Monitoring Cruise at the Western Long Island Sound Disposal Site, November 1987

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From 17 to 23 November 1987, field operations were conducted at the Western Long Island Sound Disposal Site (WLIS) to provide information on the fates and effects of past and recent disposal operations. Both the precision bathymetric and REMOTS surveys at WLIS indicated an accumulation of recently-deposited dredged material at the "B" mound, where the disposal buoy had been located since 1 September 1986. Based on comparisons with the previous year's bathymetric results, the "C" and "A" disposal mounds at WLIS were found to be unchanged.

The lack of significant differences between reference and on-site stations in REMOTS parameters such as RPD depths, percentage of Stage III organisms, and OSI values suggested an overall absence of seafloor disturbance related to dredged material disposal at the site. Furthermore, the significantly higher OSI values calculated at both reference and on-site stations suggested that overall benthic habitat quality improved in 1987 compared to August 1986 and October 1985.

Chemical analyses of surface sediments showed contaminant concentrations only at "Low" or "Moderate" *levels;* these levels were consistent with those found previously at the site. Only Pb, Zn, and Fe at station 3-A near the active "B" disposal mound exhibited concentrations which were both significantly higher than reference levels and clearly related to disposal.

Reflecting the general pattern of sediment contaminant levels, body burdens of Cd, Pb, Cu, Fe, Hg, and PCB's in Nephtys from WLIS disposal mound stations 3-E, 3-A, and 3-I generally were either below detection limits, significantly less than, or not significantly different from those at the reference stations and were consistent with levels found in previous studies. The *exception to this was a significant elevation of Cu in the polychaetes from station 3-A near the active "B" disposal mound.* The lack of a corresponding significant elevation in Cu concentrations in surface sediments at this station made it difficult to establish a clear association between sediment contaminant levels and biological uptake.

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MONITORING CRUISE AT THE WESTERN LONG ISLAND SOUND DISPOSAL SITE NOVEMBER 1987

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. An average of 153,000 cubic meters (200,000 $yd^{3)}$ of dredged material has been deposited annually at the site since disposal first began in March 1982. 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 1986-87 disposal season (1 September 1986 to 1 May 1987). Scow estimates indicated that 18,000 m^3 (23,000 yd^3) of dredged sediments were disposed at the buoy during this time period. The material was predominantly sand with lesser amounts of silt and clay. Chemical contaminants present were generally at "Low" concentrations (interim guidelines, New England River Basins Commission (NERBC), 1980). "Moderate" levels of the following metals occurred in some of the dredged material: lead (28% of the material), arsenic (17%), and mercury (33%).

From 17 to 23 November 1987, field operations were conducted at WLIS to provide information on the fates and effects of past and recent disposal operations. The field operations included a precision bathymetric survey, REMOTS® sediment-profile photography, and sediment sampling for chemical and physical analyses. In addition, the deposit-feeding polychaete Nephtys incisa was collected for body burden analysis of selected contaminants, and vertical profiles of temperature, salinity, and dissolved oxygen were obtained at selected stations in the disposal site and at reference stations. The objectives of the 1987 monitoring cruise at WLIS were to:

- delineate the extent and topography of the recently-deposited dredged material at the disposal site and assess environmental impacts related to past and recent disposal;
- assess the long-term transport of chemical contaminants along the axis of predominant water movement;

- provide additional baseline data on the relationship between sediment contamination and the biological uptake of contaminants by benthic infauna; and
- characterize the depth gradient of dissolved oxygen and assess near-bottom dissolved oxygen concentrations in and around the disposal site in relation to benthic habitat conditions.

2.0 METHODS

2.1 Bathymetry and Navigation

The precise 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 at known benchmarks at Eatons Neck Light, NY and the Norwalk, CT power plant. 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 a Raytheon DE-719 Precision Survey Fathometer with a 208 kHz transducer and an SSD-100 Digitizer, as described in DAMOS Contribution #48 (SAIC, 1985). The fathometer was calibrated to a reference speed of sound of 4800 ft/sec. The actual 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). This value was used during the analysis of the bathymetry data to correct the depth values.

The bathymetric survey was conducted at WLIS on 17 November 1987. Thirty-three lanes were run east and west at a 25 meter lane spacing over an 800 by 800 meter survey area centered approximately at the WLIS "A" mound (Figure 1-1). During analysis, raw bathymetric data were standardized to Mean Low Water by correcting for ship draft and 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

The previous REMOTS® survey at WLIS was conducted in August 1986. REMOTS® photography was used to detect and map the distribution of thin (1-20 cm) dredged material layers. This capability complements the precision bathymetric data which can resolve bottom elevation changes greater than 15 cm in depth. In addition, REMOTS® was used to map benthic disturbance gradients and to monitor the process of infaunal recolonization on and adjacent to the disposal mounds. A detailed description of REMOTS® photograph acquisition, analysis, and interpretative rationale was given in DAMOS Contribution #60 (SAIC, 1989).

Three replicate photographs were obtained at each of sixty-eight REMOTS® stations occupied at WLIS between 17 and 23 November 1987 (Figure 2-1). The 7 x 9 station grid with 200 m spacing was centered slightly north of the "A" disposal mound. In order to compare ambient and on-site conditions, three replicate photos were also obtained at each of five reference stations located outside the disposal site boundaries. The names of four of these reference stations (3000E, 2000W, 2000S and 2000N) indicate their distance (in meters) and compass bearing from station 3-E near the center of the REMOTS® grid. The fifth reference station, WLIS-REF, was located approximately 2200 m northeast of station 3-E.

While the 1987 REMOTS® sampling grid was centered in the same approximate location as the August 1986 grid, it encompassed a larger area because the stations were spaced farther apart (200 m in 1987 versus 100 m in 1986). In order to better delineate the extent of the dredged material deposited during the past year's disposal activities and to document any changes in bottom conditions, the results of the present REMOTS® survey are compared, where applicable, with the results of the August 1986 survey.

2.3 Dissolved Oxygen

The depth gradient in dissolved oxygen was characterized at selected REMOTS® stations on 23 November 1987, using a Rexnord Instruments Model 66 dissolved oxygen probe interfaced to 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. The dissolved oxygen probe 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). The vertical hydrographic profiles were obtained during REMOTS® photo acquisition.

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.

The Rexnord Model 66 probe is a polarographic oxygen electrode (platinum-lead galvanic couple with a potassium-iodide electrolyte). The probe was covered with a 1 mm thick diffusion membrane. Calibration of the Rexnord Model 66 was performed at the SAIC Oceanographic Service Center by the standard method of comparison with Winkler titration (Strickland and Parsons, 1972). Calibration must be done whenever the membrane and/or electrolyte are changed. The calibration of the conductivity, temperature, and pressure sensors on the STD-12 was performed by the manufacturer. Salinity was calculated from conductivity data based on procedures described by Perkin and Lewis (1980).

2.4 Sediment Sampling and Analysis

Triplicate sediment samples were collected with a 0.1 m^2 Smith-McIntyre grab sampler at fifteen stations (including reference stations WLIS-REF, 3000E, 2000S, 2000W, and 2000N) located in the vicinity of the disposal site (Figure 2-2). Six of these stations (1000W, 3-A, 3-E, 3-I, 1000E and 2000E) were aligned along an east-west transect in order to assess the transport of contaminants in the direction of the dominant current regime. At each station, six polycarbonate plastic core liners (6.5 cm ID) were pushed into each sediment grab sample and extracted; the top 2 cm of sediment from five of these cores were combined and placed into bags for subsequent chemical analysis by the NED laboratory. The top 2 cm of the remaining core from each of the triplicate grab samples were combined and placed into a bag for subsequent physical analysis by the NED laboratory. The samples were kept on ice until delivered to the laboratory where they were stored at 4C until analyzed. The parameters measured include grain size, trace metals (Hg, Pb, Zn, As, Fe, Cd, and Cu), total PHC's and PCB's, and % total organic carbon. Analytical methods were those of the U.S. Environmental Protection Agency (Plumb, 1981).

2.5 Body Burden Analysis

Test organisms for body burden analysis were collected at six stations (including the reference stations WLIS-REF, 2000W and 2000E) using a Smith-McIntyre grab sampler (Figure 2-2). At each station, sediment was sieved through a 2 mm mesh and individuals of the deposit-feeding polychaete Nephtys incisa were isolated and placed in seawater at ambient temperature. Sufficient biomass was collected at each station for triplicate chemical analyses. The animals were allowed to purge any sediment from their guts for 24 hours before they were frozen for transport to the laboratory, where the tissue was analyzed for five metals (Fe, Cd, Hg, Pb and Cu) and PCBs (as Aroclor 1254). The analyses were conducted by Environmental Monitoring Laboratory, Inc. of Wallingford, CT.

A general description of the procedures followed for the body burden analyses is given in DAMOS Contribution #48 (SAIC, 1985). All metal analyses were conducted using the methods described by the U. S. Environmental Protection Agency (1983). Samples were also analyzed for their PCB content (expressed as Aroclor 1254) following EPA methods (US EPA, 1977).

3.0 RESULTS

3.1 Bathymetry

The "A", "B", and "C" disposal mounds known to exist at the WLIS site all were detected within the survey area (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 (Figure 3-2). The present results indicate that since 1986, the minimum depth of mound "B" had decreased by 0.75 m, while the minimum depths of mounds "A" and "C" have remained unchanged. Bathymetric charts of the area surrounding mound "B" in 1986 (Figure 3-3) and 1987 (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.

The decrease in depth observed at the "B" mound was the result of disposal operations taking place there during both the 1986-87 disposal season as well as the first part of the 1987-88 season (from 1 September 1987 until the time of the present survey in November 1987). Depth difference calculations indicated that between the August 1986 and November 1987 bathymetric surveys, a total of 14,240 m^3 of dredged material was added to mound "B". Tabulation of scow logs for the same period indicated that approximately 46,090 m^3 (60,210 yd^3) of dredged material were deposited at or near the buoy. The scow logs suggest that the majority of scow loads were disposed within 100 m of the buoy, although individual loads may have been disposed up to 360 meters from the buoy in all directions. These recorded scow log positions are subject to a number of reporting errors (receiver phase shift, human recording errors, etc.) and are difficult to verify with certainty.

3.2 REMOTS® Sediment-Profile Photography

Recently-deposited (i.e., since August 1986) 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). In some of the replicate photos from these two stations, the "fresh" dredged material was distinguished by its characteristic extremely low-reflectance and lack of an RPD (Figure 3-6). In other photos, the material had a "mottled" appearance caused by alternating high and low reflectance patches (Figure 3-7). A significant sand component was often present in these predominantly fine-grained sediments.

Relict or "weathered" dredged material was evident in the immediate vicinity of the "B" mound, as well as at stations on or near the "A" and "C" mounds. Dredged material occurred at REMOTS® stations throughout this same area in the August 1986 survey (SAIC, 1988b). At some stations, distinct layers of relict material were readily apparent and could be measured (Figure 3-8). Other stations exhibited relict material characterized by discontinuous sand layers and/or patches of low reflectance mud at depth (Figure 3-9). Apparent dredged material occurred at reference station 3000E (Figure 3-10), and relict dredged material layers also were visible at stations 5-M and 7-M near the southeast perimeter of the sampling grid (away from the disposal mounds).

The majority of REMOTS® on-site and reference stations consisted of silt-clay sediments (4 phi, Figure 3-11). As previously indicated, 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). As in 1986, a few of these stations, particularly those near the "C" mound, had discontinuous sand layers representing inputs of allocthonous (i.e., disposed) material (Figure 3-9). The 4-3 phi major mode at several other on-site stations and at reference station 2000S presumably was due to some minor amount of natural heterogeneity in ambient sediments in this part of Long Island Sound.

The frequency distributions of small-scale surface boundary roughness values for both on-site and reference stations indicate that most values were in the range 0.0 to 0.6 cm (Figure 3-12), with no significant difference between the two distributions (Mann-Whitney U-test; $p \neq 0.6653$). In addition, boundary roughness values at both the reference and on-site stations have not changed significantly since the 1986 survey (Mann-Whitney U-test, $p = 0.4911$ for reference, $p = 0.6182$ for on-site). In 1986, evidence of small-scale physical and biogenic bottom disturbance was noted in many of the WLIS REMOTS® photographs. This was presumed to represent the lingering effects of Hurricane Gloria on the region. Physical bottom disturbance in the present survey appeared to be limited to stations in the immediate vicinity of the "B" mound, where active disposal was occurring.

The frequency distributions of apparent RPD values for both on-site and reference stations have major modes in the 3.0 cm class interval (Figure 3-13). The average apparent RPD depth for the on-site stations was 3.0 cm, with areas in the vicinity of the mound (stations 1-A, 3-A, 3-C, 3-E, 5-A, 5-C, 5-E) and to the south having lower values (Figure 3-14). Two reference stations, WLIS-REF and 3000E, had mean apparent RPD depths 2 cm. Together, the five reference stations had an average apparent RPD depth (2.7 cm) slightly shallower than the on-site stations; however, there was no significant difference in the distribution of RPD values in the two areas (Mann-Whitney U-test; $p = 0.3486$). Both the on-site and reference RPD values have increased significantly since the 1986 REMOTS® survey (Mann-Whitney U-test, $p = 0.001$ for on-site and $p < 0.001$ for reference).

Approximately 53% of all the photos obtained at both on-site and reference stations exhibited Stage III infauna, compared to 50% in August 1986 and 33% in August 1985. In the replicate photos from many stations, both Stage I and Stage I on III successional seres were observed (Figures 3-15 and 3-16). This within-station variability suggests that while Stage III organisms occurred throughout the site, their local distribution was patchy. Only Stage I organisms were observed at reference station 2000W and at a cluster of stations in the southeast corner of the sampling grid. At most stations, the Stage I organisms included both small, tubicolous, surface-dwelling polychaetes, as well as the near-surface dwelling, opportunistic mactrid bivalve Mulinia lateralis (Figures 3-15 and 3-17).

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.). A cluster of stations in the southeast corner of the sampling grid and stations 1-A, 3-C, and 5-C in the immediate vicinity of the active "B" disposal mound had mean OSI values +6 (Figure 3-18). The low values at the "B" mound reflect the physical disturbance due to recent disposal. Elsewhere, the low values were caused by a lack of, or patchiness in, Stage III infauna. Generally, OSI values exceeded +6 at the majority of on-site stations and at all reference stations.

The frequency distribution of reference station OSI values has major modes at the 6, 9 and 11 class intervals, while the on-site station values are clustered around major modes of 7 and 11 (Figure 3-19). The polymodality in these distributions generally reflects the patchy distribution of Stage III organisms at individual stations, which resulted in a wider range of calculated OSI values among the replicates. There was no significant difference in OSI values between the on-site stations (overall mean OSI = 7.7) and the reference stations (overall mean = 7.6)(Mann-Whitney U-test, $p = 0.6511$). Compared to 1986, OSI values have increased significantly at both on-site and reference stations at WLIS (Mann-Whitney U-test, $p < 0.001$ in both cases). This is largely due to the deeper RPD at many stations, and also to the slight increase in the number of photos indicating the presence of Stage III organisms.

3.3 Dissolved Oxygen

On 23 November 1987, near-bottom dissolved oxygen (DO) concentrations at selected REMOTS® on-site stations ranged between 9.61 mg/ℓ and 13.20 mg/ℓ (Figure 3-20). Near-bottom DO concentrations on the same day at reference stations WLIS-REF, 2000N and 3000E were 9.67 mg/ℓ, 12.56 mg/ℓ, and 9.87 mg/ℓ, respectively. The values obtained during the morning and early afternoon on 23 November (i.e., between 0950 h and 1330 h) ranged between 10.86 mg/ℓ and 13.20 mg/ℓ. These values were uniformly higher than the values obtained in the late afternoon (i.e., between 1624 h and 1748 h), which ranged between 9.61 mg/ℓ and 9.87 mg/ℓ.

Plots of the depth gradients in dissolved oxygen, temperature, salinity, and density (as sigma-t) at the selected on-site and reference REMOTS® stations indicated in Figure 3-20 are given in the Appendix. There is little variation in the appearance of these plots among the different stations. The plot from station -5-C (Figure 3-21) is representative of all the CTD/DO plots obtained at both grid and reference stations during the morning and early afternoon hours. These plots show that temperature, salinity, density, and dissolved oxygen values were uniform from the surface to the bottom, suggesting a vertically well-mixed water column. The CTD/DO plot from station 7-G (Figure 3-22), which is representative of the stations sampled in the late afternoon, shows a slight temperature drop of about 1C in the near-surface water (upper 5-10 m of the water column) accompanied by a very small decrease in salinity. However, as was the case earlier in the day, DO concentrations remained vertically homogenous.

3.4 Sediment Sampling and Analysis

Sediments collected at the fifteen sampling stations (Figure 2-2) consisted of various combinations of silt, silty clay, silty sand, and sandy silt (Table 3-1). Shells were present at all stations. Generally, stations south of the disposal site (2000S, 1000SE and 1000SW) as well station 3-E near the "A" mound were dominated by fine, medium and coarse sands. Silt, with a significant sand component, occurred at stations WLIS-REF, 3000E, 2000E, 2000N, 1000NW, and 3-I. Elsewhere, silt-clay was the dominant grain size fraction.

The mean sediment concentrations of Pb at station 1000NW and Zn at stations 2000W and 3-A (Table 3-2) were at the extreme lower end of the "Moderate" category, according to the New England River Basin Commission's interim guidelines (NERBC, 1980). At all other on-site and reference stations, the mean sediment concentrations of Hg, Pb, Zn, As, Cd, and Cu were at NERBC "Low" levels (Table 3-2). Statistical analyses indicated that the concentration of Hg at stations 1000NW and 1000E, as well as the concentrations of Pb, Zn and Fe at station 3-A, were significantly elevated compared to reference concentrations (Table 3-3 and Figure 3-23). All other metal concentrations were either significantly less than or not significantly different from the reference values.

Concentrations of PCB's in composite sediment samples at each station were well below the 1.0 ppm level considered to be confirmation of high contamination according to the NERBC interim guidelines (Table 3-2 and Figure 3-23). Reference station 3000E had the highest mean PCB concentration among all the stations sampled, but the lack of replication precluded statistical testing for significant differences. Although NERBC guidelines do not exist for PHC's (petroleum hydrocarbons) and % TOC (percent total organic carbon, Table 3-2 and Figure 3-23), statistics show that PHC and % TOC values at the on-site stations were either significantly less than or not significantly different from the corresponding reference values (Table 3-3). The mean sediment concentration of PHC's at reference station 2000N was roughly an order of magnitude higher than those at either the other reference stations or the on-site stations. All three replicate values at this station were considered outliers and were therefore not pooled with the other reference station values in performing the reference versus on-site statistical tests.

3.5 Body Burden Analysis

The results of the triplicate analyses for five trace metals (Cd, Pb, Cu, Fe, and Hg) in body tissues of Nephtys collected at WLIS were reported on a dry weight basis (Table 3-4 and Figure 3-24). Body burden concentrations of Hg were below the analytical detection limits at all stations. With one exception, concentrations of Cd, Pb, Cu, and Fe in the polychaetes at mound stations 3-E, 3-A, and 3-I were not significantly different from the pooled reference values (Table 3-5). Only Cu in the polychaetes from station 3-A near the active "B" disposal mound was significantly elevated compared to the pooled reference concentrations of this metal.

Detectable levels of PCB's (as Aroclor 1254) occurred in Nephtys at both the reference and on-site stations (Table 3-6 and Figure 3-24). Among the six stations, the polychaetes from reference station 2000W had the highest mean level of PCB's while those from reference station WLIS-REF had the lowest. However, there was no statistically-significant difference between the body burden concentrations of PCB's at any of the three on-site stations versus the pooled reference stations (Table 3-5).

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 deposited material occurred around the buoy in a broad, circular mound having a radius of about 100 m.

A discrepancy of 31,850 m^3 existed between the scow log volume estimate of 46,090 m^3 and the depth difference calculation of 14,240 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. 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 estimate of 27,331 m^3 of dredged material.

Comparing the corrected scow log estimate with the depth difference calculation still results in roughly 13,100 m^3 of dredged material which cannot be accounted for on the bottom. Examination of the scow logs confirmed that disposal did take place up to 360 meters away from the buoy, which could result in thin, patchy layers of dredged material that could be missed by both precision bathymetry and REMOTS. Considering the inaccuracies usually associated with routine scow log estimates of volume and the relatively small amount of material involved, a better comparison cannot be expected. Yet, calculation of the standard error of the volume difference estimate (SAIC, 1989) resulted in an upper 95% confidence limit of 27,554 m^3. The corrected scow log volume estimate falls within this range.

4.2 REMOTS® Sediment-Profile Photography

One objective of the REMOTS® survey at WLIS was to delineate the extent of dredged material deposited during the past year at the "B" disposal mound. The REMOTS® results indicate that recently-deposited 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 1987 bathymetric and 1986 REMOTS® surveys.

To better delineate the extent of the dredged material deposit, the 1987 survey grid was expanded from the 1986 survey to include more area to the north, east, and west. While this expansion increased the total area of coverage, it also increased the distance between sampling points and consequently lowered the number of stations directly over the disposal mounds. This resulted in a lower percentage of photos exhibiting dredged material (fresh or relict) compared to the 1986 survey. In addition, less material was deposited prior to the 1987 survey compared to 1986. It is likely that the signature of the relict dredged material had become erased or obscured at some stations, chiefly as a result of bioturbation and chemical "weathering." This would also serve to explain why fewer photos exhibited dredged material compared to 1986.

The presence of apparent dredged material at station 3000E is not surprising considering that this station is located within the boundaries of the historic Eatons Neck disposal site (see Figure 1-1). This may partly explain why this station had the highest mean PCB concentration among those tested. However, only one out of the three replicate REMOTS® photos from this station exhibited dredged material, while the other two replicates showed ambient bottom unaffected by disposal. Evidently, the disposed material was not widespread in this location, suggesting a relatively small volume was originally deposited there several years ago when the Eatons Neck site was active. It is also possible that the material was deposited more recently as a result of a single errant disposal event; however, the proximity of the two historic disposal sites west and east of WLIS serves as the most ready explanation for the occurrence of dredged material at outlying grid or reference stations where normally it would not be expected.

A second objective of the REMOTS® survey at WLIS was to assess benthic habitat quality relative to measured near-bottom dissolved oxygen concentrations. 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 suggests 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.

Significantly deeper RPD depths, coupled with a slight increase in the number of Stage III organisms at both reference and on-site stations, suggest that overall benthic habitat quality in this portion of the Sound continued to improve in 1987 relative to surveys conducted in October 1985 (following the passage of Hurricane Gloria) and August 1986. This is reflected in the significantly higher OSI values calculated at both reference and on-site stations in 1987 compared to either October 1985 or August 1986. The November 1987 RPD and OSI values did not differ significantly from those found in the August 1985 pre-hurricane survey of the site. The physical bottom disturbance associated with the hurricane caused some erosion of surface oxidized layers and resulted in shallower RPD depths and stressed benthic communities. In the August 1986 survey, the relatively shallow RPD values and the corresponding low OSI values at on-site and reference stations were attributed to seasonal depletion of oxygen (hypoxia) in near-bottom waters, a Sound-wide phenomenon. The November 1987 survey occurred at a time of year when the water column was well-mixed and near-bottom dissolved oxygen concentrations were high. This strong seasonality must be taken into account when comparing year-to-year benthic conditions based on REMOTS® results.

The relatively healthy benthic conditions and high DO concentrations observed at WLIS in November make it impossible to test the 1986 hypothesis and 1987 prediction that stressed benthic habitats at the site were unrelated to disposal activities, but resulted from the region-wide phenomenon of near-bottom hypoxia. However, the results of an EPA-sponsored study showed that hypoxic near-bottom water was present at WLIS in mid-August 1987 (SAIC, 1988a). At that time, the near-bottom DO concentration measured at a station at the WLIS disposal site was 2.24 mg/ℓ, while the average RPD depth was 3.4 cm and the average OSI value was 7.8. These latter two values suggest that the bottom was not disturbed or stressed at the time of sampling, in contrast with August 1986 when near-bottom hypoxia had extremely adverse effects on the seafloor at WLIS. In fact, in the EPA study, it was found that stressed benthic conditions attributable to near-bottom hypoxia were largely confined to stations west of the entrance to Hempstead Harbor (about 1.8 km, or 1.1 miles, west of WLIS) in 1987. These observations support the conclusion that the degree of stress to the benthic habitat as a result of seasonal hypoxia can vary both temporally and spatially in Long Island Sound, but these adverse effects are unrelated to disposal activities. The healthy benthic conditions observed apparently were due to both the high near-bottom DO concentrations at the time of sampling, as well as an absence of stress related to seasonal near-bottom hypoxia in the weeks and months preceding the survey.

4.3 Dissolved Oxygen Regime

The objective of the CTD/DO sampling at WLIS was to measure the depth gradients in temperature, salinity, and dissolved oxygen in order to help interpret benthic habitat observations. Generally, all of the parameters measured on 23 November exhibited remarkable uniformity from the surface to the bottom at both the reference and disposal site stations. The slight decrease in temperature in the upper 5-10 m observed late in the day may reflect an exchange of heat resulting from cold air overlying the relatively warm water as dusk approached. The uniformity in the vertical gradients of temperature, salinity, and DO at each station suggests that the water column was well-mixed at the time of sampling. This is not surprising considering that the sampling occurred in late autumn, well after the breakdown of the seasonal thermocline in Long Island Sound and at a time when more frequent and intense wind-induced mixing of the water column might be expected. In the absence of a strong and persistent pycnocline at WLIS, it is not likely that near-bottom hypoxia or anoxia would develop.

Throughout the day on 23 November, the entire water column remained supersaturated with respect to DO. For example, it has been calculated that the maximum solubility of oxygen in seawater with a temperature of 10C and salinity of 28 ppt at an atmospheric pressure of 760 mm Hg would be 9.45 mg/ℓ (Weiss, 1970). The lowest DO value measured at WLIS (9.61 mg/ℓ) exceeded this maximum solubility value. The fact that this oxygen supersaturation was observed at all depths again suggests that the water column was extremely well-mixed at the time of sampling. The observed trend of decreasing dissolved oxygen concentrations at both reference and on-site stations as the day progressed on 23 November might indicate that the waters in this area were beginning to return to equilibrium (i.e., becoming less supersaturated) with respect to DO, or it could reflect an influx of lower DO parcels of water as a result of tidal movement.

4.4 Sediment Sampling and Analysis

The results of physical testing of sediments at WLIS, which showed that mixtures of silt-clay, silty sand, or sandy silt predominated at the stations tested, generally agreed well with the results obtained in the REMOTS® survey (see Table 3-1 and Figure 3-11). The significant fractions of medium and fine sands at station 3-E and, to a lesser extent, at station 3-I reflect past and recent additions of dredged material consisting of sand with lesser amounts of silt-clay. The predominance of sands at all three stations located south of the disposal location (1000SW, 2000S and 1000SE) suggests that this material occurs naturally in this area. Elsewhere, the results of both physical testing and REMOTS® mapping indicated that silt-clay (i.e., > 4 phi) sediments predominate.

The results of the sediment chemistry analyses showed that concentrations of metals at most of the stations tested were either below analytical detection limits, were significantly less than or did not differ significantly from those measured at the reference stations. The significant elevations of Pb, Zn, and Fe at station 3-A most likely were related to recent inputs of dredged material at the "B" disposal mound, especially in the case of Pb which was at "Moderate" levels in 28% of the disposed material (as determined from chemical analyses as part of the pre-disposal permitting process). Although As and Hg were also at "Moderate" levels in the material submitted for testing prior to disposal, their concentrations as well as the concentrations of the other metals for which NERBC guidelines exist were at "Low" or minimal "Moderate" levels at all stations. Likewise, significant contamination in terms of Fe, % TOC, PHC's, and PCB's was not observed at any of the sampled stations.

The objective of the sediment chemical analyses was to assess whether contaminants deposited at the WLIS site as a result of past and on-going disposal were subject to further resuspension and transport, possibly resulting in long-term accumulation outside the site boundaries. Only Hg at station 1000NW outside the disposal site boundaries showed a statistically-significant elevation above reference levels. However, the mean concentration of Hg at this station (0.22 ppm) was quite low (i.e., NERBC "Low") and could reasonably be considered a background level. Likewise, a very low but statistically-elevated concentration of Hg occurred at station 1000E within the disposal site. It is notable that this metal was also somewhat elevated ("Moderate" levels) in 33% of the recently-disposed material (determined from the pre-disposal chemical analyses). However, it is difficult to conclude that the Hg had been transported from the disposal mounds because there was no Hg elevation at any of the mound stations. All the other contaminants measured at stations outside the disposal site were at levels not significantly different from background (i.e., reference) levels. Furthermore, the concentration ranges of the metals found at WLIS were comparable to levels found in DAMOS surveys conducted in August 1985 and 1986 (SAIC, 1987; 1988b), and similar to levels found by Grieg et al. (1977) in the vicinity of the site and by Benninger et al. (1979) in central Long Island Sound. Together, these facts strongly suggest that contaminants associated with dredged sediments disposed over several years (i.e., since 1982) at the WLIS site were not being transported and accumulating in detectable concentrations outside the site.

An assessment of the concentration gradients of Pb, Zn, and Fe (the three contaminants which showed a significant disposal-related signature at station 3-A near the disposal point) further suggests a lack of contaminant re-suspension, transport, and accumulation outside the site boundaries. If transport had occurred along the east-west transect defined by stations 1000W, 3-A, 3-E, 3-I, 1000E, and 2000E (the axis of predominant current movement), a decreasing concentration gradient going from station 3-A to the outlying stations would be expected. In fact, graphs of the sediment chemistry data generally do not illustrate such concentration gradients (Figure 3-23) and none of the outlying transect stations showed elevated concentrations of Pb, Zn, and Fe relative to background levels. This supports the conclusion that these contaminants were not transported from station 3-A to stations outside the disposal site boundaries, consistent with the prediction that sediment-associated contaminants would remain deposited within the mound.

The order of magnitude elevation of PHC's at reference station 2000N could have resulted from an event such as a local oil or gas spill/discharge, or it may be due to contamination during sample collection or analysis. Since the chemical analyses performed were for total PHC's, which encompasses a large number of compounds, the exact nature of the contamination cannot be determined. It is noteworthy, however, that none of the other measured parameters at this station were elevated. If the PHC elevation was caused by the inadvertent disposal of contaminated dredged material, concomitant elevations in one or more of the metals or in PCB's might be expected.

4.5 Body Burden Analysis

Reflecting the general pattern of sediment contaminant levels, body burdens of Cd, Pb, Cu, Fe, Hg, and PCB's in Nephtys from WLIS disposal mound stations 3-E, 3-A, and 3-I generally were either below detection limits, significantly less than, or not significantly different from those at the reference stations. The exception to this was a significant elevation of Cu in the polychaetes from station 3-A, which was near the active disposal mound. Except for Cu, the ranges for all metal and PCB concentrations found in Nephtys in this survey were consistent with the ranges found in August 1986 (SAIC, 1988b), and were well below the ranges found by Munns et al. (in press) in Nephtys collected on dredged material at the FVP mound in central Long Island Sound. Thus, there was little evidence of contaminant bioaccumulation as a result of long-term exposure of the polychaetes to dredged material at the site.

It is possible that some uptake of Cu by the polychaetes could have occurred through contact with the surface sediments at station 3-A, which exhibited the second highest mean concentration of Cu among the eight stations tested (Table 3-2 and Figure 3-23). However, sediment Cu levels at station 3-A were not significantly elevated compared to the reference sediment concentrations (Table 3-3). This makes it difficult to establish a clear association between sediment contamination and biological uptake in this instance. To further assess the relationship between sediment contamination and the biological uptake of contaminants, a nonparametric test for association (Spearman's coefficient of rank correlation) between the mean sediment concentrations and respective mean body burdens of a particular contaminant was performed. Only the four contaminants (Pb, Cu, Fe, and PCB's) displaying both body burdens and surface sediment concentrations above detection limits could be tested. In all cases, the body burden levels were not significantly associated with the sediment concentrations of the four contaminants (Spearman's rho = 0.04 for Pb, 0.49 for Cu, -0.30 for PCB's and 0.35 for Fe, $p > 0.05$ in all cases).

5.0 CONCLUSIONS

Both the precision bathymetric and REMOTS® surveys at WLIS indicated an accumulation of recently-deposited dredged material at the "B" mound, where the disposal buoy had been located since 1 September 1986. The deposited material occurred around the buoy in a broad, circular mound having a radius of about 100 m. Based on comparisons with the previous year's bathymetric results, the "C" and "A" disposal mounds at WLIS were found to be unchanged. Relict dredged material was visible in the REMOTS® photos from stations at and in the vicinity of these two mounds.

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 an overall absence of seafloor disturbance related to dredged material disposal at the site. Furthermore, the significantly higher OSI values calculated at both reference and on-site stations suggested that overall benthic habitat quality improved in 1987 compared to August 1986 and October 1985 (following the physical seafloor disturbance resulting from Hurricane Gloria). The relatively healthy benthic conditions observed at WLIS in 1987 reflected both high near-bottom DO concentrations at the time of sampling, as well as an absence of stress related to seasonal near-bottom hypoxia in the weeks and months preceding the survey.

Physical testing of sediments at WLIS showed good agreement with the results obtained in the REMOTS® survey; mixtures of silt-clay, silty sand, or sandy silt predominated at the stations sampled. Chemical analyses of surface sediments showed contaminant concentrations only at "Low" or minimal "Moderate" levels; these levels were consistent with those found previously at the site. Only Pb, Zn, and Fe at station 3-A near the active "B" disposal mound exhibited concentrations which were both significantly higher than reference levels and clearly related to disposal. The absence of a decreasing concentration gradient in levels of Pb, Zn, and Fe going from station 3-A to the outlying stations, coupled with the fact that none of the outlying transect stations showed elevated concentrations of these three metals relative to background (i.e., reference) or historic levels, suggests that resuspension and transport had not occurred.

Reflecting the general pattern of sediment contaminant levels, body burdens of Cd, Pb, Cu, Fe, Hg, and PCB's in Nephtys from WLIS disposal mound stations 3-E, 3-A, and 3-I generally were either below detection limits, significantly less than, or not significantly different from those at the reference stations and were consistent with levels found in previous studies. The exception to this was a significant elevation of Cu in the polychaetes from station 3-A near the active "B" disposal mound. The lack of a corresponding significant elevation in Cu concentrations in surface sediments at this station made it difficult to establish a clear association between sediment contaminant levels and biological uptake. Statistical tests for association between mean sediment concentrations and body burdens also indicated a lack of significant correlation.

Generally, the annual REMOTS® surveys conducted since 1984 at the WLIS Disposal Site and nearby reference stations have lead to the conclusion that the western Long Island Sound region represents a "stressed" benthic environment, as a result of the regional high levels of anthropogenic organic loading (e.g., sewage effluent), restricted water exchange, and seasonal hypoxic or dysaerobic dissolved oxygen levels in near-bottom waters. Ambient sediments typically are highly reduced (high sediment oxygen demand and very low optical reflectance in REMOTS® photos) and characterized by relatively shallow RPD depths, particularly during the warmer summer months. These stressed conditions were exacerbated by the physical bottom disturbance caused by Hurricane Gloria in September 1985 and the severe near-bottom hypoxia which occurred in August 1986. Overall, the results of the November 1987 REMOTS® survey at WLIS represent a return to the relatively "normal" conditions observed in August 1985 (higher level benthic recolonization). This has been attributed to the lack of severe hypoxic stress at the site during 1987 and also because the 1987 survey was performed in November, when water column dissolved oxygen values were exceedingly high.

The monitoring results of the past five years at WLIS lead to the conclusion that benthic community conditions at the site are controlled largely by the regional phenomena mentioned earlier, in particular low near-bottom dissolved oxygen concentrations and seasonal water-column stratification in western Long Island Sound. These "outside" forces act to determine the health of the benthic environment at the disposal site and how it responds to the relatively minor and very localized physical disturbance resulting from dredged material disposal. At this site more than any other, it is imperative that results of seasonal DAMOS monitoring be interpreted within this regional context.

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Table 3-1

Results of Physical Testing of Sediment Collected at WLIS, November 1987. Grain Size Classifications are based on the Udden-Wentworth Scale.

Station	Visual Description	% Granule and Larger	% Medium and Coarse Sand	% Fine Sand	% Silt-Clay
WLIS-Ref	sandy silt, some shell	16	17	14	53
2000W	grey silt, some sand and shells	<1	5	2	93
2000S	silty grey sand some shells	<1	28	40	32
2000N	grey silt with sand, some shells	9	10	5	76
3000E	grey silt with sand, some shells	<1	8	19	73
3-A	grey silt some shells	<1	5	7	88
3-I	grey sandy silt some shells	<1	20	12	68
3-E	grey silty sand some shells	8	36	12	44
1000E	grey silty clay some sand and shells	2	6	8	84
1000SE	grey silty sand some shells	10	40	20	30
1000W	grey silty clay some shells	0	1	2	97
1000SW	grey silty sand some shells	2	56	16	26
1000NW	grey silt with sand, some shells	2	9	16	73
1000NE	grey silty clay some shells	0	<1	4	96
2000E	grey silt with sand, some shells	0	5	13	82

Table 3-2

Results of Chemical Analyses of Sediment Collected at WLIS, November 1987
(Concentrations based on Dry Weight; PHC's = Petroleum Hydrocarbons;
TOC = Total Organic Carbon)

Station/Replicate	Hg ppm	Pb ppm	Zn ppm	As ppm	Fe ppm	Cd ppm	Cu ppm	PHC's ppm	PCB's ppb	TOC %
WLIS-Ref/1	0.13	47	139	5.0	28,000	Nd	59	710	-	1.15
WLIS-Ref/2	0.16	43	142	5.7	32,000	Nd	59	380	-	1.21
WLIS-Ref/3	0.13	39	125	3.2	33,000	Nd	48	310	-	1.11
Mean	0.14	43	135	4.6	31,000	-	55	467	70*	1.16
±Std. Dev.	0.02	4	9	1.3	2,600	-	6	214	-	0.05
2000W/1	0.11	68	214	6.7	36,000	Nd	116	540	-	1.68
2000W/2	0.14	72	218	6.6	37,000	Nd	114	460	-	1.54
2000W/3	0.13	85	214	7.0	37,000	Nd	119	580	-	1.78
Mean	0.13	75	215	6.8	36,700	-	116	527	70*	1.67
±Std. Dev.	0.02	9	2	0.2	600	-	3	61	-	0.12
2000S/1	0.05	23	84	2.5	14,000	Nd	47	380	-	0.77
2000S/2	0.12	41	119	3.7	18,000	Nd	63	190	-	0.81
2000S/3	0.06	26	93	2.5	15,000	Nd	51	Nd	-	0.98
Mean	0.08	30	99	2.9	15,700	-	54	285	40*	0.85
±Std. Dev.	0.04	10	18	0.7	2,100	-	8	-	-	0.11
3000E/1	0.24	58	-	5.3	-	-	-	270	-	1.52
3000E/2	0.20	55	-	4.9	-	-	-	310	-	1.31
3000E/3	0.23	69	-	5.1	-	-	-	420	-	1.33
Mean	0.22	61	-	5.1	-	-	-	333	220*	1.39
±Std. Dev.	0.02	7	-	0.2	-	-	-	78	-	0.12

* = Composite sample   Nd = Below minimum detection limit
- = Not analyzed

Table 3-2 continued

Station/Replicate	Hg ppm	Pb ppm	Zn ppm	As ppm	Fe ppm	Cd ppm	Cu ppm	PHC's ppm	PCB's ppb	TOC %
2000N/1	0.10	54	192	5.8	29,000	Nd	99	8,930	-	1.40
2000N/2	0.06	29	128	5.9	29,000	Nd	59	5,570	-	0.99
2000N/3	0.16	53	196	5.9	27,000	Nd	122	7,280	-	1.29
Mean	0.11	45	172	5.9	28,300	-	93	7,260	70*	1.23
±Std. Dev.	0.05	14	38	0.1	1,200	-	32	1,680	-	0.21
3-A/1	0.20	75	203	5.2	34,000	Nd	111	660	-	1.48
3-A/2	0.17	69	221	5.6	40,000	Nd	101	570	-	1.29
3-A/3	0.17	75	220	5.6	39,000	Nd	105	560	-	1.30
Mean	0.18	73	215	5.5	37,700	-	106	597	130*	1.36
±Std. Dev.	0.02	3	10	0.2	3,200	-	5	55	-	0.11
3-I/1	0.15	65	196	5.9	33,000	Nd	85	450	-	1.56
3-I/2	0.14	67	213	6.4	39,000	Nd	91	550	-	1.68
3-I/3	0.50	156	175	2.5	11,000	4	74	1,200	-	0.94
Mean	0.26	96	195	4.9	27,700	-	83	733	120*	1.39
±Std. Dev.	0.20	52	19	2.1	14,700	-	9	407	-	0.40
3-E/1	0.12	59	159	4.5	27,000	Nd	72	390	-	1.21
3-E/2	0.12	58	131	4.3	18,000	Nd	59	410	-	1.11
3-E/3	0.16	45	147	4.8	21,000	Nd	58	720	-	1.12
Mean	0.13	54	146	4.5	22,000	-	63	507	100*	1.15
±Std. Dev.	0.02	8	14	0.3	4,600	-	8	185	-	0.06

* = Composite sample   Nd = Below minimum detection limit
- = Not analyzed

Table 3-2 continued

Station/Replicate	Hg ppm	Pb ppm	Zn ppm	As ppm	Fe ppm	Cd ppm	Cu ppm	PHC's ppm	PCB's ppb	TOC %
1000SE/1	0.15	40	-	3.6	-	-	-	300	-	0.85
1000SE/2	0.04	29	-	2.3	-	-	-	230	-	0.73
1000SE/3	0.02	19	-	1.7	-	-	-	Nd	-	0.52
Mean	0.07	29	-	2.5	-	-	-	265	60*	0.70
±Std. Dev.	0.07	10	-	1.0	-	-	-	-	-	0.17
1000W/1	0.10	68	-	3.8	-	-	-	510	-	1.49
1000W/2	0.12	59	-	5.7	-	-	-	1,070	-	1.43
1000W/3	0.14	67	-	6.1	-	-	-	490	-	1.46
Mean	0.12	65	-	5.2	-	-	-	690	100*	1.46
±Std. Dev.	0.02	5	-	1.2	-	-	-	329	-	0.03
1000SW/1	0.06	30	-	2.3	-	-	-	240	-	1.05
1000SW/2	0.04	49	-	2.2	-	-	-	Nd	-	0.69
1000SW/3	0.09	27	-	3.3	-	-	-	150	-	0.77
Mean	0.06	35	-	2.6	-	-	-	195	40*	0.84
±Std. Dev.	0.03	12	-	0.6	-	-	-	-	-	0.19
1000NW/1	0.26	224	-	4.9	-	-	-	350	-	1.17
1000NW/2	0.22	44	-	5.1	-	-	-	250	-	1.14
1000NW/3	0.17	49	-	5.7	-	-	-	260	-	1.35
Mean	0.22	106	-	5.2	-	-	-	287	80*	1.22
±Std. Dev.	0.04	102	-	0.4	-	-	-	55	-	0.11

* = Composite sample

- = Not analyzed

Nd = Below minimum detection limit

Table 3-2 continued

Station/Replicate	Hg ppm	Pb ppm	Zn ppm	As ppm	Fe ppm	Cd ppm	Cu ppm	PHC's ppm	PCB's ppb	TOC %
1000NE/1	0.12	56	-	4.7	-	-	-	570	-	1.31
1000NE/2	0.11	57	-	5.4	-	-	-	480	-	0.78
1000NE/3	0.11	57	-	5.7	-	-	-	420	-	0.35
Mean	0.11	57	-	5.3	-	-	-	490	90*	0.81
±Std. Dev.	0.01	1	-	0.5	-	-	-	75	-	0.48
1000E/1	0.20	70	-	5.8	-	-	-	650	-	1.98
1000E/2	0.78	60	-	5.6	-	-	-	300	-	0.59
1000E/3	0.17	63	-	5.5	-	-	-	650	-	1.76
Mean	0.38	64	-	5.6	-	-	-	533	190*	1.44
±Std. Dev.	0.34	5	-	0.2	-	-	-	203	-	0.75
2000E/1	0.32	72	192	5.1	32,000	Nd	79	350	-	1.35
2000E/2	0.15	53	172	4.0	29,000	Nd	72	380	-	1.41
2000E/3	0.23	57	181	5.5	32,000	Nd	76	510	-	1.25
Mean	0.23	61	182	4.9	31,000	-	76	413	100*	1.34
±Std. Dev.	0.08	10	10	0.8	1,700	-	4	85	-	0.08

* = Composite sample
\- = Not analyzed

Nd = Below minimum detection limits

Table 3-3

Results of Statistical Testing for Significant Differences in Chemical Concentrations in Sediment Collected at WLIS, November 1987

	Variable							
Station	Hg	Pb	Zn	As	Fe	Cu	PHC's*	% TOC
3-A	ns	+	+	ns	+	ns	ns	ns
3-I	ns	ns	ns	ns	ns	ns	ns	ns
3-E	ns	ns	ns	ns	ns	ns	ns	ns
1000SE	ns	ns	0	-	0	0	ns	-
1000W	ns	ns	0	ns	0	0	ns	ns
1000SW	-	ns	0	-	0	0	-	-
1000NW	+	ns	0	ns	0	0	ns	ns
1000NE	ns	ns	0	ns	0	0	ns	ns
1000E	+	ns	0	ns	0	0	ns	ns
2000E	ns	ns	ns	ns	ns	ns	ns	ns

+ = concentrations significantly higher than pooled reference station values ($p \leq 0.05$, Mann-Whitney U-test)

- = concentrations significantly less than pooled reference station values ($p \leq 0.05$, Mann-Whitney U-test)

ns = concentrations not significantly different from pooled reference station values ($p > 0.05$, Mann-Whitney U-test)

0 = not applicable; chemical analysis was not performed

* = values for station 2000N not included among pooled reference station values (rejected as outliers)

Table 3-4

Trace Metals in Body Tissues (Dry Weight) of *Nephtys*
Collected at WLIS, November 1987

	Concentration (ppm)				
Station/Replicate	Cd	Pb	Cu	Fe	Hg
WLIS REF/1	0.2	3.9	26.1	612	<0.04
WLIS REF/2	0.5	1.9	24.7	730	<0.03
WLIS REF/3	0.3	2.5	18.6	543	<0.03
Mean	0.3	2.8	23.1	628	-
±Std. Dev.	0.2	1.0	4.0	95	-
2000W/1	0.2	2.9	33.5	530	<0.02
2000W/2	0.2	2.8	31.9	505	<0.03
2000W/3	0.1	2.4	32.3	475	<0.02
Mean	0.2	2.7	32.6	503	-
±Std. Dev.	0.1	0.3	0.8	28	-
2000E	0.2	1.8	26.6	614	<0.03
2000E	0.2	1.1	28.0	608	<0.03
2000E	0.2	1.2	30.5	682	<0.03
Mean	0.2	1.4	28.4	635	-
±Std. Dev.	0	0.4	2.0	41	-
3-E (CTR)/1	0.2	1.6	36.5	516	<0.02
3-E (CTR)/2	0.1	1.0	30.9	560	<0.03
3-E (CTR)/3	0.2	1.7	32.9	530	<0.02
Mean	0.2	1.4	33.4	535	-
±Std. Dev.	0.1	0.4	2.8	22	-
3-A/1	0.3	1.6	34.0	668	<0.02
3-A/2	0.2	3.3	33.6	583	<0.03
3-A/3	0.5	1.1	32.8	819	<0.02
Mean	0.3	2.0	33.5	690	-
±Std. Dev.	0.2	1.2	0.6	120	-
3-I/1	0.2	1.6	36.3	617	<0.03
3-I/2	0.1	1.9	33.4	702	<0.02
3-I/3	0.2	2.8	31.3	564	<0.03
Mean	0.2	2.1	33.7	628	-
±Std. Dev.	0.1	0.6	2.5	70	-

Table 3-5

Results of Statistical Testing for Significant Differences in Chemical Concentrations in Body Tissues of *Nephtys* Collected at WLIS, November 1987.

	Variable					
Station	Cd	Pb	Cu	Fe	Hg	PCBs (as Aroclor 1254)
3-E (CTR)	ns	ns	ns	ns	0	ns
3-A	ns	ns	+	ns	0	ns
3-I	ns	ns	ns	ns	0	ns

+ = concentrations significantly higher than the pooled reference concentrations ($p \leq 0.05$, Mann-Whitney U-test)

ns = no significant difference between station values and pooled reference values ($p > 0.05$, Mann-Whitney U-test)

0 = not applicable, statistical tests were not performed because concentrations were below analytical detection limits

Table 3-6

PCB's (as Aroclor 1254) in Body Tissues (Dry Weight) of *Nephtys* Collected at WLIS, November 1987. Concentrations in ppb.

Station/Replicate	Aroclor 1254 (ppb)	Mean ± Std. Dev.
WLIS-REF/1	207.2	
WLIS-REF/2	210.4	
WLIS-REF/3	231.9	216.5 ± 13.4
2000W/1	320.6	
2000W/2	287.0	
2000W/3	343.0	316.9 ± 28.2
2000E/1	283.9	
2000E/2	303.8	
2000E/3	290.8	292.8 ± 10.1
3-E (CTR)/1	237.6	
3-E (CTR)/2	349.3	
3-E (CTR)/3	318.7	301.9 ± 57.7
3-A/1	261.2	
3-A/2	215.4	
3-A/3	302.7	259.8 ± 43.7
3-I/1	244.6	
3-I/2	301.3	
3-I/3	248.8	264.9 ± 31.6

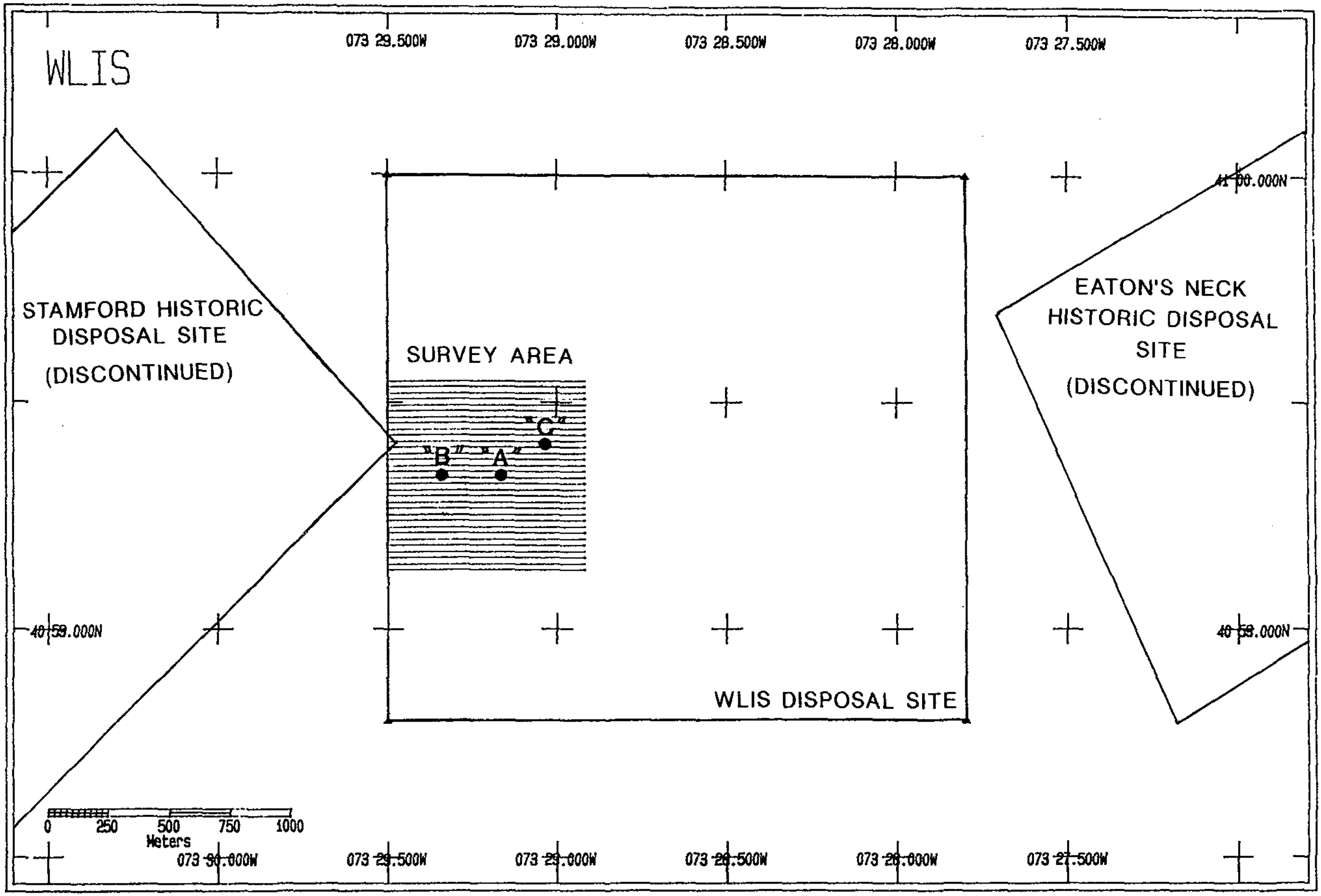


Figure 1-1. The Western Long Island Sound disposal site (WLIS) showing the bathymetric survey lanes and the location of the three disposal mounds ("B", "A", and "C") near the western site boundary.

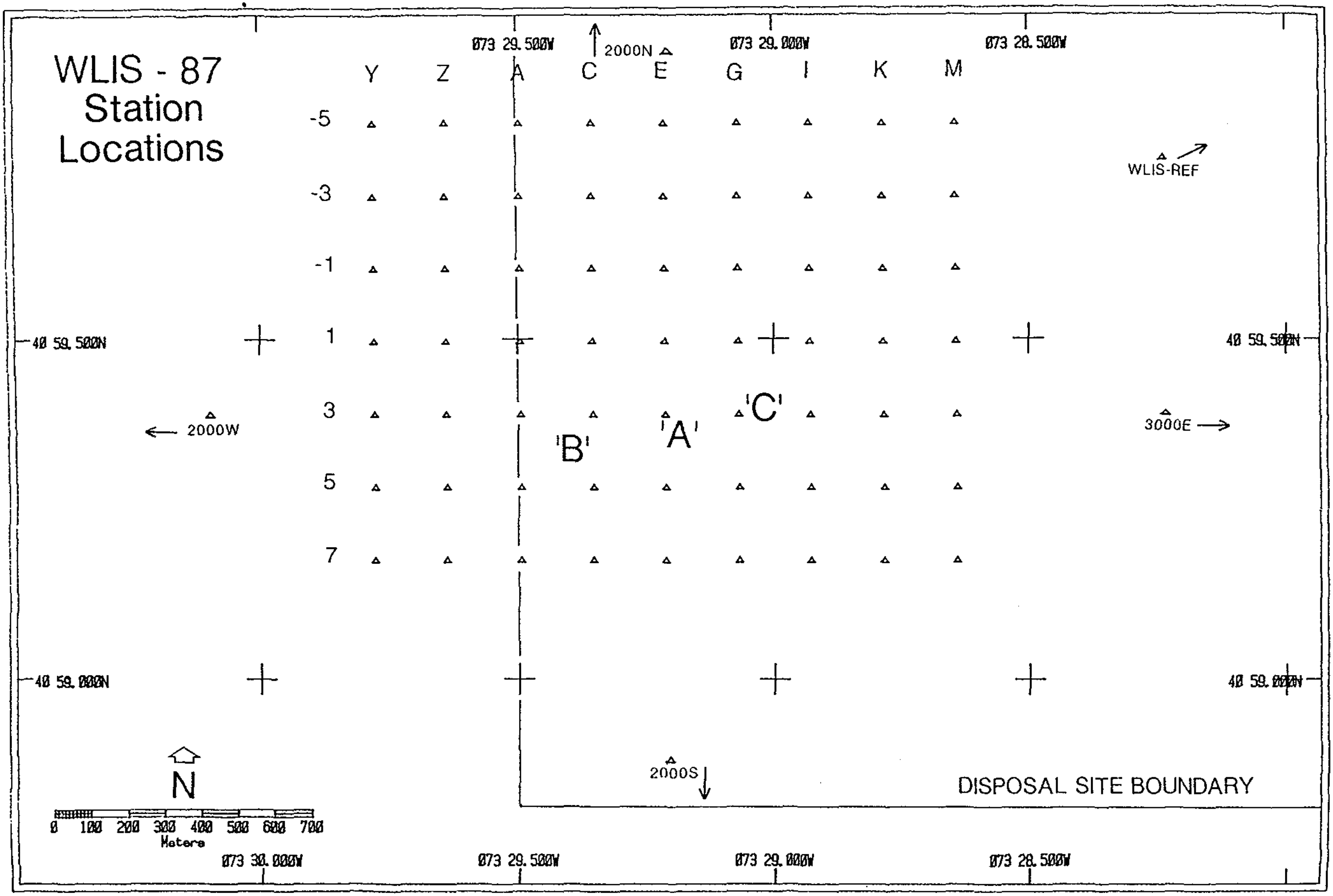


Figure 2-1. Locations and designations of REMOTS stations (triangles) at the WLIS disposal site, November 1987. The approximate locations of the five outlying reference stations (2000W, 2000N, 2000S, 3000E and WLIS-REF) are indicated by arrows, and the locations of the "B", "A", and "C" disposal mounds are also indicated.

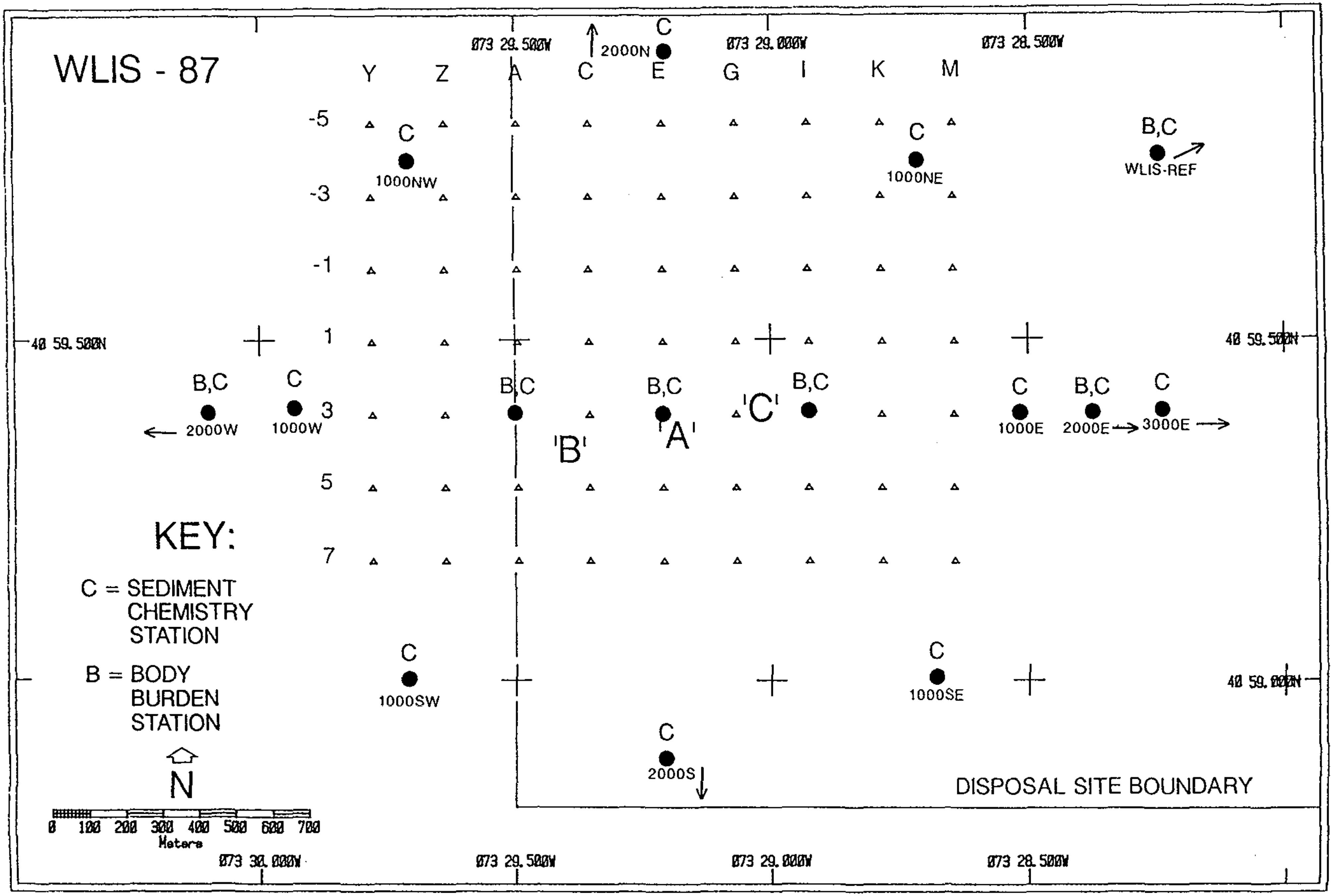


Figure 2-2. Sediment chemistry and body burden stations at WLIS, November 1987. Most of the stations, indicated by the solid dots, are named based on their distance (in meters) and compass bearing from station 3-E near the center of the REMOTS grid. The "B", "A", and "C" disposal mounds are also indicated.

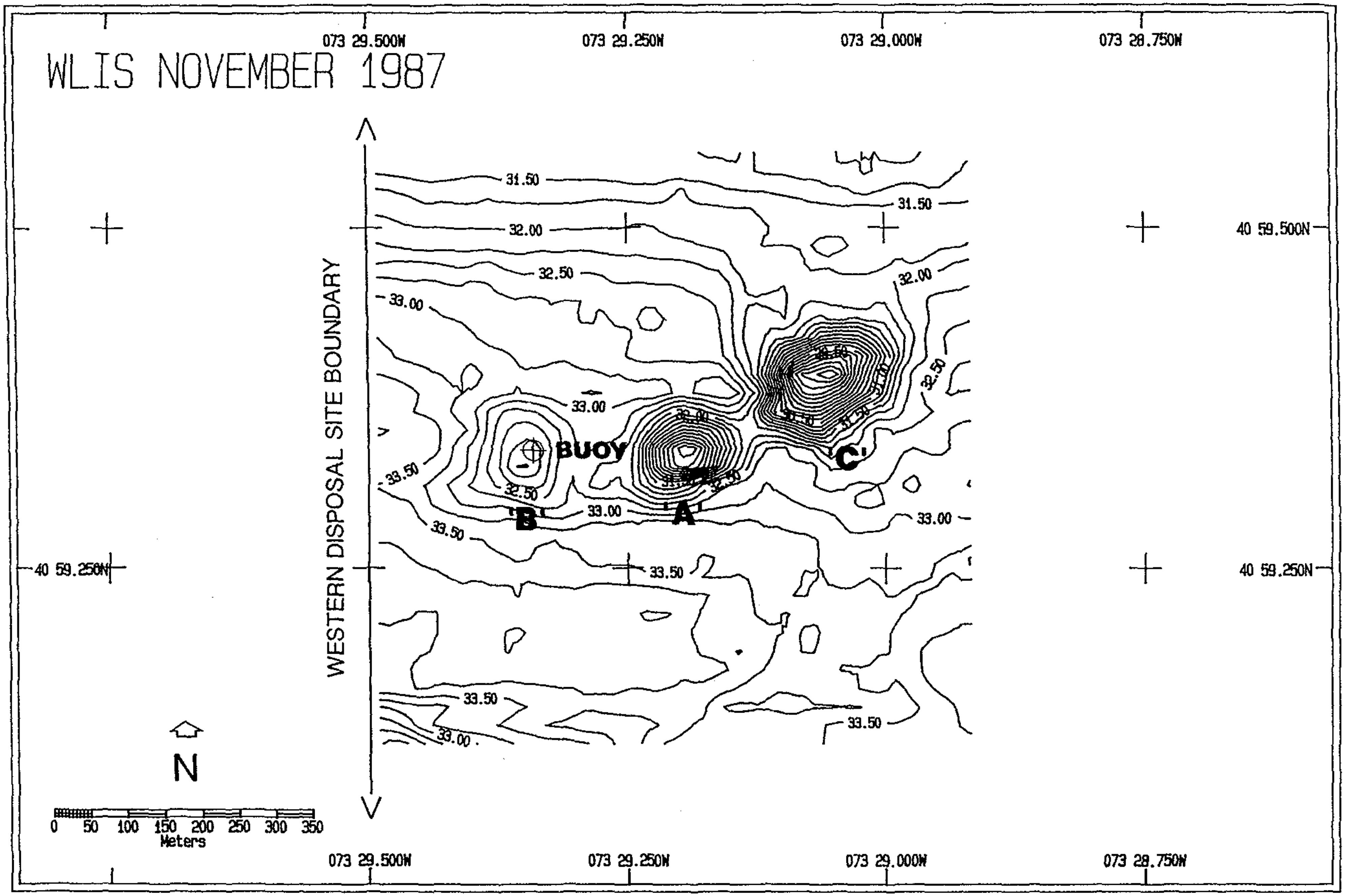


Figure 3-1. Bathymetric contour chart of the WLIS disposal site, November 1987. The "B", "A", and "C" disposal mounds are labeled. Depths are in meters.

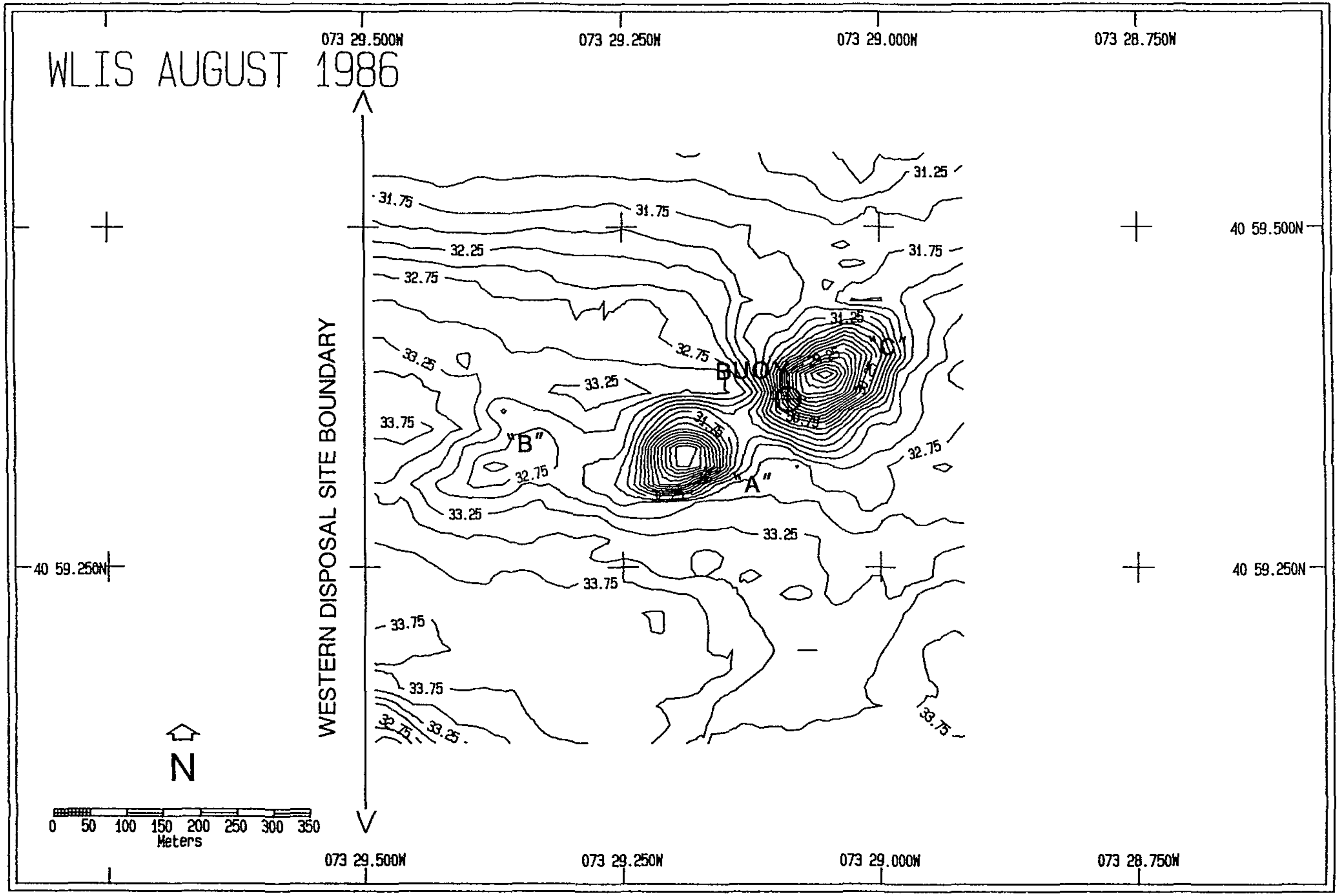


Figure 3-2. Bathymetric contour chart of the WLIS disposal site, August 1986. The "B", "A", and "C" disposal mounds are labeled. Depths are in meters.

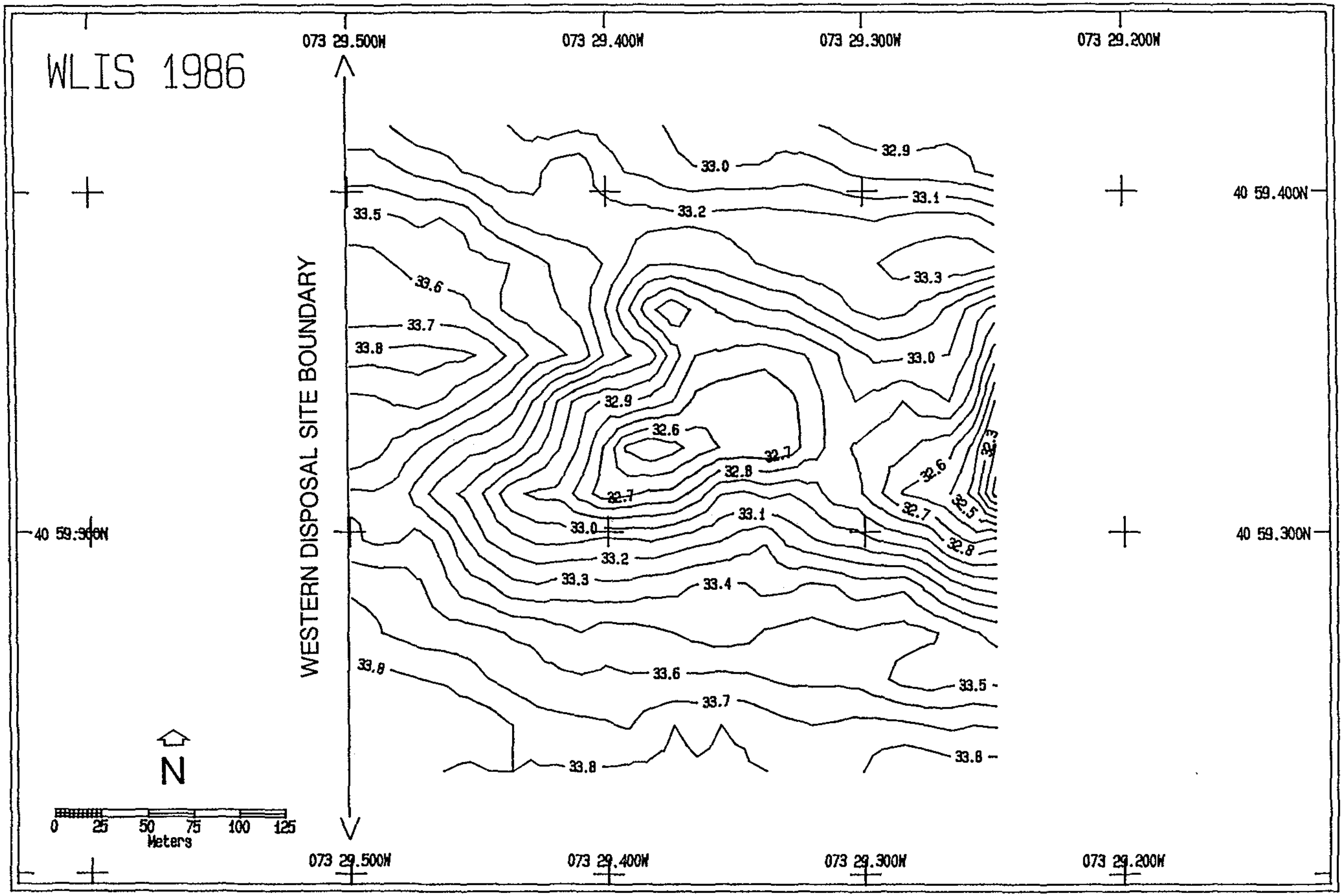


Figure 3-3. Bathymetric contour chart of the area surrounding the WLIS "B" mound, August 1986. Depths are in meters.

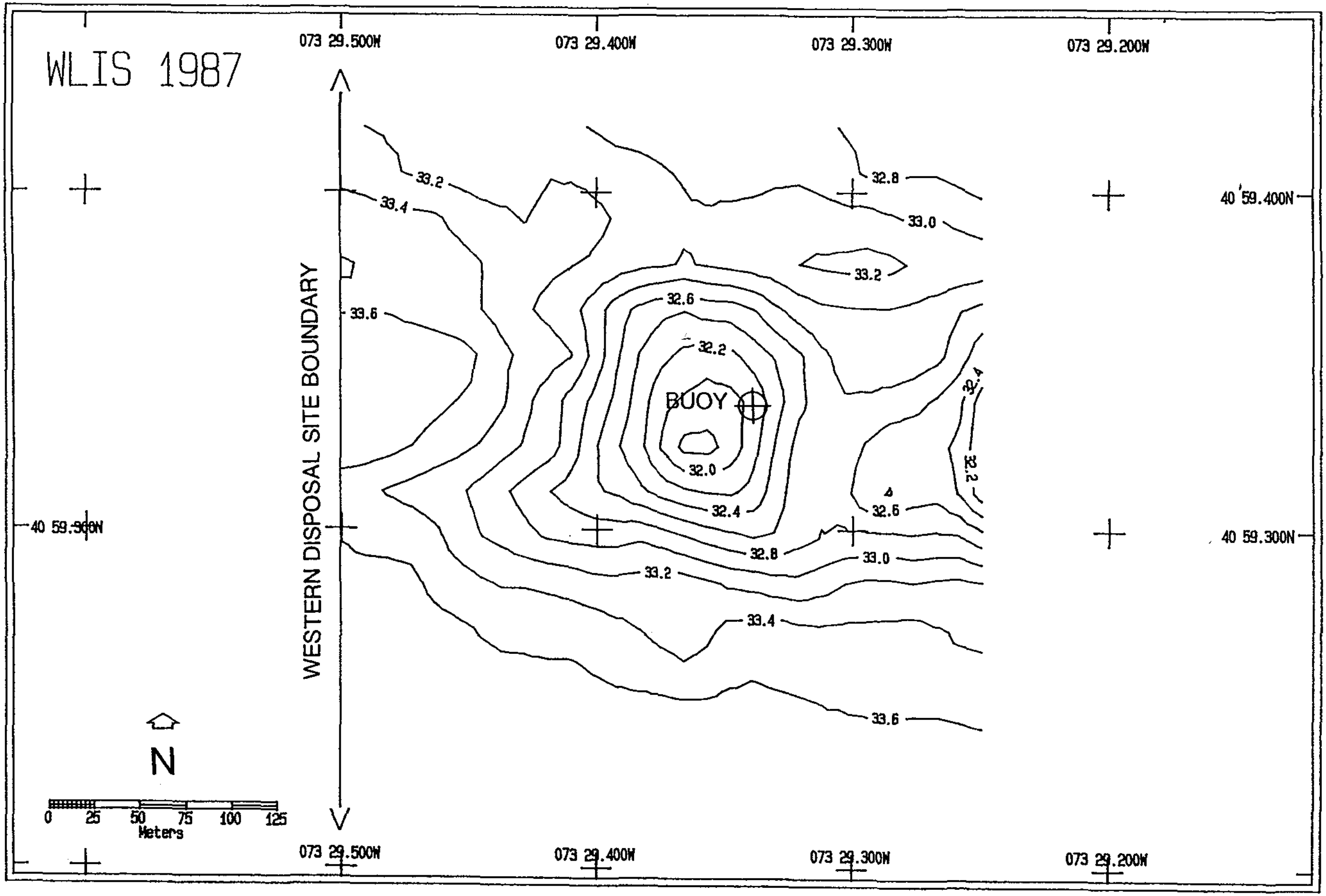


Figure 3-4. Bathymetric contour chart of the area surrounding the WLIS "B" mound, November 1987. Depths are in meters.

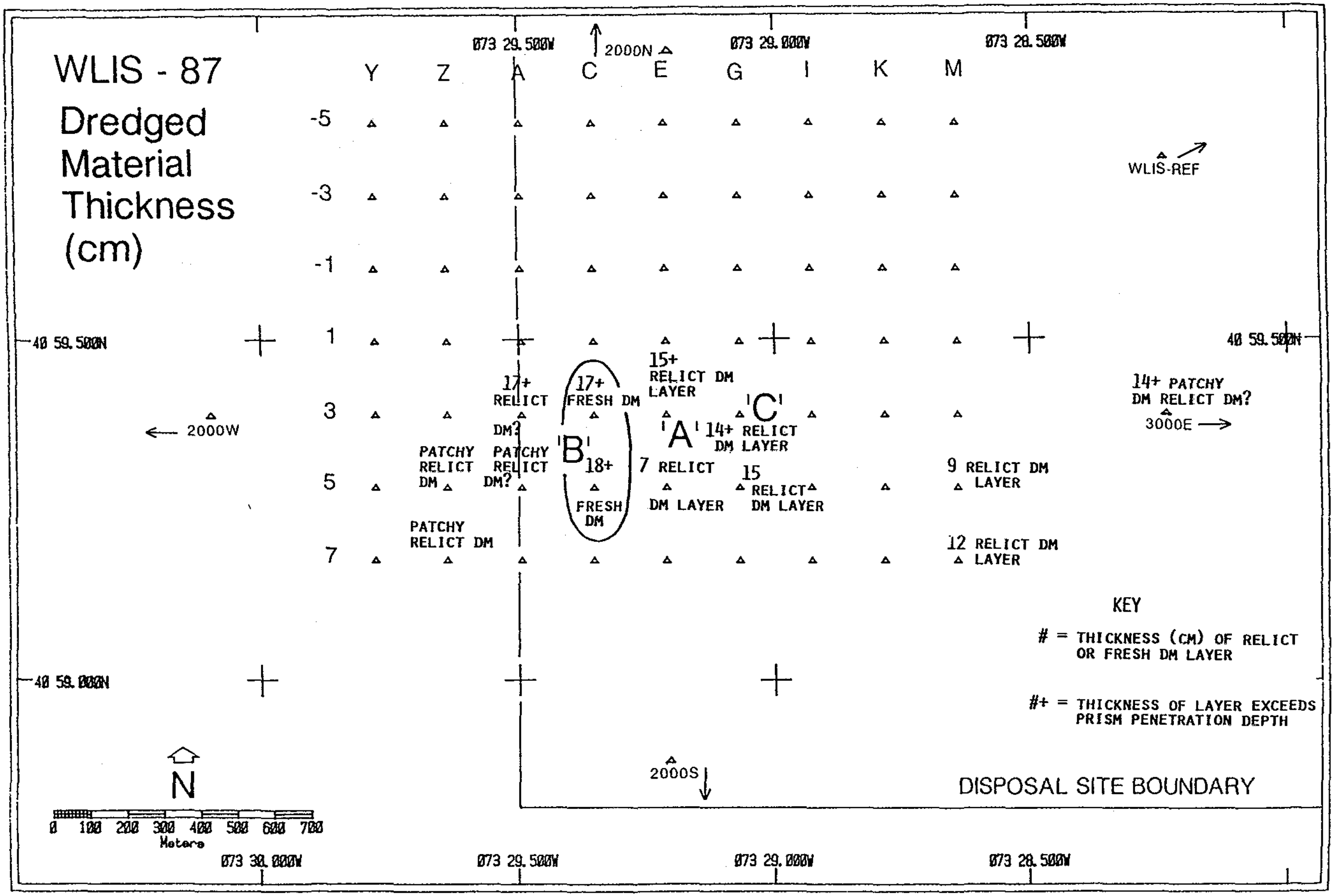


Figure 3-5. Distribution of dredged material at the WLIS disposal site, November 1987. The contour delimits stations having apparent dredged material deposited since the previous REMOTS survey in August 1986. Dredged material was not apparent at stations where no values are indicated.

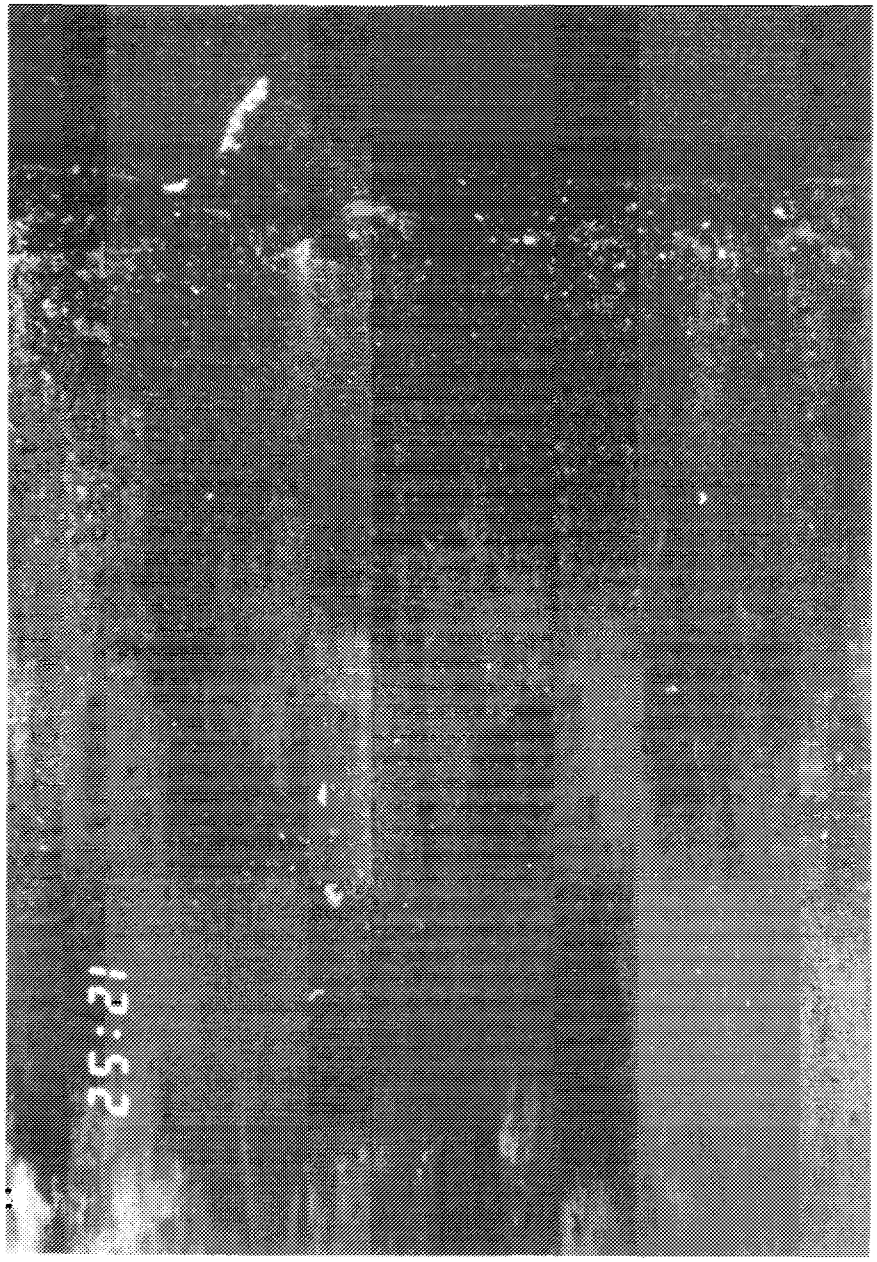


Figure 3-6. REMOTS® image from station 3-C directly on the WLIS "B" mound showing "fresh" dredged material exceeding the depth of penetration of the camera prism. This material, composed primarily of silt-clay, is characterized by its extremely low reflectance and lack of an RPD. In this instance, it also has a significant sand component. Scale of image = 1X.

Figure 3-7. REMOTS® image from station 5-C at the WLIS "B" mound showing "fresh" dredged material which has a mottled appearance caused by alternating high and low reflectance patches of silt-clay. The material, which also has a significant sand component, exceded the depth of prism peneteration at this station. Scale = 1X.

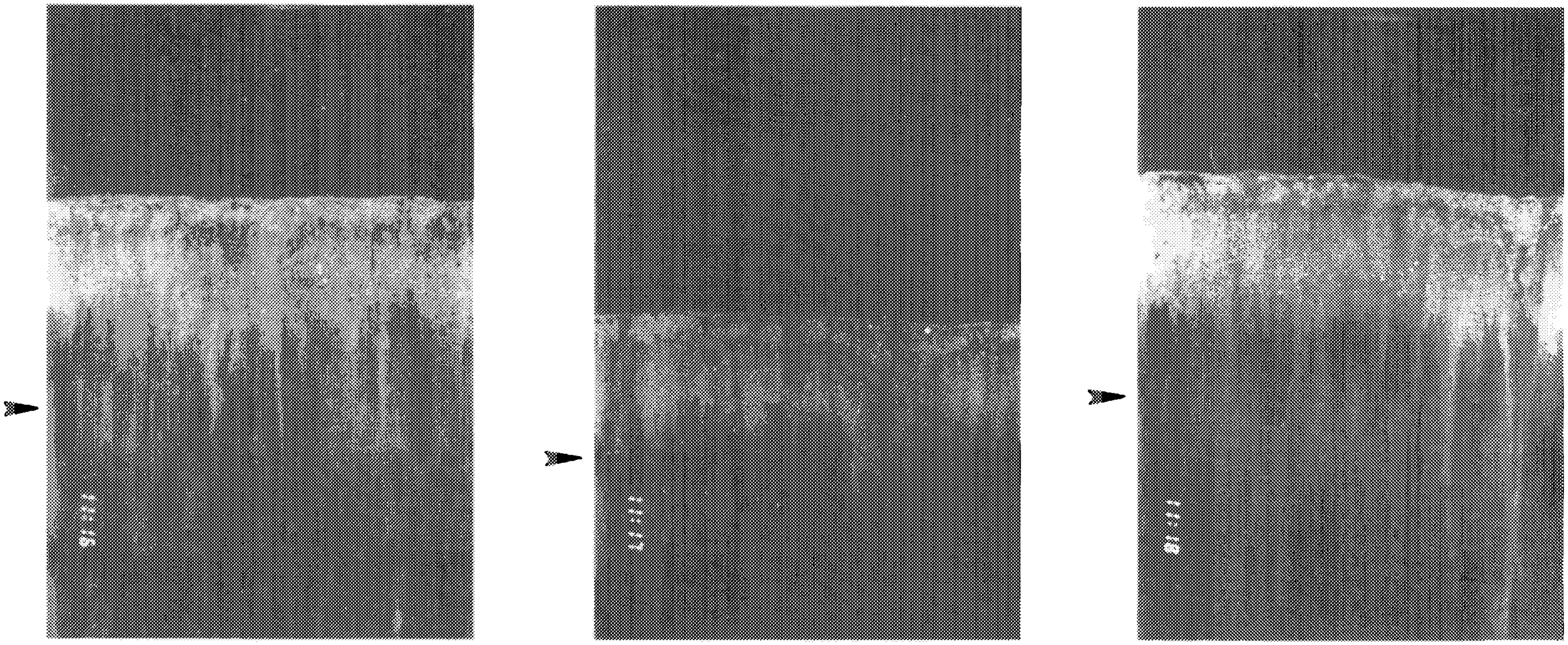


Figure 3-8. Three replicate REMOTS images from station 5-E showing a relict dredged material layer extending from the surface to a depth of approximately 7 cm. The bottom of the layer, distinguished by its characteristic low reflectance, is marked by the arrows. When first deposited, the entire layer probably had extreme low reflectance (see Figure 3-6). It has since undergone reworking by infaunal organsims and has been oxidized near the surface, leaving only the partial low-reflectance signature at depth. Approximate scale of images = 0.45X.

Figure 3-9. Discontinuous sand layers and patches of low reflectance mud at depth distinguish the relict dredged material in this REMOTS® image from station 3-G. This station is located at disposal mound "C". Scale of image = 1X.

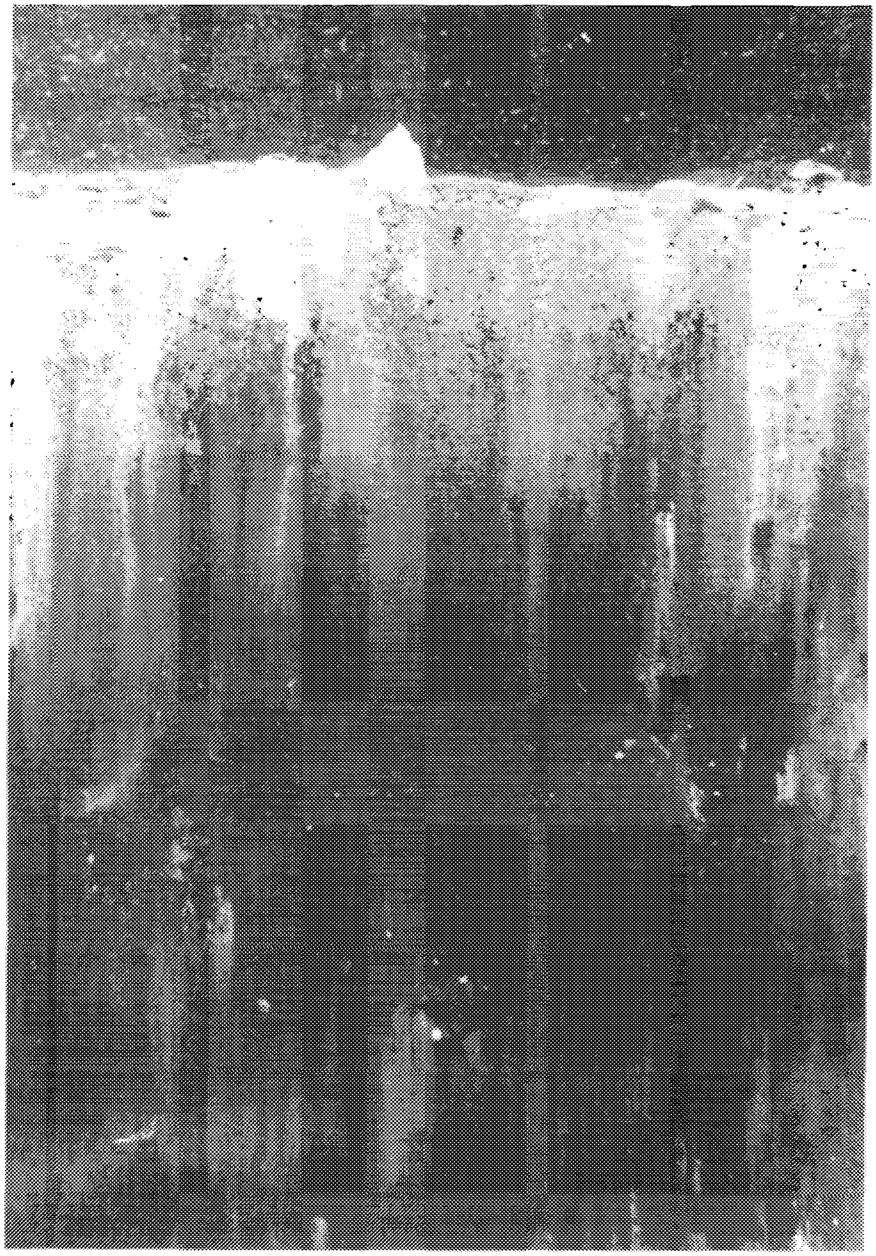


Figure 3-10. REMOTS® image from reference station 3000E showing apparent dredged material exceding the depth of prism penetration. The material is distinguished by its extreme low-relectance at depth. Scale = 1X.

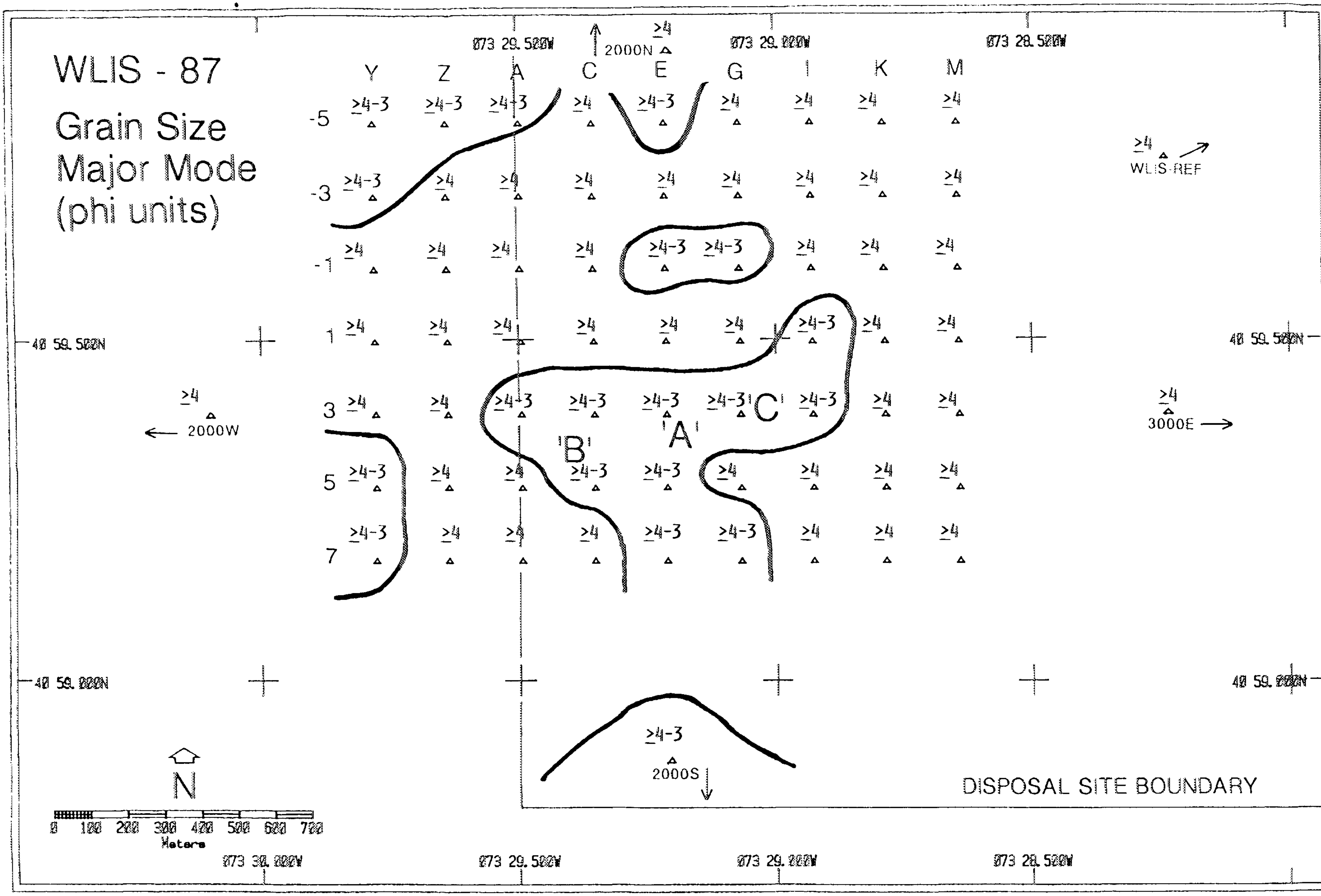
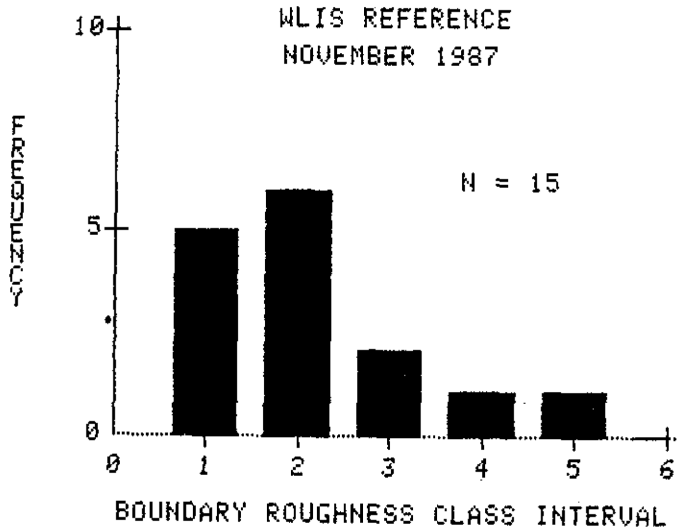
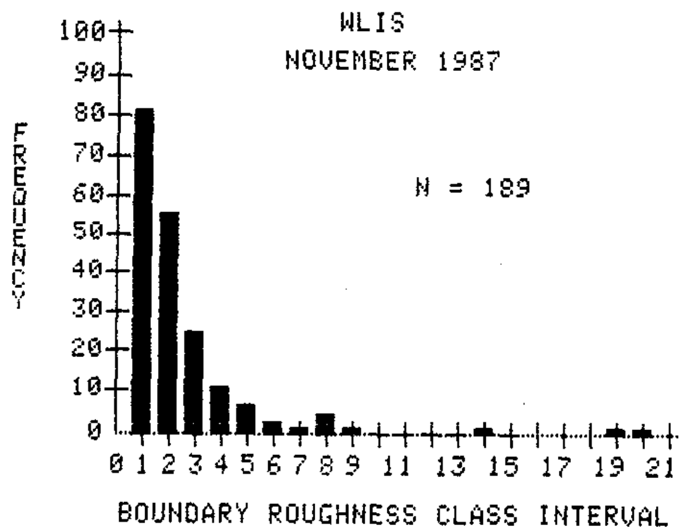


Figure 3-11. Map of sediment grain size major mode (in phi units) at the WLIS disposal site, November 1987. The contours delimit areas having a major mode of >4-3 phi (fine sand/silt/clay).

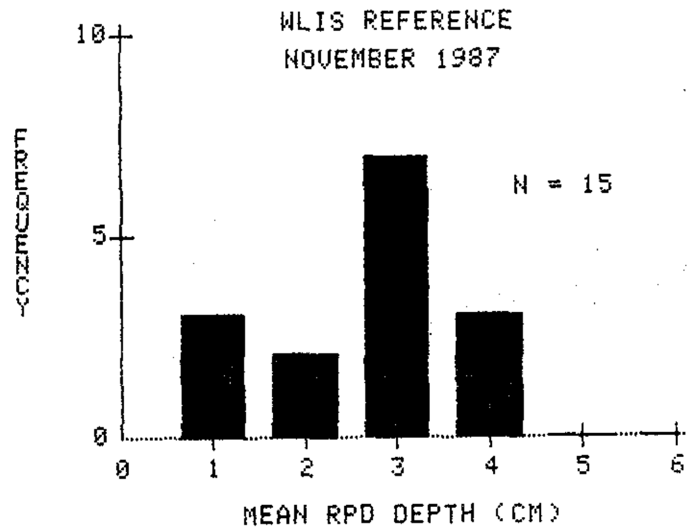




KEY:

CLASS INTERVAL	RANGE OF VALUES (cm)
1	0.0 - 0.6
2	0.6 - 1.0
3	1.0 - 1.4
4	1.4 - 1.8
5	1.8 - 2.2
6	2.2 - 2.6
7	2.6 - 3.0
8	3.0 - 3.4
9	3.4 - 3.8
10	3.8 - 4.2
11	4.2 - 4.6
12	4.6 - 5.0
13	5.0 - 5.4
14	5.4 - 5.8
15	5.8 - 6.2
16	6.2 - 6.6
17	6.6 - 7.0
18	7.0 - 7.4
19	7.4 - 7.8
20	7.8 - 8.2
21	8.2 - 8.6

Figure 3-12. Frequency distributions of small-scale surface boundary roughness values for all replicates at both reference and onsite REMOTS® stations at WLIS, November 1987.



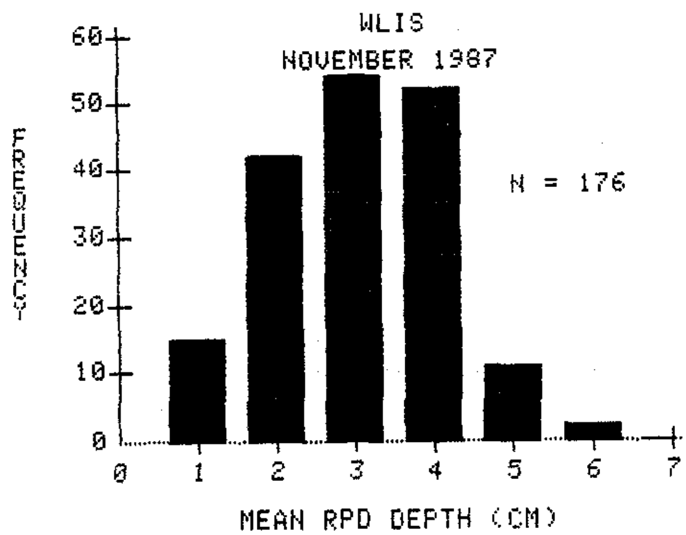


Figure 3-13. Frequency distributions of apparent RPD depths for all replicates at both the reference and onsite REMOTS® stations at WLIS, November 1987.

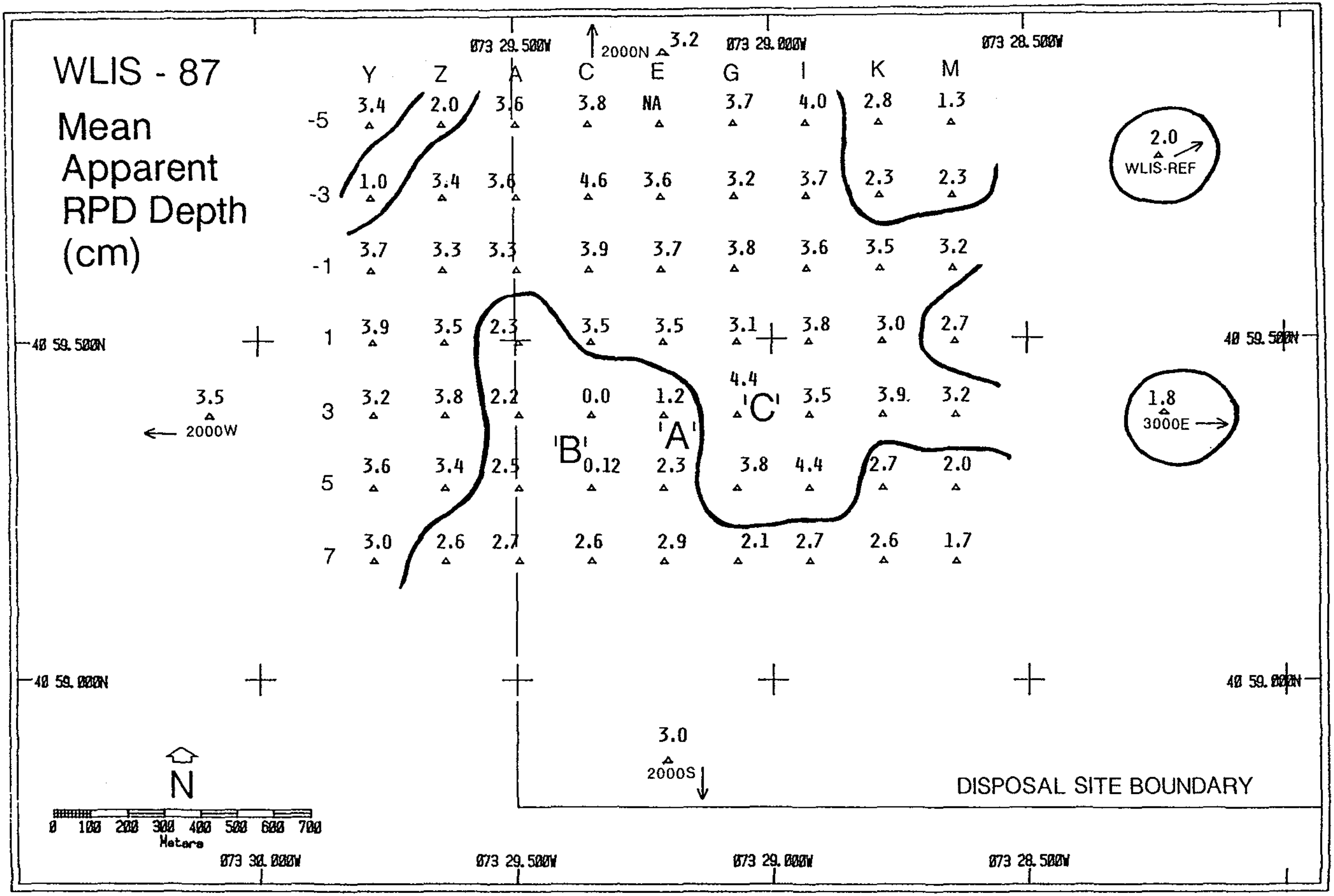


Figure 3-14. The distribution of apparent RPD depths (cm), averaged by station, at WLIS in November 1987. The contours delimit stations having mean apparent RPD depths $\leq$ 3 cm.

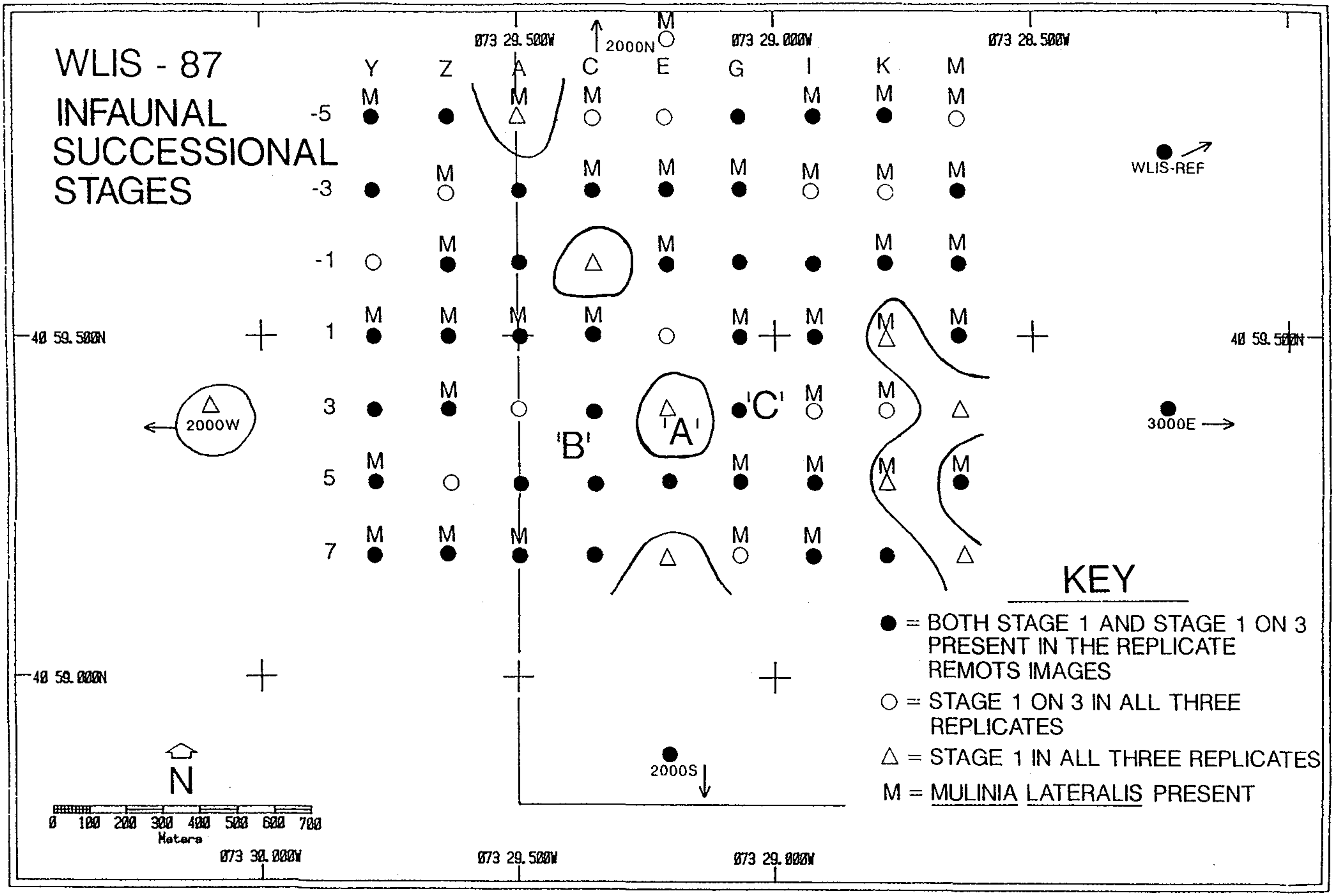


Figure 3-15. The distribution of infaunal successional stages at the WLIS disposal site, November 1987. The contours delimit areas having only Stage I taxa present.

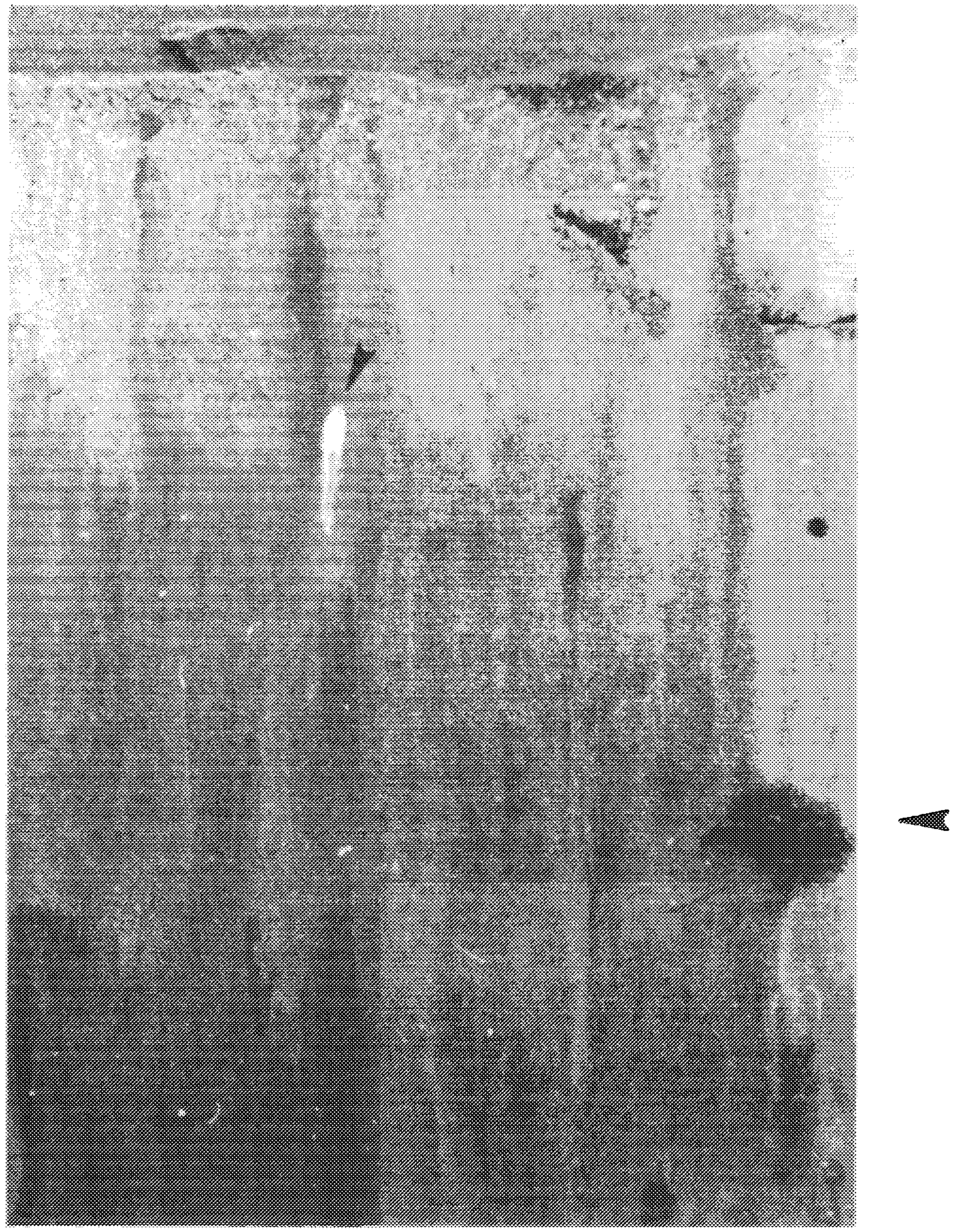


Figure 3-16. REMOTS® image from station -5-M illustrating a Stage I on III successional stage. Small, tubicolous Stage I polychaetes are barely visible at the sediment surface, while feeding voids mark the presence of head-down deposit-feeding Stage III taxa at depth (bottom arrow). The Stage III polychaete Nephtys incisa is also visible at depth (top arrow). Scale = 1X.

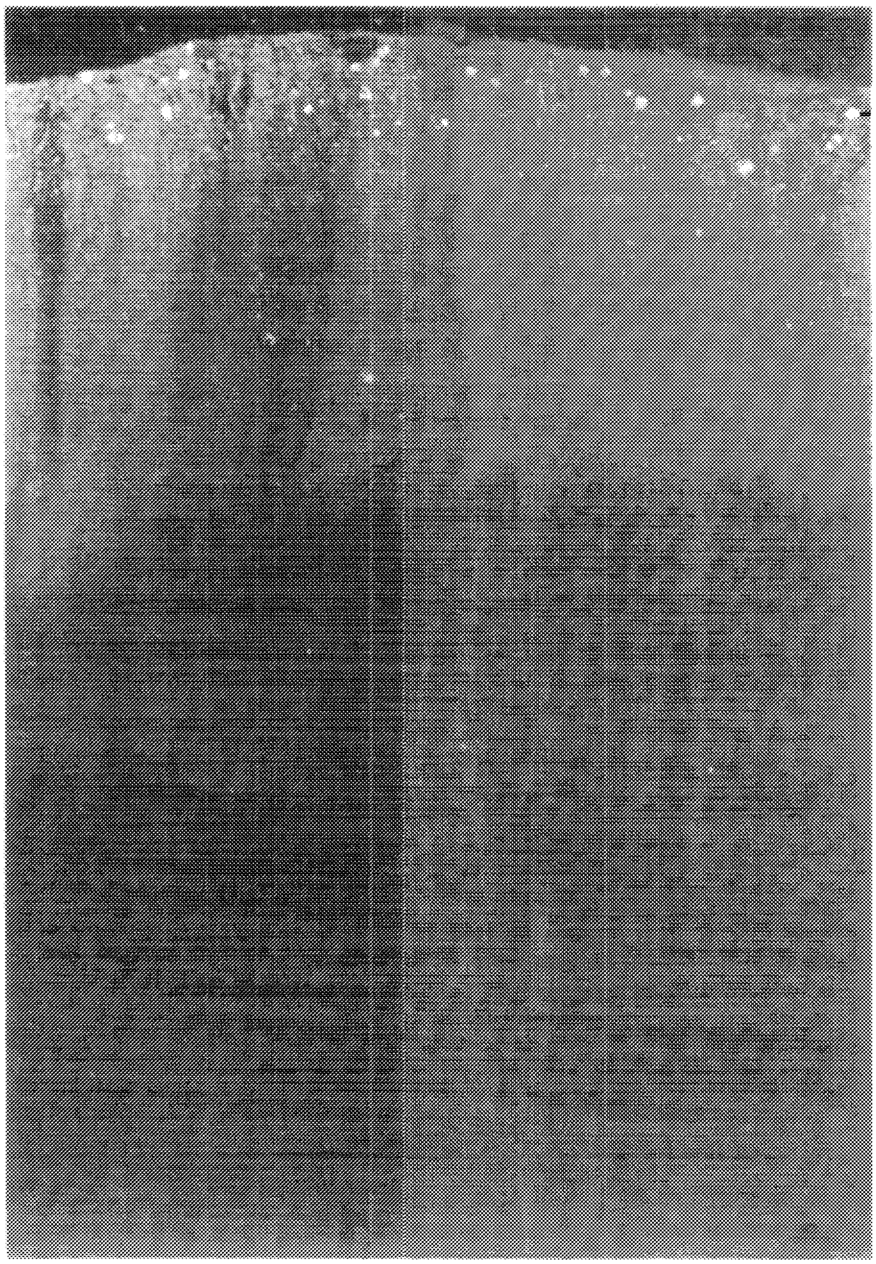


Figure 3-17. A dense assemblage of the opportunistic, Stage I bivalve Mulinia lateralis (white spheres) is visible near the sediment surface in this REMOTS® image from station -1-Y. Small, Stage I polychaetes also can be seen at the sediment surface. Scale = 1X.

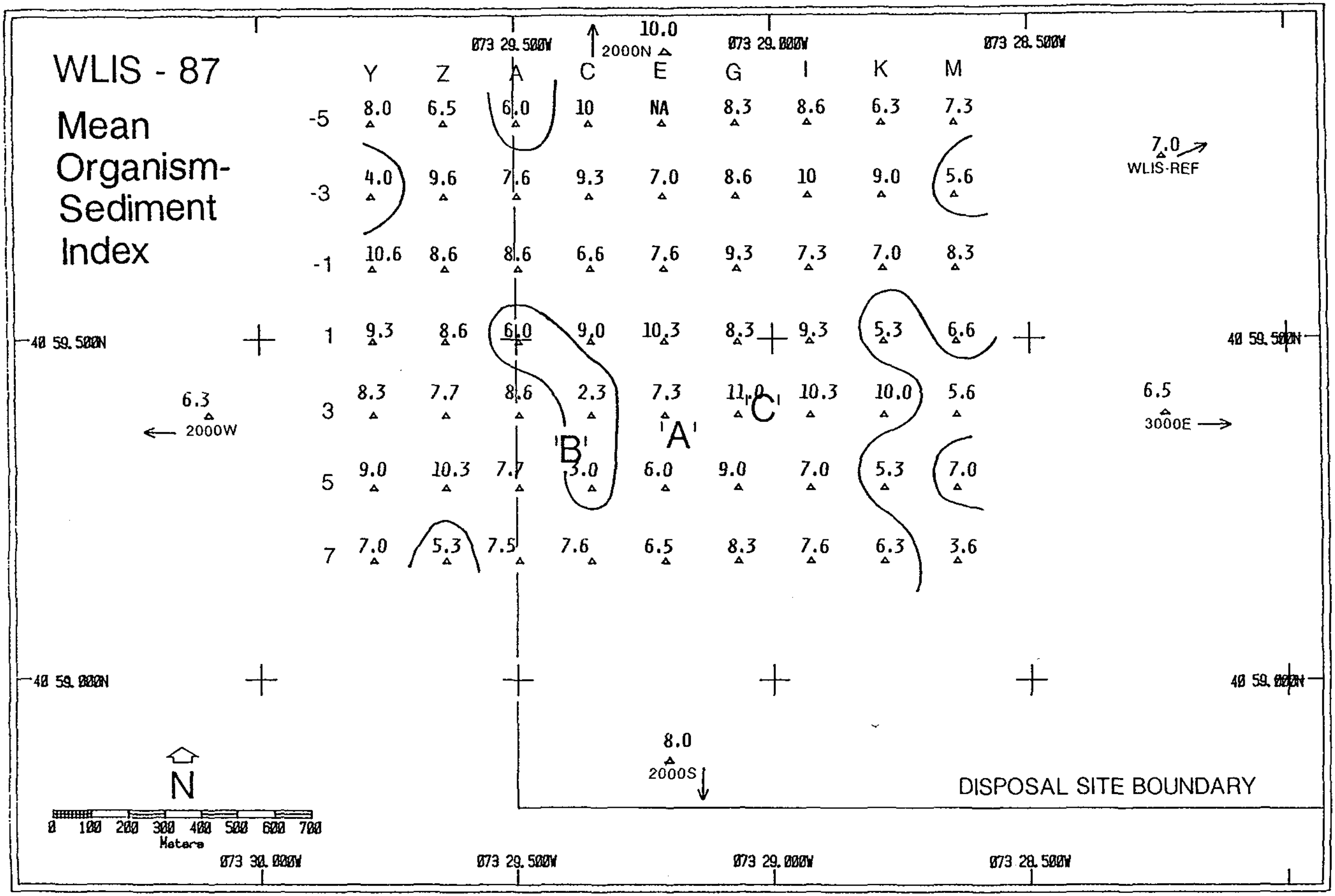
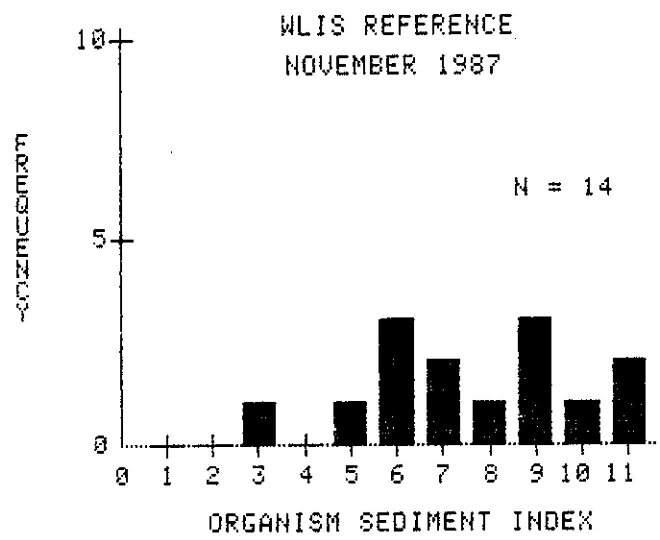


Figure 3-18. The distribution of Organism-Sediment Indices, averaged by station, at the WLIS disposal site, November 1987. The contours delimit stations having mean OSI values $\leq +6$.



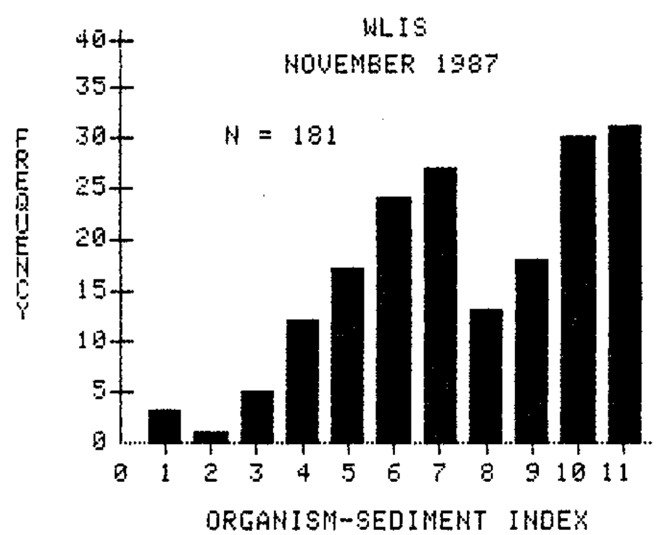


Figure 3-19. Frequency distributions of Organism-Sediment Index values for all replicates at both the reference and onsite stations at WLIS, November 1987.

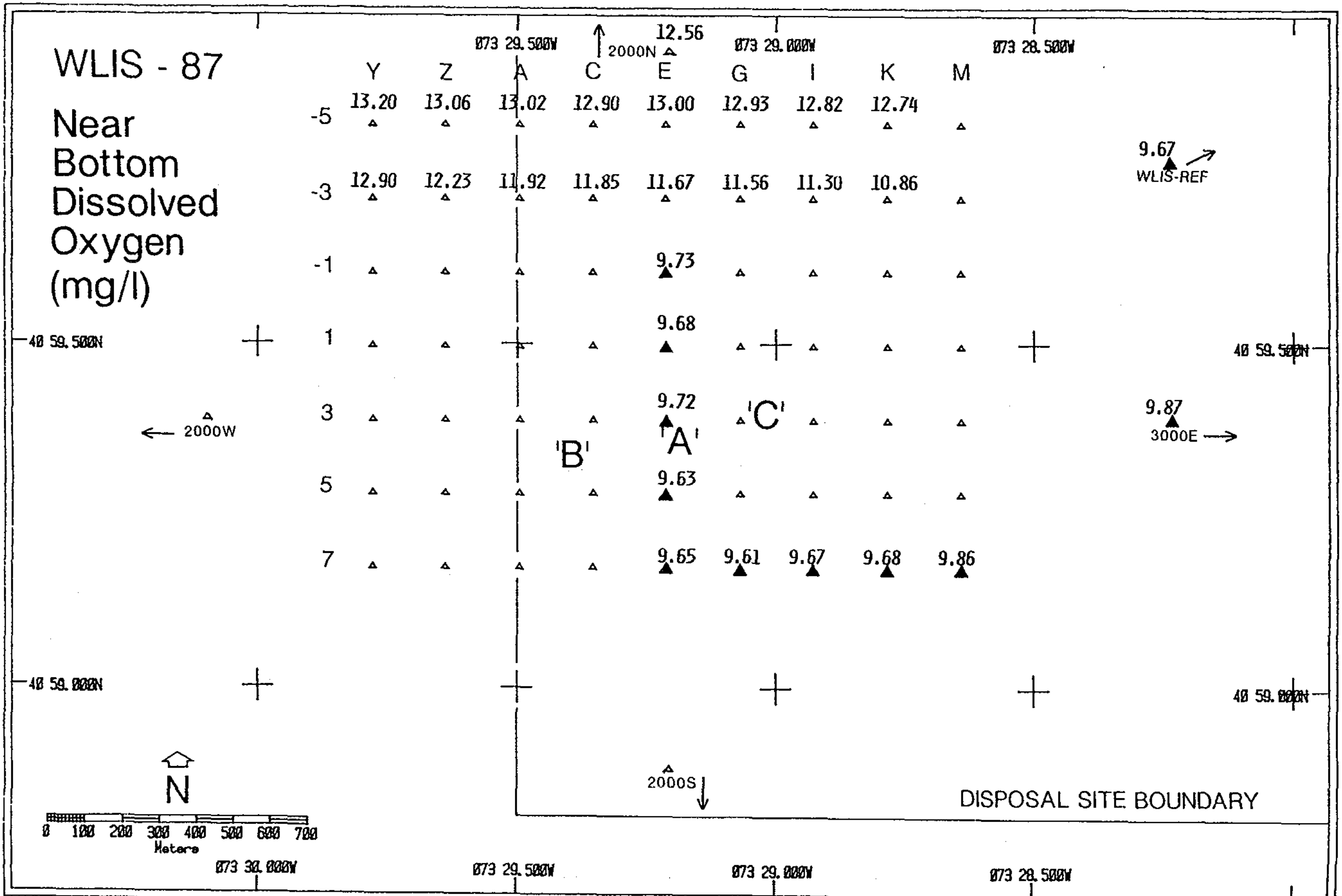


Figure 3-20. Near-bottom dissolved oxygen concentrations (mg/l) measured at selected REMOTS onsite and reference stations at WLIS, November 1987. Solid triangles mark stations sampled during the late afternoon (between 1624 h and 1748 h). Open triangles mark stations sampled during the morning and early afternoon (between 0950 h and 1330 h).

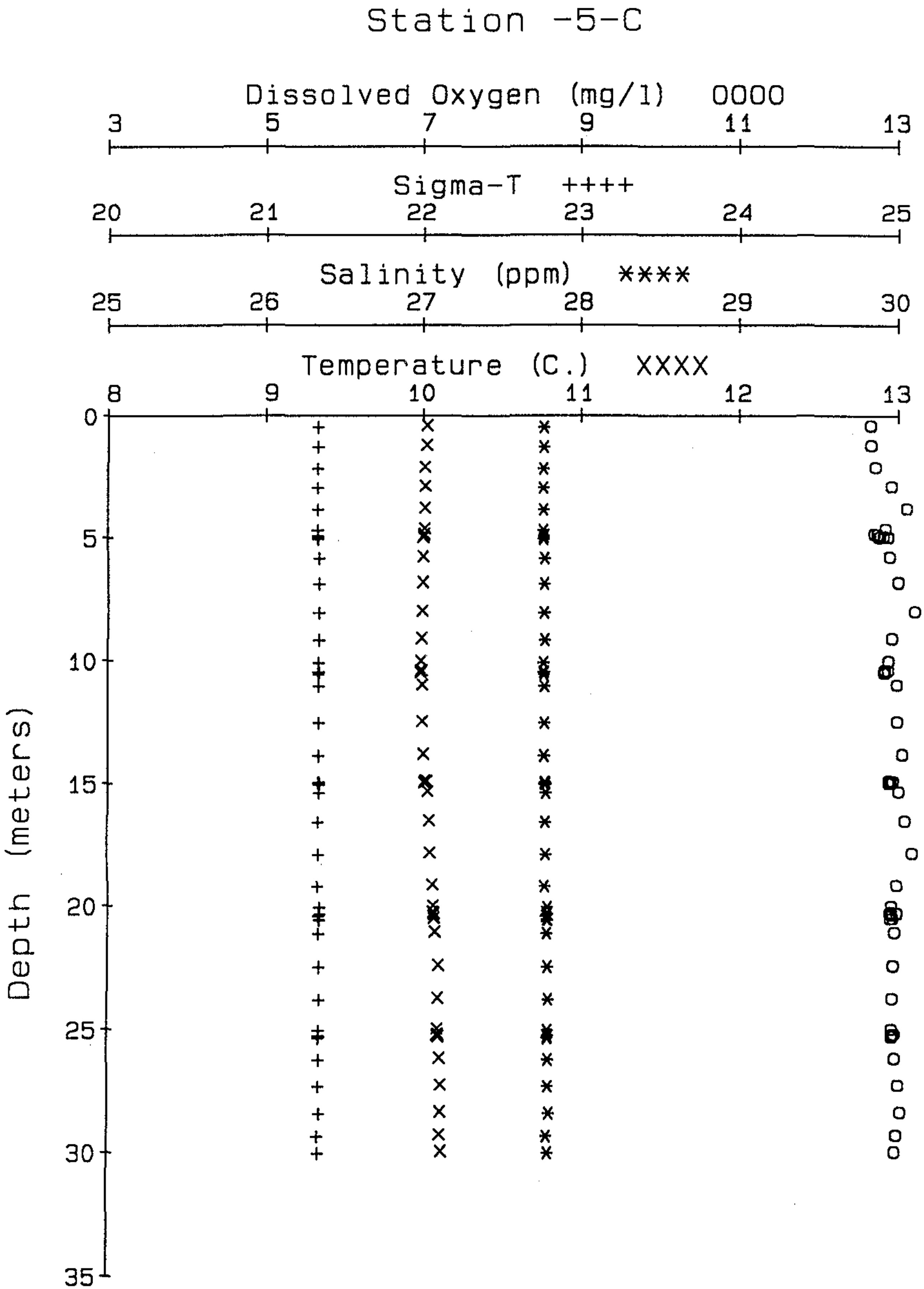


Figure 3-21. Representative CTD/DO plot obtained at WLIS station -5-C in November 1987.

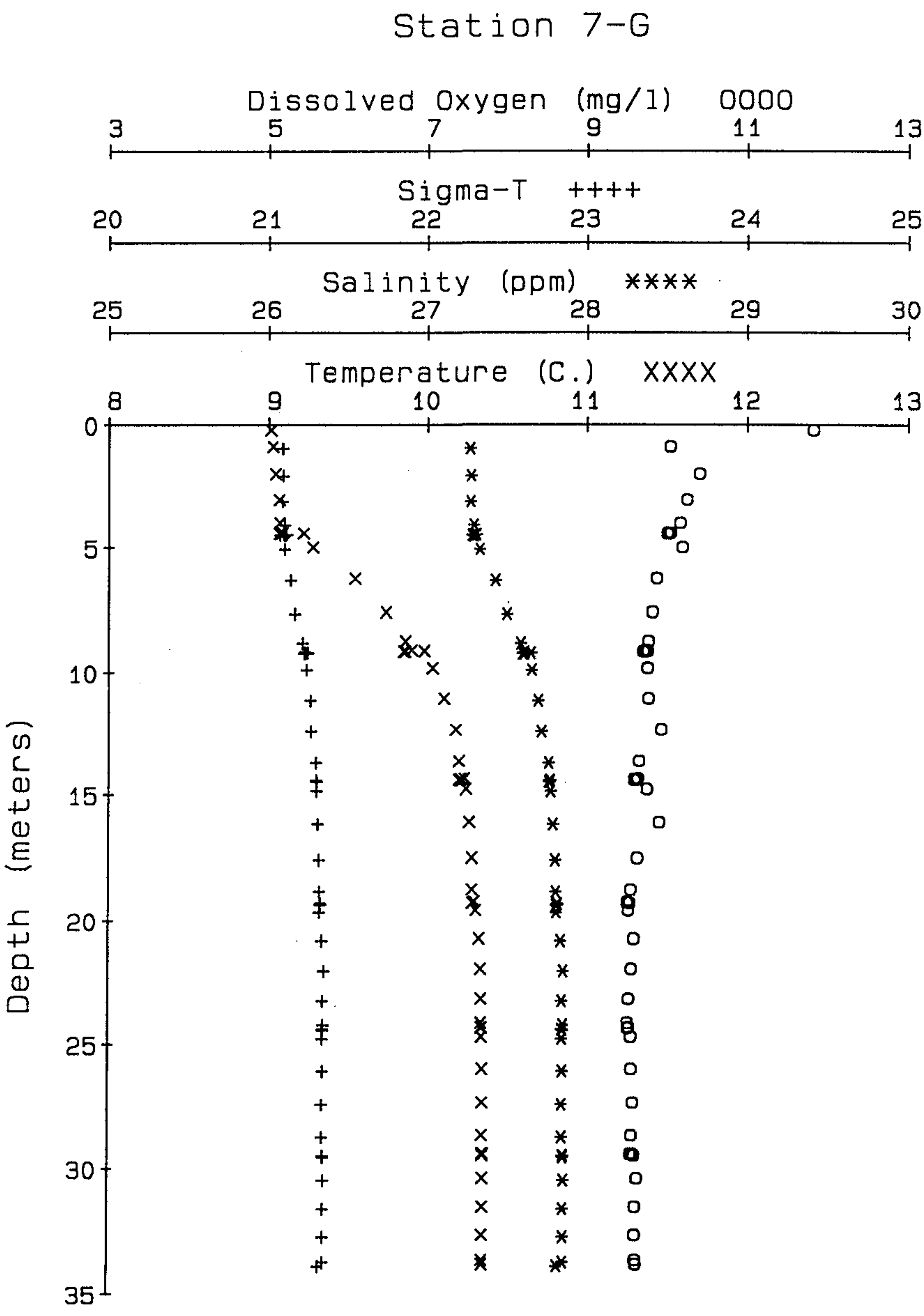


Figure 3-22. Representative CTD/DO plot obtained at WLIS station 7-G in November 1987.

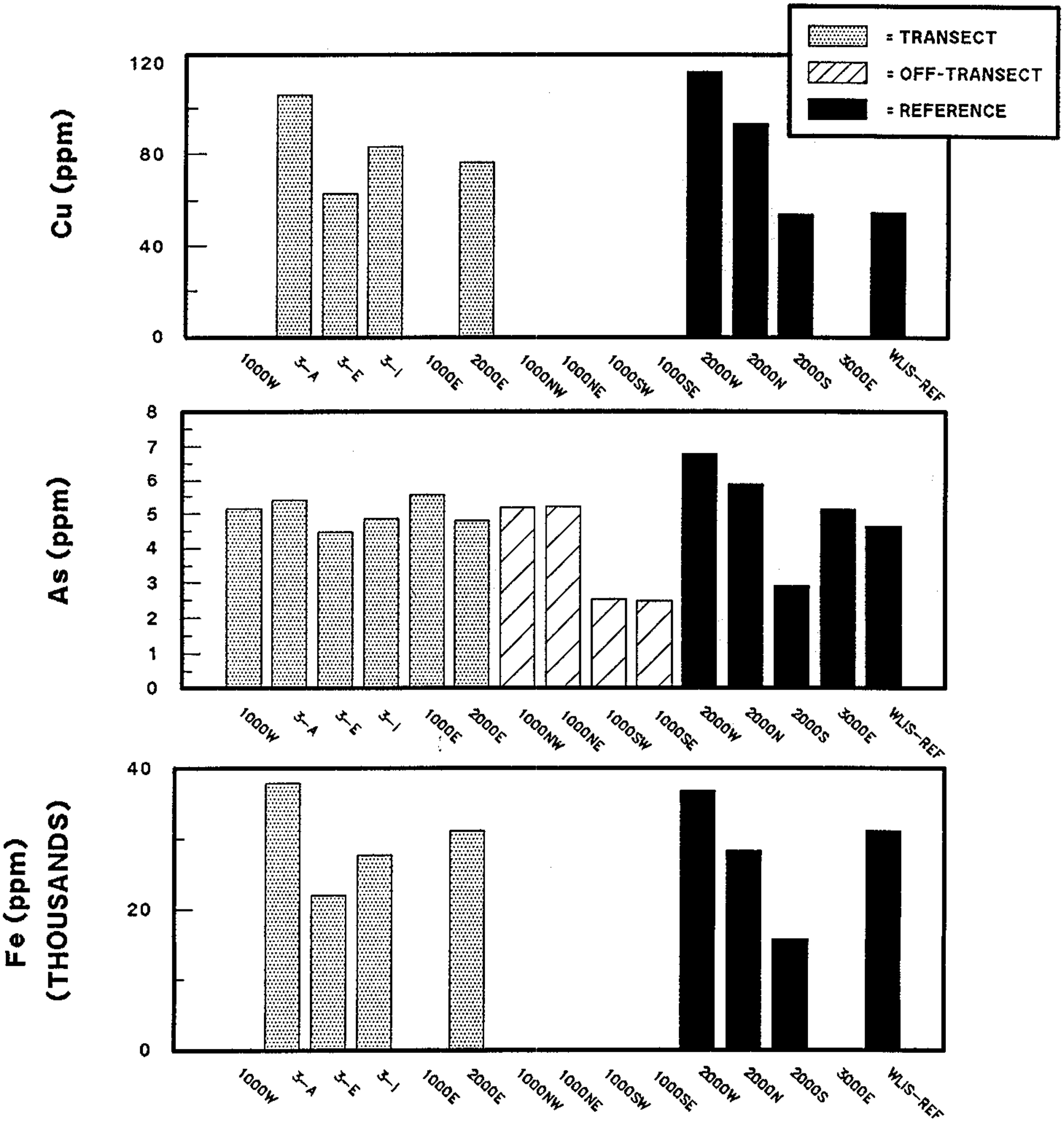


Figure 3-23. Trace metal, % TOC, PHC, and PCB concentrations in sediment collected at WLIS, November 1987. All concentrations are based on dry weights of sediment. Values are missing at stations where certain chemical analyses were not performed.

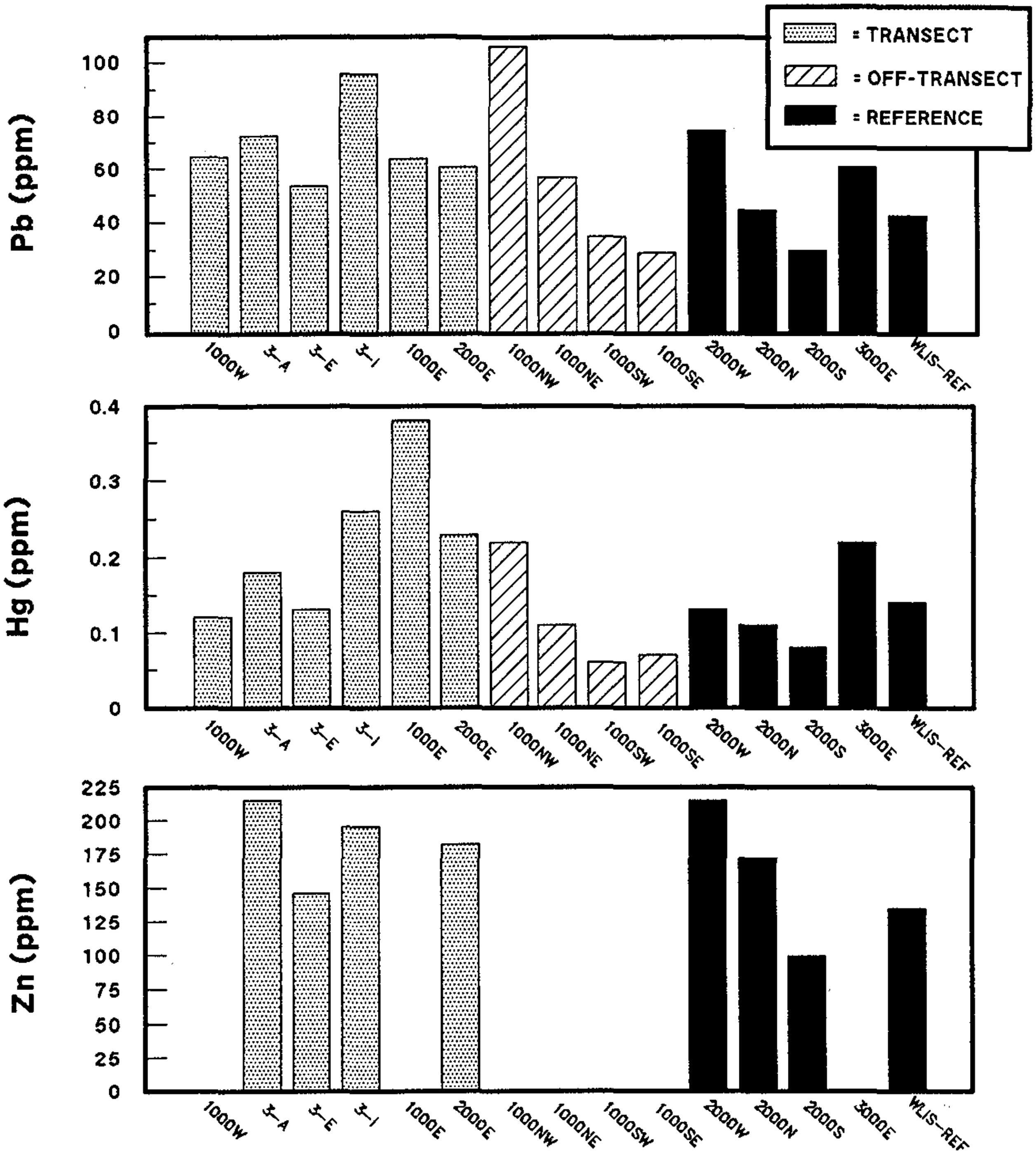


Figure 3-23, continued.

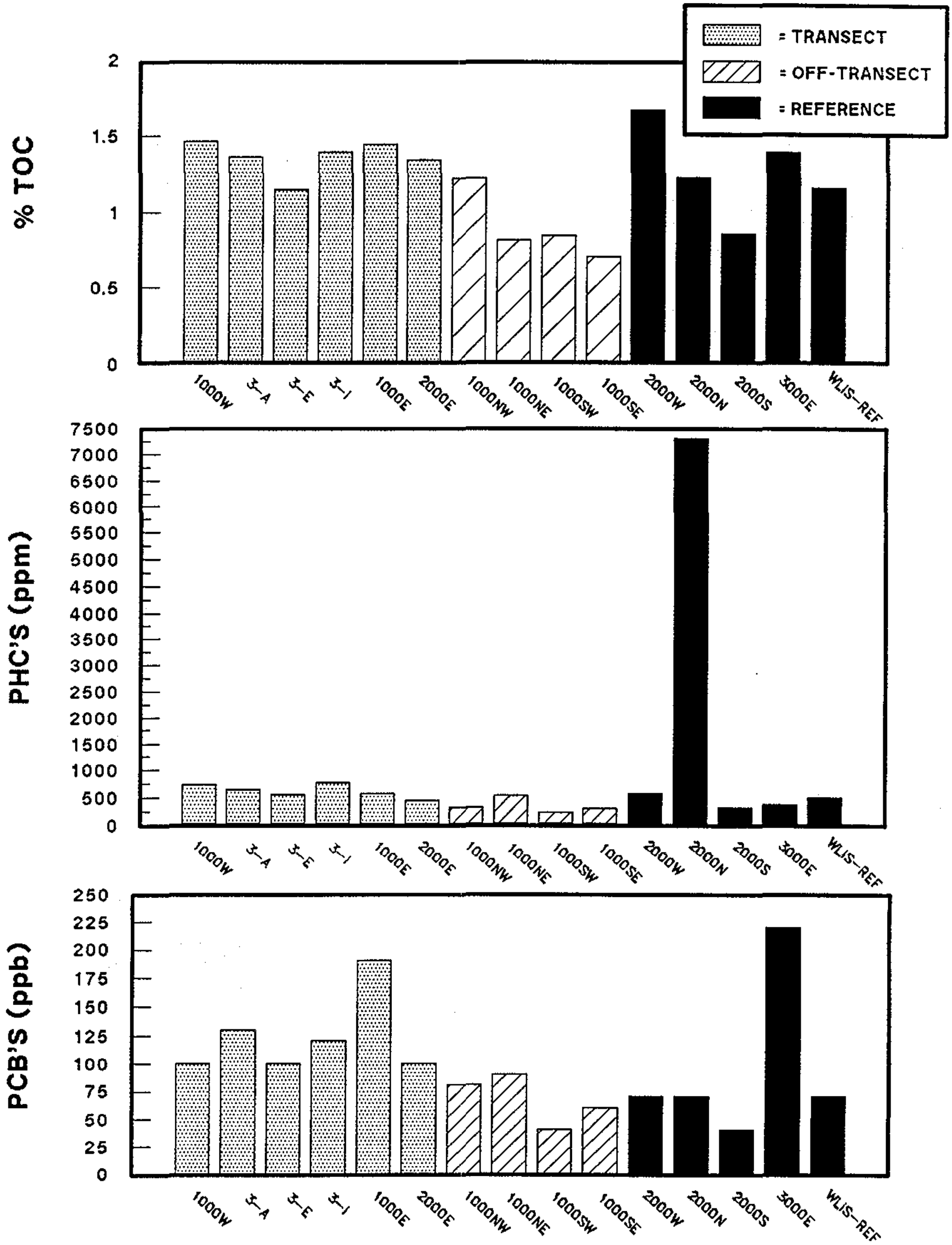


Figure 3-23, continued.

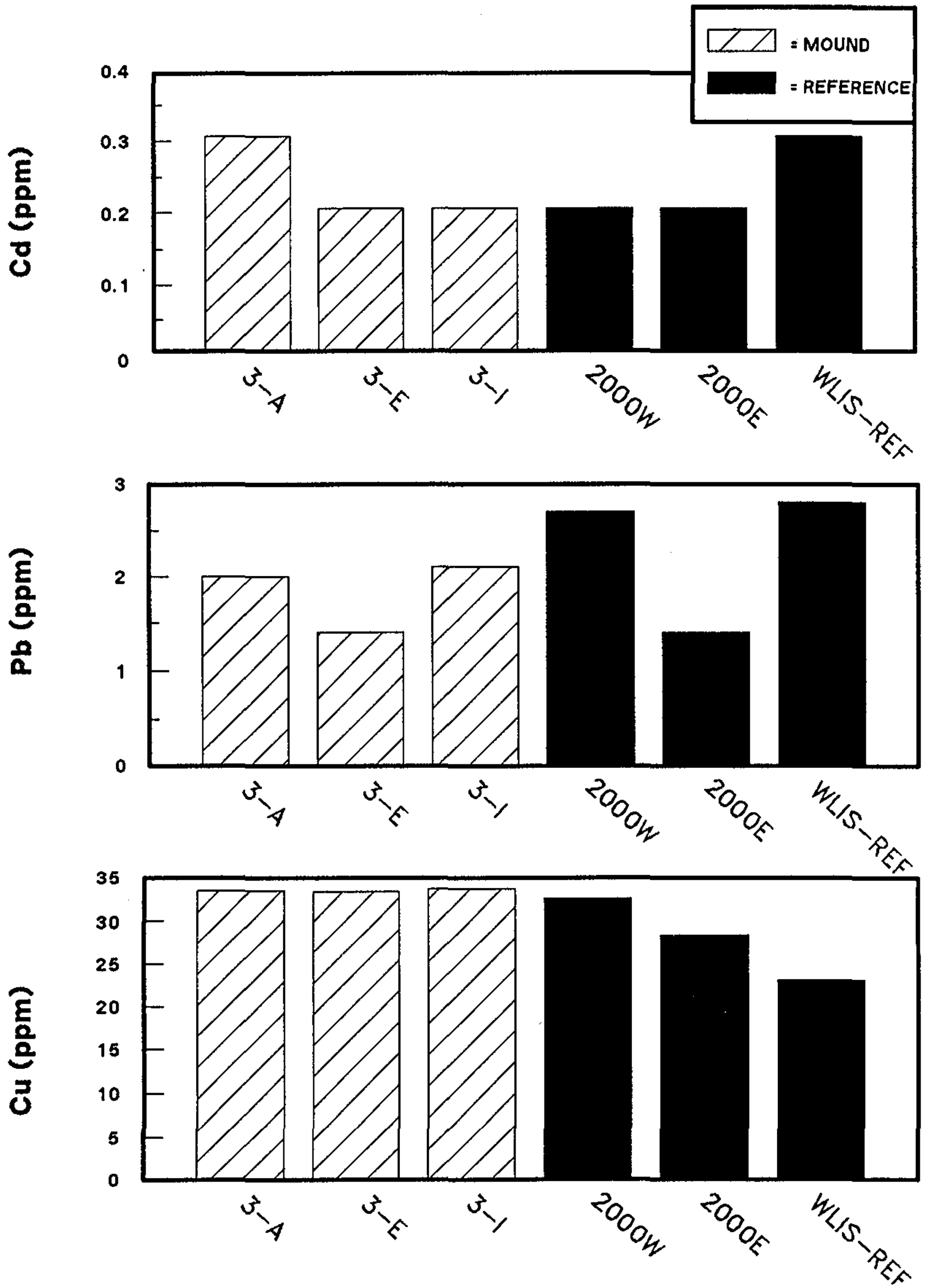


Figure 3-24. Trace metal and PCB (as Aroclor 1254) concentrations in body tissues (dry weight) of Nephtys collected at WLIS, November 1987.

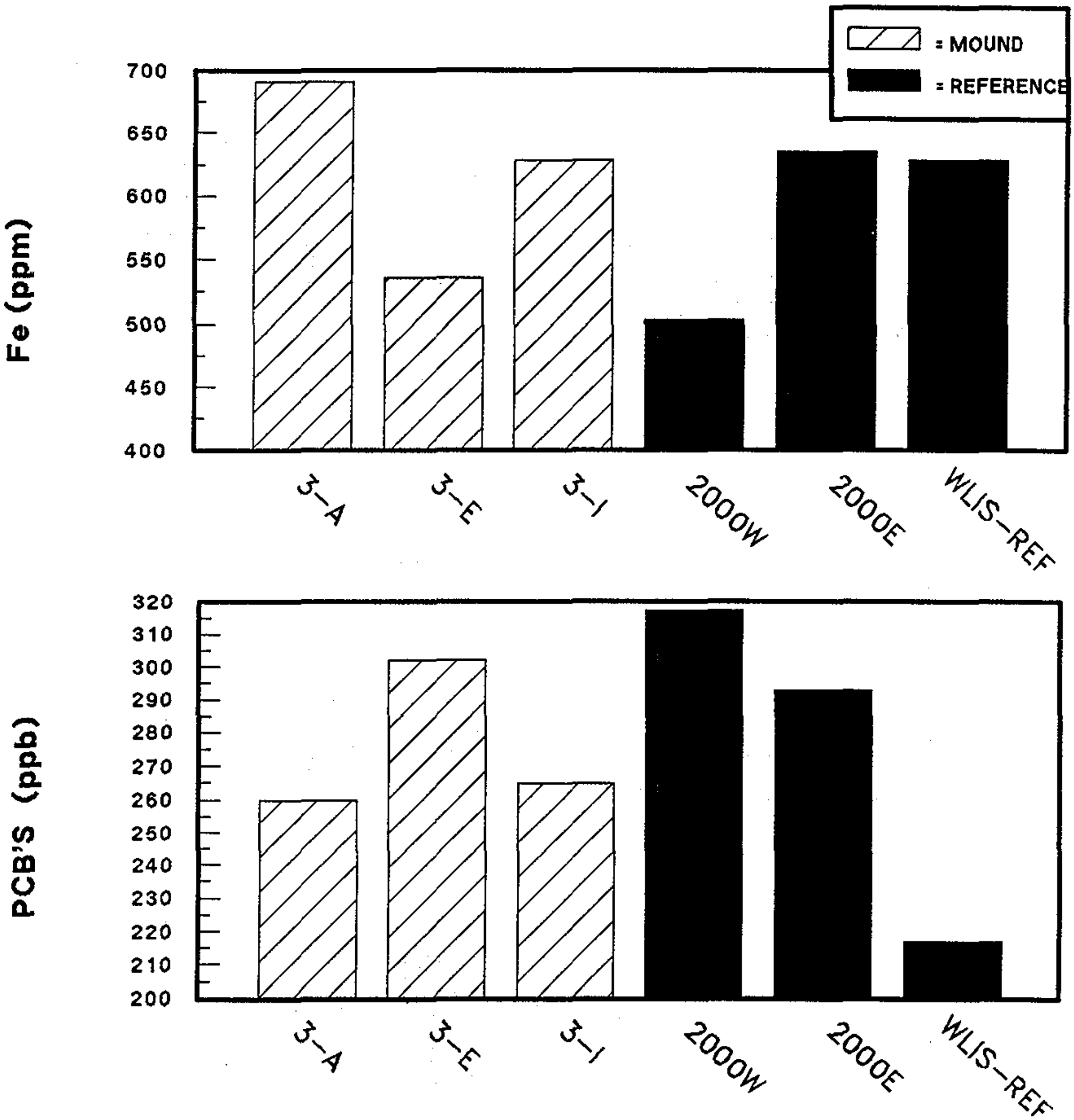
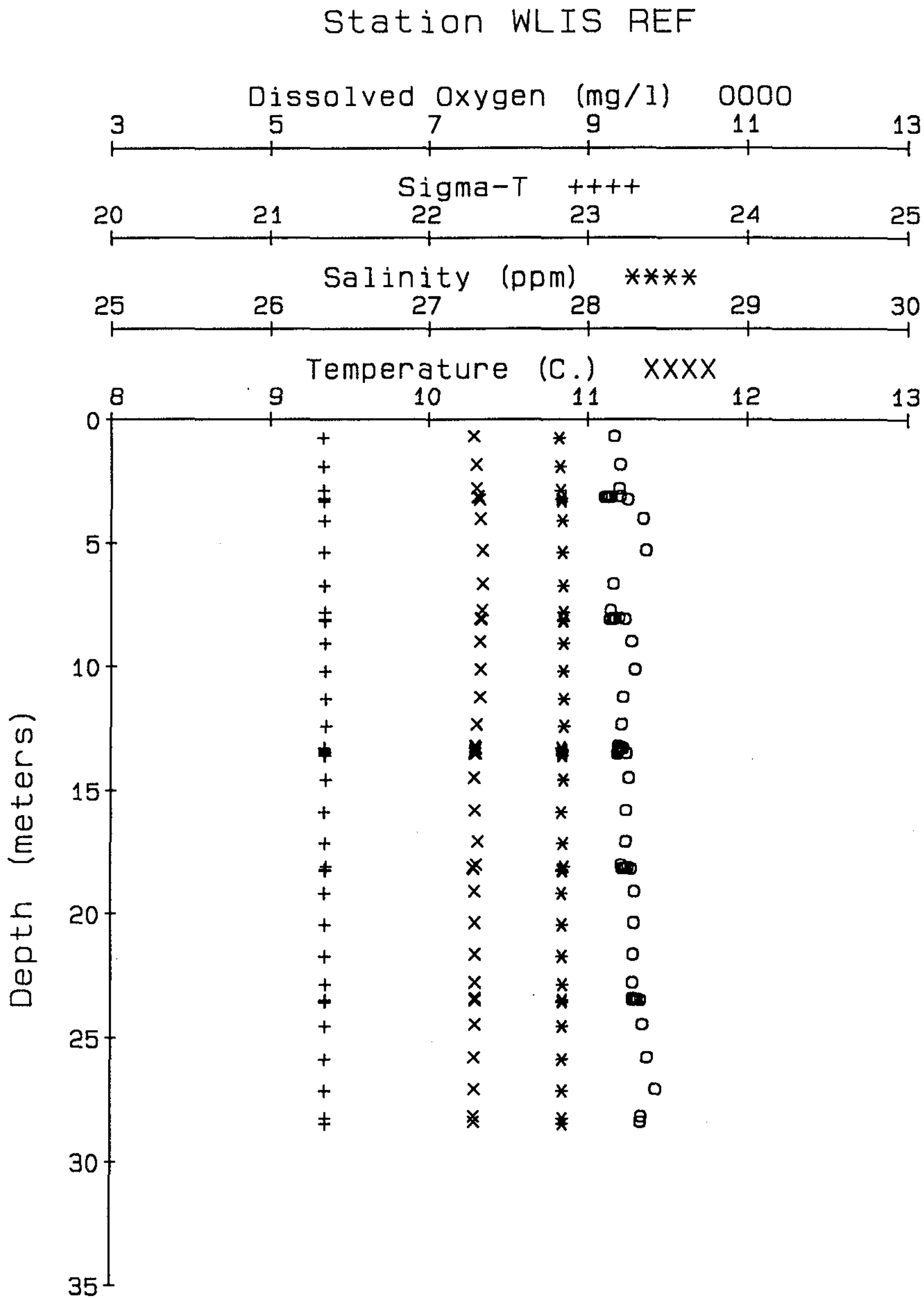
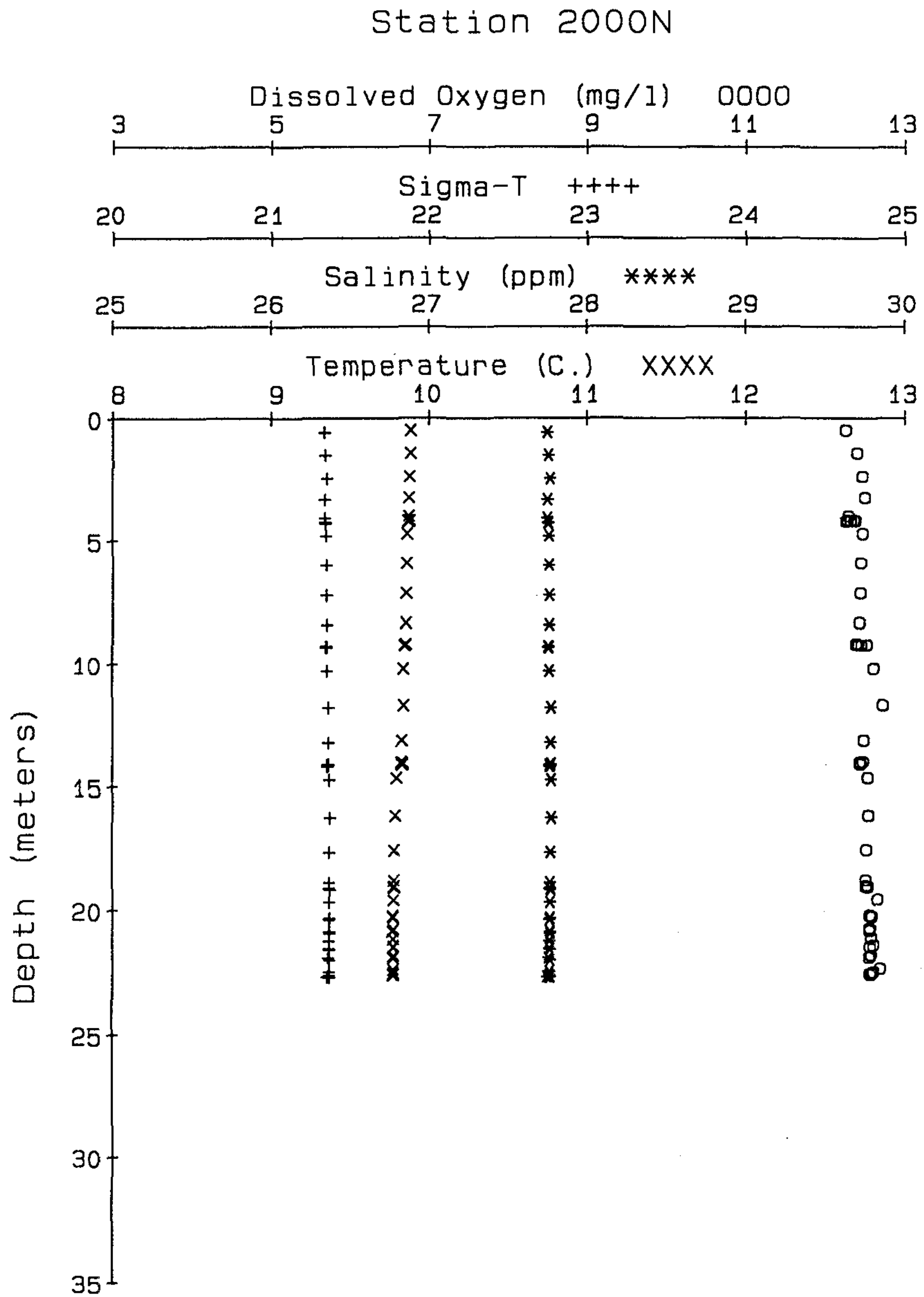
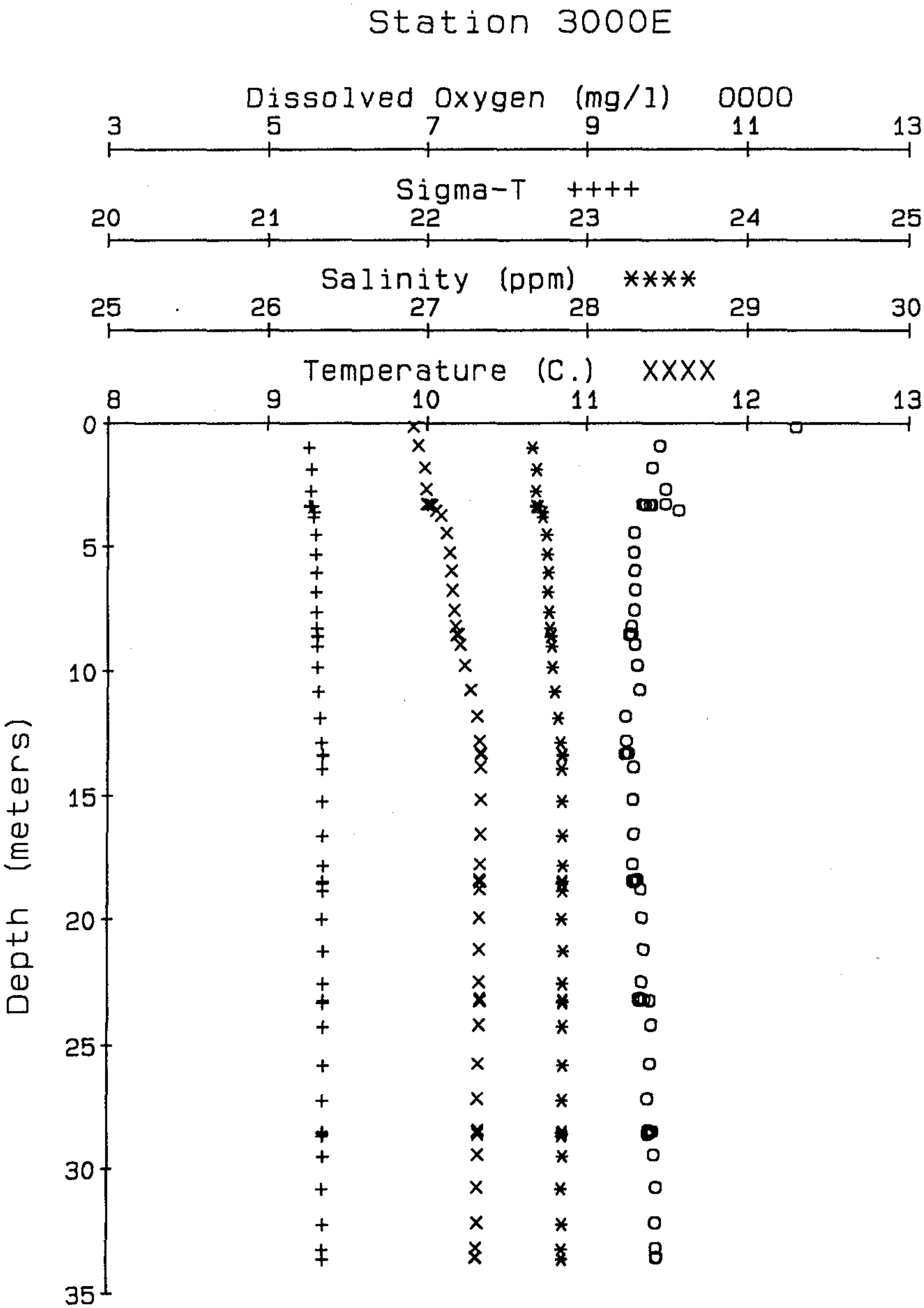


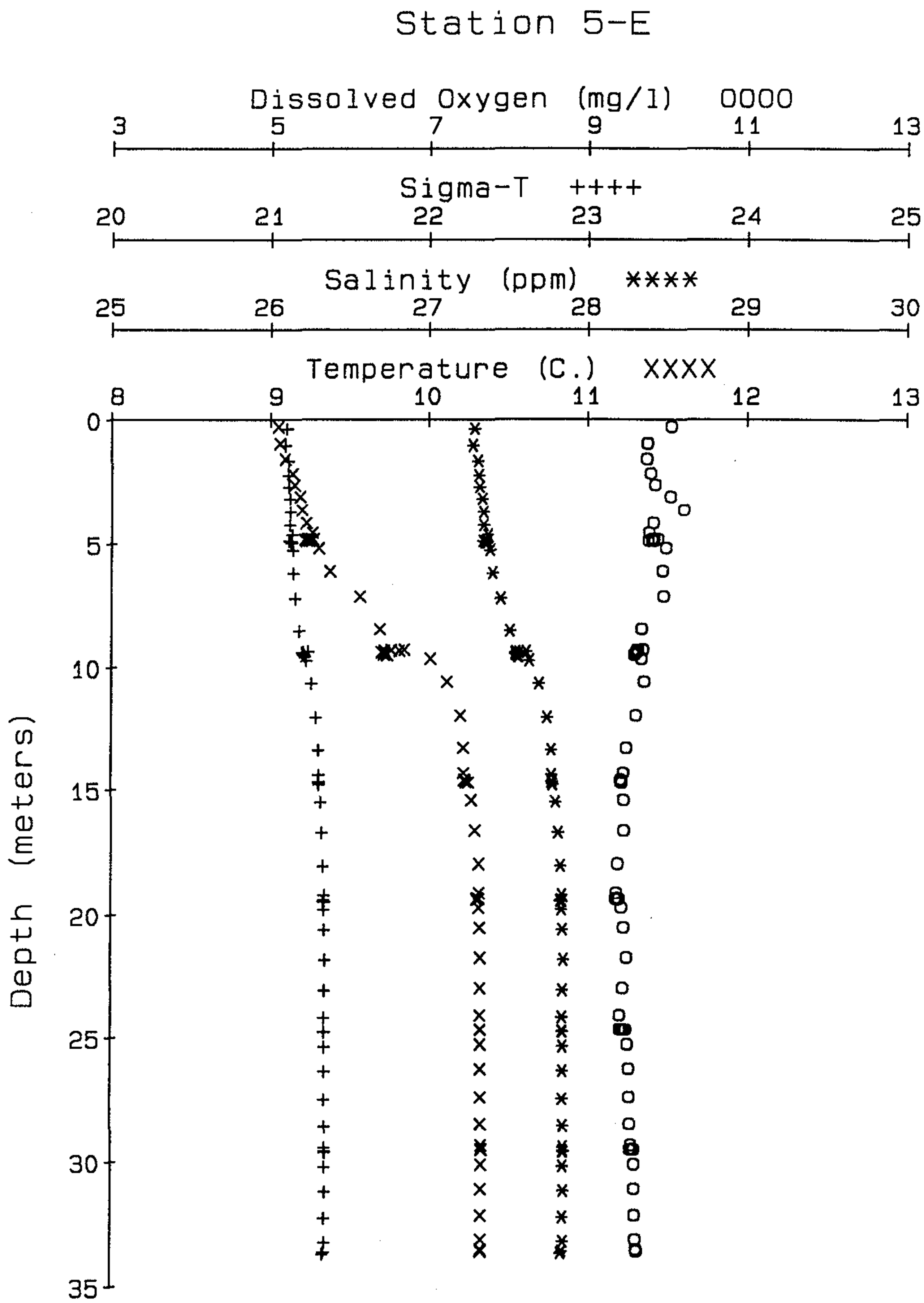
Figure 3-24, continued.

APPENDIX

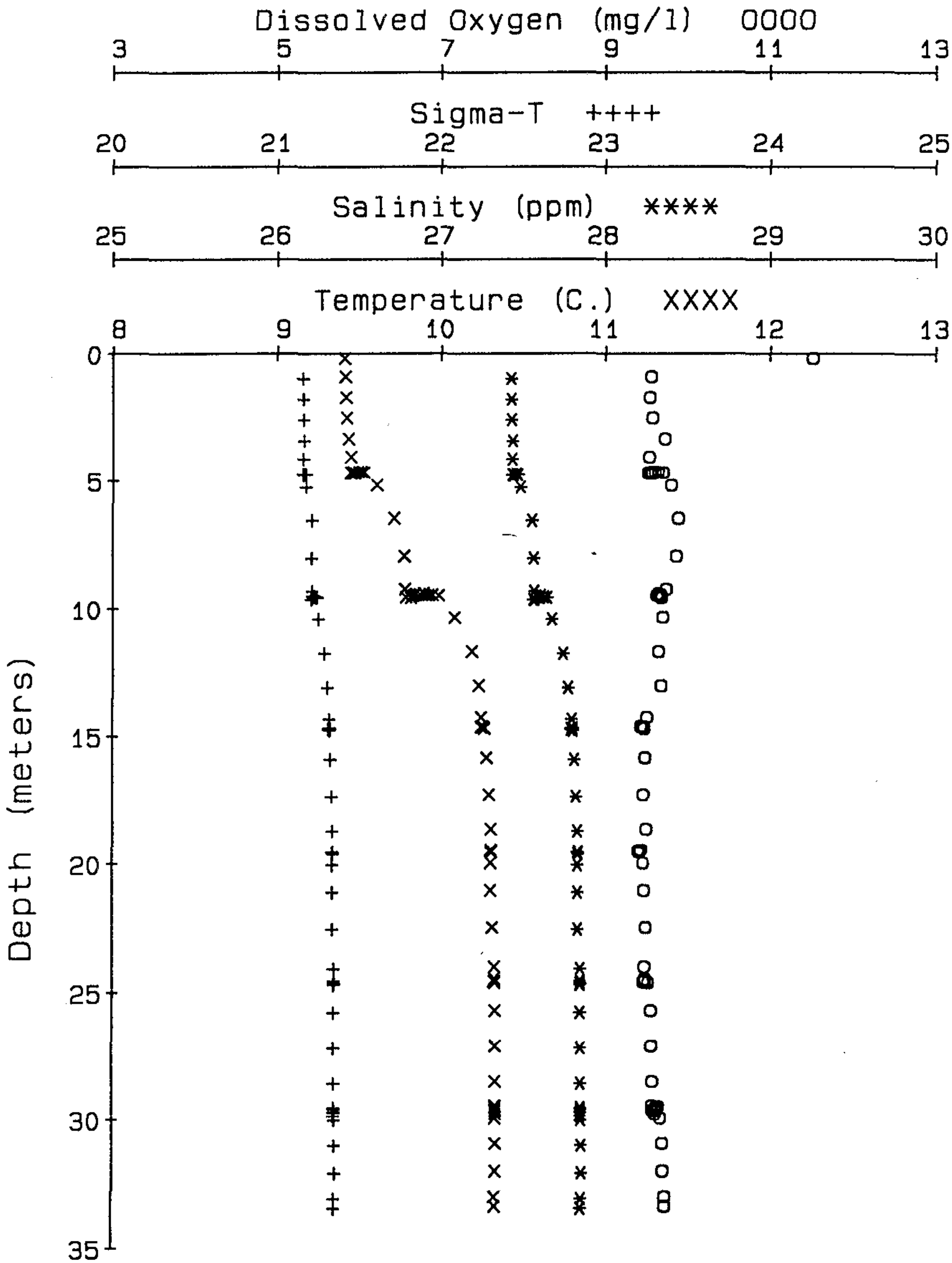

Station WLIS REF
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station 2000N
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

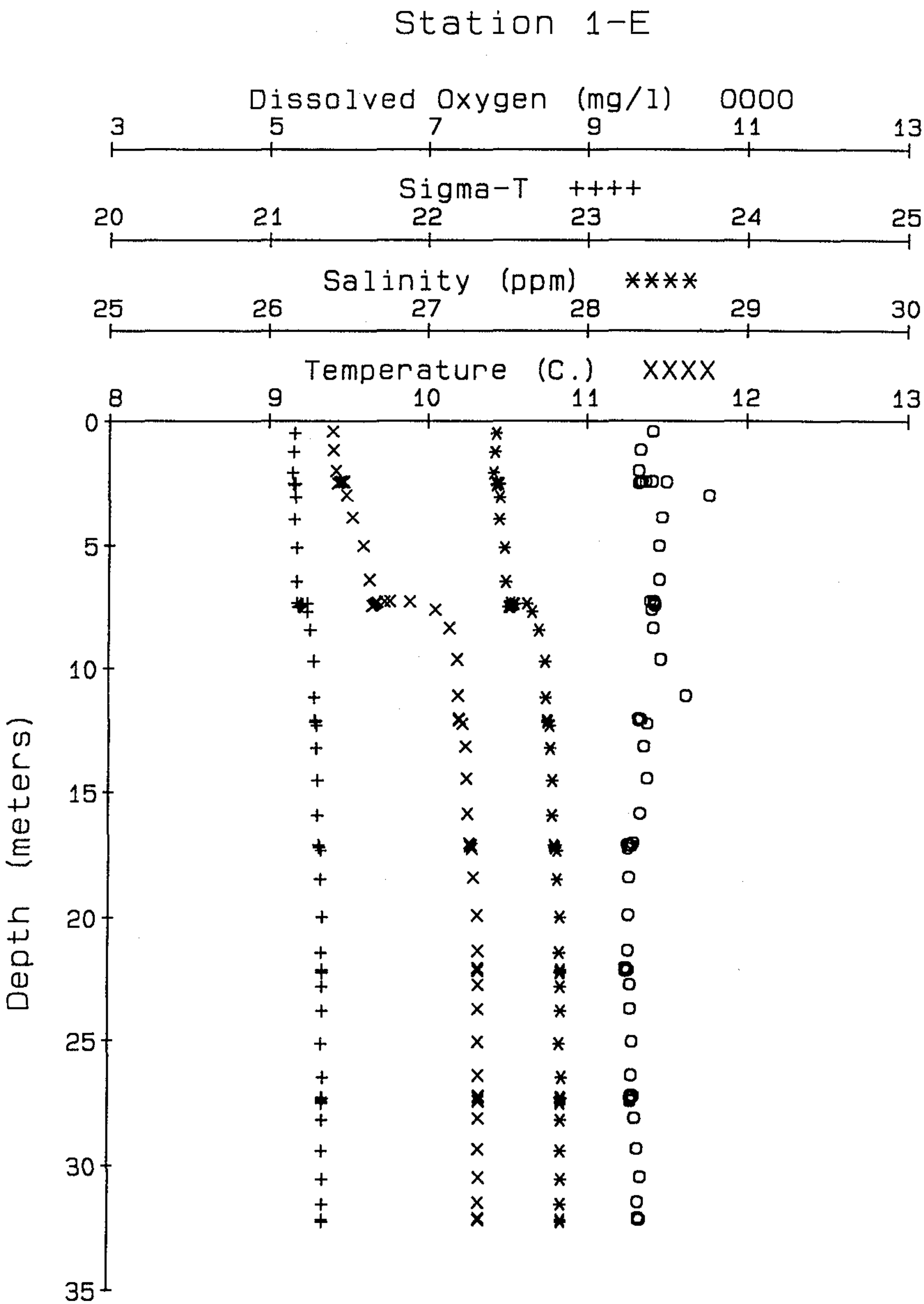

Station 3000E
Dissolved Oxygen (mg/l) OOOO
3
5
7
9
11
13
Sigma-T ++++
20
21
22
23
24
25
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
8
9
10
11
12
13
0
5
10
15
20
25
30
35
Depth (meters)

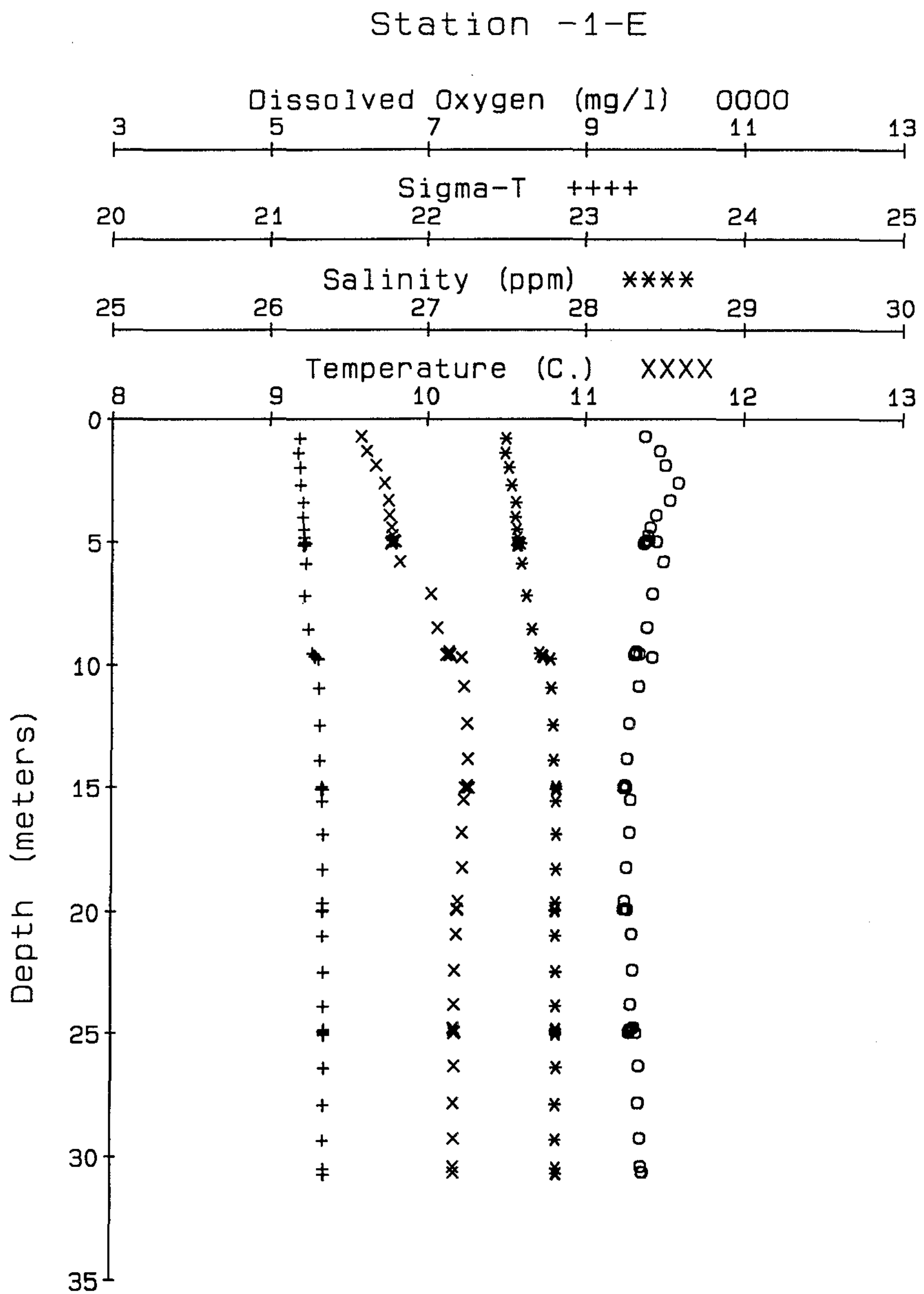

Station 5-E
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

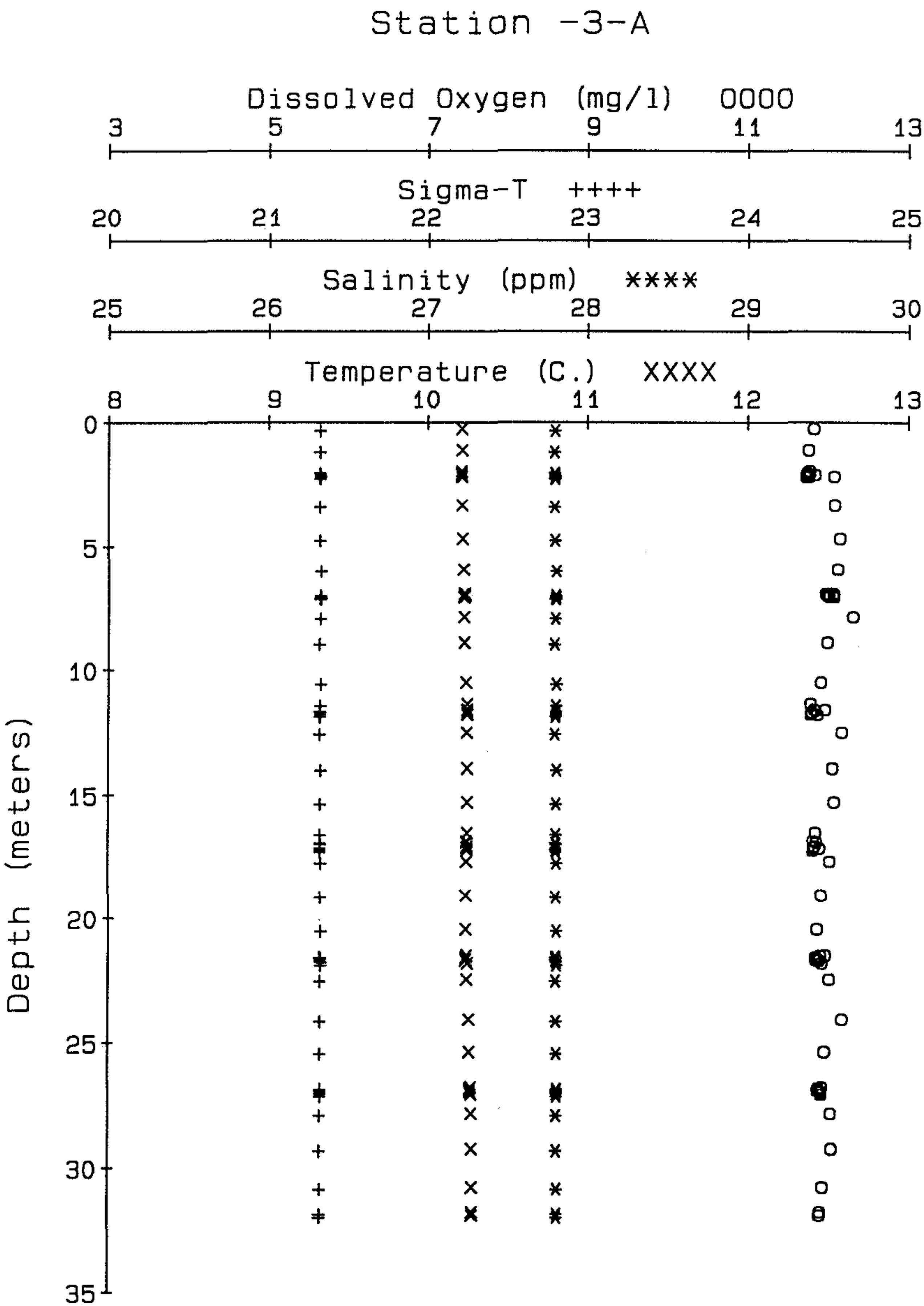
Station 3-E

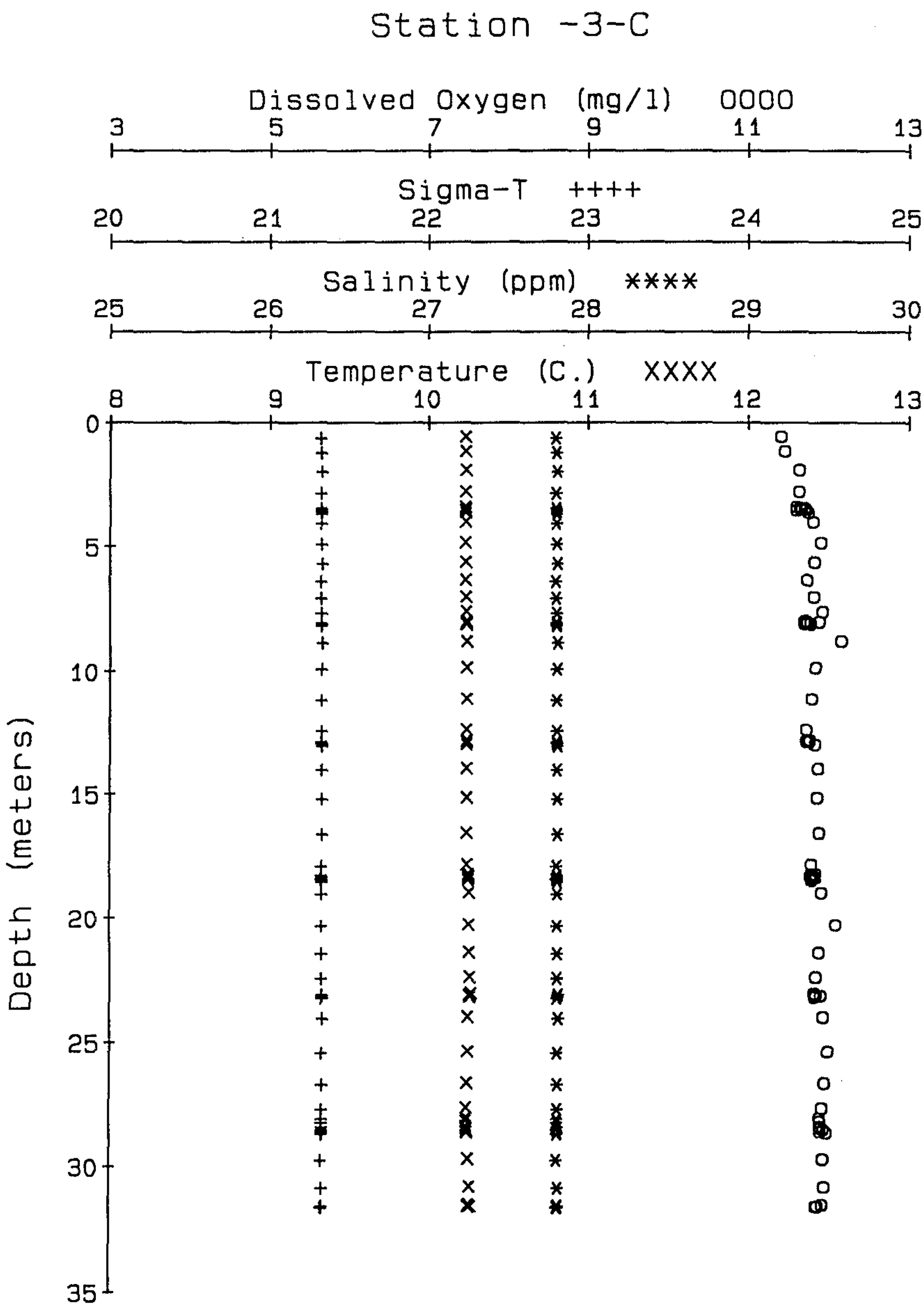


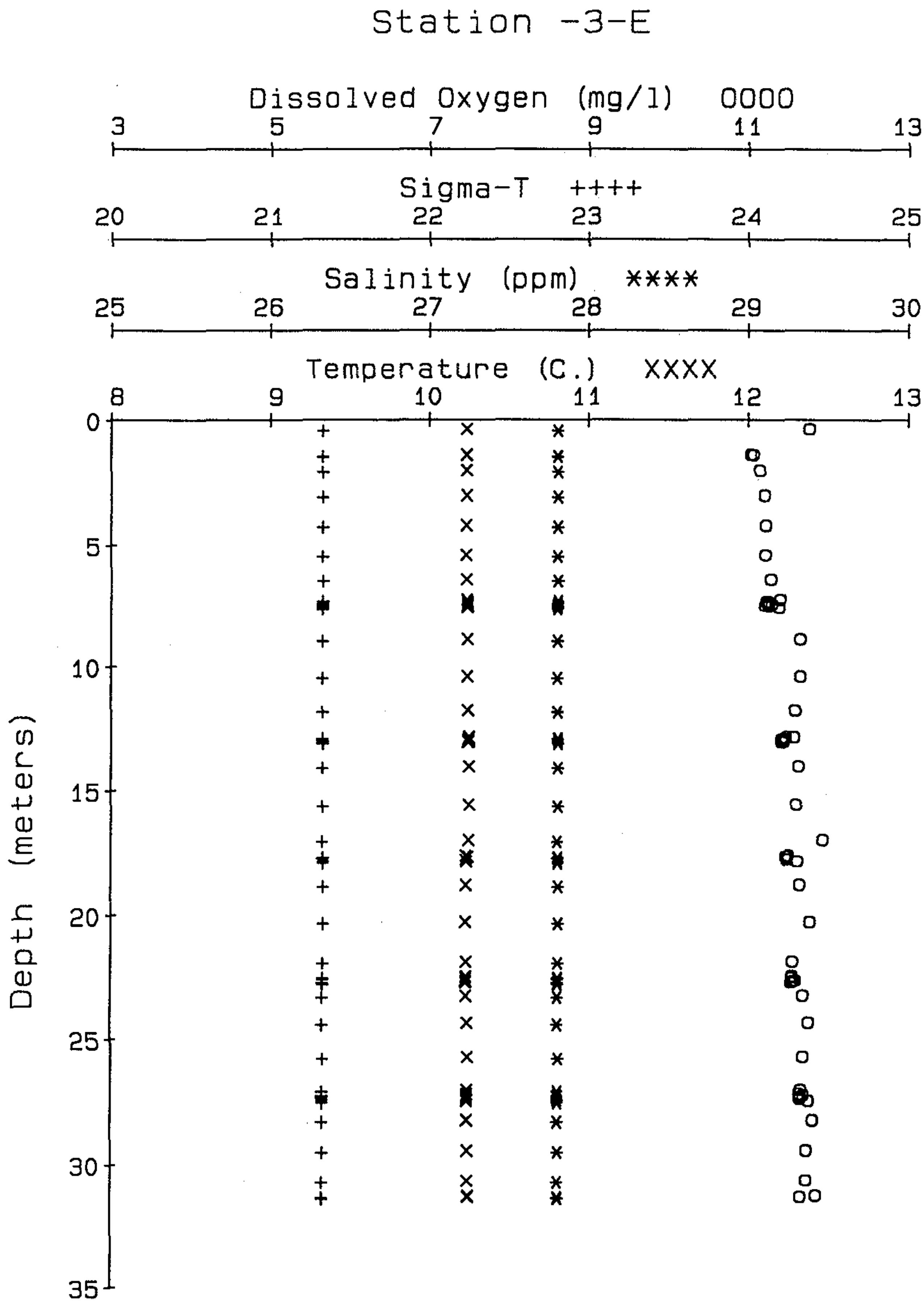
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
0 5 10 15 20 25 30 35
Depth (meters)

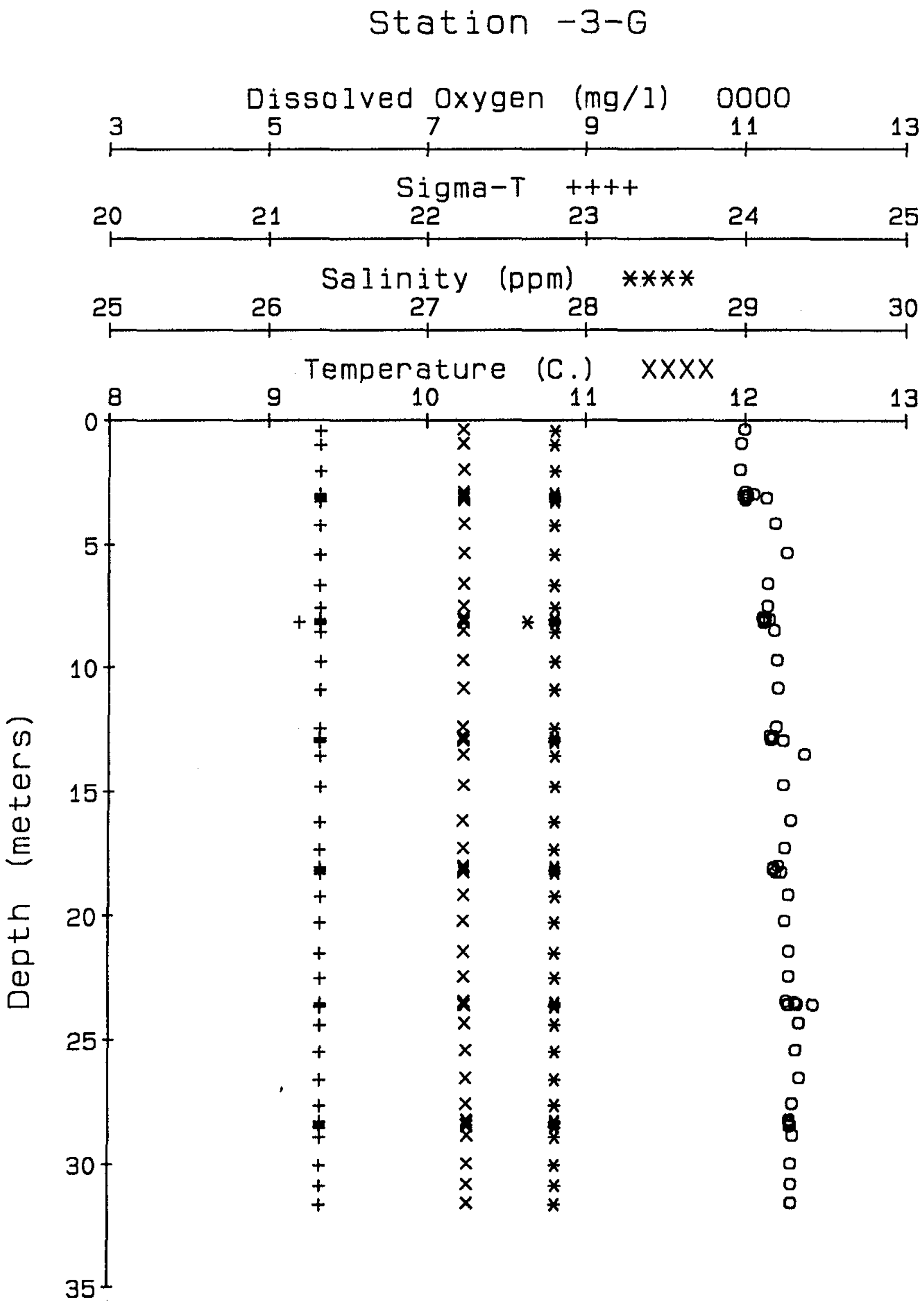

Station 1-E
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station -1-E
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station -3-A
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

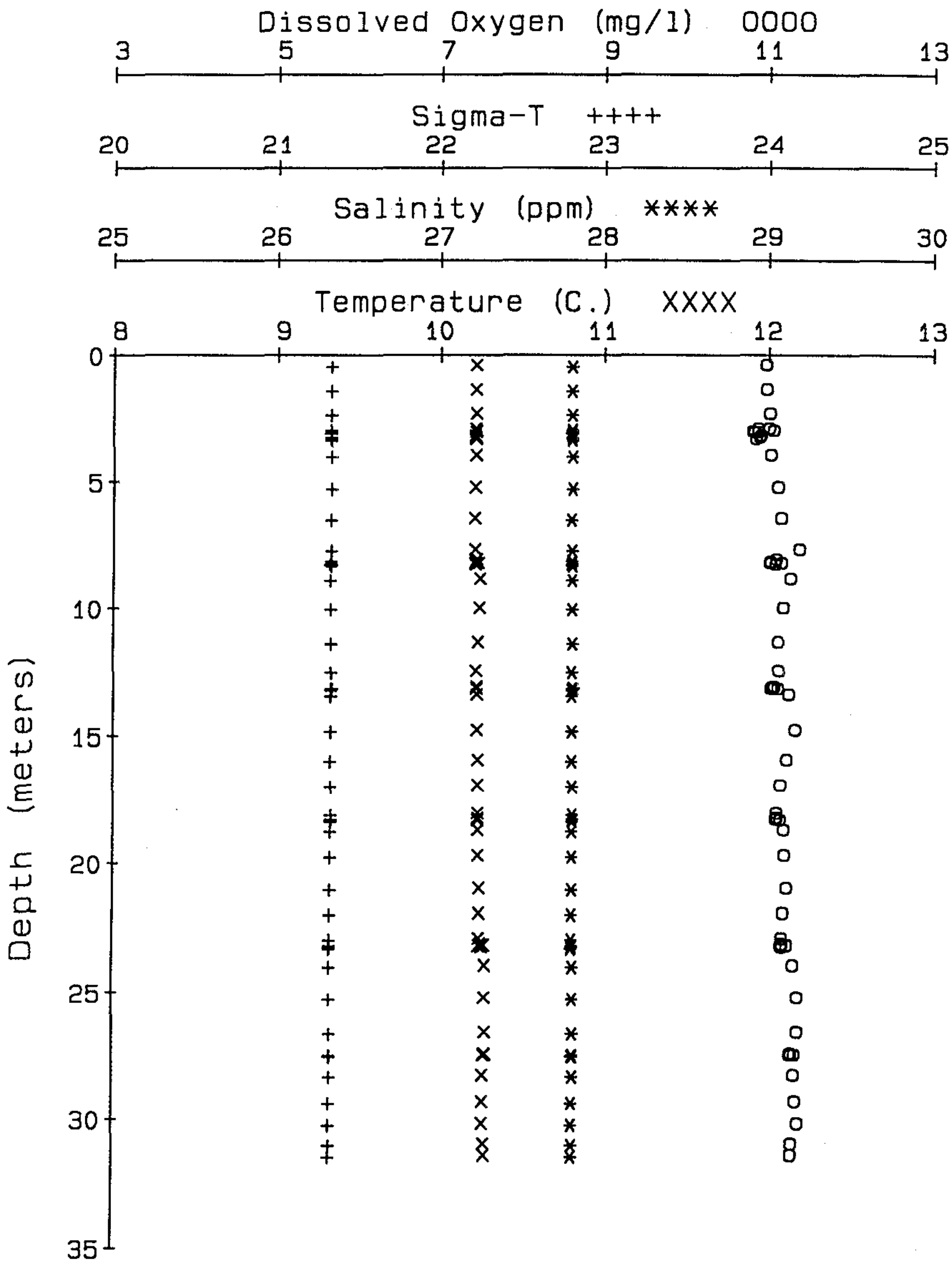

Station -3-C
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station -3-E
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

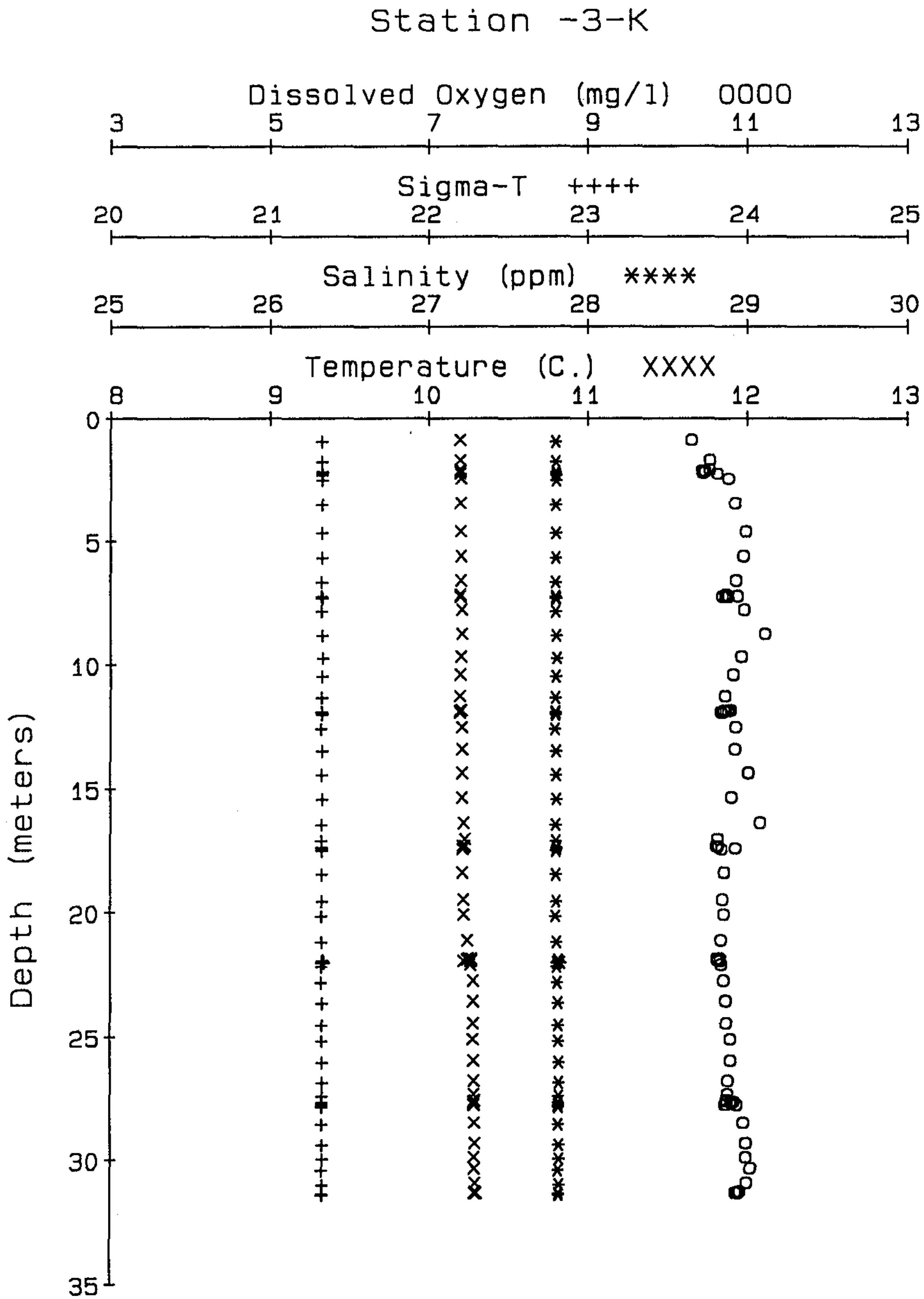


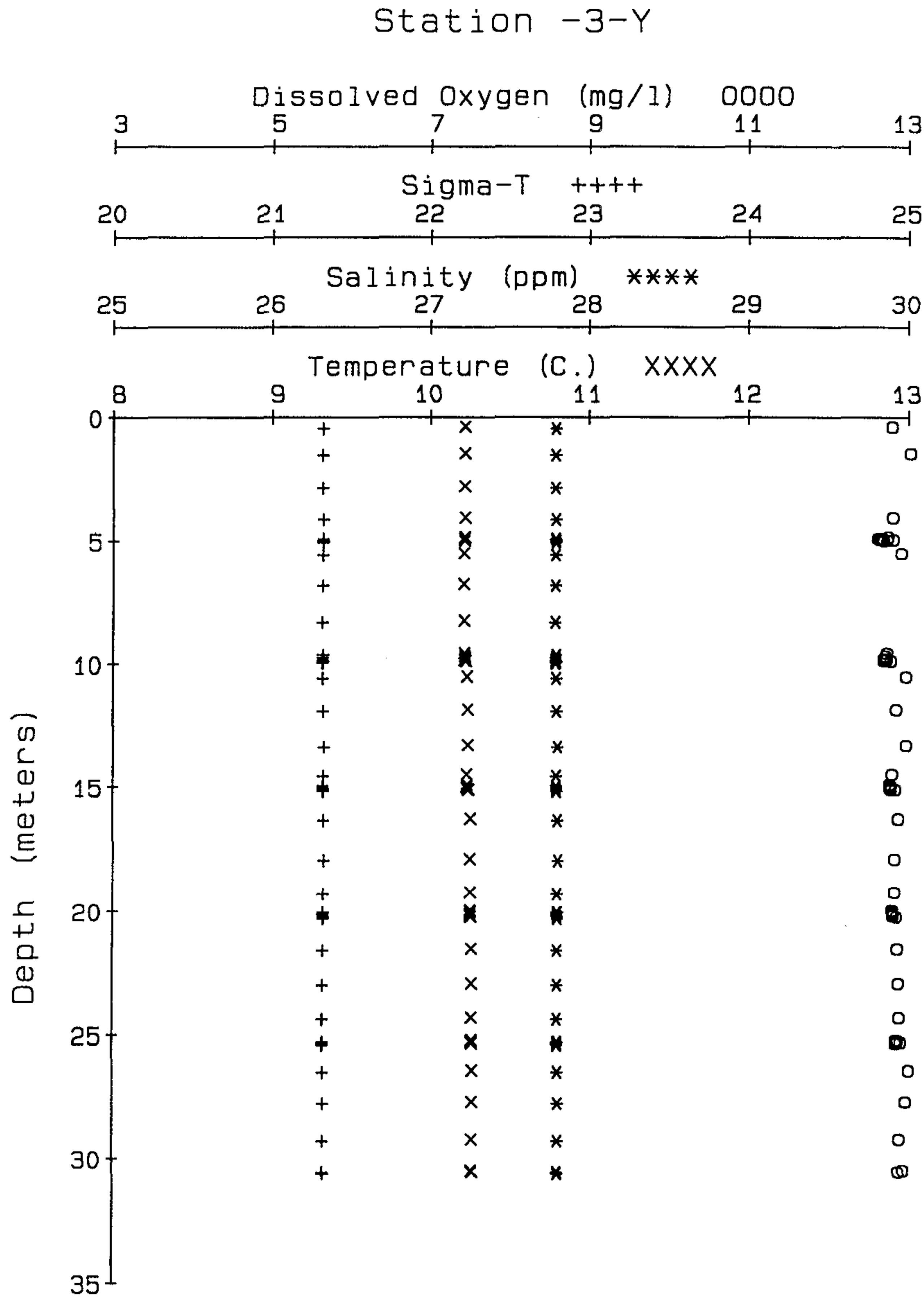
Station -3-G
Dissolved Oxygen (mg/l) OOOO
3
5
7
9
11
13
Sigma-T ++++
20
21
22
23
24
25
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
8
9
10
11
12
13
Depth (meters)
0
5
10
15
20
25
30
35

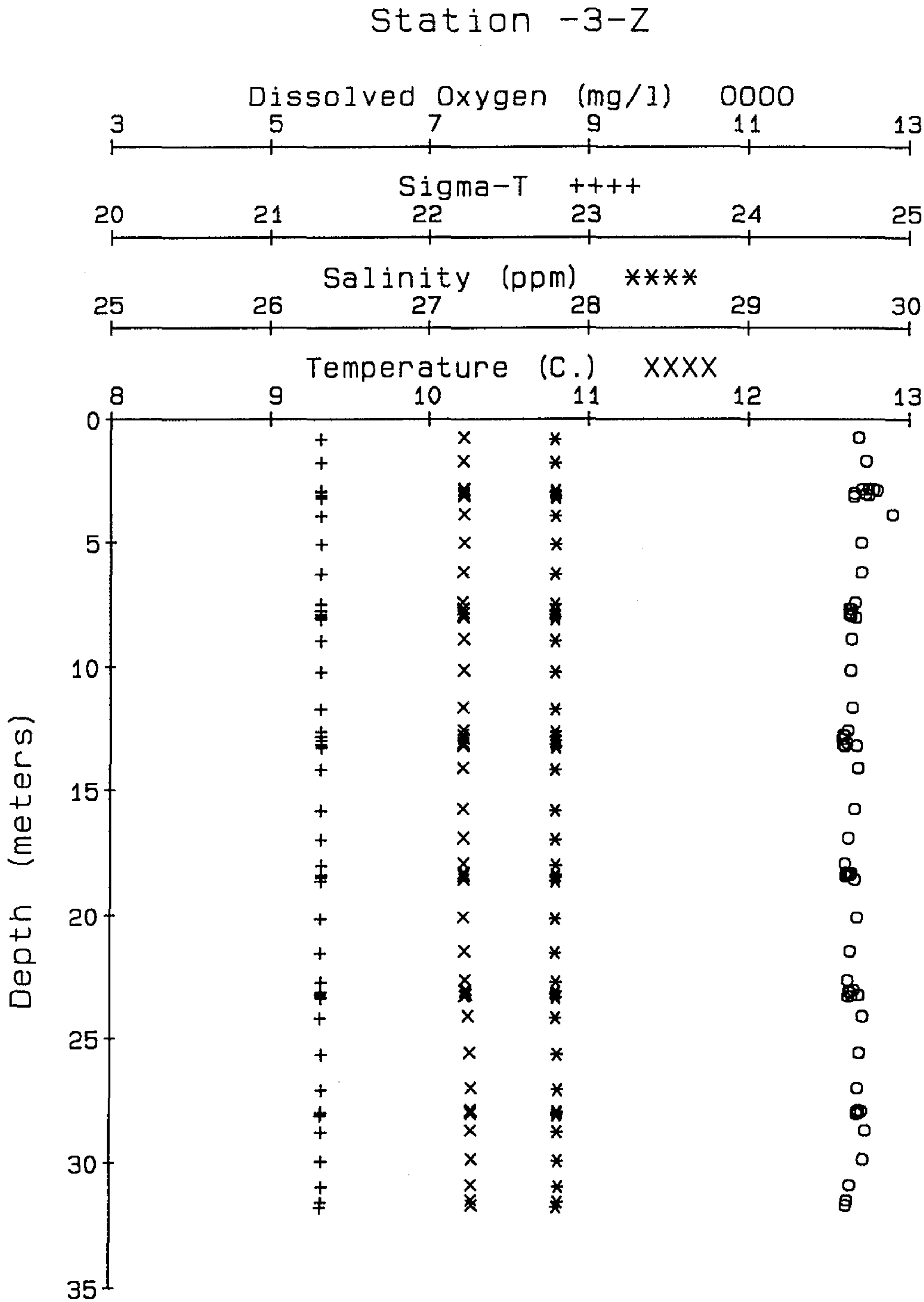
Station -3-I

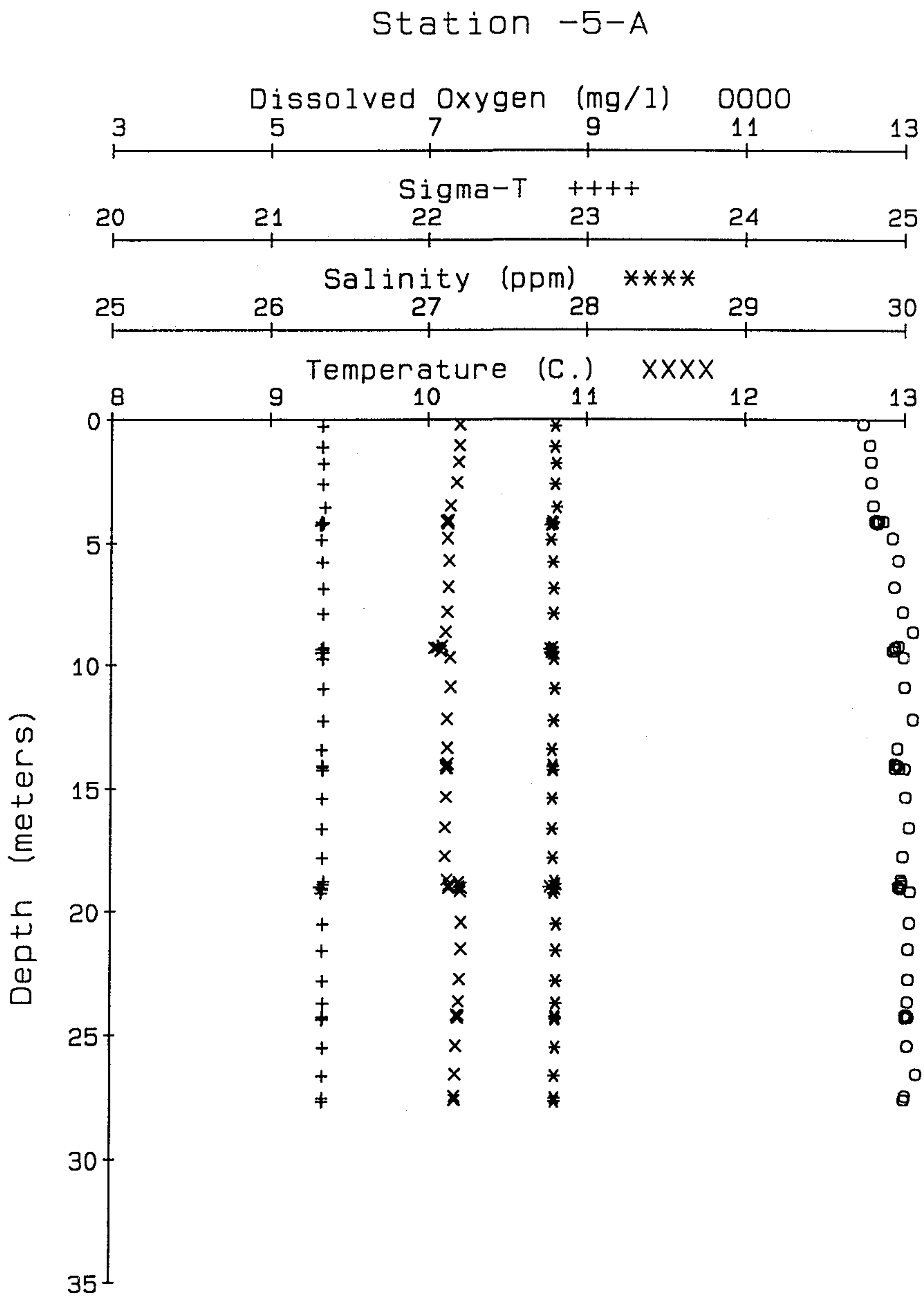


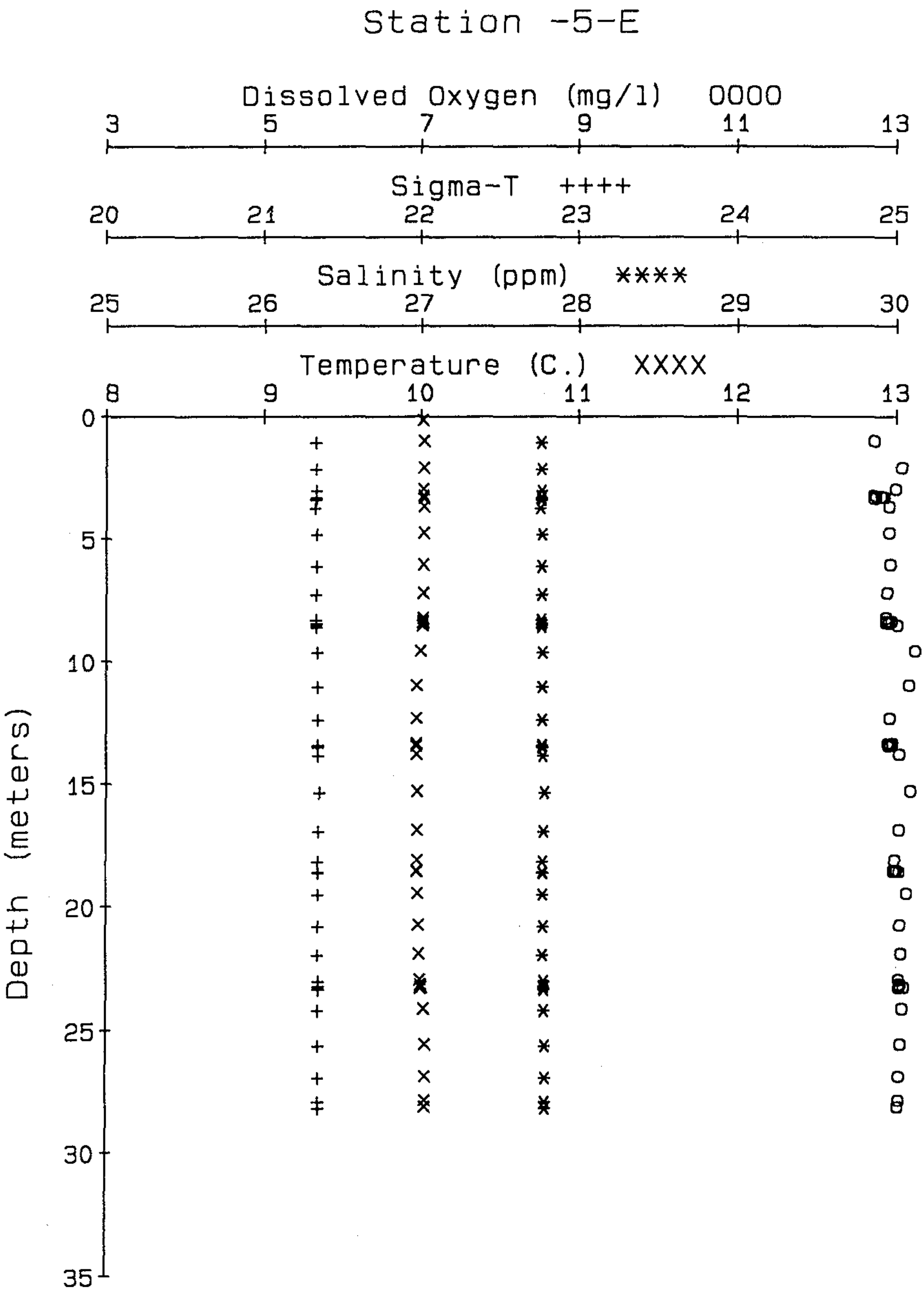
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

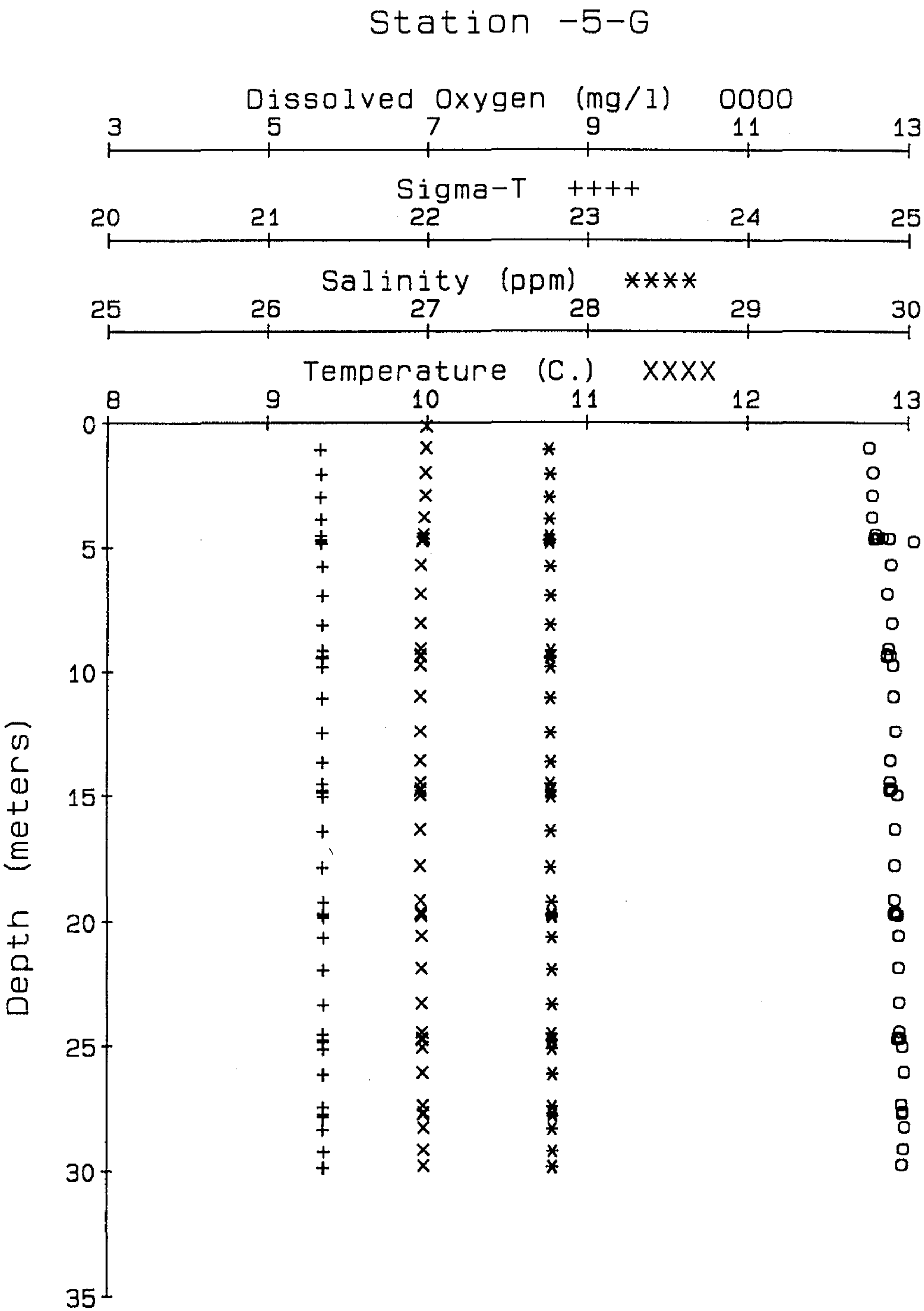

Station -3-K
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
0 5 10 15 20 25 30 35
Depth (meters)

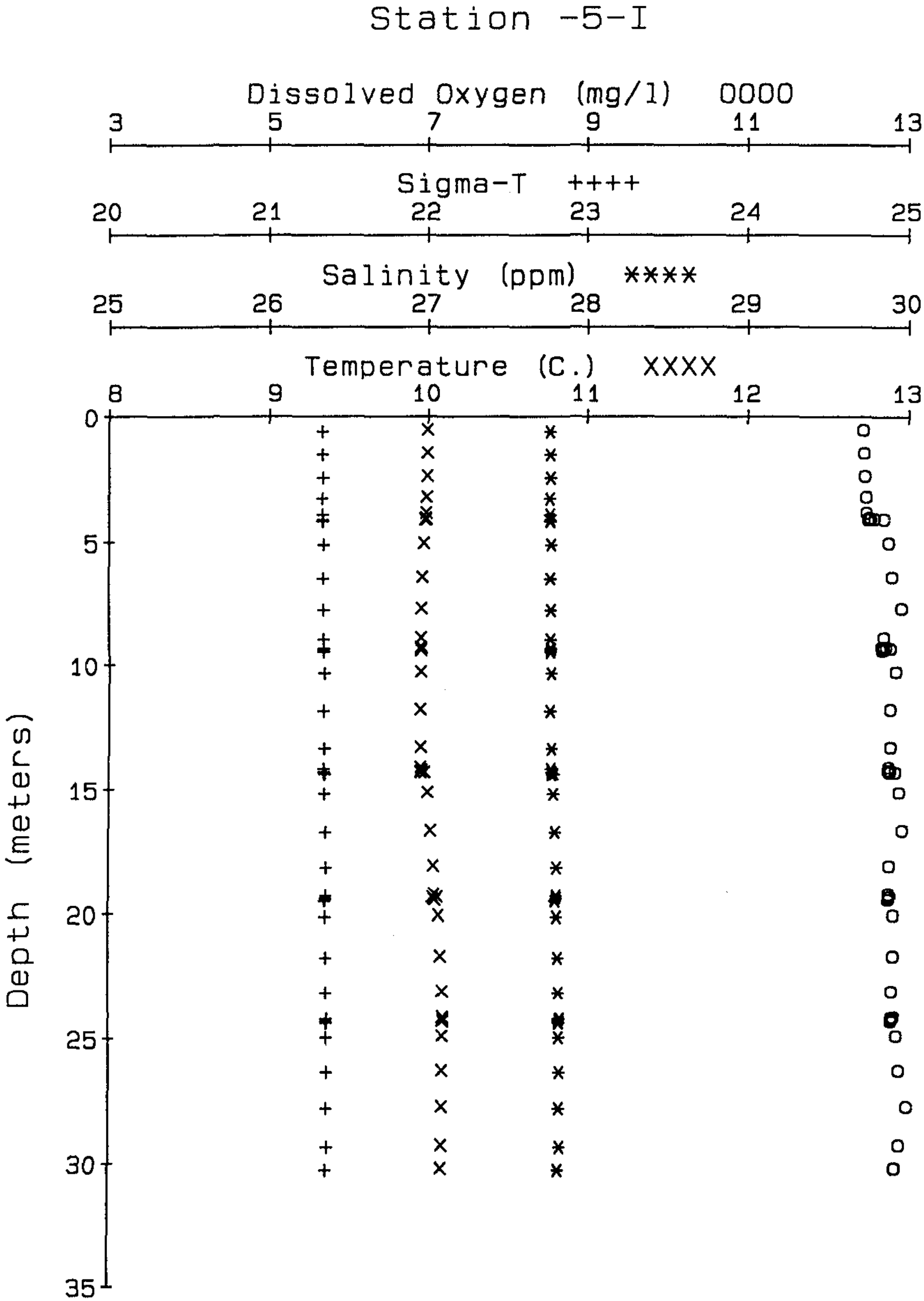

Station -3-Y
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

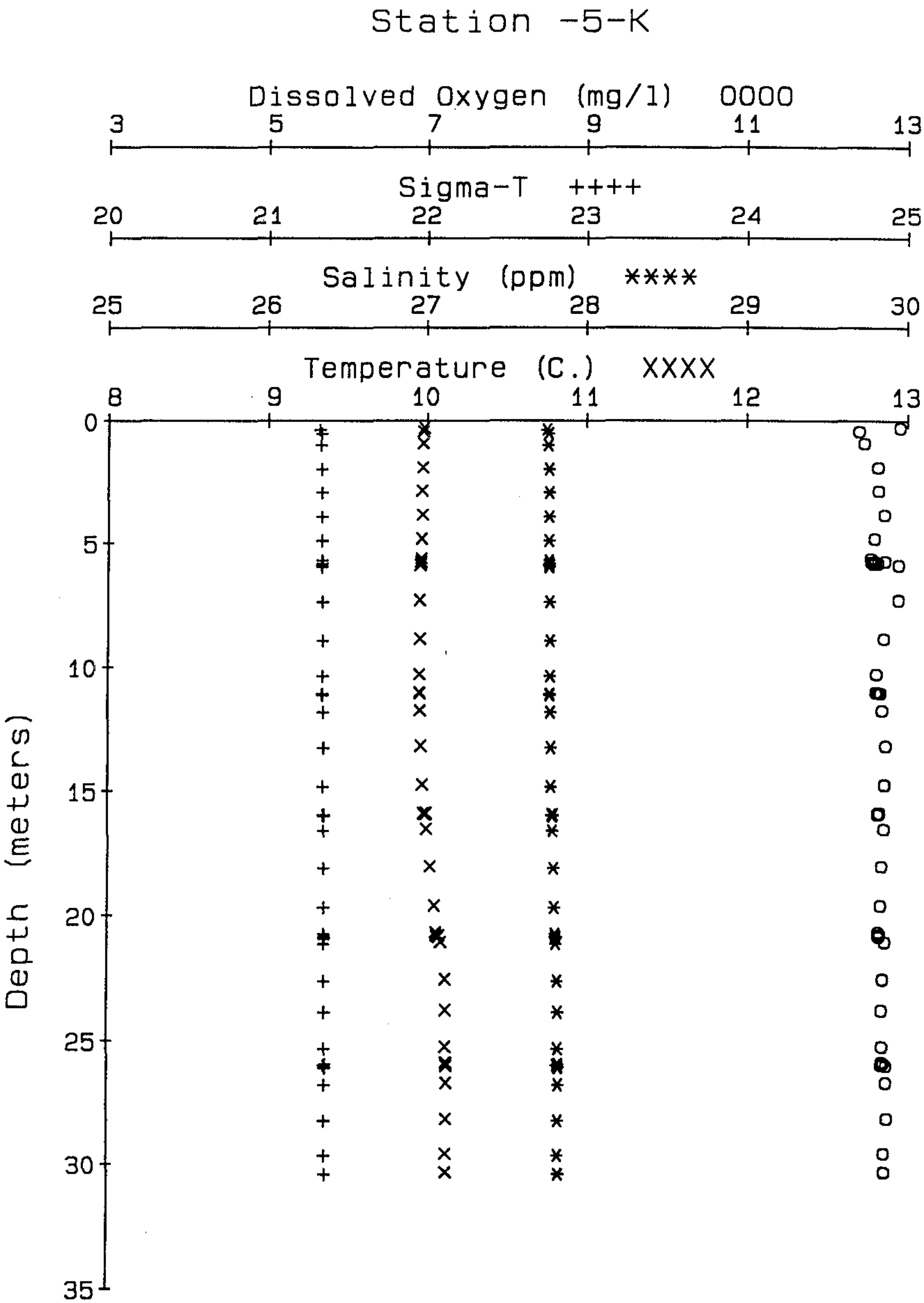

Station -3-Z
Dissolved Oxygen (mg/l) OOOO
3
5
7
9
11
13
Sigma-T ++++
20
21
22
23
24
25
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
8
9
10
11
12
13
0
5
10
15
20
25
30
35
Depth (meters)


Station -5-A
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station -5-E
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

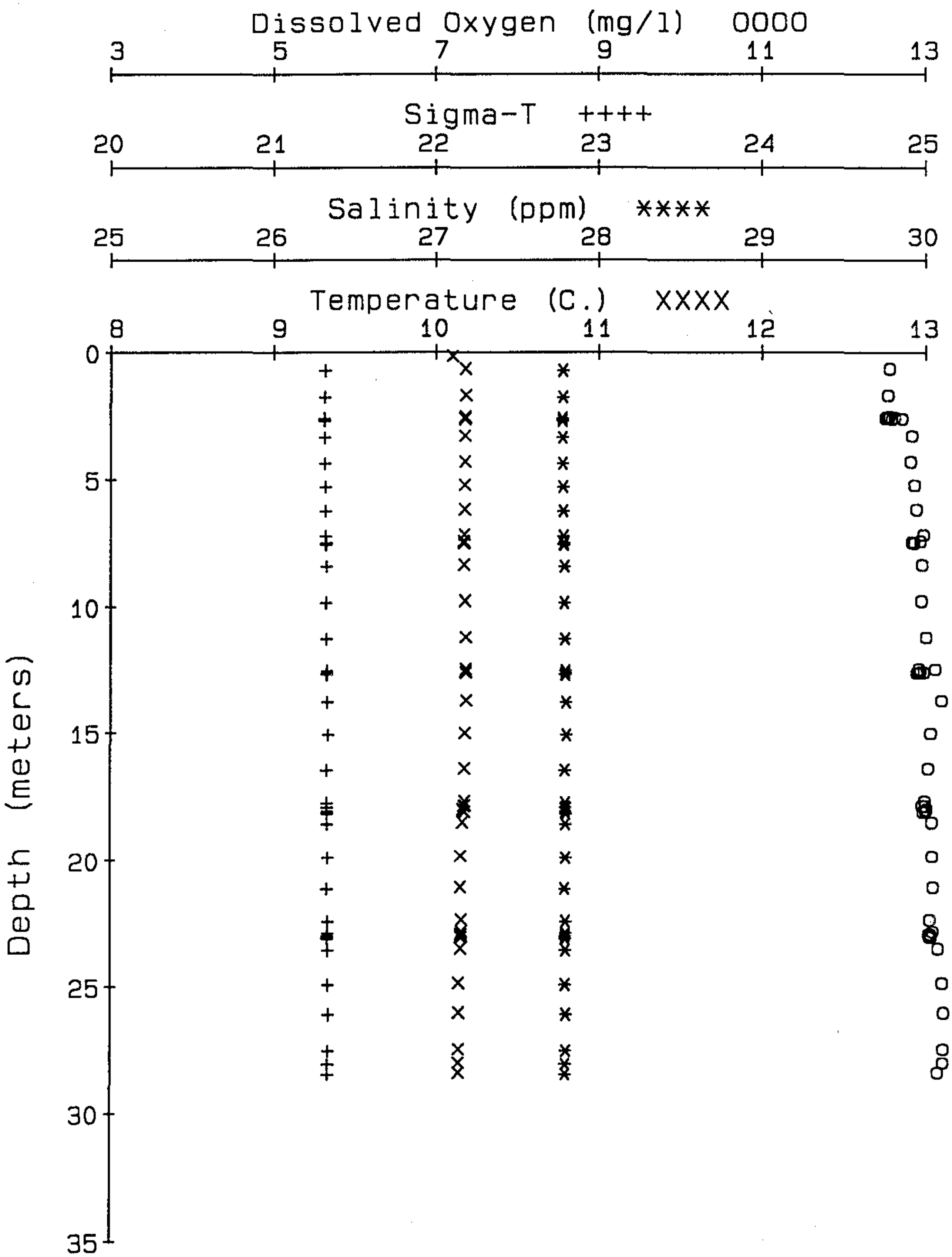

Station -5-G
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station -5-I
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

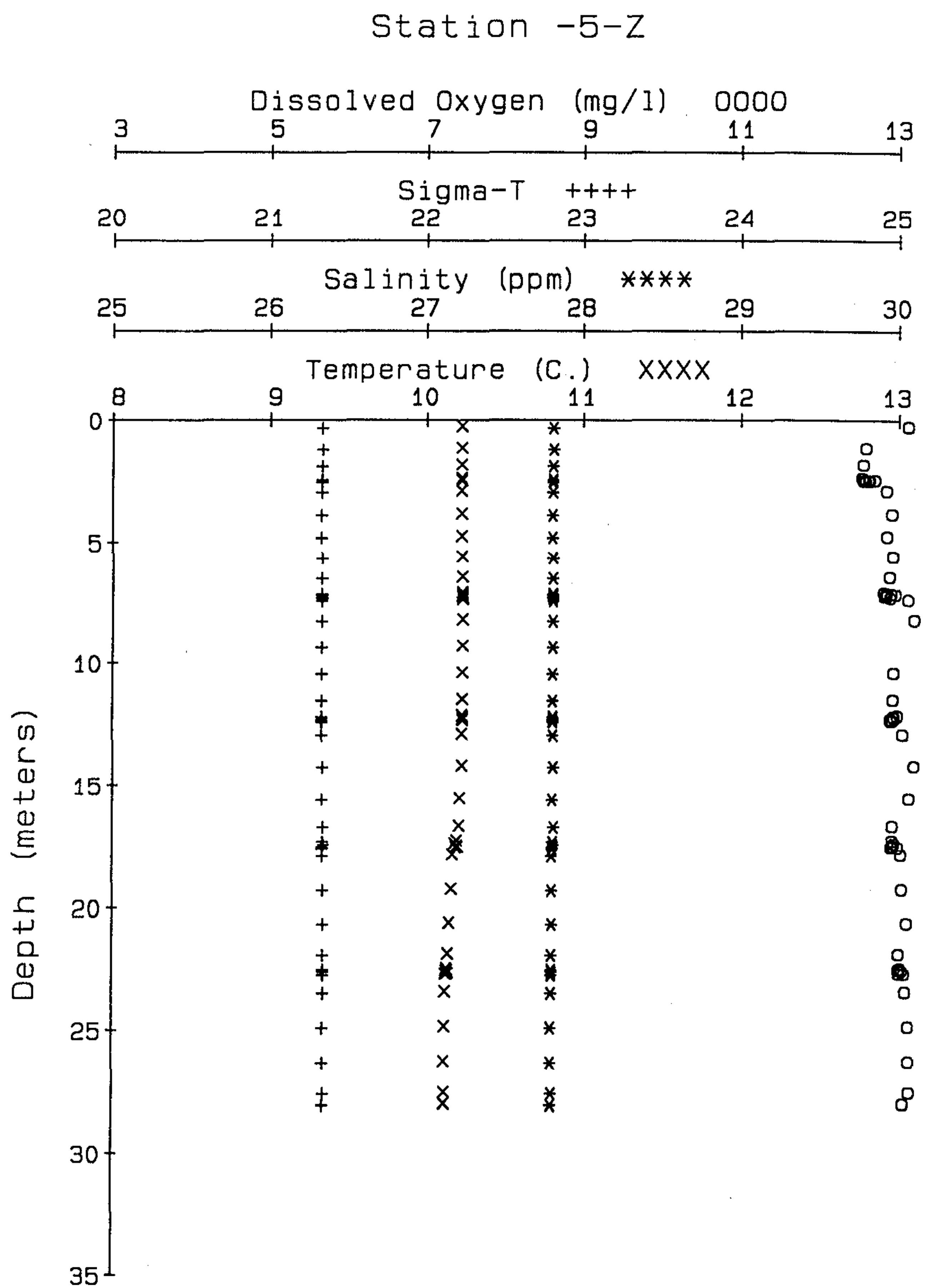


Station -5-K
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

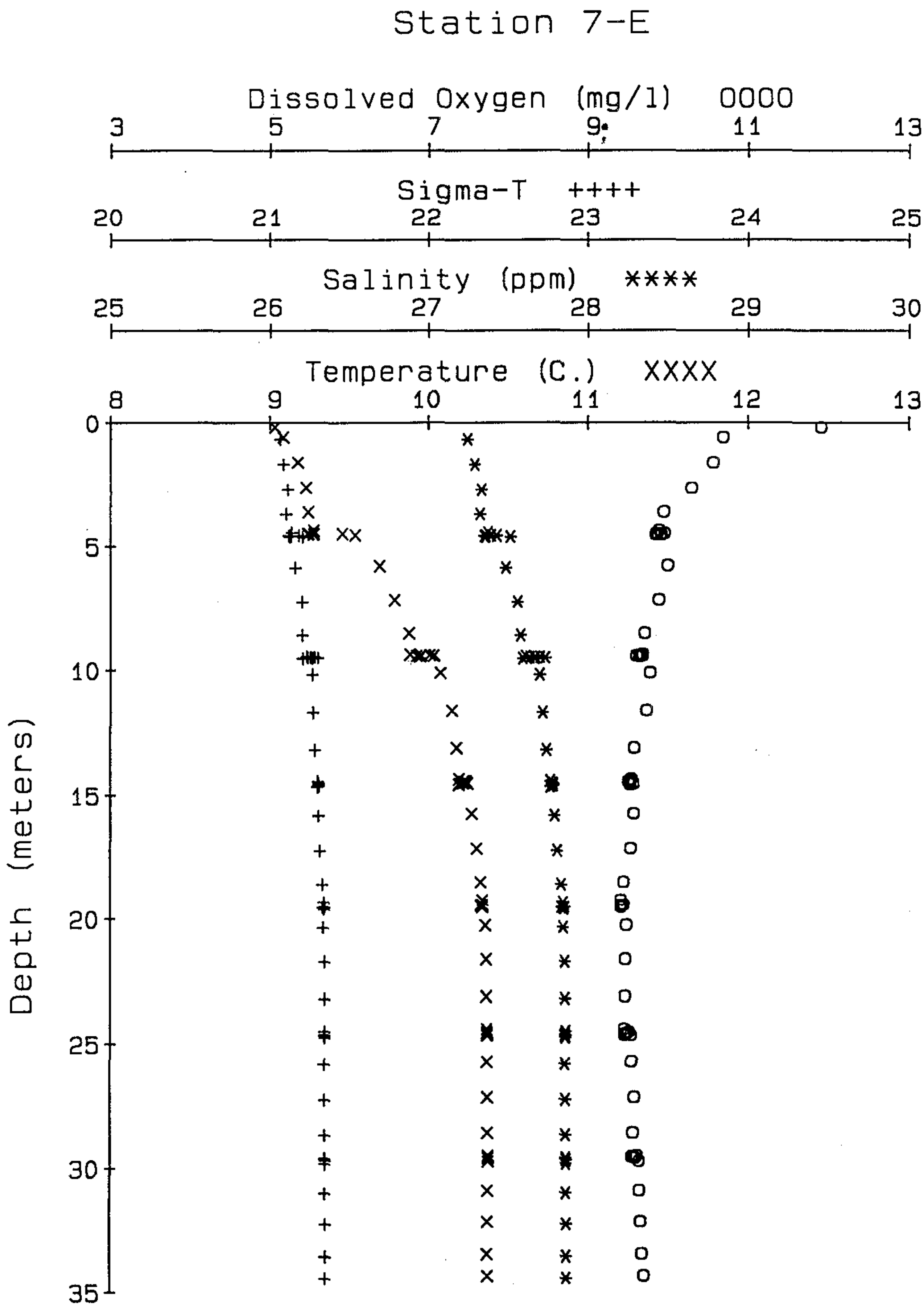
Station -5-Y



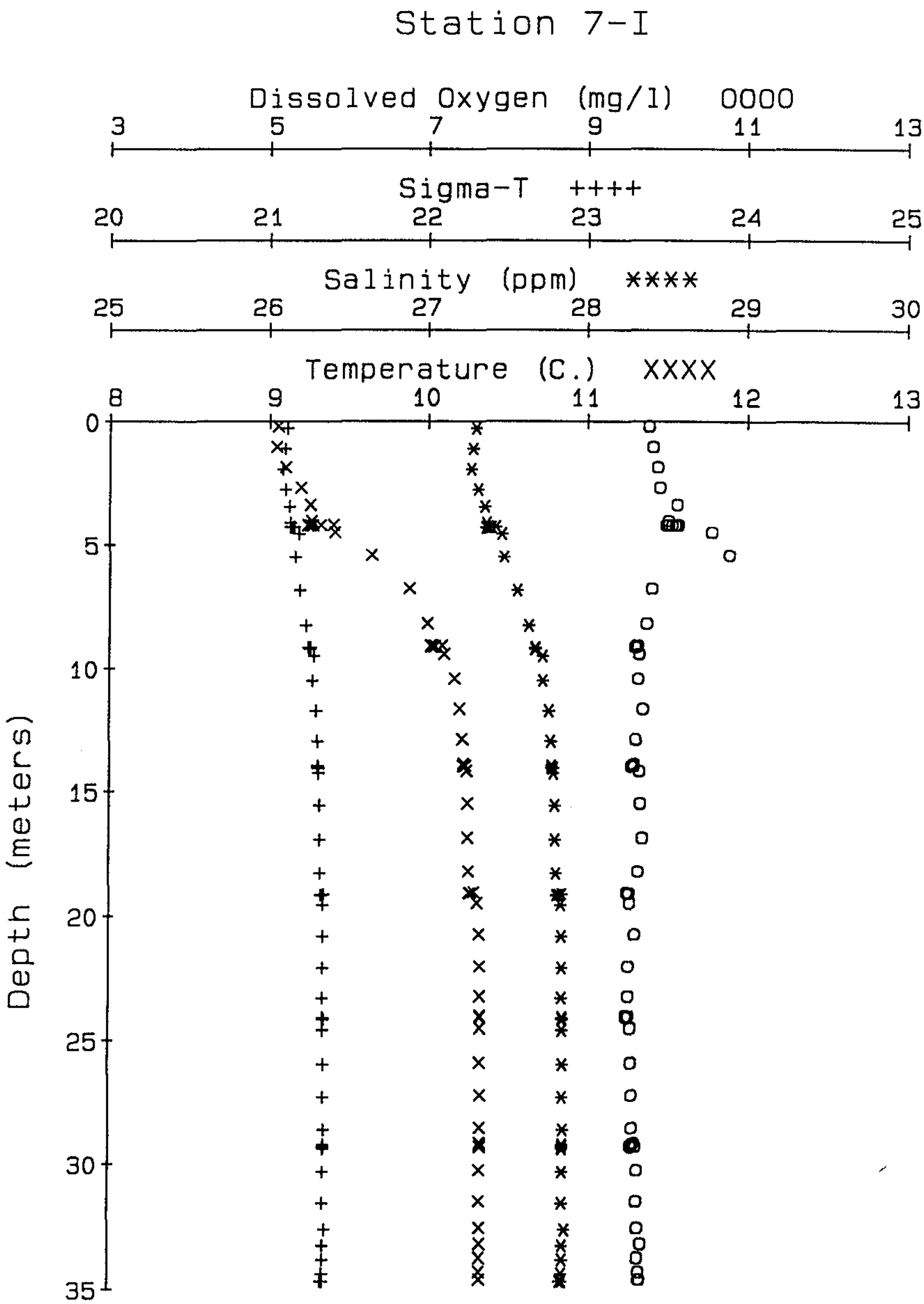
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

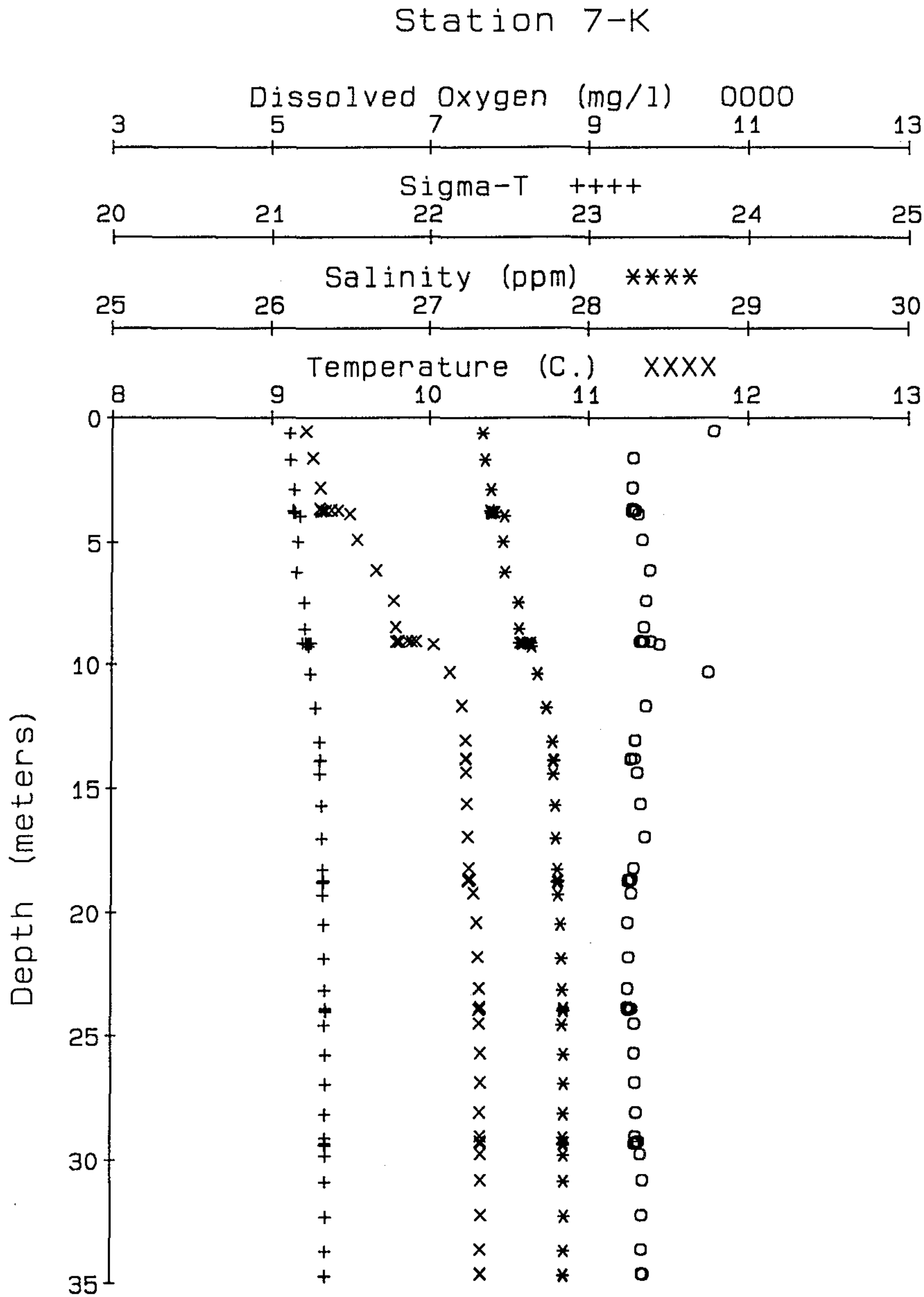


Station -5-Z
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35

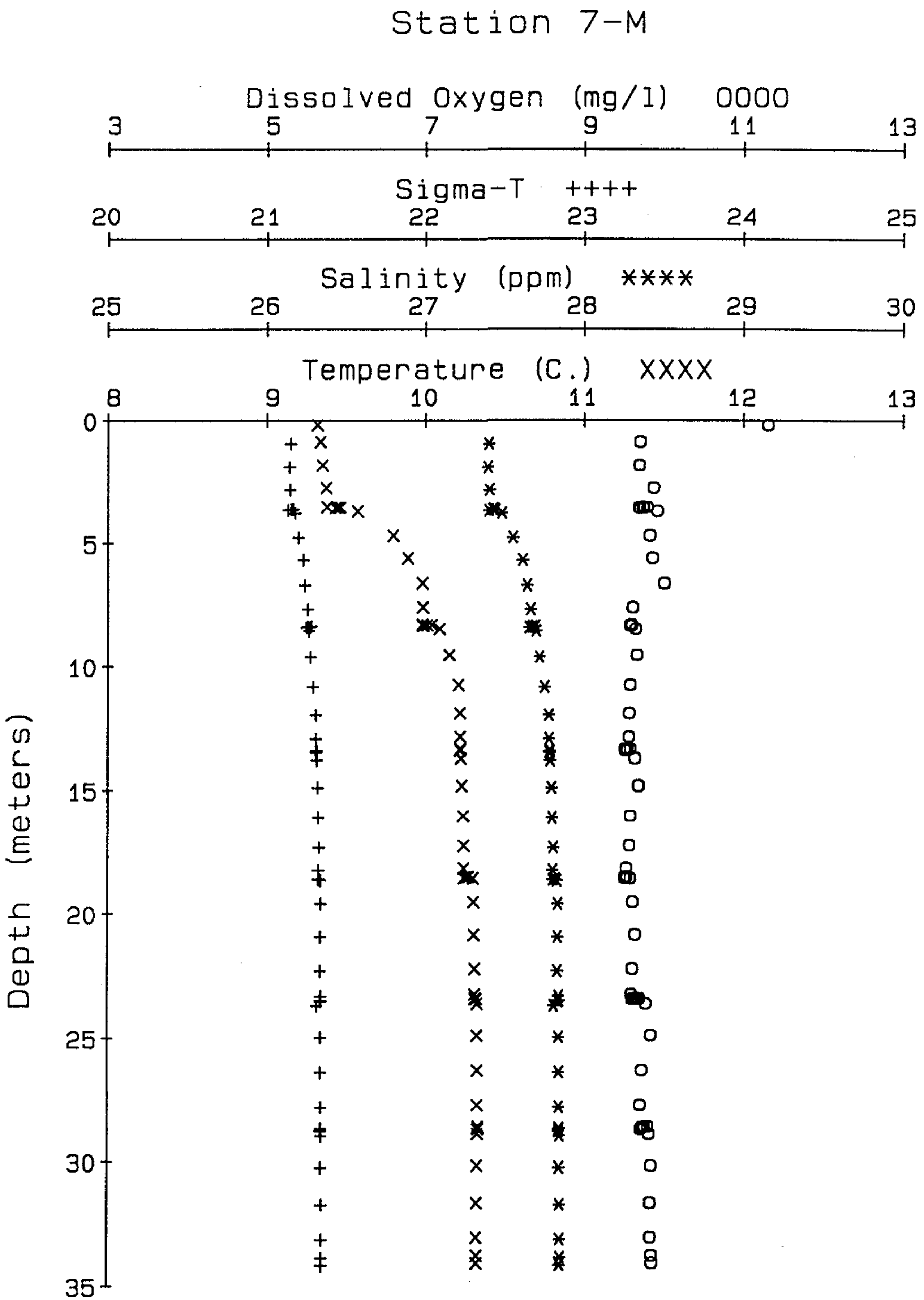


Station 7-E
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station 7-I
Dissolved Oxygen (mg/l) OOOO
3
5
7
9
11
13
Sigma-T ++++
20
21
22
23
24
25
Salinity (ppm) ****
25
26
27
28
29
30
Temperature (C.) XXXX
8
9
10
11
12
13
Depth (meters)
0
5
10
15
20
25
30
35



Station 7-K
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35


Station 7-M
Dissolved Oxygen (mg/l) OOOO
3 5 7 9 11 13
Sigma-T ++++
20 21 22 23 24 25
Salinity (ppm) ****
25 26 27 28 29 30
Temperature (C.) XXXX
8 9 10 11 12 13
Depth (meters)
0 5 10 15 20 25 30 35