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# LIMNOLOGY OF A BORROW-PIT LAKE

by

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## INTRODUCTION

This study documents some early physical, chemical and biological changes in one of many lakes which originated recently in Wisconsin as a result of excavation to obtain fill for highway construction.* Such lakes are designated as borrow-pit lakes. Their number is increasing rapidly, with advances in excavating techniques and expanded highway construction involving large quantities of road-fill. Several of these excavations were created near the city of Portage, Columbia County, Wisconsin, in 1962. On one we were able to obtain data from within several weeks of the time the removal of material had ceased and water level stabalized at the ground water intercept, through several months after the lake's first complete period of mixing and normal stratification.

## OBJECTIVES

The principle objective was to determine as nearly as possible the initial thermochemical structure of a lake before it experiences its first turnover. By following changes in the lake over several seasons the usual pattern of seasonal change could be compared with first year occurrences.

Initial conditions can be strikingly dissimilar to lake conditions following turnover and thereafter--so dissimilar as to cause changes in the plankton population, both in relative numbers and in species. Measurements of these early changes in the plankton population without the presence of fishes would have been desirable; however, several species of fish established themselves early in the period of study.

## GEOGRAPHY

The borrow-pit lake lies in the bottomland between the Wisconsin River and the Baraboo River, in the southernmost part of the crescent-shaped Wisconsin Central Plain (Martin, 1932). Surficial deposits are primarily alluvium (flood-plain fine sand, fine sandy loam, and silt loam, intermixed with peat and muck deposits). Figure 1 illustrates soil types near the lake.

Surface drainage is generally southeasterly and parallel with the Wisconsin River. Relief is exceptionally low and smaller streams in the vicinity are commonly stagnant pools. Spring floods are minimal in the immediate vicinity of the borrow-pit; the lake and a nearby stream exhibit amplitudes of 1 to 1½ feet in spring. Figure 2 is a detailed map of surface drainage in the area.

*This study was conducted as part of Wisconsin't Lake and Stream Classification Program, in conjunction with the Research and Planning Division.

## GEOLOGY

The principle bedrock is Upper Cambrian sandstone, covered with a mantle of alluvium as much as 350 feet thick in the Wisconsin River Valley. South and west of the lake at a distance of about three miles Pre-Cambrian quartzite forms a range which reached elevations 400-600 feet above the river flood-plain. Pre-Cambrian granite lies about 550 feet below the surface at Portage, just north of the lake (Weidman and Schultz, 1915). The log of a well recently drilled at the borrow-pit illustrates the depth of alluvial deposits (Figure 3). It is reasonable to assume that the gravel reached at a depth of 373 feet could extend another 100 feet before sandstone or granite is reached.

## PHYSICAL CHARACTERISITCS

### Methods

Records of the excavator, and personal observations using sounding leads, sonar, and various bottom-sampling devices provided an impression of the shape of the basin and bottom composition. A hydrographic map was prepared on February 15, 1964, in the field with sonar soundings made through the ice in a 50 ft. grid (Figure 4). Standard limnological apparatus was used to determine temperature and transparency (secchi disk). A small electronic thermistor thermometer with cable delineated in feet and meter graduated in degrees Fahrenheit was most frequently used, and was occasionally checked against a thermistor unit graduated in degrees Celsius and meters. The secchi disk is a standard eight inches in diameter with two black and two white quadrants and line graduated in feet.

The lake was visited once each month, usually within the second week, at which time all measurements were taken.

### Morphometry

The lake has an area of 7.93 acres, is approximately 737 feet on its long axis, approximately 438 feet on its short axis and has a maximum depth of 41 (±1) feet and a mean depth of 25 ft. $\left(\bar{z} = \frac{V}{A}\right)$. The basin is exceptionally uniform with a 1:3.75 slope from water's edge to the 40-foot contour around most of the shore. The bottom below 40 feet (about 0.75 acres) is flat, with a slight pitch to the southeast.

The water volume has been calculated $\left(V = \int_{z=0}^{z=z_m} A_z \cdot d_z\right)$ as 198.47 acre feet, or 320,132 cubic yards, which approximates the volume of sand removed by the excavator.

There are no inlets or outlets; however, a small intermittent stream lies directly south of the lake and is connected to the lake in its southernmost corner during high water. This stream connects with stagnant pools on the northeast edge of the lake which are part of the major (intermittent) stream draining the immediate area. With the exception of the southernmost corner, land around the lake is generally 4 to 8 feet above the water.

## Transparency

This is a relatively clear lake with secchi disk readings ranging from 3 feet in April of 1963 to 15 feet in January and July of 1963; range of disk readings in 1964 were 4 feet in August and 14 feet in July. Transparency was least in spring (1963) following ice break-up, and was presumably linked with the spring bloom of blue-green algae. Mid-winter and mid-summer were the clearest periods. If there was a fall plankton pulse, which would have exhibited itself in reduced transparency, it was not evident from disk readings made on a monthly basis in 1962 and 1963. However, in 1964 during August, September, and October transparency did diminish. October samples, prepared by filtering with Millipore apparatus revealed a high density of the diatoms, *Fragillaria* and *Asterionella*.

## Temperature

Profiles of temperature (Figure 5) were prepared for each month, starting in July, 1962, about two weeks after the pond had filled and water levels stabilized. Without benefit of a spring mixing period, a sharp thermocline was not present in July and the temperature graded somewhat irregularly from 80° F at the surface to about 46° F at 16 feet, and remained the same from that point to the bottom at 40 feet. Through August and September of 1962 a sharp thermocline was present; however, its amplitude was not great and the entire temperature range from surface to bottom was only about 20-25° F. When the lake was visited in October the thermocline was being depressed and by mid-November it had been destroyed. From December 1962, through March, 1963, a temperature inversion existed with bottom temperatures near 42° F while temperatures under the ice remained near 33° F. In April, 1963 the lake again became homothermous.

In the second summer, the thermocline was observed to be gradually depressed through the summer with a surface-to-bottom difference of about 30-35° F. The thermocline was depressed more than was expected in May when the lake was homothermous to 15 feet with a surface temperature of 56° F. A review of climatic conditions during the two weeks preceding sampling offers an explanation (Figure 6). Temperatures were unseasonably high in the first week; extremes became closer and temperatures dropped in the second week, accompanied by a general increase in average wind speed, which could have depressed the thermocline. Following this, air temperatures again increased and mixing increased surface water temperatures without affecting the temerature profile below 15 feet. By September the epilimnion encompassed the upper 19 feet of water, whereas in 1962 it had only encompassed 16 feet. By October, 1963 the thermocline had been depressed to 23 feet and surface temperatures were 10° F cooler. A nearly homothermous condition existed in November with slightly cooler water below 35 feet. Observations which shall be mentioned later indicated that complete mixing had not occurred by the time of our November visit. Conditions in the winter of 1963-64 beneath the ice were quite similar to the 1962-63 winter; however, the lake became ice-free two weeks earlier (March 17, 1964 compared to April 1, 1963).

The physical characteristics involved may be summarized as follows: The borrow-pit lake has an exceptionally uniform basin with slope in the littoral zone which will be unstable, since the bottom is sand and easily transported. The water is quite clear through the year except for a period in spring following ice-out.

Thermal conditions which existed just after filling have not been repeated in following observations. The amplitude of vertical summer temperature differences was normally greater than that observed during the first summer. The thermocline began to appear in May and June and was continually depressed through the summer to October. In winter the bottom temperatures were approximately 42° F; a winter increase of about 2° F was observed, indicating heat gained from the bottom.

## CHEMICAL CHARACTERISTICS

### Methods

A three-liter Kemmerer water bottle was used to collect samples at one meter intervals from surface to bottom for routine analyses. Samples were obtained for oxygen determination by allowing narrow-mouthed polyethylene bottles to fill and overflow several times their volume. These were then treated by the Winkler-modified sulfamic acid method. Of the remaining water in the Kemmerer about a liter was collected in a polyethylene bottle for pH, total alkalinity, and specific conductance determinations which were made upon return to our station. Methyl orange was used in the acid-base titration for alkalinity since the authors were most familiar with this indicator. A small Hellige portable color comparator with appropriate indicating dyes and color discs was used to determine pH. All analyses were usually completed within four hours after the samples were collected.

An Industrial Instruments portable stream conductivity meter with cell K = 1.0 was used to measure resistance after samples had been warmed near room temperature. Conductance was assumed to change 2.5% per degree Celsius over a 10° C. range about 25° C. (Smith, 1962) and specific conductance at 25° C. is the reported value.

### Dissolved Oxygen

The late summer and fall months offer the best example of the differences between the first year and the following year with respect to dissolved oxygen profiles (Figure 7). Without benefit of spring mixing, dissolved oxygen concentrations were lower in the first summer; however, the thermocline was observed to maintain its dissolved oxygen concentration as summer progressed and the upper limit of the thermocline was depressed. In Figure 8 lines of equal dissolved oxygen concentration are plotted against depth and time, as are the upper limits of the thermocline, for the period July, 1962 through December, 1963. Through the second summer dissolved oxygen concentrations were considerably higher above and in the thermocline; however, concentrations were observed to diminish in deeper waters much more so than in the first summer. By October of both years dissolved oxygen profiles were fairly similar.

There was indication of a slight thermoclinal maximum from June, 1963 through October, 1963. During this period dissolved oxygen concentrations near the thermocline increased from 103 percent to 121 percent saturation, based on the solubility table of Whipple and Whipple (APHA, 1960). Secchi disk readings during this period averaged 12 feet; collectively this four-month period had the greatest average transparency. The four months preceding only averaged 5.3 feet and the four following averaged 9 feet.

## Alkalinity and Specific Conductance

Profiles of monthly alkalinity and specific conductance are presented in Figures 9 and 10. It is evident that unusual conditions in the vertical distribution of electrolytes existed in the first summer. Both profiles are somewhat indicative of meromixis. Following the fall period of mixing, specific conductance readings indicated only slight tendencies to stagnation. In most cases the range in measurements at any one time fell within the error of measurement. From September to fall turnover, ranges in alkalinity were the greatest, on the order of 30-40 mg/l difference from top to bottom. Surface alkalinity, about 80 mg/l $CaCO_3$ in the first summer, was about 105-115 mg/l in the second summer, and 92-110 mg/l in the third summer. Alkalinity was entirely bicarbonate until May, 1963 when pH first was measured above 8.0.

## pH

The hypolimnion exhibited acid conditions during the first summer (Figure 11). pH was usually stable above and below the thermocline with a shift of about one pH unit with one meter change of depth at the thermocline. During both winters of observation pH was observed to decrease uniformly with depth by about 0.5 pH unit. The hypolimnion did not become acid during the second and third summers.

## Calcium:Magnesium

Analyses were conducted for calcium and magnesium on all water samples collected July 11, 1964 in order to prepare profiles of their concentration during stratification (Table 1). As is expected at the thermocline (more specifically at the depth at which pH decreased signalling an increase in free $CO_2$), the ratio of Ca:Mg increased. Of the two ions calcium is the less soluble at ordinary $CO_2$ concentrations. Magnesium, though present in lesser quantity, is much more soluble. Since $CaCO_3$ becomes more soluble with increase in $CO_2$ pressure, the Ca:Mg ratio will naturally increase with depth (Hutchinson, 1957).

TABLE 1

Calcium and Magnesium Profiles and Ratios for the Borrow-Pit Lake, July 11, 1964

| $D_m$ | Ca++(Mg/l) | Mg++(Mg/l) | Ca:Mg | pH |
|---|---|---|---|---|
| 0 | 19.1 | 13.8 | 1.38 | 8.9 |
| 1 | 19.1 | 14.1 | 1.35 | 8.9 |
| 2 | 19.1 | 14.1 | 1.35 | 8.9 |
| 3 | 19.1 | 14.1 | 1.35 | 8.7 |
| 4 | 22.0 | 14.1 | 1.56 | 8.4 |
| | | | | Thermocline |
| 5 | 19.5 | 14.3 | 1.36 | 8.9 |
| | | | | pH drop |
| 6 | 26.5 | 13.8 | 1.92 | 7.3 |
| 7 | 26.9 | 14.0 | 1.92 | 7.2 |
| 8 | 28.2 | 14.3 | 1.97 | 7.1 |
| 9 | 27.4 | 14.6 | 1.87 | 7.1 |
| 10 | 29.7 | 13.7 | 2.17 | 7.1 |
| 11(B) | 28.8 | 15.4 | 1.87 | 7.1 |

## Additional Chemical Analyses

Samples for "complete" chemical analysis were collected in April, 1963 during the spring turnover. In this way the necessity for composite sampling was avoided. Results are compared with analyses from nearby wells and the Wisconsin River (Table 2). In most respects the borrow-pit analysis lies between the relatively soft river and the moderately hard wells. Exceptions are iron, sodium, and potassium; the latter two are much higher in the river sample, but analytical procedures may account for this. The relative proportions of ions more closely approximate the river water analysis. In any case little can be said of these comparisons with so few analyses.

More meaningful are the relationships in basic field analyses between the several borrow-pits in the immediate area (Table 3). Considerable diversity with respect to pH, alkalinity, and specific conductance exists, yet all are either hard or intermediate with respect to alkalinity (Moyle, 1946). The ratio of alkalinity: specific conductance varies from 0.23 to 0.50. Since all the borrow-pits lie within the same soil and geologic province and within the same river valley, more uniform relationships would be expected (Rodhe, 1949); yet there is obviously considerable variation in the electrolytic composition of these waters. We are inclined to believe the ratio is a function of age of the pond with respect to use of the immediate watershed for agricultural purposes (implying fertilization). Those ponds with the lowest ratios are, in this instance, known to have been recently excavated on crop lands and do still receive drainage from cultivated fields. The pond under study lies within the lands known not to have been cultivated for the last 10 years, and should therefore represent a stable relationship between alkalinity and conductance. The ratio of all such measurements made thus far for the borrow-pit is 0.436 with a standard error of 0.053 ($S^2$ = .00285); at no time has this ratio reached the lows of ponds on cultivated lands.

TABLE 2

Comparative Analyses of Water From the Portage Area

| | Borrow-Pit[1] | Portage Well #1[2] | Portage Well #2[3] | Wisconsin River Portage[4] |
|---|---|---|---|---|
| Date of Sampling | 1963 | 1950 | 1950 | 1906-07 |
| Total Alkalinity ($ppm\ CaCO_3$) | 104 | 274 | 214 | 48 |
| Calcium ($Ca^{++}$) | 27.2 | 74 | 57 | 14.0 |
| Magnesium ($Mg^{++}$) | 10.6 | 39 | 29 | 6.8 |
| Sodium ($Na^+$) | 3.0 | - | - | (8.1) |
| Potassium ($K^+$) | 0.7 | - | - | |
| Chloride ($Cl^-$) | 3.0 | 18 | 12 | 2.1 |
| Sulfate ($SO_4^=$) | 21.5 | 52 | 30 | 17.0 |
| Fe (T) | 0.14 | 0.2 | Trace | 0.2 |

TABLE 3

Characteristics of "Borrow-Pit" Lakes*

| | PH | Total Alkalinity ($ppm\ CaCO_3$) | Specific Conductance (Mmhos at 25°C) | Tot. Alk.: Sp. Cond. | Max. Depth (feet) | Area (Acres) |
|---|---|---|---|---|---|---|
| T-13-N, R-8-E, Sec. 34 (7) | 8.7 | 97 | 195 | 0.50 | 4 | 4.98 |
| T-13-N, R-8-E, Sec. 34 (8) | 8.8 | 92 | 211 | 0.44 | 3 | 2.84 |
| T-12-N, R-8-E, Sec. 15 (3) | 6.8 | 95 | 268 | 0.35 | 6 | 1.42 |
| T-12-N, R-8-E, Sec. 15 (14) | 6.6 | 70 | 305 | 0.23 | 11 | 8.25 |
| T-12-N, R-8-E, Sec. 14 (10) | 6.4 | 50 | 130 | 0.38 | 5 | 13.72 |
| T-12-N, R-8-E, Sec. 24 | 6.8 | 60 | 237 | 0.25 | 37 | 7.11 |
| T-12-N, R-9-E, Sec. 7, 18** | 7.7 | 111 | 264 | 0.42 | 41 | 7.93 |

1/ Collected April 9, 1963, by R. J. Poff, Wisconsin Conservation Department.
2/ and 3/ From USGS Groundwater Survey files, collected in 1950 for Wisconsin State Board of Health; Wells in Dresbach sandstone.
4/ Mean of 24 samples, U. S. Geological Survey, W.S.P. No. 236, p. 113, 1906-7.
*Data collected as part of Lake and Stream Classification Activity, Wisconsin Conservation Department, 1964.
**Lake under study.

A brief re-cap of chemical characteristics shows that the spring period of mixing is essential to saturation of oxygen in the epilimnion. At no time in winter have oxygen levels gone below 6 mg/l at any depth. Through the summer months the upper 30 feet generally contained sufficient oxygen to sustain most fishes (more than 2 mg/l). The period of complete mixing may fluctuate by as much as a month, as evidenced by November and March observations. A thermoclinal oxygen maximum appeared to be maintained in this clear lake through the entire summer; an additional summer's observations substantiated this.

Extreme stagnation occurred in the hypolimnion in the first summer, accompanied by acid pH and lack of dissolved oxygen.

## ZOOPLANKTON

### Methods

Each month plankton samples were taken from surface to depths of 9, 18, 27, and 36 feet with a standard cone net with No. 2 bolting cloth. Samples were preserved in 10 percent formalin and enumerated in the laboratory. Samples were diluted to 100 ml with tap water and five sedgewick-Rafter cell fields were counted. The average of the five fields was reported as organisms per unit volume. By subtracting counts of shallow samples from deep sample counts, relative numbers of organisms were obtained for strata 0-9 feet, 9-18 feet, 18-27 feet, and 27-36 feet. In some of the early samples other sampling strata were used, but the method assures comparable data. Figure 12 illustrates distribution of adult Daphnids plotted monthly, from July 1962 through August 1963. Data for later months are not presented as the number of Daphnia was too small to be illustrated in this manner. Since samples were collected at about the same time of day on each monthly visit, distribution with depth from month to month should not be biased by the diel migrations of these organisms, as they would have been at their "day depth" at the sampling time (McNaught, 1964).

### Findings

The greatest population of *Daphnia pulex* Leydig existed during the first summer. As the thermocline was depressed the bulk of the population occupied deeper waters. Numbers of *D. pulex* diminished after September, 1962; those collected in October, 1962, for the most part carried ephippial eggs. Ephippia abounded along shore until ice prevented observation. Through the months in which the lake was ice-covered (December-March) very few Cladocerans were observed in our samples.

The spring of 1963 breakup was accompanied by an increase in *Daphnia*. The species which dominated the samples at this time however, was *Daphnia galeata mendotae* Birge. The few *D. galeata mendotae* captured prior to this, during the winter (February), commonly held ephippial eggs, presumably the forerunners of the April and May population. In May, 1963 large numbers of young D. galeata mendotae were observed in the brood pouches of mature specimens as well as freely mobile. This population persisted until September, 1963, with D. pulex Leydig represented by relatively few individuals.

From October, 1963 through June, 1964 Daphnia were present in such low numbers as to evade our sampling technique. The summer of 1964 brought a considerable change in plankton population. Samples were dominated by copepods (Cyclops sp.) and rotifers (Keratella cochleas), in April, May and June. Daphnia appearing in July samples were identified as D. schdleri Sars by McNaught (personal communication) with the reservation that some confusion may exist in discriminating between D. schdleri Sars and D. pulex Leydig since they are separated by shape and size of the head and length and position of the shell spine (Brooks, 1957). At any rate their number was relatively small as was the size of individuals. In July, with the use of a Clarke-Bumpus we were able to make a quantitative estimate of the Daphnia population. A tow at 32 feet beneath the surface produced an estimated population of 11.2/L while tows at 18 and 27 feet produced 0.67/L and 0.65/L respectively. A tow at 9 feet produced only 0.04/L.

In August, 1964, Bosmina longirostris dominated the samples and has maintained its prominence through winter, 1964-65. This species first appeared in significant numbers in January, 1964.

The large crustacean, Leptodora kindtii, has infrequently occurred in our samples, being more evident in the fall, 1964 samples.

Copepods have thus far been dominated by one genus, Cyclops (species undetermined), which first appeared in appreciable numbers in October of 1962, was virtually absent through the 62-63 winter, and reappeared in June, 1963. The majority of Cyclops appeared to occupy the thermocline through the summer of 1963 (Figure 13). In October greatest numbers were observed with nauplii constituting the majority of the individuals. This condition existed through November. Greater numbers of adult copepods were observed in the winter months than through the preceding summer, but with March samples the number of nauplii again increased.

Chaborus (species undetermined), the midge larva which preys on copepods, was common the first two months of sampling and again in May of 1963. Until recently its numbers had steadily declined and through the 63-64 winter none were observed in samples. Only in a few samples of summer 1964 have Chaborus reappeared, then in limited numbers.

In summary, lake conditions in the first summer permitted a high rate of asexual Daphnia pulex Leydig reproduction. The high population in fall produced great numbers of fertile eggs, which apparently failed to develop beyond diapause, possibly because the proper stimuli were lacking. The second summer Daphnia galeata mendotae population was much smaller. Copepods became common during the second summer, produced many nauplii in the second fall and continue to be the dominant planktonic crustacean through the second winter. The copepod increase corresponds to the decrease in its major predator, Chaoborus.

## INCIDENTAL OBSERVATIONS

### Beach Erosion

Spring winds in 1963 produced waves with sufficient erosive force to create 3 foot cut-banks in the sandy windward southeast shore. The area of the immediate shoreline was exceptionally "soft" and unstable. By late summer vegetation had somewhat stabilized the shore, assisted by a drop in water level of 0.5 to 1.0 feet. Erosive action was not so great in the spring and summer of 1964 when encroaching vegetation, especially cattails, gave better protection from wave-action.

### Aquatic Vegetation

The smartweed (Polygonum pennsylvanicum) was the first rooted aquatic to occupy the pond and did so early in the first summer. By late summer milfoil (Myriophyllum) and Elodea had produced groves on the lee shore of the pond. There were few changes in aquatic vegetation until August of the second summer when cattail (Typha latifolia) and arrowhead (Sagittaria Spp.) appeared.

### Sediment Recruitment

Through the first two years there was no measurable deposit of organic sediment on the lake bottom. It appears that organic production was insufficient and allochthonous matter too sparse to produce sediments during this period. During the second year the deposit of a gray-black sediment layer was observed by using a core-type sampler. By the fall of 1964 the layer had accumulated to a depth of about 3/4 inch.

## DISCUSSION

The first few months in the existence of the borrow-pit lake were perhaps the most significant in its history thus far. During this period physical and chemical conditions were the least stable and the least representative of the lake as it may exist at a later time. A correlation exists between the size and nature of the plankton population, the quantity and dispersion of dissolved salts, the presence of dissolved gases, and the thermal structure of the lake. The initial relationship, that in the first three months of the lake's existence, has not been repeated.

Several observations indicate the absence of a basin seal in the first summer. None existed of course when the lake was dug. Ground water, on exposure to the photosynthetic process, loses ions through plankton production and as a result of oxidation, creating insoluble oxidized compounds from soluble reduced compounds and ions. The fact that a great difference in specific conductance persisted between shallow and deep waters through the first summer suggests that more saline ground water was continually entering the lake, and being more dense than surface waters, it persisted over the basin floor. As turbulence in the epilimnion depressed the thermocline through the summer an attendant decrease in dissolved oxygen in the thermocline was not observed. There was either some mixing in the thermocline or insignificant loss due to respiration.

The shift in dominant Cladocera following the first summer is a logical change. With a shallow thermocline, a much more saline hypolimnion, and very little oxygen below the thermocline, the lake had characteristics of a shallow body of water. In the second summer a deeper thermocline, more uniform salinity, and dissolved oxygen nearly to the bottom the entire summer, it became a moderately deep lake. Such a change in the inhabitable zone could easily account for a change in zooplankton population.

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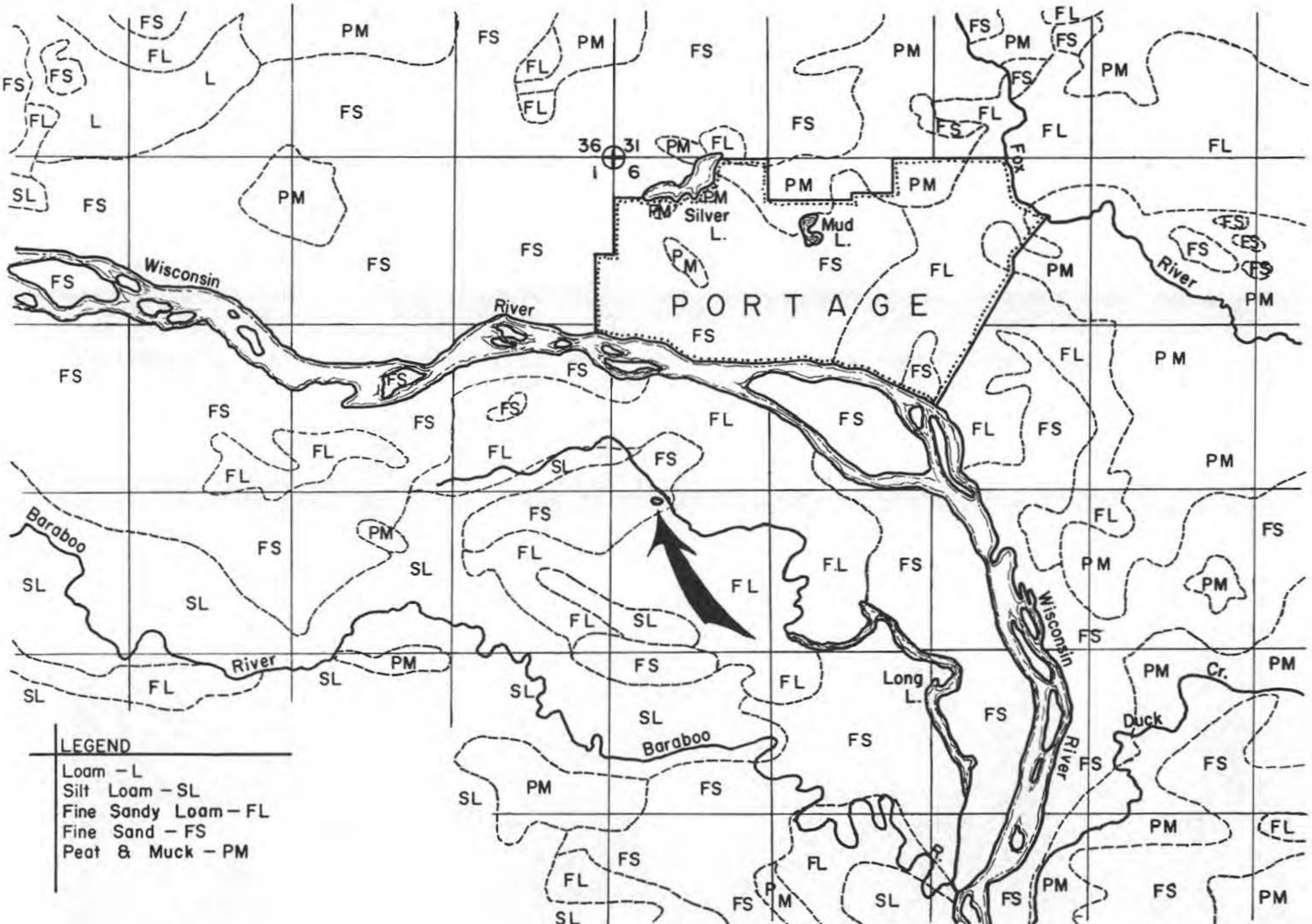


Figure 1. Soil Types. After Whitson et al., 1916.

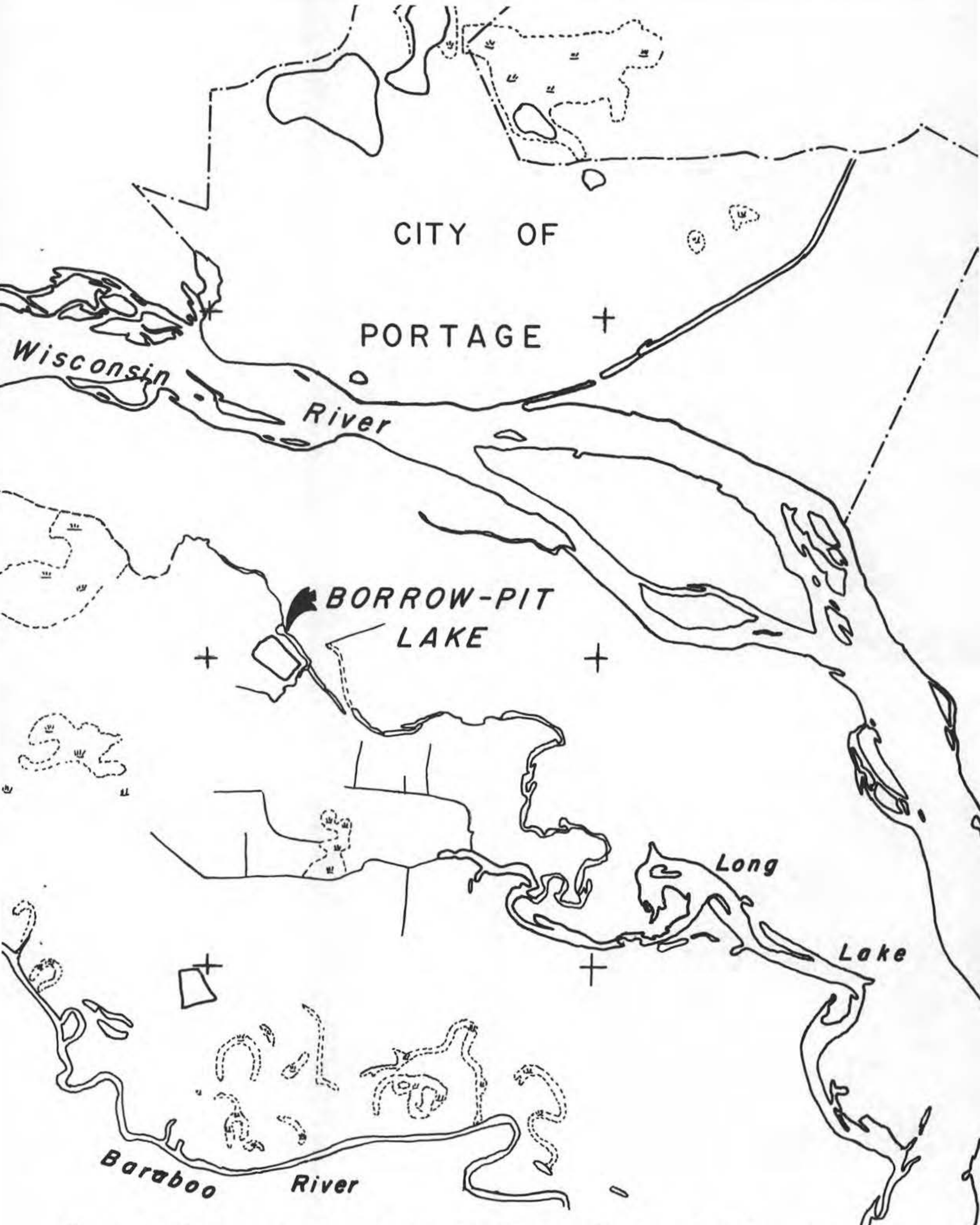


Figure 2. Surface drainage in area of Borrow Pit Lake, Columbia County.

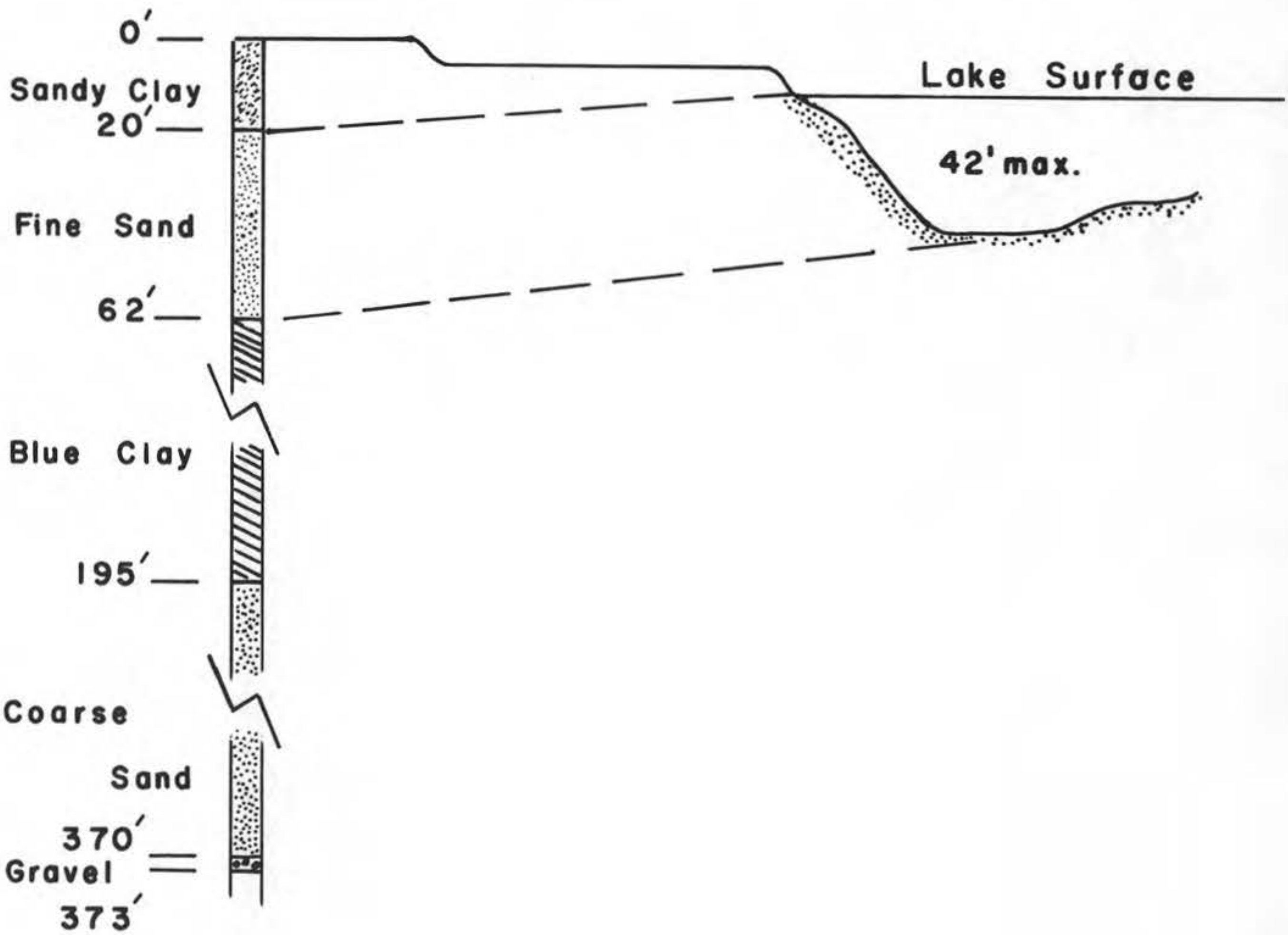


Figure 3. Log of well at Borrow Pit Lake, Columbia County.

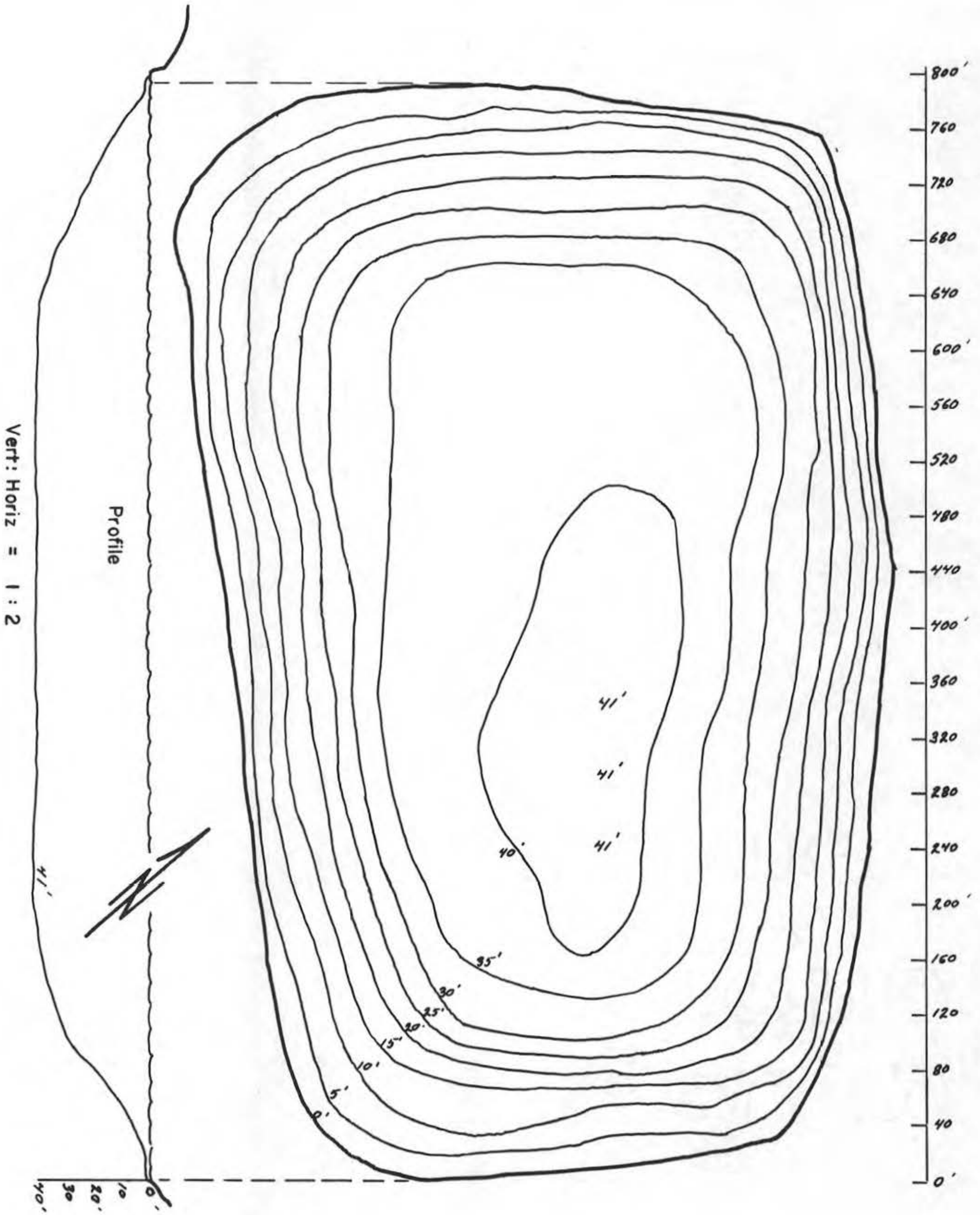


**Figure 4. Hydrographic Map of Borrow Pit Lake, Columbia County.**
Wisconsin Conservation Department: Prepared from sonar soundings. Biologist: Ronald J. Poff.
Feb. 15, 1964.

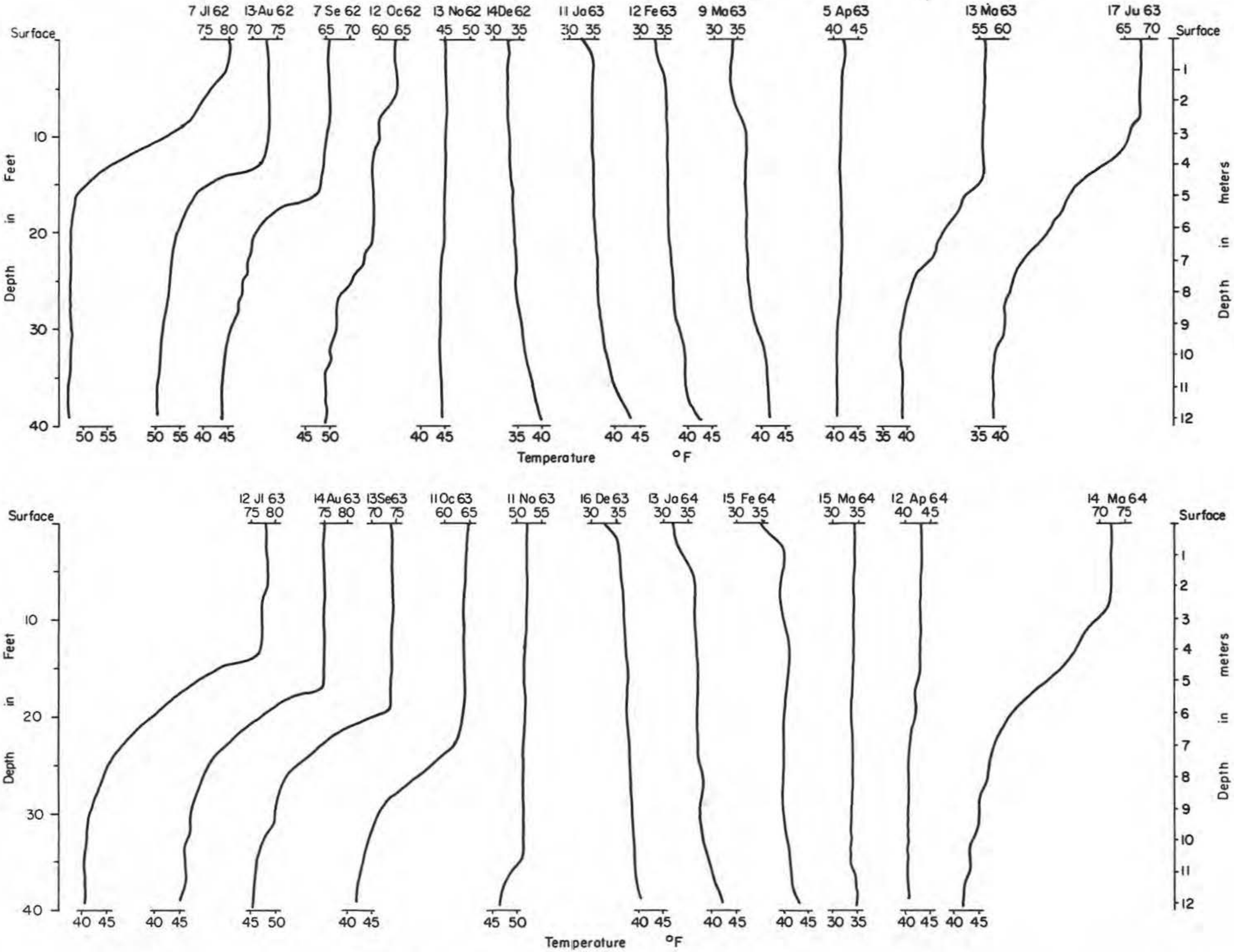


Figure 5. Temperature Profiles.

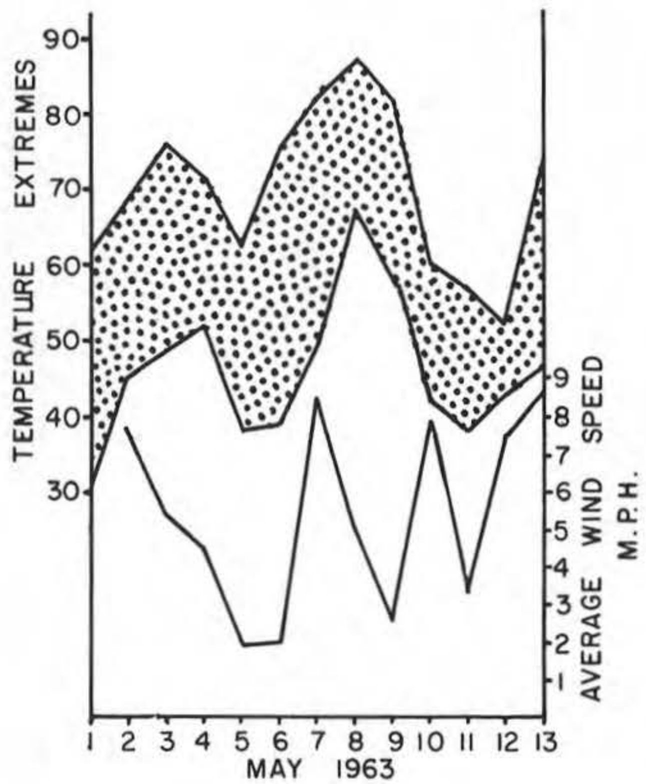


Figure 6. Climatic data for the first through the thirteenth (1–13) of May 1963.

Source: USGS Weather Bureau, Climate data from Portage Station for May 1963.

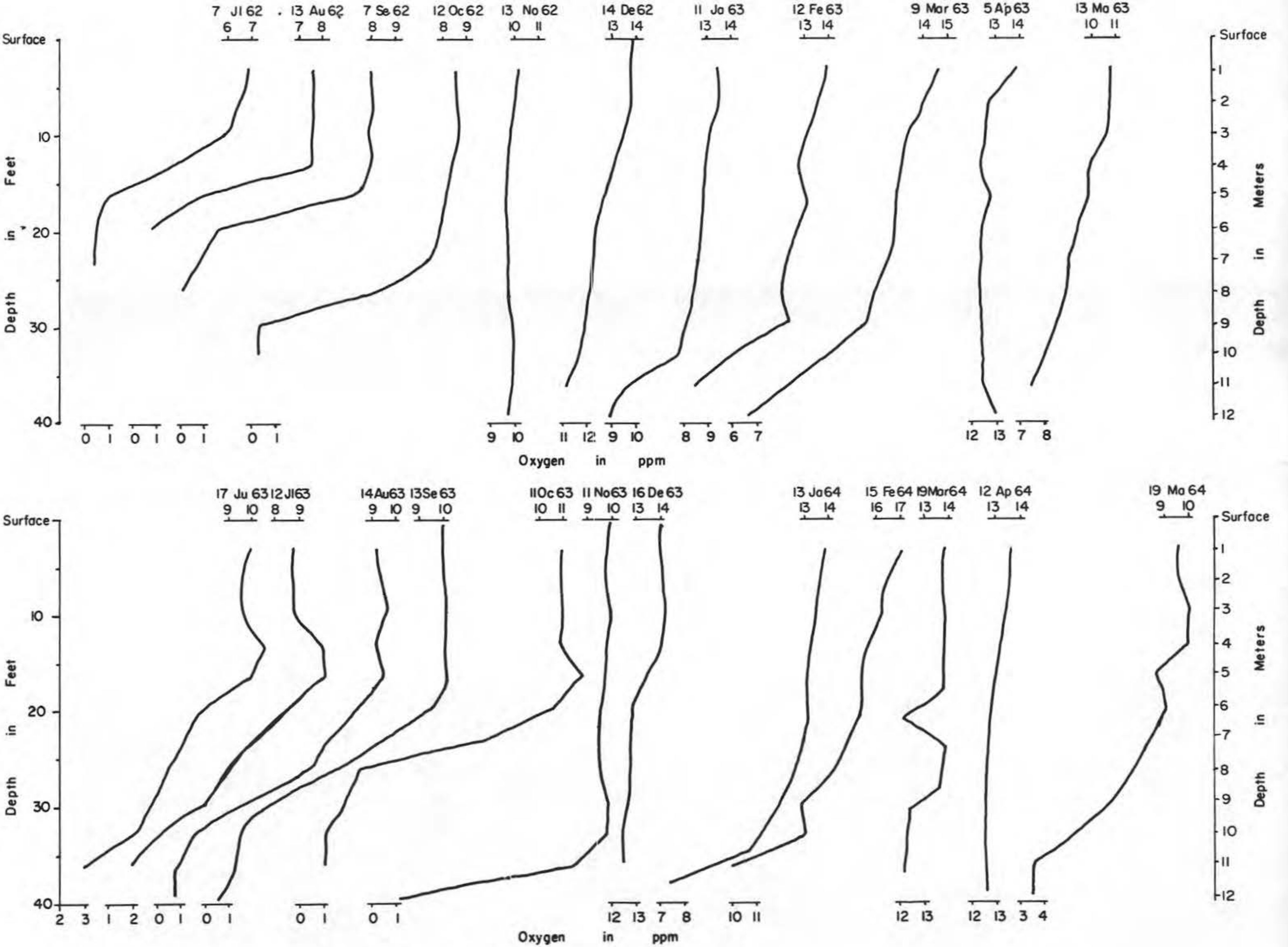


Figure 7. Oxygen Profiles.

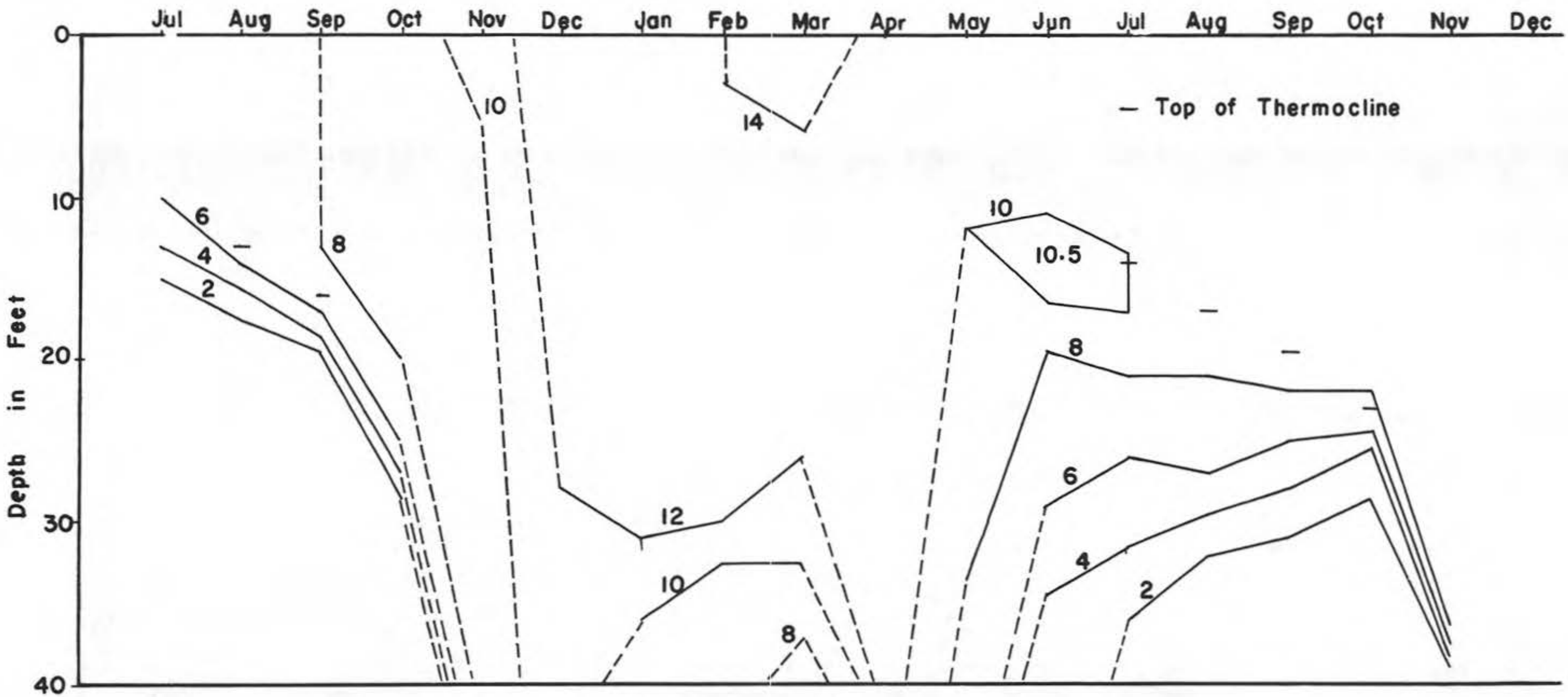


Figure 8. Lines of equal Oxygen concentration
July 1962 - November 1963

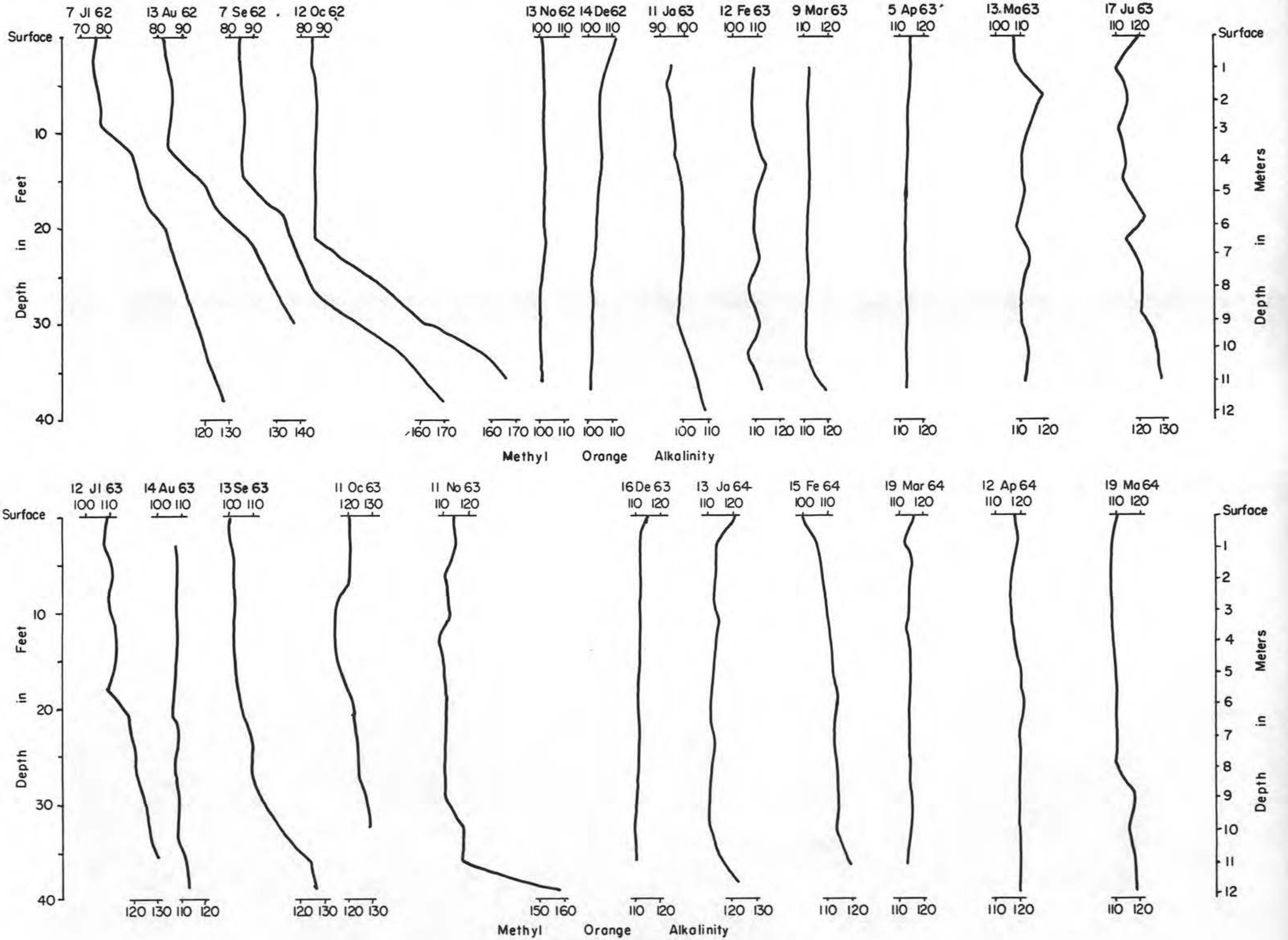


Figure 9. Methyl Orange Alkalinity Profiles.

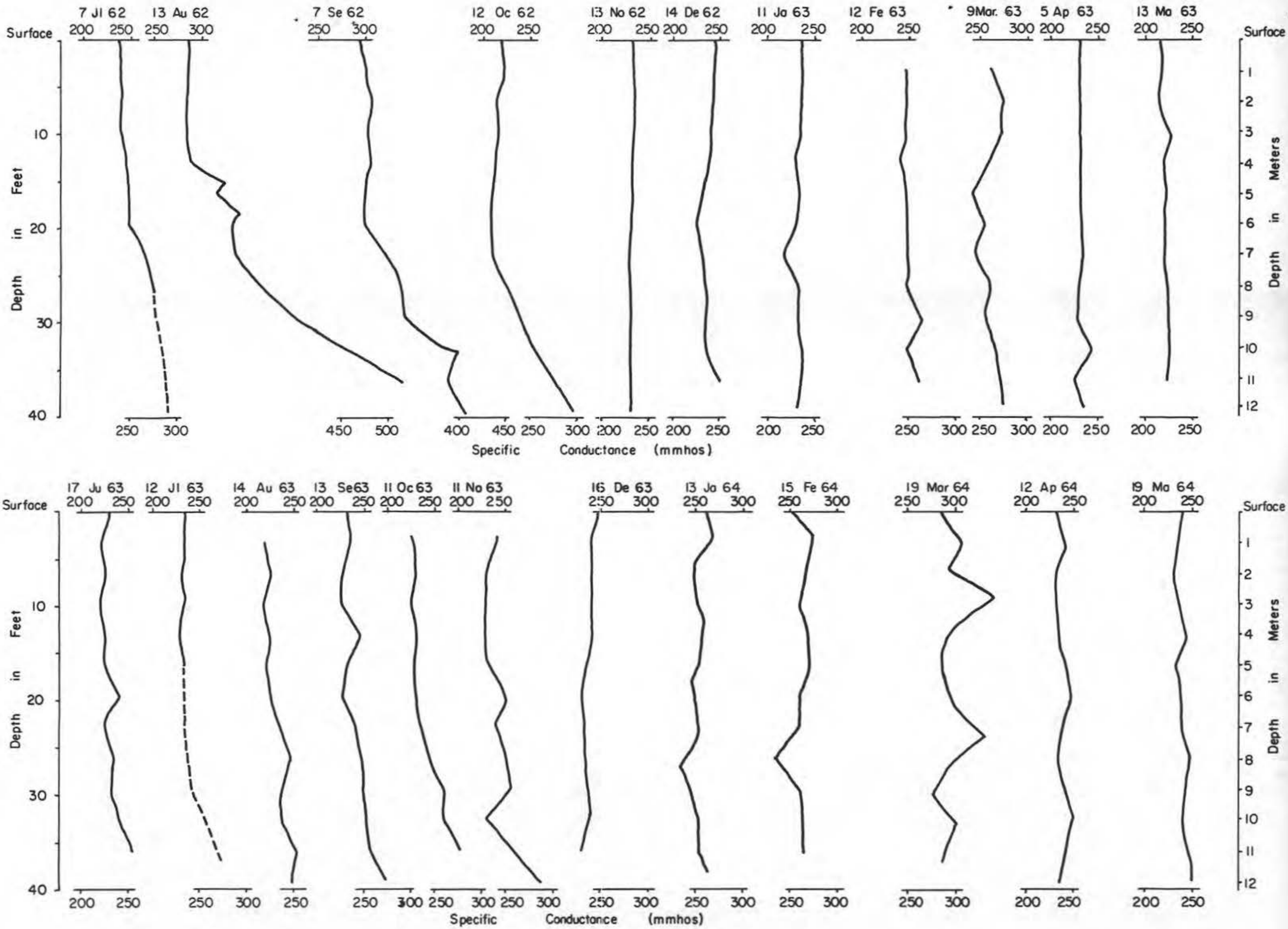


Figure 10. Specific Conductance Profiles.

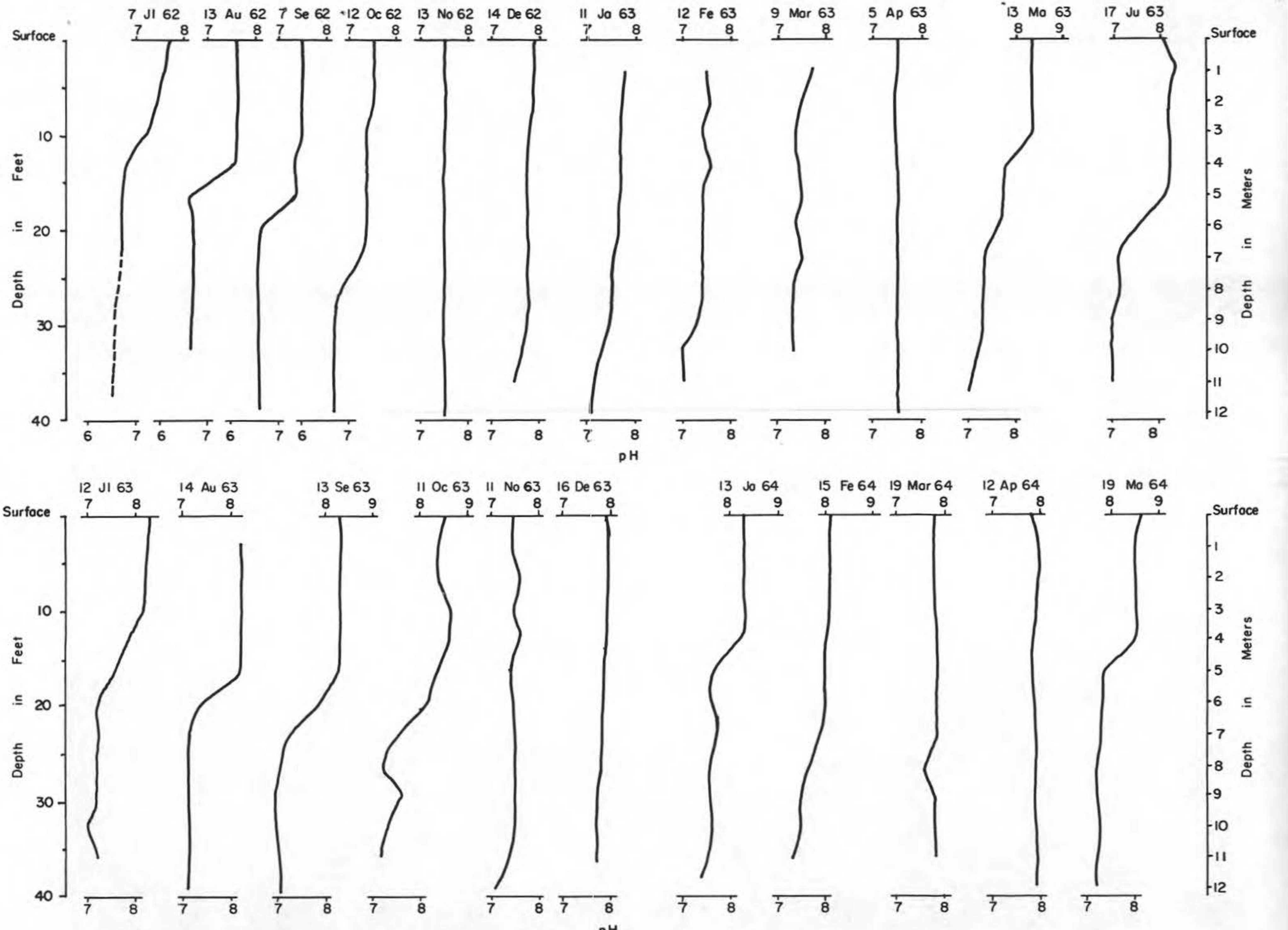


Figure 11. pH Profiles.

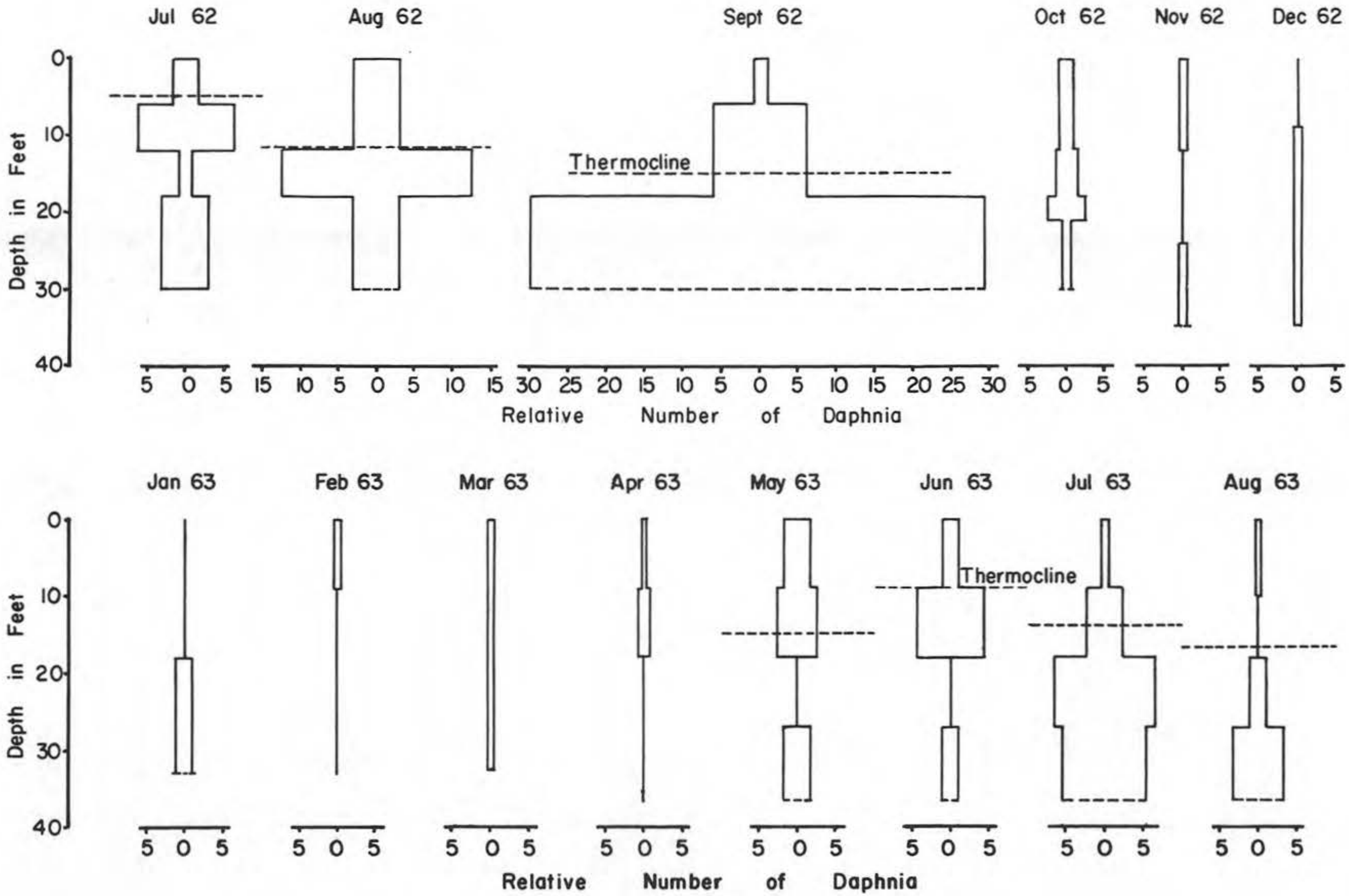


Figure 12. Distribution of Daphnia.

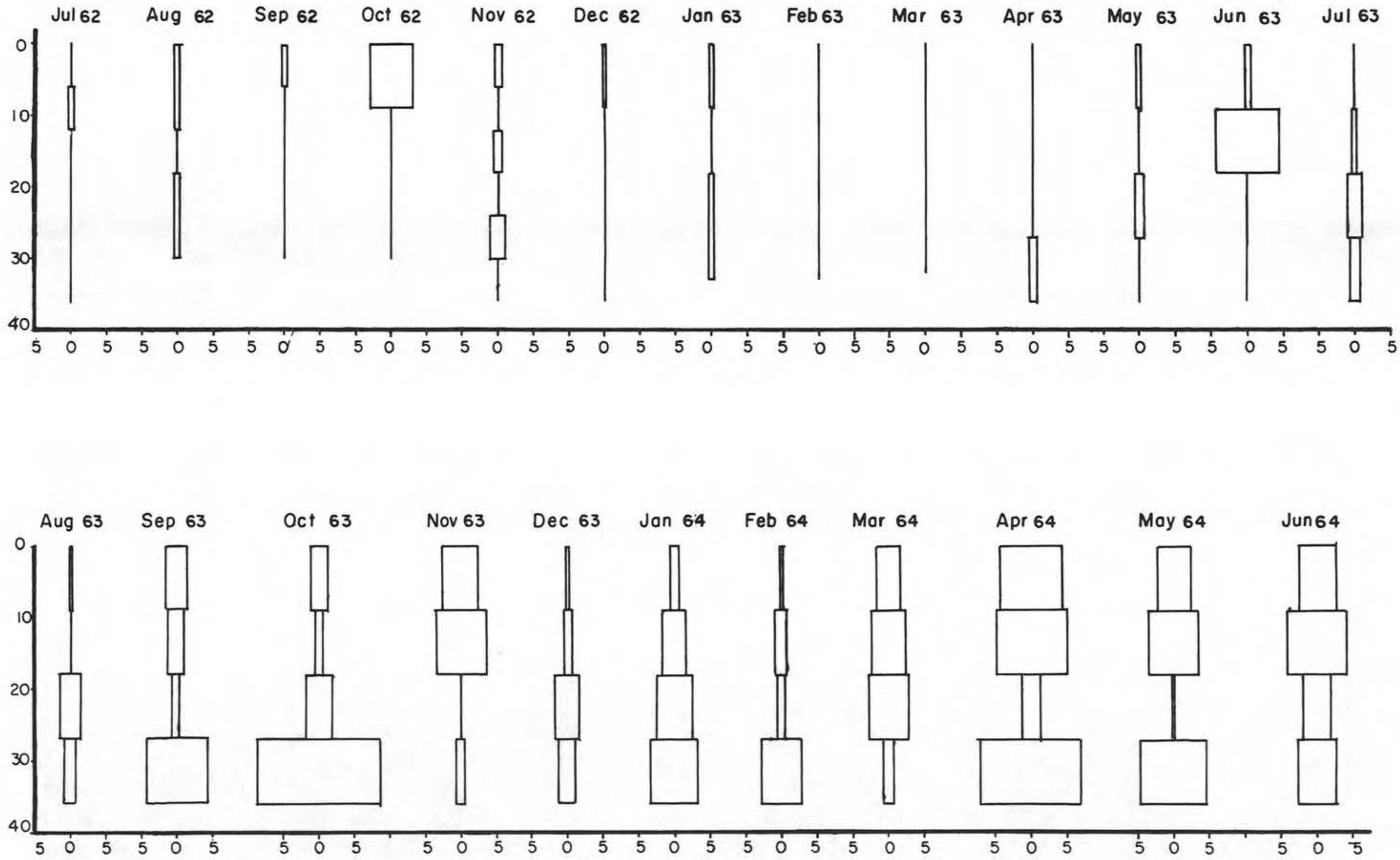


Figure 13. Copepod Distribution.