Monitoring Cruise at the New London
Disposal Site, August 1988

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Field operations were conducted at NLON from 28 July to 1 August, and 25 to 31 August, 1988. Sampling tasks included precision bathymetric and REMOTS® sediment-profile photographic surveys around the point where the disposal buoy was located during the 1987-88 disposal season. In addition, near-bottom and near-surface dissolved oxygen concentrations and vertical profiles of temperature and salinity were determined at selected disposal site and reference stations.

Dredged material deposited at the New London Disposal Site during the 1987-88 disposal season occurred as a generally circular, gently-sloping mound with a maximum thickness of 1.5 meters, located just south of the buoy. Based on changes in bathymetry, the radius of the new mound to the north, east and south was estimated to be roughly 200 to 250 m, while the REMOTS® results further extended the observed radius of dredged material deposit from 250 to 350 m, primarily in an eastern direction. This was close to the predicted radius of 250 to 300 meters for the new deposit. The results of both the bathymetric and REMOTS® surveys indicated the newly disposed dredged material to be situated well within the disposal site boundaries.

The generally high near-bottom dissolved oxygen levels in the water column in conjunction with the occurrence of Stage III taxa observed in the REMOTS® photographs from many of the disposal site stations 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 equivalent at disposal site and reference stations and were clearly within the aerobic range. There was no indication that dredged material disposal operations adversely affected dissolved oxygen concentrations in the region.

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES:

FIGURES:

LIST OF FIGURES (continued).

LIST OF FIGURES (continued).

MONITORING CRUISE
AT THE NEW LONDON DISPOSAL SITE
AUGUST 1988

1.0 INTRODUCTION

The New London Disposal Site (NLON) covers a one square nautical mile area and is located approximately two nautical miles south of the mouth of the Thames River, CT. This site, centered at latitude 41°16.1'N and longitude 72°04.6'W, has been monitored by the DAMOS program since 1977. Several disposal points or mounds currently exist at NLON as a result of past and recent disposal operations.

Field operations were conducted at NLON from 28 July to 1 August, and 25 to 31 August, 1988. Sampling tasks included precision bathymetric and REMOTS® sediment-profile photographic surveys around the point where the disposal buoy was located during the 1987-88 disposal season (Figure 1-1). Previous surveys performed at this site include those of July 1986 and 1987 (SAIC, 1989; 1990b). The objectives of the 1988 survey were to delineate the extent and topography of recently-deposited dredged material from the past year's disposal activities at the buoy. In addition, near-bottom and near-surface dissolved oxygen concentrations and vertical profiles of temperature and salinity were determined at selected disposal site and reference stations. The objectives of sampling were to characterize depth gradients and assess near-bottom dissolved oxygen concentrations relative to REMOTS® benthic analyses at and near the disposal site.

According to scow log estimates, a total of 104,000 m of dredged material from 10 projects was deposited within 50 meters of the buoy at the New London Disposal Site during the 1987-88 disposal season. The 1988 monitoring scheme at NLON was designed to verify the following predictions:

- the sediment disposed during the 1987-88 season would result in the formation of a mound having a radius of approximately 250 to 300 meters, and
- near-bottom dissolved oxygen concentrations would be similar at stations within the disposal site compared to stations within the reference areas.

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 for 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 Millstone Point and New London Lighthouse (SAIC, 1985). A detailed description of the navigation system and its operation can be found in DAMOS Contribution #60 (SAIC, 1989).

Depths were determined to a resolution of 3.0 cm (0.1 feet) using an Odom DF3200 Echotrac® Survey Recorder with a narrow-beam 208 kHz transducer. The speed of sound used in depth calculations was determined from 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. 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).

The bathymetric survey conducted at the New London Disposal Site on 26 and 31 August 1988 encompassed a 1600 X 1600 m grid with 25 m lane spacing, centered at coordinates 41°16.235 N and 72°04.492 W (Figure 1-1). This was the same grid used in the bathymetric survey of the site in July 1987, allowing the calculation of depth differences at the disposal site. It should be noted that the coordinates of the disposal buoy during the 1987-88 disposal season were 41°16.100 N and 72°04.350 W, placing it approximately 150 m west of its location during the 1986-1987 disposal season (41°16.092 N and 72°04.234 W).

2.2 REMOTS® Sediment-Profile Photography

REMOTS® sediment-profile photographic surveys of the New London Disposal Site have been carried out since June 1984. REMOTS® photography has been used to detect and map the distribution of thin (2 mm to 20 cm) dredged material layers, map benthic disturbance gradients, and monitor the process of infaunal recolonization on and adjacent to the disposal mound. A detailed description of REMOTS® photograph acquisition, analysis, and interpretative rationale is given in DAMOS Contribution #60 (SAIC, 1989).

With the exception of five stations, the REMOTS® stations occupied on 28 July, 1 and 25 August 1988 were at the same locations occupied during the last survey of the current disposal mound (NL-86) in July 1987. Three replicate photographs were obtained at each of 33 stations, located in a 6 X 5 grid of 200 m spacing, centered at the disposal buoy (Figure 2-1). Additional stations were located at 800S (i.e., 800 meters south of station CTR), 1000S, and 600E. Stations 1000E, 1500NW, 400NW, 400SE, and 800SE were included in the NLON 1987 REMOTS® survey but were not sampled in the present study. Thirteen REMOTS® stations, arranged in a cross-shaped pattern and spaced 100 m apart, were also occupied at each of three reference locations to allow comparisons between ambient and on-site conditions. These stations were located 2,500 m west (W-Ref), 1,500 m northeast (NE-Ref), and 3,300 m northeast (NLON-Ref) of station Center. In order to 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 survey have been compared with the results of the July 1987 survey.

2.3 CTD and Dissolved Oxygen Sampling

The depth gradients in temperature, salinity and dissolved oxygen were characterized at selected REMOTS® stations using a CTD probe (Applied Microsystems, Ltd. Model STD-12®) with attached Rexnord® dissolved oxygen probe (Royce Instruments Model 66®). A complete description of this instrument package is given in DAMOS Contribution #66 (SAIC, 1990b). The CTD 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 mounted on the camera base such that its sensor was located approximately 6 cm above the sediment surface when the camera was resting on the bottom. In this configuration, vertical hydrographic profiles were obtained with each deployment of the camera.

At selected REMOTS® stations, a Niskin bottle was used to obtain water samples approximately one meter above the bottom and one meter below the surface. At some of these stations, an additional sample was obtained at an intermediate depth. A 300-ml subsample was drawn from the Niskin bottle following retrieval, and the dissolved oxygen concentration was determined immediately using a modification of the standard Winkler titration method (Strickland and Parsons, 1972; Parsons et al., 1984). The purpose of this sampling was to provide an *in situ* calibration of the Rexnord® dissolved oxygen probe.

3.0 RESULTS

3.1 Bathymetry

The five historical disposal mounds at the New London Disposal Site were easily recognized in both the 1987 and 1988 precision bathymetric surveys: NL-RELIC, NL-I, NL-II, NL-III, and NL-85 (Figures 3-1 and 3-2). During the 1987-88 disposal season, a new disposal mound was formed at the buoy location approximately 150 meters west of the NL-85 mound. A comparison of enlarged areal maps from the 1987 and 1988 bathymetric surveys of the 700 by 700 m area encompassing the new mound showed the presence of this recently disposed dredged material (Figures 3-3 and 3-4). Additional "pockets" of dredged material were formed at scattered points within approximately 200 to 250 m of the disposal buoy. The predominant mound formed during the 1987-88 disposal season was generally circular, with gradually rising slopes; there were changes in depth on the mound slopes of up to 0.5 m over a 20 m distance. The mound had a maximum thickness at the apex of 1.5 m and a minimum depth of 17.0 m. The minimum depth at the NL-85 mound showed a slight decrease from 15.5 m in 1987 to 15.25 m in 1988, indicating some recent disposal at this point. The minimum depths of NL-RELIC (13.0 m), NL-I (15.5 m), NL-II (15.5 m), and NL-III (14.5 m) did not change from the July 1987 survey.

During the 1987-88 disposal season a total of 104,000 m of dredged sediment was deposited at the New London Disposal Site buoy according to scow log estimates. The depth matrices from the 1987 and 1988 bathymetric surveys were compared for the 700 X 700 meter area encompassing the new disposal mound (Figures 3-3 and 3-4). This resulted in a volume difference calculation of approximately 52,000 m^3 of material deposited since the July 1987 survey based on bathymetric techniques.

3.2 REMOTS® Sediment-Profile Photography

Dredged material layers presumed to be recently deposited (i.e., during the 1987-88 disposal season) were evident in the REMOTS® photographs from seven stations in the area within 250 to 350 m of the new disposal buoy (Figure 3-5). Precise boundaries for the distribution of newly disposed dredged material were difficult to determine because the new buoy location was only 150 m west of the previous year's location, resulting in a large overlap of recently disposed material with material from previous years at the NL-85 mound. In addition, "relict" dredged material was also identified at several stations to the northeast of the new mound, presumably material deposited previously on the flanks of the NL-II and NL-III mounds formed during the early 1980's. This relict dredged material generally occurred at the same stations which showed relict deposits in the July 1987 REMOTS® survey of the site. At stations where recently deposited dredged material was detected, it generally had a thickness exceeding the penetration of the REMOTS® camera prism (6.8 - 15.2 cm; Figure 3-5). Stations in the vicinity of the NL-85 mound, (i.e. CTR, 200E) obviously received "fresh" material deposited on top of material deposited from 1985 to early 1987.

However, this apparent "fresh" dredged material did exhibit relatively consistent patterns in stratigraphy, grain-size, and optical reflectance at different stations. At most stations the material was poorly sorted, varying mainly in the degree of fine sand mixed with a silt/clay fraction. For example, at 200W (the new disposal buoy location), a fine sand over silt over fine sand stratigraphy was apparent (Figure 3-6). This type of stratigraphic pattern most likely resulted from sequential disposal events. The sediment surface at 200W showed only a sand layer, devoid of large worm tubes, surface amphipods or hydroids, indicating a recently deposited sedimentary layer at this station. In addition, the cross-sectional sediment profile generally showed uniformly low reflectance without a high reflectance redox layer, indicating low pore-water oxygen availability. All these sediment characteristics are typical of recently deposited dredged material.

Photographs taken at stations such as 2-200SE displayed highly reduced sediment with a thickness greater than camera prism penetration, and only a thin surface layer of oxidized sediment (Figure 3-7). Again a well-developed redox layer was not present; the distinct surface layer reflected a change in grain-size primarily, rather than a change in redox conditions. At station 200E, low reflectance sediment also predominated, but randomly arranged patches of lighter sediment were present as well (Figure 3-8). In addition, the sediment surface was quite irregular with a large boundary roughness value, another common characteristic of recently deposited dredged material.

In contrast, at station 2-200NE (identified as relict dredged material), the cross-sectional sediment profile was not as reduced, and well developed Stage III feeding voids were present (Figure 3-9). In addition, the fine sand layer present at stations closer to the new buoy location was not present at 2-200NE; instead a relatively dense layer of worm tubes was present at the sediment surface, indicating that very recent disturbance at the site had not occurred. At stations such as 400W (identified as having received no dredged material), a dense layer of hydroids and worms were present, indicating that a major disturbance had not occurred in the recent past (Figure 3-10).

The majority of REMOTS® grid and reference stations consisted of silt-clay sediments with some fine sand (grain-size major mode of $\geq$ 4-3 phi, Figure 3-11). Some of the stations having either relict or fresh dredged material exhibited grain size major modes ranging from silt and fine sand (4-3 phi) to silt-clay ($\geq$ 4 phi), reflecting past and recent inputs of fine sand and/or mud having a significant sand component. However, proportionately more stations in the reference areas had coarser sediment grain-size major modes (4-3 phi). This distinction in grain-size most likely resulted from the predominantly fine grained material deposited at the disposal site.

The majority of small-scale surface boundary roughness values at the disposal site stations (i.e., those grid stations within the disposal site boundary) fell in the range from 0 to 9.3 cm, while those at the reference stations were in the range from 0.1 to 2.0 cm (Figure 3-12). Boundary roughness values at the disposal site stations were not found to be significantly different from those at the reference stations (Mann-Whitney U-test, $p = 0.1533$). In addition, boundary roughness values at the disposal site in the present report were not significantly different from those measured in the July 1987 survey (Mann-Whitney U-test, $p = 0.6712$).

The frequency distribution of apparent RPD depths for the REMOTS® stations within the disposal site boundary had a major mode at the 3.0 cm class interval, while the distribution of RPD depths for the reference stations had a major mode at the 2.0 cm class interval (Figure 3-13). This apparent discrepancy was an artifact caused by minimal camera penetration at many of the reference stations; consequently RPD depths could not be adequately evaluated. The biased distribution and small sample size of pooled reference station replicates made statistical comparisons invalid. However, the RPD depths at the disposal site from the present study were found to be significantly shallower than those measured in the July 1987 survey (Mann-Whitney U-test, $p < 0.001$), with the mean RPD depth for disposal site stations in 1987 and 1988 being 4.0 and 3.1 respectively.

In the present (1988) survey, RPD depths less than 3.0 cm occurred at six stations to the south and east of the buoy (Figure 3-14). Most of these were stations identified as having recently-deposited dredged material, and one (2-200NE) was identified as having relict dredged material (Figure 3-5). With these exceptions however, the RPD depths at disposal site stations generally exceeded 3.0 cm.

Stage I organisms were exclusively present at seven stations within the disposal site boundaries and at all the reference stations that had adequate penetration (Figure 3-15). At the remaining twenty-four disposal site stations however, there was evidence of Stage III taxa (i.e., head-down deposit-feeding infauna) in at least one of the replicate photographs. Most of these stations were designated as having either a Stage III or Stage I on III successional stage. In the July 1987 survey, 96% of the replicate photographs at the stations within the disposal site boundaries showed evidence of Stage III taxa, compared to 58% in August 1988.

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, intense demersal predator foraging, etc.). Only three disposal site stations (2-200SW, 4-400SW, 2-200SE) had mean OSI values +6, resulting from shallow RPD depths and/or the absence of Stage III infauna (Figure 3-16). At many of the reference stations OSI values were indeterminate due to an inability to measure RPD depths and/or determine infaunal successional stages. For those reference stations where OSI values could be calculated, the frequency distribution major mode was +4, while the frequency distribution of OSI values for disposal site stations had a major mode at +10 (Figure 3-17). OSI values for the disposal site stations were obviously greater than the pooled reference station OSI values, again mainly due to the sampling artifact caused by poor prism penetration at many of the reference stations. The OSI values from the disposal site stations were significantly lower than those calculated from the July 1987 REMOTS® survey (Mann-Whitney U-test, $p < 0.001$).

3.3 CTD and Dissolved Oxygen Sampling

On July 28, near-bottom dissolved oxygen concentrations at the disposal site stations ranged between 5.3 and 7.2 mg/ℓ, while a concentration of 8.3 mg/ℓ was measured consistently at several disposal site stations on August 25 (Table 3-1). Near-bottom dissolved oxygen concentrations at the three reference stations, also measured on August 25, were consistent with those measured at the disposal site stations sampled on the same day and ranged from 8.1 to 8.3 mg/ℓ. Dissolved oxygen concentrations in the top two meters of the water column were slightly higher than those measured in near-bottom waters sampled on both days at the disposal site, and reference stations. Surface water dissolved oxygen concentrations at the disposal site stations ranged from 6.3 to 7.4 mg/ℓ on July 28th and 8.3 to 8.5 on August 25th. Concentrations of dissolved oxygen in surface waters at the reference stations (sampled on August 25th), were similar to the disposal site stations sampled on the same day and displayed ranges between 8.3 and 8.9 mg/ℓ. Dissolved oxygen levels in mid-depth water samples taken at random stations were intermediate between the surface and near-bottom concentrations. This suggests a steady decrease in dissolved oxygen levels from surface to bottom on 28 July and a nearly constant level of dissolved oxygen throughout the water column at the stations sampled on 25 August, 1988.

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 depth gradients were similar at all the stations sampled on 28 July; the plot from disposal site station 4-200SE is representative (Figure 3-18). This plot indicated a slight stratification in the water column at the time of sampling, at a depth of approximately 6 m. Temperatures ranged between 18.8°C at the surface to 17.7°C at depth. Concomitant increases in salinity and density (as sigma-t) with depth suggested a relatively stable stratification of the water column. On the August 25th sampling, there were no distinct depth gradients at both the disposal site stations and the reference stations. The plots from disposal site station 600S (Figure 3-19) and reference station WREF/300S (Figure 3-20) are representative. In these plots there was no evidence of a thermocline below 1 to 3 m from the surface. Temperature ranged from 17.8°C at the surface to 17.1°C at depth. Salinity, density and dissolved oxygen concentrations also lacked evidence of strong depth gradients, with dissolved oxygen concentrations consistently remaining at or above 8 mg/ℓ.

4.0 DISCUSSION

The objective of the combined REMOTS® and precision bathymetric surveys was to delineate the extent and topography of the deposit resulting from the past year's disposal at the New London Disposal Site. The bathymetric survey showed a newly-formed disposal mound approximately 150 m west of the NL-85 mound. In addition, scattered "pockets" of dredged material were identified within approximately 250 m of the buoy as a result of disposal during the 1987-1988 disposal season (Figure 3-3). The new mound had a maximum thickness of 1.5 meters at its apex, centered just south of the new buoy location. Based on changes in bathymetry, the radius of the new mound was determined to be between 200 to 250 m, representing a volume change of 52,000 m^3 of dredged material deposited during the 1987-88 disposal season.

A depth difference contour plot of the 700 by 700 m area encompassing the new disposal mound was prepared by subtracting 1987 depths from those recorded in the 1988 bathymetric survey (Figure 4-1). This plot illustrated the topography of material detected in the 1988 survey alone, representing only material deposited during the 1987-88 disposal season. The new mound centered slightly south of the disposal buoy was more readily apparent in this presentation, as were the smaller deposits primarily south and northeast of the buoy. The 0.1 m contour lines delimited the distribution of dredged material as detected by bathymetry, indicated that newly disposed material was confined to this 490,000 m^2 region (Figure 4-1). Newly deposited dredged material was clearly situated well within the disposal site boundary (approximately 500 m south and 200 m east of this region).

The results of the REMOTS® survey confirmed the dredged material distribution indicated in the bathymetric survey. "Fresh" dredged material was identified at all the stations where the bathymetric depth difference contour plot indicated new dredged material disposal. In addition, the REMOTS® survey also identified what appeared to be newly deposited dredged material at stations 200E and 2-200SE (Figure 4-2). These stations were located beyond the 0.1 m contour line in the depth difference plot, which was based on acoustic measurements that can only reliably detect differences in depth of approximately 10 to 15 cm. Because REMOTS® photography can detect the presence of thinner layers of dredged material, this technique extended the observed radius of newly deposited material distributed around the buoy from 250 to 350 m (extending primarily to the east, Figure 4-2).

This was close to the predicted radius of 250 to 300 m for the new mound; however, this prediction was based on an original estimated volume of 85,000 m^3 disposed material. The final scow log volume estimate of 104,000 m^3 disposed material exceeds the earlier estimate and could help account for the slightly wider "footprint" of the new mound. It is possible that the REMOTS® mapping may have overestimated the extent of the recent deposit, because the contouring was between relatively widely-spaced stations (200 m). In addition, there were the aforementioned difficulties in distinguishing between fresh and "relict" dredged material layers at several of the stations located close to the flanks of NL-II and NL-III, as well as stations actually on top of the older NL-85 mound.

Despite these considerations, the REMOTS® results showed the new mound to extend slightly farther to the east, and to a lesser extent to the north and south than indicated from the bathymetric survey (darker shaded area, Figure 4-3). When the area representing the flanks of the mound (that area detected by REMOTS® alone as having recently received inputs of dredged material) was measured, it was found to occupy 97,212 m^2 (stippled area, Figure 4-2). A reasonable estimate of the thickness of fresh dredged material layers in these areas would be 15 cm, based on the maximum thickness observed in the REMOTS® photographs (Figure 3-5). This is a conservative estimate, because for all stations on the REMOTS® grid when "fresh" material was encountered, it occurred with thicknesses greater than camera prism penetration. Using this thickness estimate of 15 cm results in an additional estimated volume of 14,582 m^3 of material on the mound flanks not included in the bathymetric depth difference calculation. Adding this to the depth difference volume estimate of 52,000 m^3 resulted in a final total of roughly 66,600 m^3 of dredged material detected on the bottom using these two techniques in combination.

The total volume estimate of 66,600 m^3 represents 64% of the scow log estimate of 104,000 m^3 of dredged material disposed within the site boundaries in the 1987-88 disposal season. This agrees with the results found by Tavolaro (1984), which showed that volume estimates based on scow log records considerably overestimate the amount of disposed dredged material because of the significant amount of interstitial water associated with the dredged material in the barges. The same study showed that "depth difference" volume estimates based on successive bathymetric surveys were approximately 41% less than the scow log volume estimates because of compaction of the dredged material on the bottom following disposal, as well as the water content factor. The discrepancy between the scow log estimate and the depth difference volume estimate experienced at NLON in 1988 is consistent with the results of previous surveys both at this and at other Long Island Sound disposal sites (SAIC, 1990a; 1990c).

The shallower RPD depths found at the reference stations compared to the disposal site stations were due largely to poor penetration of the REMOTS® camera prism. The poor penetration suggests that more compact (i.e., lower water content) sediments occurred at some of the reference stations in comparison to the disposal site stations. Significantly deeper prism penetration had occurred at the same reference stations in the 1987 survey, despite the fact that more camera weights were used during the field operations in 1988.

Comparison of replicates taken at NE-REF in the 1987 and 1988 REMOTS® surveys indicated that a surface layer of loosely packed, bioturbated sediment visible in 1987 was no longer present in 1988 (Figure 4-4 a & b). Some of the 1988 replicates from NLON-REF also showed evidence of small bedforms at the sediment surface, as well as an apparent influx of sandy material in comparison to the previous year's photographs (Figure 4-5 a & b). In 1987, the surface sediment at the reference stations had a well-developed redox layer and was densely colonized by both surface tube-dwelling and shallow-burrowing gammarid amphipods. In 1988, there was no trace of these organisms or the surface bioturbated layer containing their burrows. One possible explanation is that the surface layer was eroded in response to a high energy storm event, resulting in the small but visible bedforms, an apparent influx of sandier material, and the disappearance of the amphipods which are quite sensitive to current action (e.g., Biernbaum, 1979). Alternately, it is possible that the changes in sediment grain-size and compactness occurred in response to faunal changes in the local population of shallow-dwelling amphipods. If this population suddenly crashed, it would make the underlying sediments more susceptible to erosion. At the New London reference stations, the underlying, loosely-packed sediment in 1987 appeared to have been reworked extensively by infaunal amphipods. This layer might have easily been eroded even by normal currents in the area, and the observed increase in the sand component of the surface sediments may reflect the winnowing fine-grained sediment. As a result, the sediment at the reference stations in 1988 was noticeably more compact and lacked the bioturbated layer which had previously been observed. Such localized effects would explain why similar erosion of surface layers was not observed at the disposal site stations.

While no Stage III organisms were reported in the 1988 reference station photographs (in comparison to the dense population observed in the 1987 survey), it is impossible to be sure whether this was representative of the reference areas in 1988, or whether some Stage III organisms were actually present and not seen due to poor camera prism penetration. However, the sediment surface at NE-REF and NLON-REF in particular was noticeably devoid of re-colonization by amphipods, suggesting that the surface disturbance, whether physically- or biologically-initiated, was recent. In comparing the New London reference station photographs from 1987 to 1988, it is important to recognize the role of natural disturbance in structuring benthic habitats (e.g., Wiens, 1977; Thistle, 1981). It is equally important to recognize how benthic organisms, in particular amphipods, may significantly stabilize and otherwise modify the sedimentary environment (e.g., Mills, 1976; Young, 1968; Rhoads, 1974).

RPD depths at the disposal site stations in the present survey were significantly shallower than those reported in 1987. In addition, Stage III organisms were reported in 58% of the 1988 disposal site station replicates in comparison to 96% reported in the 1987 disposal site station replicates. This suggested that disturbance has occurred at the disposal site since the time of the previous year's survey. This was related in part to dredged material disposal, at least at those stations located within the mapped distribution of dredged material.

For those stations within the mapped distribution of dredged material (Figure 3-5), the shallower RPD depths reported for the present survey in comparison to the 1987 survey could reflect a higher sediment content of labile organic matter. This would result in an increased sediment oxygen demand in the recently disposed material compared to underlying relict dredged material or ambient sediments. The reduced percentage of Stage III organisms reported for these stations since the 1987 REMOTS® survey also could reflect within-station patchiness in the Stage III distribution.

It should be noted that the REMOTS® surveys from 1988 and 1987 were conducted during the same time of year, allowing roughly the same amount of recovery time following disposal operations. However, approximately 36,500 m^3 more dredged material was deposited in the 1987-88 season compared to the 1987-86 season (scow log estimates of 104,000 m^3 and 67,500 m^3 respectively). It is possible that the nature of the material disposed during the 1987-88 disposal season could have inhibited colonization of Stage III organisms more than the material deposited during the previous season. Other factors such as the variation in time between sequential deposits at the site (i.e., the frequency of disturbance) could also have played a role in these observed changes. However, despite their reduced numbers since the previous year's survey, Stage III organisms were observed in two or three of the replicates from most of the REMOTS® stations within the mapped distribution of fresh dredged material in 1988.

It is important to note that only three of the seven stations within the disposal site boundary showing the presence of Stage I taxa exclusively were stations identified with dredged material of any kind (Figures 3-5 & 3-15). The rest of the stations with Stage I taxa were considerably south of the buoy location and roughly 200 m from the southern border of the mapped distribution of dredged material (Figure 3-5). For these stations, some other form of disturbance is implied to have caused the observed retrograde conditions. It is possible that disturbance at these disposal site stations could have been the result of heightened energy regimes as inferred from the dramatic temporal change seen at the reference stations. However, evidence of this process (e.g., bedforms) was not observed in any disposal site station photographs, making it difficult to hypothesize increased bottom energy as the primary agent for disturbance in this region. The apparent retrograde successional stages at some of the disposal site stations could simply be the result of stochastic variation or poor colonization success. In addition, physical disturbance from activities such as bottom trawling or increased predator foraging could result in benthic habitat disturbance. In order to eliminate speculation and adequately characterize the nature of such indications of disturbance at the disposal and reference stations, near-bottom current measurements during the previous year would have been required.

The objective of the CTD/DO sampling was to assess near-bottom dissolved oxygen concentrations at the disposal site and reference stations and to consider these results in relation to benthic habitat conditions at the disposal site. Dissolved oxygen depth gradients indicated no difference throughout any part of the water column between disposal site and reference stations. Those stations sampled during July 27-28, 1988 indicated a slight thermocline at approximately 6 m from the surface, and gradually increasing salinities and densities with depth which stabilized to constant levels between 5 and 8 m from the surface. Dissolved oxygen concentrations for stations sampled in July varied by approximately 1.5 mg/ℓ from surface to near-bottom waters.

For those disposal site stations and all the reference stations sampled in August, the slight stratification detectable in the water column in July was no longer evident. A very slight temperature gradient occurred in the top 1-2 m of water, and no clear gradients in salinity or density were determined. Dissolved oxygen concentrations at or above 8 mg/ℓ (near saturation) were measured in surface and near-bottom waters at both disposal site and reference stations, indicating a nearly constant and highly "aerobic" level of dissolved oxygen throughout the water column. This verifies the prediction that dissolved oxygen concentrations would be similar between the disposal site and reference stations.

These nearly constant depth gradients through the water column are characteristic of winter or storm conditions where strong winds blowing across the water surface result in a well-mixed water body with little stratification. It is important to note here that the 2-3 days prior to the CTD sampling done August 28th had wind conditions high enough to cause cancellation of the field operations which had been scheduled for those days. The observed lack of depth gradients likely reflects these local meteorological conditions that occurred immediately prior to sampling. However, even in the dissolved oxygen data obtained July 27-28, 1988 at NLON, which indicated slight stratification in the water column, the lowest near-bottom dissolved oxygen concentration was well above hypoxic conditions (5.3 mg/ℓ, Table 3-1). While the lack of depth gradients observed from the August CTD casts may not represent conditions at the disposal site throughout the whole summer, there is no indication in the REMOTS® photographs of adverse conditions on the benthic community from near-bottom depletion of dissolved oxygen levels.

This agrees well with earlier findings 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). The apparent absence of severe hypoxic stress in 1987 and 1988 (up to and including the time of sampling) largely explains the continued presence of Stage III assemblages at the active disposal mound in both years. The 1988 results confirmed that in the absence of severe hypoxia, relatively healthy benthic conditions existed at the disposal site following dredged material deposition.

5.0 CONCLUSIONS

Dredged material deposited at the New London Disposal Site during the 1987-88 disposal season occurred as a generally circular, gently-sloping mound with a maximum thickness of 1.5 meters, located just south of the buoy (Figure 4-1). Based on changes in bathymetry, the radius of the new mound to the north, east and south was estimated to be roughly 200 to 250 m, while the REMOTS® results further extended the observed radius of dredged material deposit from 250 to 350 m, primarily in an eastern direction. This was close to the predicted radius of 250 to 300 meters for the new deposit. The results of both the bathymetric and REMOTS® surveys indicated the newly disposed dredged material to be situated well within the disposal site boundaries.

Based on the combined results of bathymetric and REMOTS® surveys, an estimated 66,600 m^3 of dredged material accumulated at the NLON buoy during the 1987-88 disposal season. This was less than the scow log volume estimate of 104,000 m^3 of disposed material. However, such discrepancies are expected because of the inaccuracies of scow estimates, the compaction of the dredged material on the bottom following disposal, and the significant amount of interstitial water associated with the dredged material in the barges.

It is evident that some degree of stress was occurring within the disposal site due to the reduced number of Stage III organisms and lowered RPD depths reported since the previous year's REMOTS® survey. However, the majority of REMOTS® stations within the disposal site boundary that showed only Stage I taxa were beyond the mapped distribution of dredged material. This implied that some form of disturbance unrelated to dredged material disposal must have been occurring at these disposal site stations in particular.

Because there were no indications of heightened energy regimes (such as bedforms), other disturbance factors, such as bottom trawling or intensive predator (e.g., fish) foraging, may have been responsible for the observed retrograde successional stages.

Comparison of replicate photographs from NE-REF and NL-REF between 1987 and 1988 revealed a significant change in the benthic population at these stations. A loss of the loosely-packed bioturbated surface layer, as well as the presence of small bedforms and slightly sandier material, implied either that the area had been affected by a high-energy storm event or a faunal change in the local amphipod population occurred which made the sediment more susceptible to erosion. Such processes would have resulted in significant sediment compaction at the surface, explaining the difficulties encountered in camera penetration as well as the lack of Stage III organisms. Future surveys at these stations should provide documentation of their re-colonization by local amphipod populations and ultimately by Stage III infauna. If similar evidence of possible physical disturbance is found during future studies, near-bottom current meter measurements may be warranted.

The generally high near-bottom dissolved oxygen levels in the water column in conjunction with the occurrence of Stage III taxa observed in the REMOTS® photographs from many of the disposal site stations 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 equivalent at disposal site and reference stations and were clearly within the aerobic range. There was no indication that dredged material disposal operations adversely affected dissolved oxygen concentrations in the region.

6.0 REFERENCES

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TABLE 3-1

Dissolved Oxygen Values at the New London Disposal Site, July and August, 1988. Units are mg/ℓ.

Sample Date	Station	Bottom (1m Off Bottom)	Middle (Mid-depth)	Surface (2m Below Surface)
7/27-28/88				
	4-400NW	7.200	------	*6.497
	4-400NE	6.146	------	7.200
	200N	5.268		7.376
	400W	6.497		*5.971
	CTR	7.200	*5.795	6.322
	400E	*5.619		
8/25/88				
	200S	8.262	------	8.262
	6-400SW	8.262	------	8.469
	600S	8.262	------	8.262
	6-400SE	8.262	------	8.469
	1000S	8.262	------	8.262
	W-REF	8.055		8.262
	NE-REF	8.262		8.675
	NLON-REF	8.262		8.882

* Floc in Sample

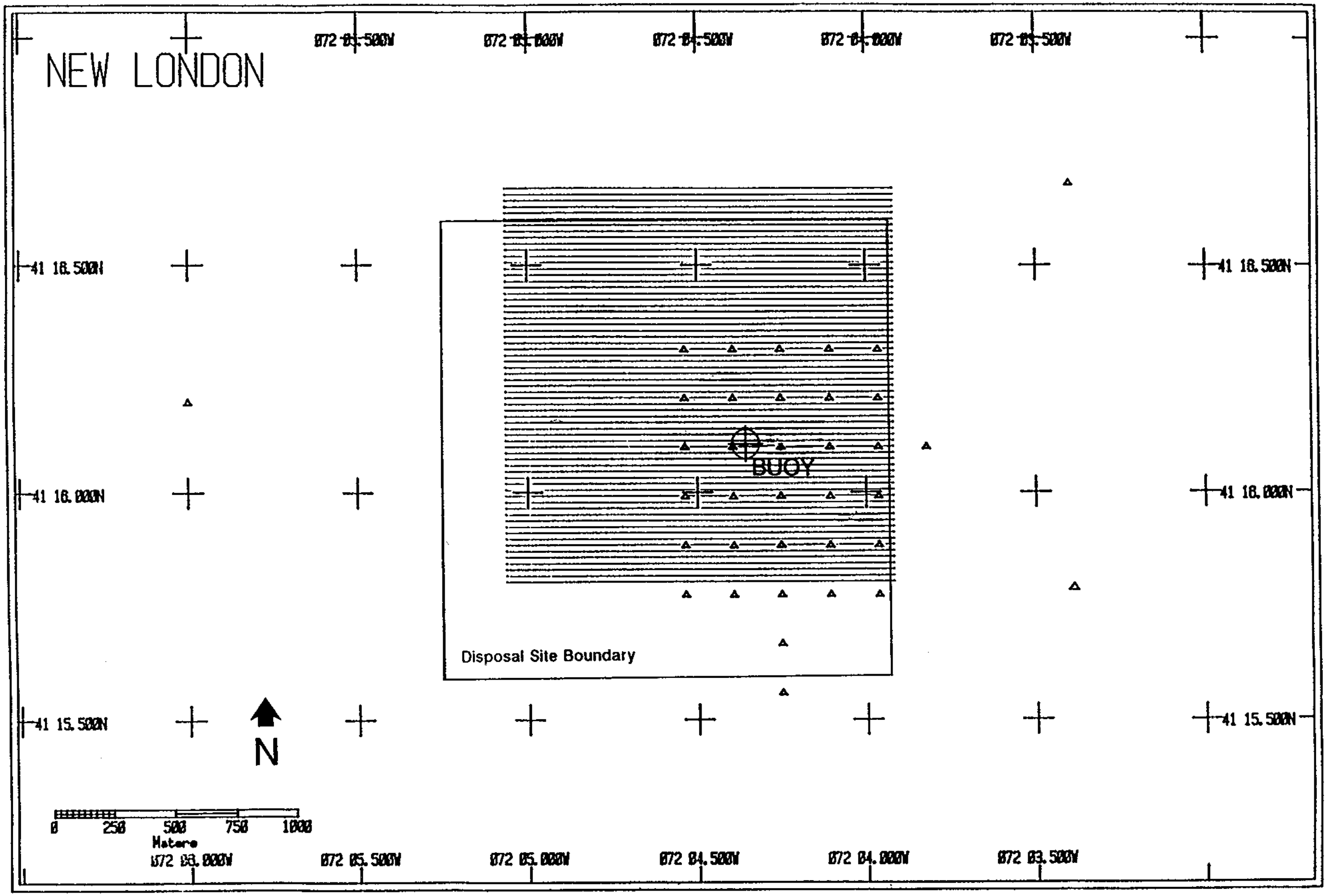


Figure 1-1 Bathymetric survey lanes and REMOTS® stations occupied in 1988 at the New London Disposal Site.

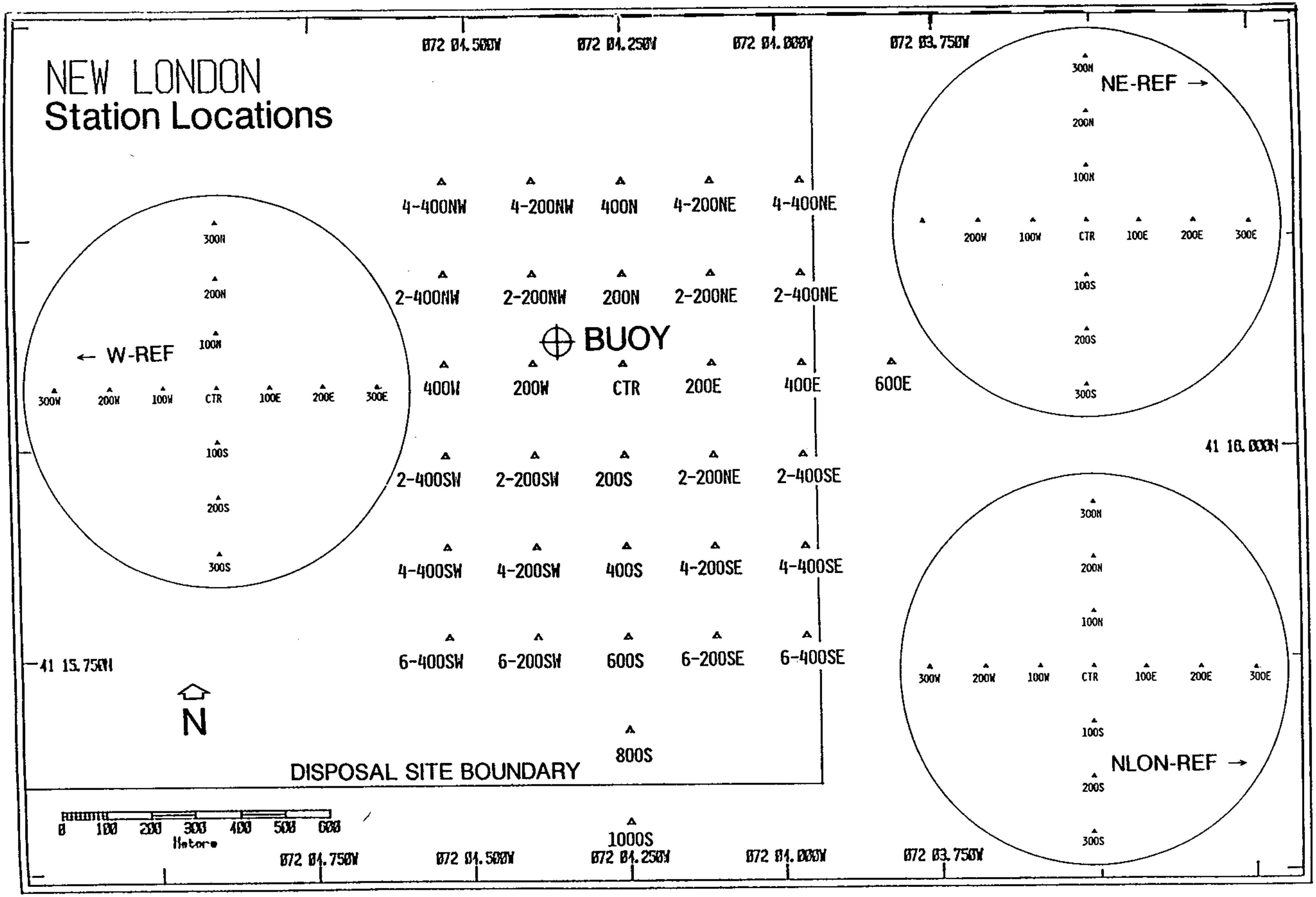


Figure 2-1 Locations and designations of REMOTS® stations (triangles) at NLON, August, 1988. Cross-shaped grids with 100 m station spacing were used at the three outlying reference sites (W-REF, NE-REF, and NLON-REF).

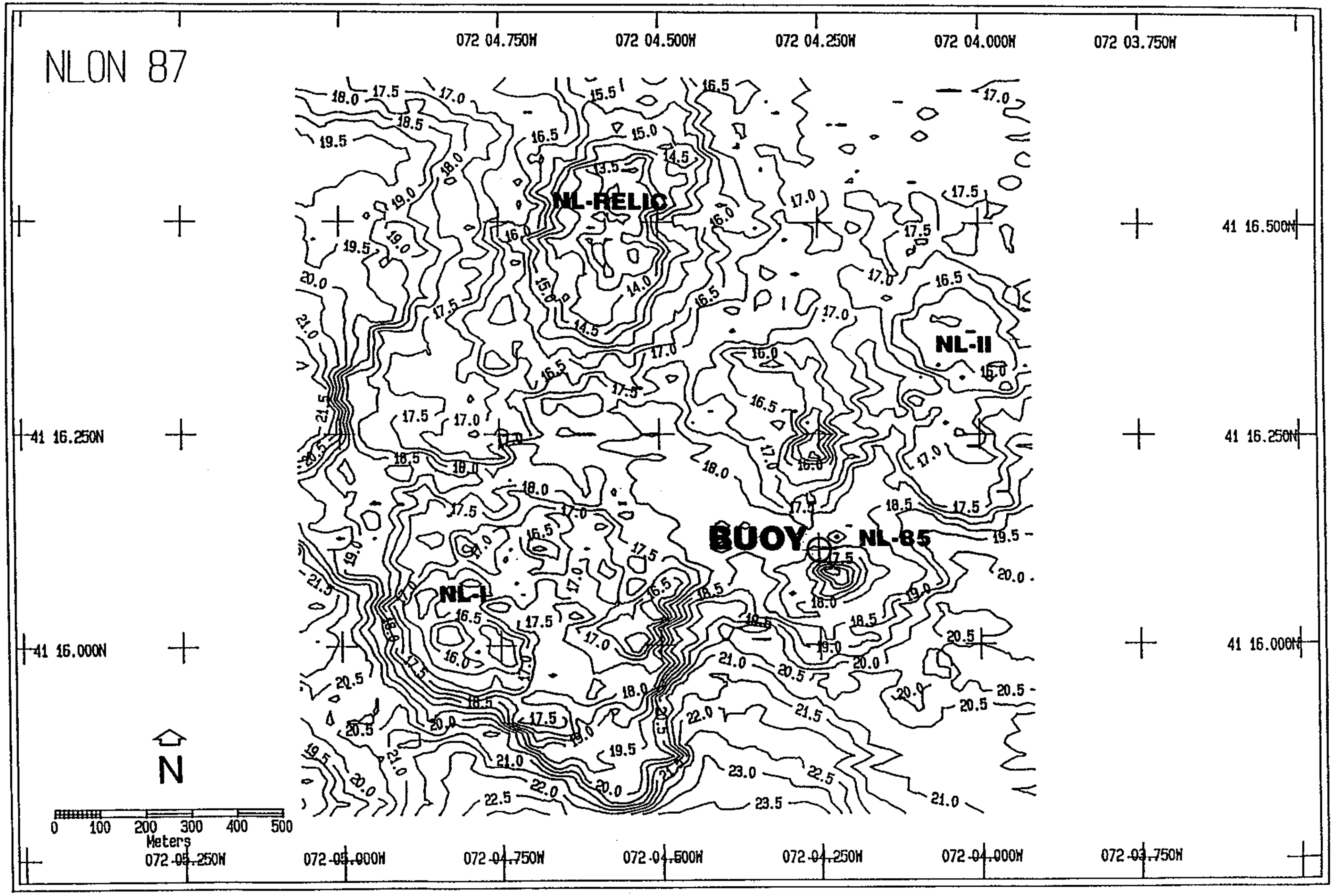


Figure 3-1 Bathymetric contour chart of NLON, July 1987. Depth contours at 0.5 m intervals.

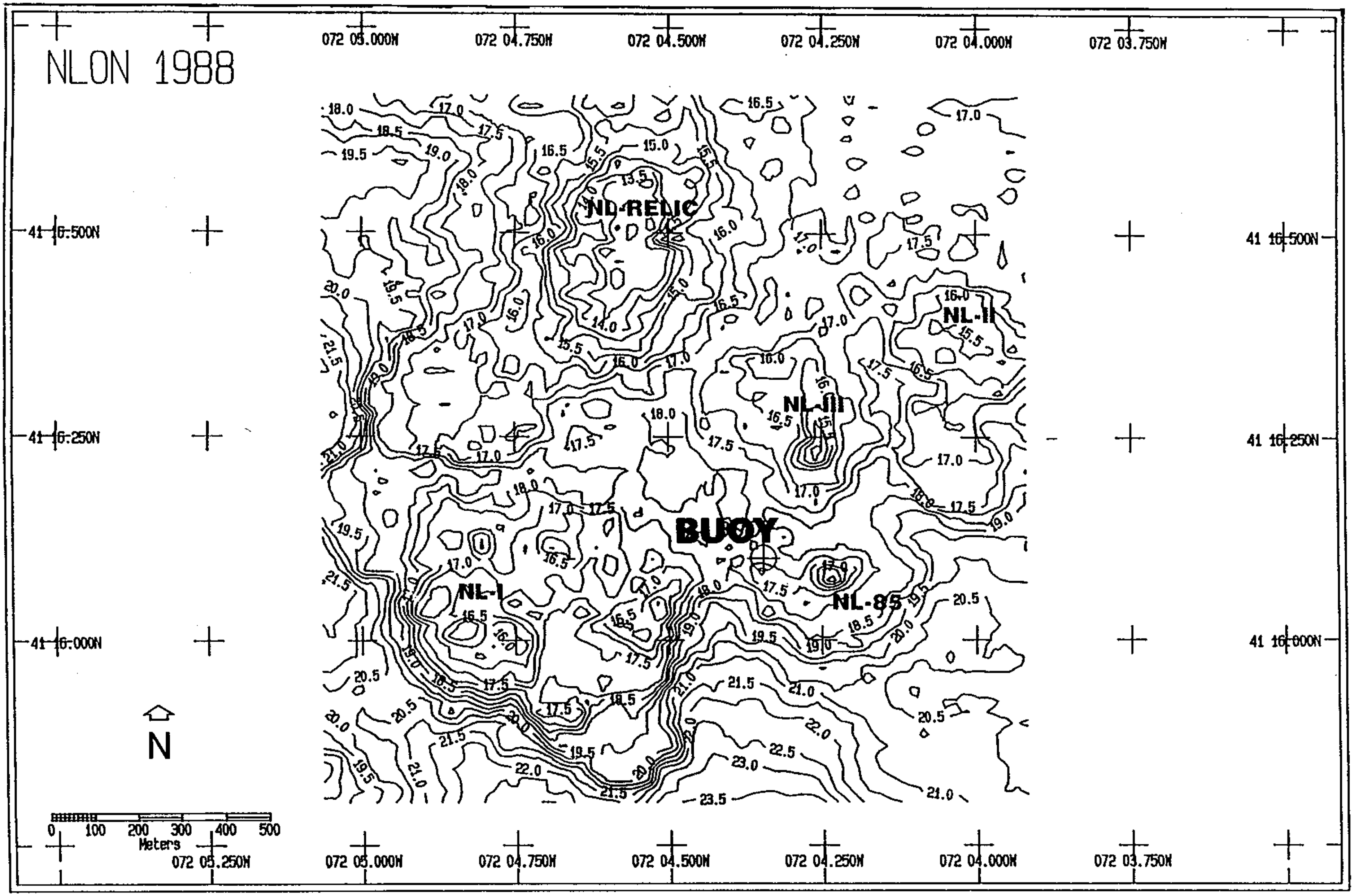


Figure 3-2 Bathymetric contour chart of NLON, August 1988. Depth contours at 0.5 m intervals.

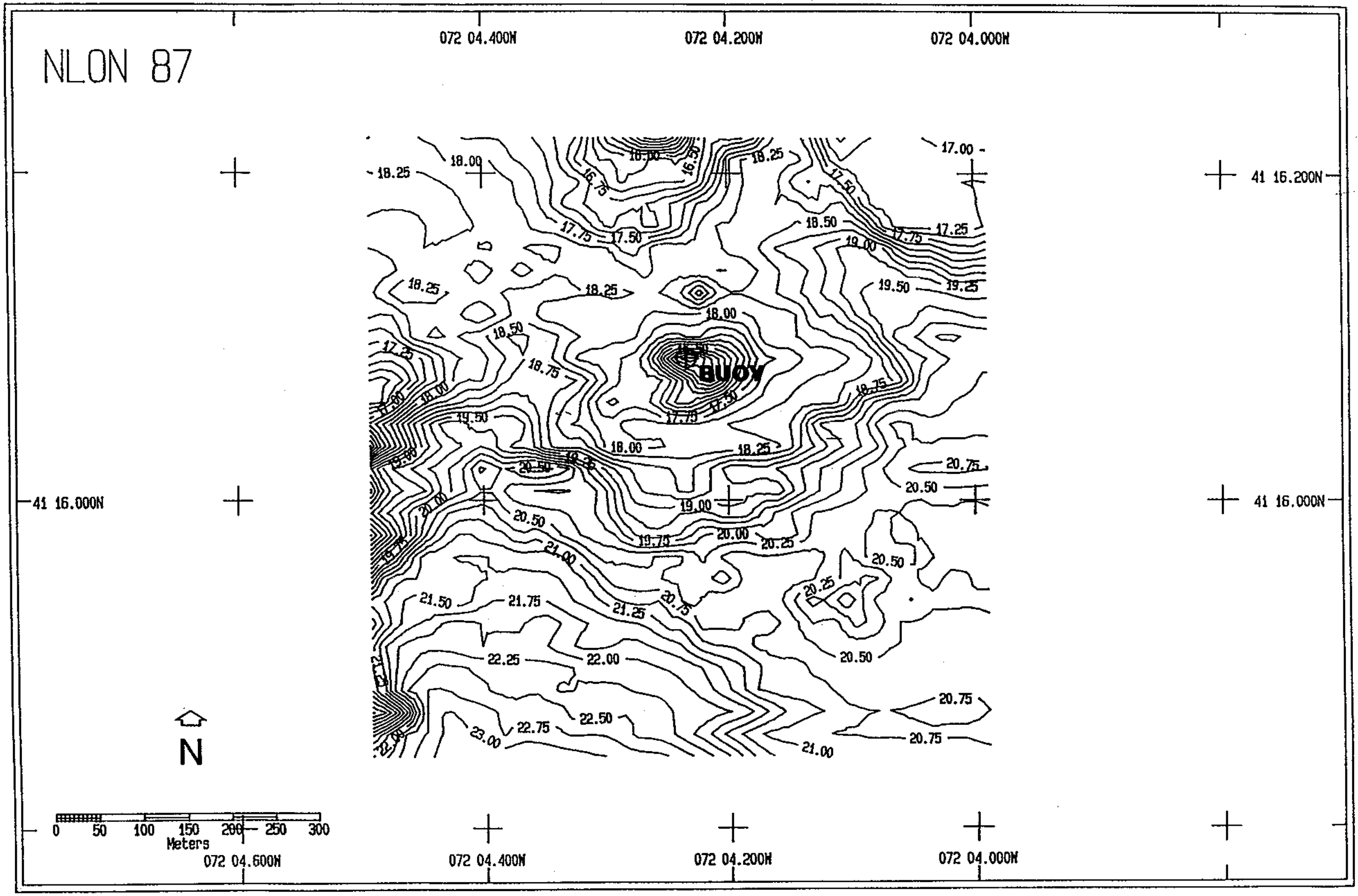


Figure 3-3 Bathymetric contour chart from July 1987 showing the 700 X 700 meter area encompassing the NL-85 disposal mound, and the area where the new mound was formed at the buoy location during the 1987-88 disposal season. Depth contours at 0.25 m intervals.

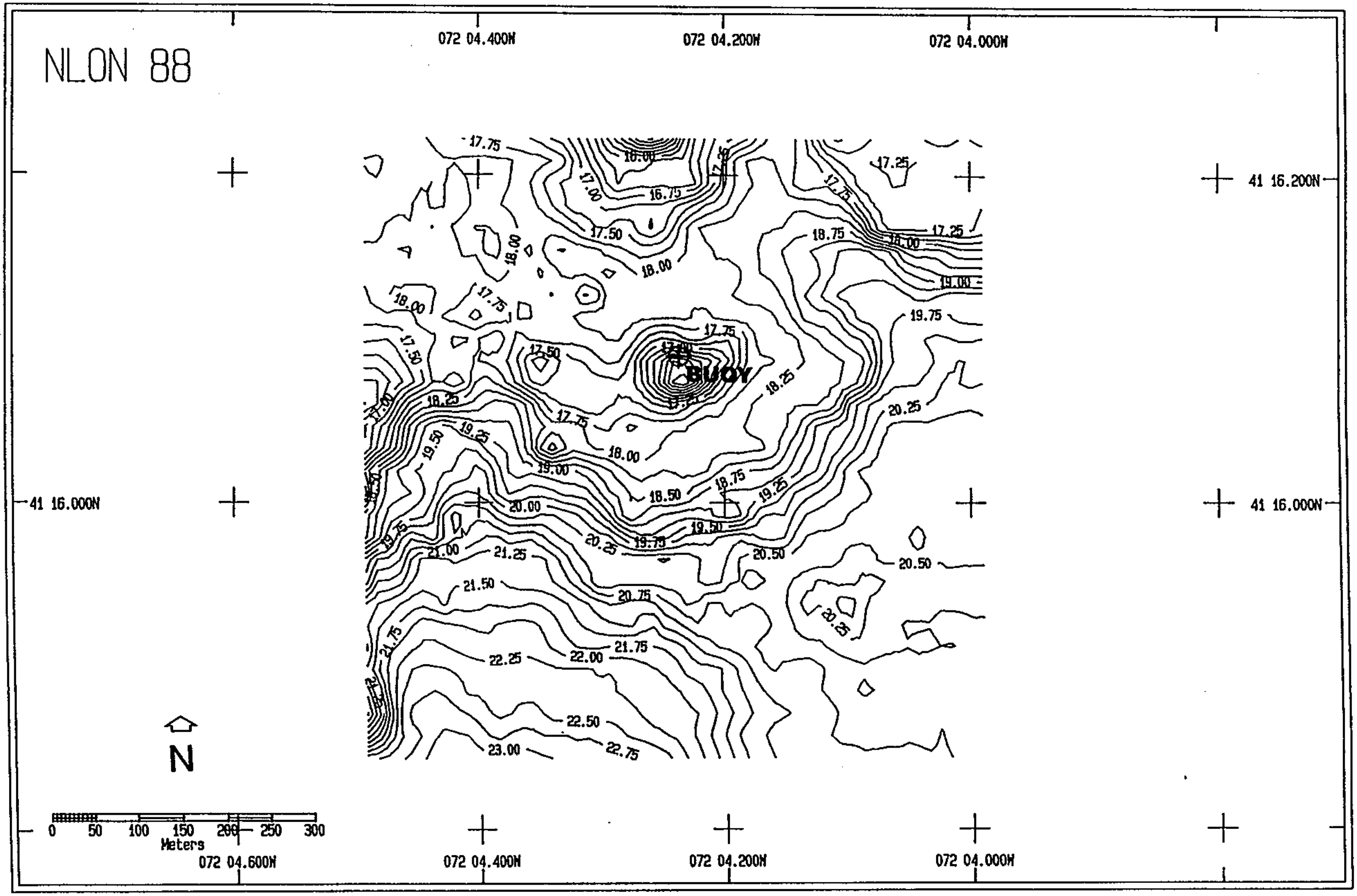


Figure 3-4 Bathymetric contour chart from August 1988 showing the 700 X 700 meter area encompassing the new mound south of the buoy location. Depth contours at 0.25 m intervals.

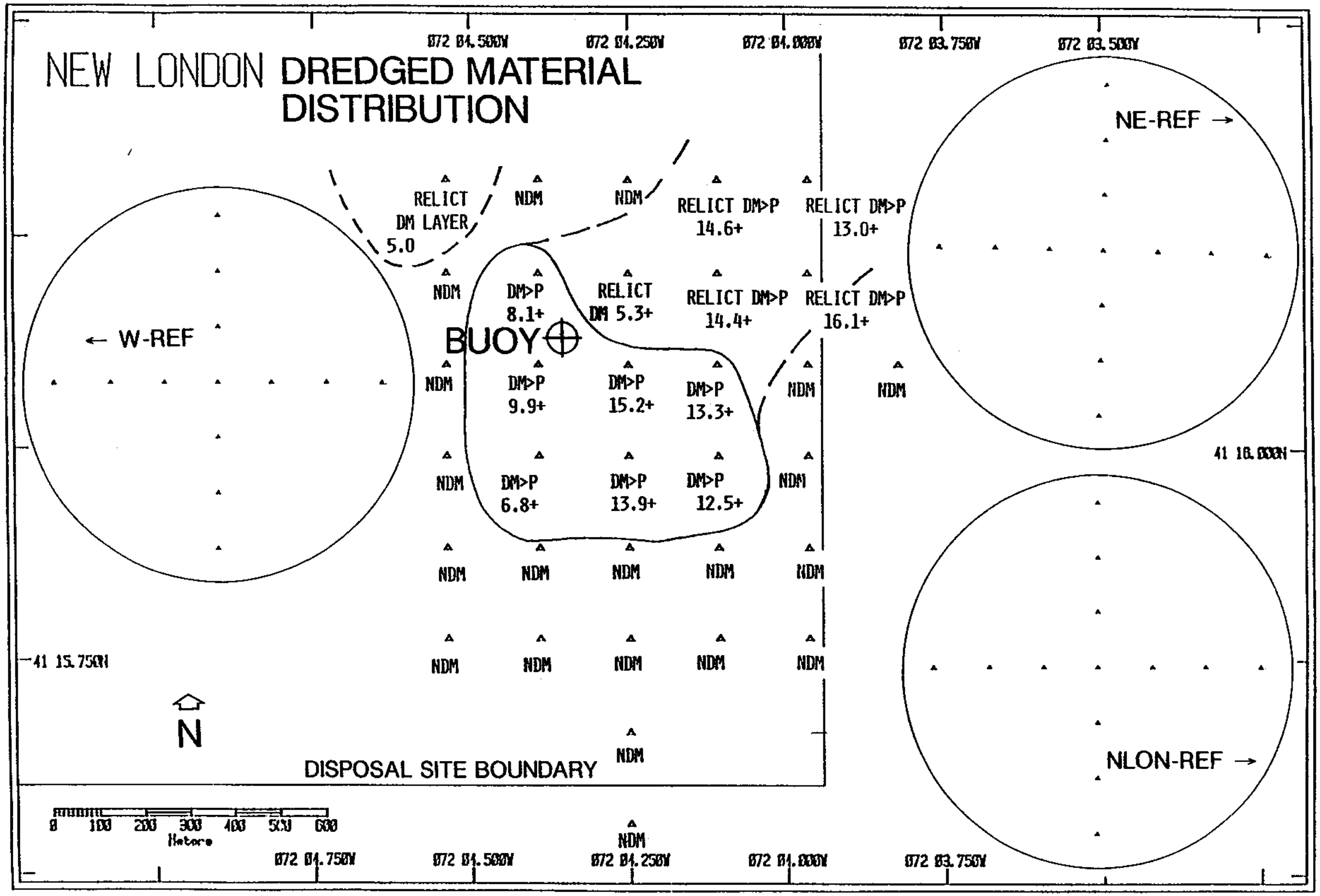


Figure 3-5 The mapped distribution of dredged material at NLON in August 1988, as inferred from REMOTS® photography. The solid contour delimits stations having apparent "fresh" dredged material layers (i.e., deposited during the 1987-88 disposal season). The dashed contours delimit stations having apparent "relict" dredged material layers (i.e., deposited prior to the 1987-88 disposal season).

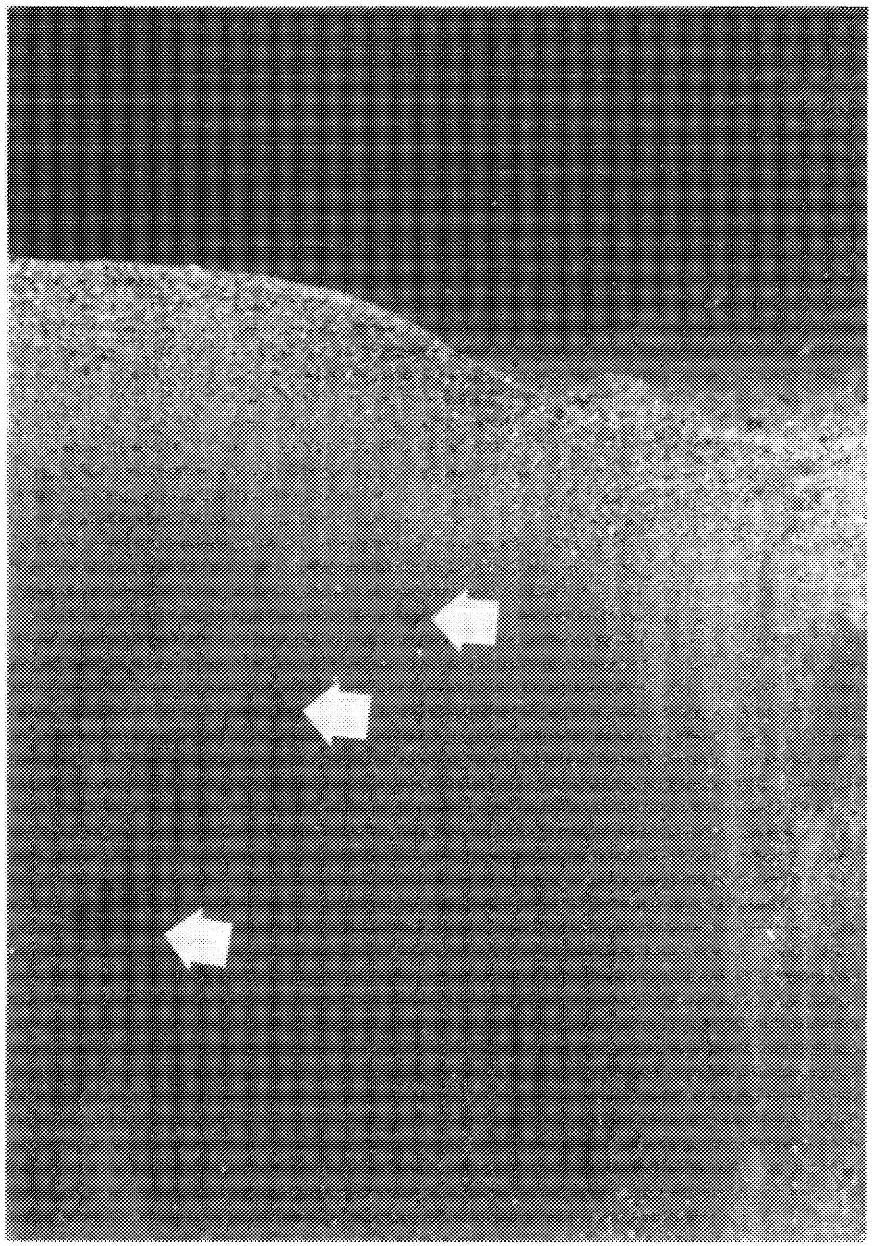


Figure 3-6 REMOTS® photograph from disposal site station 200W showing a fine sand/silt/fine sand stratigraphy within a poorly sorted sediment matrix. The sediment column has uniformly low light reflectance, as well as small Stage III feeding voids, indicated with arrows.

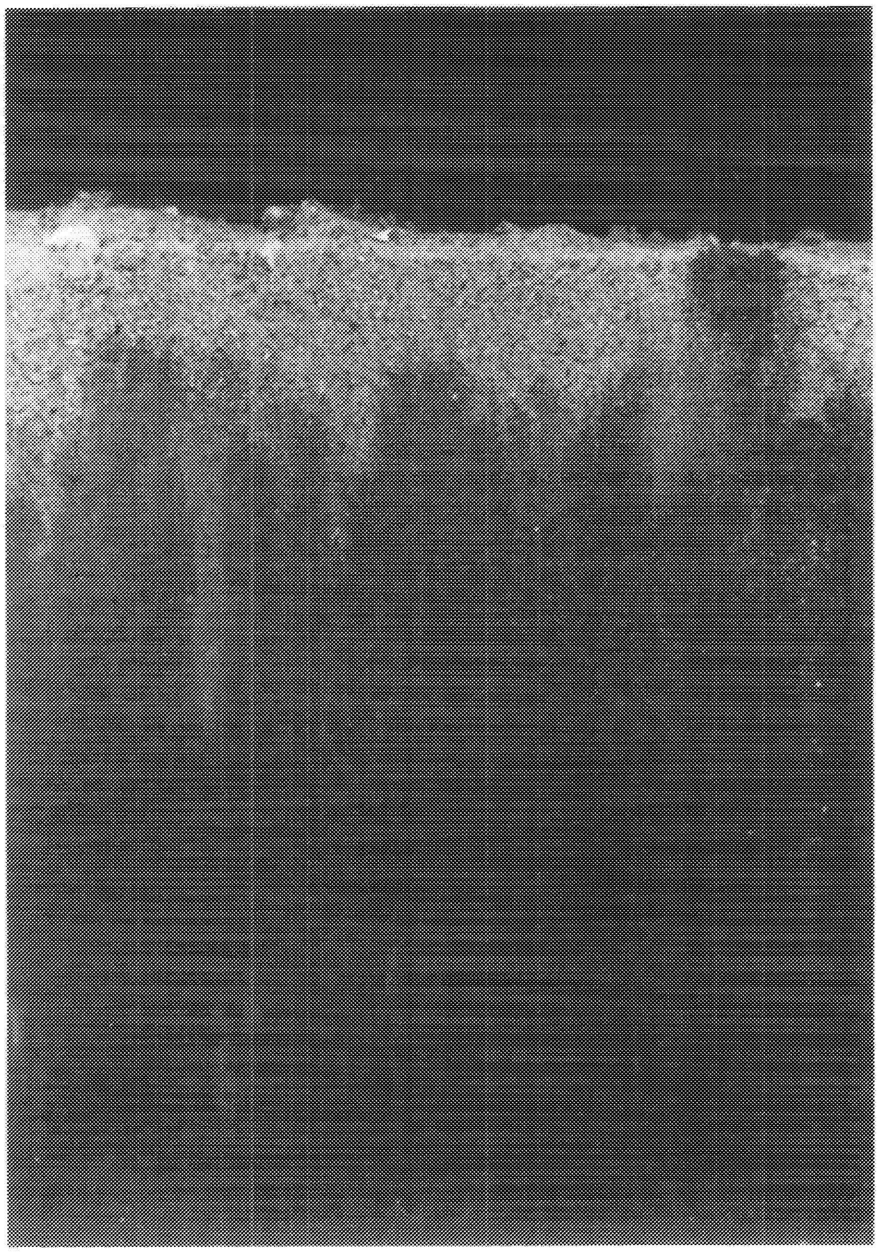


Figure 3-7 REMOTS® photograph from disposal site station 2-200SE showing dark sediment with a sand layer at surface, devoid of worm tubes or hydroids, indicating that material was recently disposed.

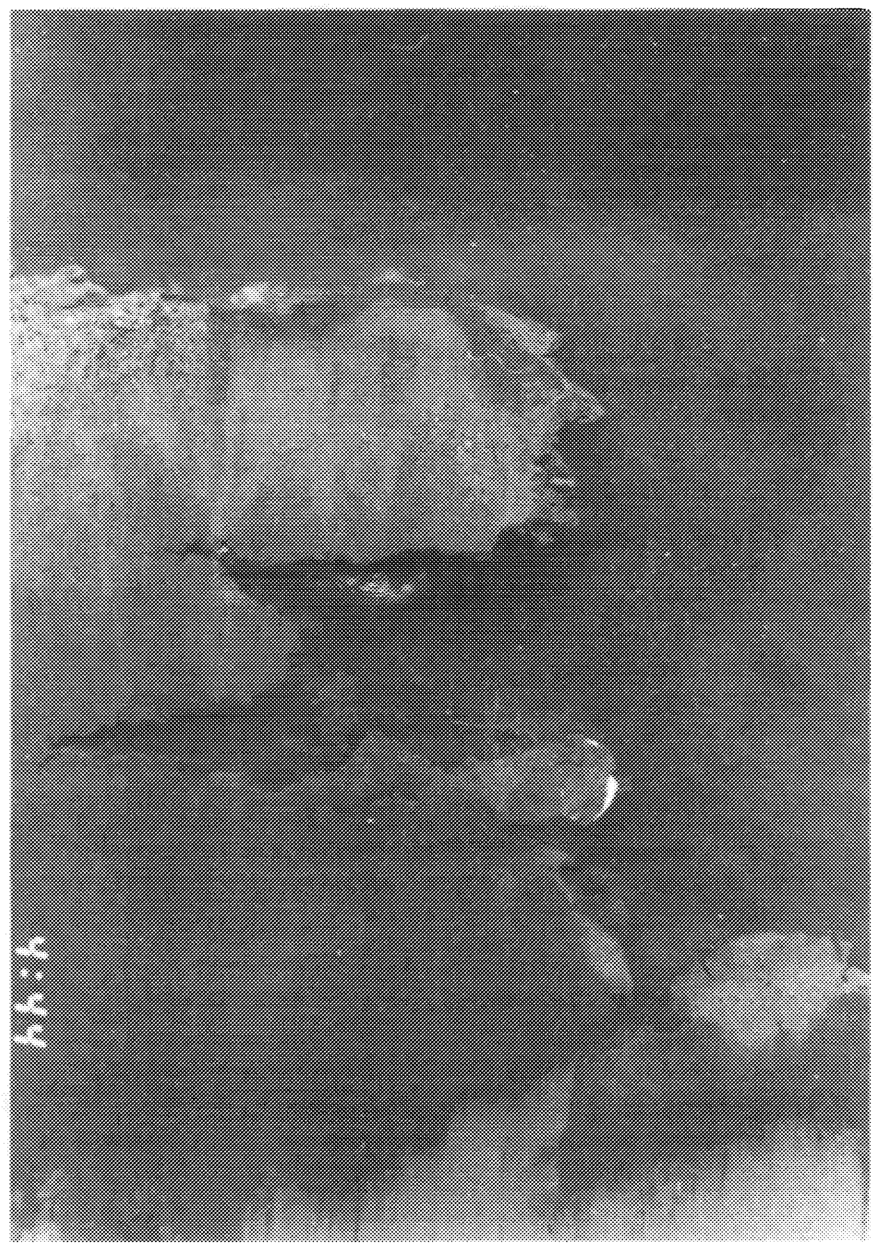


Figure 3-8 REMOTS® photograph from disposal site station 200E showing large boundary roughness and chaotically arranged patches of high reflectance sediment.

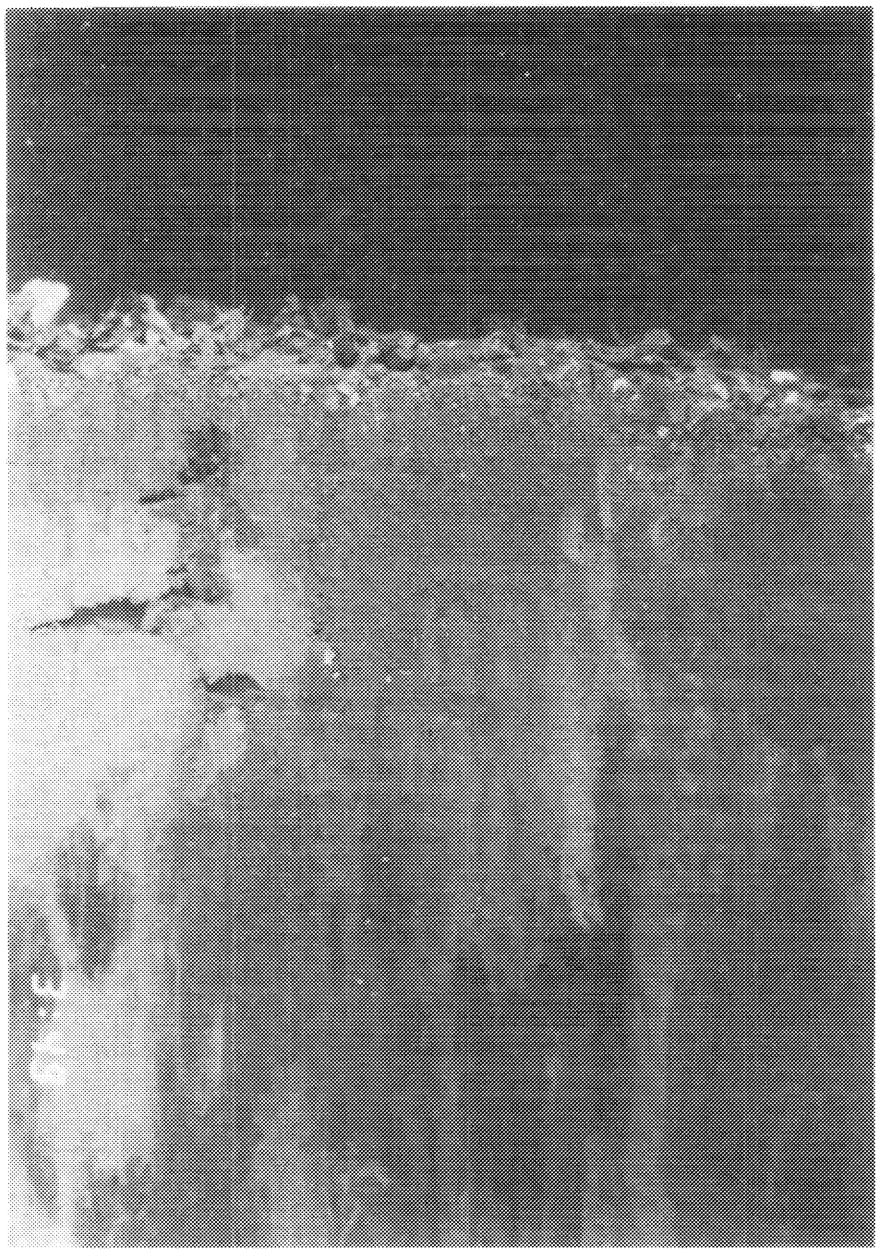


Figure 3-9 REMOTS® photograph from disposal site station 2-200NE showing tube mats at surface and Stage III feeding voids surrounded by high reflectance sediment.

Figure 3-10 REMOTS® photograph from disposal site station 400W showing a surface layer densely packed with hydroids and worm tubes.

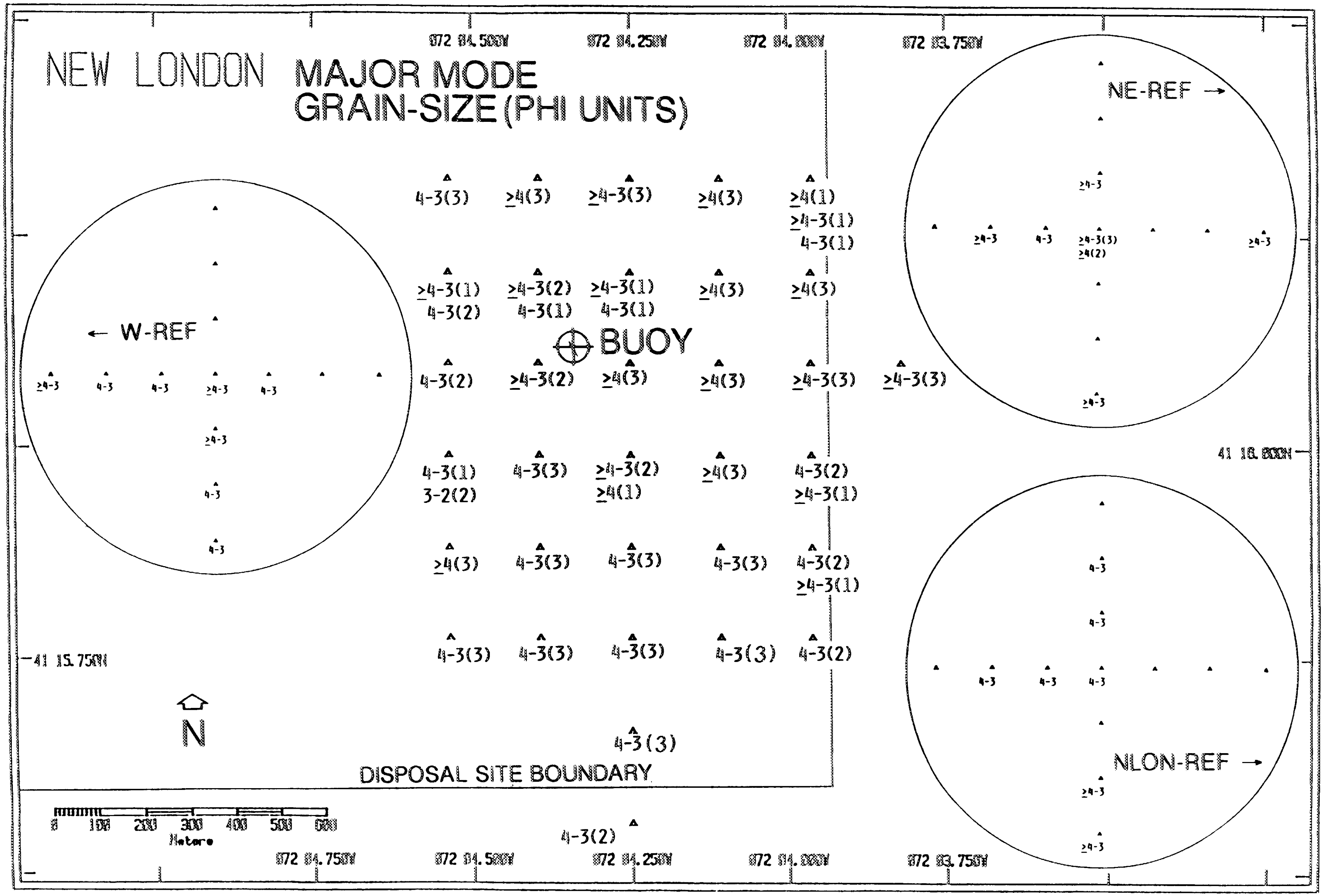


Figure 3-11 Map of sediment grain size major mode (in phi units) at NLON in August 1988. The number in parenthesis is the number of replicate REMOTS® photographs showing a particular grain size. Those stations with no grain size major mode indicated could not be measured due to poor camera penetration.

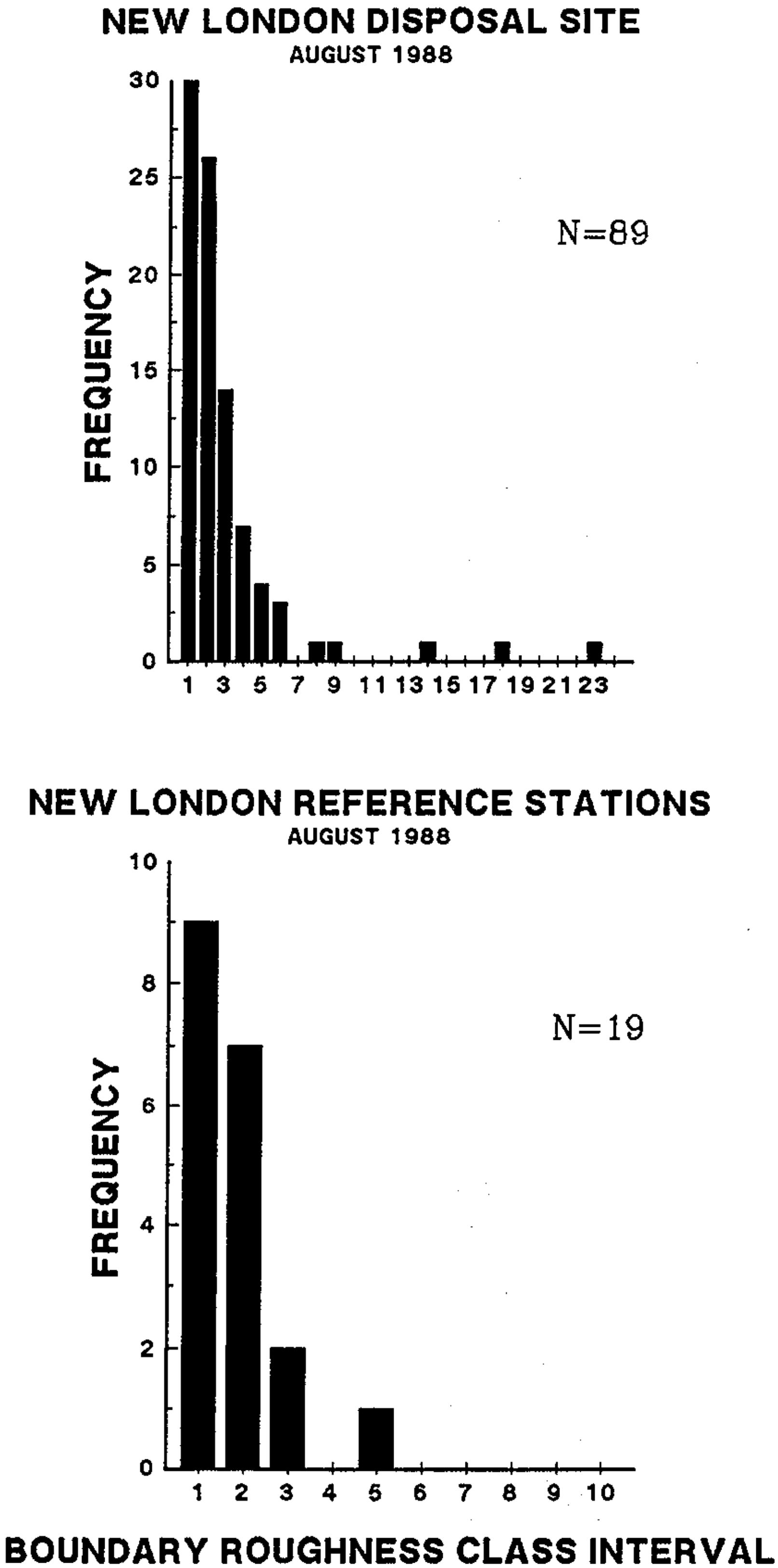


Figure 3-12 Frequency distributions of small-scale surface boundary roughness values for all replicates at both the reference and disposal site stations at NLON in August 1988. N = number of replicates.

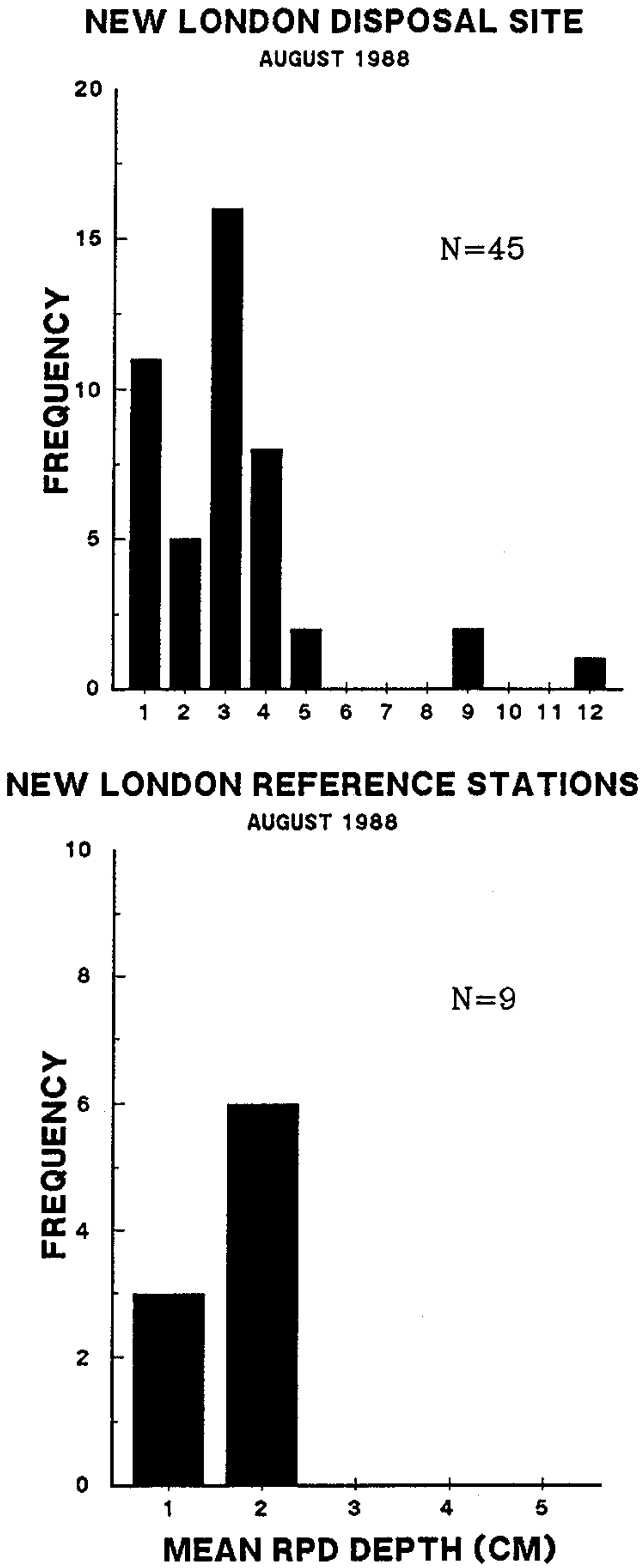


Figure 3-13 Frequency distributions of apparent RPD depths for all replicates at both the reference and disposal site stations at NLON in August 1988. N = number of replicates.

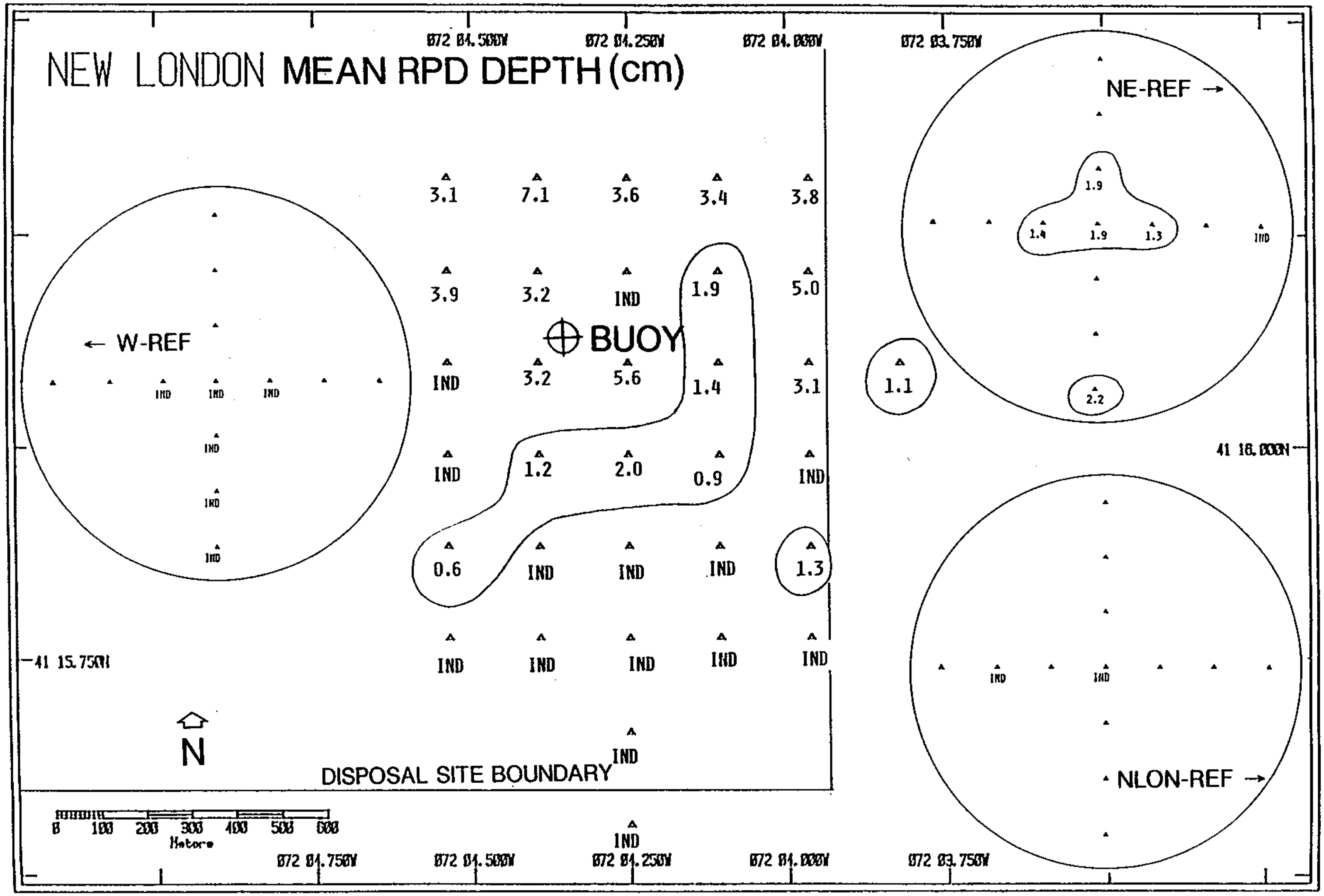


Figure 3-14 The mapped distribution of apparent RPD depths (cm) averaged by station, at NLON in August 1988. The contour delimits stations having mean apparent RPD depths < 3 cm. At the reference stations, the mapped RPD values were based on a single REMOTS® photograph. Those stations where the mean RPD depth could not be measured despite adequate camera penetration have been indicated with IND = indeterminate. Those stations with no annotation could not be evaluated due to poor camera penetration.

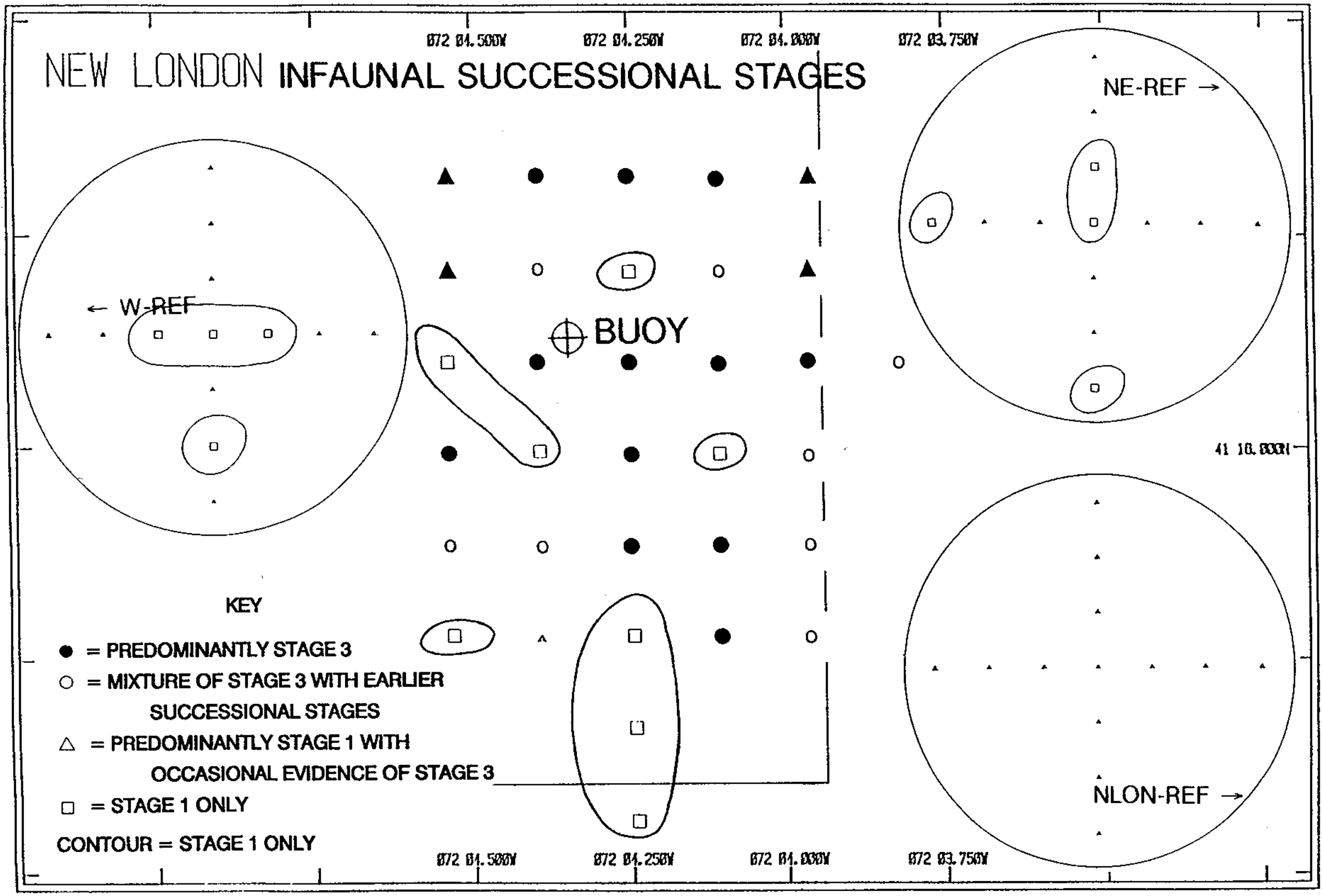


Figure 3-15 The mapped distribution of infaunal successional stages at NLON in August 1988. Successional stages mapped at the reference stations were based on a single REMOTS® photograph. Those stations without a mapped successional stage (open triangle) were found to be indeterminate due to poor camera penetration.

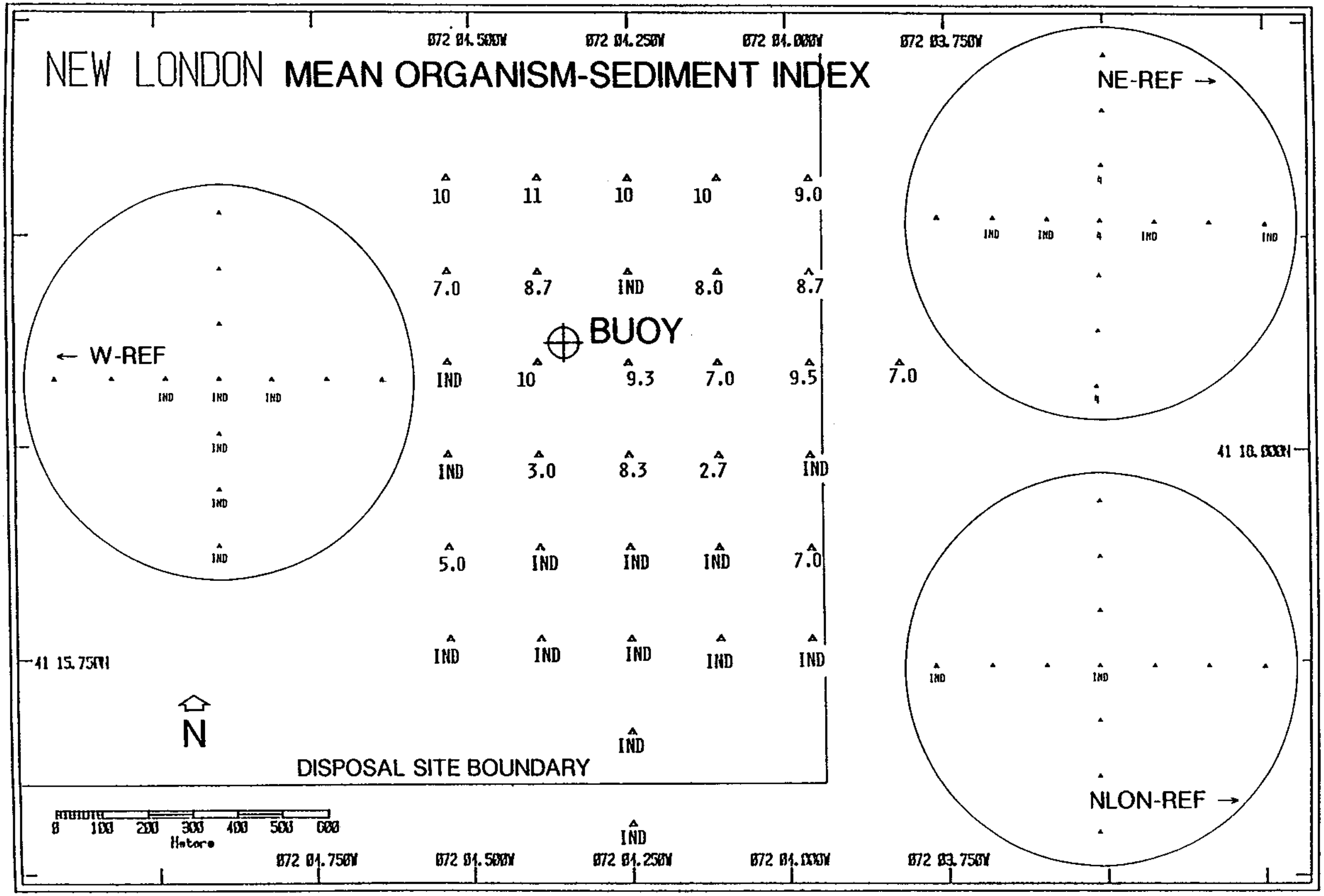


Figure 3-16 The mapped distribution of Organism-Sediment Indices, averaged by station at NLON in August 1988. OSI values at the reference stations were based on a single REMOTS® photograph. Those stations where OSI values could not be determined because of parameters involved in the index calculation have been indicated with IND = indeterminate. Those stations with no annotation could no be evaluated due to poor camera penetration.

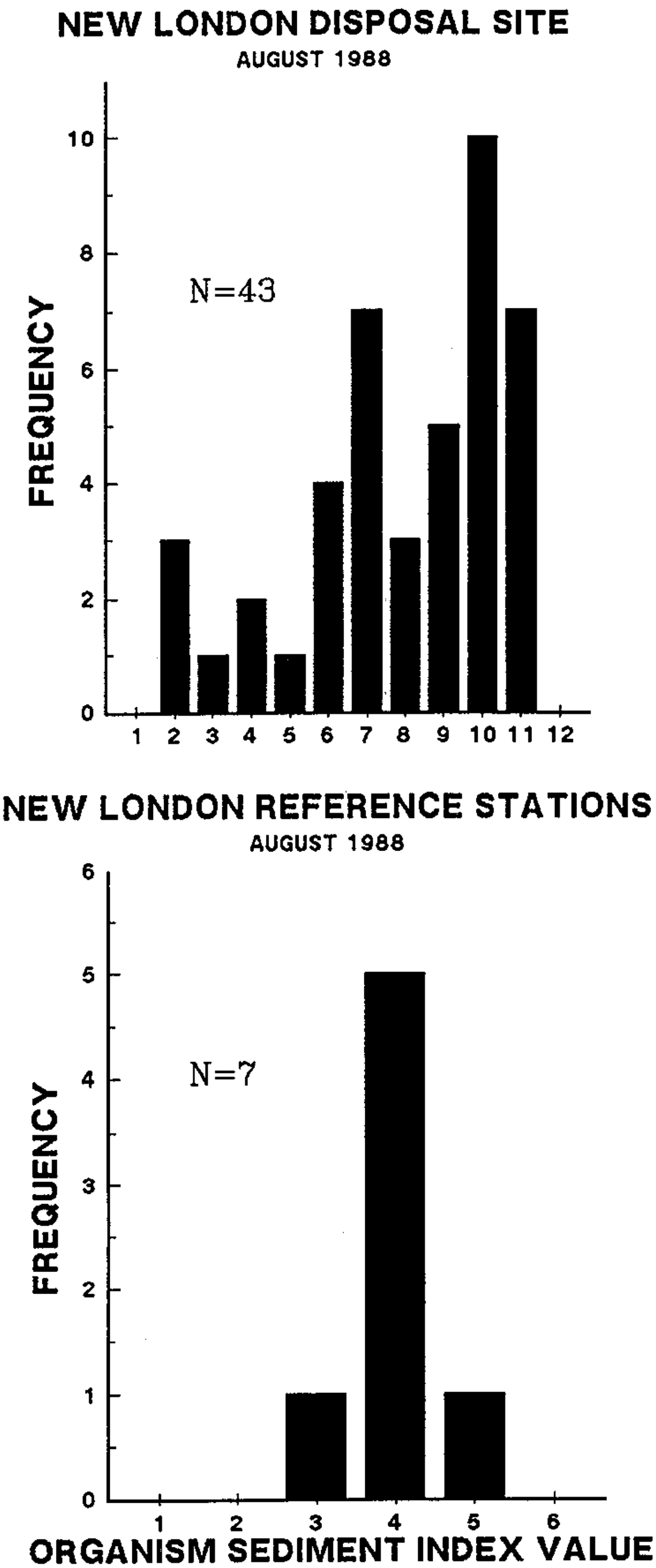


Figure 3-17 Frequency distributions of Organism-Sediment Indicies for all replicates at both the reference and disposal site stations at NLON in August 1988. N = number of replicates.

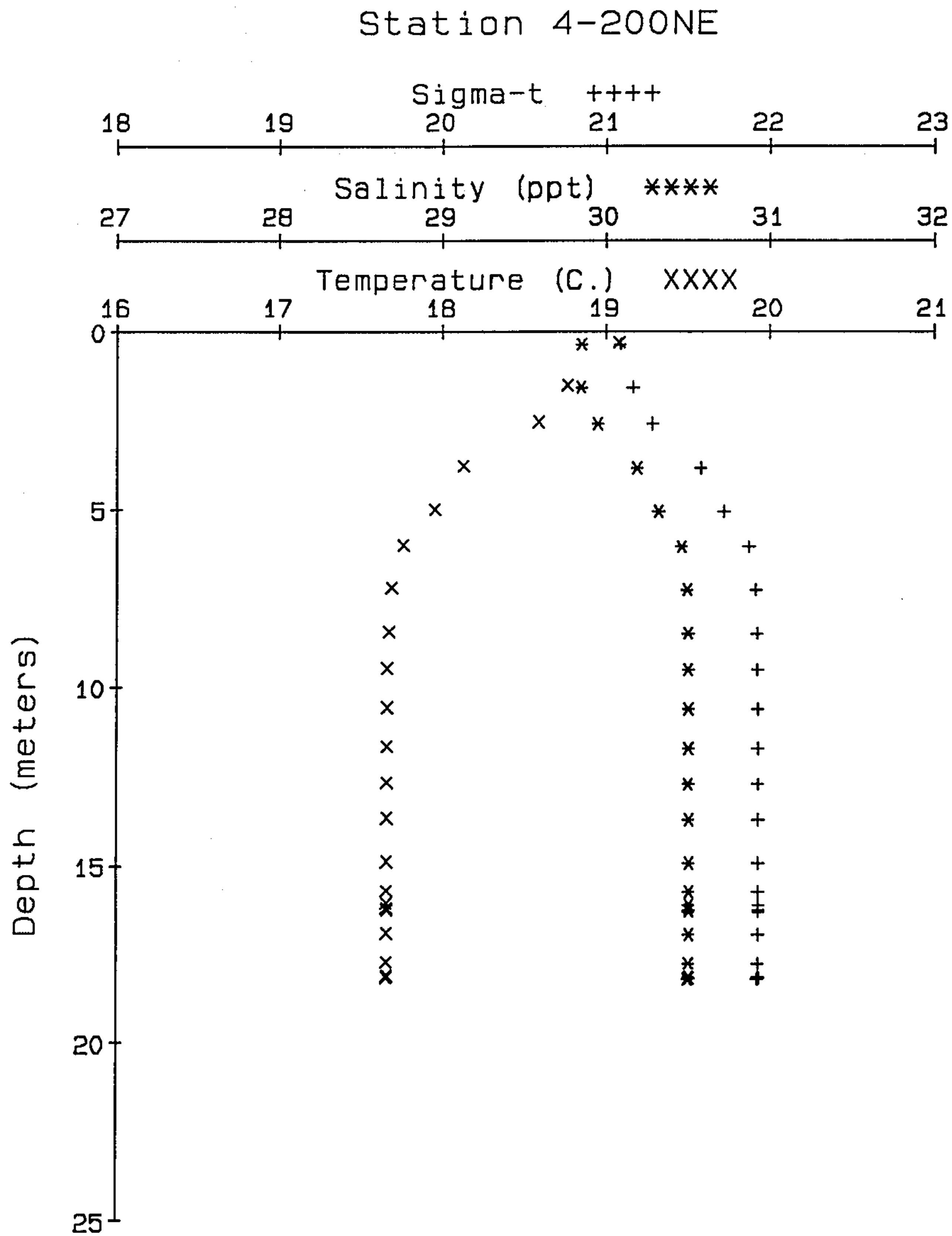


Figure 3-18 CTD plot from disposal site station 4-200NE, representative of those obtained July 28, 1988.

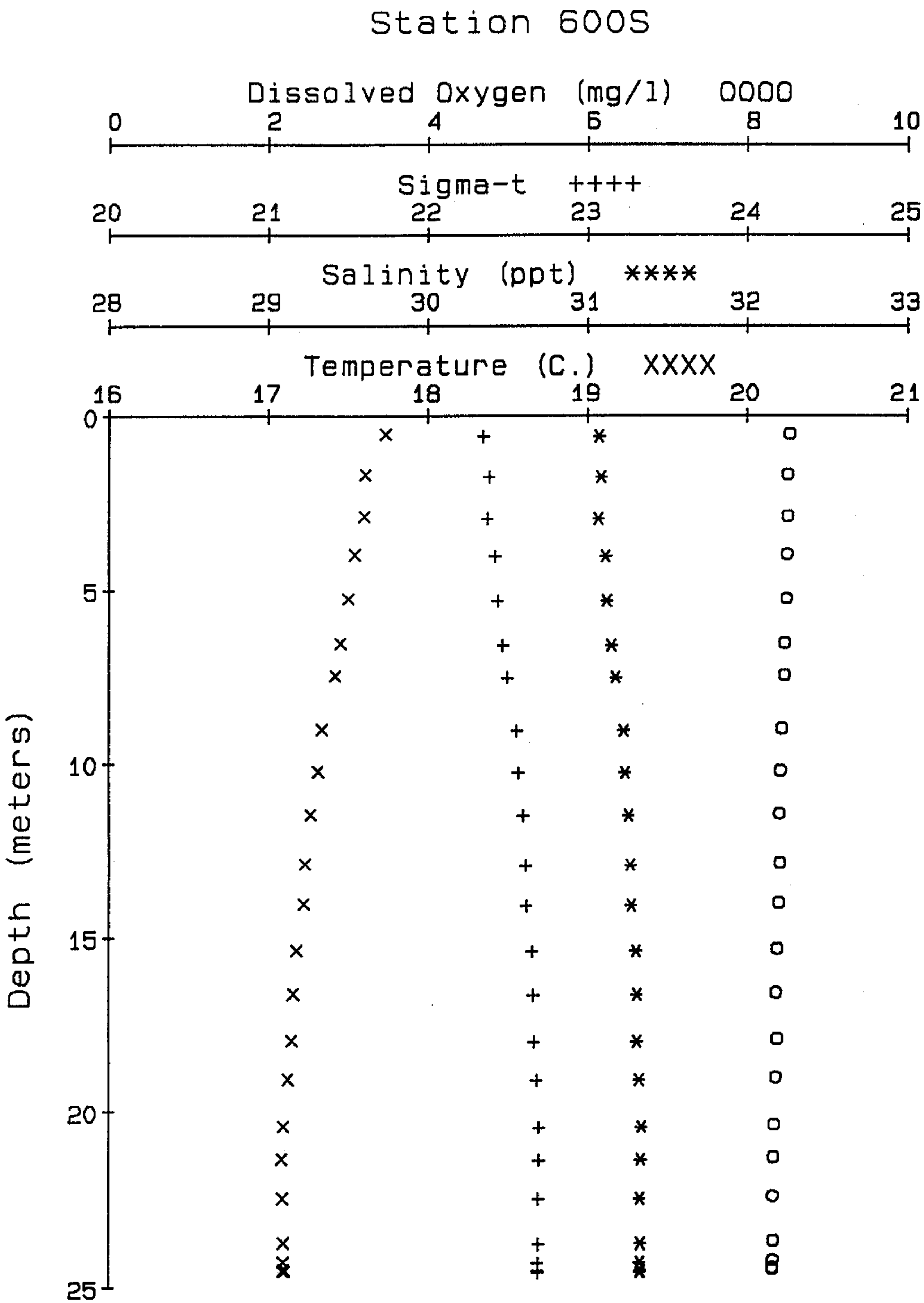


Figure 3-19 CTD plot from disposal site station 600S, representative of those obtained August 25, 1988.

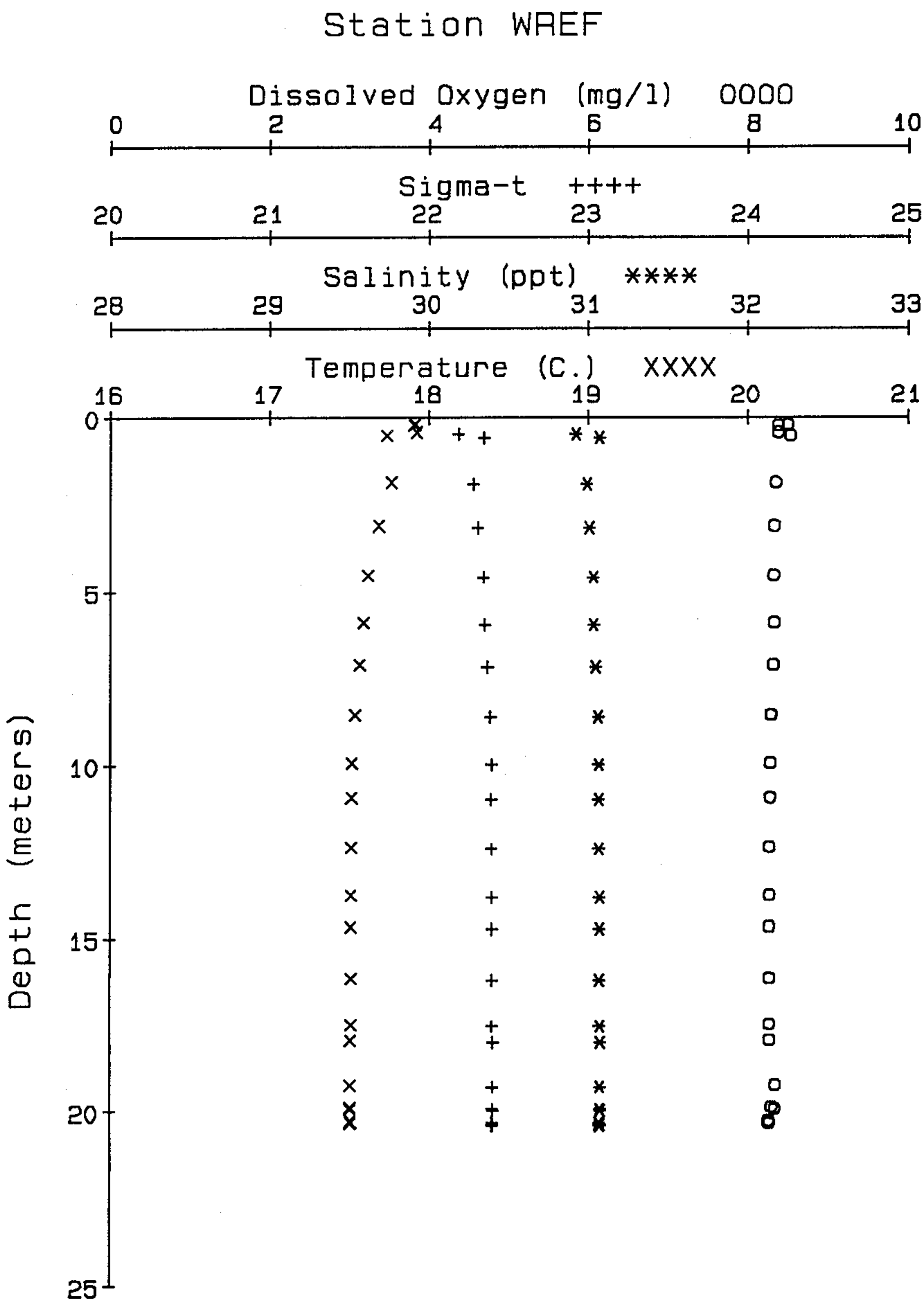


Figure 3-20 CTD plot from reference station W-REF, representative of those obtained August 25, 1988.

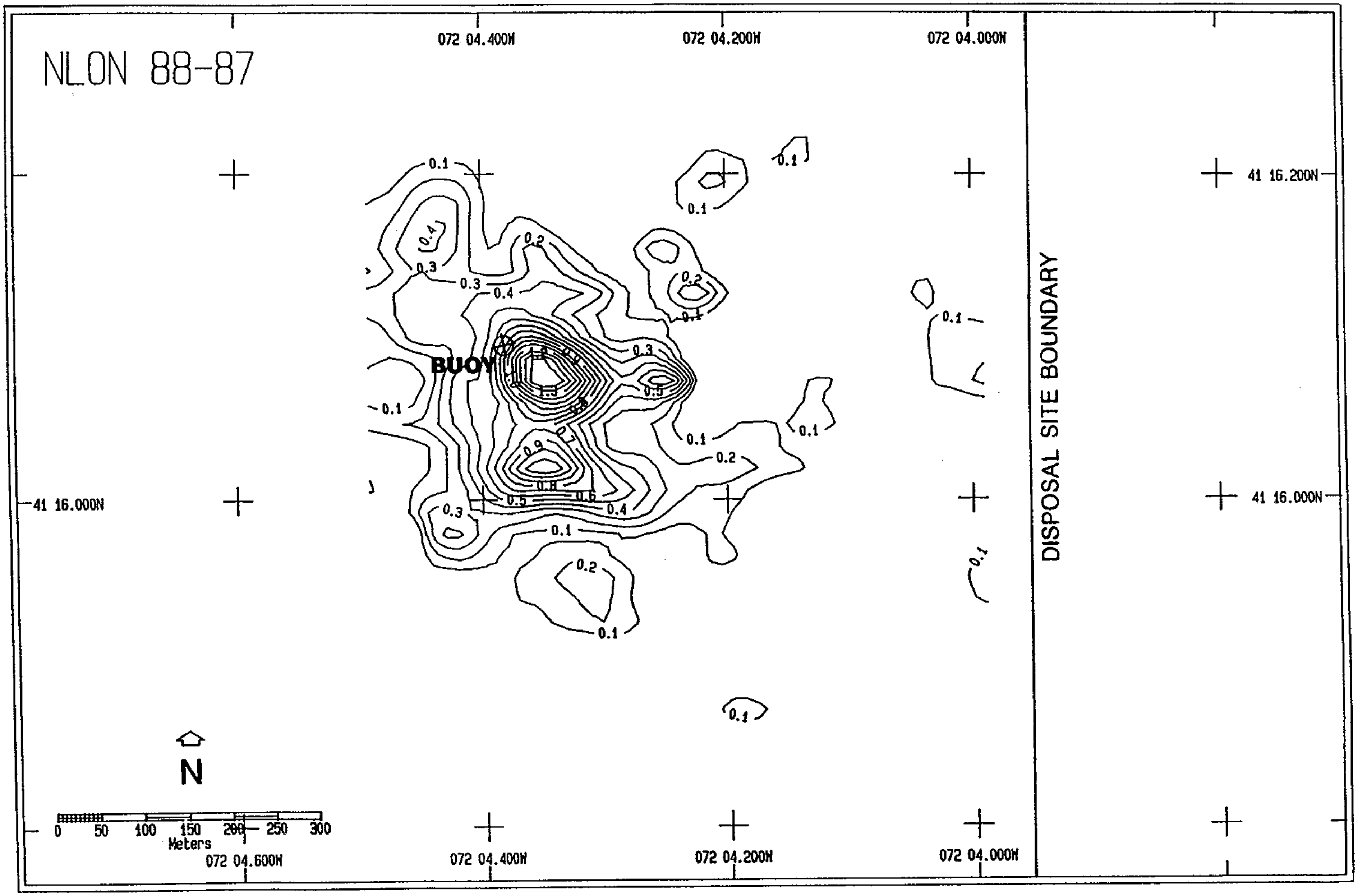


Figure 4-1 Depth difference contour map based on comparison of the 1987 and 1988 depth matrices in the 700 X 700 m area encompassing the new mound. Contours at 0.1 m intervals.

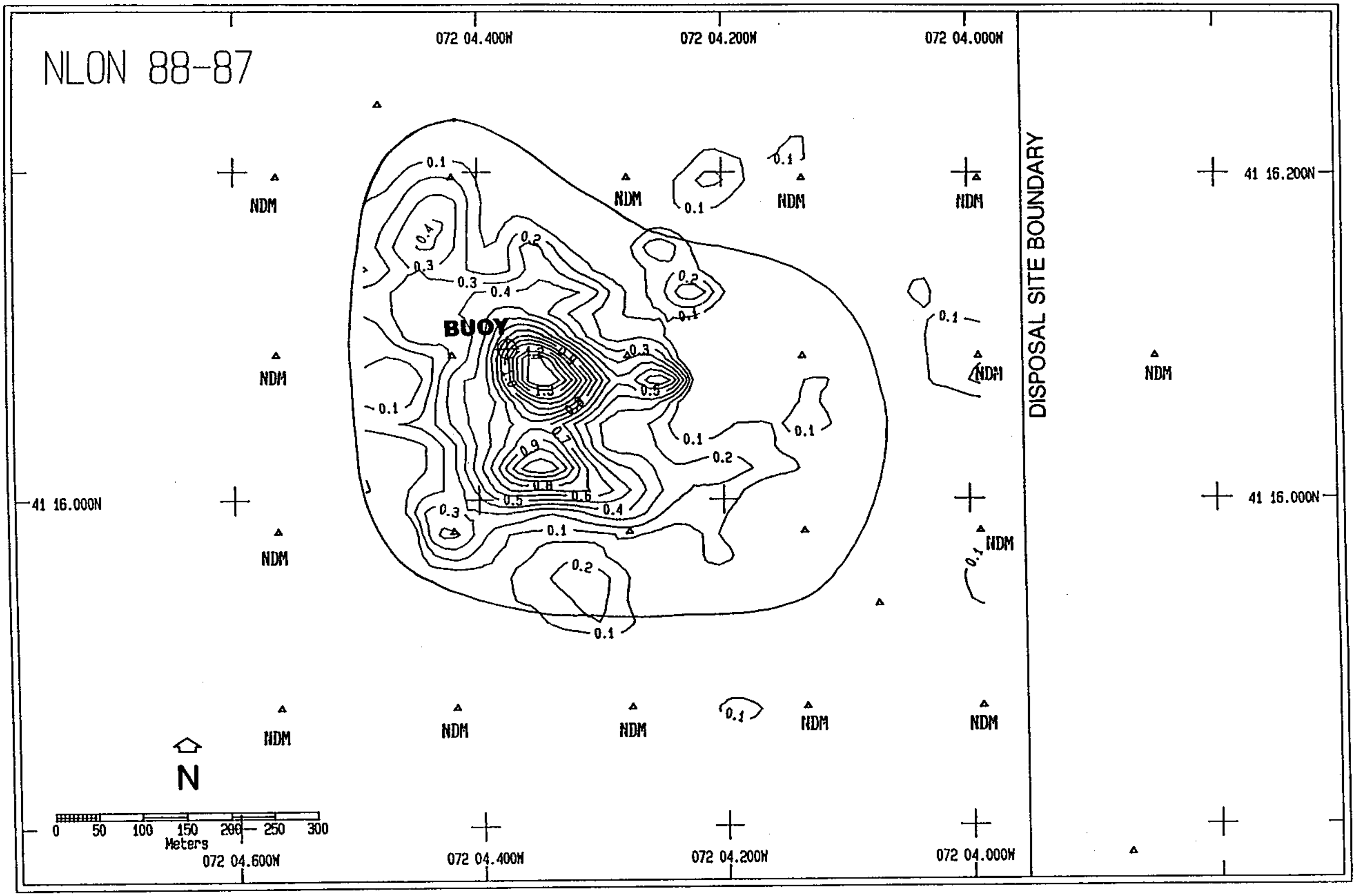


Figure 4-2 Depth difference contour map of the 700 X 700 meter area encompassing the new mound, showing the distribution of dredged material as detected by REMOTS® photography superimposed on the new mound as detected by bathymetric techniques. Triangles denote REMOTS® stations.

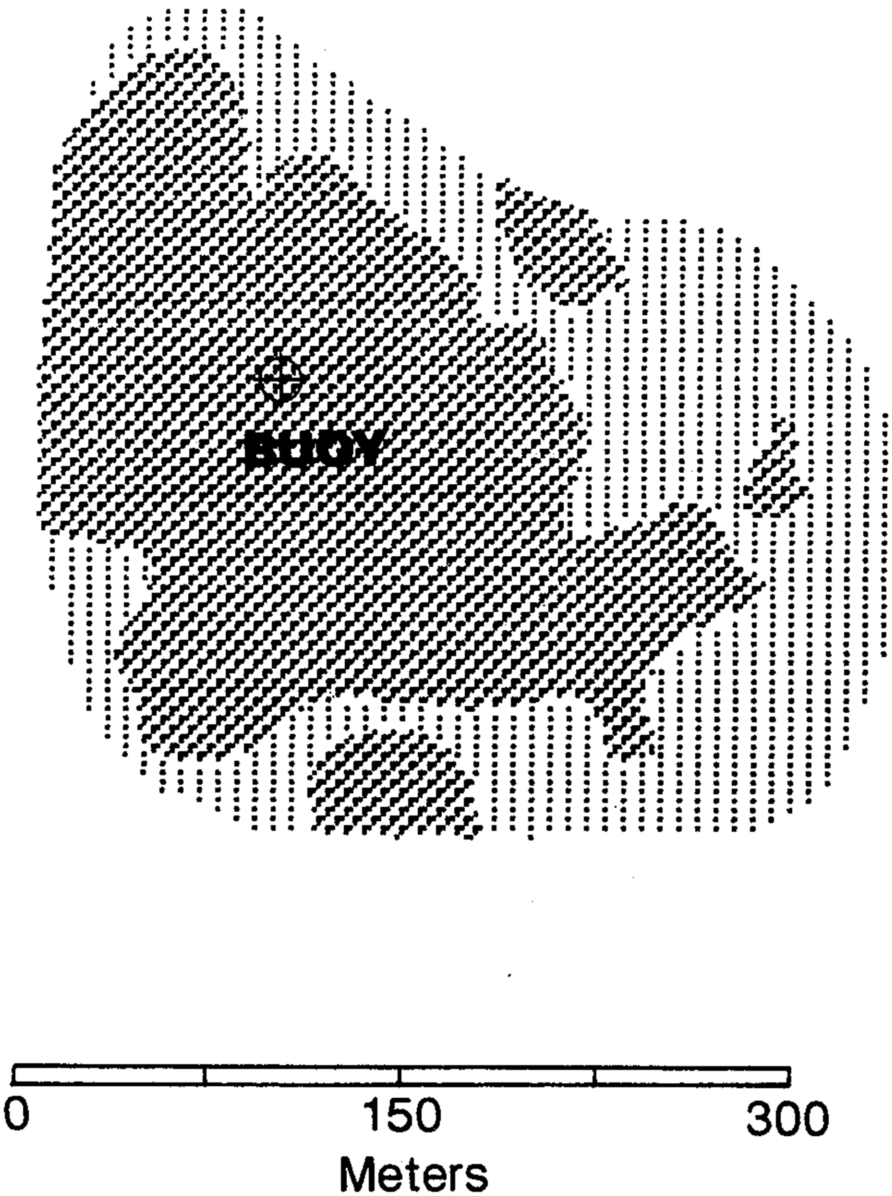
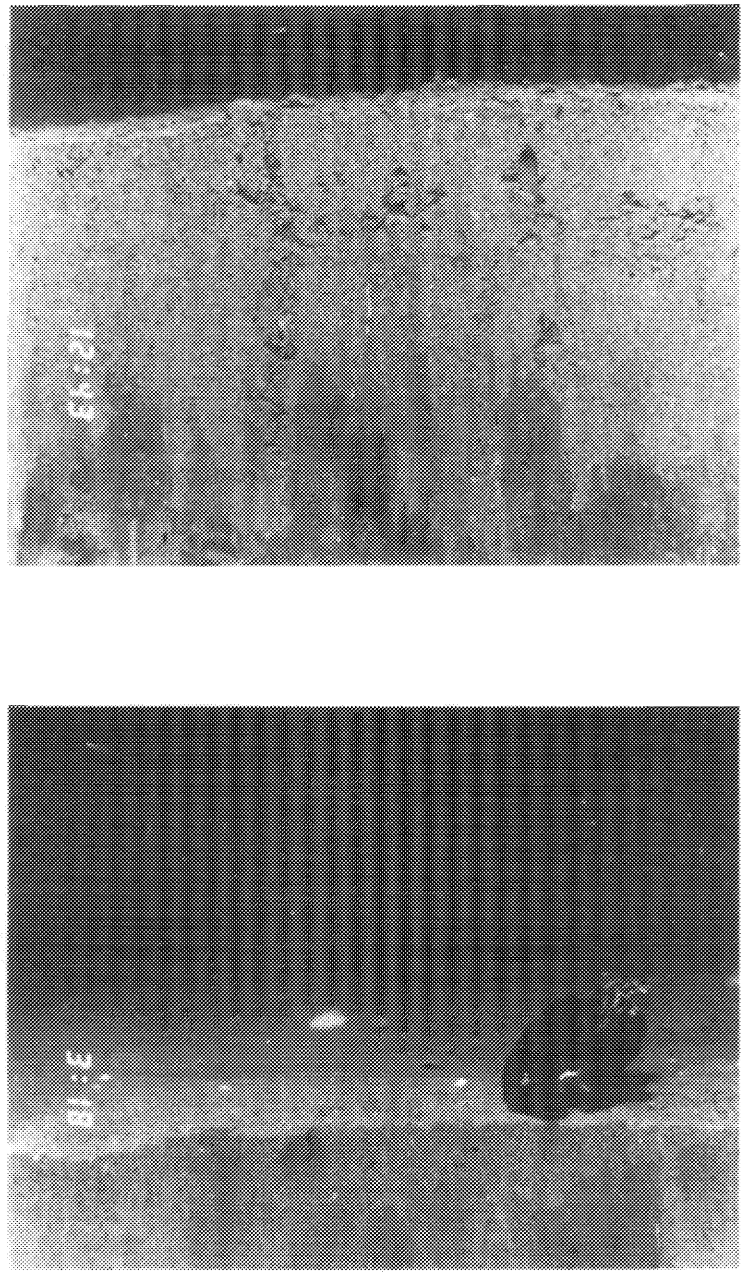


Figure 4-3 Computer digitized representation of the new mound based on Figure 4-2. The dark-shaded area represents the dredged material distribution as detected by bathymetry; changes in depth determined by acoustic methods within this area were used to calculate the "depth difference" volume estimate of dredged material. The lighter-shaded area represents the mound flank as determined by REMOTS®, and its area was used to calculate the additional volume of dredged material not detected by bathymetric techniques.

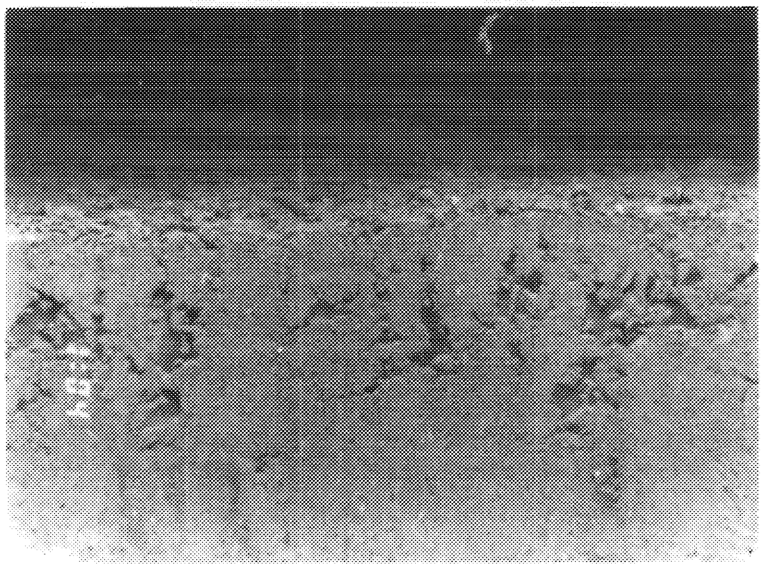
A

B

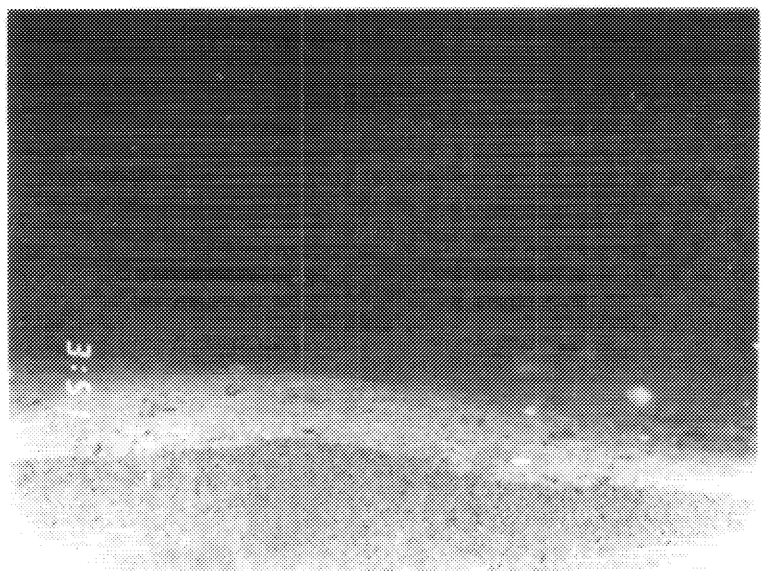


Figures 4-4 a & b REMOTS® photographs from station NE-REF/CTR in 1987 (a) and in 1988 (b) showing a loss of the loosely packed surface layer of sediment from bioturbation of gammarid amphipods. Comparison of the positional fixes recorded at the time these photographs were taken verified their locations to be within 2 m of each other.

A

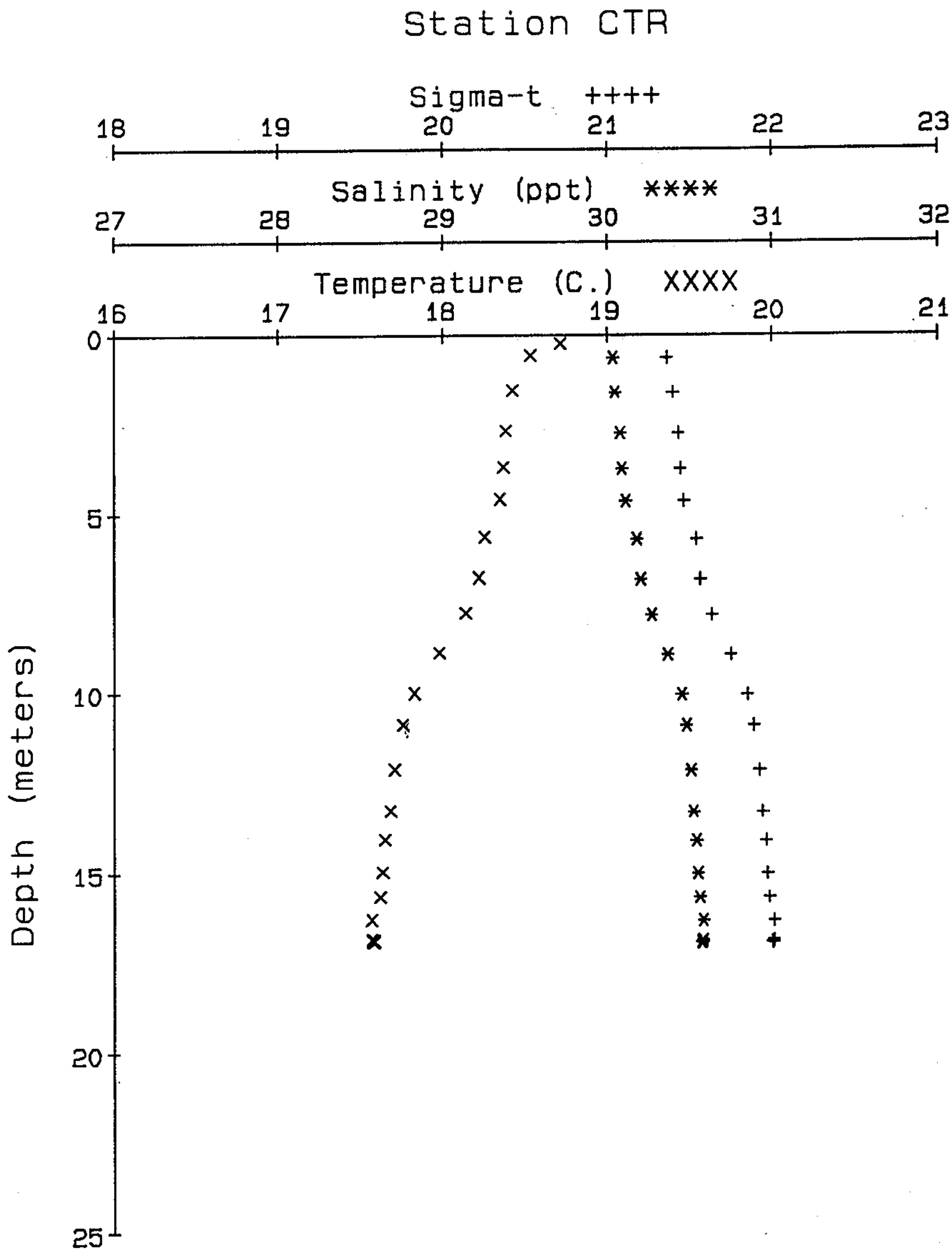


B

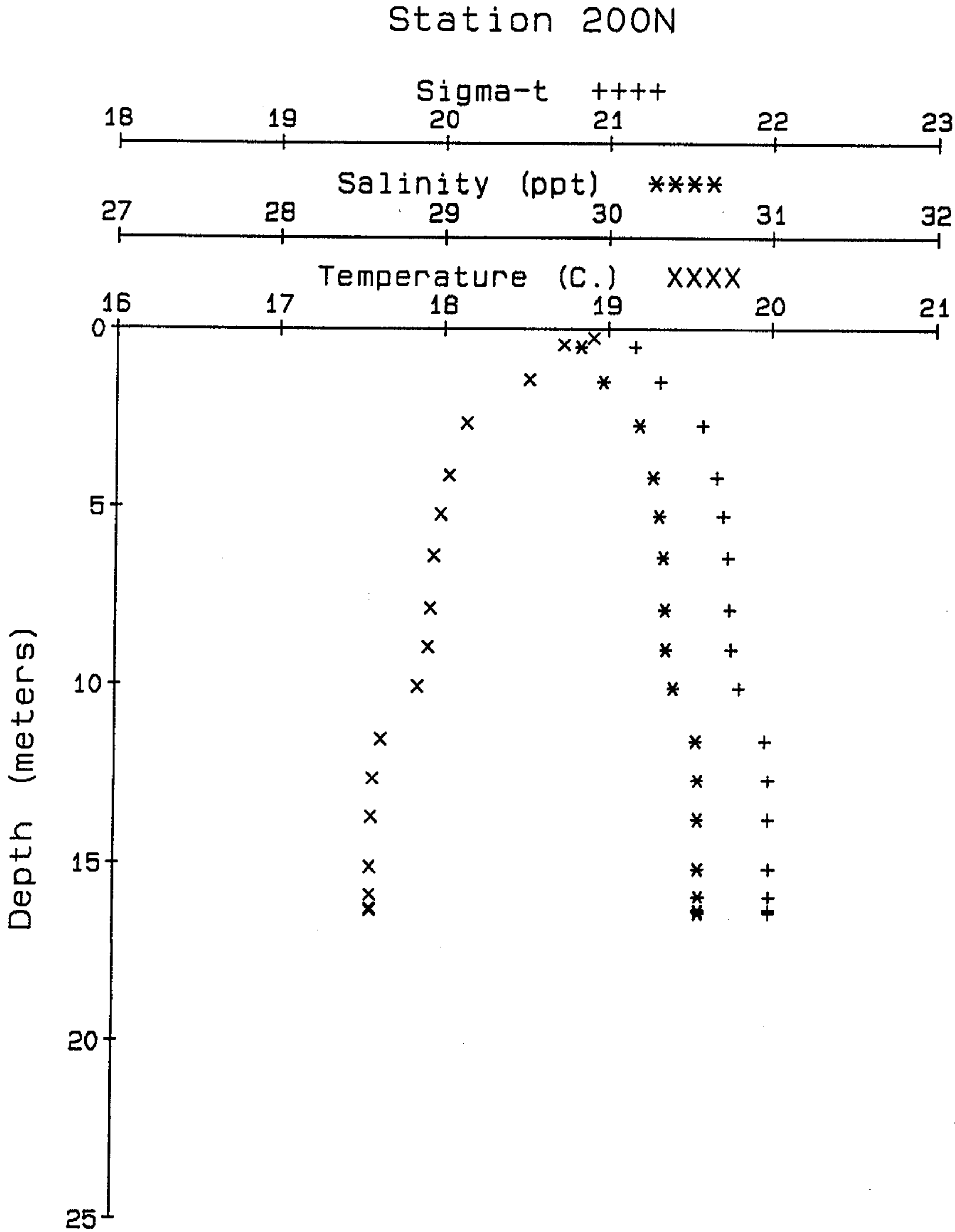


Figures 4-5 a & b REMOTS® photographs from station NLON-REF/CTR in 1987 (a) and in 1988 (b) showing a loss of the loosely packed surface layer of bioturbated sediments, as well as indication of a small bedform at the surface in the 1988 photograph.

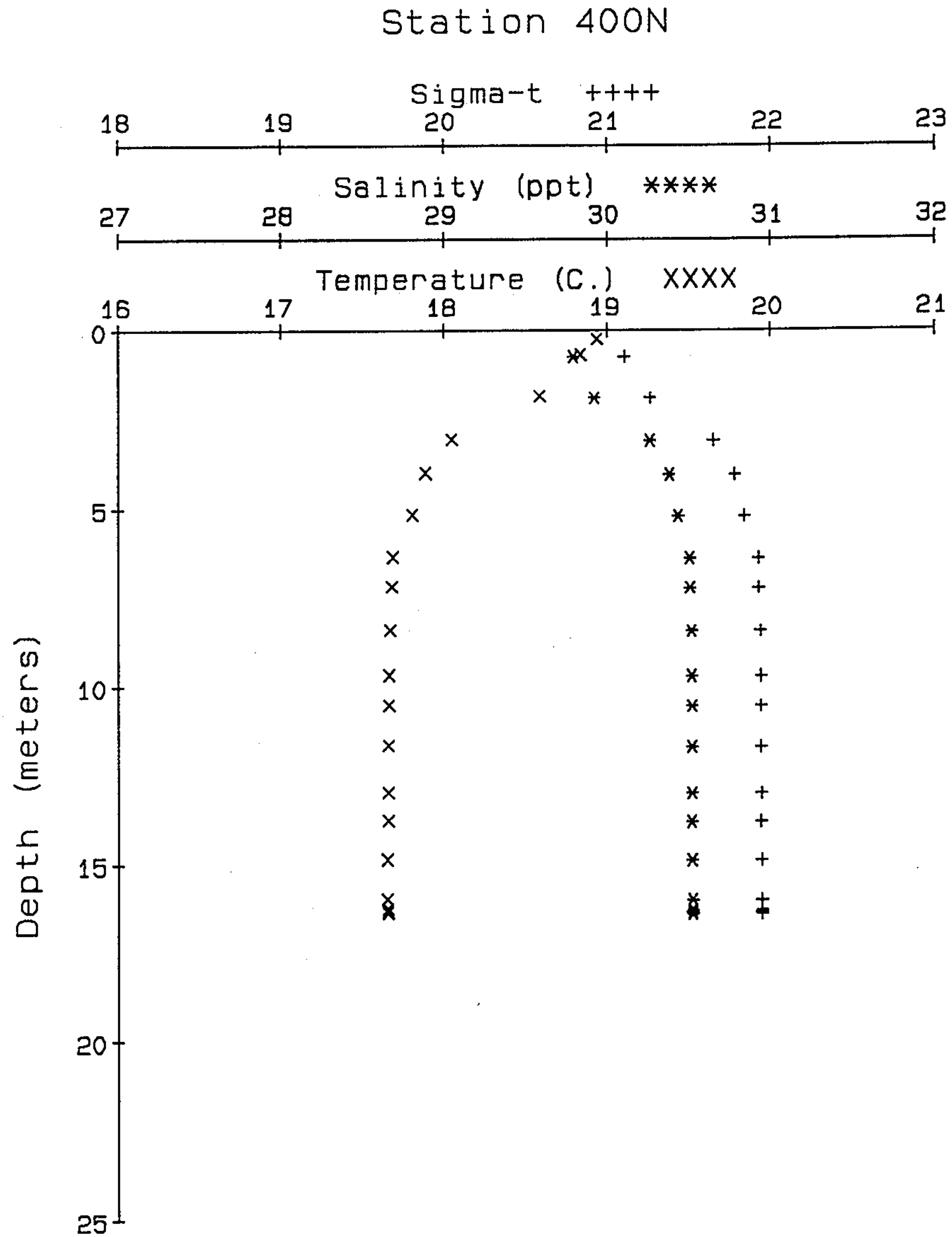
APPENDIX

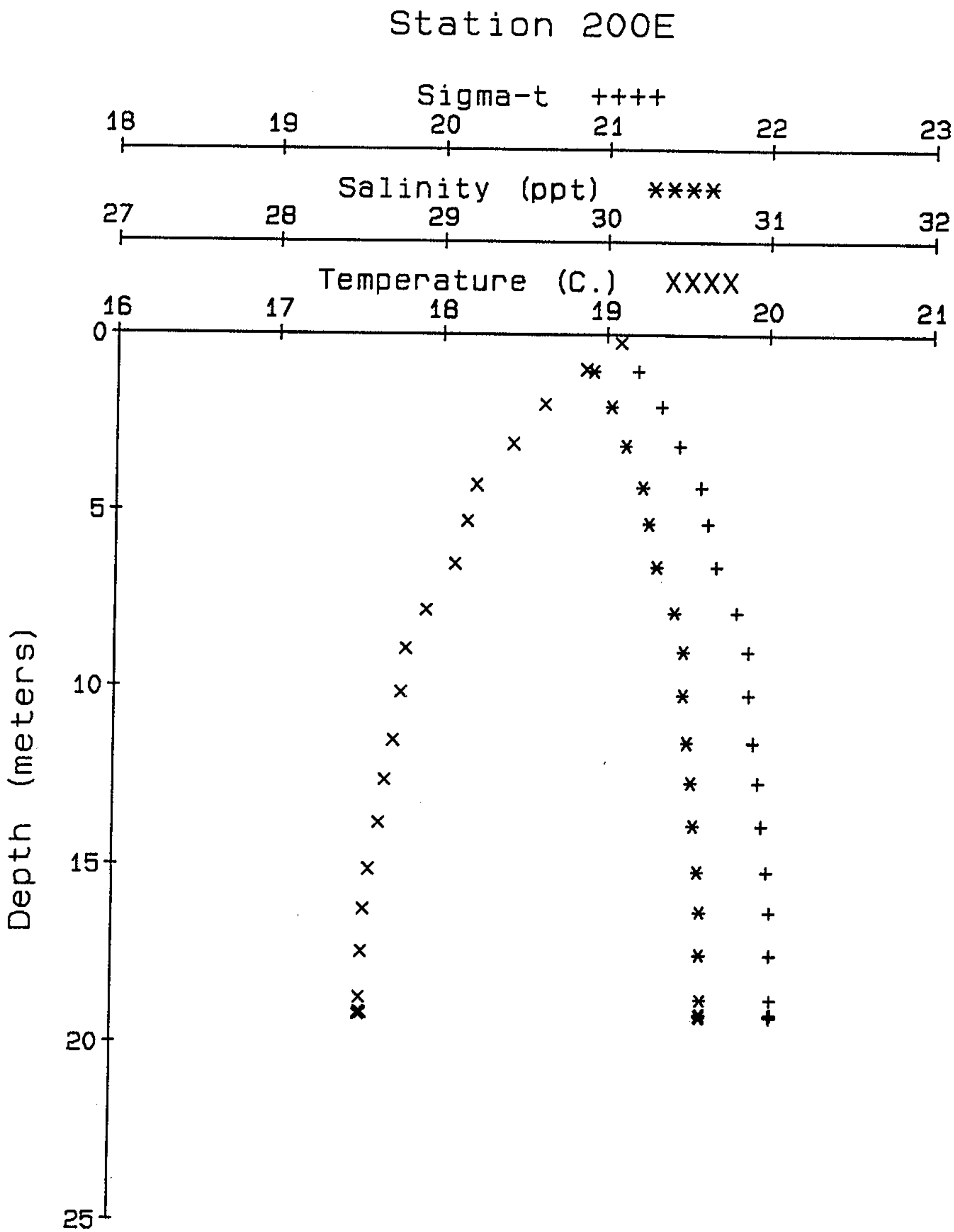


Station CTR
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
30
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
Depth (meters)
0
5
10
15
20
25



Station 200N
Sigma-t ++++
18 19 20 21 22 23
Salinity (ppt) ****
27 28 29 30 31 32
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25


Station 400N
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
30
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
Depth (meters)



Station 200E
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
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31
32
Temperature (C.) XXXX
16
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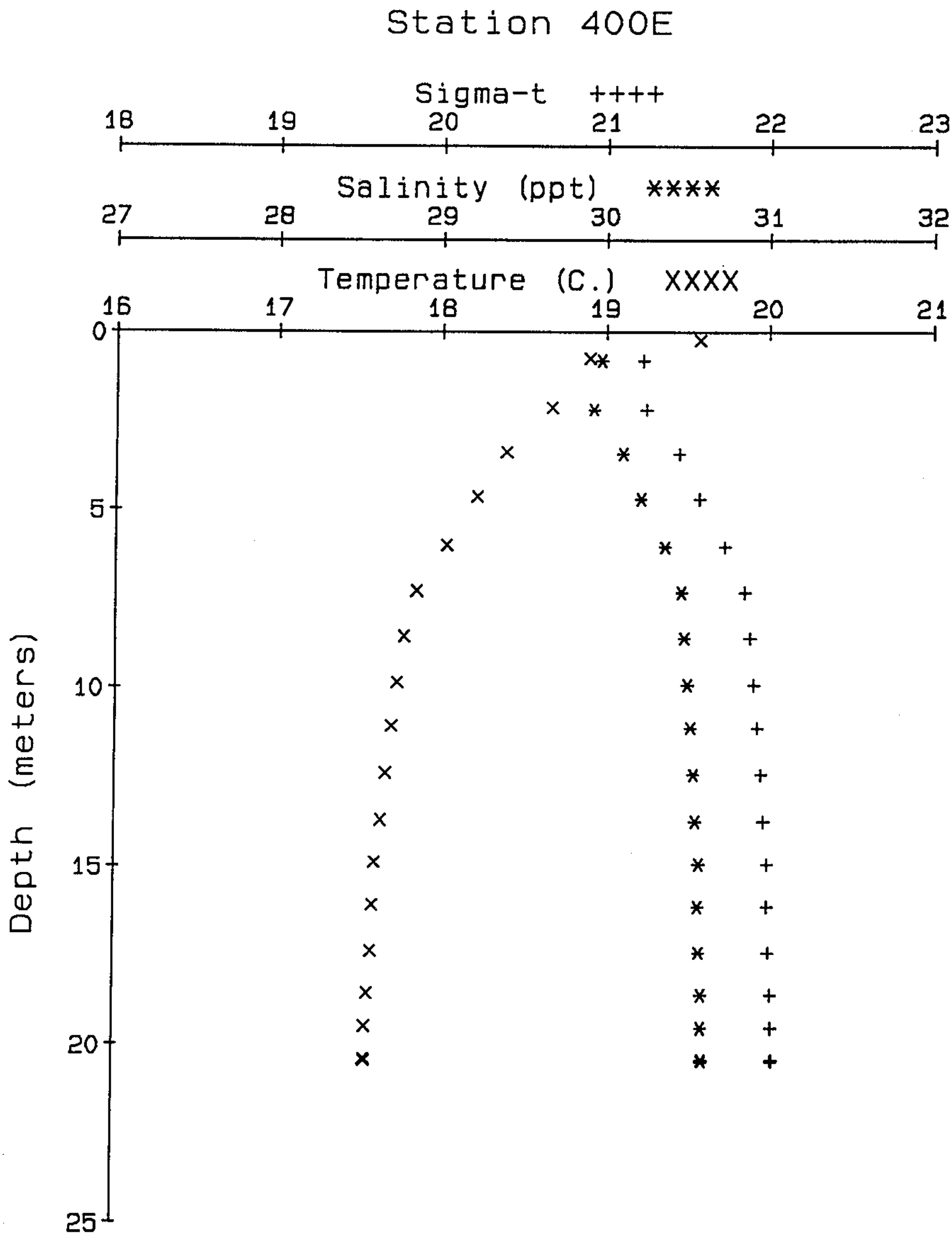
Depth (meters)
0
5
10
15
20
25


Station 400E
Sigma-t ++++
18
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22
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Salinity (ppt) ****
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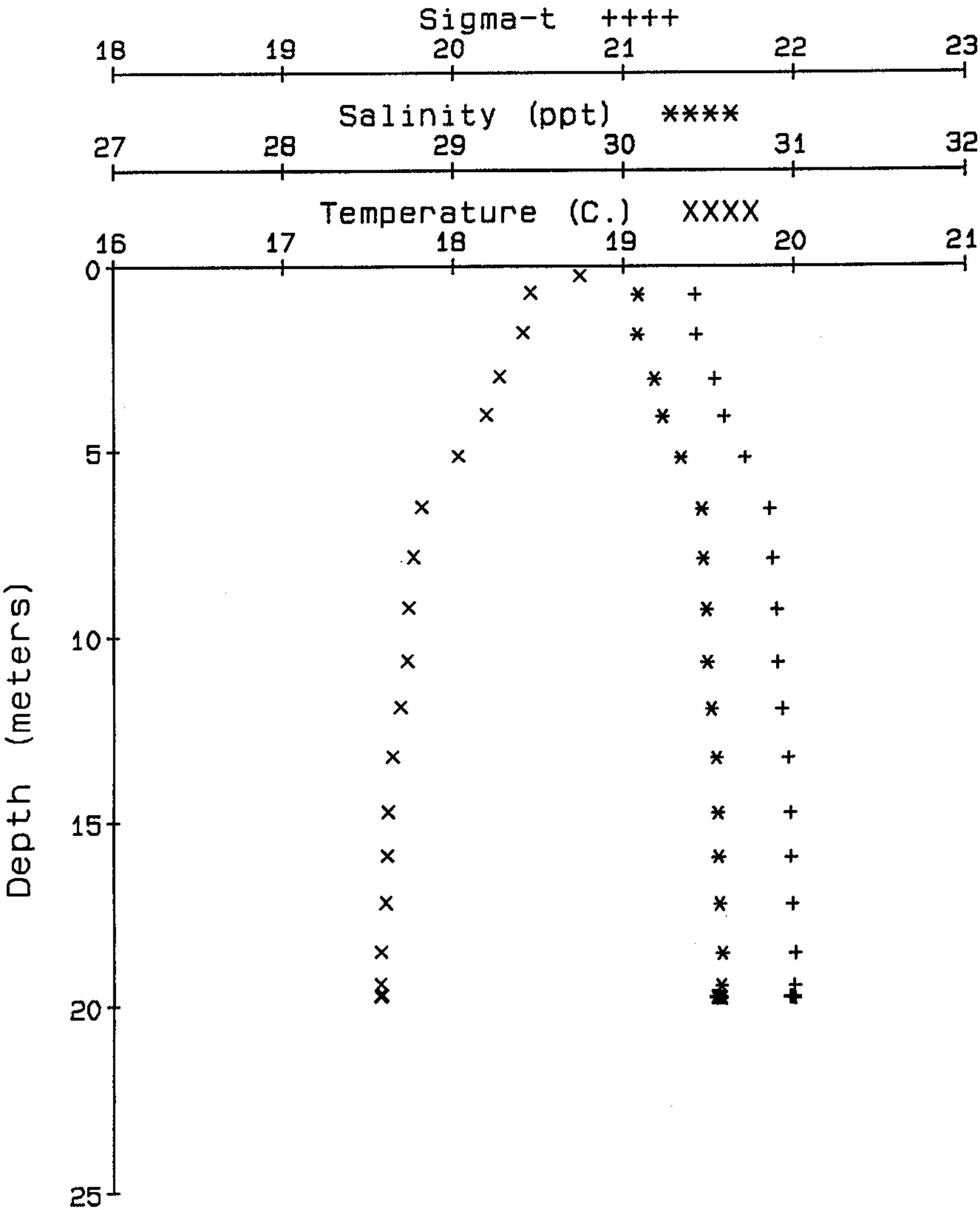
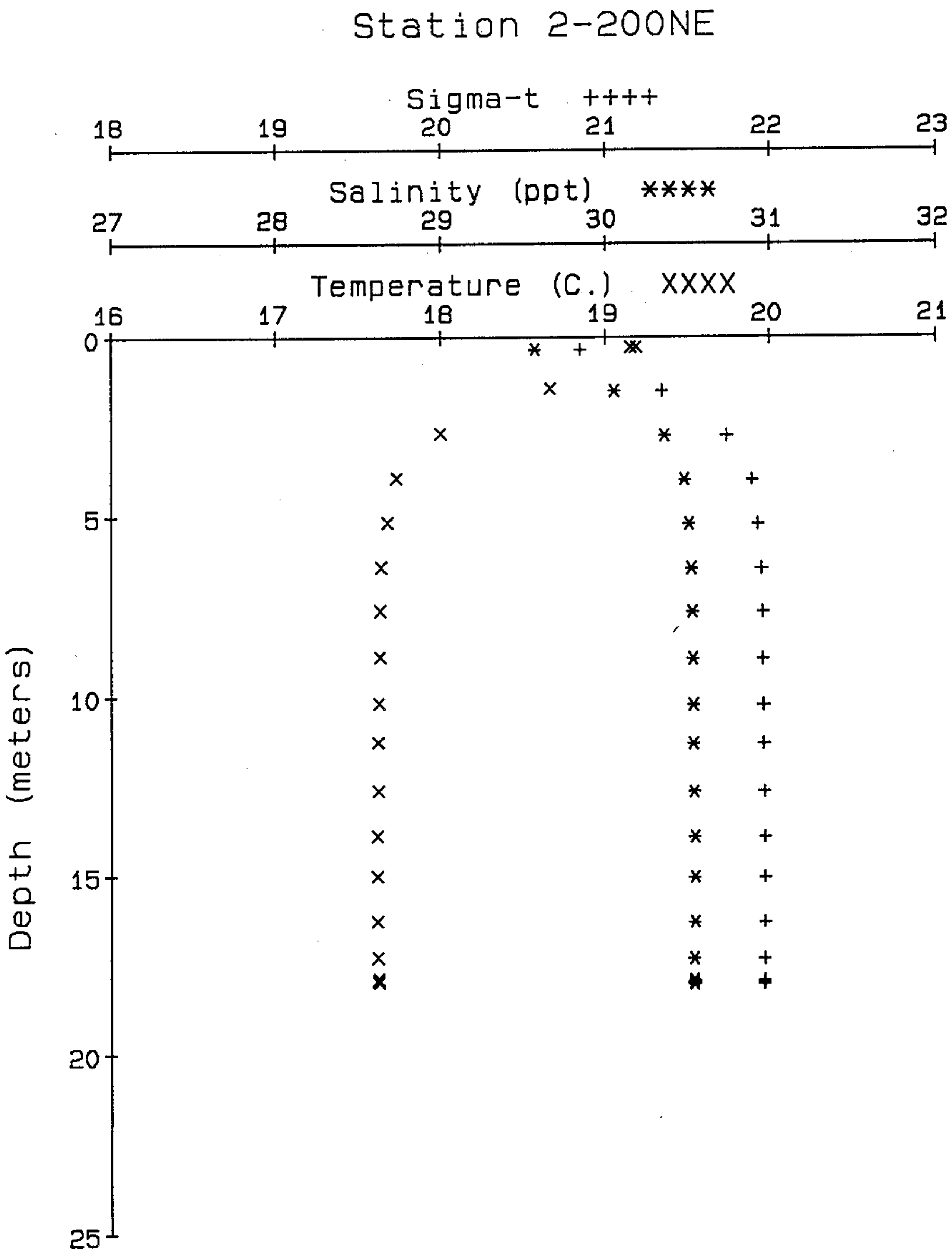
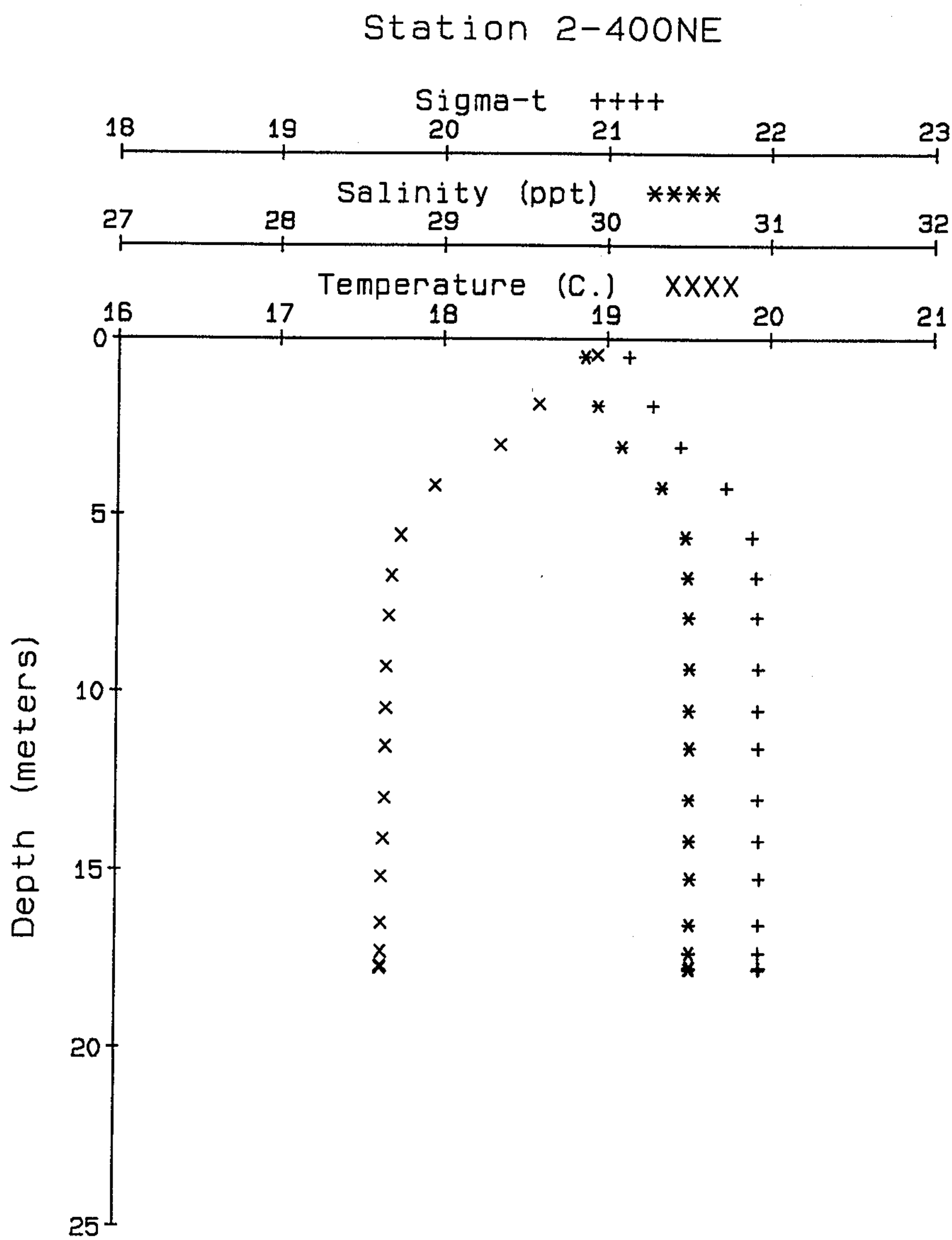
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
Depth (meters)

Station 600E

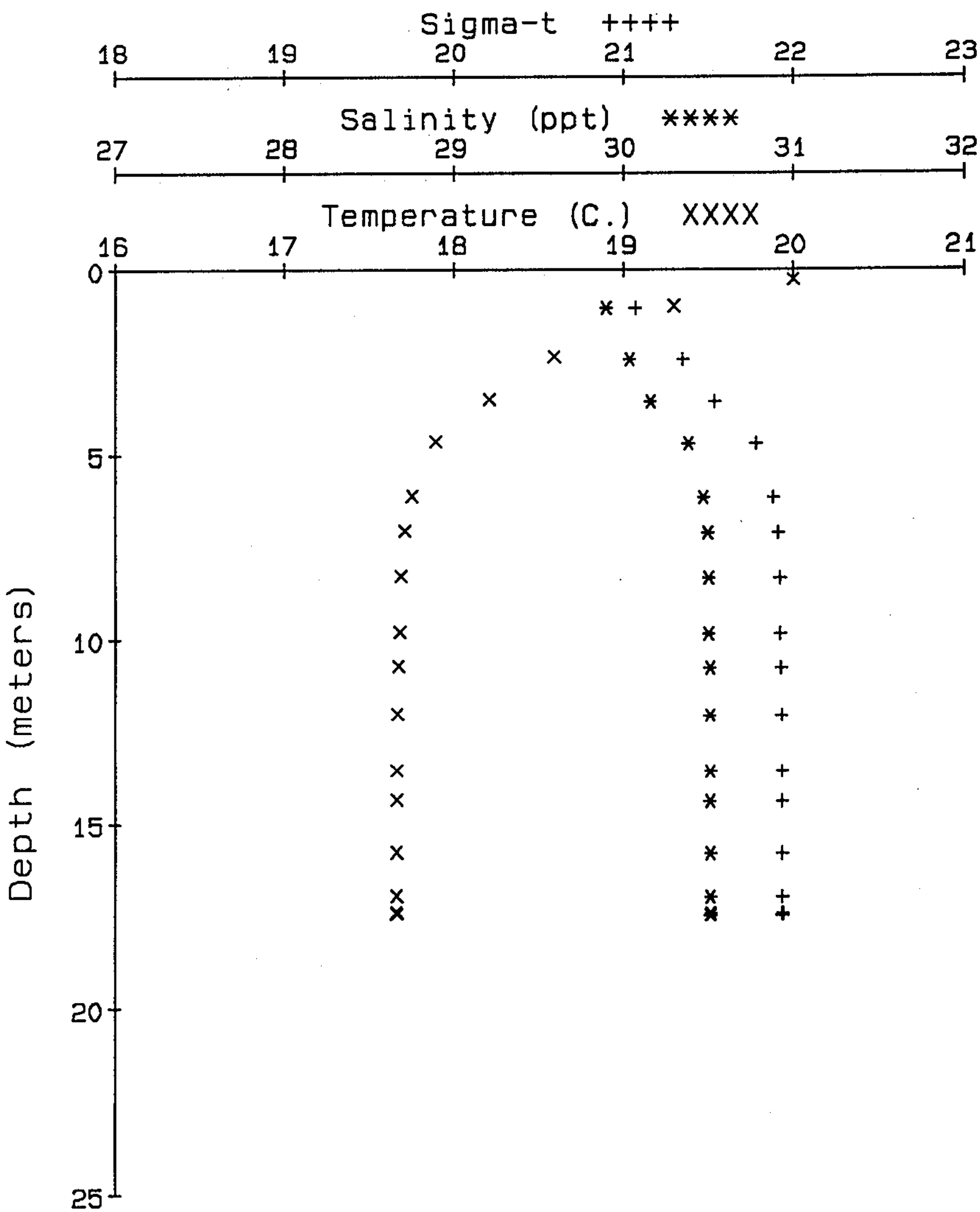


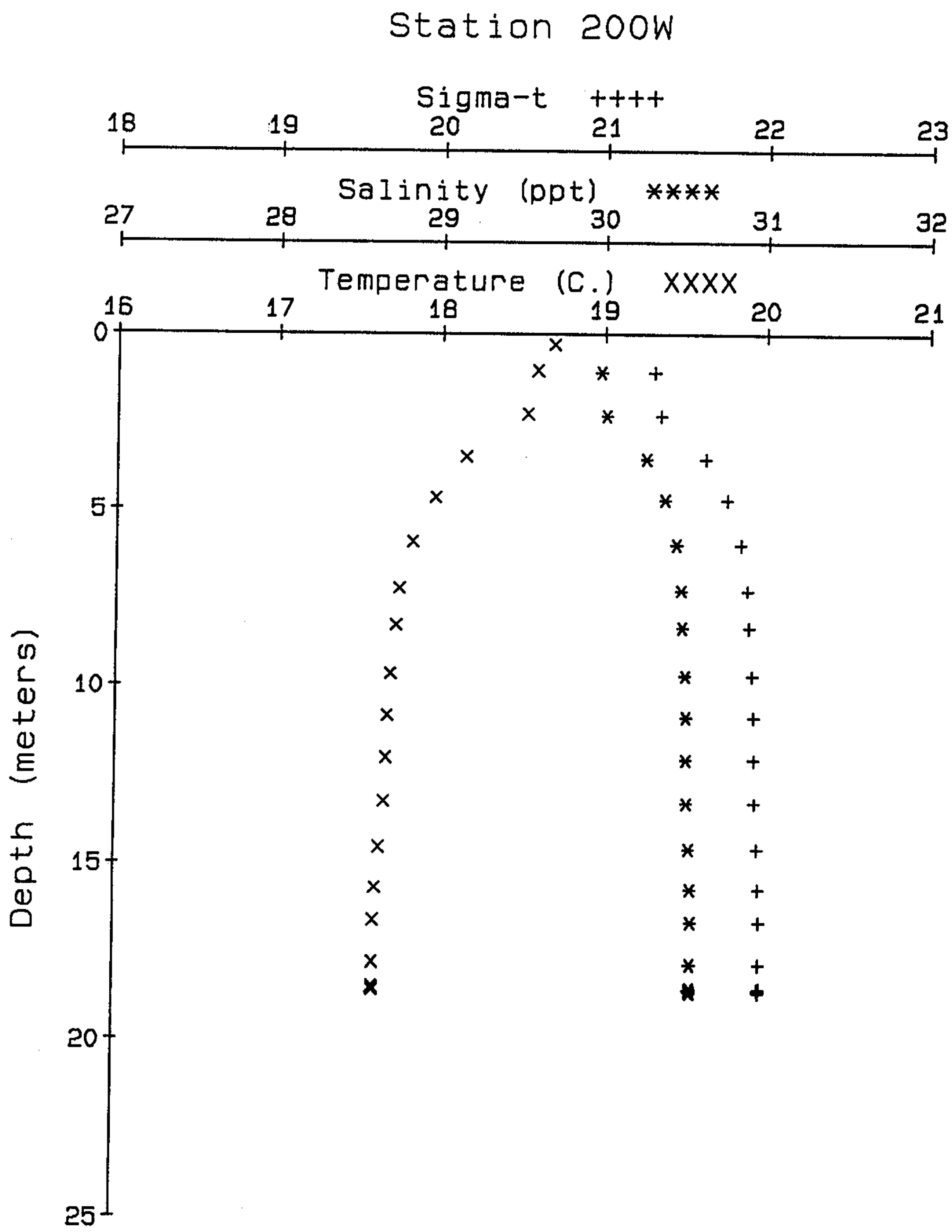

Station 2-200NE
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
30
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
Depth (meters)
0
5
10
15
20
25



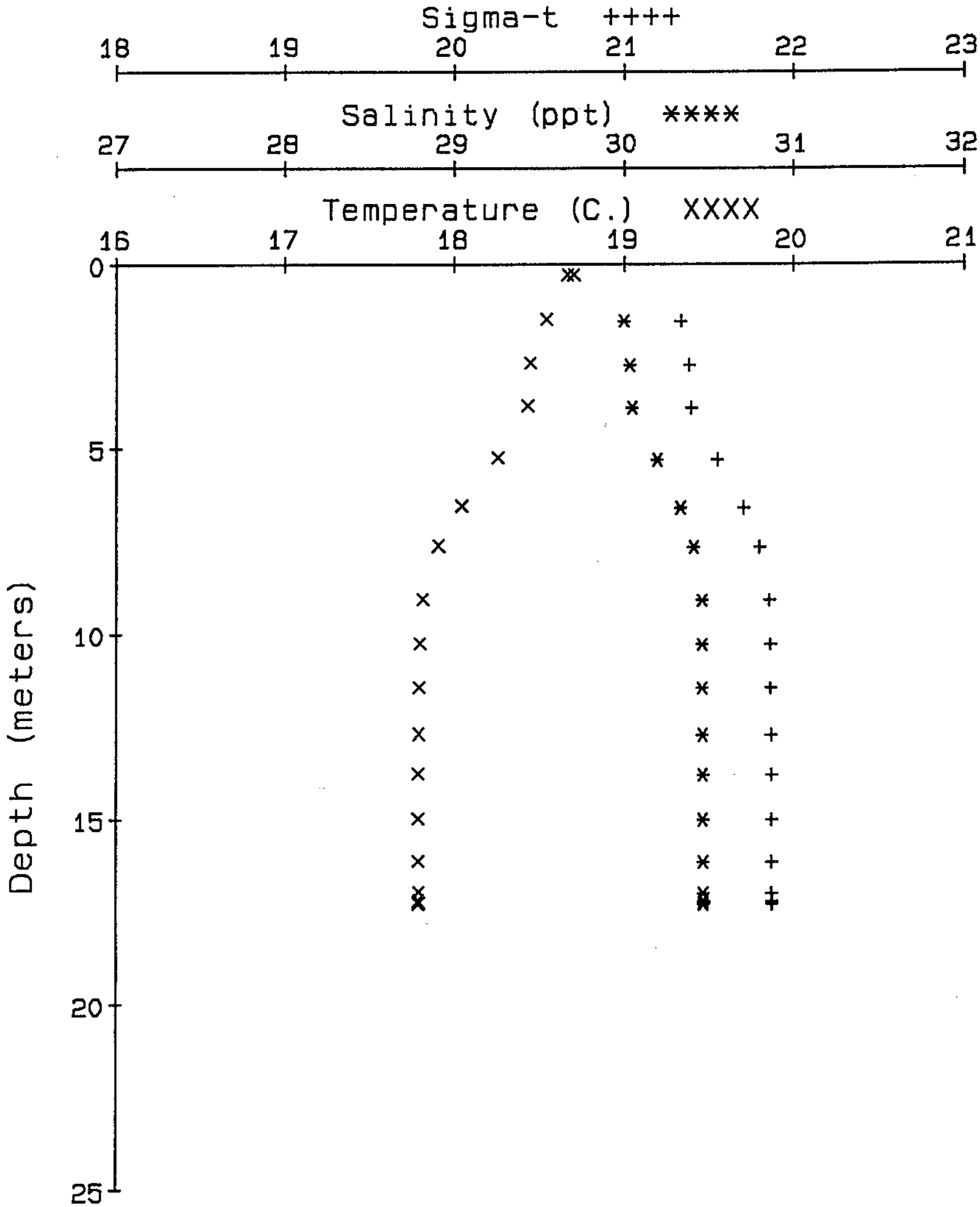
Station 2-400NE
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
30
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
Depth (meters)

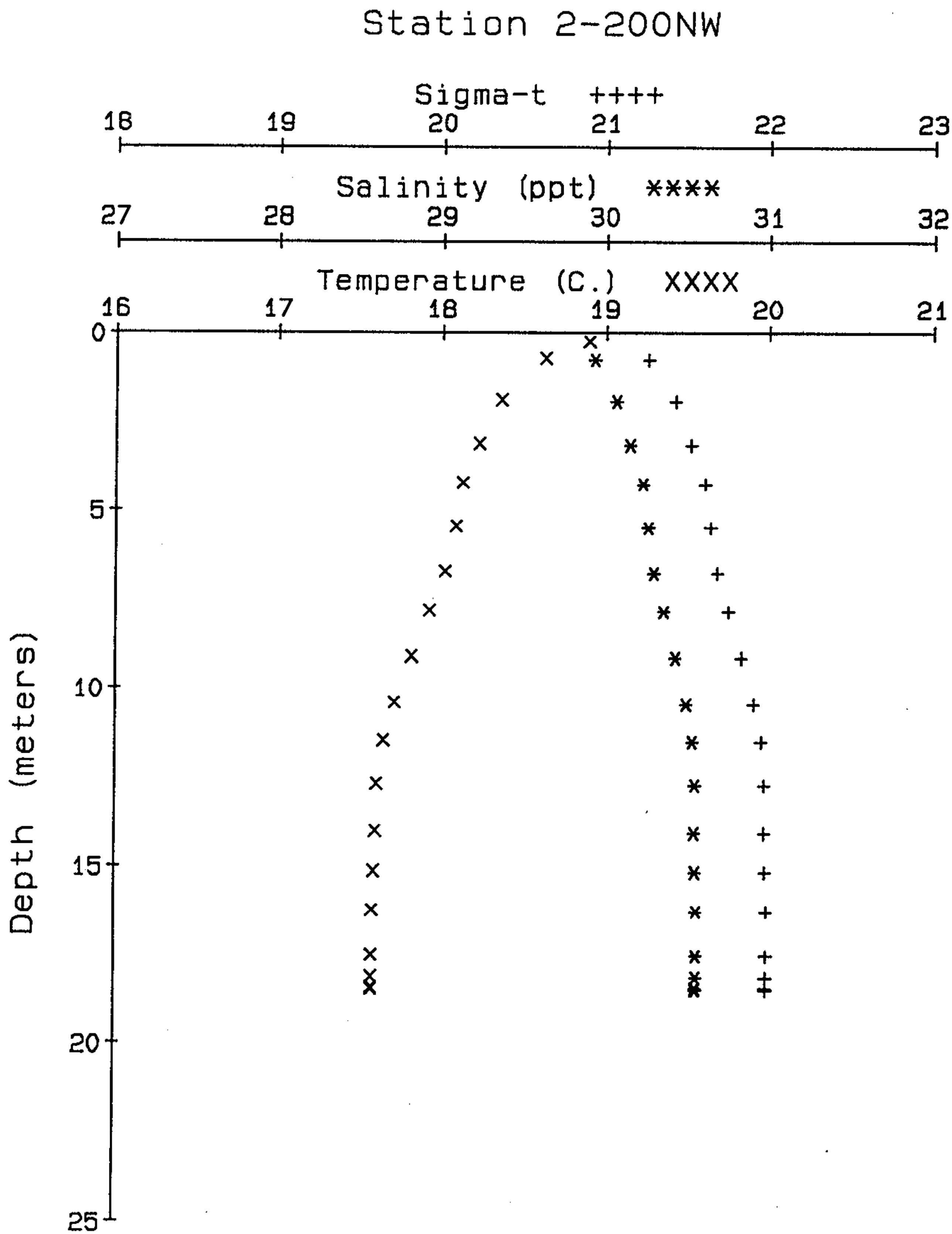
Station 4-400NE

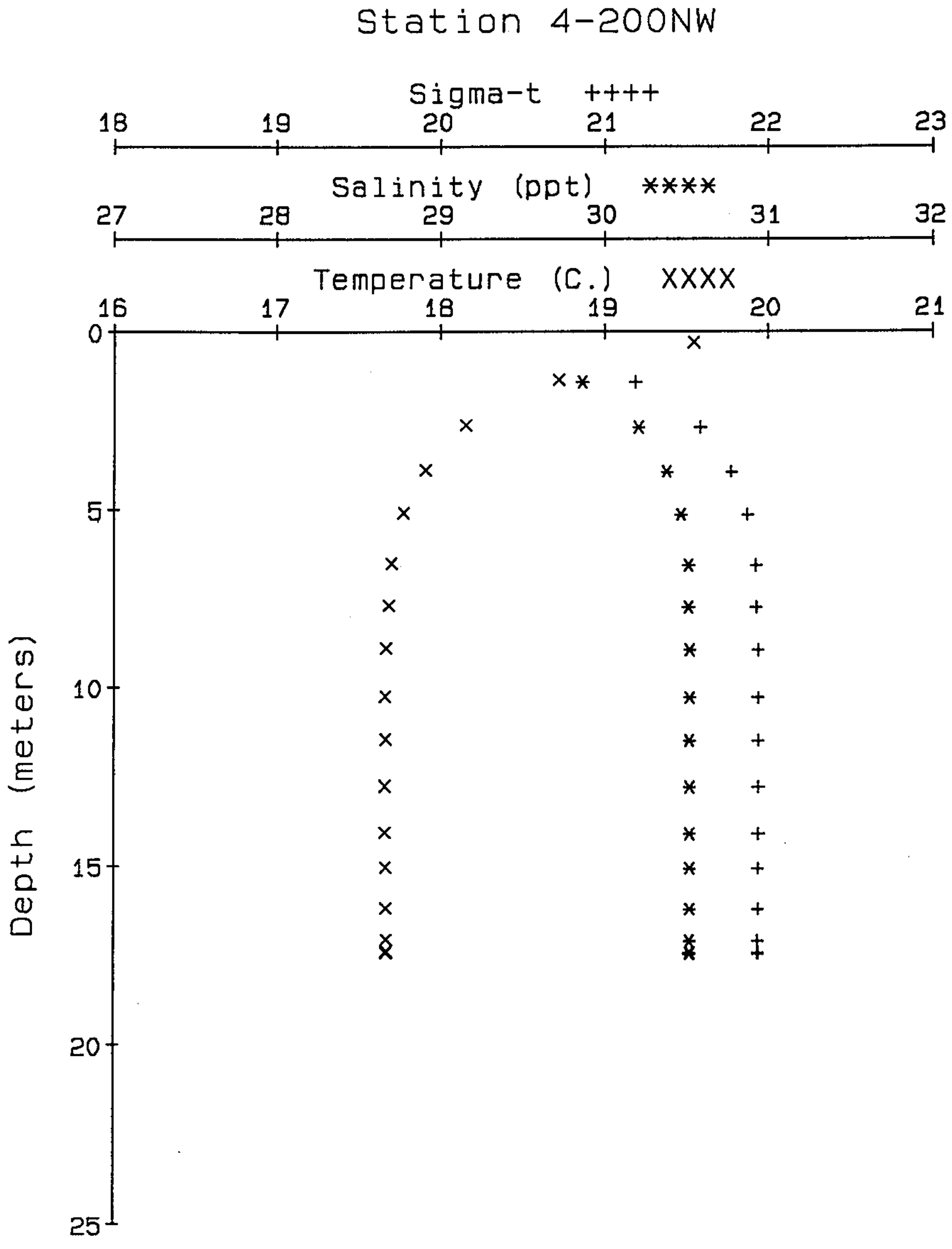



Station 200W
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
30
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
Depth (meters)

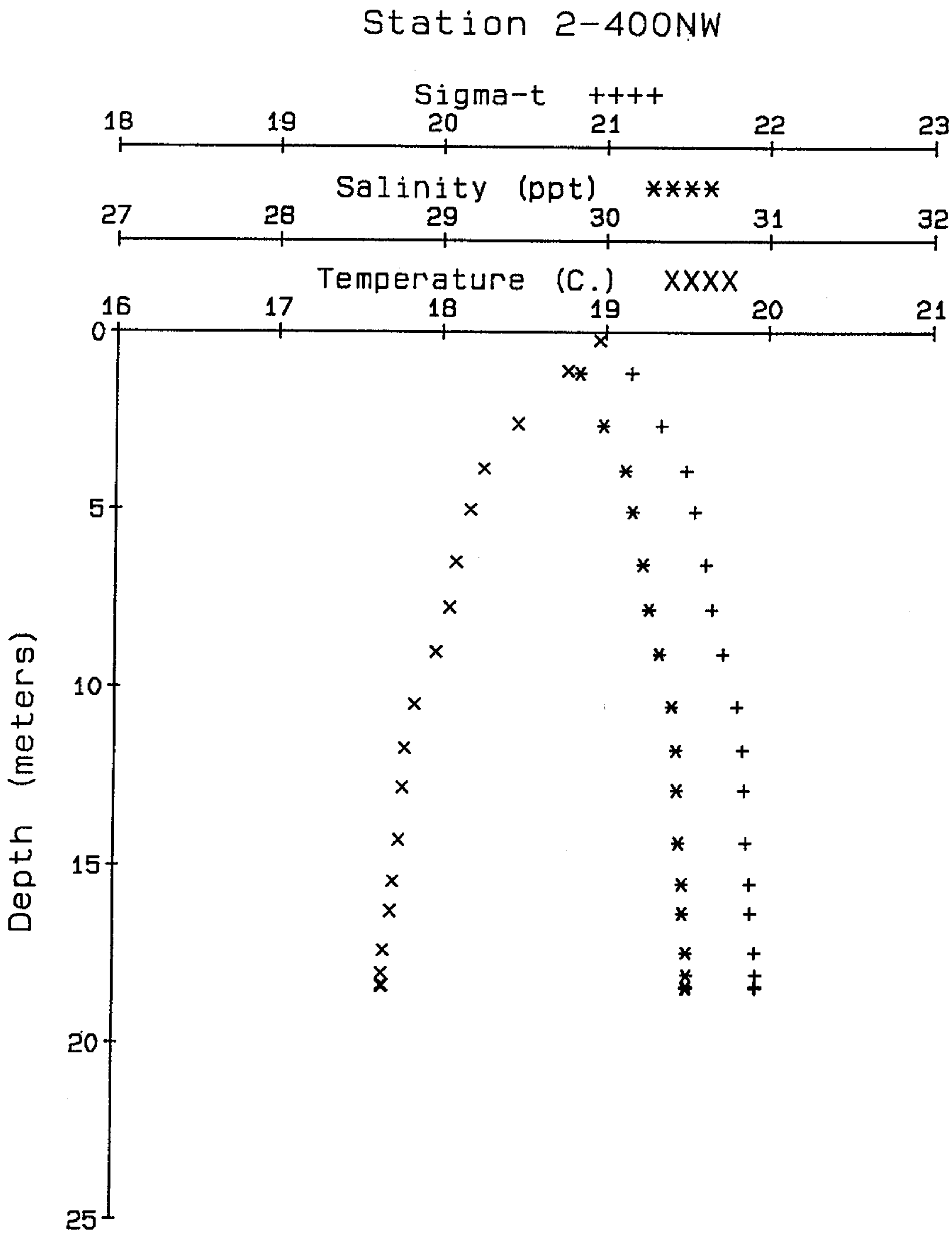
Station 400W



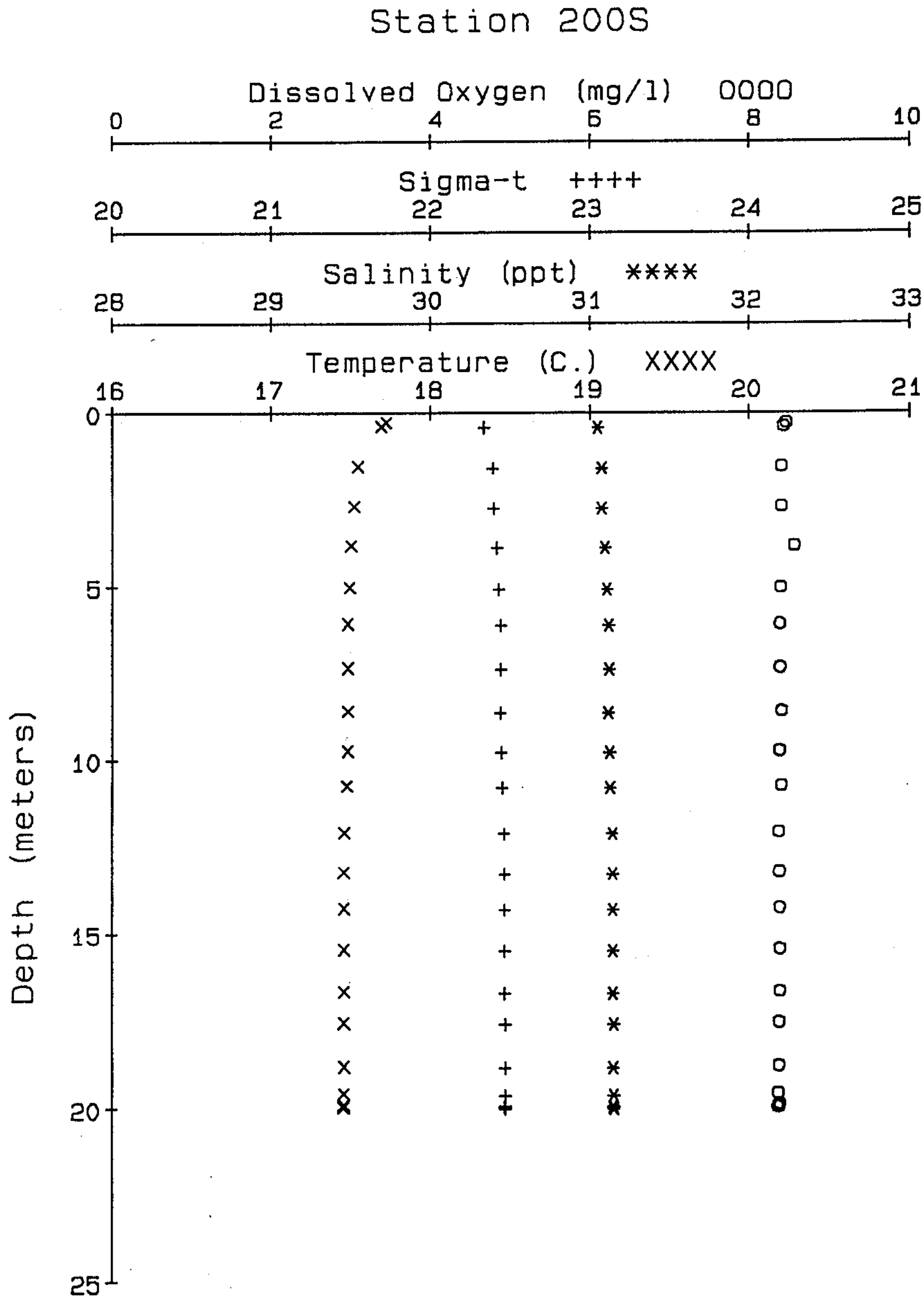

Station 2-200NW
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
30
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
Depth (meters)
0
5
10
15
20
25



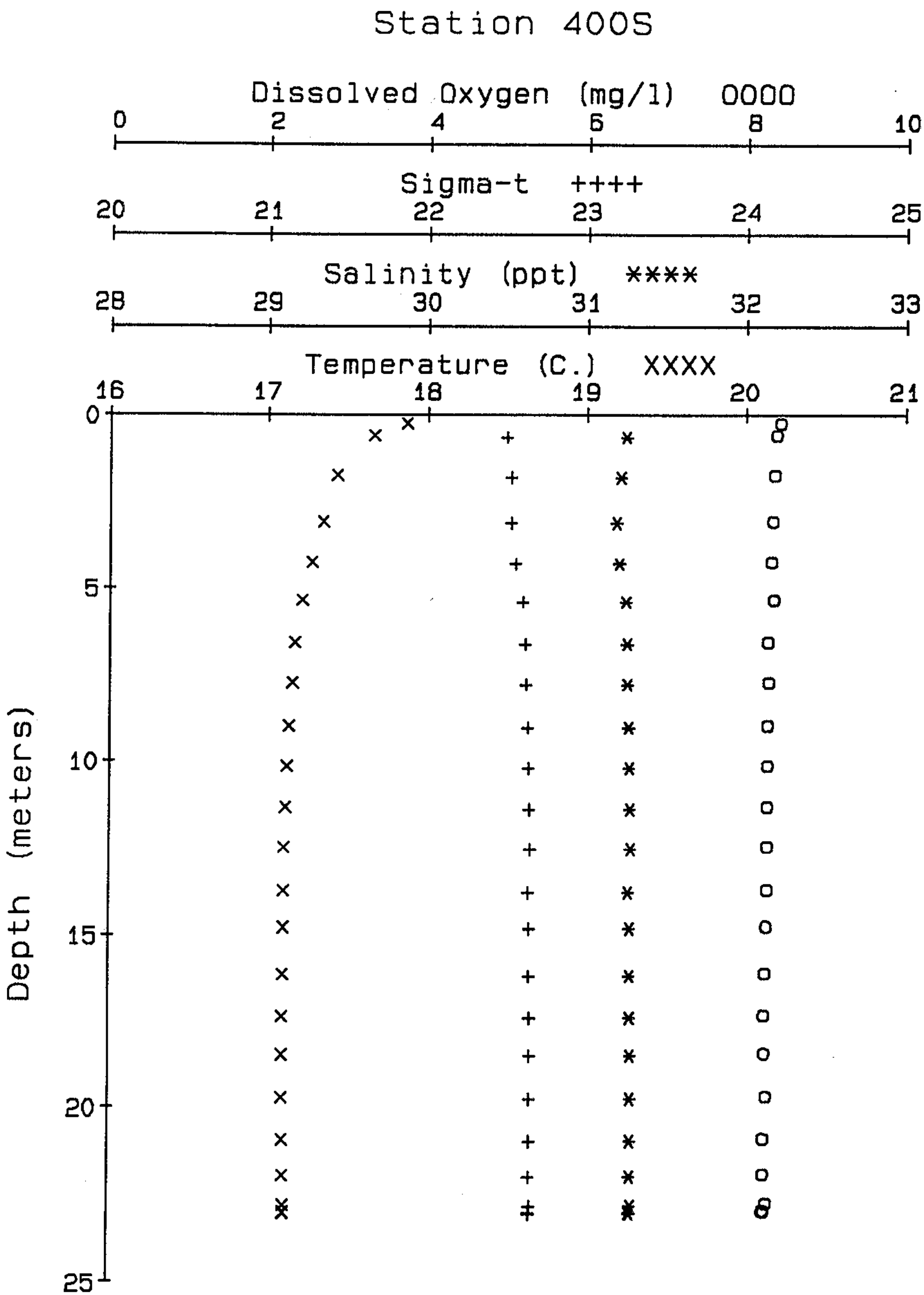
Station 4-200NW
Sigma-t ++++
18
19
20
21
22
23
Salinity (ppt) ****
27
28
29
30
31
32
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
Depth (meters)



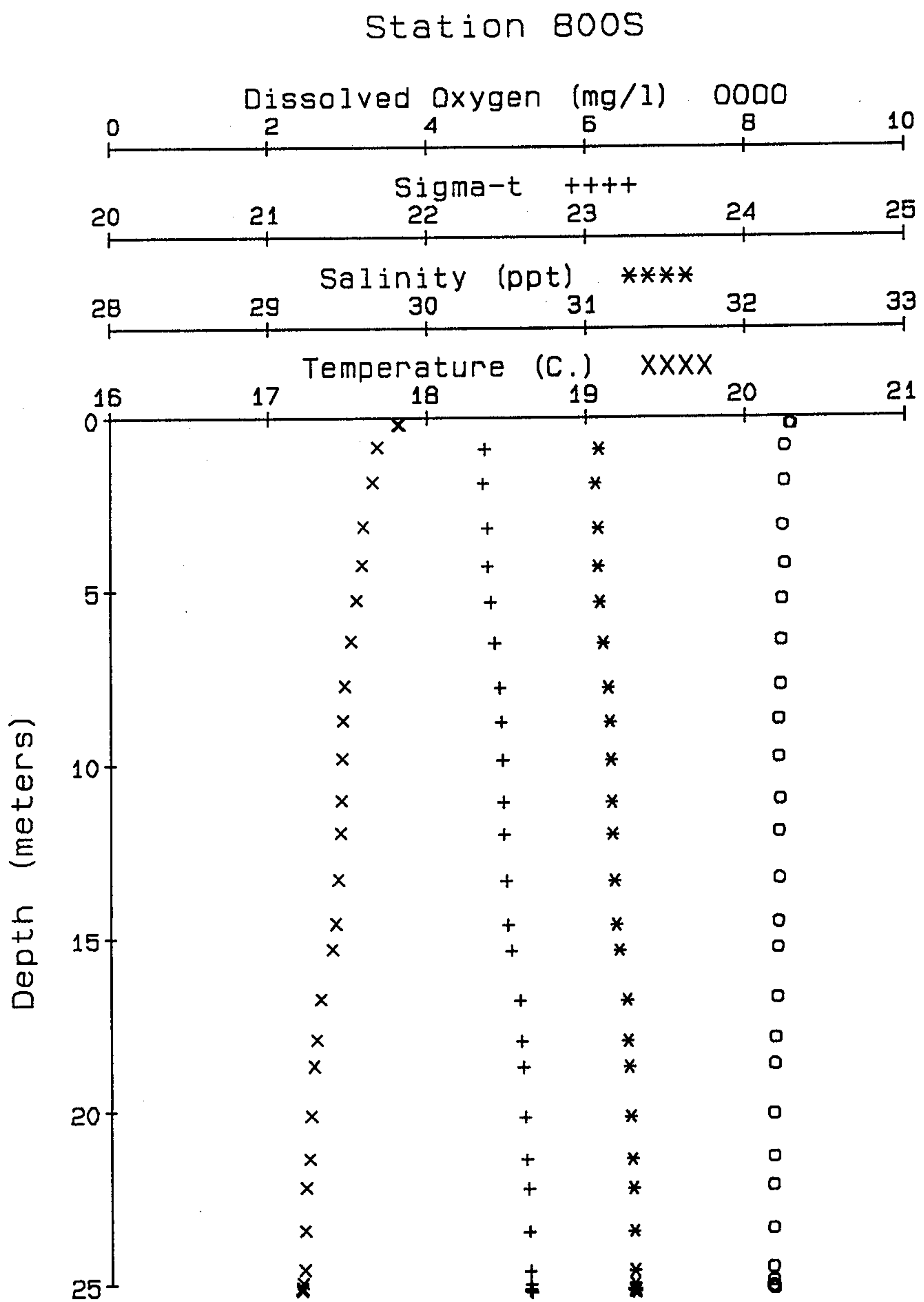
Station 2-400NW
Sigma-t ++++
18 19 20 21 22 23
Salinity (ppt) ****
27 28 29 30 31 32
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

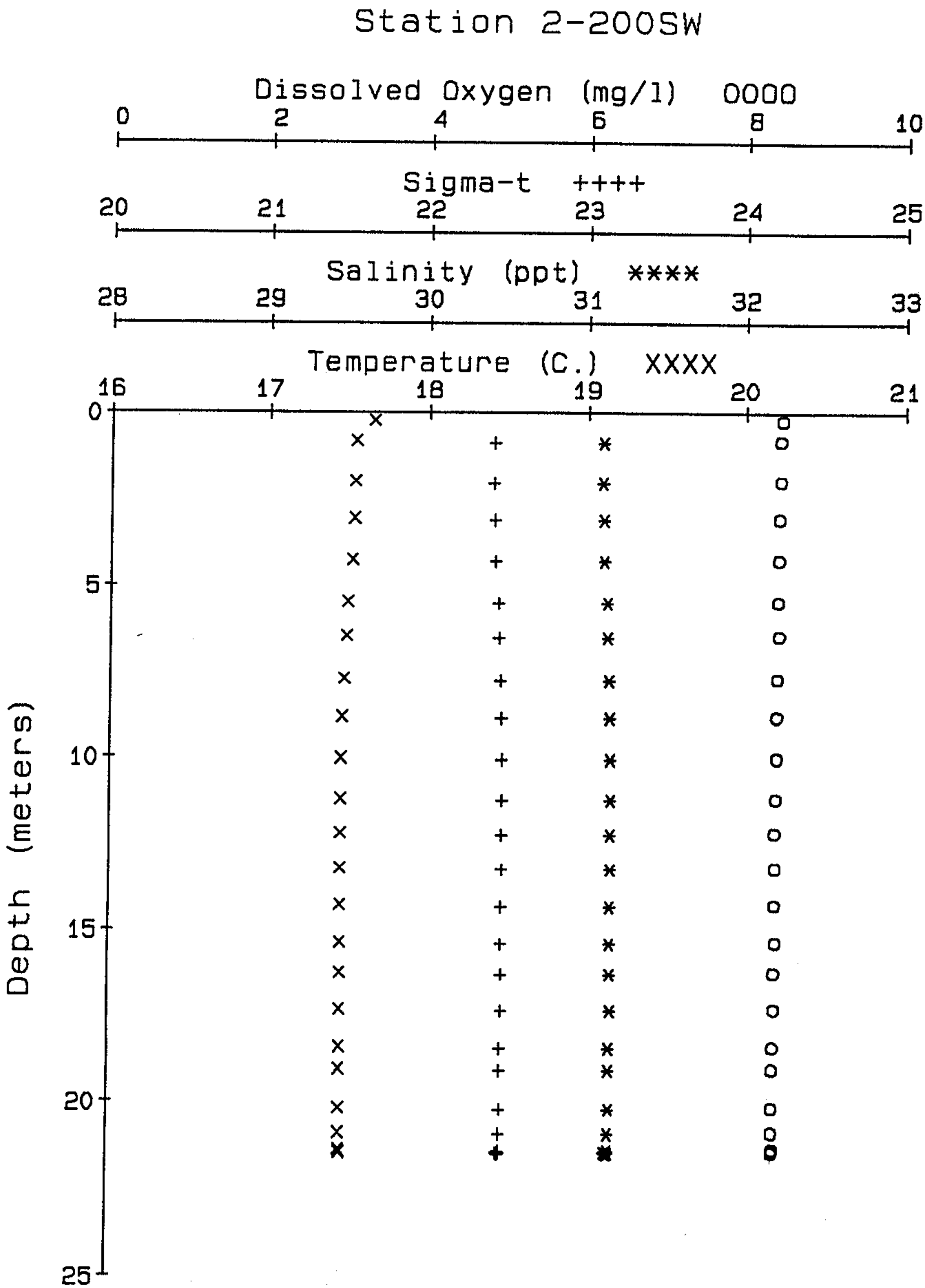


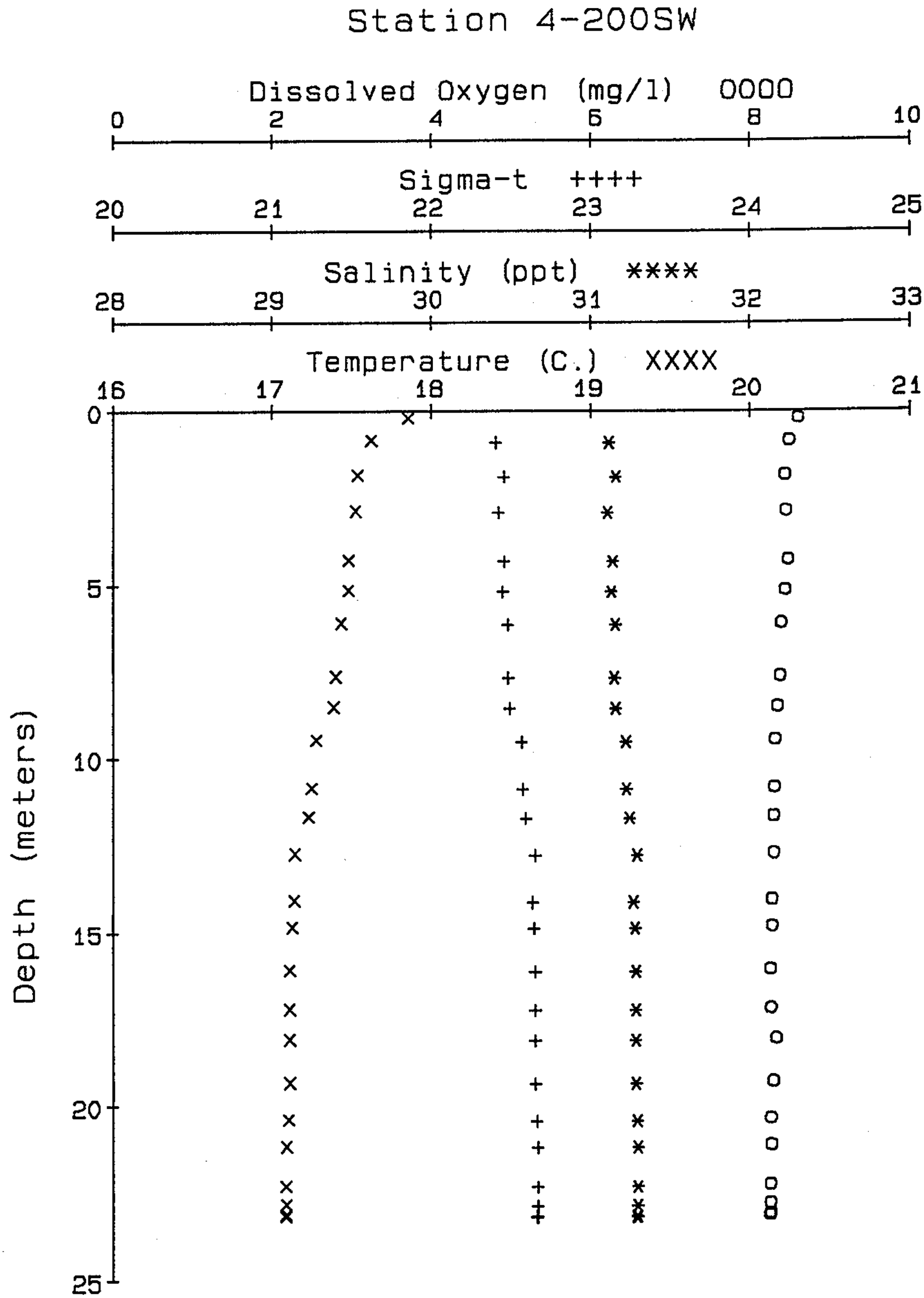
Station 200S
Dissolved Oxygen (mg/l) OOOO
0
2
4
6
8
10
Sigma-t ++++
20
21
22
23
24
25
Salinity (ppt) ****
28
29
30
31
32
33
Temperature (C.) XXXX
16
17
18
19
20
21
Depth (meters)
0
5
10
15
20
25



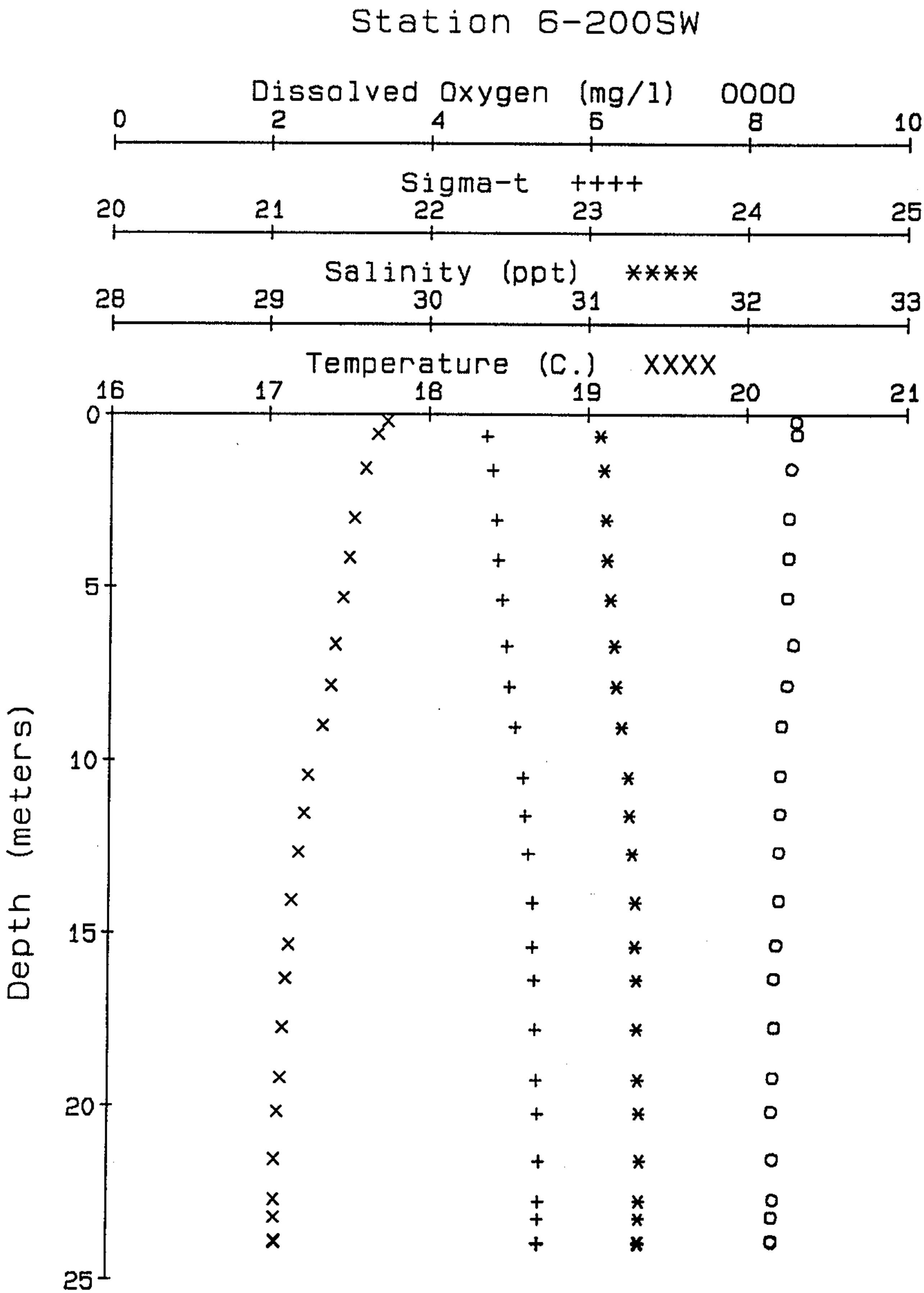
Station 400S
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25


Station 800S
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

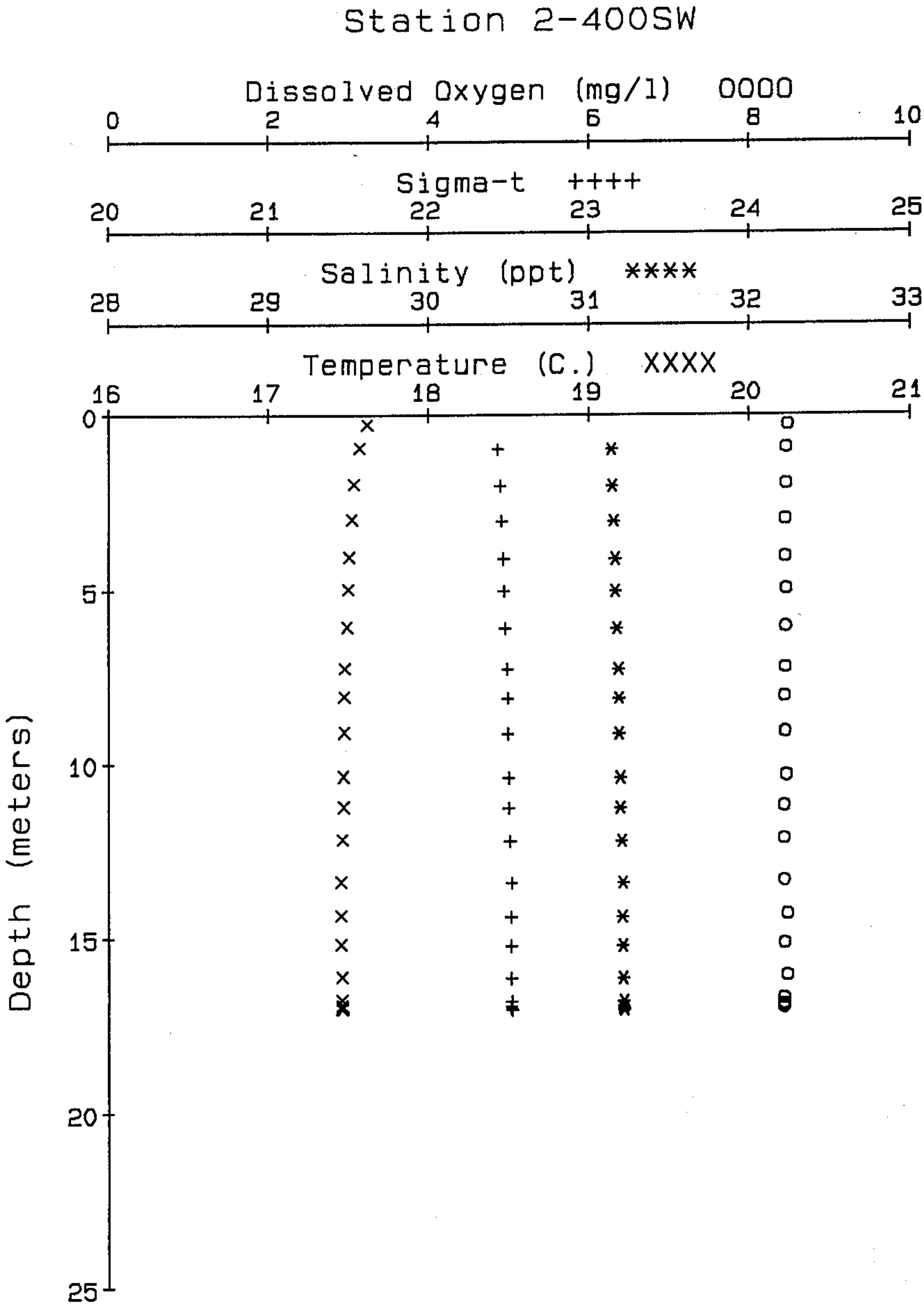

Station 2-200SW
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

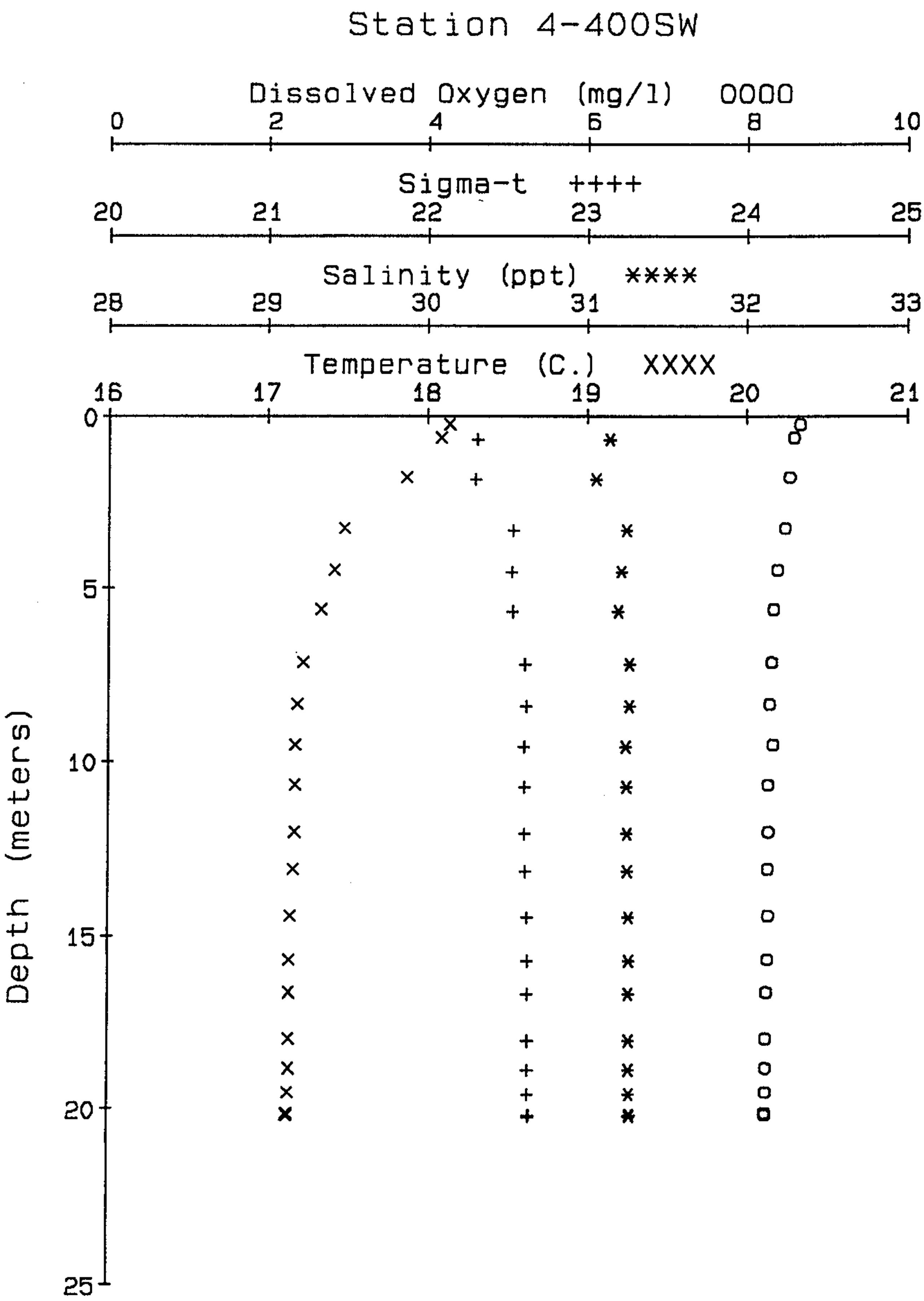


Station 4-200SW
Dissolved Oxygen (mg/l) OOOO
0
2
4
6
8
10
Sigma-t ++++
20
21
22
23
24
25
Salinity (ppt) ****
28
29
30
31
32
33
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
Depth (meters)

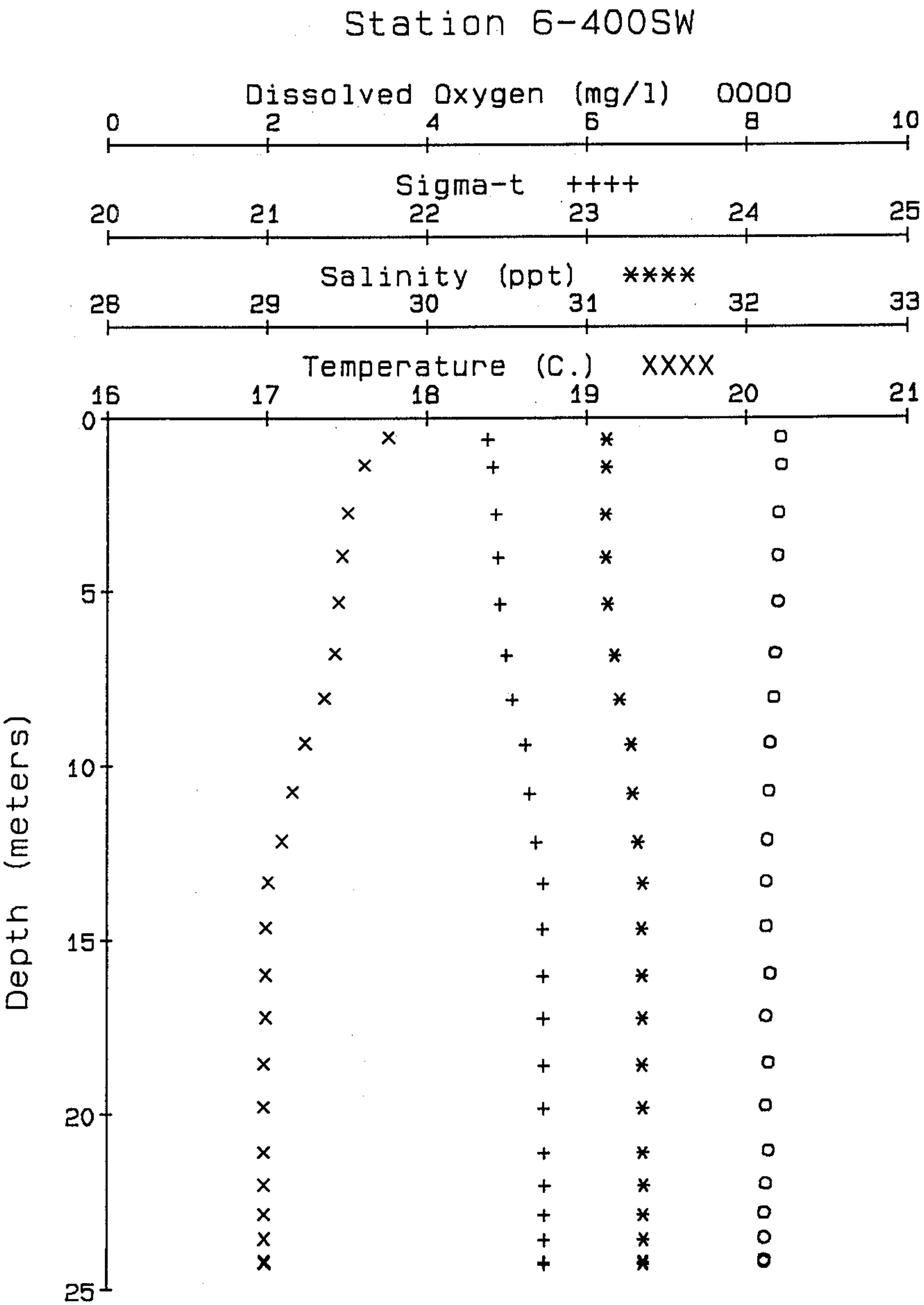


Station 6-200SW
Dissolved Oxygen (mg/l) 0000
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

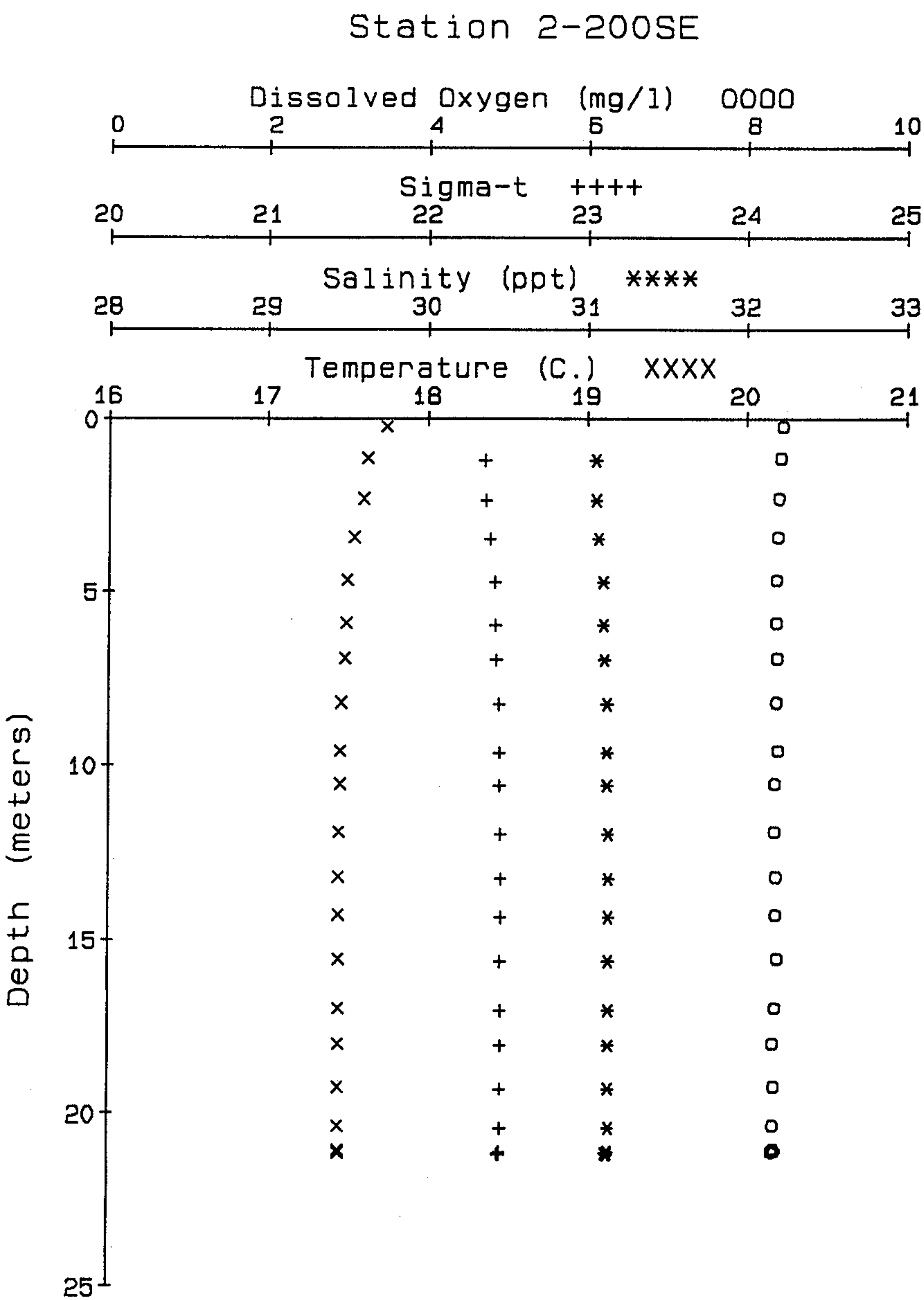

Station 2-400SW
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

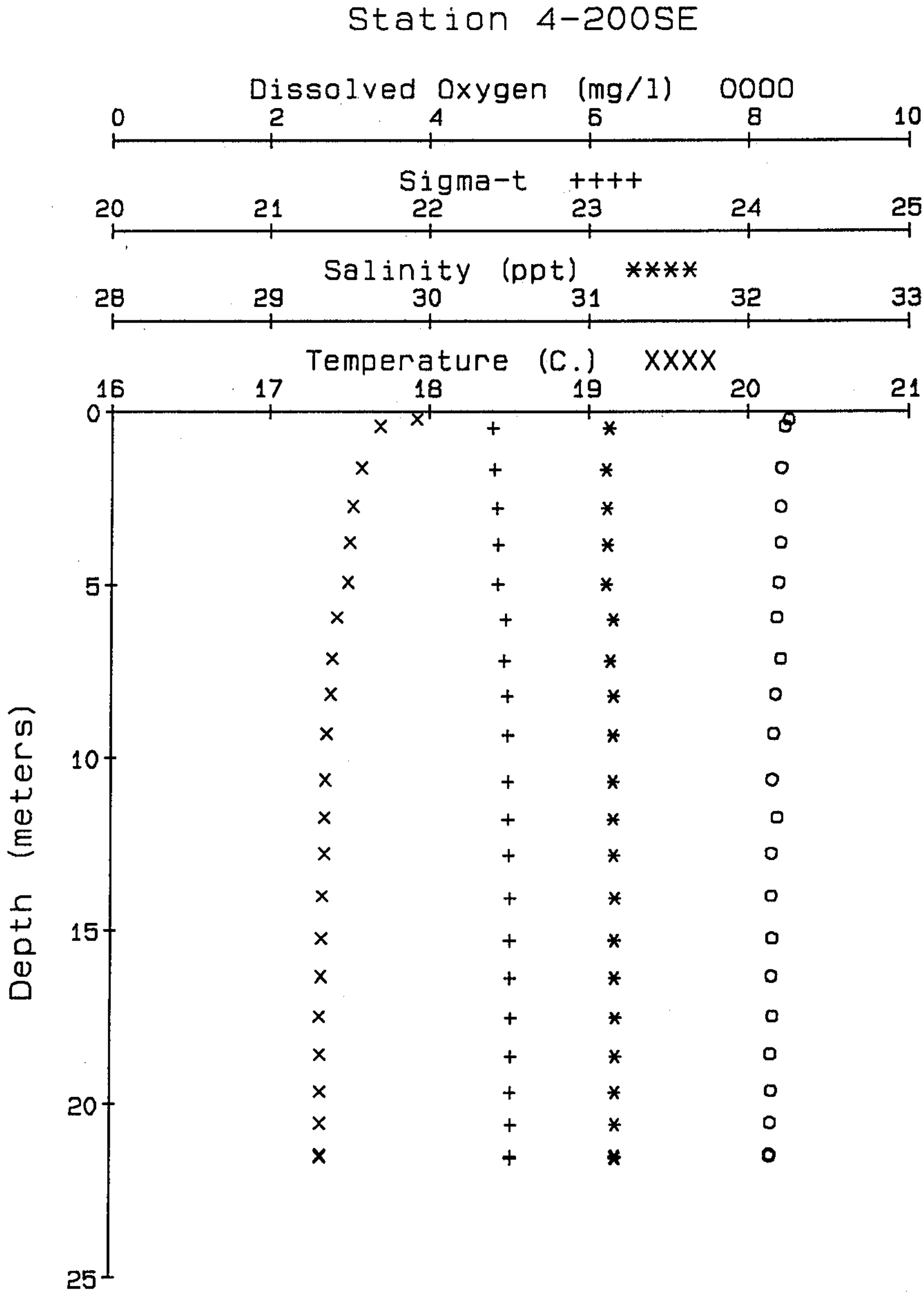


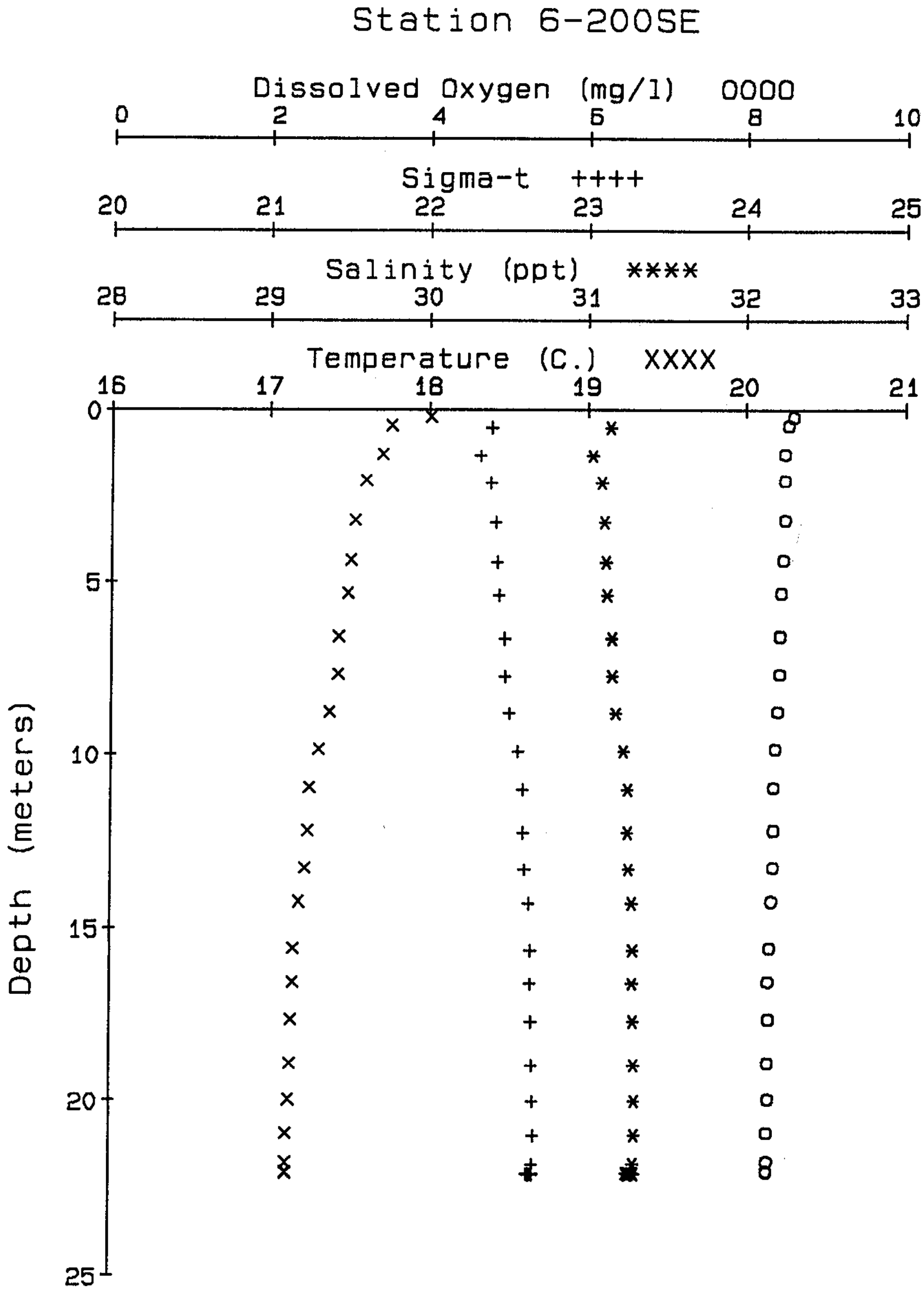
Station 4-400SW
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

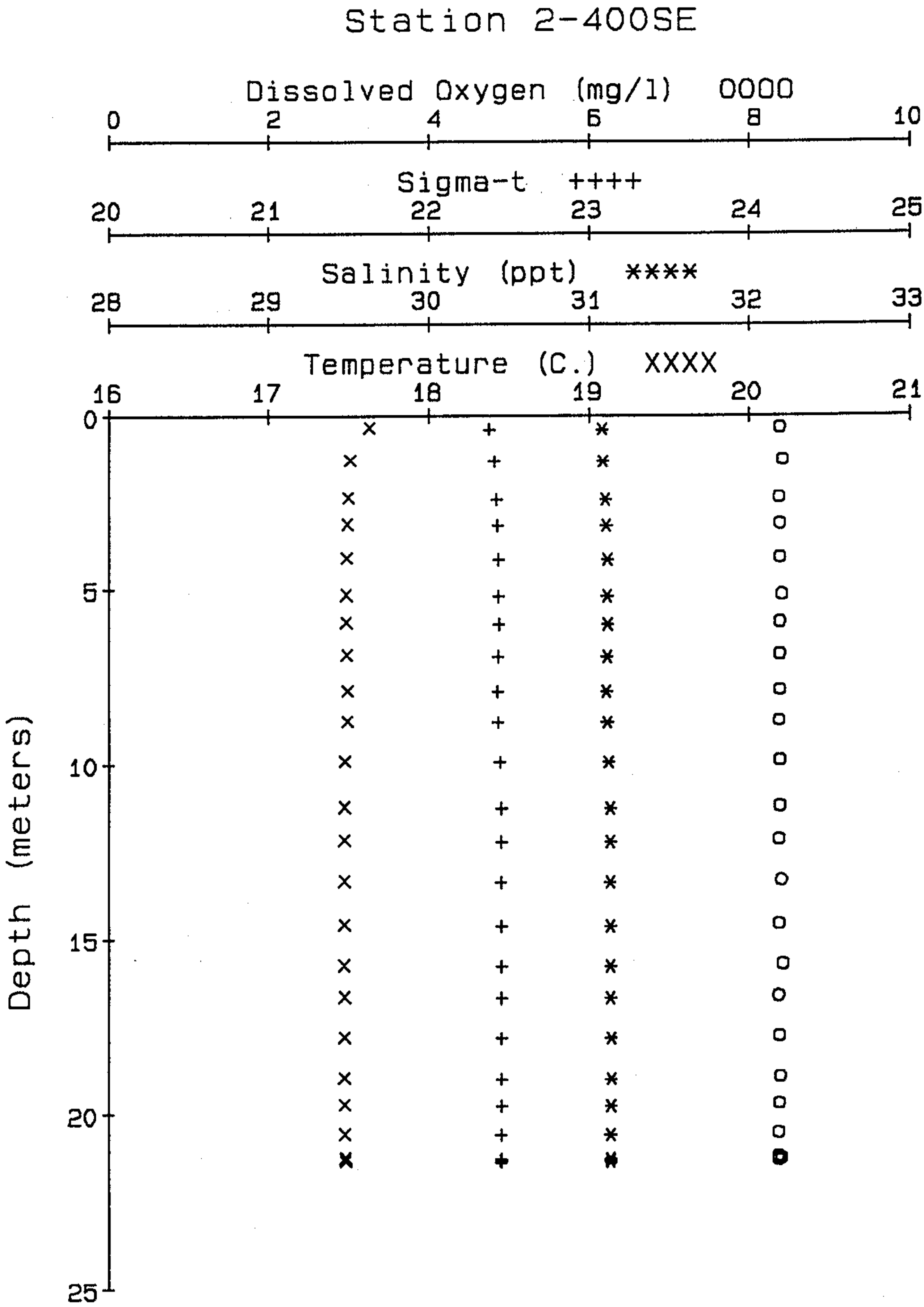


Station 6-400SW
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25
Depth (meters)

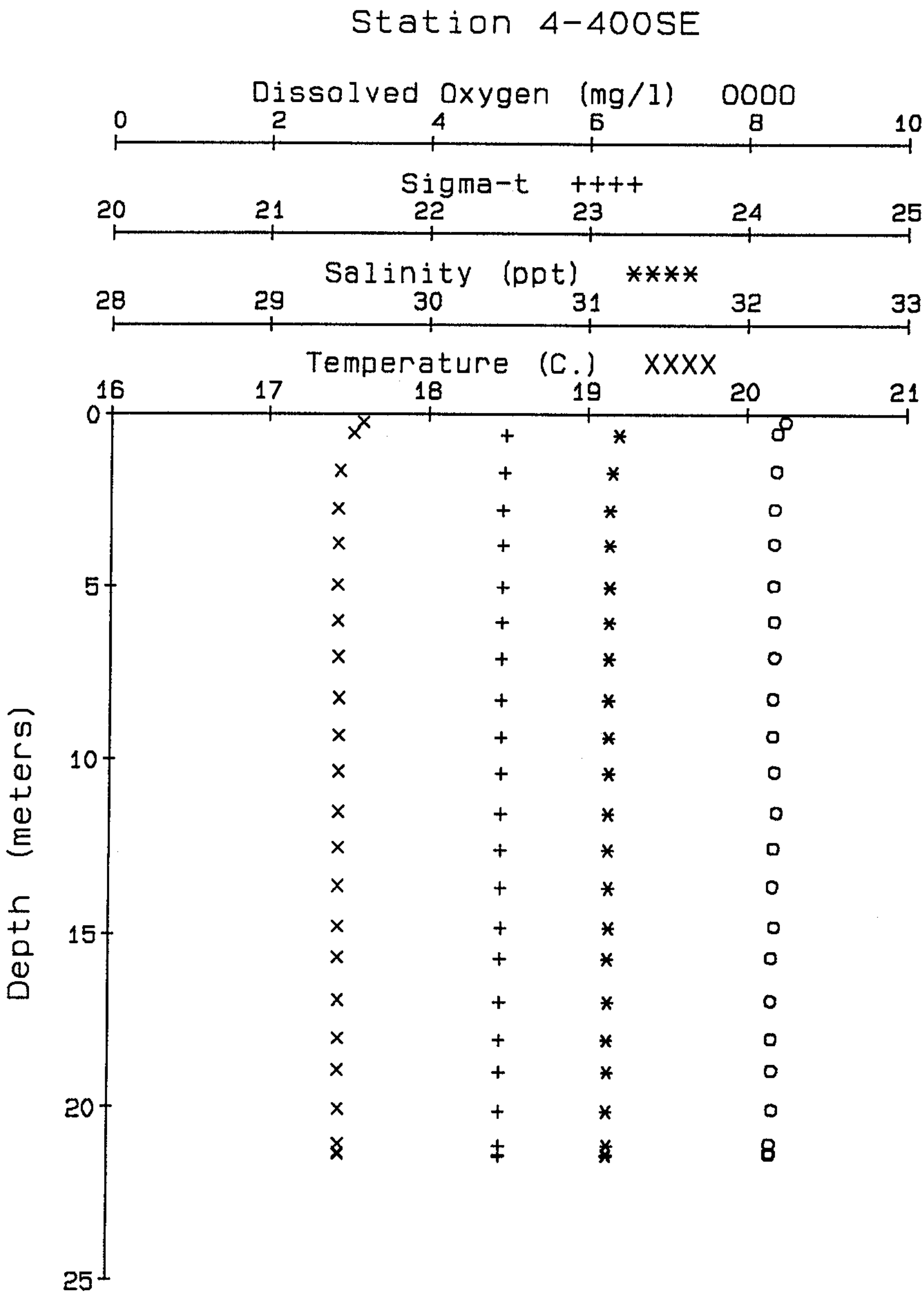

Station 2-200SE
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

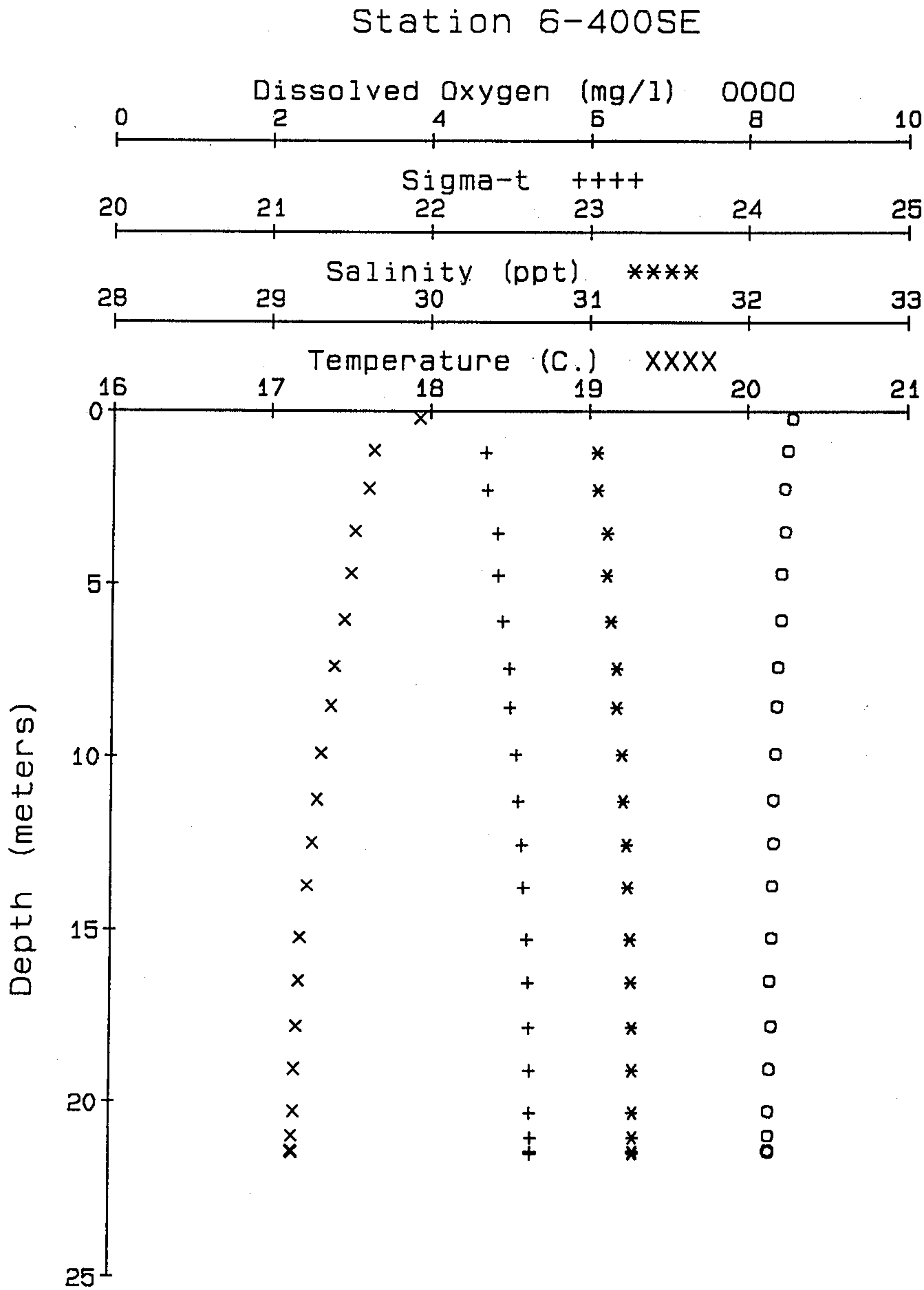

Station 4-200SE
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

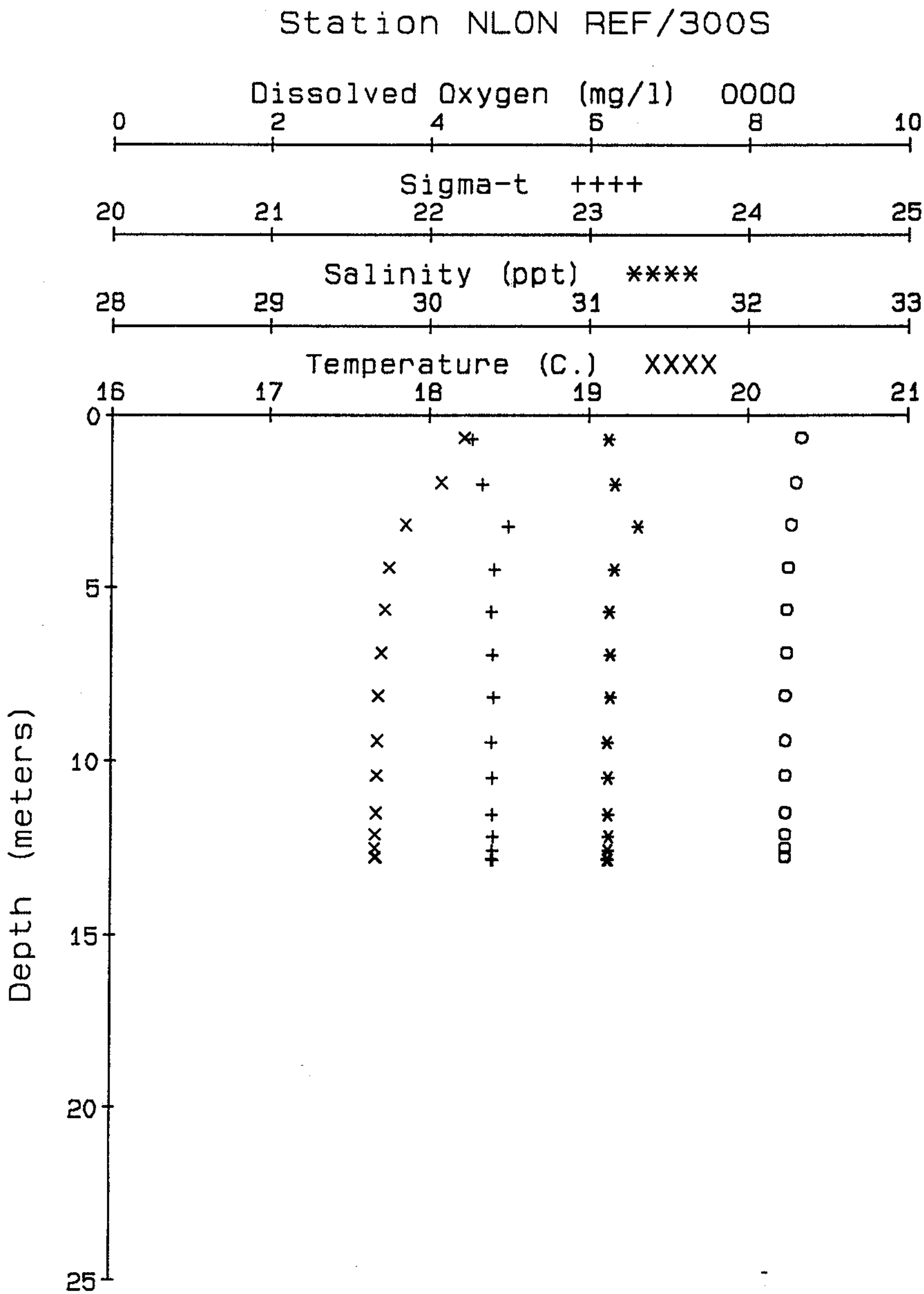

Station 6-200SE
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25
Depth (meters)



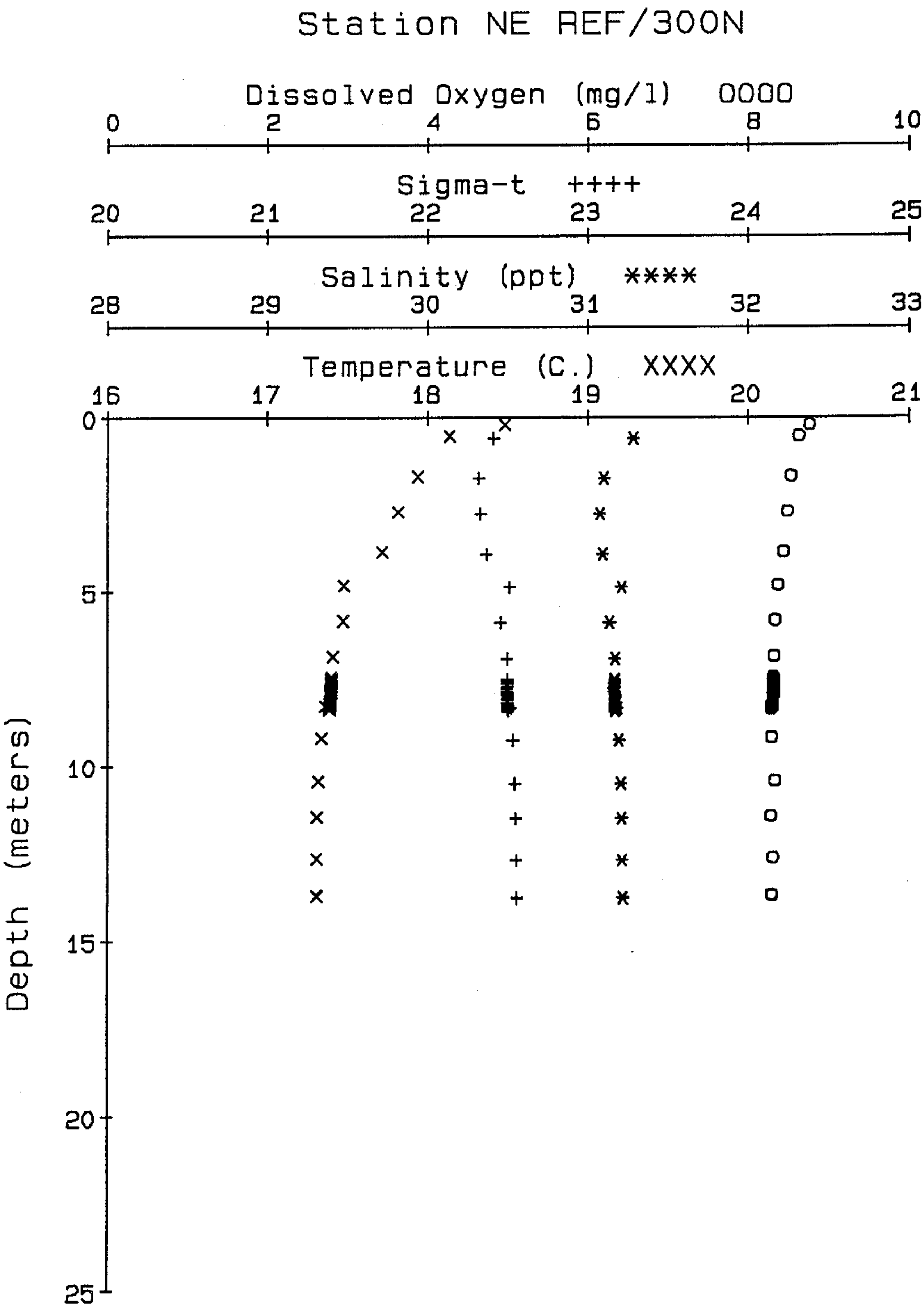
Station 2-400SE
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25


Station 4-400SE
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25

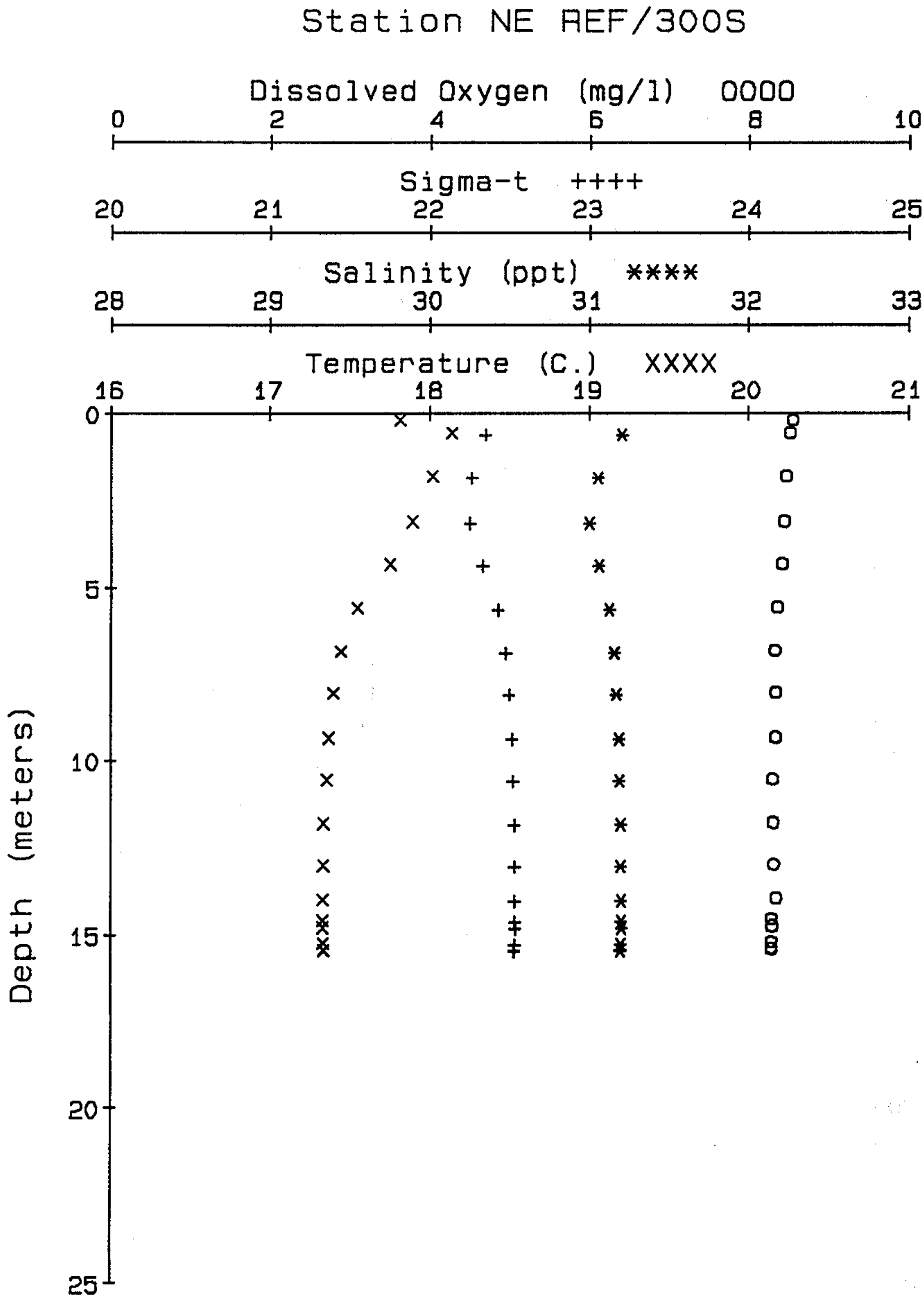

Station 6-400SE
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25



Station NLON REF/300S
Dissolved Oxygen (mg/l) OOOO
0
2
4
6
8
10
Sigma-t ++++
20
21
22
23
24
25
Salinity (ppt) ****
28
29
30
31
32
33
Temperature (C.) XXXX
16
17
18
19
20
21
0
5
10
15
20
25
Depth (meters)



Station NE REF/300N
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
0 5 10 15 20 25
Depth (meters)


Station NE REF/300S
Dissolved Oxygen (mg/l) OOOO
0 2 4 6 8 10
Sigma-t ++++
20 21 22 23 24 25
Salinity (ppt) ****
28 29 30 31 32 33
Temperature (C.) XXXX
16 17 18 19 20 21
Depth (meters)
0 5 10 15 20 25