Monitoring Cruise at the
Western Long Island Sound
Disposal Site, July 1988

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From 19 to 22 July 1988, field operations were conducted at WLIS to provide information on the fate of recently-disposed dredged material and assess the environmental effects of past and recent disposal operations. The field operations consisted of a precision bathymetry survey, REMOTS® sediment-profile photography, measurements of near-bottom and near-surface dissolved oxygen concentrations, and determination of the vertical profiles of temperature and salinity at selected stations.

Both the precision bathymetric and REMOTS® surveys at WLIS indicated an accumulation of recently-deposited dredged material at the "B" mound. The deposited material occurred around the buoy in a broad, circular mound up to 2.0 m thick having a radius of about 100 m. The minimum depths of the "C" and "A" disposal mounds remained unchanged since the previous bathymetric survey in November 1987. Relict dredged material was visible in the REMOTS® photos from stations at and in the vicinity of these two mounds, consistent with the results of the November 1987 REMOTS® survey.

The lack of significant differences between reference and on-site stations in such REMOTS® parameters as RPD depths, percentage of Stage III organisms, and OSI values suggested that any seafloor disturbance related to dredged material disposal at the site was minimal. This disturbance primarily was physical in nature and limited to the immediate vicinity of the active "B" disposal mound. The July 1988 results further suggested a continuation of the trend of improving benthic habitat conditions at the site since it was severely stressed by the passage of Hurricane Gloria in September 1985 and by region-wide near-bottom hypoxia in August 1986. This trend was marked by continued colonization of the site by Stage III taxa.

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AT THE WESTERN LONG ISLAND SOUND DISPOSAL SITE
JULY 1988

1.0 INTRODUCTION

The Western Long Island Sound Disposal Site (WLIS) is located 2.5 nautical miles north of Lloyd Point, NY, between the Stamford and Eatons Neck historic disposal grounds. Since disposal first began at the site in March 1982, varying quantities of dredged material have been deposited annually. As a result, three dredged material disposal mounds ("A", "B", and "C") currently exist at the site (Figure 1-1).

The disposal buoy was located at the "B" mound at coordinates 40 59.340 N and 73 29.346 W during the 1987-88 disposal season (1 September 1987 to 1 June 1988), identical to its position during the 1986-87 season. Tabulation of scow logs indicated that approximately 52,842 m^3 (69,074 yds^3) of dredged material were deposited at or near the buoy between 17 November 1987 (when the last bathymetric survey occurred at the site) and the end of the 1987-88 disposal season on 1 June 1988.

From 19 to 22 July 1988, field operations were conducted at WLIS to provide information on the fate of recently-disposed dredged material and assess the environmental effects of past and recent disposal operations. The field operations consisted of a precision bathymetry survey, REMOTS® sediment-profile photography, measurements of near-bottom and near-surface dissolved oxygen concentrations, and determination of the vertical profiles of temperature and salinity at selected stations. The objectives of the 1988 monitoring cruise at WLIS were to:

- delineate the extent and topography of the dredged material deposited at the site since the November 1987 survey, and
- characterize dissolved oxygen depth gradients as well as assess near-bottom dissolved oxygen concentrations relative to REMOTS® benthic analyses at and near the disposal site.

2.0 METHODS

2.1 Bathymetry and Navigation

The precision navigation required for all field operations was provided by the SAIC Integrated Navigation and Data Acquisition System (INDAS). This system uses a Hewlett-Packard 9920 series computer to collect position, depth, and time data for subsequent analysis as well as providing real-time navigation. Positions were determined to an accuracy of 3 meters from ranges provided by a Del Norte Trisponder System. For the present survey, shore stations were established in Connecticut at known benchmarks at Greenwich Point and the Norwalk electric-generating facility (SAIC, In prep.). A detailed description of the navigation system and its operation can be found in DAMOS Contribution #60 (SAIC, 1989).

The depth was determined to a resolution of 3.0 cm (0.1 feet) using an Odom DF3200 Echotrac® Survey Recorder with a narrow-beam 200 kHz transducer. The speed of sound was determined from the water temperature and salinity data measured by an Applied Microsystems® CTD/DO probe (see Section 2.3 below). The speed of sound and the transducer depth were entered into the fathometer to adjust the depth values being transmitted to the computer.

The bathymetric survey was conducted at WLIS on 20 July 1987. Thirty-three lanes were run east and west at a 25 meter lane spacing over an 800 by 800 meter survey grid centered approximately at the WLIS "A" mound (Figure 1-1). The same grid and lane spacing was used as in the previous bathymetric survey of the site in November 1987. During analysis, raw bathymetric data were standardized to Mean Low Water by correcting for changes in tidal height during the survey. A detailed discussion of the bathymetric analysis technique is given in DAMOS Contribution #60 (SAIC, 1989).

2.2 REMOTS® Sediment-Profile Photography

REMOTS® photography was used to detect the distribution of thin (1-20 cm) dredged material layers, map benthic disturbance gradients, and monitor the process of infaunal recolonization on and adjacent to the disposal mounds. A detailed description of REMOTS® image acquisition, analysis, and interpretative rationale is given in DAMOS Contribution #60 (SAIC, 1989).

The REMOTS® stations occupied at WLIS on 21 and 22 July 1988 were the same ones occupied during the last survey performed in November 1987. Three replicate photos were obtained at each station in a 7 x 9 grid with 200 m spacing, centered slightly north of the "A" disposal mound (Figure 2-1). In addition, thirteen REMOTS® stations, arranged in a cross-shaped pattern and spaced 100 m apart, were occupied at each of three reference sites to allow comparisons between ambient and on-site conditions. These reference sites were located 2000 m west (2000W), 2000 m south (2000S), and 2200 m northeast (WLIS-REF) of station 3-E near the center of the REMOTS® grid (Figure 2-1).

2.3 CTD and Dissolved Oxygen Sampling

The depth gradients in temperature and salinity were characterized at selected REMOTS® stations using a CTD probe (Applied Microsystems, Ltd. Model STD-12®). The STD-12® (used to measure conductivity, temperature, and pressure) was mounted vertically on the REMOTS® camera frame such that its sensors were located approximately 42 cm from the camera base. A dissolved oxygen probe (Rexnord® Instruments Model 66), interfaced to the CTD, was attached to the bottom of the REMOTS® camera frame to make measurements as close to the sediment-water interface as possible (approximately 6 to 9 cm above the bottom). In this configuration, vertical hydrographic profiles were obtained with each deployment of the camera.

The STD-12® is capable of sampling up to 8 scans per second and can store up to 7648 scans in 56k of internal RAM (random access memory). Commands are sent to and data read from the instrument with a Compaq® Portable II microcomputer via an RS-232 serial interface. Prior to commencing the REMOTS® survey, the STD-12® was set to internally log data at 1 second intervals. The data were downloaded to the microcomputer during REMOTS® film changes and stored on floppy disks for later analysis. Salinity was calculated from conductivity data based on procedures described by Perkin and Lewis (1980).

The Rexnord® Model 66 probe is a polarographic oxygen electrode (platinum-lead galvanic couple with a potassium-iodide electrolyte). Field calibration of the probe was performed by obtaining water samples at selected REMOTS® stations approximately *one meter above the bottom and one meter below the surface using a* Niskin® bottle. Following retrieval of a water sample, the Rexnord probe was placed inside the Niskin® bottle while a 300-ml subsample was withdrawn for determination of the dissolved oxygen concentration using a modification of the standard Winkler titration method (Strickland and Parsons, 1972; Parsons et al., 1984). A calibration curve was generated by plotting the raw voltages obtained from the Rexnord® probe against the Winkler DO concentrations determined simultaneously in the Niskin® bottles.

3.0 RESULTS

3.1 Bathymetry

Depth at the disposal point over mound "B" decreased 2.0 meters since the November 1987 survey, while depths at mounds "A" and "C" remained unchanged (Figure 3-1). In August 1986, mounds "A", "B", and "C" had minimum depths of 29.50 m, 32.50 m, and 27.75 m, respectively. The November 1987 results indicated that the minimum depth of mound "B" had decreased by 0.75 m to approximately

31.75 m, while the minimum depths of mounds "A" and "C" remained unchanged. In the present survey, the minimum depths at mounds "A", "B", and "C" were 29.50 m, 29.75 m, and 27.78 m, respectively. Bathymetric charts of the area surrounding mound "B" in August 1986 (Figure 3-2), November 1987 (Figure 3-3), and July 1988 (Figure 3-4) illustrate the changes in depth which were due to the addition of dredged material within a radius of approximately 100 m around the buoy.

Depth difference calculations indicated that between the November 1987 and July 1988 bathymetric surveys, a total of 23,370 m^3 of dredged material was added to the area within about 200 m of the disposal buoy. Tabulation of scow logs for the same period indicated that approximately 52,842 m^3 (69,074 yds^3) of dredged material were deposited at or near the buoy.

3.2 REMOTS® Sediment-Profile Photography

Recently-deposited (i.e., since November 1987) dredged material exceeding the depth of prism penetration occurred at stations 3-C and 5-C in the immediate vicinity of the WLIS "B" mound (Figure 3-5). This material had a "mottled" appearance caused by alternating high and low reflectance streaks (Figure 3-6), and it also exhibited a significant sand component in many photos (Figure 3-7).

As in the November 1987 survey, relict or "weathered" dredged material was evident at stations on or near the "A" and "C" mounds. For example, station 3-G at the "C" mound continued to exhibit poorly-sorted relict material characterized by discontinuous sand layers at depth (Figure 3-8). Likewise, a distinct relict dredged material layer about 7 cm deep remained visible at station 5-E near the "A" mound. Some stations located away from the three disposal mounds (-1-Y, -1-Z, -1-A, -1-K, -1-M, -1-I, 1-K, 1-M, and 7-G) also exhibited indistinct, low-reflectance horizons at depth suggestive of relict dredged material layers (Figure 3-9).

The majority of REMOTS® on-site and reference stations consisted of silt-clay sediments (> 4 phi, Figure 3-10). As in 1987, a cluster of stations in the immediate vicinity of both the active ("B") and recent ("A" and "C") disposal mounds exhibited a significant sand component and were mapped with a grain size major mode of >4-3 phi (fine sand/silt/clay). Likewise, sediments having a >4-3 phi major mode continued to occur at stations near the northwest corner of the sampling grid and at reference station 2000S.

The frequency distribution of apparent RPD depths for the disposal site stations had a major mode at the 3.0 cm class interval, while the corresponding frequency distribution for the reference stations had major modes at the 2 and 4 cm class intervals

(Figure 3-11). The average apparent RPD depth for the disposal site stations was 3.1 cm, with almost an equal number of station values falling above and below this mean. The pattern of RPD depths across the site appeared to be irregular (Figure 3-12), and the RPD at many stations was patchy and interrupted by reduced material extending to the surface from depth (Figure 3-13).

The five reference stations had an average apparent RPD depth (2.9 cm) slightly shallower than the disposal site stations; however, there was no significant difference in the distribution of RPD values at the reference versus the disposal site stations (Mann-Whitney U-test; p = 0.6225). The RPD layers at many reference stations were characterized by the same patchiness exhibited at the disposal site stations (see Figure 3-13). The RPD depths at the disposal and reference sites had not changed significantly since the November 1987 REMOTS® survey (Mann-Whitney U-test, p = 0.6832 for the disposal site and p = 0.5712 for the reference sites).

Approximately 64% of all the photos obtained at WLIS (including both disposal site and reference stations) exhibited Stage III infauna, compared to 53% in November 1987, 50% in August 1986 and 33% in August 1985. At many stations, all three replicate photos showed Stage I on III successional seres (Figure 3-14). In the replicates at other stations, both Stage I on III seres as well as either Stage I or Stage I going to Stage II seres were evident. As in 1987, the Stage I organisms at many stations included both small, tubicolous, surface-dwelling polychaetes, as well as the near-surface dwelling, opportunistic mactrid bivalve Mulinia lateralis (Figure 3-15). Stage I going to Stage II seres were designated where the Stage I assemblage appeared to be particularly well-established and shallow-deposit-feeding errant polychaetes and/or shallow-dwelling tellinid bivalves served as evidence of developing a well-established deposit-feeding assemblage (Figure 3-15). Only Stage I organisms were observed at four disposal site stations (-1-Y, -1-G, -1-I and 3-C) and in the single photos obtained at some reference site stations (Figure 3-14).

Based on the results of past REMOTS® surveys, Organism-Sediment Index (OSI) values of +6 or less are considered indicative of chronically-stressed benthic habitats and/or those which have experienced recent disturbance (e.g., erosion, dredged material disposal, hypoxia, demersal predator foraging, etc.). Only five disposal site stations (-1-Z, -3-C, -1-I, 3-C and 5-E) had mean OSI values +6 (Figure 3-16). The low values at and near the "B" mound reflected physical disturbance due to recent disposal. Elsewhere, the low values were caused by either a lack or patchy distribution of Stage III infauna. Generally, mean OSI values exceeded +6 at the majority of on-site stations and at all three reference sites.

The frequency distributions of reference and disposal site station OSI values both have major modes at 11, although a substantial number of lower values also were calculated (Figure 3-17). This wide range of OSI values reflects both the patchy distribution of Stage III organisms at individual stations, as well as the relatively wide range of RPD depths resulting from the presence of discontinuous patches of reduced sediment near the sediment-water interface at many stations. There was no significant difference in OSI values at the disposal site stations versus the pooled reference site stations (Mann-Whitney U-test, $p = 0.6511$). In both cases, the overall average OSI value was 8.0. The OSI values at both the disposal and reference sites were not significantly different from those calculated in the November 1987 REMOTS® survey (Mann-Whitney U-test, $p = 0.2150$ for the disposal site and $p = 0.5306$ for the reference sites).

3.3 CTD and Dissolved Oxygen Sampling

The lack of linearity in the calibration curve computed for the Rexnord® DO probe led to the discovery that the platinum tip on the probe was partially disconnected during sampling; this resulted in a wide variance in the probe's response. Without the calibration curve, continuous vertical profiles of DO concentrations could not be accurately calculated from probe voltages measured in the field. However, near-bottom and near-surface DO concentrations at selected disposal site stations and at the reference sites were determined by Winkler titration. Near-bottom DO concentrations at the disposal site stations ranged between 3.5 and 4.6 mg/ℓ, while those measured at the three reference sites ranged between 3.5 and 4.2 mg/ℓ (Table 3-1). DO concentrations one meter below the surface were significantly higher at all stations, ranging between 7.2 and 7.8 mg/ℓ at the disposal site and 7.6 and 10.2 mg/ℓ at the reference sites. Mid-depth water samples taken at random stations indicated that DO concentrations probably decreased steadily from surface to bottom on the day of sampling. For example, at disposal site station 7-Y, DO measured 3.5 mg/ℓ near the bottom, 5.1 mg/ℓ at mid-depth, and 7.6 mg/ℓ near the surface.

Plots of the depth gradients in temperature, salinity, and density (as sigma-t) at selected disposal site and reference REMOTS® stations are given in the Appendix. The plot from station 3-E (Figure 3-18) generally is representative of all the stations. This plot indicates that at the time of sampling, the water column was well-stratified, as evidenced by the distinct thermocline which generally occurred at a depth of about 10 m. Temperatures ranged between 21C at the surface to 16.5C at depth. Concomitant increases in salinity and density (as sigma-t) with depth suggested a relatively stable stratification of the water column, making it resistant to large-scale vertical mixing.

4.0 DISCUSSION

4.1 Bathymetry

The objective of the bathymetric survey at WLIS was to delineate the extent and topography of the dredged sediment deposit resulting from the past year's disposal activities. The results indicated a significant accumulation of dredged material at the "B" mound, where the disposal buoy had been located since 1 September 1986. The disposed material occurred around the buoy in a broad, circular deposit up to 2.0 m thick having a radius of about 100 m.

A discrepancy of 29,472 m^3 existed between the scow log volume estimate of 52,842 m^3 and the depth difference calculation of 23,370 m^3 of disposed material. The scow log volume is assumed to be an overestimate due to the significant amount of interstitial water associated with the dredged material in the barges and the self-compaction of the material after it is disposed. In addition, the new material could have caused additional compaction of the material disposed in earlier years. In a mass balance study in the New York Bight, Tavolaro (1984) determined an apparent decrease in volume of 40.7% when comparing the scow log volume and the volume estimated by comparing pre- and post-disposal bathymetric surveys. Applying this factor to the present data results in a corrected scow log volume estimate of approximately 31,300 m^3 of dredged material.

A comparison of the corrected scow log estimate of 31,300 m^3 with the depth difference calculation of 23,370 m^3 showed a difference of approximately 8,000 m^3 of dredged material which could not be accounted for on the bottom. Examination of the scow logs from 1987 confirmed that some disposal took place up to 360 meters away from the buoy, but scow log positions can be subject to a number of reporting errors and are difficult to verify with certainty. Disposal at such distances from the buoy would have resulted in dredged material being beyond the area used to compare the November 1987 and July 1988 bathymetric surveys (a 350 x 350 m area around the center of the "B" mound) and therefore not represented in the depth difference volume estimate. At WLIS in 1987 and at other DAMOS disposal sites surveyed in recent years, the corrected scow log volume estimate consistently has been higher than the depth difference volume estimate. This suggests that the scow log volume estimate correction factor (40.7%) may require re-evaluation based on a comprehensive mass balance study.

4.2 REMOTS® Sediment-Profile Photography

One objective of the REMOTS® survey at WLIS was to delineate, in conjunction with the precision bathymetric survey, the extent of dredged material deposited during the past year at the "B" disposal mound. The results indicate that recently-deposited (i.e., since November 1987) dredged material occurred at two stations in the immediate vicinity of the "B" mound. This correlates well with the acoustically-determined changes in depth noted in this location. Likewise, relict dredged material was noted at stations at and in the vicinity of the "C" and "A" mounds, consistent with the results of both the 1988 bathymetric and 1987 REMOTS® surveys. The indistinct, low-reflectance horizons noted at some stations away from the three mounds (Figure 3-9) serve as indirect evidence of disposal which might have occurred anytime in the past, probably well before the 87-88 disposal season. Apparently these errant disposal events were not all that common, because the resulting relict dredged material layers present at these locations appeared relatively thin and are widely-spaced.

A second objective of the REMOTS® survey at WLIS was to assess environmental impacts related to dredged material disposal. The lack of significant differences between reference and disposal site stations in such REMOTS® parameters as RPD depths, percentage of Stage III organisms, and OSI values indicated a rapid recovery by the ambient benthic community; the seafloor disturbance caused by dredged material disposal was apparently rather transient as detected at the benthic population level. This disturbance primarily was physical in nature and limited to the immediate vicinity of the active "B" disposal mound, where stations 3-C and 5-E exhibited OSI values +6. The low OSI values at a small number of stations elsewhere at the site were caused by variable RPD layers or within-station patchiness in the distribution of Stage III infauna. At each reference site, apparent between-station variability in such parameters as the RPD, OSI and infaunal successional stage was most likely due to the fact that only one REMOTS® image was obtained at the individual stations. Because of the patchy distribution of benthic organisms, and in some cases RPD depths, it is recommended that additional replicate photographs be obtained at each individual reference site station in future surveys. This would match the level of replication employed at the disposal site and would allow a better assessment of any apparent variability or sampling artifact caused by using the cross-shaped station pattern at the reference sites.

In November 1987, significantly greater RPD depths coupled with a slight increase in the number of Stage III organisms at both reference and disposal site stations lead to the conclusion that overall benthic habitat quality at WLIS had improved relative to the stressed conditions noted during a period of near-bottom hypoxia in August 1986. This was reflected in the significantly higher OSI values in 1987 compared to 1986. The 1988 results suggested a continuation of this trend. While RPD depths and OSI values were not significantly different in 1988 compared to 1987, there was an increase in the percentage of replicate photos showing evidence of head-down, deposit-feeding Stage III organisms. This serves as one indication that relatively healthy benthic conditions continued to exist both at the site and in the general area outside the site between the November 1987 and July 1988 surveys. The patchy RPD layers which existed at many stations may have been a direct consequence of the sediment-reworking activities of Stage III organisms. It appears that the reduced sediments which typically extended to the surface in many of the photos (see Figure 3-13) were transported from deeper zones as a result of burrowing and/or "conveyor-belt" feeding by the larger infauna.

4.3 CTD and Dissolved Oxygen Sampling

The objective of the CTD/DO sampling at WLIS was to assess near-bottom dissolved oxygen concentrations in relation to benthic habitat conditions at and in the vicinity of the site. As indicated, the REMOTS® results suggested that relatively healthy benthic conditions existed at the time of sampling, although near-bottom dissolved oxygen concentrations at both the disposal and reference sites were near the hypoxic range (Table 4-1). The strong thermal stratification of the water column apparent in the CTD profiles most likely contributed to the observed vertical distribution of DO. Past experience has shown that in Long Island Sound, the lack of mixing associated with a strong and persistent pycnocline during the warmer summer months can exacerbate oxygen depletion in near-bottom waters. Furthermore, the solubility of oxygen in seawater declines as water temperature and salinity increase (Weiss, 1970). Dissolved oxygen concentrations remained at or close to saturation in the surface waters and were slightly higher at reference stations 2000W and 2000S. This reflected the normal spatial and temporal variability in near-surface DO which might be expected in any estuarine area over a 6 to 8 hour sampling period.

The relatively healthy benthic conditions at WLIS as seen in the REMOTS® photos suggest a general absence of stress which might otherwise be attributed to near-bottom hypoxia in the weeks and months preceding the survey. On a larger time scale, it was found that seasonal hypoxia was not as severe or widespread in Long Island Sound in the summer of 1987 compared to the preceding year (SAIC, 1988). This might help to explain the continued improvement in benthic conditions noted at WLIS in 1987 and 1988, as well as the generally healthy conditions noted at the other Long Island Sound disposal sites (CLIS and NLON) in 1987. Conditions observed at WLIS in July 1988 may still have represented the "pre-hypoxic" condition in this region of the Sound, with the possibility that hypoxia developed later in the summer with attendant adverse sediment effects. However, the dramatic change in both the high reflectance of the oxidized sediment layers in the REMOTS® photos and the increased region-wide appearance of Stage III infauna as compared with results from 2-4 years ago lend increasing support to our conclusions from earlier studies that the stressed conditions noted earlier were unrelated to disposal but resulted from region-wide hypoxia or, in 1985, physical seafloor disturbance due to the passage of Hurricane Gloria. Apparently, seasonal hypoxic effects in 1987 and the first half of 1988 (up until the July 1988 survey) were not as severe as they were in the past, and the benthic communities in and around the disposal site were not showing as much evidence of stress as they had in previous years.

5.0 CONCLUSIONS

Both the precision bathymetric and REMOTS® surveys at WLIS indicated an accumulation of recently-deposited dredged material at the "B" mound. The deposited material occurred around the buoy in a broad, circular mound up to 2.0 m thick having a radius of about 100 m. The minimum depths of the "C" and "A" disposal mounds remained unchanged since the previous bathymetric survey in November 1987. Relict dredged material was visible in the REMOTS® photos from stations at and in the vicinity of these two mounds, consistent with the results of the November 1987 REMOTS® survey.

The lack of significant differences between reference and on-site stations in such REMOTS® parameters as RPD depths, percentage of Stage III organisms, and OSI values suggested that any seafloor disturbance related to dredged material disposal at the site was minimal. This disturbance primarily was physical in nature and limited to the immediate vicinity of the active "B" disposal mound. The July 1988 results further suggested a continuation of the trend of improving benthic habitat conditions at the site since it was severely stressed by the passage of Hurricane Gloria in September 1985 and by region-wide near-bottom hypoxia in August 1986. This trend was marked by continued colonization of the site by Stage III taxa.

The generally healthy benthic conditions observed in the REMOTS® photos suggested an absence of stress related to near-bottom hypoxia in the weeks and months preceding the survey. At the time of sampling, dissolved oxygen levels in near-bottom waters were near the hypoxic range at both disposal and reference stations. This might have signaled the beginning of seasonal near-bottom hypoxia in this region of the Sound, as it developed in response to thermal stratification of the water column. No evidence of extreme adverse effects of the low dissolved oxygen levels were apparent in the sediments. The low DO levels measured near the bottom at both the disposal site and reference stations support earlier studies which showed this was a region-wide phenomenon unrelated to disposal.

Overall, the results of the July 1988 survey indicate a continuation of the trend of improved benthic conditions noted at WLIS after the November 1987 REMOTS® survey (SAIC, 1990). Similar to conclusions reached from the November 1987 survey, it appears that this trend represents a return to relatively "normal" conditions at the site. Such conditions were noted after the August 1985 REMOTS® survey, prior to both Hurricane Gloria in September

1985 and the severe hypoxia which occurred in western Long Island Sound in the summer of 1986. The improved conditions at WLIS have been attributed to the lack of severe hypoxic stress in this region of the Sound during 1987 and 1988. Several investigations in recent years conducted by the University of Connecticut and SUNY-Stony Brook for EPA Region I have concluded that near-bottom hypoxia observed in western and central Long Island Sound during the summer months occurred in response to a combination of excessive anthropogenic organic loading (primarily sewage discharge) and seasonal water-column stratification. The response of the local benthic environment to dredged material disposal at the WLIS site is primarily influenced by these persistent and recurrent regional phenomena.

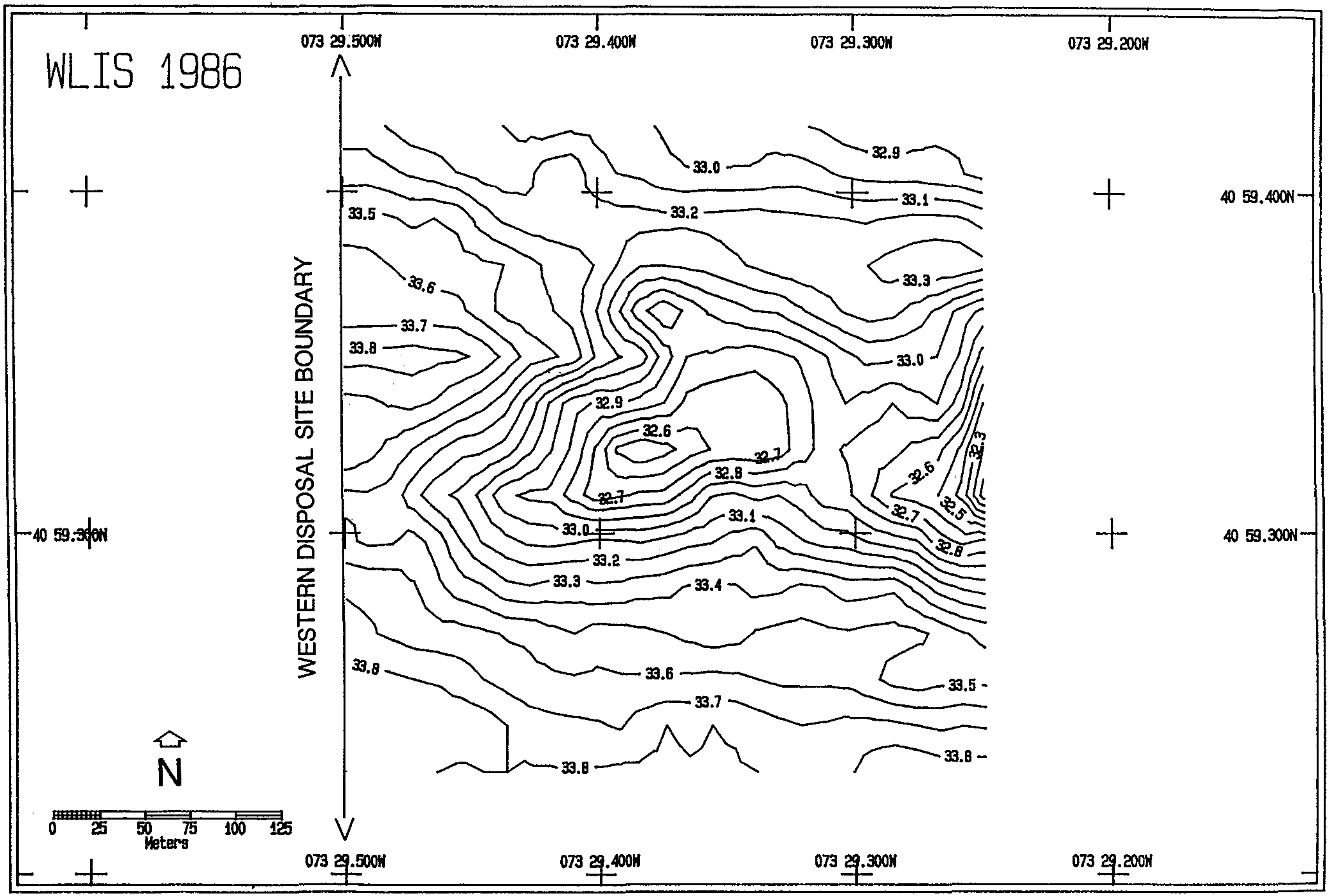

Figure 3-2. Bathymetric contour chart of the area surrounding the WLIS "B" mound, August 1986. Depths are in meters.

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Table 3-1

Near-bottom and Near-surface Dissolved Oxygen Concentrations at Selected Disposal Site and Reference Stations at WLIS, July 1988

Station	Near-Bottom DO (mg/ℓ)	Near-Surface DO (mg/ℓ)
7-M	4.1	7.8
7-K	4.1	7.2
7-I	4.1	7.4
7-Y	3.5	7.6
2000W	3.5	10.2
2000S	3.9	8.1
WLIS-REF	4.2	7.6

Table 4-1

Ecologically Important Dissolved Oxygen Ranges as Determined from Permanently Stratified Low-Oxygen Marine Basins (from Rhoads and Morse, 1971)

Dissolved Oxygen Range (mg/ℓ)	Facies
> 3.0	Aerobic
3.0 to 0.41	Hypoxic*
0.4 to 0.14	Dysaerobic
< 0.14	Anaerobic

* The hypoxic facies has been added to the Rhoads and Morse (1971) basin model by Dr. Barbara Welsh, University of Connecticut, to include responses of high metabolic rate demersal or benthic megafauna.

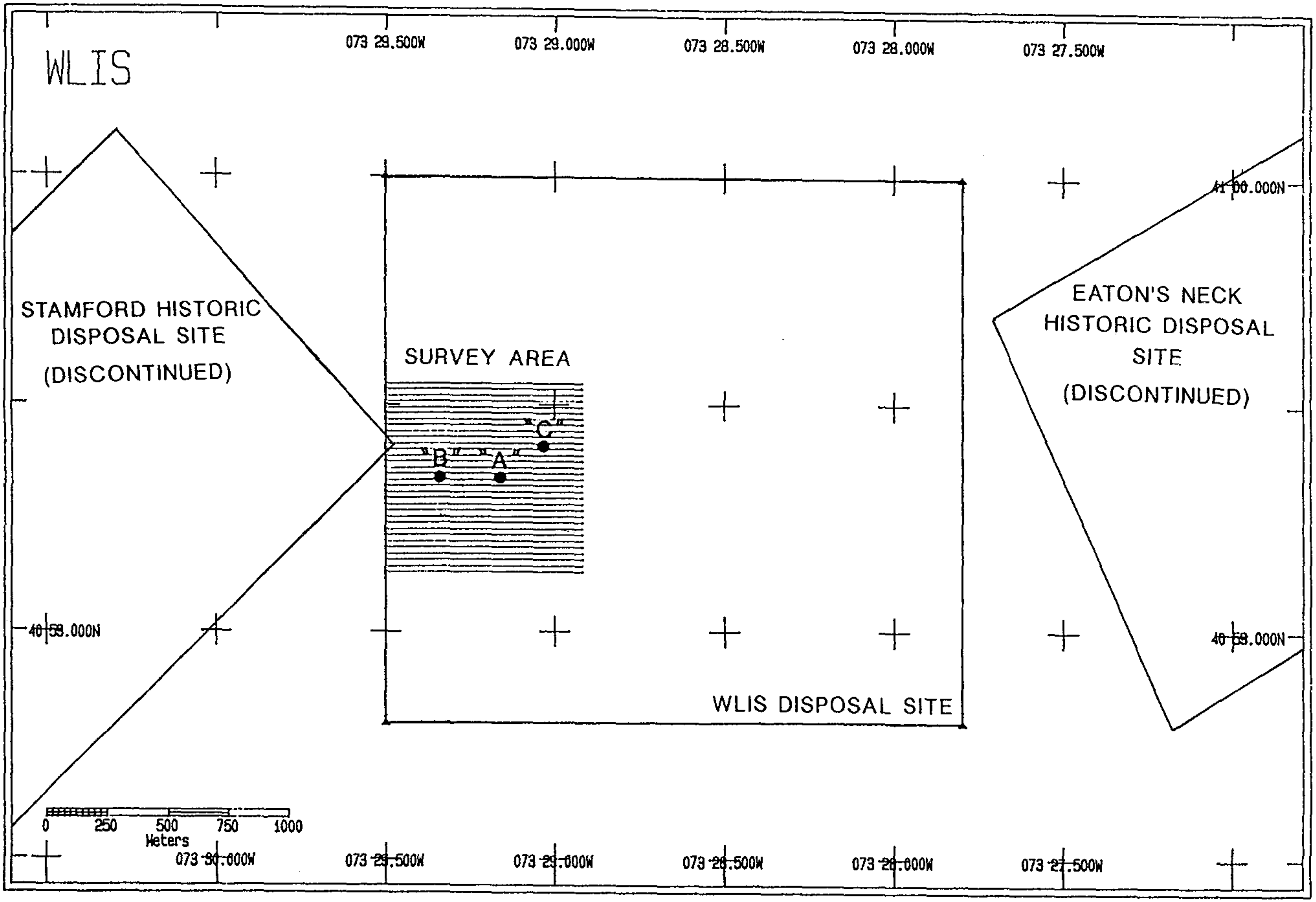


Figure 1-1. The Western Long Island Sound disposal site (WLIS) showing the bathymetric survey lanes and the location of the three disposal mounds ("B", "A", and "C") near the western site boundary.

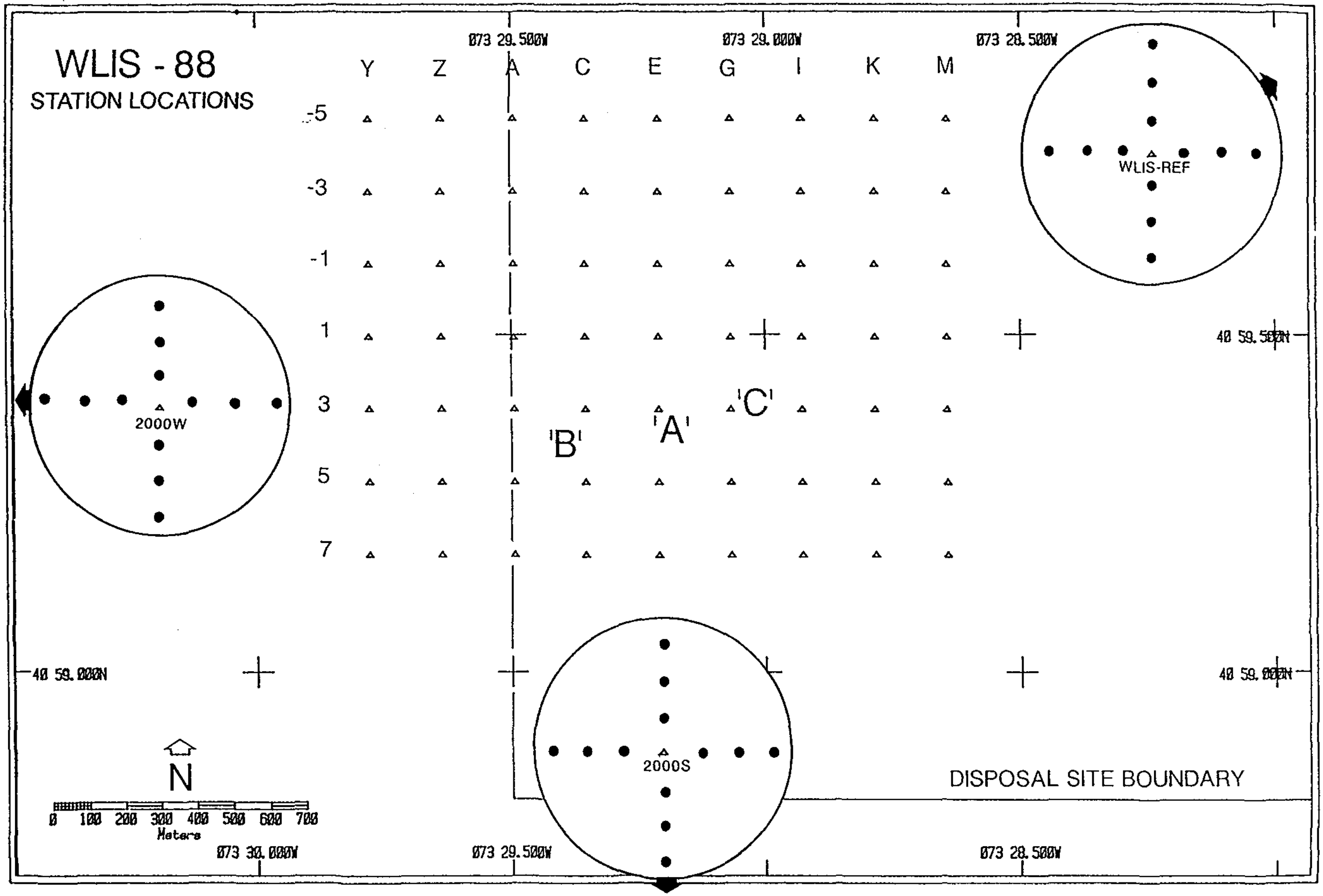


Figure 2-1. Locations and designations of REMOTS stations (triangles) at the WLIS disposal site, July 1988. Cross-shaped grids with 100 m station spacing were used at the three outlying reference sites (2000W, 2000S, and WLIS-REF). These grids are circled and their locations indicated by arrows. The locations of the "B", "A", and "C" disposal mounds are also indicated.

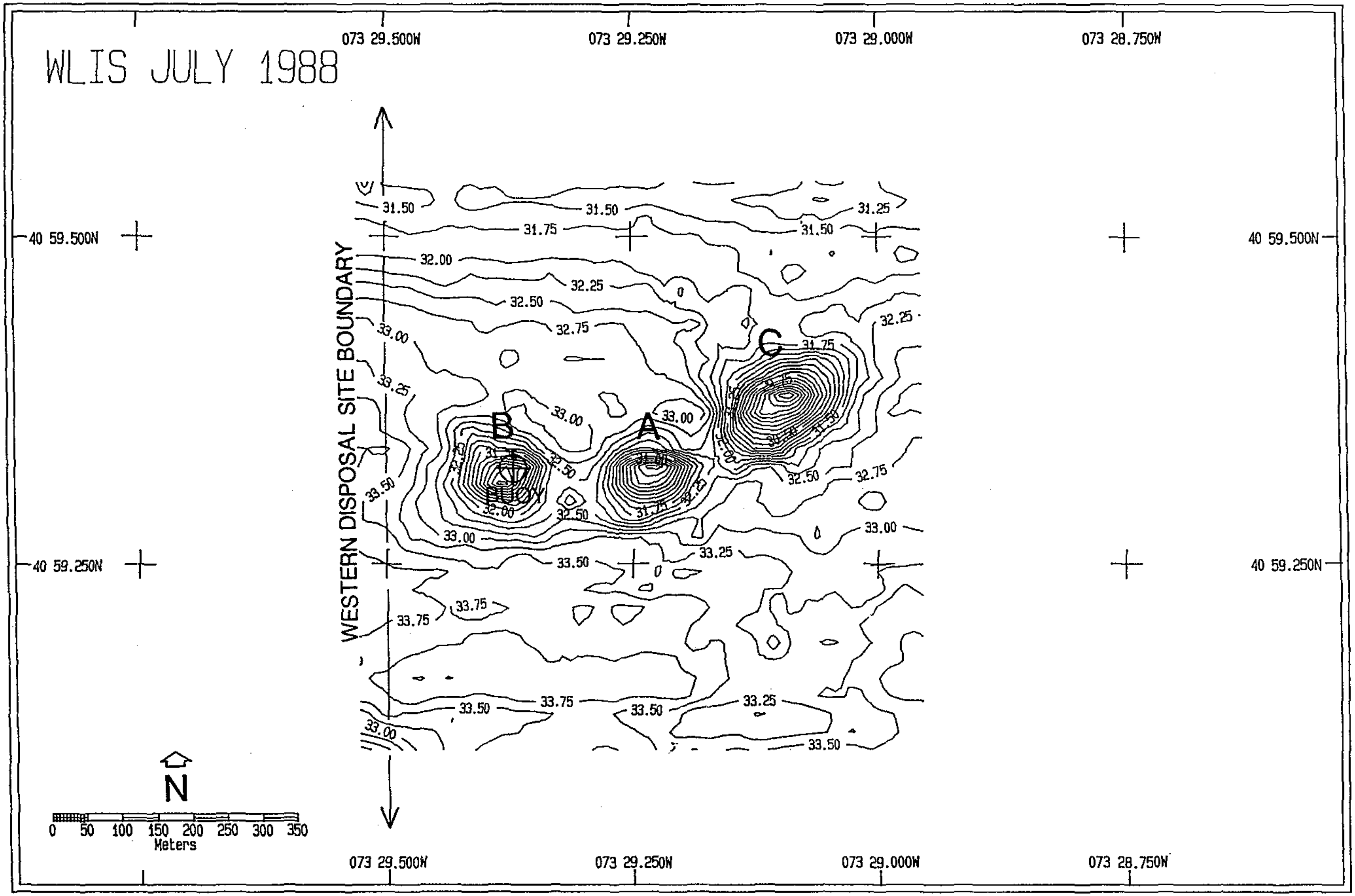


Figure 3-1. Bathymetric contour chart of the WLIS disposal site, July 1988. The "B", "A", and "C" disposal mounds are labeled. Depths are in meters.

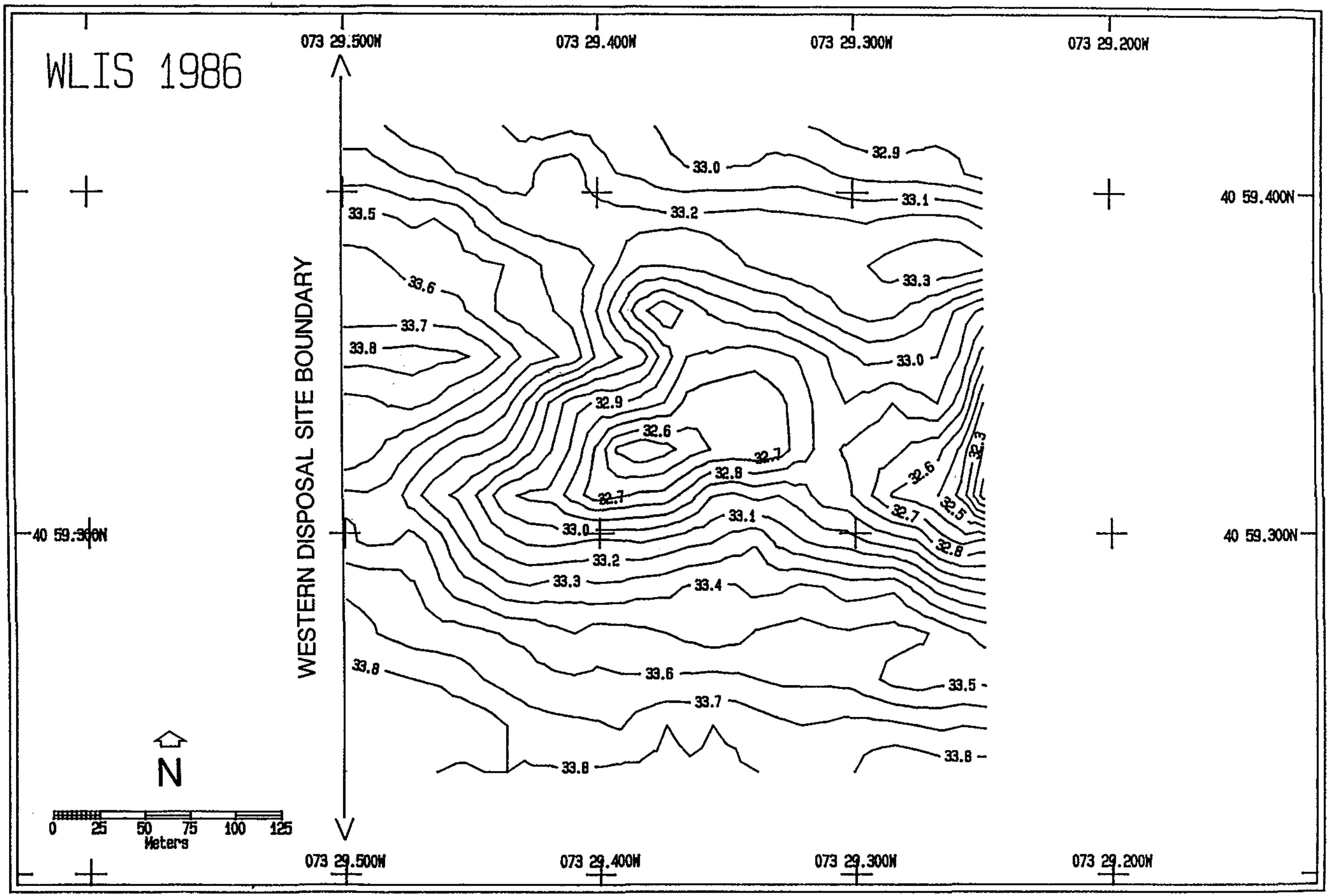


Figure 3-2. Bathymetric contour chart of the area surrounding the WLIS "B" mound, August 1986. Depths are in meters.

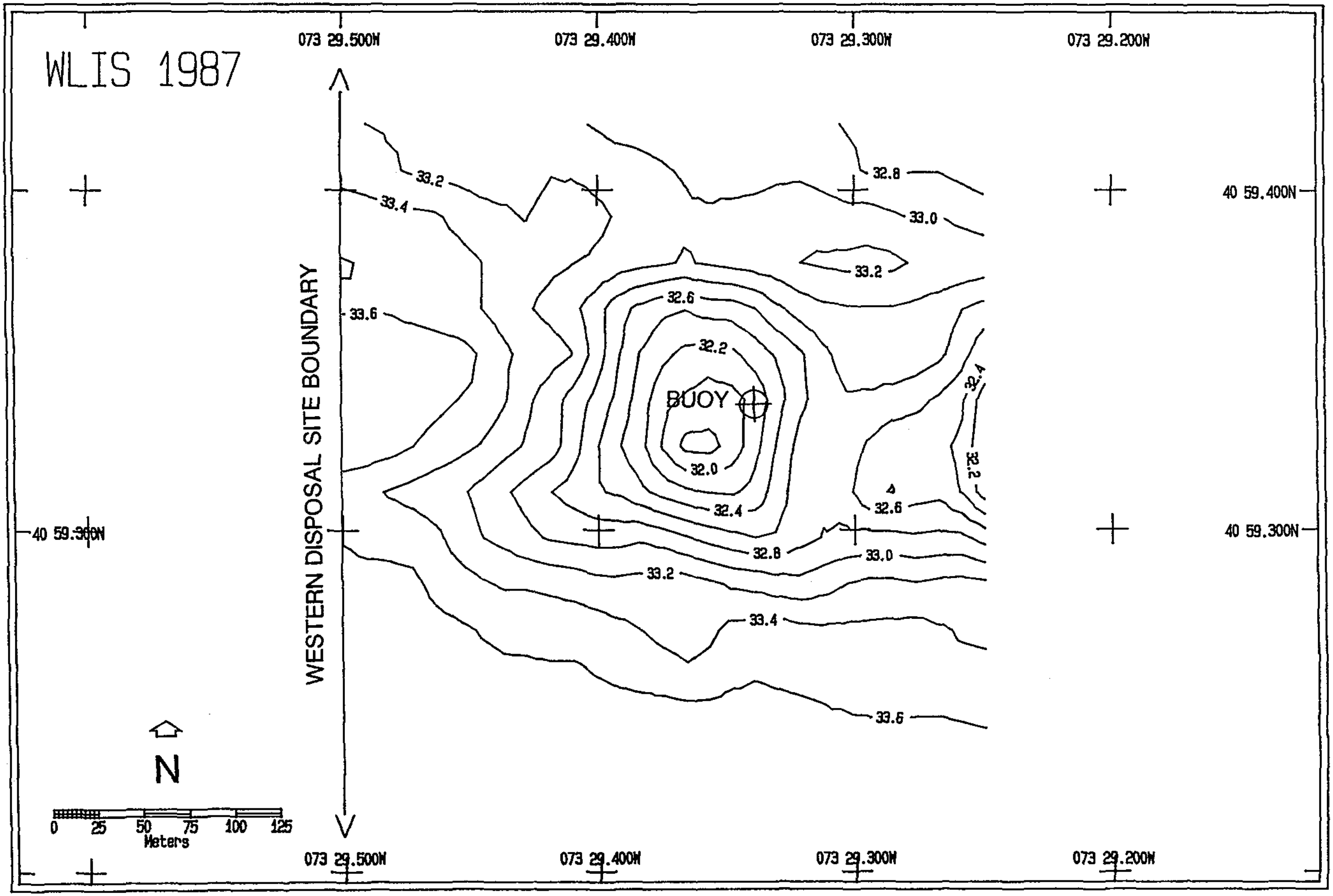


Figure 3-3. Bathymetric contour chart of the area surrounding the WLIS "B" mound, November 1987. Depths are in meters.

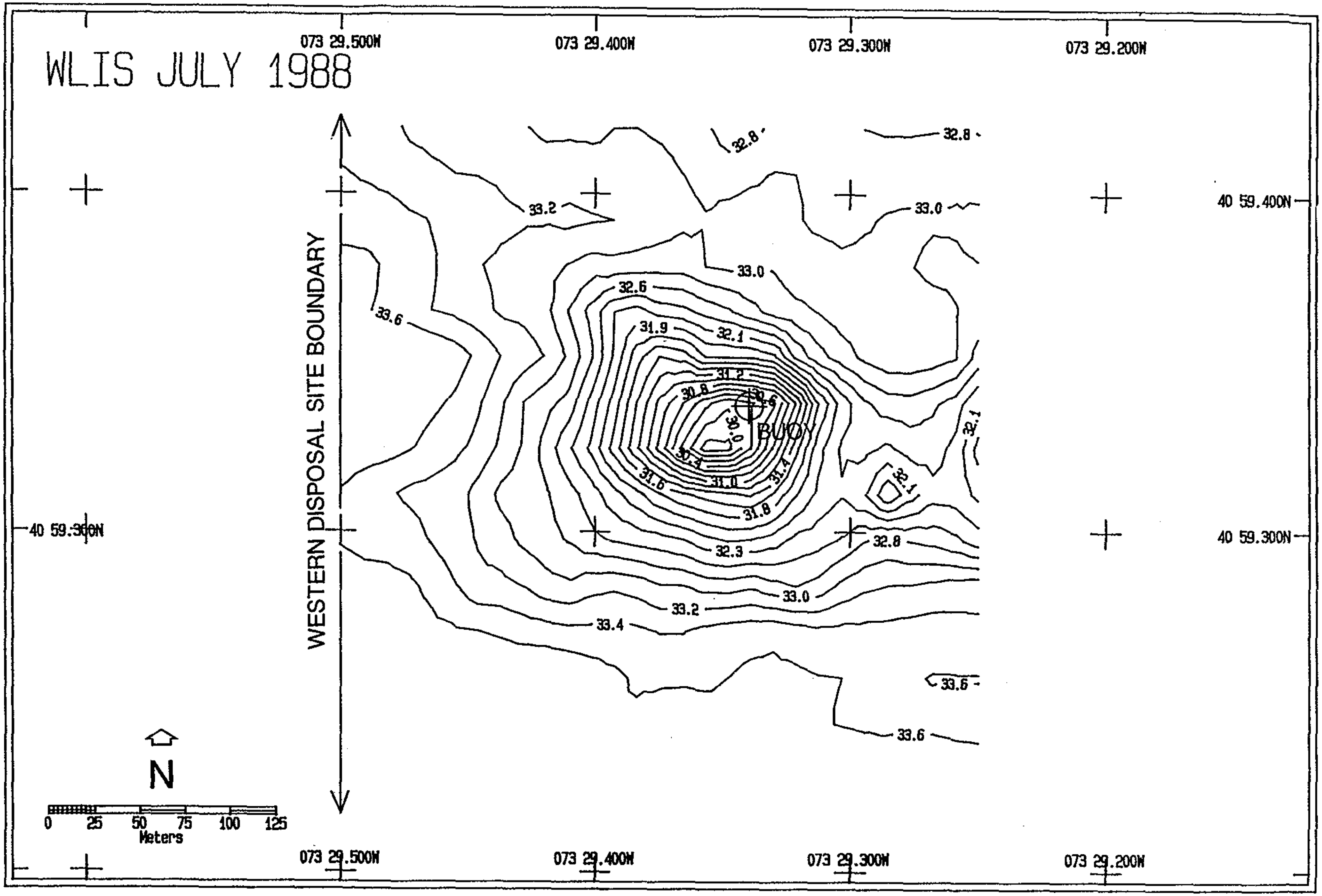


Figure 3-4. Bathymetric contour chart of the area surrounding the WLIS "B" mound, July 1988. Depths are in meters.

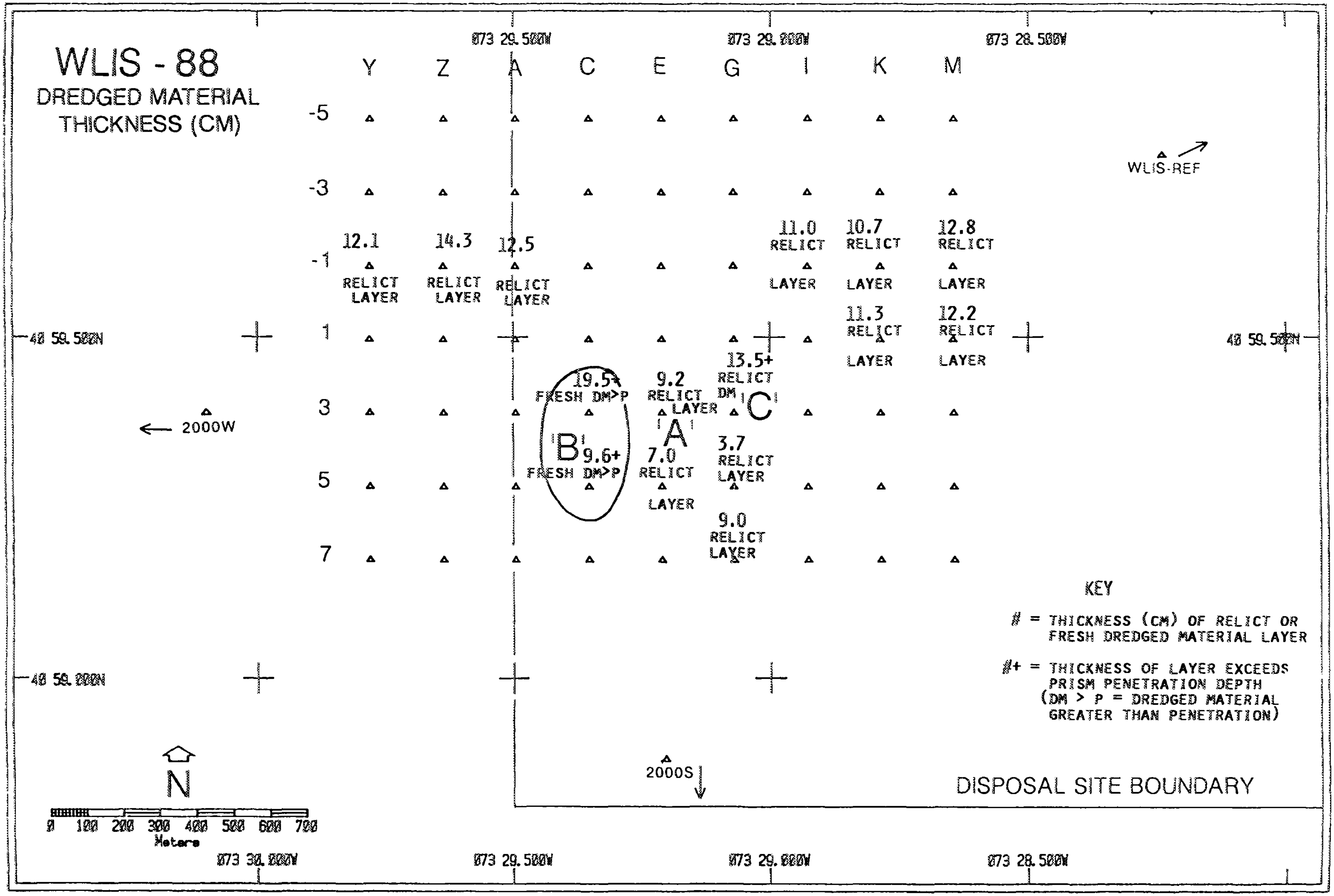


Figure 3-5. Distribution of dredged material at the WLIS disposal site, July 1988. The contour delimits stations having apparent dredged material deposited since the previous REMOTS survey in November 1987. Dredged material was not apparent at stations where no values are indicated.

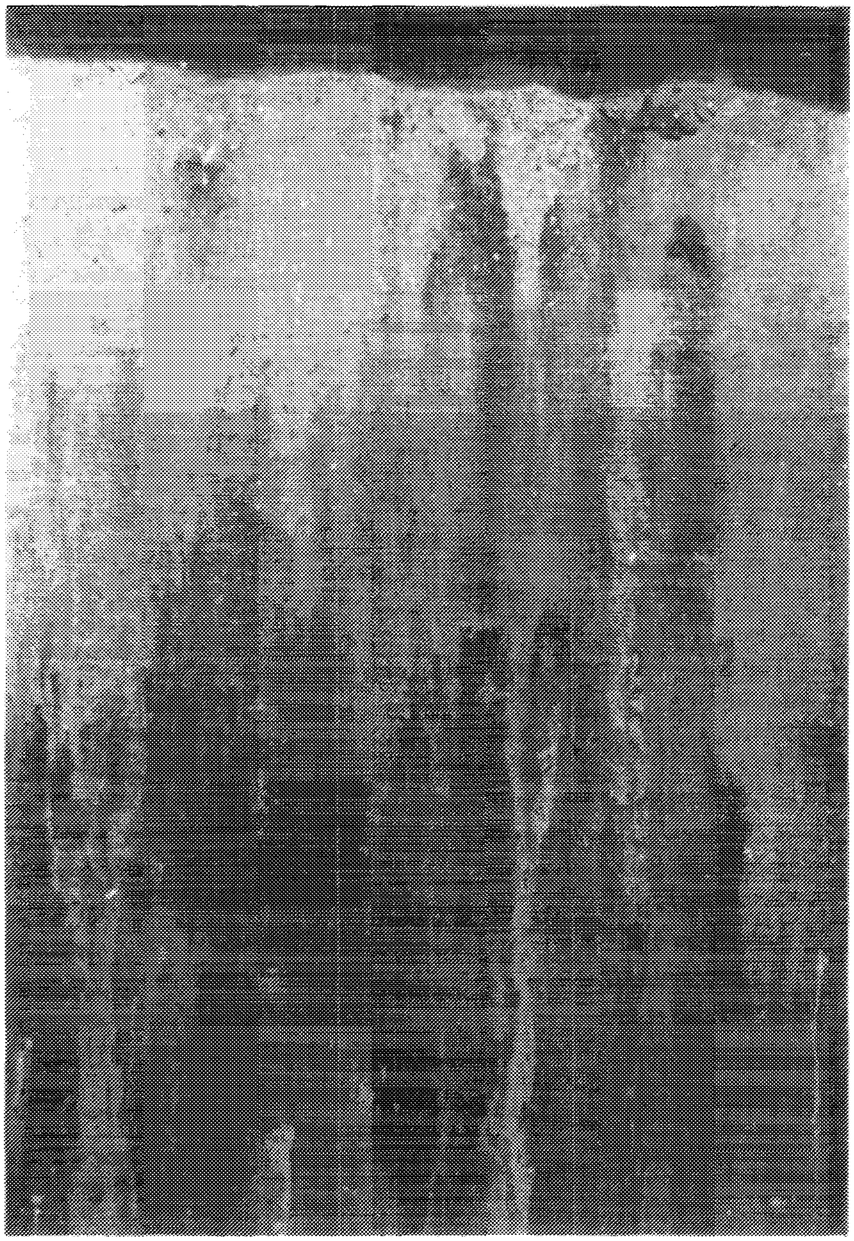


Figure 3-6. REMOTS® image from station 3-C directly on the WLIS "B" mound showing "fresh" dredged material exceeding the depth of penetration of the camera prism. The streaky appearance at depth is due to smearing by the REMOTS® prism and the high water content of this fine-grained (silt-clay) material. It is notable that a relatively deep RPD has developed since the material was deposited. Scale of image = 1X.

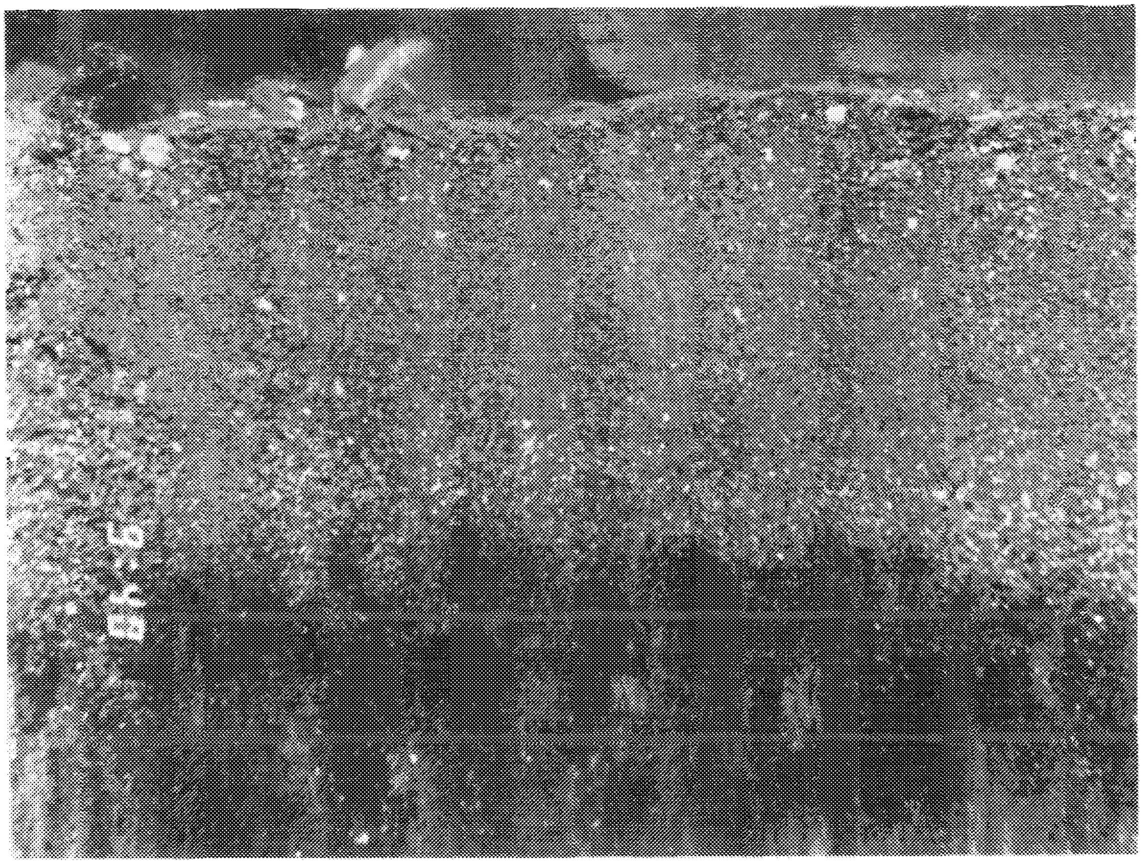


Figure 3-7. REMOTS® image from station 5-C at the WLIS "B" mound showing poorly-sorted, "fresh" dredged material distinguished by its significant sand component. This material exceeds the depth of prism penetration in this image. Scale = 1X.

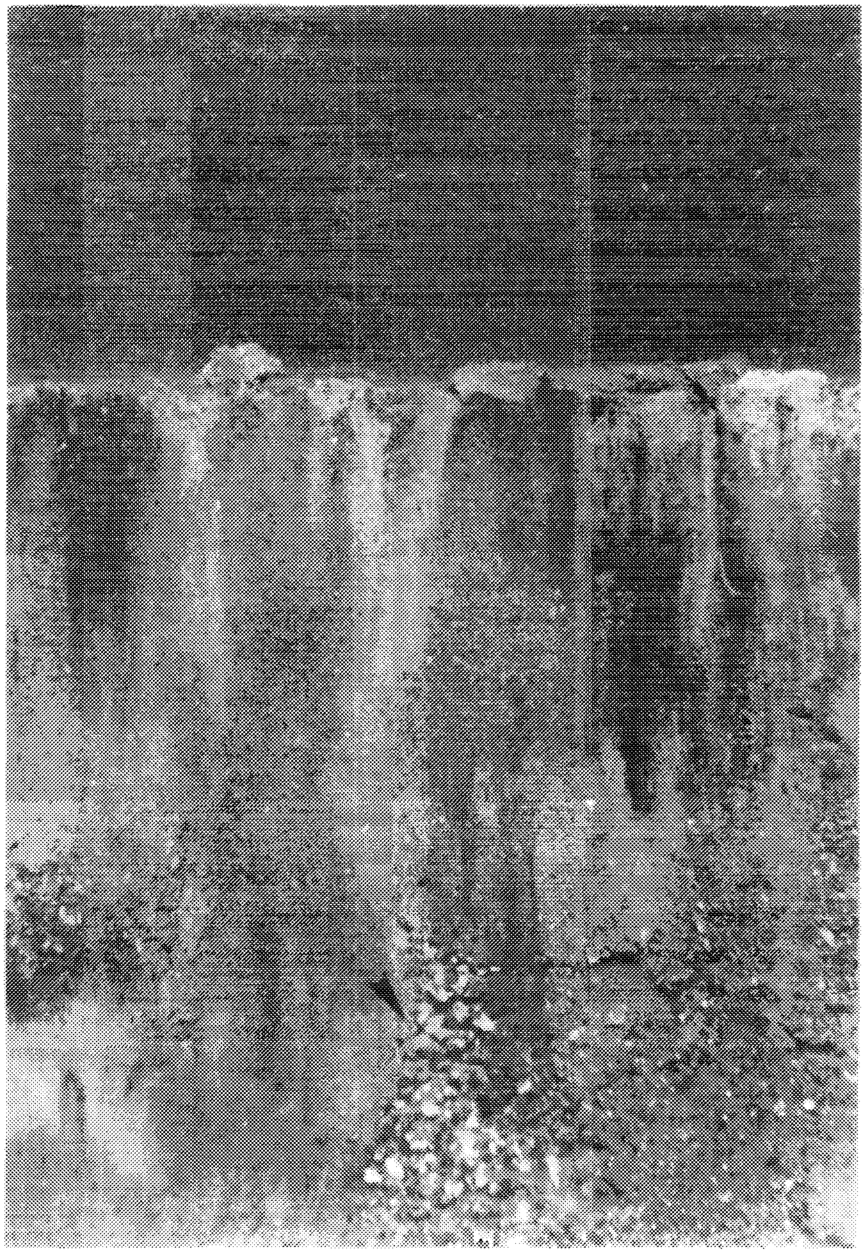


Figure 3-8. Discontinuous sand layers at depth (arrow) distinguish the relict dredged material in this REMOTS® image from station 3-G. This station was located at disposal mound "C". Scale of image = 1X.

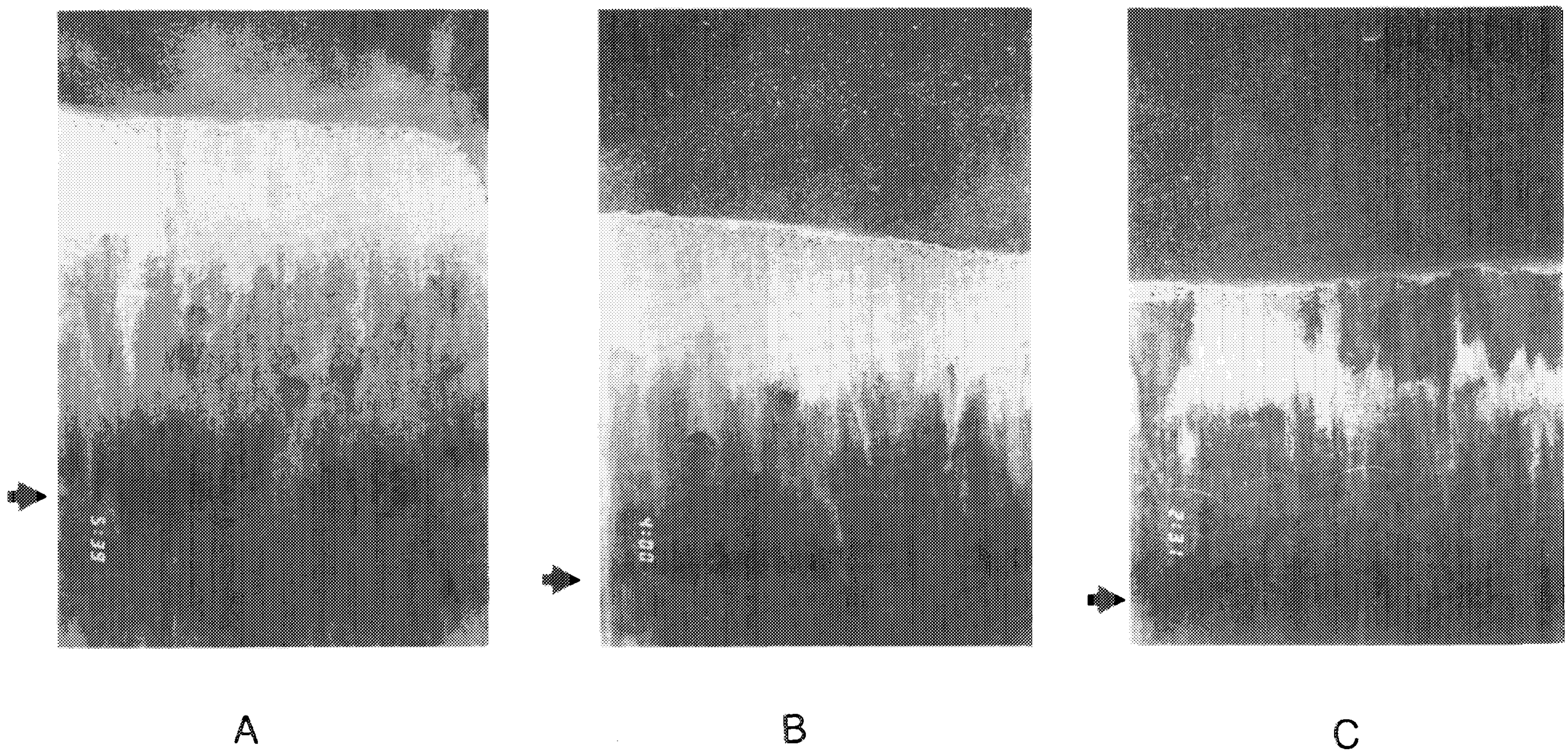


Figure 3-9. Relatively indistinct, discontinuous, low-reflectance bands (arrows) are visible at depth in these REMOTS images from stations 1-M (A), -1-A (B), and -1-I (C). Such low-reflectance bands were interpreted to represent the preservation of a relict dredged material horizon in the sediment. Approximate scale of images = 0.45X.

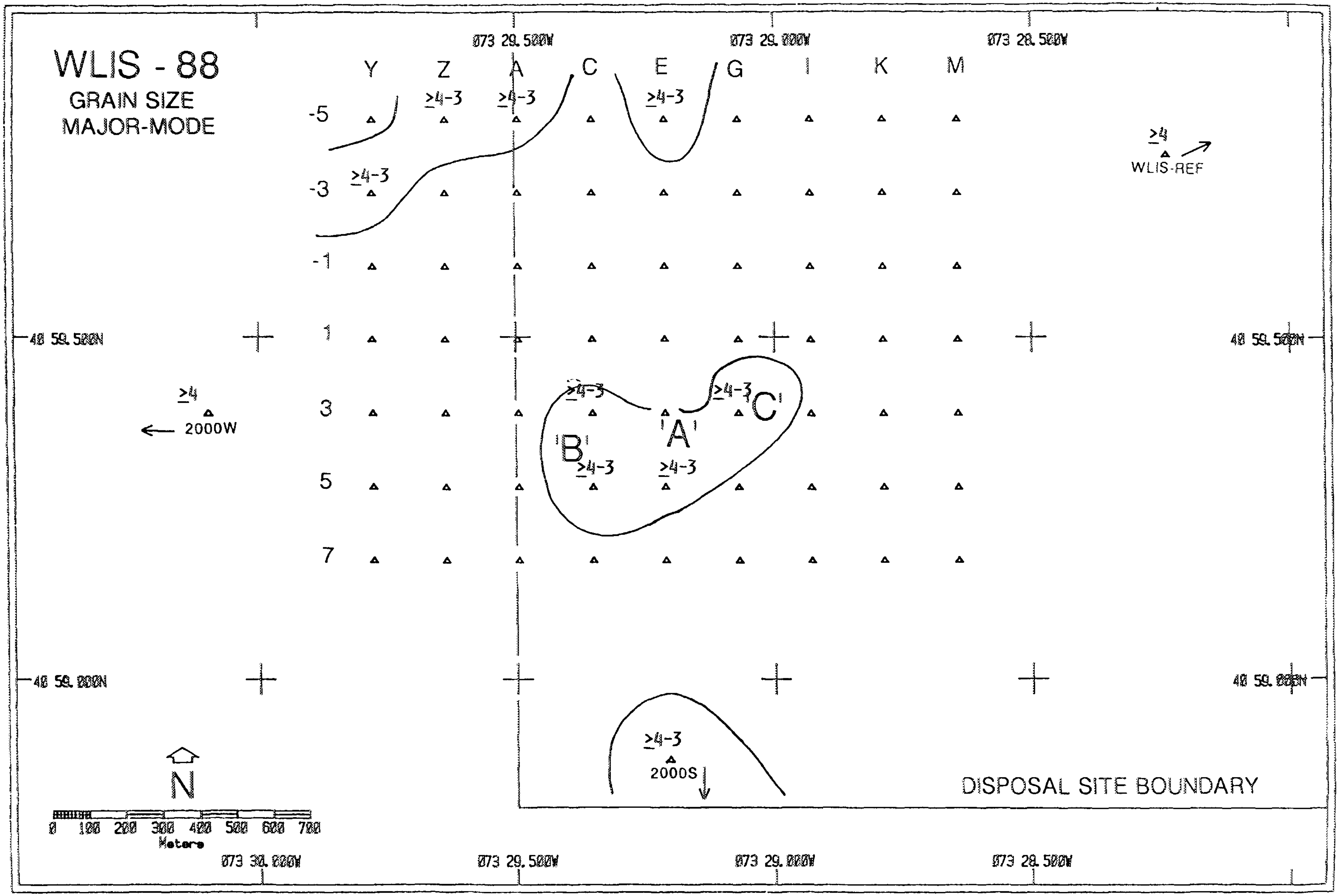


Figure 3-10. Map of sediment grain size major mode (in phi units) at the WLIS disposal site, July 1988. The contours delimit areas having a major mode of >4-3 phi (fine sand/silt/clay). Sediments at all other stations exhibited a major mode of > 4 phi (silt/clay).

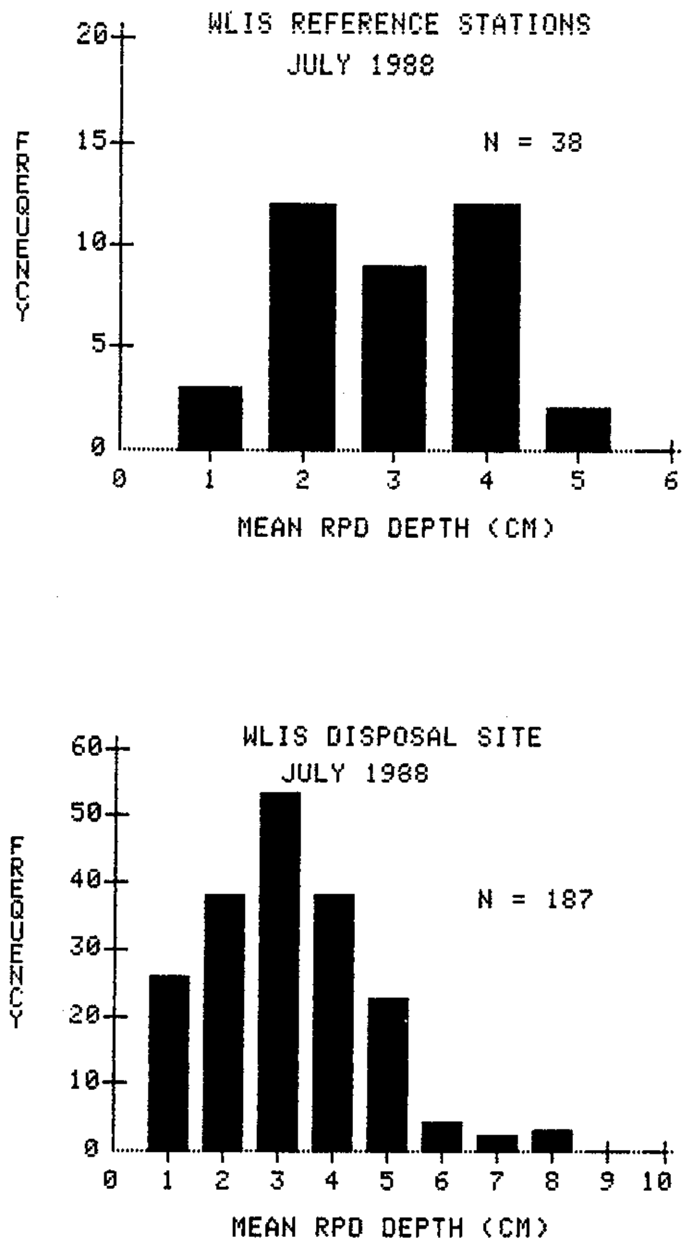


Figure 3-11. Frequency distributions of apparent RPD depths for all replicates at both the reference and onsite REMOTS® stations at WLIS, July 1988.

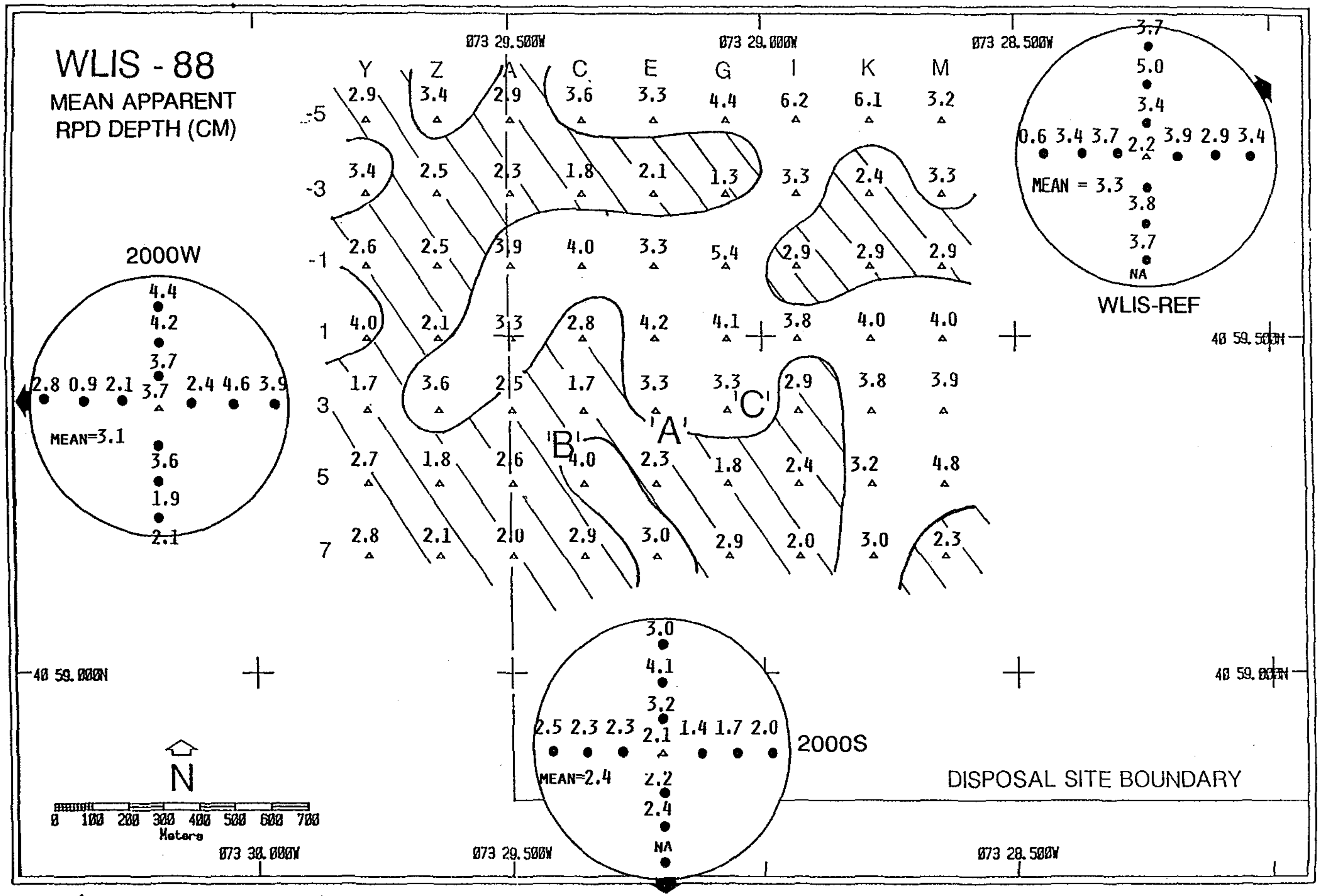


Figure 3-12. The distribution of apparent RPD depths (cm), averaged by station, at the WLIS disposal site in July 1988. The contours delimit stations having mean apparent RPD depths ≤ 3 cm. At the reference sites, the mapped RPD values are based on a single REMOTS® image per station.

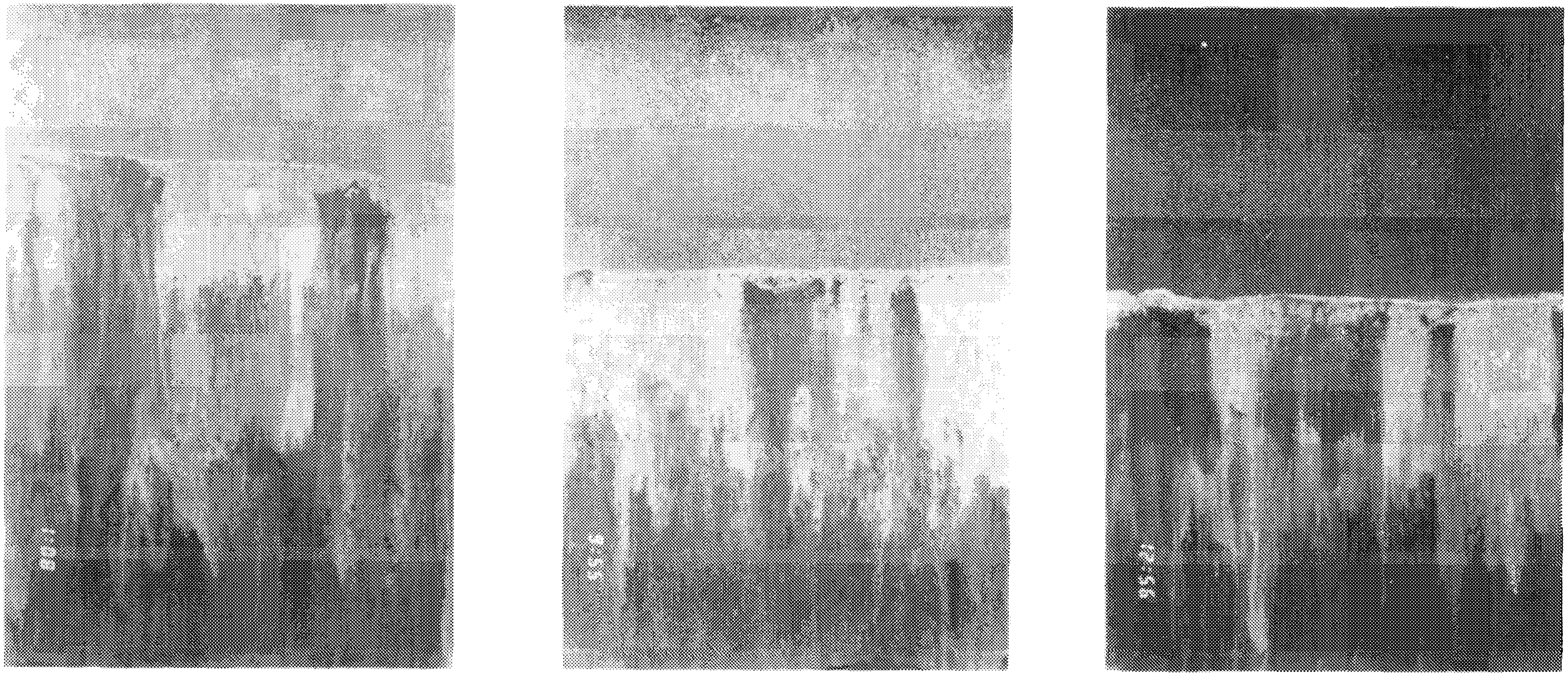


Figure 3-13. Three REMOTS images illustrating the patchy RPD layers which occurred at many disposal site and reference stations. These patchy RPD's were caused by reduced sediment from depth extending upward into the oxygenated zone and in many cases reaching the sediment surface. Approximate scale of images = 0.45X.

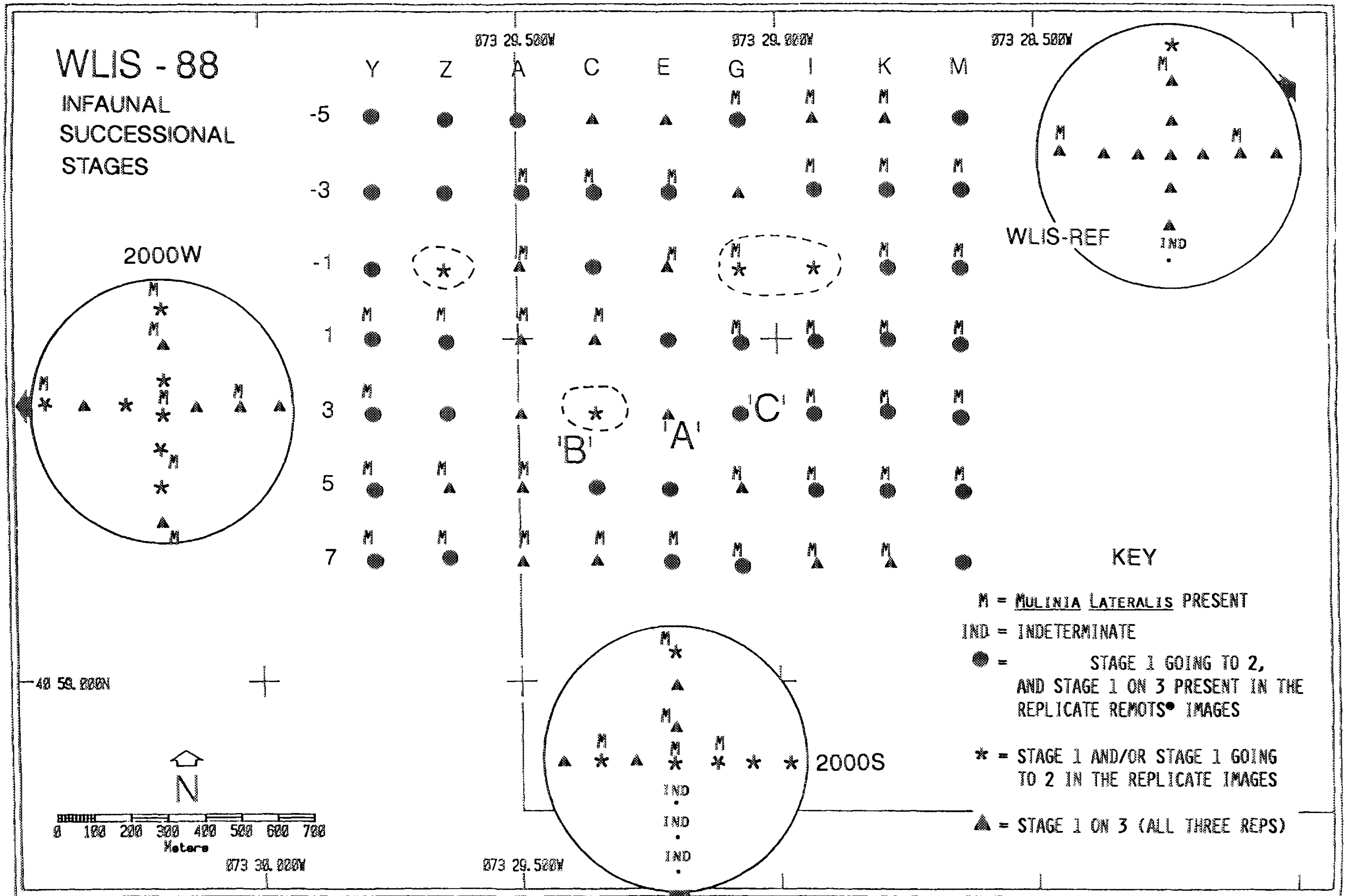


Figure 3-14. The distribution of infaunal successional stages at the WLIS disposal site, July 1988. The contours delimit areas which had only Stage I and/or Stage I going to II taxa apparent in the replicate REMOTS® images. At least one replicate image showed evidence of Stage III taxa at all the other disposal site stations. Successional stages mapped at the reference sites were based on a single REMOTS® image per station.

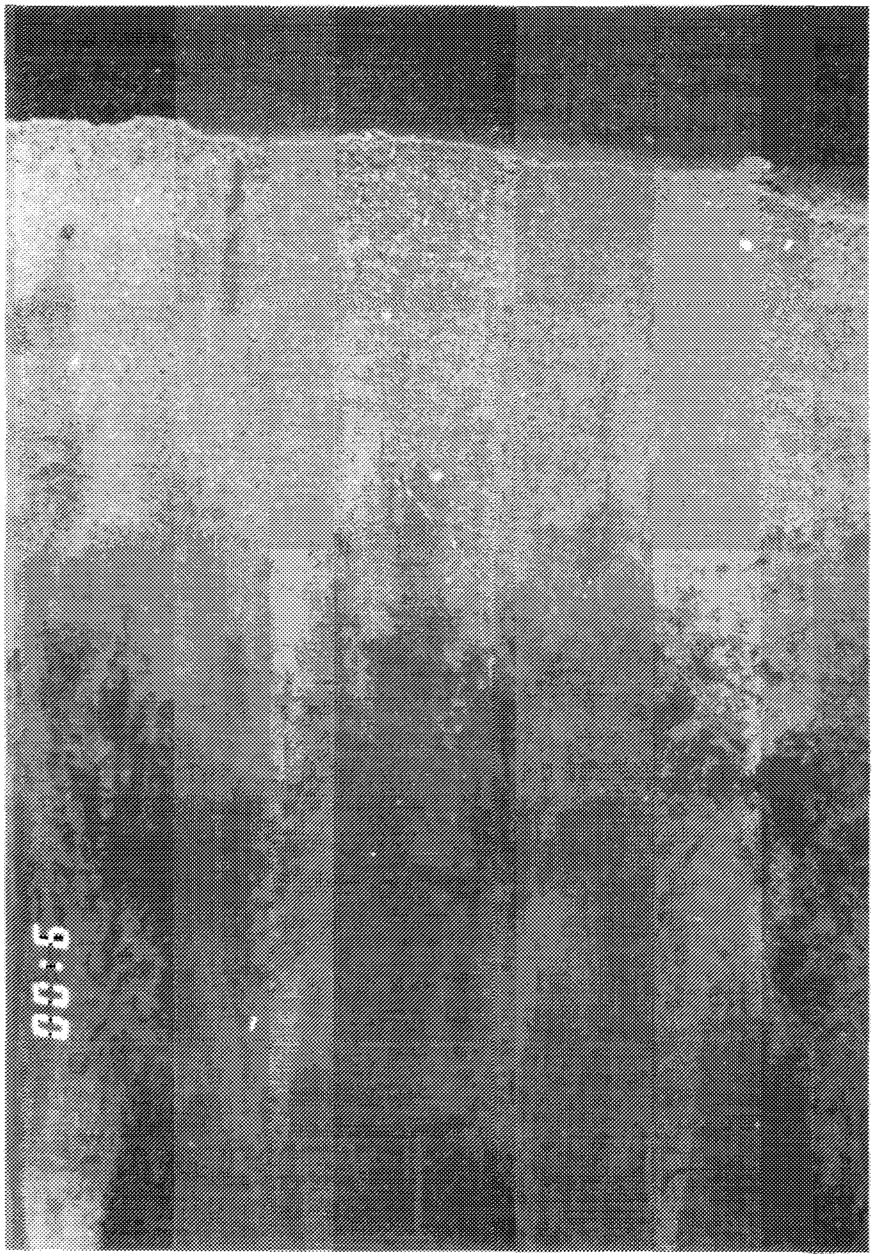


Figure 3-15. REMOTS® image from station 3-K showing a well-established Stage I assemblage consisting of small, tubicolous polychaetes at the sediment surface, as well as the near-surface dwelling, opportunistic mactrid bivalve *Mulinia lateralis* just below the surface (arrow). The dark, thread-like structures barely visible within the RPD layer are probably deposit-feeding errant polychaetes. Very small, shallow-dwelling bivalves also occur below the sediment surface, giving this image a Stage I going to II designation. Scale = 1X.

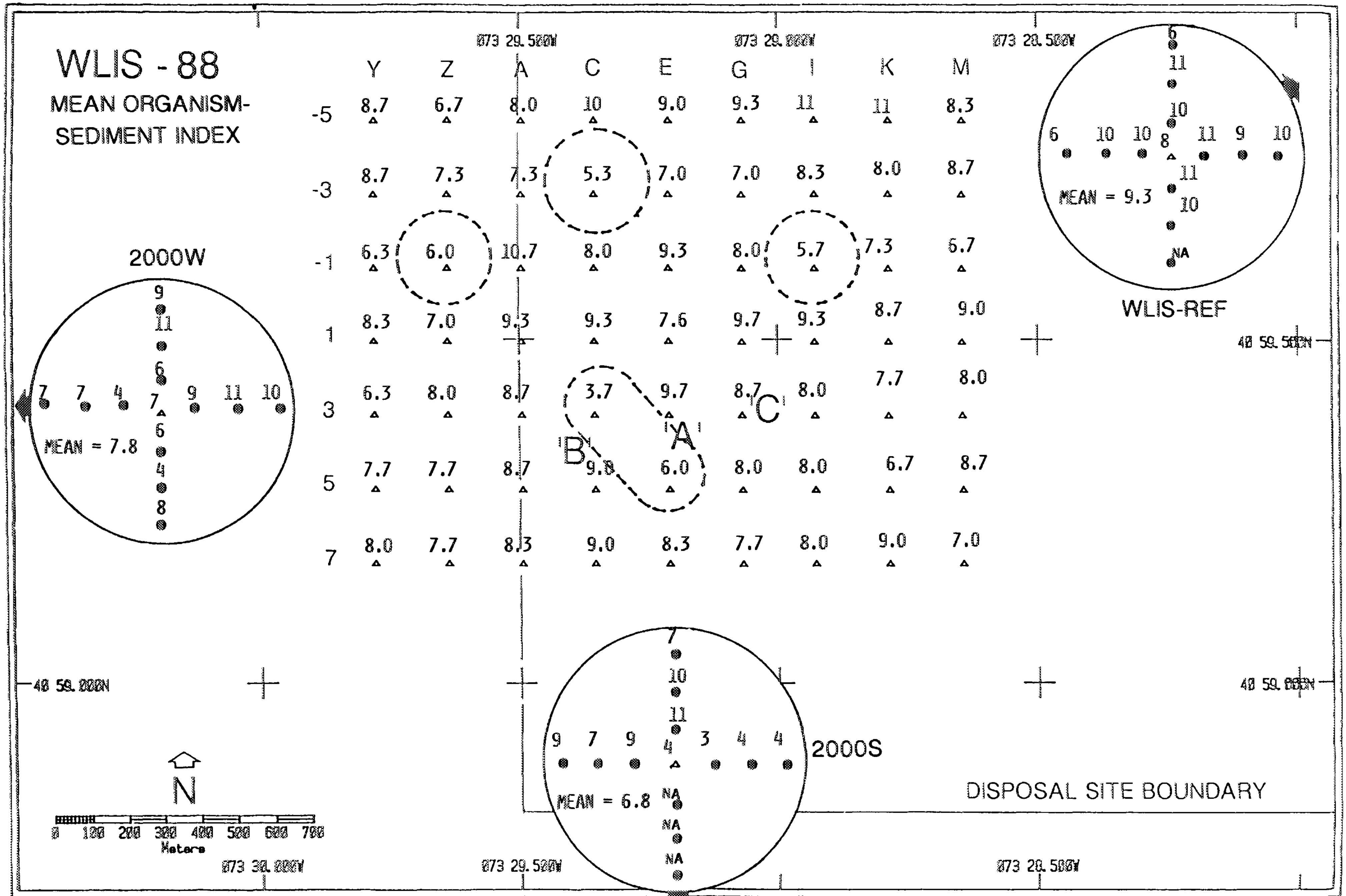


Figure 3-16. The distribution of Organism-Sediment Indices, averaged by station, at the WLIS disposal site in July 1988. The contours delimit stations having mean OSI values ≤ +6. OSI values at reference site stations were calculated based on a single REMOTS image. NA = not applicable (the OSI could not be calculated because the successional stage was indeterminate).

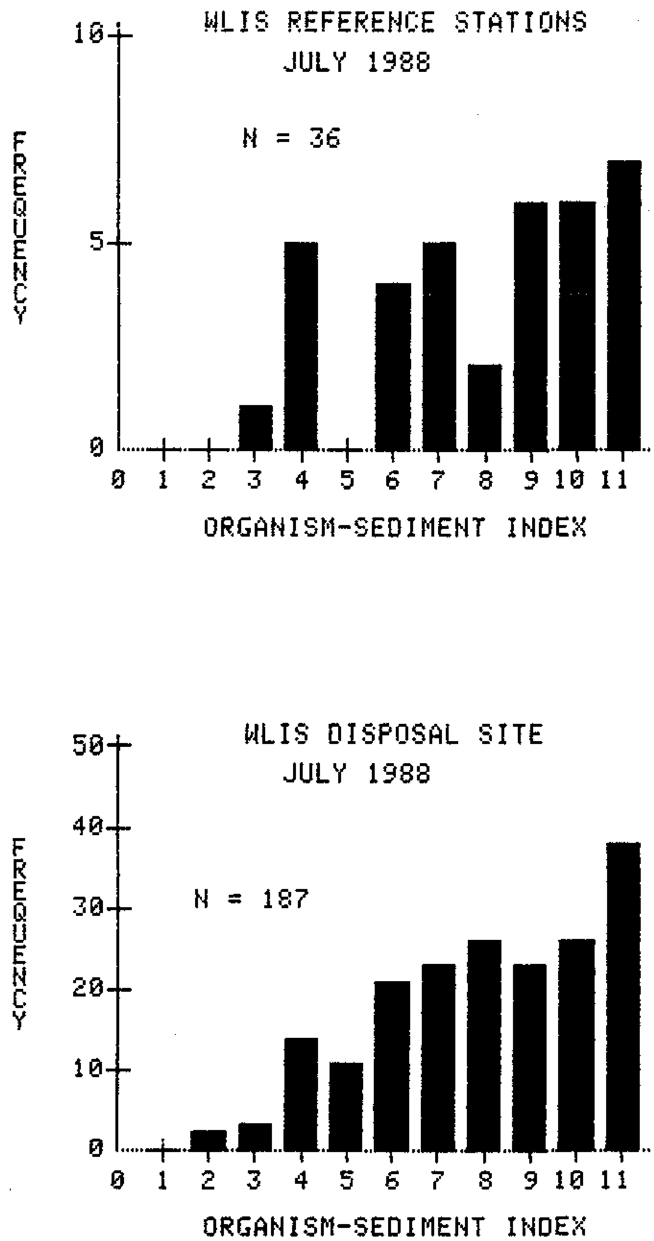


Figure 3-17. Frequency distributions of Organism-Sediment Index values for all replicates at both the reference and disposal site stations at WLIS, July 1988.

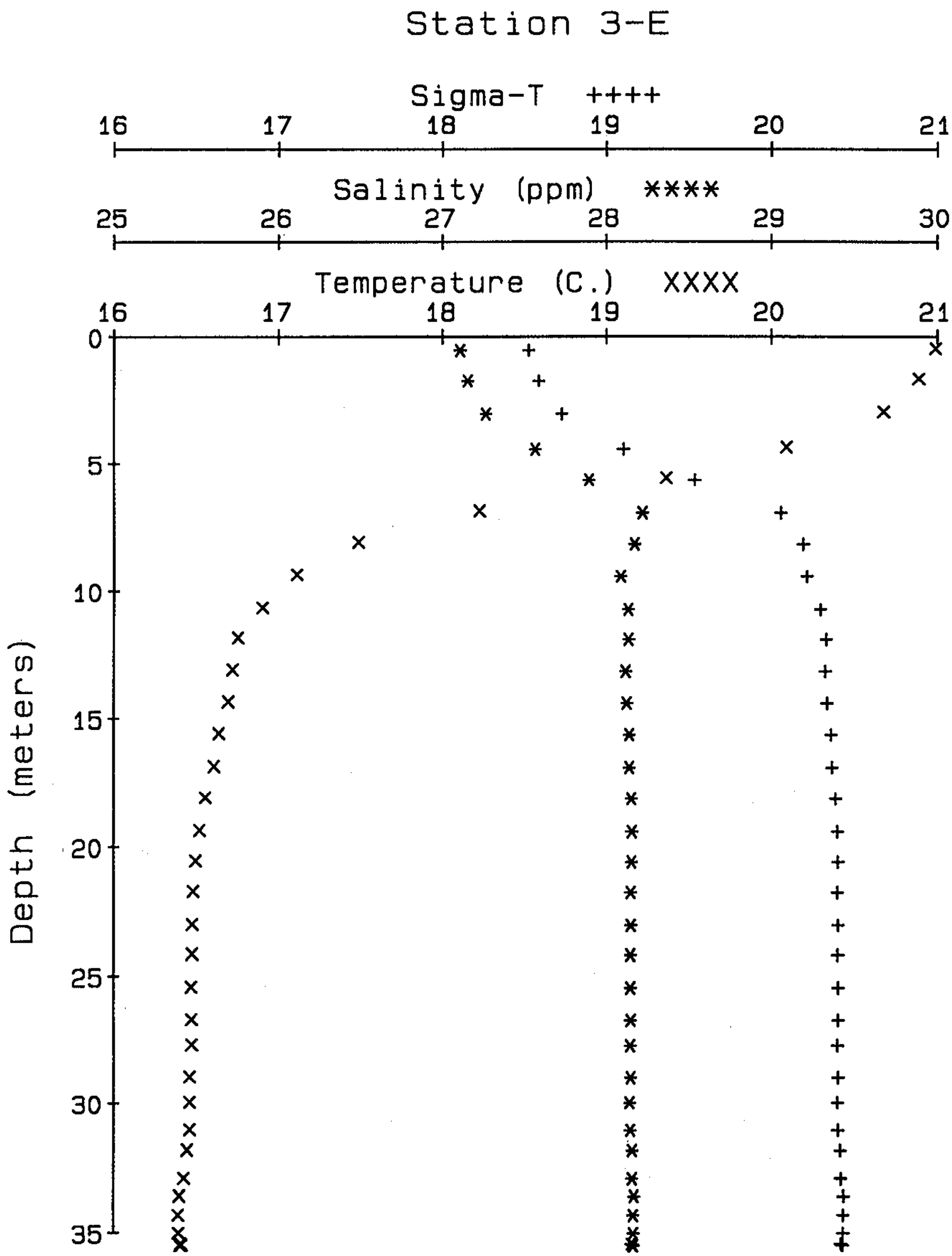
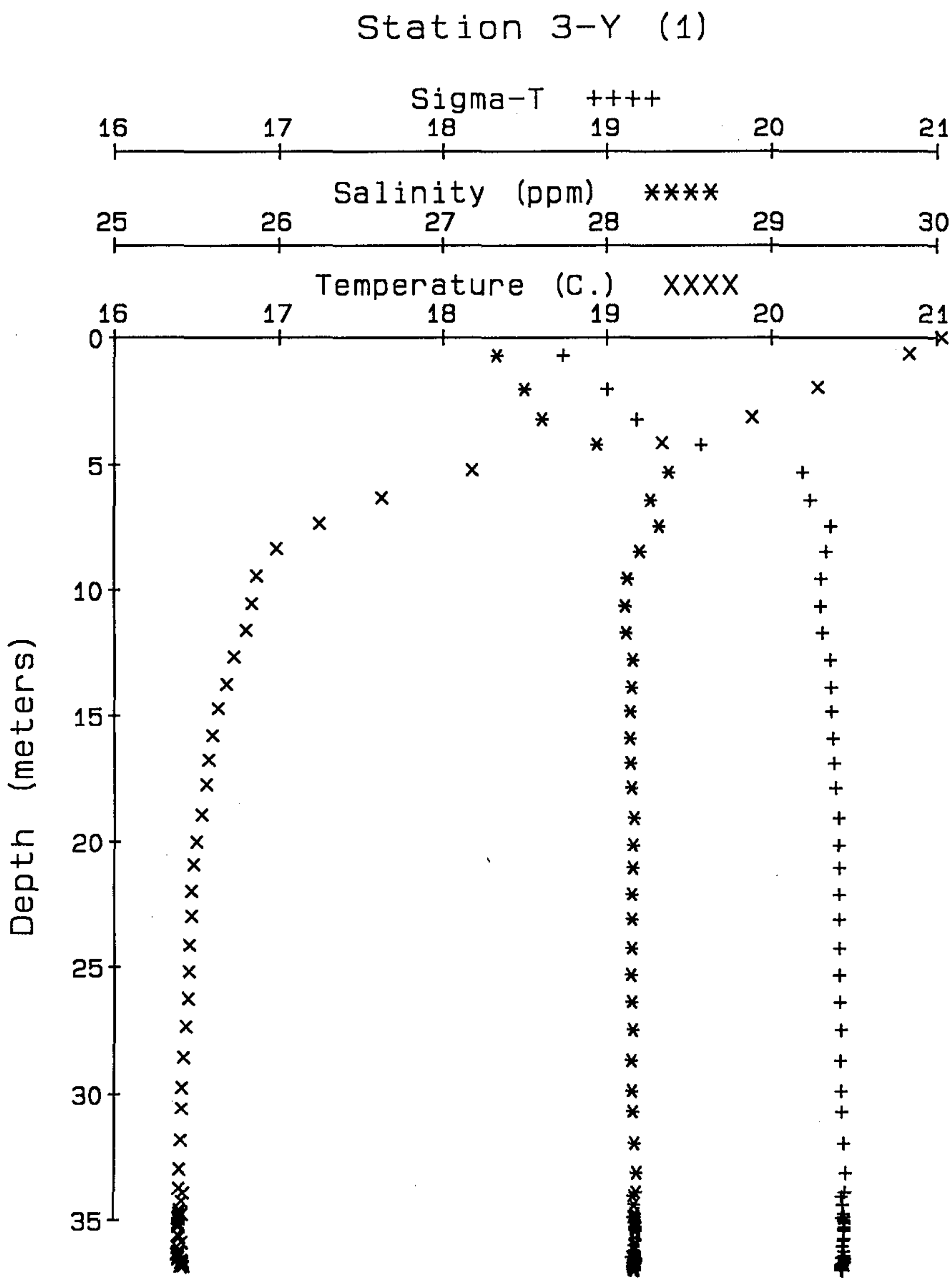
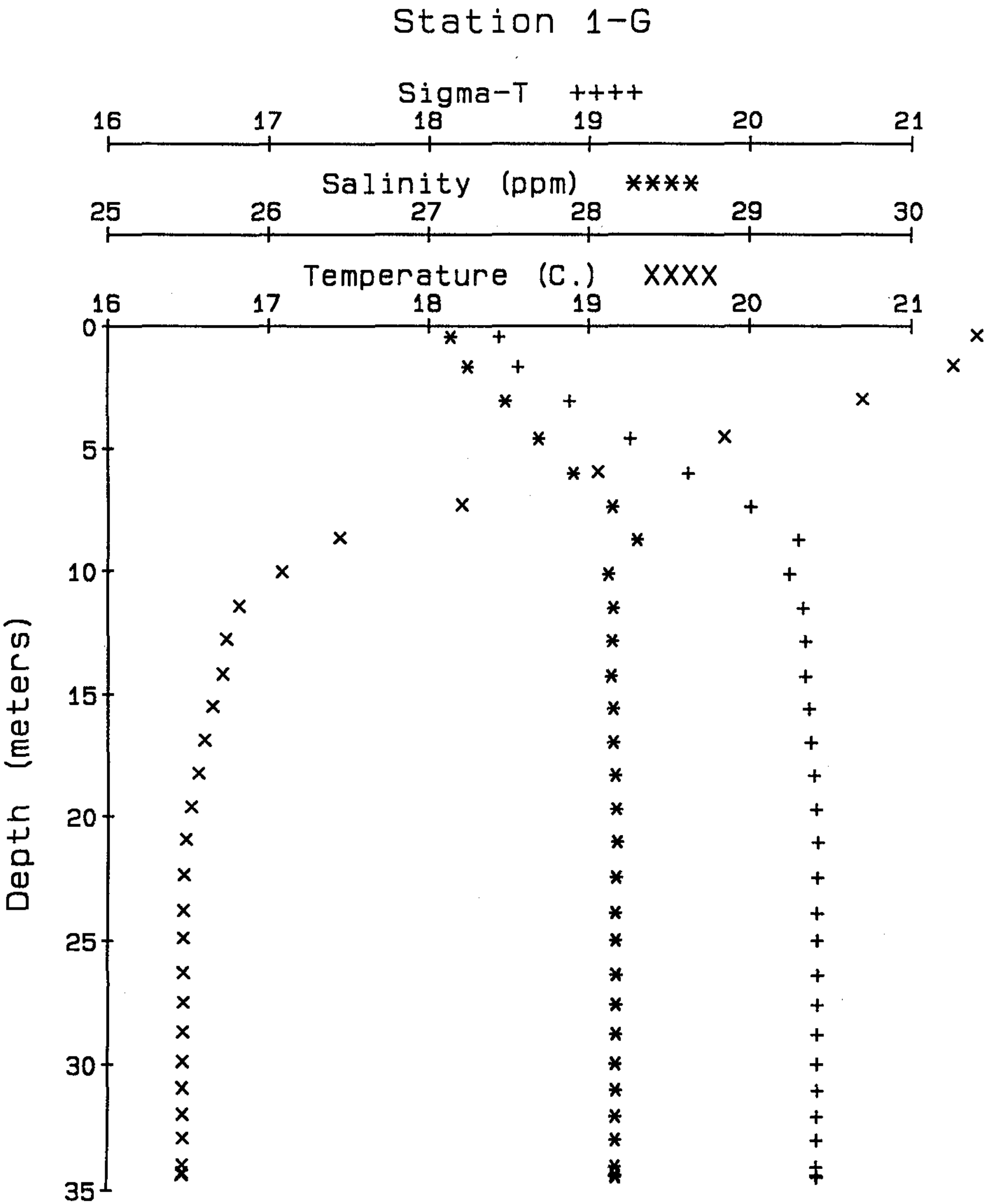


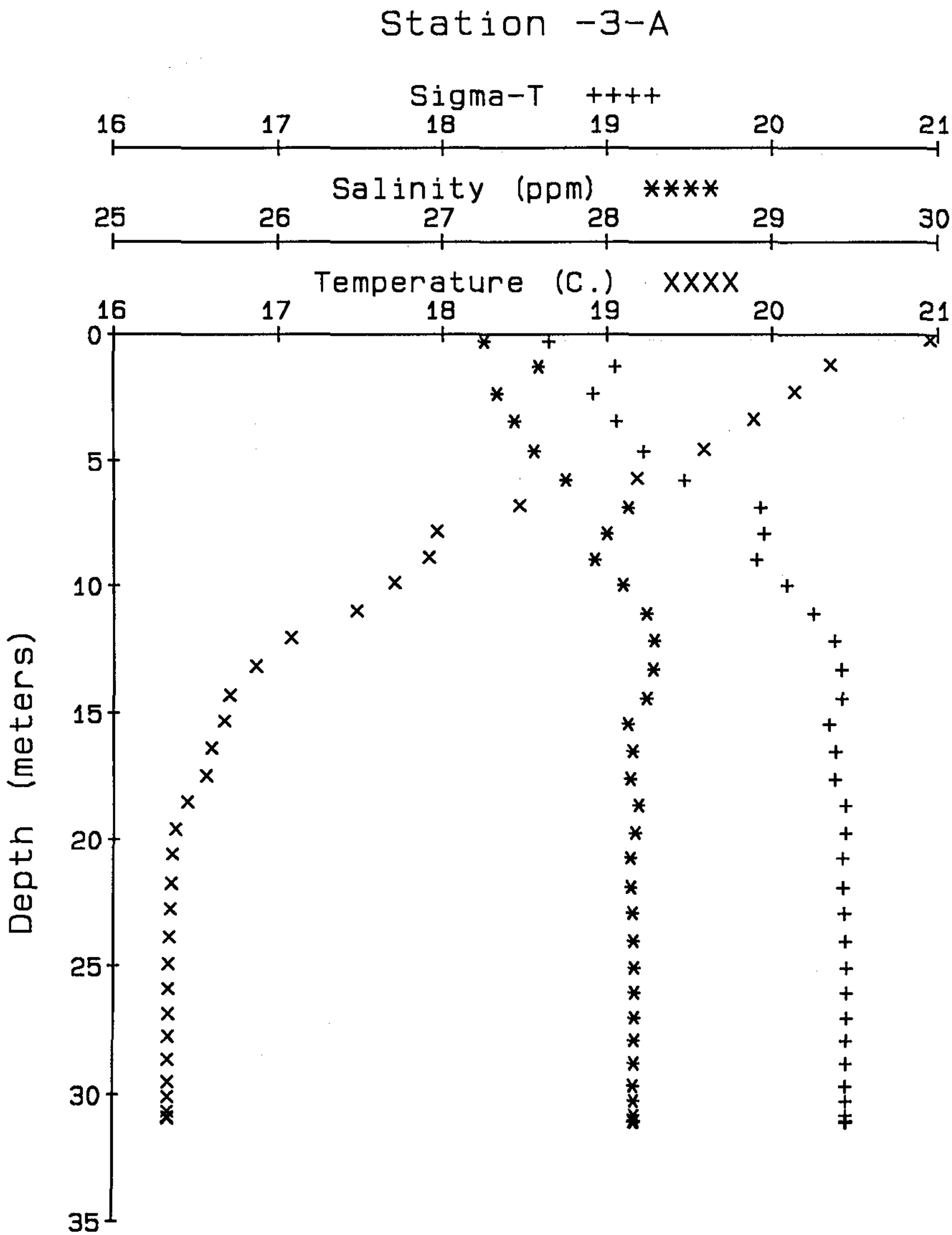
Figure 3-18. Representative CTD/DO plot obtained at WLIS station 3-E in July 1988.

APPENDIX

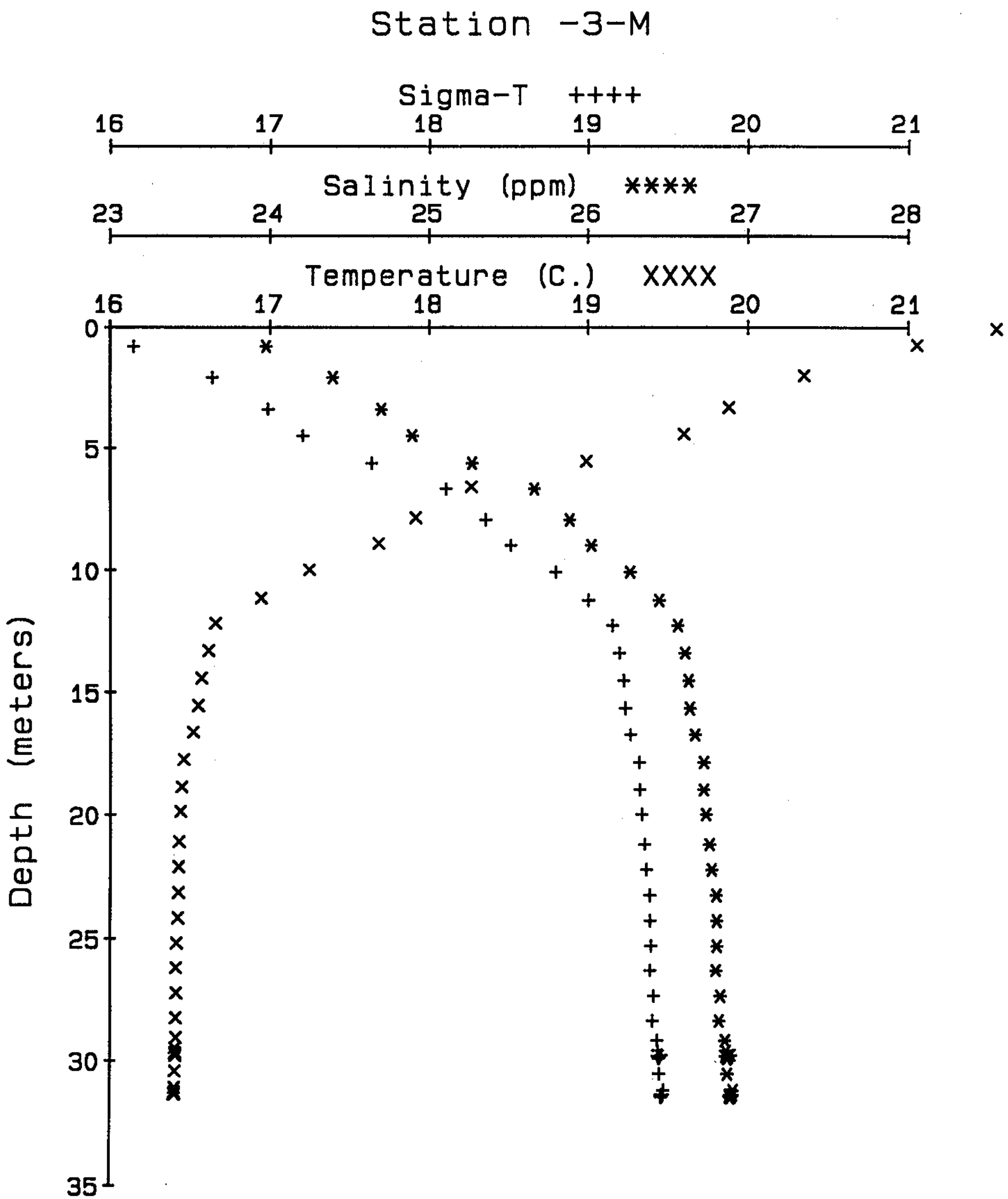


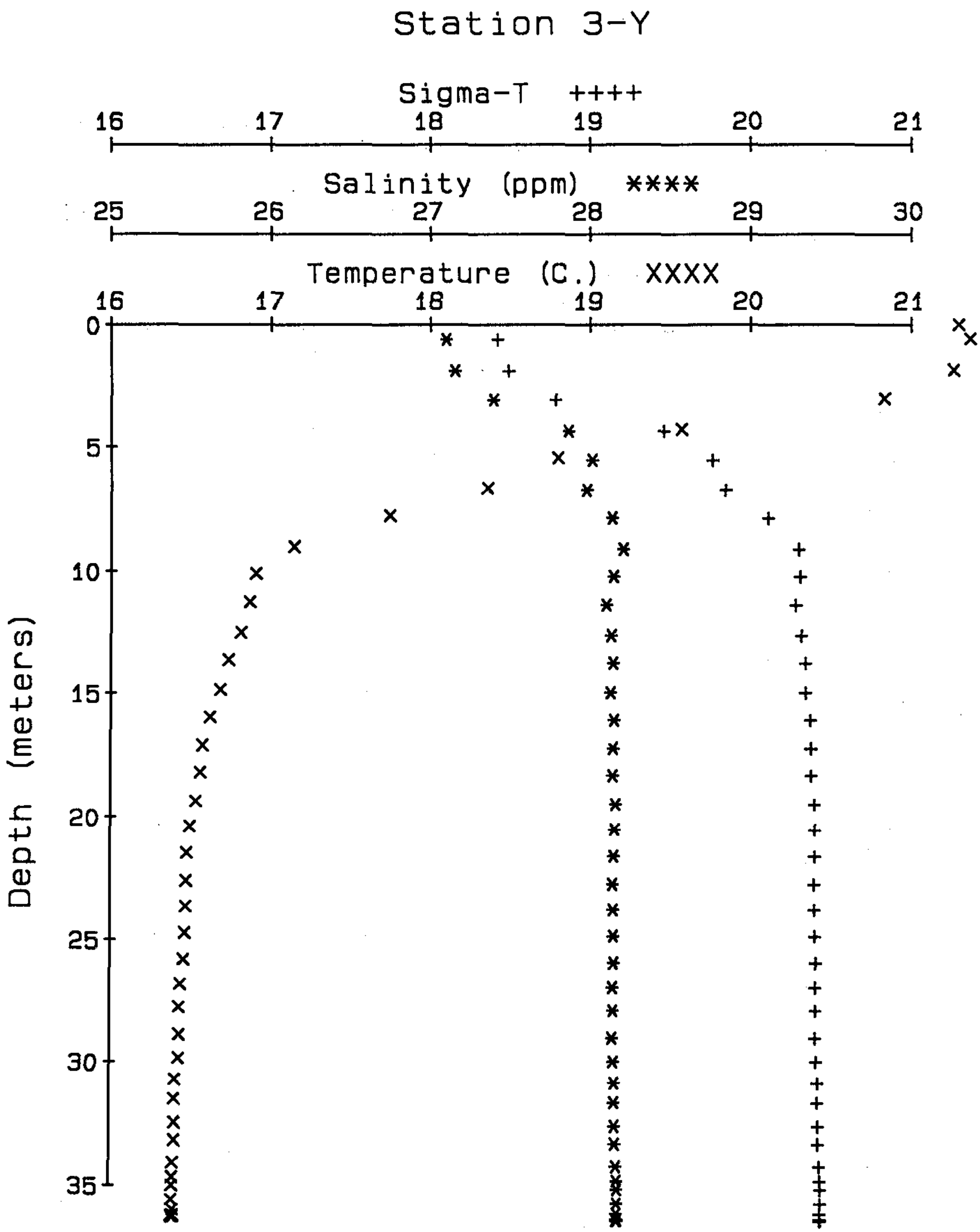
Station 3-Y (1)
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)

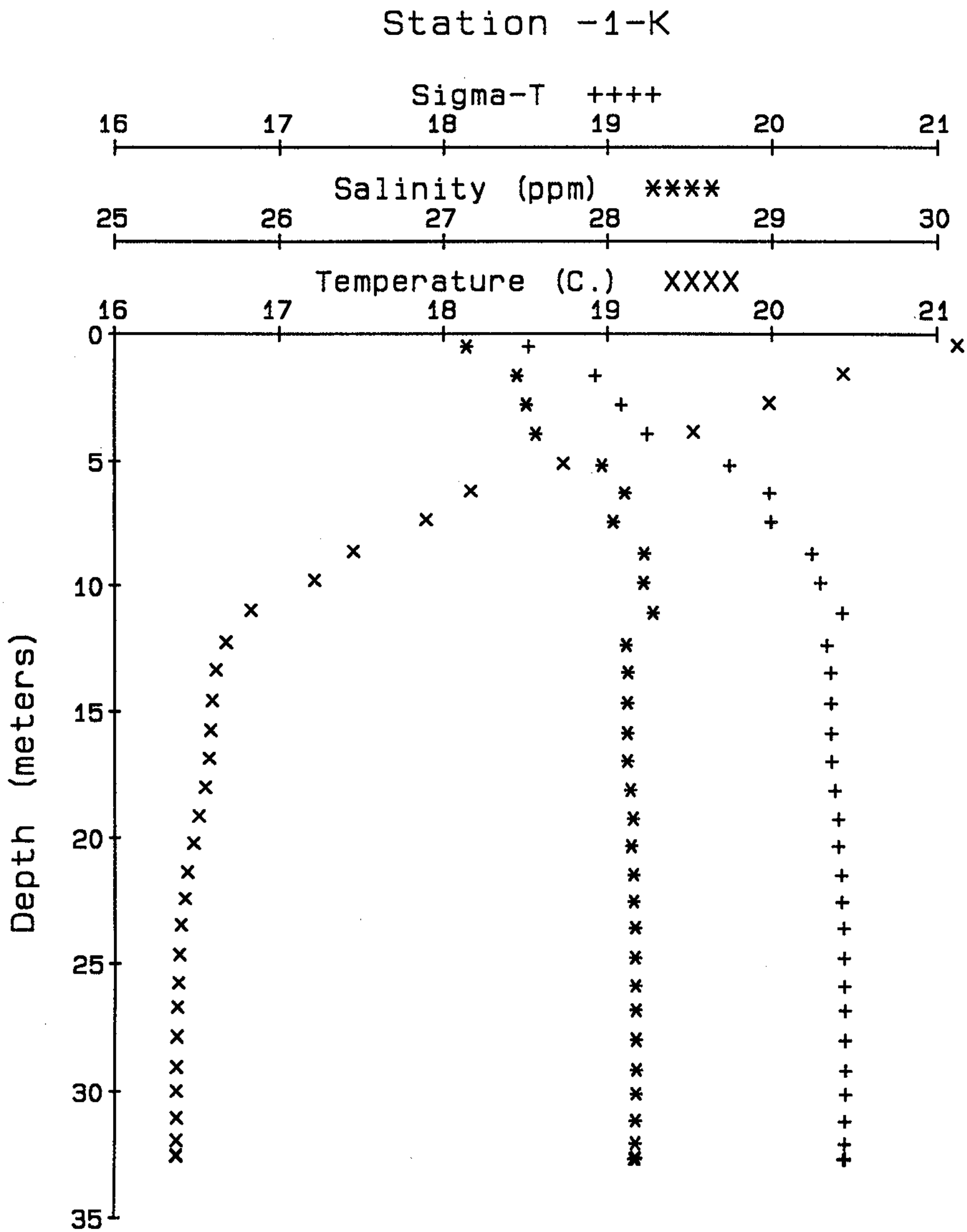

Station 1-G
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

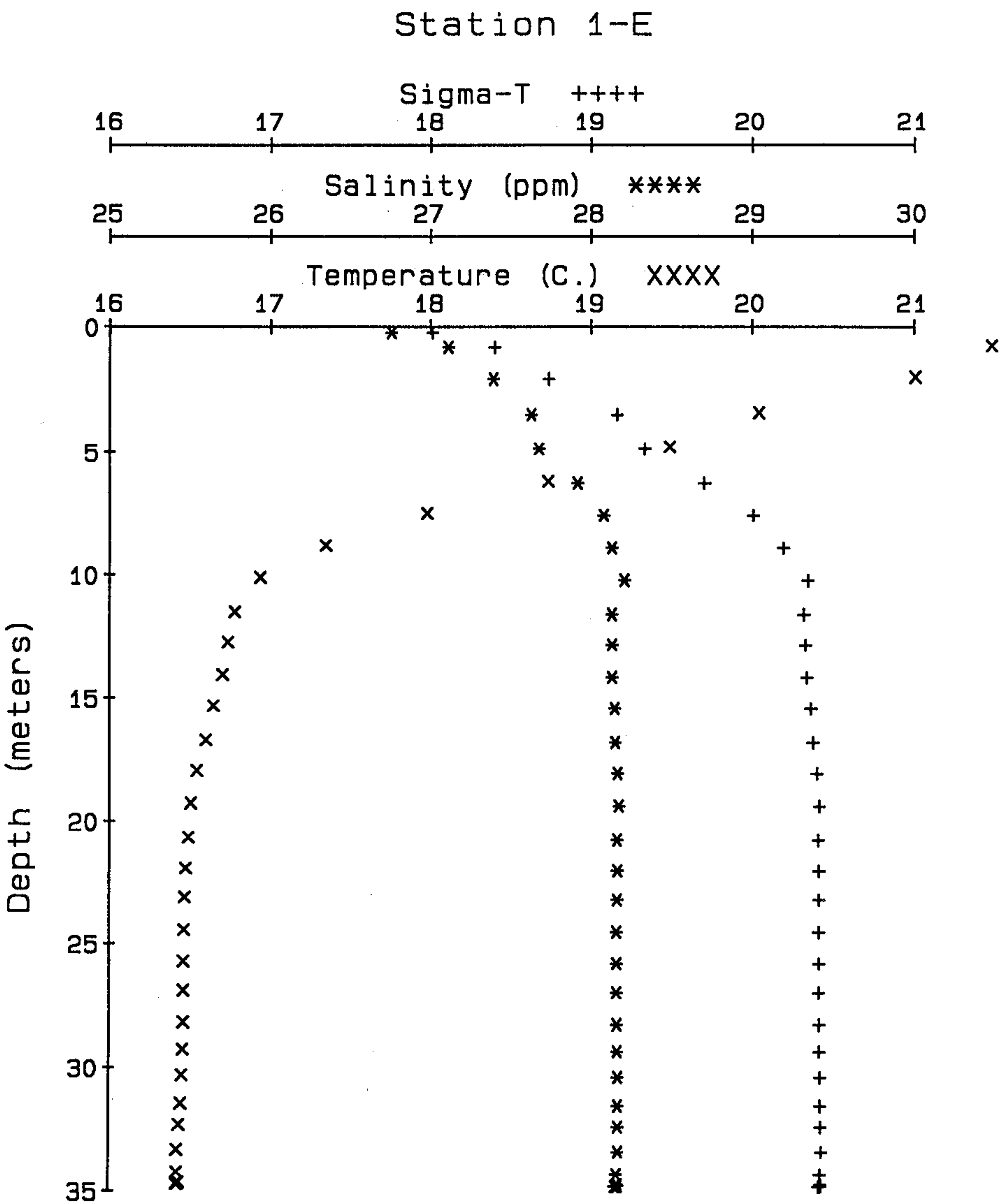


Station -3-A
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

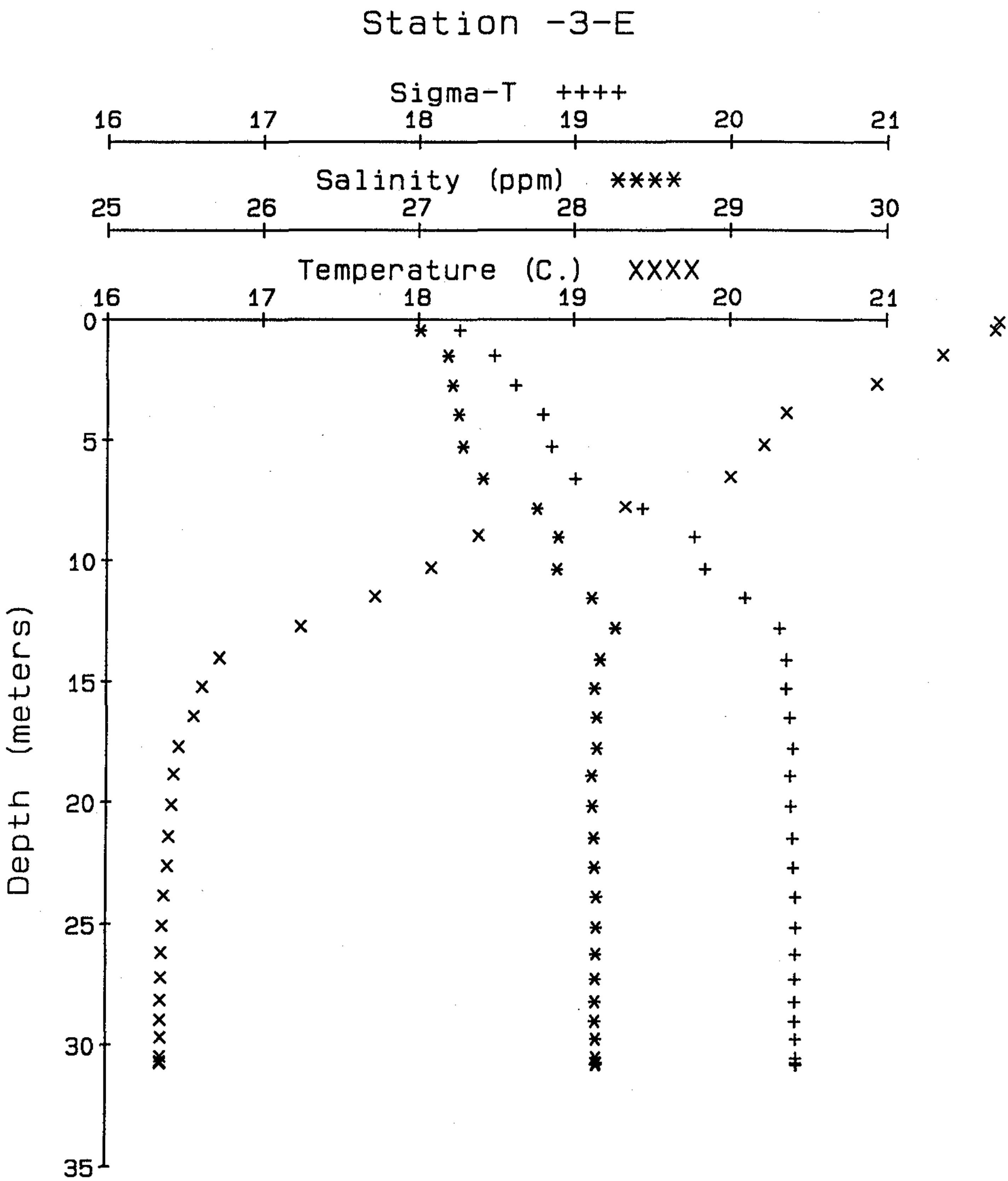

Station -3-M
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
23 24 25 26 27 28
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35


Station 3-Y
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)

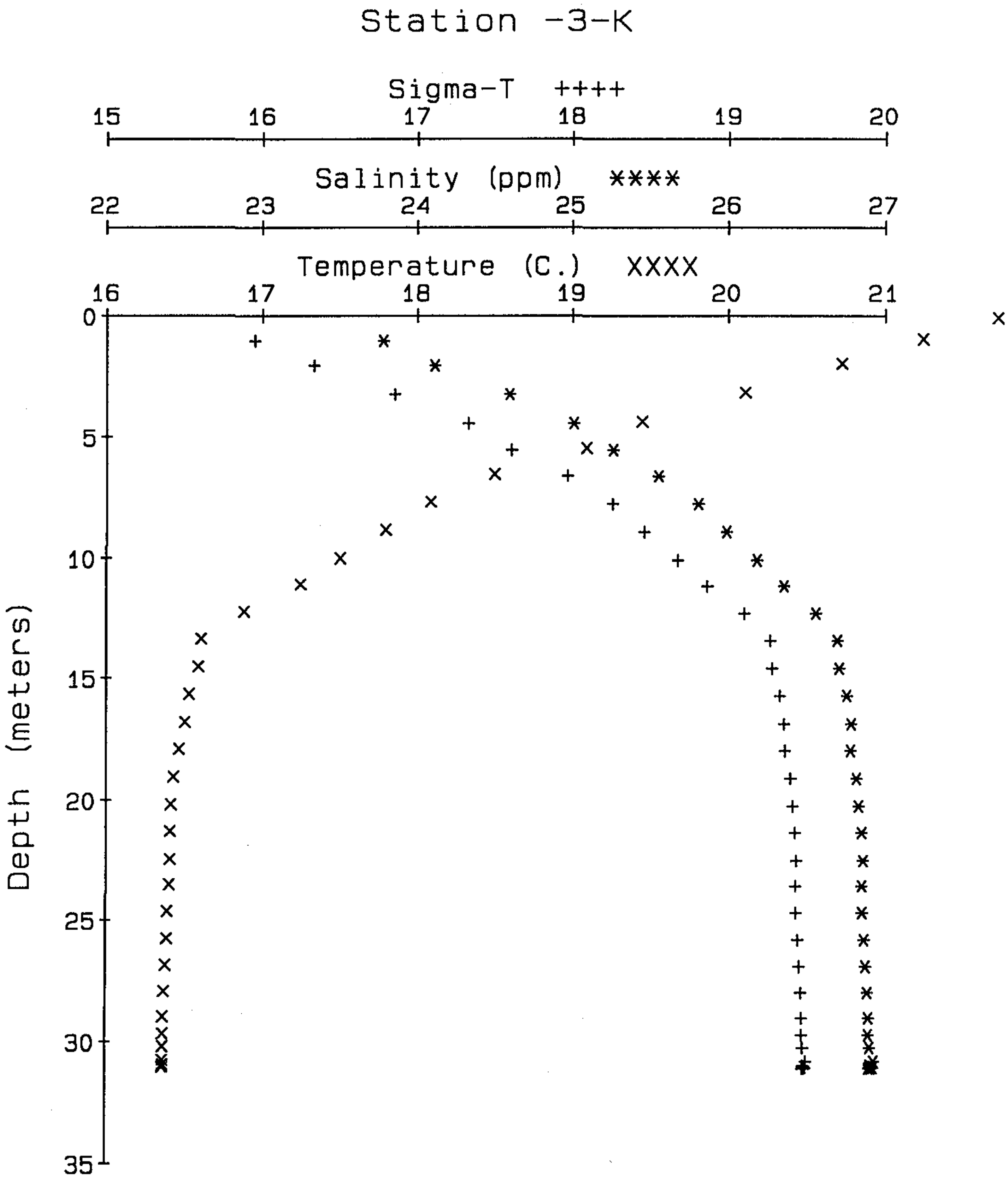

Station -1-K
Sigma-T ++++
16
17
18
19
20
21
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
16
17
18
19
20
21
Depth (meters)
0
5
10
15
20
25
30
35

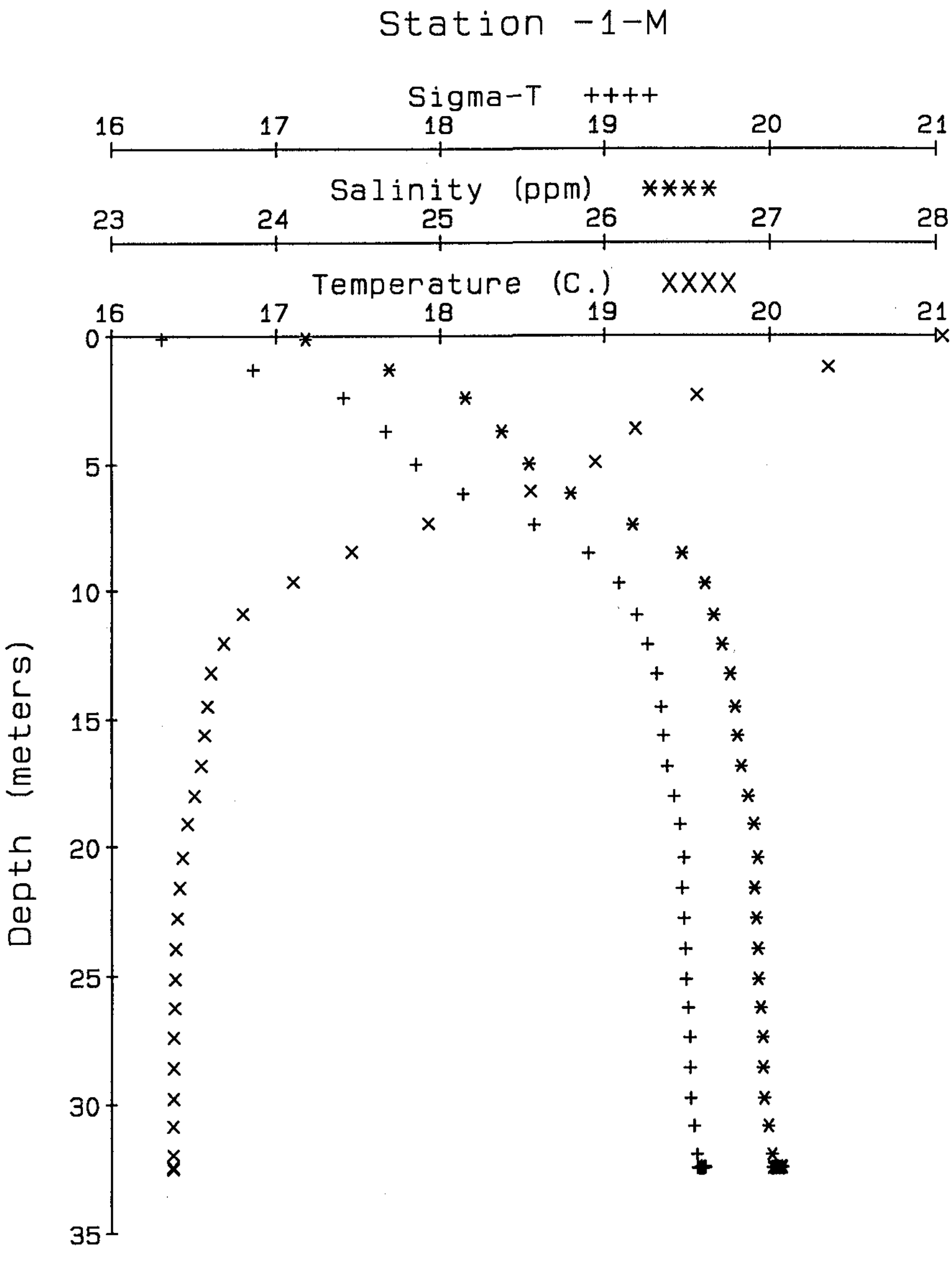


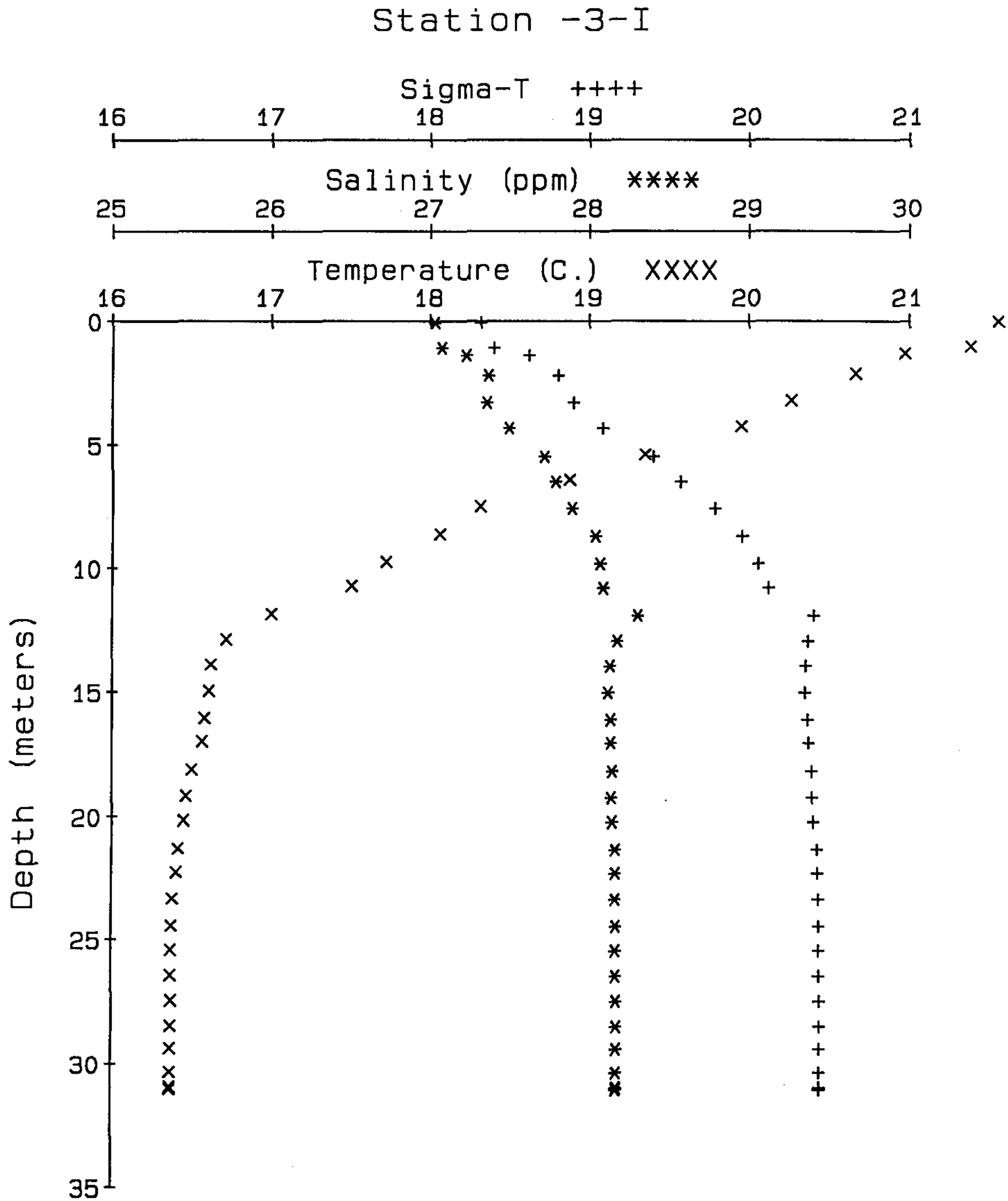
Station 1-E
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35



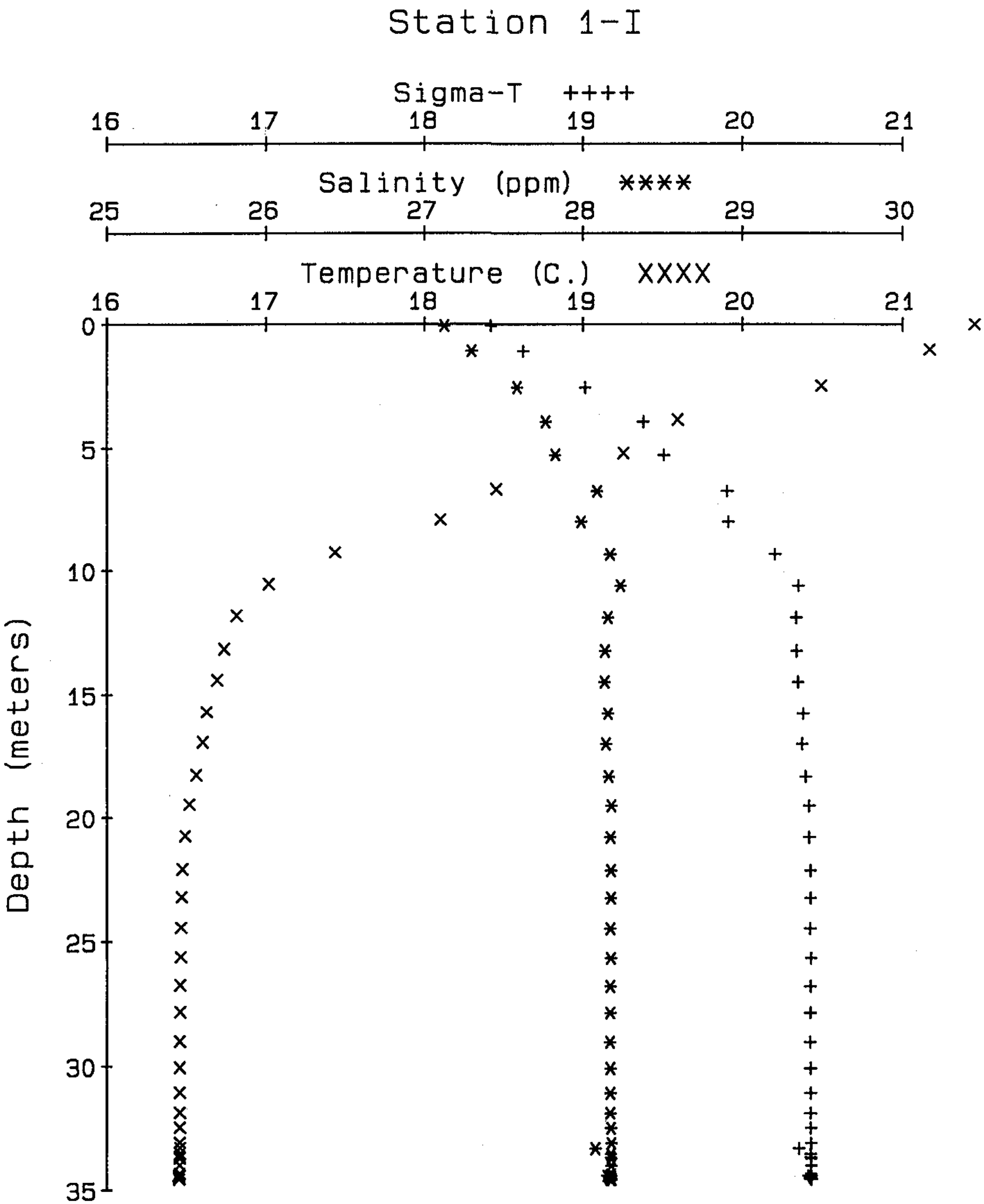
Station -3-E
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

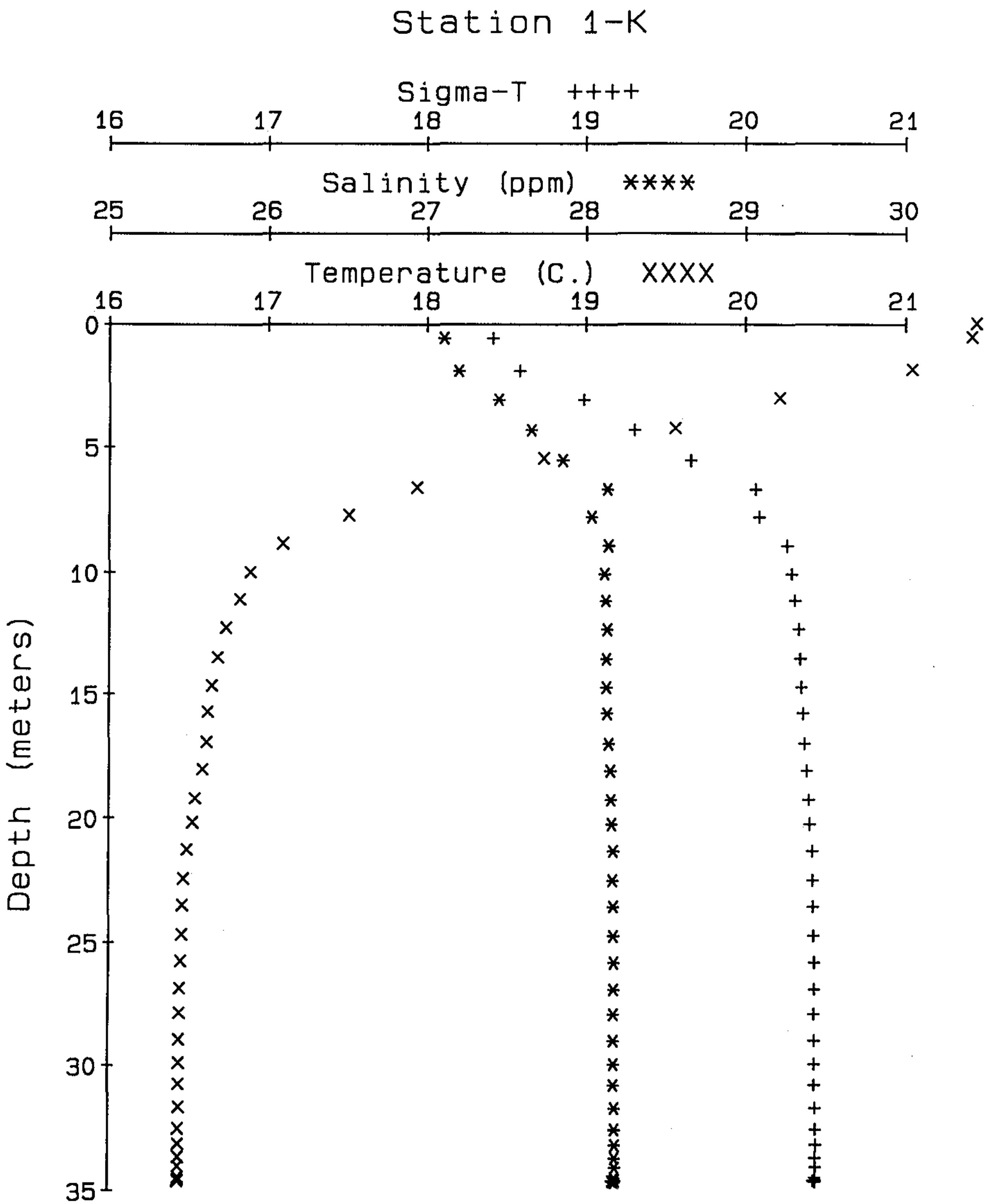

Station -3-K
Sigma-T ++++
15 16 17 18 19 20
Salinity (ppm) ****
22 23 24 25 26 27
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)


Station -1-M
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
23 24 25 26 27 28
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)



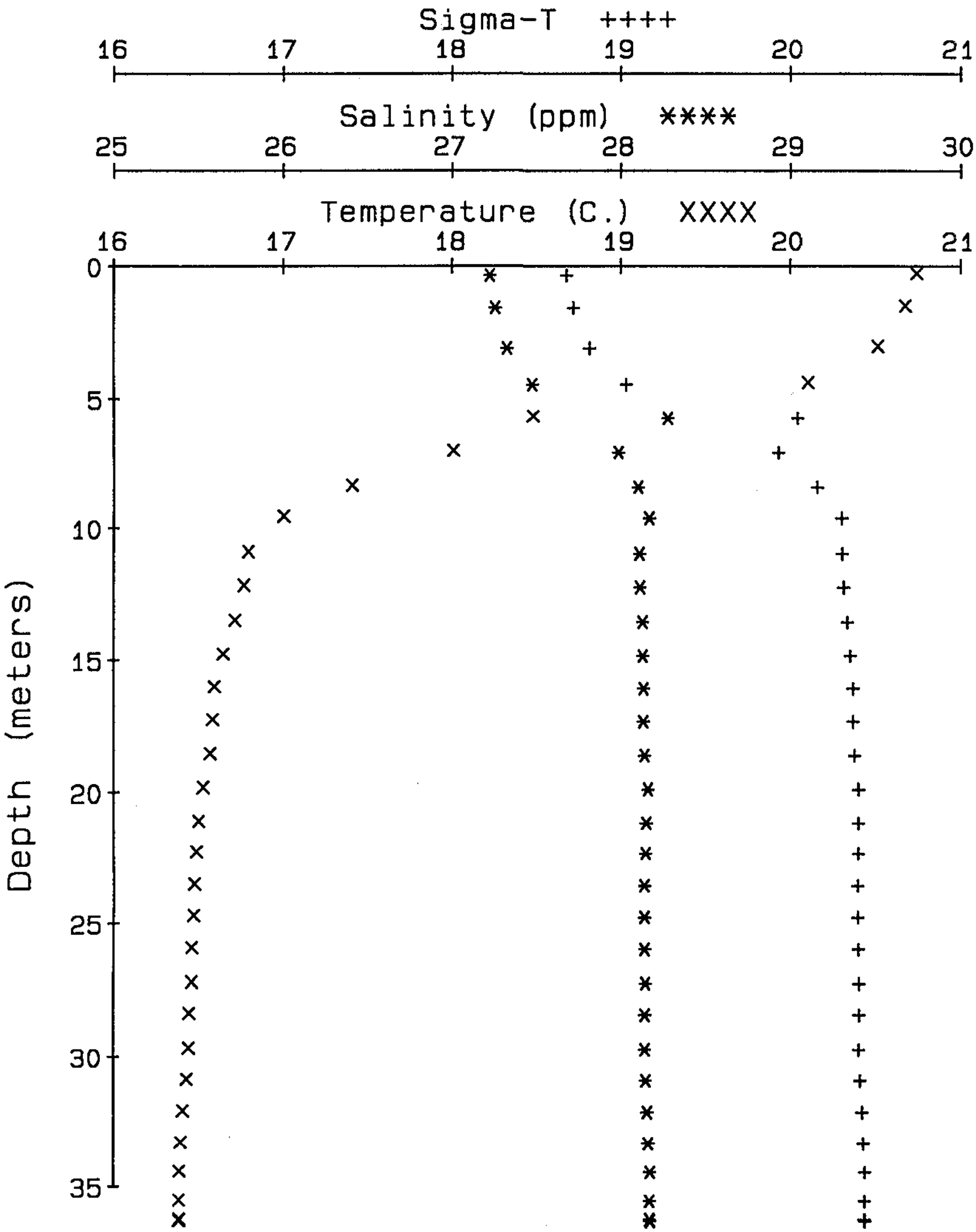
Station -3-I
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

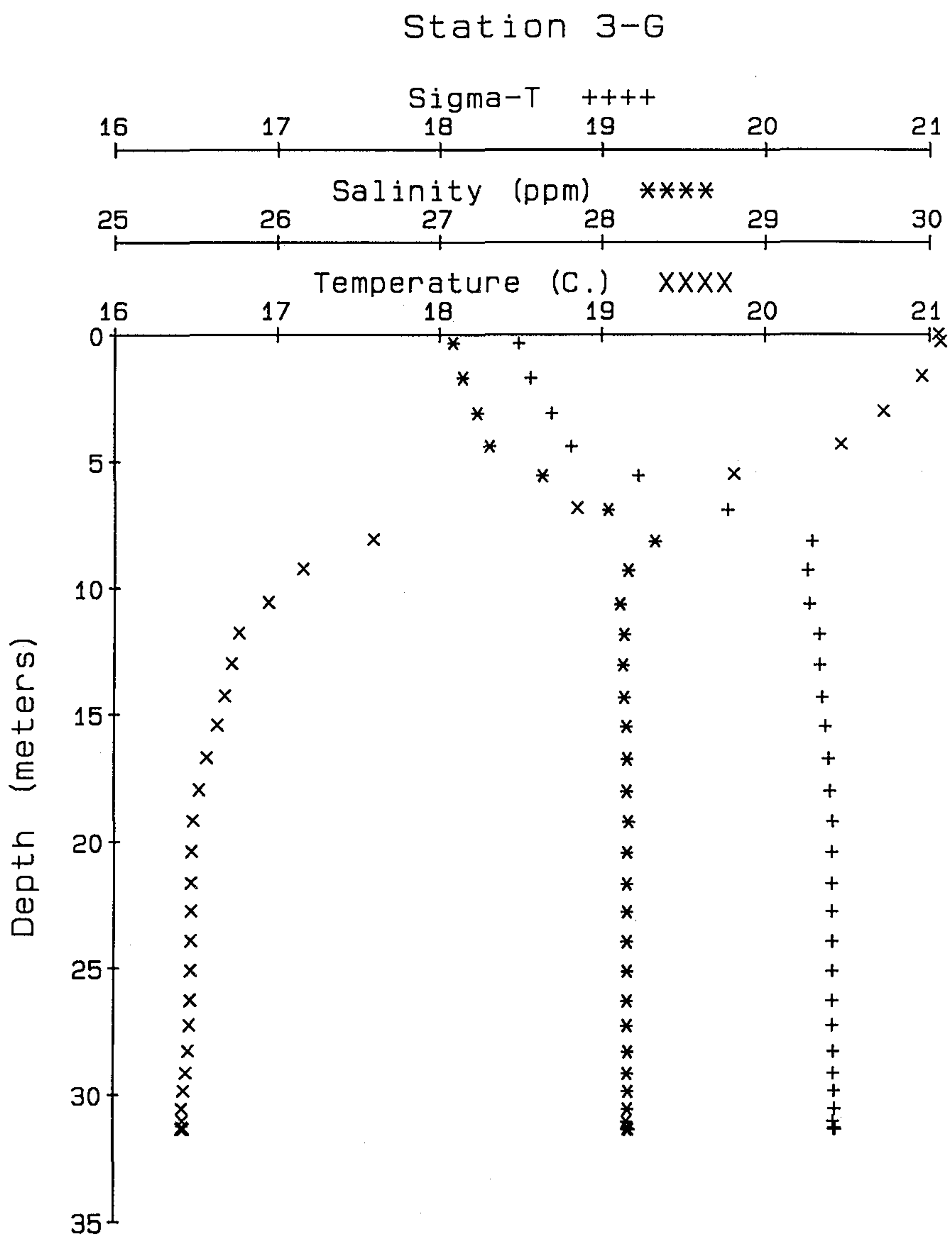

Station 1-I
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35



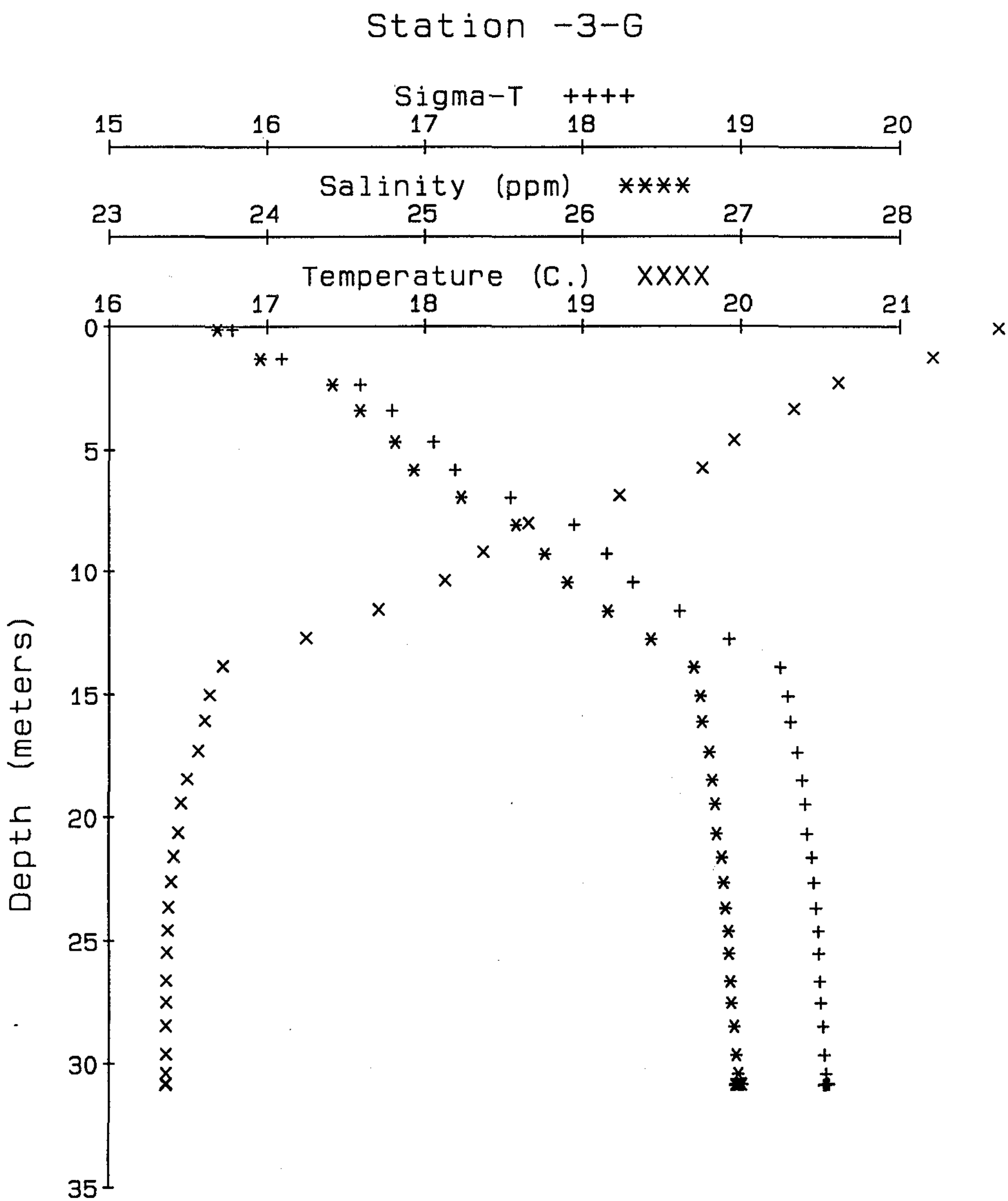
Station 1-K
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)

Station 3-Z

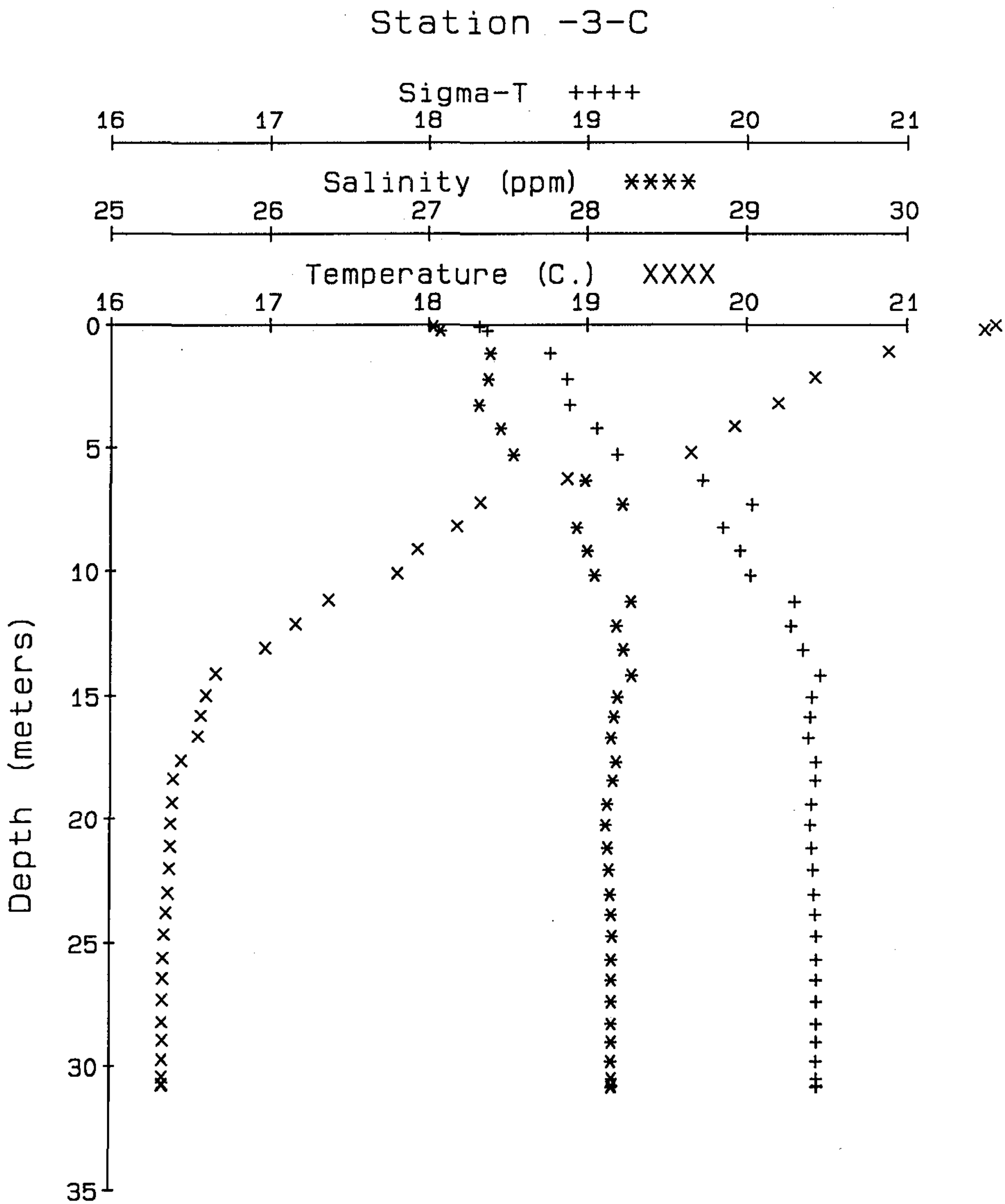

Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35



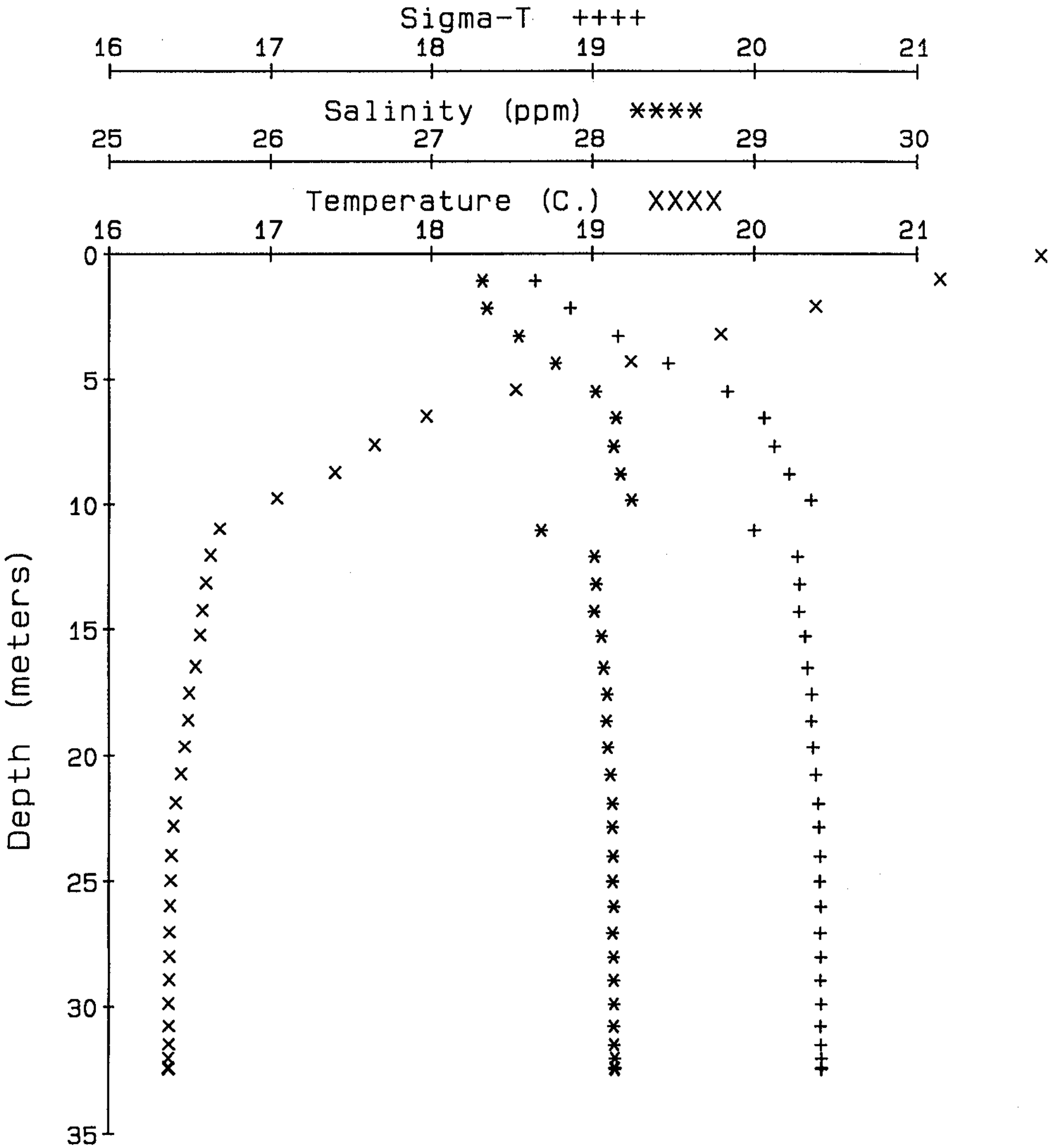
Station 3-G
Sigma-T ++++
16
17
18
19
20
21
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
30
35
Depth (meters)

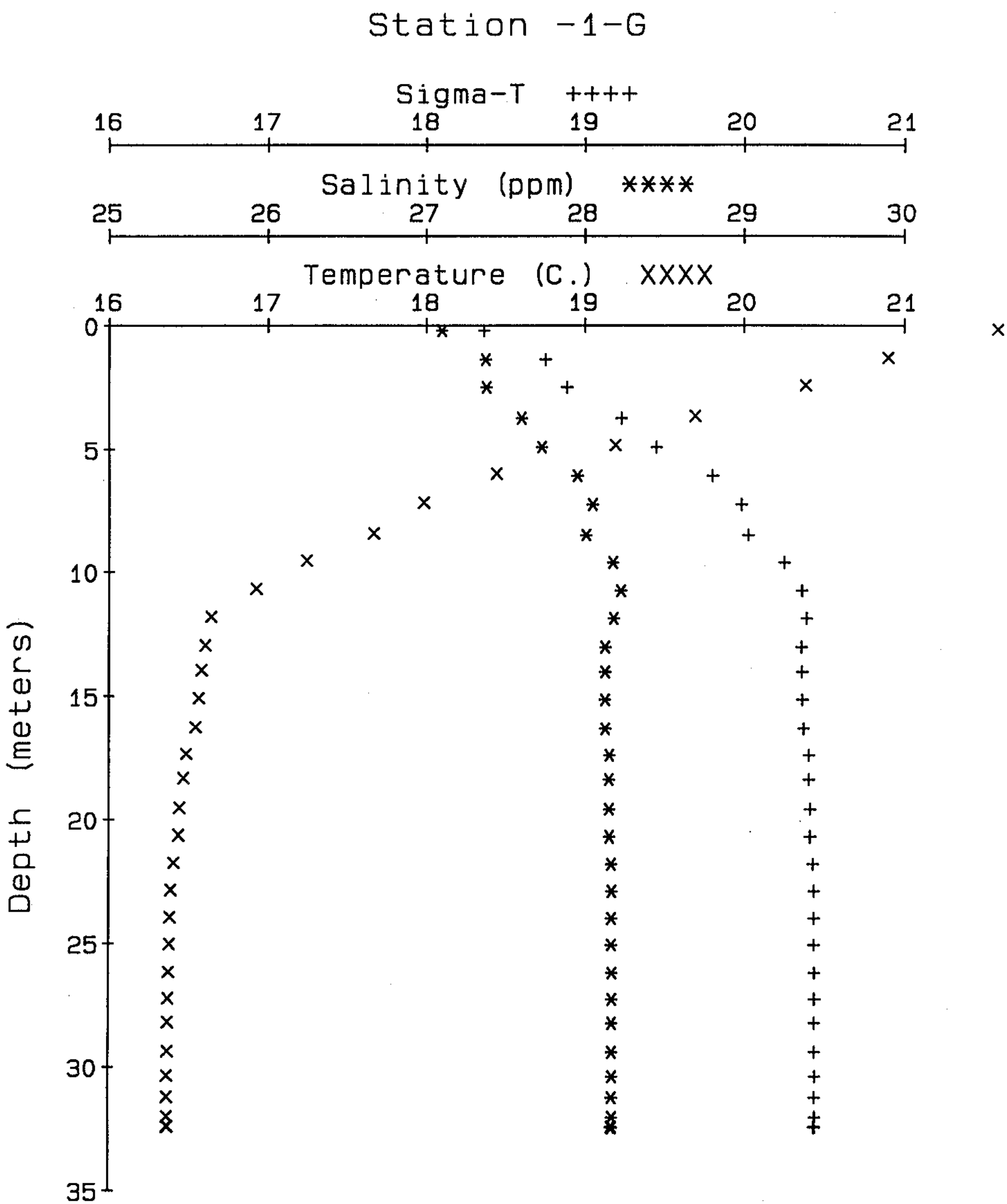


Station -3-G
Sigma-T ++++
15 16 17 18 19 20
Salinity (ppm) ****
23 24 25 26 27 28
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

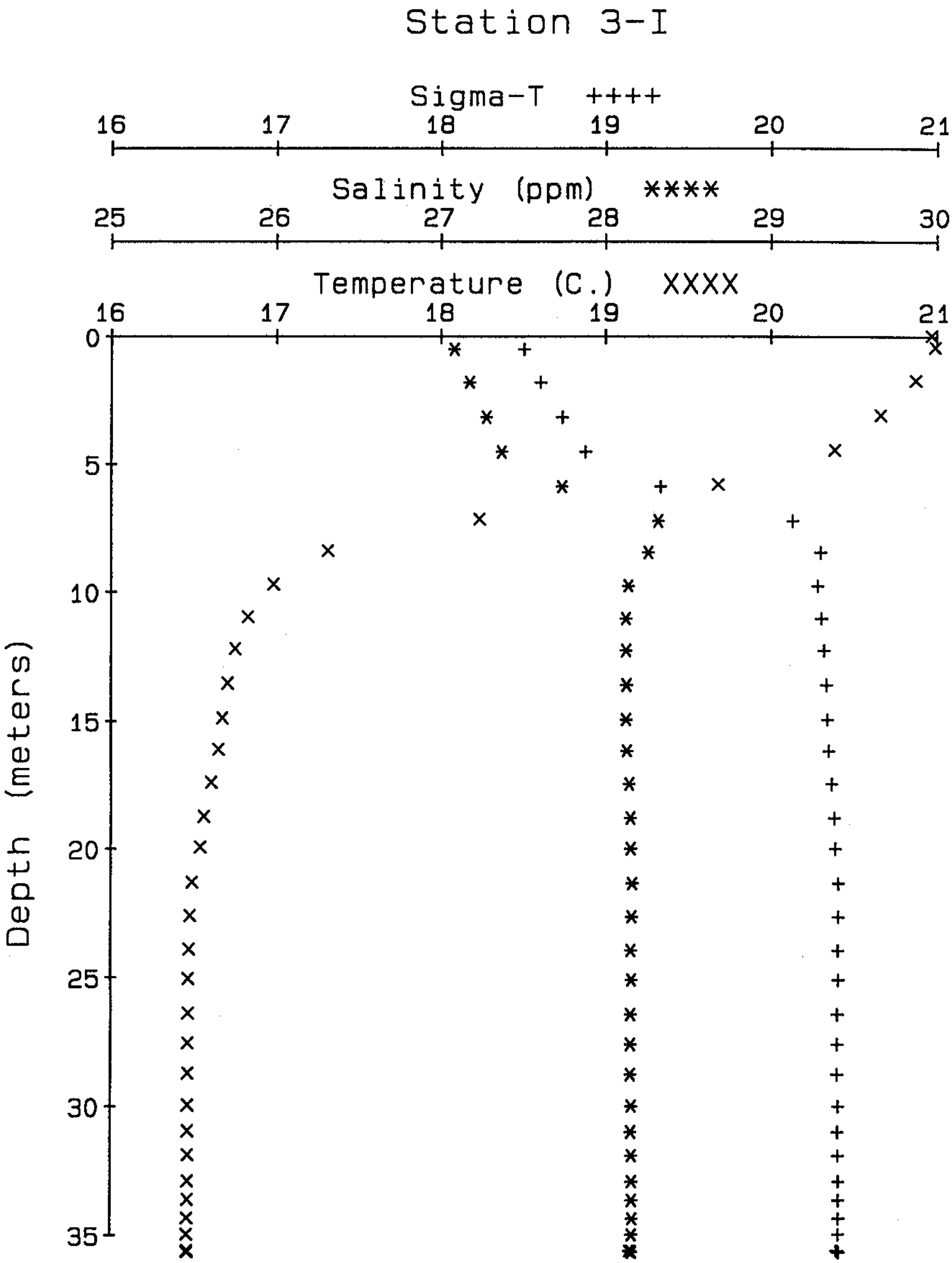

Station -3-C
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

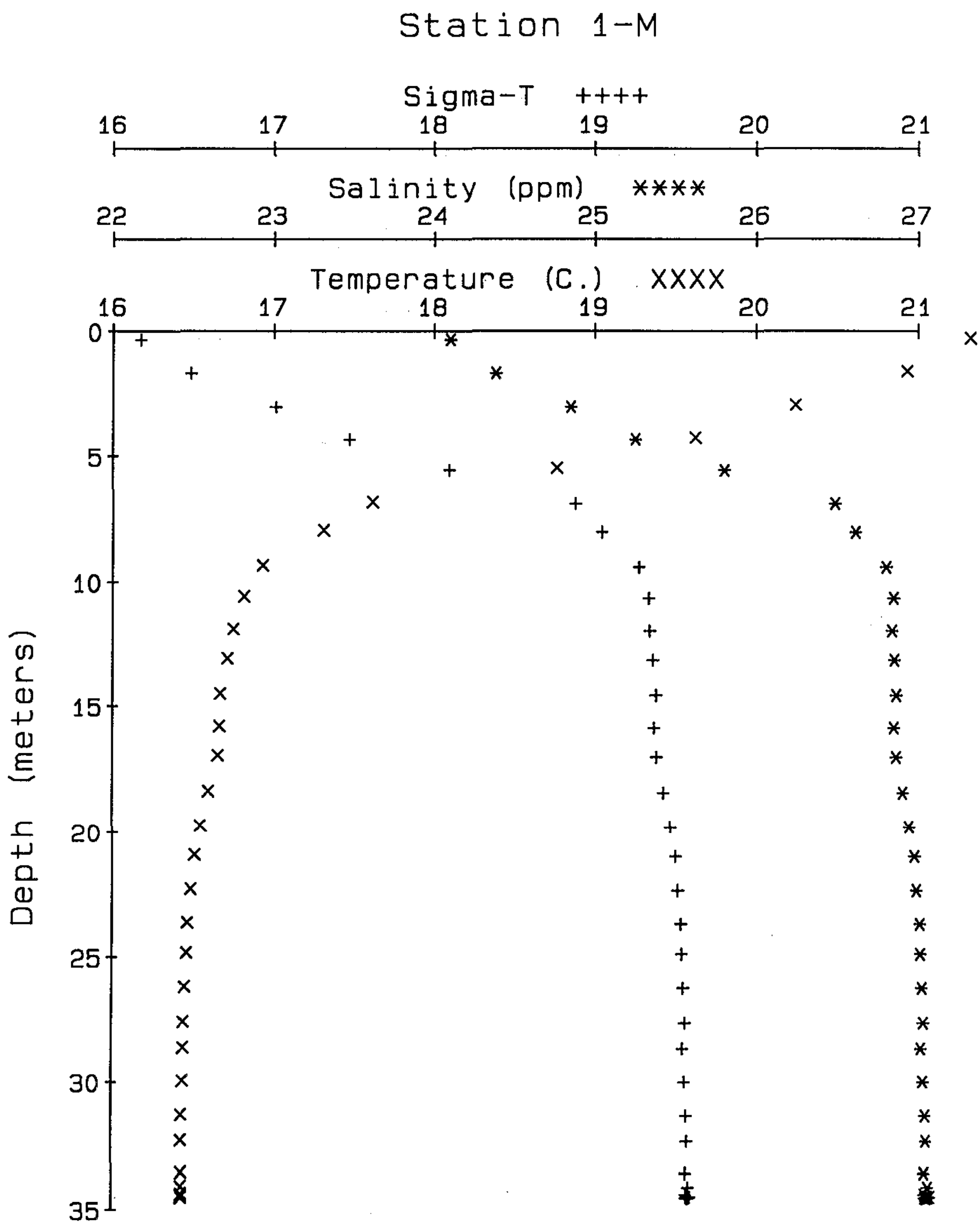
Station -1-I

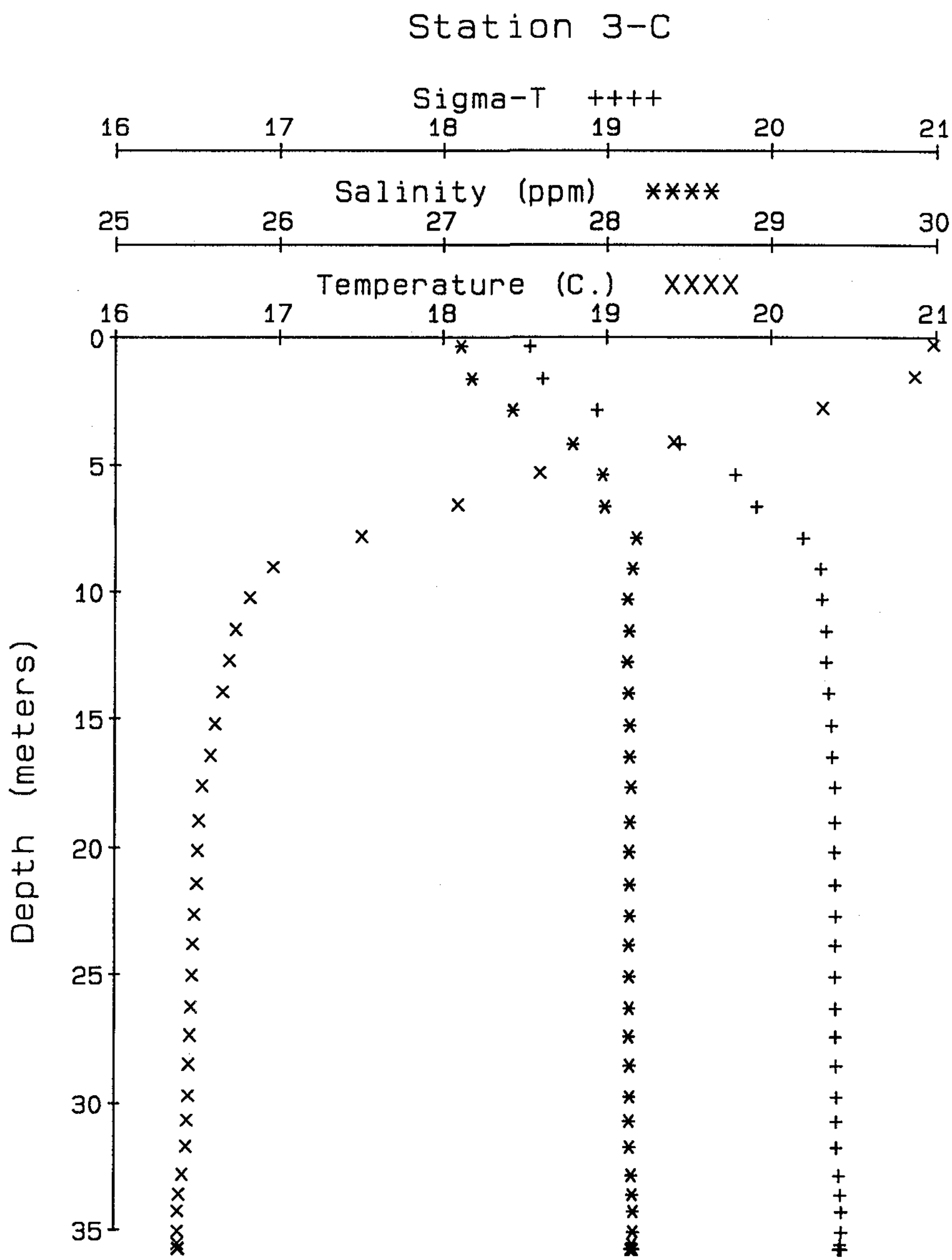

Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35



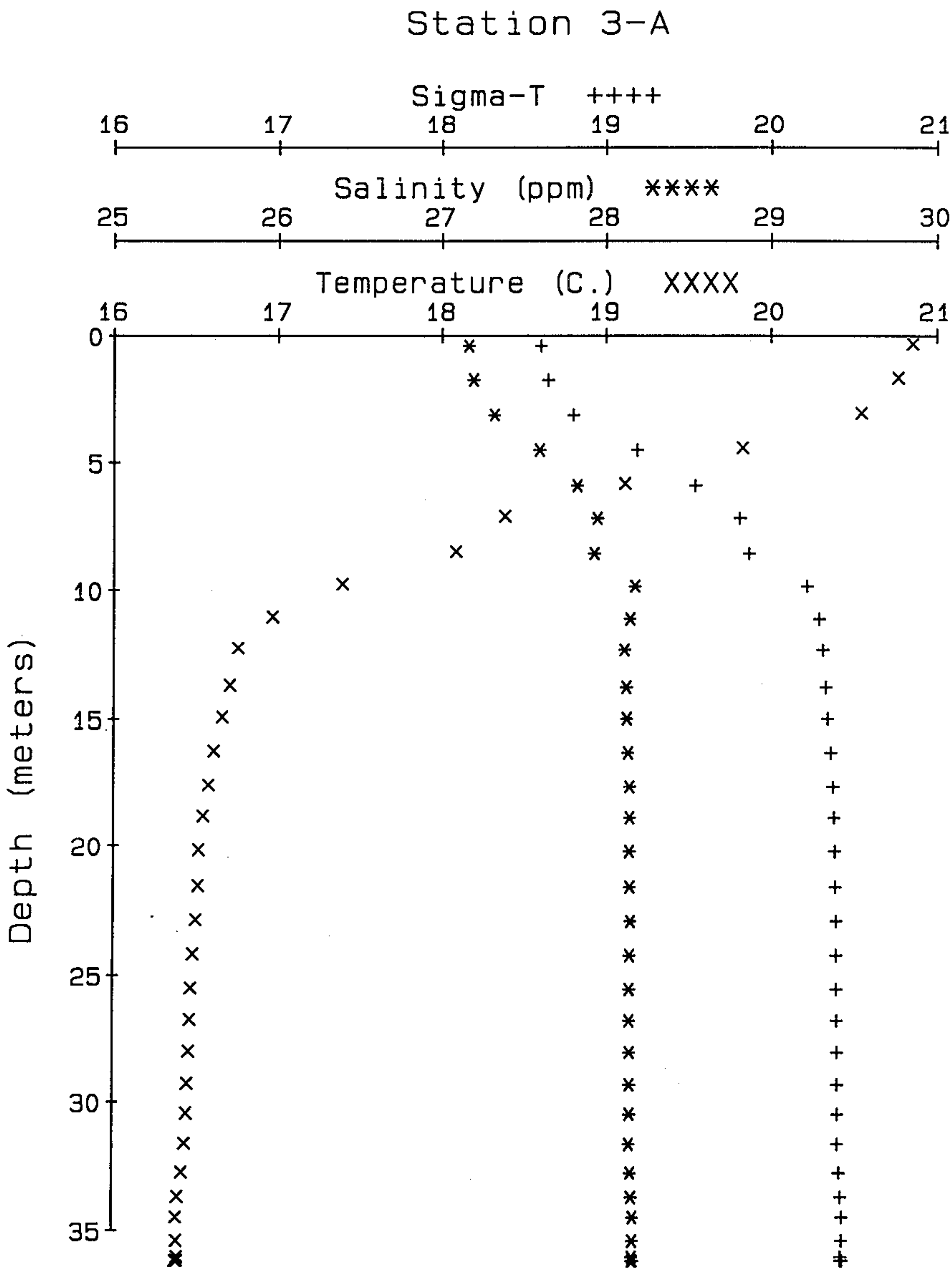
Station -1-G
Sigma-T ++++
16
17
18
19
20
21
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
30
35
Depth (meters)

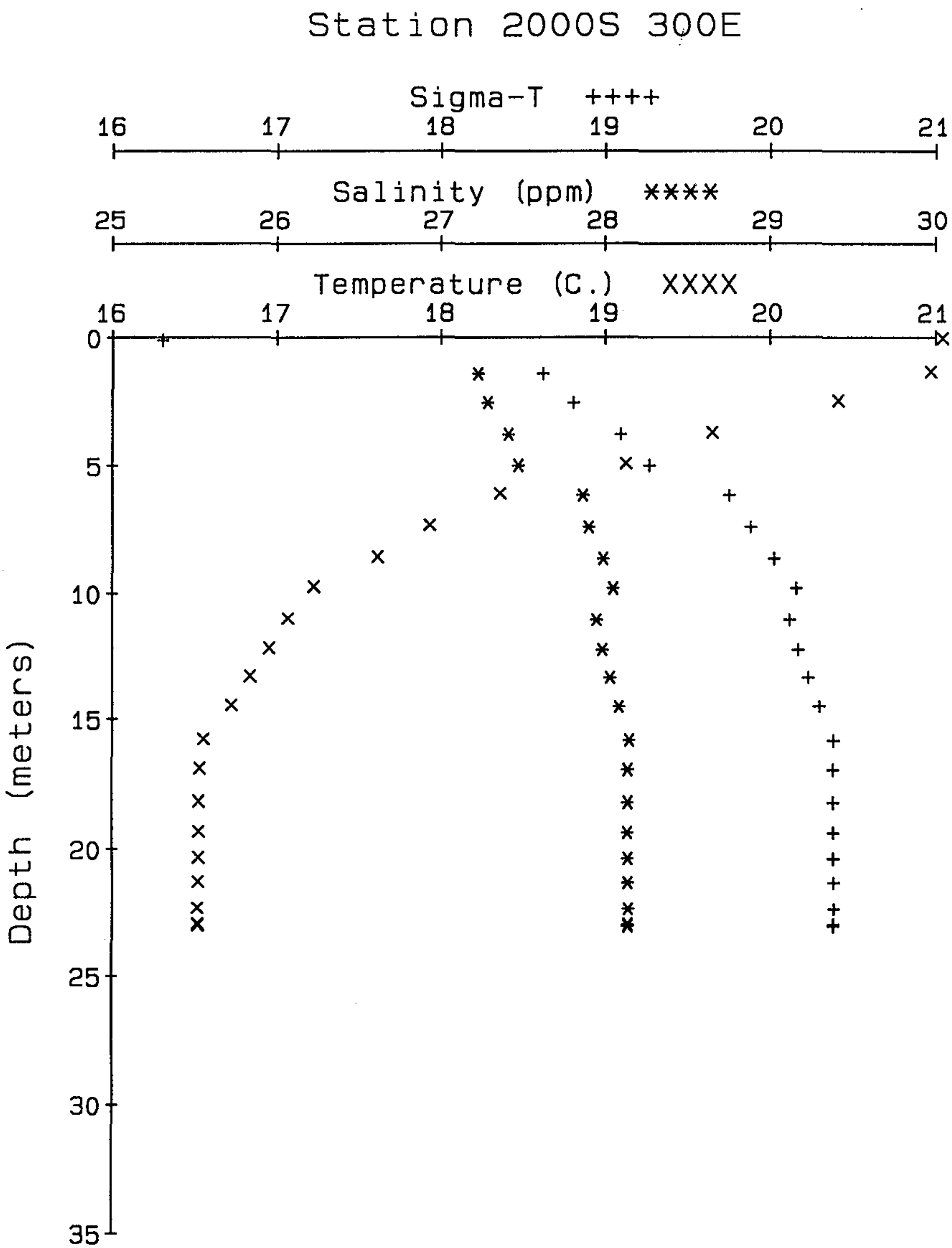

Station 3-I
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)


Station 1-M
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
22 23 24 25 26 27
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

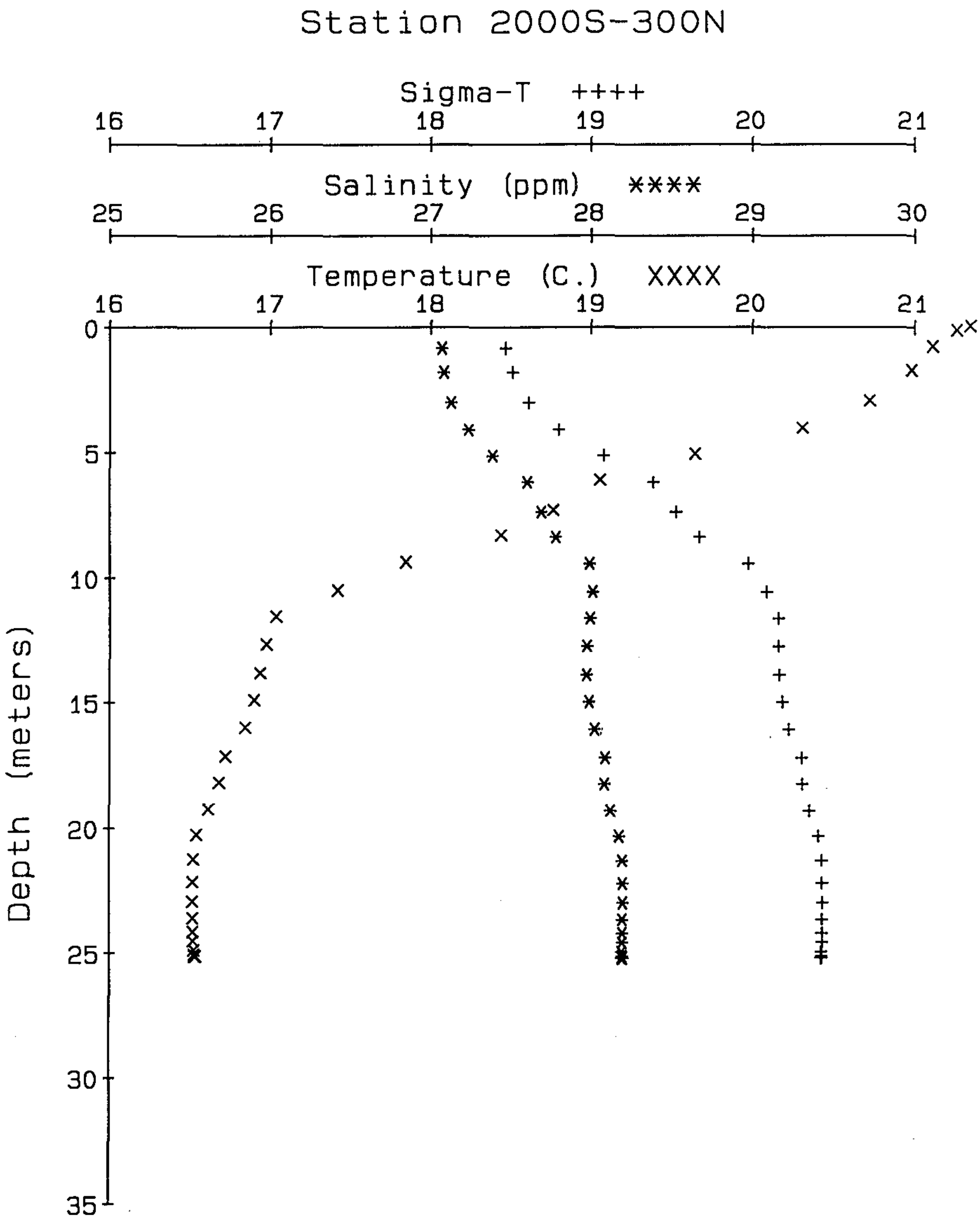


Station 3-C
Sigma-T ++++
16
17
18
19
20
21
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
30
35
Depth (meters)


Station 3-A
Sigma-T ++++
16
17
18
19
20
21
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
30
35
Depth (meters)

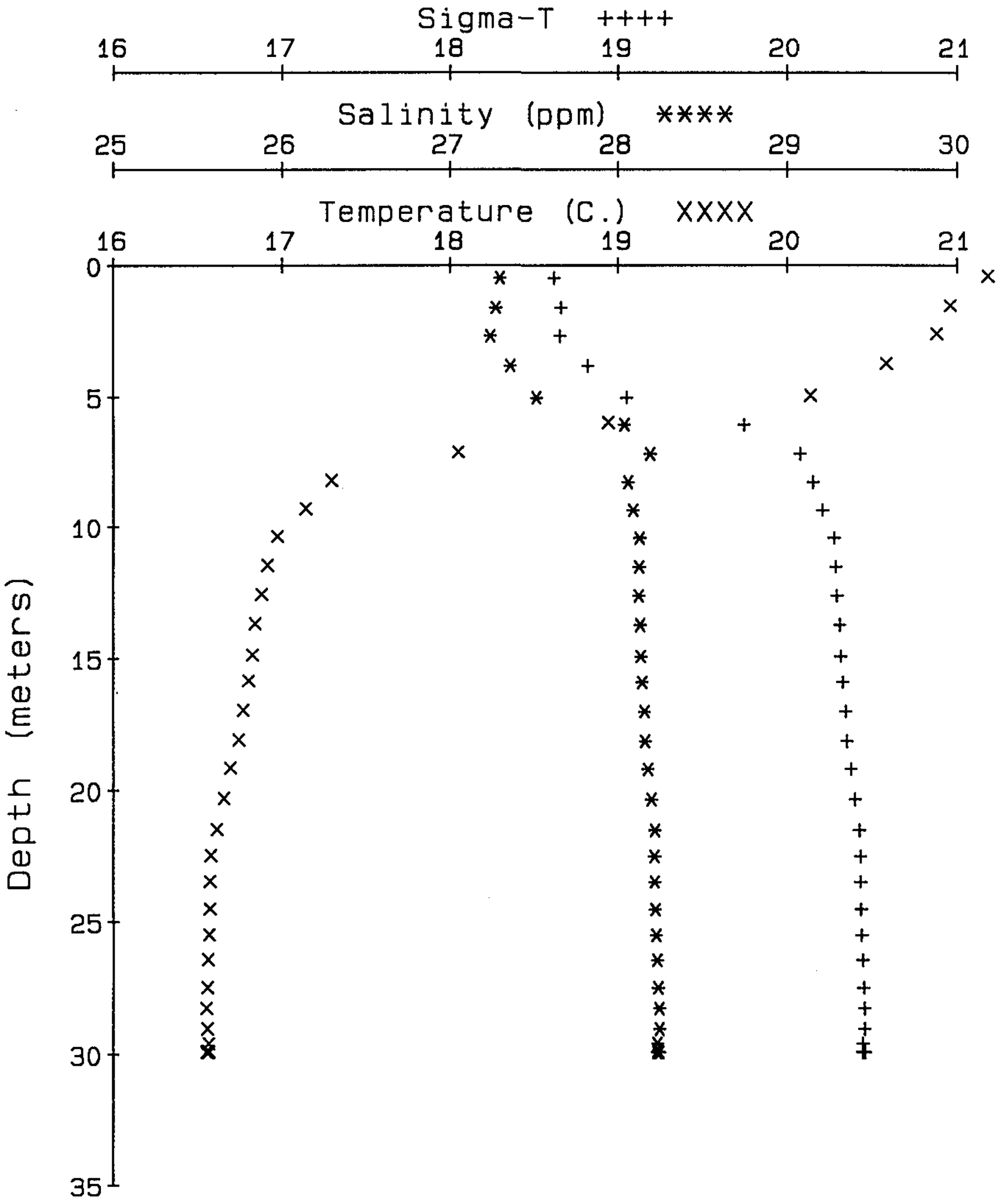


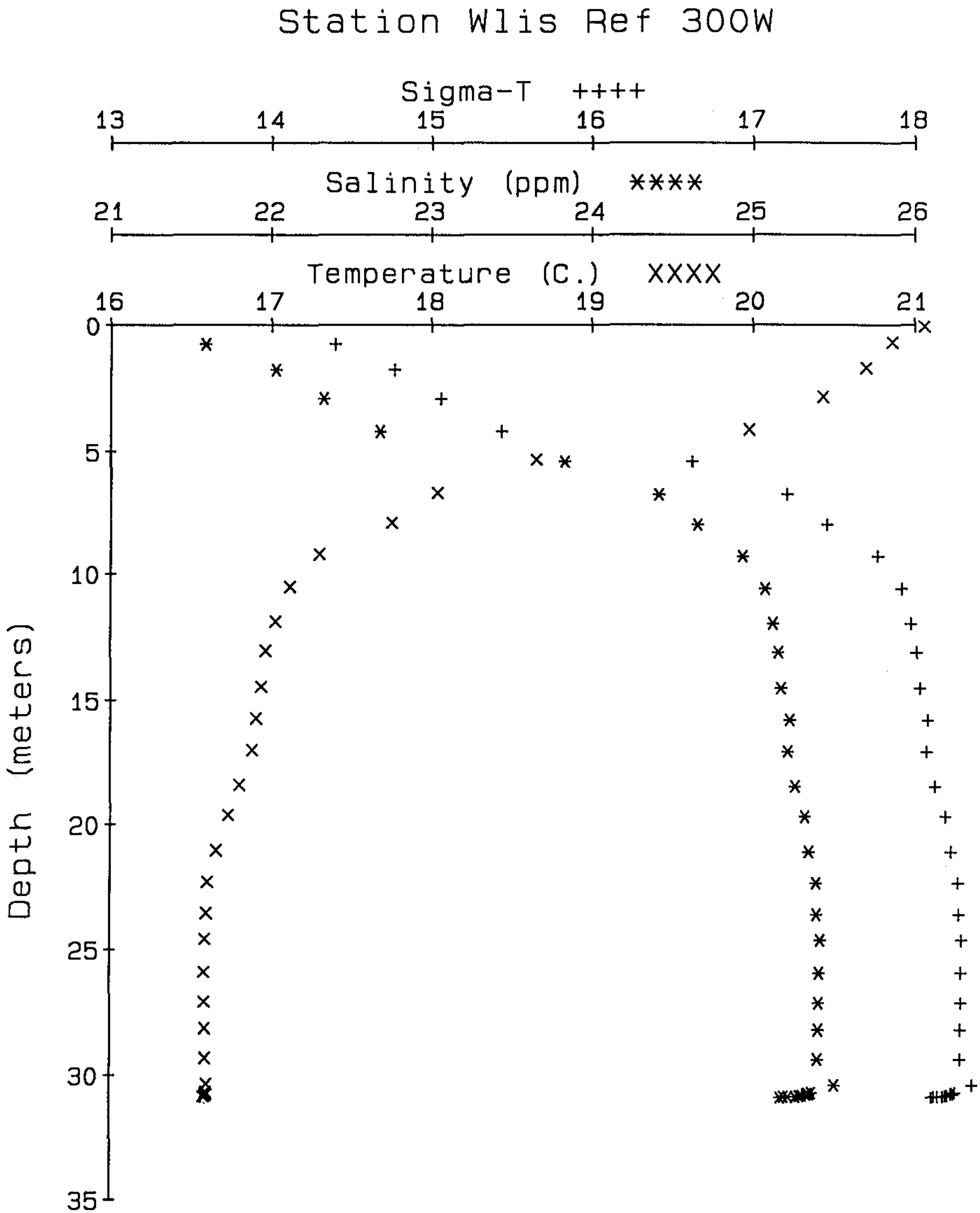
Station 2000S 300E
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35

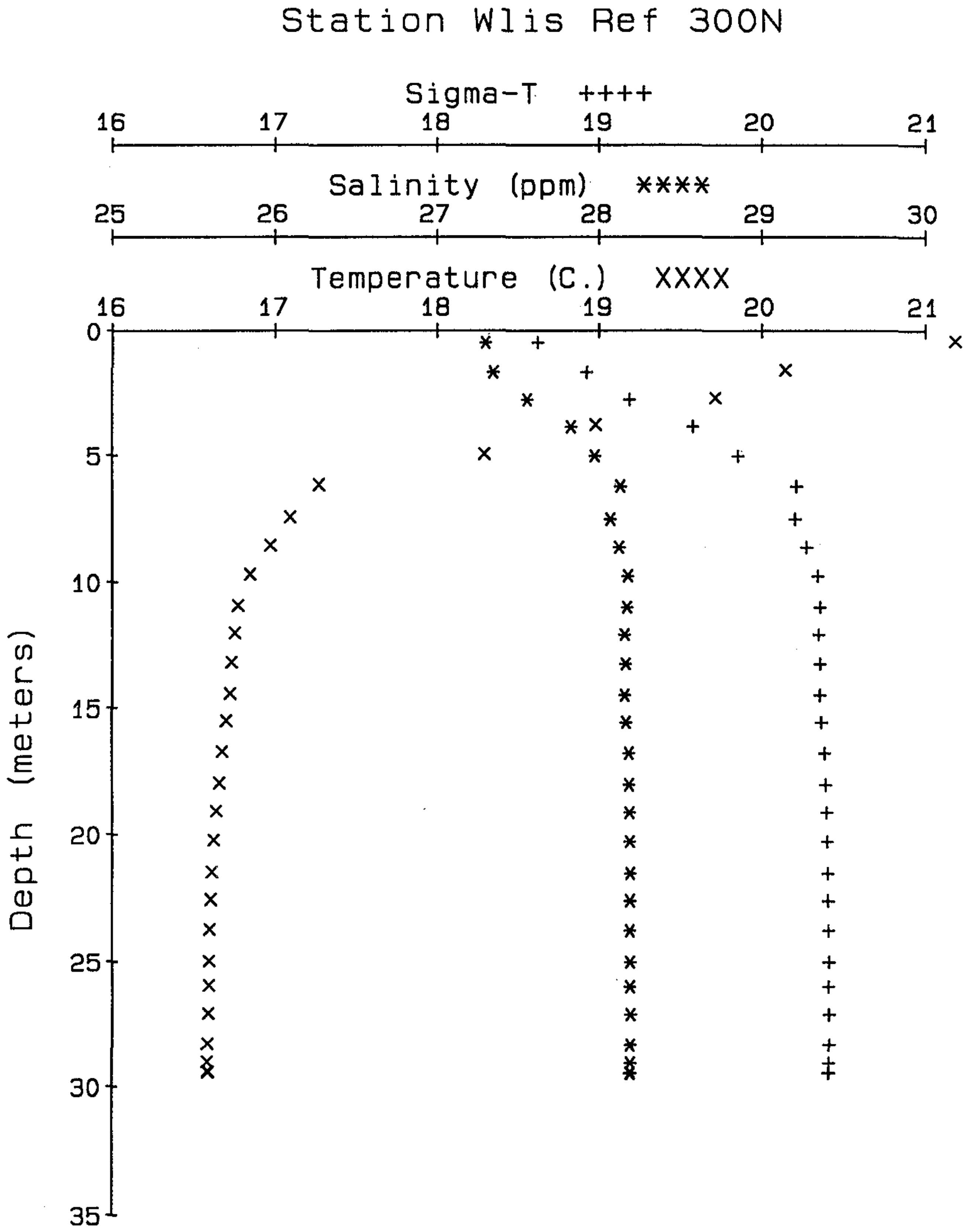


Station 2000S-300N
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)

Station Wlis Ref 300E




Station Wlis Ref 300W
Sigma-T ++++
13 14 15 16 17 18
Salinity (ppm) ****
21 22 23 24 25 26
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25 30 35
Depth (meters)


Station Wlis Ref 300N
Sigma-T ++++
16 17 18 19 20 21
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25 30 35