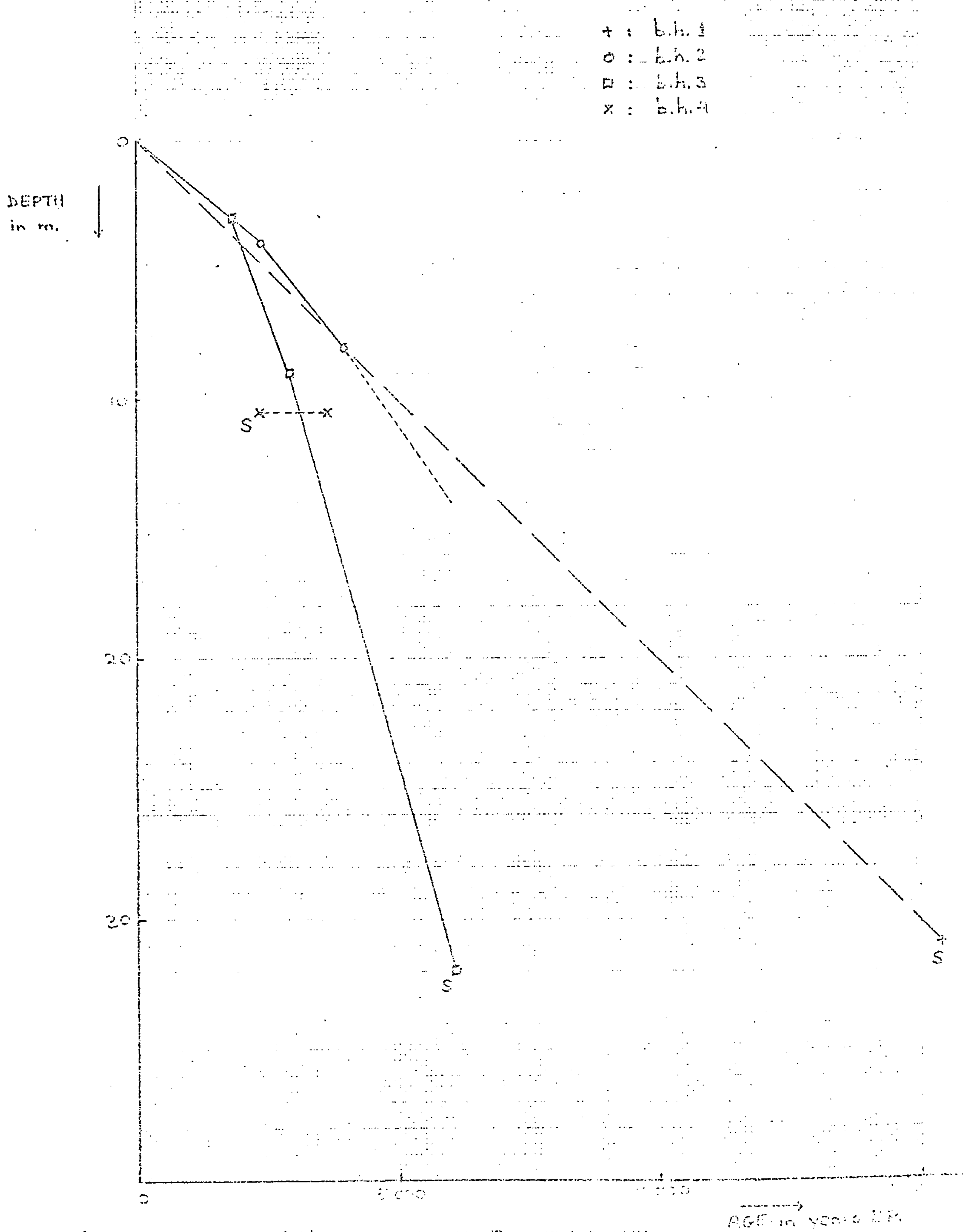

FIG. 16. VARIATION OF AGE OF THE SEDIMENT WITH DEPTH.
HORIZONS OF CALCAREOUS MATERIAL ARE INDICATED BY 'S'.

TABLE 1 : Deuterium measurements of lake-, ground- and ocean water. (δ^{D}-values in ‰)

		1.7.70	1.8.70	1.11.70	1.1.71	1.11.71
ister's Point	lake water	+ 22		+ 19	+ 19	+ 16
ıarter's Creek	lake water	+ 12		+ 2	+ 14	
ssengeni	lake water	+ 5		+ 4	+ 5	
ld Jetty	ground water	- 9	- 10			
engwane	ground water	- 5	- 5			
ission Rocks	ocean water	- 5			+ 9	

TABLE 2 : Oxygen-18 concentrations of the ocean water at Mission Rocks

Date	δ^{18} (‰)
1.7.70	+ 0,55
1.8.70	+ 0,53
1.12.70	+ 0,59
1.1.71	+ 0,69
1.3.71	+ 0,49

TABLE 3 : Oxygen-18 measurements of river water

Date \ River	Umfolozi δ^{18}(‰)	Mkuze δ^{18}(‰)
1.5.71	- 2,55	
1.6.71	- 2,43	- 1,28
1.7.71	- 1,37	+ 1,44
1.8.71	- 1,11	- 0,44
1.9.71	- 3,69	- 1,27
1.10.71		+ 2,48
1.11.71		+ 0,84
1.12.71	- 1,86	+ 1,53
1.1.72		- 1,74
1.2.72		- 1,80
9.2.72		- 3,12
29.2.72	- 4,24	- 3,52
1.4.72	- 2,25	- 2,78
1.5.72	-	- 2,07
1.9.72	- 0,10	

29.2.72

River	δ^{18}(‰)
Nyalazi	- 3,69
Mkuze (Thring's)	- 4,57
Mzinene	- 4,23
Hluhluwe	- 4,34

TABLE 4 : Rainfall and lakewater data for the period 1.7.70 - 1.9.72

Date	Lister's Point					Charter's Creek					Essengeni	
	Rain			Lake		Rain			Lake		Lake	
	amount (mm)	δ^{18} (‰)	δ^{D} (‰)	δ^{18} (‰)	sal. (‰)	amount (mm)	δ^{13} (‰)	δ^{D} (‰)	δ^{18} (‰)	sal. (‰)	δ^{18} (‰)	sal. (‰)
1.7.70	13,0	- 2,34	0	+ 2,88	87,7	34,4	-	-	+ 1,13	43,5	+ 0,65	32,3
1.8.70	1,5	-	-	+ 2,92	88.8	7,2	- 2,01	+ 4,5	+ 1,72	51,0	+ 1,26	31,0
1.9.70	11,7	-	-	+ 3,27	96,8	3,1	-	-	+ 2,40	56,8	+ 1,07	29,0
1.10.70	3,3	- 3,50	- 10	+ 3,46	109,5	49,2	- 4,58	-16	+ 2,23	54,8	- 1,19	22,0
1.11.70	93,5	- 4,84	- 21	+ 2,37	91,6	126,5	- 4,82	-16	- 0,22	31,0	+ 0,54	33,6
1.12.70	98,0	- 1,25	+ 3	+ 2,33	84,0	57,9	- 1,56	- 2	+ 1,29	38,6	+ 0,57	33,0
1.1.71	46,0	- 0,67	+ 7	+ 3,30	95,5	39,9	- 0,78	+ 7	+ 2,42	48,1	+ 0,62	35,5
1.2.71	58,5	- 1,09	- 1,5	+ 3,26	93,2	162,5	- 4,90	-25	+ 1,11	34,6	+ 0,64	32,4
1.3.71	71,2	- 2,32	- 12	+ 3,07	93,3	152,1	- 3,91	-18	+ 1,20	36,6	+ 0,74	33,8
1.4.71	76,0	- 2,50	- 10	+ 3,28	89,7	75,1	- 2,89	+ 1	+ 1,61	31,6	+ 0,21	28,5
1.5.71	52,0	- 4,22	- 24	+ 1,73	84,2	62,2	- 4,73	-24	- 0,39	41,2	- 0,83	34,6
1.6.71	102,1	- 1,09	+ 7	+ 1,99	73,5	118,5	- 3,08	- 6	+ 0,66	28,5	+ 0,64	20,3
1.7.71	5,5	- 2,80	- 8	+ 2,04	71,0	14,3	- 3,73	- 9	+ 0,81	39,9	+ 0,23	36,8
1.8.71	26,5	- 2,23	- 3,5	+ 2,22	73,8	64,0	- 2,90	- 9	+ 1,36	43,0	+ 1,07	33,0
1.9.71	3,0	-	-	+ 2,89	77,0	11,0	-	-	+ 1,60	50,7	+ 1,46	37,3
1.10.71	17,5	- 1,46	+ 8	+ 2,61	78,9	42,5	- 1,40	+ 2	+ 1,70	49,4	+ 0,32	29,2
1.11.71	10,5	- 2,23	-	+ 2,37	75,1	116,9	- 1,44	+ 6	+ 1,91	50,0	+ 0,91	32,9
1.12.71	73,4	- 5,39	- 28	+ 2,48	77,2	43,4	- 4,18	-16	+ 2,03	52,8	+ 2,01	48,8
1.1.72	156,5	- 2,31	- 3	+ 2,35	71,5	170,1	- 4,20	-25	+ 2,13	46,5	+ 1,93	49,1
1.2.72	139,0	- 2,59	- 13	+ 1,80	65,5	148,7	- 3,84	-17,5	+ 1,03	45,0	- 2,71	13,8
1.3.72	286,5	- 3,48	- 12	- 1,82	23,3	435,5	- 6,80	-45,6	- 0,51	30,0	- 0,93	28,9
1.4.72	147,6	- 2,46	- 8	- 0,81	23,1	163,6	- 2,73	-10,4	- 0,32	25,8	- 0,25	28,2
1.5.72	22,0	- 1,32	0	- 0,50	22,6	76,2	- 2,17	- 2	- 0,06	22,6	-	23,8
1.6.72	70,5	- 2,68	- 7	+ 3,71	21,0	141,7	- 2,72	-13	- 0,32	20,0	- 0,40	20,0
1.7.72	60,0	-	-	+ 0,25	21,0	77,9	-	-	+ 0,07	20,3	+ 0,15	19,7
1.8.72	40,0	- 2,68	- 3,5	+ 0,60	20,3	25,4	- 2,78	- 0,4	+ 2,28	18,0	+ 1,78	18,4
1.9.72	0,0	-	-	+ 1,36	22,7	12,2	-	-	+ 1,00	20,8	+ 0,79	34,0

TABLE 5 : Rainfall- and lakewater data for the period 1.10.72 - 1.9.73

	Lister's Point				Charter's Creek				Essengeni
	Rain			Lake	Rain			Lake	Lake
Date	amount (mm)	δ^{18} (‰)	δ^{D} (‰)	sal. (‰)	amount (mm)	δ^{18} (‰)	δ^{D} (‰)	sal. (‰)	sal. (‰)
1.10.72	12,0	- 0,74	+ 12,8	26,2	3,0	- 1,79	+ 4,3	25,2	34,8
1.11.72	19,7	- 0,70	+ 10	34,7	27,9	- 0,49	+11,3	29,9	35,1
1.12.72	97,9	- 1,78	- 5,2	28,3	109,8	- 2,07	- 3,3	32,2	32,9
1.1.73	43,4	- 1,89	- 6	-	75,6	- 2,12	- 1,8	-	-
1.2.73	37,5	+ 0,40	+ 17,5	39,0	26,4	- 1,20	+ 8,6	37,6	33,7
1.3.73	62,0	- 1,46	+ 3,3	39,8	77,3	- 2,26	- 0,3	32,7	33,0
1.4.73	9,0	- 1,08	+ 10,6	45,7	32,8	- 1,41	+12,4	35,4	31,7
1.5.73	56,0	- 1,75	+ 4,7	45,4	97,3	- 3,60	- 3,6	33,6	33,0
1.6.73	13,0	- 1,52	+ 0,7	44,0	19,8	- 2,64	+ 2,4	34,9	34,4
1.7.73	9,0	-	-	46,5	4,6	-	-	36,5	36,8
1.8.73	3,5	+ 1,26	+ 22,3	50,0	30,4	- 1,88	+ 4	39,5	34,4
1.9.73	57,6	- 4,48	- 15,8	47,4	238,1	-	-	29,6	29,9

TABLE 6 : Oxygen-18 concentrations of the groundwater at Old Jetty and Sengwane in comparison with the salinity of the lakewater at Sengwane

Station / Date	Old Jetty	Sengwane	
	δ^{18} (‰)	δ^{18} (‰)	sal. (‰)
1.7.70	- 3,17	- 2,38	78,5
1.8.70	- 3,26	- 2,17	84,2
1.9.70	- 3,30	- 1,35	92,8
1.10.70	- 3,38	- 1,84	84,4
1.11.70	- 3,36	- 3,40	81,1
1.12.70	- 3,32	- 3,28	-
1.1.71	- 3,16	- 2,42	94,2
1.2.71	- 3,34	- 1,73	95,9
1.3.71		- 2,96	81,4
1.4.71	- 3,26	- 2,70	73,9
1.5.71	- 3,37	- 2,87	77,7
1.6.71		- 2,78	61,0
1.7.71	- 3,52	- 2,51	67,0
1.8.71		- 2,17	66,5
1.9.71		- 2,82	73,9
1.10.71		- 2,71	69,6
1.11.71		- 2,79	72,4
1.12.71		- 2,69	76,5
1.1.72		- 2,67	62,3
1.2.72		- 1,21	54,7
1.3.72	- 3,67	- 3,69	35,0
1.9.72	- 3,76	- 3,54	20,3

TABLE 7 : Oxygen-18 and salinity data for the lakewater during and after the floods of February 1972

Station No. and name / Date		9.2.72*		29.2.72		1.5.72		1.9.72	
		δ^{18} (‰)	sal. (‰)	δ^{18} (‰)	sal. (‰)	δ^{18} (‰)	sal. (‰)	δ^{18} (‰)	sal. (‰)
1	NPB Jetty		29,5	- 2,06	17,3		23,8		34,5
2	Bridge		28,8	- 0,99	24,5		23,7		34,5
3	Narrows		26,9	- 0,93	27,3	+ 0,01	23,6	+ 0,70	34,5
4	Essengeni	- 0,40	28,2	- 0,93	27,3		23,8	+ 0,79	34,0
5	Potter's Channel		29,5	- 0,64	29,3	- 0,26	23,8	+ 0,68	31,5
6	Mitchell Island		33,5	- 0,50	32,5	- 0,01	23,8	+ 0,98	21,3
7	Old Jetty	- 0,90	33,5	- 0,63	29,8		22,9		21,4
8	Charter's Creek	+ 0,35	32,8	- 0,51	30,0	- 0,06	22,6	+ 1,00	20,8
9	Dead Tree Bay	- 0,99	38,7	- 0,58	32,5	- 0,11	22,5	+ 0,97	20,5
10	Fanies Island	- 0,38	37,2	- 0,59	35,0	- 0,08	21,3	+ 1,13	20,4
11	Tewati	- 0,09	44,0	- 0,58	37,0	- 0,21	20,0	+ 1,00	20,2
12	Hell's Gates	- 0,20	30,0	- 1,49	24,5	- 0,27	17,8	+ 1,36	21,2
13	Nyalazi ri. mouth		38,0	- 2,77	10,5	+ 0,20	17,2	+ 1,10	18,4
14	Hluhluwe ri. mouth		46,5	- 3,44	8,7	- 0,53	18,7	+ 1,18	21,4
15	Lister's Point		45,3	- 1,82	23,3	- 0,50	22,6	+ 1,36	22,7
16	Sengwane	+ 0,33	45,3	- 0,55	35,0	- 0,21	17,4	+ 0,98	20,3
17	Selly's Lakes mouth		41,3	- 0,96	31,2	- 0,61	16,7	+ 1,29	20,8
18	Selly's Lakes upstream						16,0		
19	Bird Island		9,2		32,6		1[illegible],6		20,3
20	Mkuze ri. mouth	- 4,28	fresh	- 3,04	fresh	- [illegible],07	3,5	+ 1,0[illegible]	17,8
21	Mkuze ri. upstream	- 3,12	fresh	- 3,52	fresh		fresh		12,2
22	North Island	- 0,23		- 0,75		- 0,83		+ 1,29	
23	½ way Mkuze ri. - Hell's Gates	- 1,41		- 0,93		- 0,57		+ 1,13	
24	Lane Island	+ 0,46		- 0,96		- 0,45		+ 1,[illegible]6	

* Salinity data from 16.2.72

TABLE 8 : Tritium concentrations of fresh-, sea and lakewater

Precipitation, weighted seasonal averages

	1970 - 1971	1971 - 1972
Durban	19,7	17,6 T.U.
Estcourt	39,7	31,0 T.U.

Riverwater, weighted seasonal averages

	1970 - 1971	1971 - 1972
Tugela	27,2	25,9 T.U.

Groundwater

Station	Date	T.U.
Old Jetty	1.12.1970	15,4 ± 0,9
Old Jetty	1.4.1971	11,1 ± 1,0
Eastern Shore b.h. 13, 1,50 - 1,60 m	8.2.1972	15,4 ± 0,7
Eastern Shore b.h. 13, 0,50 - 0,60 m	8.2.1972	21,1 ± 0,7
Eastern Shore b.h. 6, 1,00 - 1,15 m	8.2.1972	20,9 ± 0,9

Seawater

Station	Date	T.U.
Mission Rocks	1.12.1970	2,2 ± 0,6
30 km from coast	Feb./Mar. 1972	6,8 ± 0,8
45 km from coast	June 1972	5,1 ± 0,8
" " " "	Sept. 1972	2,7 ± 0,4
15 km from coast	Nov. 1972	5,4 ± 0,7
45 " " "	Mar. 1973	4,6 ± 0,6
45 " " "	Aug. 1973	3,6 ± 0,1
45 " " "	Dec. 1973	4,6 ± 0,6

Lakewater

Date / station	Essengeni	Charter's Creek	Lister's Point	Bird Island
1.12.1970	6,9 ± 0,6	10,9 ± 0,9	17,7 ± 1,2	
1.4.1971	8,1 ± 0,6	11,2 ± 0,9		
1.1.1972	15,4 ± 0,8			
1.2.1972	10,5 ± 0,4			
1.3.1972	10,2 ± 0,8			
1.4.1972	10,8 ± 0,9			
1.5.1972	10,7 ± 0,8	11,6 ± 0,8		13,3 ± 0,9
1.9.1972		13,3 ± 0,8		12,1 ± 0,8
1.7.1973		7,5 ± 0,8	10,7 ± 0,7	
Oct. 1973				10,7 ± 0,7

TABLE 9 : Analysis of the sediment samples taken during October 1973

Sample No.	Borehole No.	Depth (m)	Salinity (‰)	δ^{18}_{SMOW} (‰)	T-conc. (T.U.)	Description of the sample
M 303	4	1,5	23,5	+ 0,55	6,8 ± 0,7	
M 304	4	3,0	24,0	+ 1,71		black clay
M 305	4	4,5	29,0	+ 1,45	4,1 ± 0,6	black clay, some shells
M 306	4	6,0	15,0	+ 1,22		id.
M 307	4	7,5	19,0	+ 1,34		id.
M 308	4	9,0	17,5	+ 0,84		id.
M 309	4	10,5	17,0	+ 1,24		id.
M 310	4	12,0	25,0	+ 1,66	0,7 ± 0,5	clayish sand with shells
2482	5	0,0	28,0	+ 0,39	10,7 ± 0,7	lakewater
M 311	5	6,0	38,0		11,0 ± 0,9	sandy clay with shells
M 312	5	7,5	39,0	+ 1,49		id.
M 313	5	8,0	32,0	+ 1,24		id.
M 314	5	9,0	32,0	+ 0,87	11,1 ± 0,7	sand with shells
M 315	5	10,5	39,0	+ 0,95	4,1 ± 0,6	fine sand, some clay
M 316	5	11,0	34,0	+ 0,25		coarse sand, with shells
M 317	5	12,0	38,0	+ 0,89	3,5 ± 0,7	fine sand, some clay
M 318	6	4,5	37,0	+ 1,43	11,5 ± 0,7	clay, few shells
M 319	6	6,0	34,0	+ 1,68	9,9 ± 0,7	sandy clay with shells
M 320	6	7,0	23,5	+ 0,58		clayish sand
M 321	6	7,5	27,0	+ 0,11	5,1 ± 0,4	calceous sand
M 322	7	4,5	30,0	- 0,02	7,9 ± 0,6	clay
M 323	7	6,0	11,0	- 1,21		sandy clay
M 324	7	7,5	4,2	- 3,84	1,6 ± 0,6	clay
M 325	7	9,0	6,8	- 3,44		id.
M 326	7	12,0	4,8	- 2,85	1,7 ± 0,6	id.
M 327	7	13,5	3,3	- 3,61		id.
M 328	7	15,0	5,2	- 2,74	4,5 ± 0,6	id.
M 329	7	18,0	14,2	- 1,30	-	id.

TABLE 10 : Results of the carbon-14 measurements of sediment samples taken during November 1964 and October 1973

borehole No.	sampling date	total depth (m)	sample depth (m)	material	age before present (yr)	Anal. No.
1	Oct. '73	32	31	shells	15435 ± 155	Pta-1240
2	Nov. '64	14	4	organic	2380 ± 80	GrN-4533
2	Nov. '64	14	8	organic	3960 ± 60	GrN-4535
3	Nov. '64	33	3	organic	1820 ± 90	GrN-4536
3	Nov. '64	33	9	organic	2920 ± 130	GrN-4538
3	Oct. '73	33	32	shells	6085 ± 60	Pta-1239
4	Oct. '73	13	10,5	shells	2350 ± 50	Pta-1148
4	Oct. '73	13	10,5	organic	3665 ± 65	Pta-1170
7	Oct. '73	19	7,5	organic	33400 ± 900	Pta-1153
7	Oct. '73	19	15	organic	42000 ±2500	Pta-1169