Monitoring Cruise at the Central Long Island Sound Disposal Site, August & September 1987

# Disposal Area Monitoring System DAMOS

Contribution 68
April 1990

**US Army Corps of Engineers**
New England Division

# MONITORING CRUISE AT THE CENTRAL LONG ISLAND SOUND DISPOSAL SITE AUGUST & SEPTEMBER 1987

**CONTRIBUTION #68**

April 1990

Report No.
SAIC- 88/7523&C68

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**MONITORING CRUISE AT THE**

**CENTRAL LONG ISLAND SOUND DISPOSAL SITE**

**AUGUST AND SEPTEMBER 1987**

## 1.0 INTRODUCTION

Environmental monitoring has occurred at the Central Long Island Sound (CLIS) disposal site since 1974. Past studies have generally focused on assessing the environmental impacts of dredged material disposal and determining the effectiveness of capping dredged material to isolate chemical components of environmental concern. In recent years a primary objective of monitoring efforts has been to assess the post-disposal recovery of benthic ecosystems. Figure 1-1 illustrates the location of individual disposal points or mounds within the CLIS disposal site.

Between 19 August 1987 and 11 September 1987, field operations were conducted at the CLIS site to provide information on the fate of recently-deposited dredged material and to assess environmental impacts related to past and recent disposal operations. Specifically, the objectives of the field operations were:

- To delineate the extent and topography of the dredged sediment deposit resulting from the year's disposal activities. A precision bathymetric survey and a REMOTS® sediment-profile photography survey were conducted in the area surrounding the disposal buoy at the CLIS-86 mound to test the prediction that sediment disposed during the last year had accumulated as a low, broad mound between the CLIS-86 and CS-2 disposal points. The survey area encompassed much of the CS-1 and CS-2 historic deposits and also included a region approximately 475 m northwest of the buoy where dredged material had been deposited. REMOTS® sampling also took place at four reference stations and at four other disposal mounds at the CLIS site (FVP, MQR, NHAV-83, and STNH-S) to monitor physical and biological conditions and document the process of infaunal recolonization at these previously-used disposal points;

- To assess the transport of specific contaminants present in both elevated concentrations and relatively large volumes in the dredged sediment. A transect survey, involving sediment sampling for both chemical and physical analyses, was conducted along the axis of predominant current movements to test whether sediment-associated contaminants deposited within the disposal mound were subject to resuspension, transport, and redeposition;

- To provide additional baseline information on contaminant body burden in the deposit-feeding polychaete *Nephtys incisa*. This information is being used in an initial assessment of the relation between sediment contamination and biological uptake and the potential value of this approach for special monitoring purposes. Individuals of *Nephtys incisa* were collected at transect stations along the axis of predominant current movement at the CLIS-86 mound and subsequently analyzed for concentrations of selected metals and PCB's; and

- To assess near-bottom dissolved oxygen (DO) concentrations and characterize the depth gradient in DO relative to the REMOTS® benthic analyses at the five disposal mounds surveyed. It was hypothesized in 1986 that the relatively slow rates of ecosystem recovery observed at some CLIS disposal mounds, particularly those along the deeper, southern boundary of the site (MQR, NH-83 and STNH-S), might be due in part to the Sound-wide phenomenon of seasonal hypoxia in near-bottom water. The presence of hypoxic near-bottom water at and around the disposal site for part of the summer would support the conclusion that the presence of stressed benthic communities is probably unrelated to disposal activities but more likely due to the more pervasive water column phenomenon. In order to confirm the existence and document the extent of hypoxic near-bottom water at the CLIS site, measurements of dissolved oxygen concentrations throughout the water column were taken at on-site and reference REMOTS® stations.

## 2.0 METHODS

### 2.1 Navigation and Bathymetry

The precise navigation required for all field operations was provided by the SAIC Integrated Navigation and Data Acquisition System (INDAS). A complete description of this system is provided in DAMOS Contribution #48 (SAIC, 1985). Shore stations used in the 1987 field operations were established at known benchmarks on Stratford and Lighthouse Points, CT to allow accurate comparisons with results from previous surveys.

The purpose of the precision bathymetric survey performed at the CLIS-86 mound was to delineate the extent and topography of the deposit created by the past year's disposal activity. Depth was acquired using a Raytheon DE-719 Precision Survey Fathometer with a 208 kHz transducer and a SSD-100

Digitizer, as described in DAMOS Contribution #48 (SAIC, 1985). The fathometer was calibrated by adjusting the speed of sound to the value observed on the digitizer. The reference speed of sound was adjusted to 4800 ft/sec on the digitizer. The actual speed of sound was determined from the water temperature and salinity data obtained using an Applied Microsystems CTD/DO probe. These values were used later during analysis of the bathymetry.

The bathymetric survey encompassed a 1200 x 1200 m grid centered around the CLIS-86 disposal point at coordinates 41 09.250N and 72 53.950W. Forty-nine lanes were run east and west at 25 m lane spacing. This survey configuration provided adequate coverage to visually assess the distribution of dredged sediment deposited at the CLIS-86 mound in the past year by comparision with previous surveys. The survey grid purposely encompassed an area large enough to include the region approximately 475 m northwest of the buoy where dredged material had also been deposited.

During analysis of the bathymetric data, the raw depth values were corrected to Mean Low Water by adjusting both for ship draft and for tidal changes for the duration of the survey. All depth and position data points were checked for unreasonable values so that the final contour plots did not contain errors.

## 2.2 REMOTS® Sediment Profile Photography

REMOTS® sediment-profile photographic surveys have been carried out at CLIS since August 1982. One use of REMOTS® photography is to detect and map the distribution of thin (1-20 cm) dredged material layers. This capability compliments the precision bathymetric data which can resolve bottom elevation changes greater than or equal to 20 cm in thickness. In addition, REMOTS® is used to map benthic disturbance gradients and to monitor the process of infaunal recolonization at and adjacent to disposal mounds. A detailed description of REMOTS® image acquisition, analysis and interpretative rationale is given in DAMOS Contribution #60 (SAIC, 1989a).

A total of 120 REMOTS® stations were occupied at the CLIS disposal site in August and September 1987. All station designations were based on a station's position relative to a given disposal mound's center. Three replicate REMOTS® images were obtained and analyzed at all stations. Thirty-seven of these stations were situated around the CLIS-86 disposal point (Figure 2-1) to assess the distribution of dredged material deposited in 1986 and 1987. A majority of these stations were located northwest of the disposal buoy because scow logs indicated that most of the material was deposited in this location. Seventy-nine REMOTS® stations were centered around four other CLIS mounds (FVP, MQR, NH-83, and STNH-S) to continue long-term monitoring of the physical and biological conditions at each of these previously-used disposal points.

The CLIS-86 and FVP mounds are located in the northwest and northeast corners of the CLIS site, respectively (Figure 1-1). For purposes of presentation, these mounds are discussed separately in the sections that follow. The results of the REMOTS® surveys at the MQR, NH-83 and STNH-S mounds are presented together because these three mounds, which occur as a group along the southern boundary of the CLIS site (Figure 1-1), have in past years generally exhibited lower REMOTS® Organism-Sediment Index (OSI) values than other CLIS mounds. The OSI is a multi-parameter value used to characterize habitat quality.

In order to compare ambient and on-site conditions at the five disposal mounds, four reference stations (CLIS-REF, and 4500E, 2000S, and 2500W of the CLIS-86 center) were occupied to provide information on the surrounding seafloor. The replicate values obtained at these reference stations were pooled for the statistical comparisions between reference and on-site REMOTS® parameters.

## 2.3 Sediment Sampling and Analysis

To assess the transport and redeposition of contaminants, sediment samples were collected at 13 stations (including reference stations) starting at the center of the CLIS-86 disposal mound and extending along transects in both the ebb and flood current directions (Figure 2-2). Triplicate grab samples were collected at each station using a 0.1 $m^2$ Smith-McIntyre grab sampler. Five polycarbonate plastic core liners (6.5 cm ID) were pushed into each sediment grab sample and extracted; the top 2 cm of sediment from four 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 grab were combined and placed into a bag for subsequent physical analysis by the NED laboratory. The samples were kept cold and returned to the NED laboratory where they were stored at 4C until analyzed. The parameters measured included 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).

## 2.4 Body Burden Analysis

Test organisms for body burden analysis were collected at 6 stations (including the reference station CLIS-REF) at the CLIS-86 mound (Figure 2-2) using a Smith-McIntyre grab. 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 for triplicate analyses at all of the stations. The animals were allowed to purge any sediment from their guts for 24 hours before they were frozen for transport to the laboratory for chemical analysis. These polychaetes were analyzed for five metals (Fe, Cd, Hg, Pb, and Cu) and PCBs. 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).

### 2.5 Dissolved Oxygen Measurements

The depth gradient in dissolved oxygen was characterized at REMOTS® stations at the various CLIS mounds using a Rexnord® Instruments Model 66 dissolved oxygen probe interfaced to a CTD probe (Applied Microsystems, Ltd. Model STD-12). Sampling occurred on four different days in late August and early September as follows: CLIS-86 and most of MQR were sampled on 8/26, NH-83 was sampled on 8/27, STNH-S and part of FVP were sampled on 8/28 and the remainder of FVP was sampled on 9/11. Among the reference stations, 2000S was sampled on 8/26 and 2500W was sampled on 8/28, while 4500E and CLIS-REF were sampled on 9/11.

The STD-12, used to measure conductivity, temperature, and pressure (depth), was mounted vertically on the REMOTS® camera frame such that its sensors were located approximately 42 cm from the camera base. The attached Rexnord probe was mounted horizontally on the camera base frame such that its membrane was located ca. 6 to 9 cm above the sediment surface during deployment, depending on how deep the camera frame settled into the bottom. In this configuration, vertical hydrographic profiles were conducted concurrently with the REMOTS® survey.

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. Commands are sent to and data read from the instrument with a Compaq Portable II microcomputer via an RS-232 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 is a polarographic oxygen electrode (platinum-lead galvanic couple with a potassium-iodide electrolyte). The probe was covered with a 1 mm thickness diffusion membrane. Calibration of the Rexnord Model 66 was performed at the SAIC Oceanographic Service Center by standard method of comparison with Winkler titration (Strickland and Parsons, 1972). Calibration must be done whenever the membrane and 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 following Perkin and Lewis (1980).

# 3.0 RESULTS

## 3.1 Bathymetry

Four distinct disposal mounds represented by sharp rises in topography were included within the survey area: CS-1, CS-2, CLIS-86, and part of NOR in the southeast corner of the surveyed area (Figure 3-1). According to scow logs, disposal occurred up to 400 feet (120 m) north of the buoy. Comparison of the present results with the 1986 bathymetric survey (Figure 3-2) indicates that new dredged material accumulated on the bottom approximately 75 m north of the disposal buoy, slightly northwest of the 1986 mound peak. This new mound grew from a depth of approximately 18 m in 1986 to 16.4 m in the present survey. At the 1986 mound peak, which was slightly east of the buoy, the depth changed from 17 m in 1986 to 16.4 m at present.

A field check during the disposal operations placed a second disposal point north to northwest of the buoy and up to 475 m away. To verify this, Loran coordinates taken from scow logs were converted to latitude and longitude and plotted at the same scale as the contour plots (Figure 3-3). Two distinct disposal locations existed. One scattered cluster of disposal loci occurred at and around the disposal buoy location (Location A in Figure 3-3), while the second group were oriented in a north-south direction approximately 475 m west and northwest of the buoy (Location B, Figure 3-3).

Results of the 1987 bathymetric survey show no points of rapidly changing relief which might indicate a significant accumulation of dredged material in the region west-northwest of the buoy. However, comparison with the results of the 1986 bathymetric survey shows a new fan-like lobe extending 400 m southeast of the CS-2 disposal site just inside the northwest corner of the disposal site boundary (Figure 3-1). This lobe is delineated as the area where a 0.2 m reduction in depth occurred along the 18.0, 18.2 and 18.4 m contours. More subtle changes in depth occurred northeast and east of the new lobe and southeast of the CLIS-86 mound. No distinct features define these changes but comparisons with the 1986 contour plot indicate maximum reductions in depth of up to 40 cm.

Based on Loran coordinates from scow logs dated 17 October 1986 to 1 May 1987, estimated volumes of sediment deposited at locations "A" and "B" on Figure 3-3 are approximately 37,307 $m^3$ (48,500 $yd^3$) and 74,538 $m^3$ (96,900 $yd^3$), respectively. Loran coordinates were not available for 26 loads of dredged material, representing an additional estimated volume of 27,692 $m^3$ (36,000 $yd^3$). Notes in the scow logs, however, indicate that these loads were disposed within 500 ft (152 m) north and southeast of the buoy. A small capping project conducted in May 1987 added an additional 8,400 $m^3$ (11,000 $yd^3$) of clean sediment at the disposal buoy location.

If approximately 73,399 $m^3$ (37,307 $m^3$ + 27,692 $m^3$ + 8,400 $m^3$) of sediment was disposed at and around the disposal buoy to create a blanket 30 cm thick, an approximate area 500 m by 500 m would be affected. Similarly, if 74,538 $m^3$ of sediment was deposited approximately 475 m west-northwest of the buoy to form an even layer 30 cm thick, it would cover an area of 250,000 $m^2$. The combined area, 500,000 $m^2$, with dimensions 500 m by 1000 m can easily encompass the CS-2 and CLIS-87 disposal points and could explain the dispersed nature of the disposed material.

## 3.2 REMOTS® Sediment-Profile Photography

### 3.2.1 CLIS-86

At the CLIS-86 disposal mound, recently-deposited dredged material layers were evident in a 600-700 meter diameter "circle" surrounding the buoy (station CTR; Figure 3-4). The boundaries of this mound were distinct to the north, east, and south, where outlying stations showed no evidence of dredged material. To the northwest, west, and southwest, recently-deposited sediments extended onto the flanks of the Cap Site 1 and 2 mounds, where relict dredged material layers, representing the Cap Site deposits, were evident. In the REMOTS® photographs from some stations in this vicinity, "fresh" dredged material could be distinguished from relict layers (Figure 3-5). However, at several stations in the regions 400-800 meters northwest and southwest of the disposal buoy, it was not possible to determine unequivocally whether the observed dredged material represented recent or pre-1986 deposits (Figure 3-6).

The grain size major mode at the majority of stations in the surveyed area was silt-clay (> 4 phi). Sediment identified as dredged material generally consisted of low-reflectance silt-clay having a significant sand or sand layer component (Figure 3-5). Sand layers representing dredged material were widespread in the central and western portions of the area; fine sand (3-2 phi) was predominant at station CTR (Figure 3-7). This sand probably represented the clean capping material disposed at the buoy in May. Sand layers apparently extended to 800 meters west, but at the far western stations it is likely that a portion of the sand represented material used in 1983 for capping at Cap Site 2.

Many photos having dredged material showed a microstratigraphic sequence which reflects a temporally-varying depositional pattern (Figure 3-7). At certain stations indicated in Figure 3-4, dredged material was present but was not evident in all three replicate photos, suggesting small-scale spatial variability in its distribution at these locations (Figure 3-8). Stations immediately outside the perimeter of the dredged material mound, as well as the outlying reference stations, displayed the fine-grained sediments characteristic of the central Long Island Sound seafloor. Despite the recent disposal activity, there was no significant difference in small-scale surface boundary roughness at the stations where dredged material was present (see Figure 3-4) compared with the four outlying reference stations (Mann Whitney U-test; $p = 0.06$; Figure 3-9).

Mean apparent RPD depths at the CLIS-86 mound ranged from 1.9 to 4.4 cm, with most values falling between 2.5 and 3.5 cm (Figure 3-10). There was no obvious spatial pattern in the distribution of apparent RPD depths, but RPD depths at the stations where dredged material was present were significantly shallower than those at the reference stations (Mann-Whitney U-test; $p < 0.05$; Figure 3-11). This reflects the relatively recent deposition of organic-rich dredged material at these stations. For all the stations surveyed, RPD depths had not changed significantly since the July 1986 REMOTS® survey (Mann-Whitney U-test; $p = 0.398$).

The mapped distribution of infaunal successional seres at the CLIS-86 mound (Figure 3-12) shows a group of three stations (200E, 2-200NE, and 200N) lacking evidence of Stage III infauna. Across the remainder of the area, Stage III overlain by Stage I seres predominated (Figure 3-13). A single station, 2-200NW, revealed the presence of ampeliscid amphipods (Stage II assemblage) at the surface. Stage I on Stage III were evident at all outlying reference stations. The successional pattern observed in this survey contrasts with the pattern observed in 1986, when 53% (9 of 17) of the stations surveyed around the CLIS-86 mound exhibited only Stage I seres. Apparently, marked recolonization of the region by deep-dwelling deposit-feeding taxa occurred since the summer of 1986. The widespread appearance of Stage III taxa at the active disposal area indicates that successful infaunal recolonization of the region was occurring despite recent on-going disposal activities.

Only four stations (CTR, 2-200NE, 400W and 6-400NE) exhibited relatively low mean Organism-Sediment Index (OSI) values (i.e., mean OSI < +6; Figure 3-14). The OSI values at stations where dredged material was present were significantly lower than the values at the reference stations (Mann-Whitney U-test; p =

0.150; Figure 3-15). This reflects the fact that the area in the immediate vicinity of the buoy was physically disturbed as a result of the relatively recent disposal activity. The remaining stations, as well as all reference stations, exhibited higher OSI values which are characteristic of undisturbed benthic environments.

### 3.2.2 FVP

REMOTS® stations at the FVP site (Figure 3-16) have been occupied since August 1982. The apparent extent of the dredged material mound in the present survey (Figure 3-17) was similar to that mapped in 1986. This mound occupies the same area originally overlain by a relatively thick dredged material layer (i.e., > 10 cm) during the immediate post-disposal REMOTS® survey in May 1983. The dashed line in Figure 3-17 delimits the extent of the dredged material mound as mapped in May 1983. The region between the dashed and solid lines reflects the original mound flanks (0-10 cm thickness). In the 4 years since disposal, the optical signature of the dredged material layers in these flank regions has been erased by biogenic and/or physical mixing of the low-reflectance dredged material with ambient sediments (Figure 3-18).

Sediment grain-size and textures have not changed at the FVP mound since the 1986 survey. All stations were dominated by silt-clay sediments, with a subordinate sand component near the sediment surface. A distinct sand layer, buried beneath approximately 2 cm of silt, remained evident at the center station (Figure 3-19). The sand, which has been observed at this station since January 1984, is believed to represent a lag deposit formed by the winnowing effects of bottom currents concentrated at the mound top. The subsequent deposition of silt over this lag deposit suggests that these winnowing forces had either significantly decreased in intensity or were no longer active, possibly as a result of flattening of the mound top. While most stations revealed relatively intact, undisturbed surface textures, evidence of scattered, small-scale disturbance, such as mud clasts and shell lag deposits, was present in some replicates (Figure 3-20).

Most of the area at FVP exhibited relatively deep (i.e., > 3.0 cm) mean apparent RPD values (Figure 3-21). Four central stations (CTR, 2-300NW, 200N, and 2-300NE) showed slightly shallower RPD depths. Collectively, the RPD depths at the stations where dredged material was present (see Figure 3-17) did not differ significantly from those at the CLIS reference stations (Mann-Whitney U-test; $p = 0.646$; Figure 3-22). This suggests that in terms of biogenic sediment reworking activity, the FVP mound was indistinguishable from the ambient seafloor.

Only the center station at FVP lacked evidence of Stage III infauna (Figure 3-23). This pattern is consistent with that observed in 1986, when only station 100W lacked Stage III seres. Overall, 63% of the FVP replicates and 75% of the reference replicates exhibited Stage III infauna. This is comparable to 1986, when approximately 70% of the FVP replicates exhibited Stage III infauna. This was the first time that ampeliscid amphipods (Stage II taxa) were observed in REMOTS® photographs from FVP. These amphipods, which were present at several stations to the north and east of the center, occurred as scattered individuals rather than the dense surface mat assemblages typical of these forms (Figure 3-24).

Reflecting a relatively shallow RPD depth and a lack of Stage III infauna, station CTR at FVP exhibited an average OSI value (4.7) which is considered indicative of a stressed benthic habitat (i.e., < +6; Figure 3-25). There was no significant difference between OSI values at the FVP mound stations where dredged material was present versus the pooled values at the four reference stations (Mann-Whitney U-test; $p = 0.508$; Figure 3-26). This suggests that the quality of the benthic habitat in the region where disposal had occurred at FVP was similar to that on the ambient seafloor.

### 3.2.3 MQR/NH-83/STNH-S

At the REMOTS® stations at MQR, NH-83 and STNH-S (Figure 3-27), dredged material layers thicker than the depth of penetration of the REMOTS® prism occurred in the immediate vicinity of the center of all three mounds (Figure 3-28). This is almost identical to the distribution of dredged material observed at these mounds during the previous survey of July 1986.

At the majority of stations, the dredged material retained a characteristic appearance: low reflectance, fine-grained sediment having high apparent biological and chemical oxygen demand (Figure 3-29). At a few stations (600S and 2-200SE at NH-83; 200N at STNH-S), dredged material previously observed in July 1986 was evident in only one out of the three replicate images. This suggests either that the material had a patchy distribution at these locations, or that the optical signature of the dredged material layer had been erased or distorted by biogenic and/or physical mixing of the material with ambient sediments. This latter process may explain the occurrence of discrete "relict" dredged material layers at stations located primarily near the flanks of the mounds, where continuous layers had previously been observed in July 1986 (Figure 3-30).

The grain size major mode at the majority of stations was silt-clay (> 4 phi) or very fine sand-silt-clay (> 4-3 phi). Apparent dredged material generally was characterized by high reflectance silt-clay with a subordinate sand component overlying low reflectance mud (sand over mud stratigraphy; Figure 3-29).

It is notable that the methane gas production observed at MQR station 200N in July 1986 was also evident in the present survey (Figure 3-31). This may indicate unusually high and persistent oxygen demand in the sediment at this station. In addition, the low-reflectance over high-reflectance stratigraphy observed in July 1986 at STNH-S station 200W was still evident (Figure 3-32). As suggested in 1986, a cohesive clay layer may exist in this quadrant of the disposal mound. Elsewhere at the three disposal mounds, shell lag deposits were present at some stations (Figure 3-31).

At the stations where dredged material was present at each of the three disposal mounds (see Figure 3-28), boundary roughness values did not differ significantly from those at the reference stations (Mann-Whitney U-test; $p = 0.69$ at MQR, $p = 0.33$ at NH-83, $p = 0.50$ at STNH-S). The majority of boundary roughness values fell within the range 0 to 1.0 cm, indicating a lack of enhanced surface relief at the disposal mounds (Figure 3-33). This might be expected given the fact that disposal activity had not occurred in this area for at least three years prior to the July 1987 survey.

Stations having mean apparent RPD depths less than 3 cm occurred in relatively small areas north and south of the NH-83 center and in the immediate vicinity of the STNH-S center (Figure 3-34). Compared to July 1986, there was no consistent pattern in the present mapped distribution of mean RPD values at these mounds. However, at MQR it is notable that the > 3 cm values obtained at the majority of stations were consistently deeper than in July 1986.

The frequency distributions of RPD values are remarkably similar among the three mounds and the reference stations, with most values falling between 2.5 and 4.5 cm (Figure 3-35). The RPD depths at the stations where dredged material was present were not significantly different from the reference values ($p = 0.55$ at MQR, $p = 0.68$ at NH-83, $p = 0.26$ at STNH-S; Mann-Whitney U-test). Compared to July 1986, RPD depths pooled among all the stations surveyed at each mound were significantly deeper at MQR and NH-83 ($p < 0.05$ in both cases, Mann-Whitney U-test), while they had not changed significantly at STNH-S ($p = 0.49$, Mann-Whitney U-test).

Only seven stations located in three small areas across the MQR, STNH-S and NH-83 mounds lacked evidence of Stage III infauna (Figure 3-36). Across the remainder of the three mounds and at all outlying reference stations, Stage III overlain by Stage I seres predominated (Figure 3-37). A number of stations, particularly at the STNH-S mound, were designated as Stage I going to Stage II, due to the presence of the shallow-dwelling bivalve <u>Mulinia lateralis</u> (Figure 3-32).

The successional stages observed at the three mounds contrast sharply with those observed in July 1986. At that time, only 31% of the replicate images from the MQR mound showed Stage III infauna to be present, compared with 46% in the present survey. At the NH-83 mound, the number of replicates showing Stage III increased dramatically from 24% in 1986 to 63% in this survey. Likewise, the number of Stage III replicates increased from 41% to 59% at STNH-S. At all three mounds, the increase in Stage III infauna suggests that marked recolonization of the region by deep-dwelling deposit-feeding taxa had occurred since the summer of 1986. At the MQR mound, this increase represents a continuation of the trend in recolonization noted at this site in July 1986.

Areas exhibiting relatively low average OSI values (i.e., < +6) were limited in extent and occurred east and west of the MQR center and north of the STNH-S center (Figure 3-38). At the MQR and NH-83 mounds, the OSI values at stations where dredged material was present were not significantly different from the reference values ($p = 0.10$ at MQR and $p = 0.68$ at NH-83; Mann-Whitney U-test; Figure 3-39). At the STNH-S mound, OSI values at the dredged material stations were significantly lower than those at the reference stations ($p < 0.05$, Mann-Whitney U-test). Compared to the July 1986 survey, the overall mean OSI value at each mound increased. This increase is statistically significant at the MQR and NH-83 mounds ($p < 0.001$ and $p = 0.004$, respectively, Mann-Whitney U-test). Compared with the July 1986 results, mounds in the present survey exhibited more extensive areas with OSI values characteristic of relatively undisturbed benthic environments (OSI > +6). These results reflect the general deepening of the RPD and increased colonization by Stage III infauna which characterized the MQR, NH-83, and STNH-S mounds in the year between the 1986 and 1987 surveys.

## 3.3 Sediment Sampling and Analysis

The stations where sediment sampling occurred were designated according to their position in relation to the CLIS-86 mound center, with the exception of the station located 1000 m east of the FVP mound center (station 1000E FVP). Sediments at all thirteen stations were characterized as olive gray silt or silty sand (Table 3-1). Significant amounts of fine and medium sand occurred at stations CTR, 400W, 1000N and 2000E. This sand occurred in a higher proportion than the silt at stations CTR and 1000N.

With the exception of Hg at station 400E, the mean concentrations of Hg, Pb, Zn, As, Cd and Cu (Table 3-2) were at

Class I levels at all reference and on-site stations, according to the New England River Basin Commission's (NERBC) interim criteria (NERBC, 1980). The Class II concentration of Hg at station 400E (0.52 ppm) barely exceeded the Class I upper limit of 0.50 ppm. Although NERBC criteria do not exist for Fe, PHC's (petroleum hydrocarbons) and percent total organic carbon (Table 3-2), statistics show that the mean concentration of every chemical measured in triplicate at each on-site station was either significantly less than or not significantly different from the corresponding mean reference concentration (Table 3-3). The single exception to this was a significant elevation of Cu at station 400E, even though it was at Class I levels. Graphs of the sediment chemistry results (Figures 3-40 and 3-41) show that the mean concentration of Cu at station 400E (82 ppm) was of similar magnitude to the mean concentration at the reference stations (55 ppm).

Concentrations of organochlorine pesticides and PCB's in sediments at CLIS were below the analytical detection limits at almost all of the reference and on-site stations (Table 3-4). Exceptions to this were detectable levels of PCB's as Aroclor 1242 at stations 1000E of FVP and 3500E, and as Aroclor 1248 at stations 2000S, 1000N, and 1500SW. Concentrations of PCB's at these stations were from over five times to an order of magnitude lower than the 1.0 ppm level considered to be confirmation of high contamination according to the NERBC interim criteria (NERBC, 1980). Likewise, the 0.2 ppm DDT detected at station 2000E and the 0.19 ppm DDT detected at station 400E were well below the NERBC's high-contamination standard of 0.5 ppm. Methoxychlor occurred at station 1000N at a concentration barely above the analytical detection limit.

## 3.4 Body Burden Analysis

Similar to the general pattern of sediment contaminant levels, Nephtys body burdens at stations in and around the disposal site were generally below detection limits or were either significantly less than or not different from those at the reference station. These results are to be used in an initial assessment of the relation between sediment contamination and biological uptake. Statistical tests for association between sediment concentrations and body burdens indicated a lack of significant correlation between the two. However, definitive conclusions were avoided in light of the small data set collected in this and prior surveys.

The results of the triplicate analyses for five trace metals (Cd, Pb, Cu, Fe and Hg) in body tissues of Nephtys collected at the CLIS disposal site are reported on a dry weight basis (Table 3-5). Concentrations of Cd, Pb and Hg in the polychaetes were below the analytical detection limits at both the reference and on-site stations. Body burdens of Cu at station 1500W and of Fe at all stations except CTR were significantly lower than the reference (Table 3-6). Body burdens of Cu were significantly greater than the reference levels at stations 1000E of FVP, CTR and 400W, while Fe was significantly elevated at station CTR (Table 3-6). Graphs of the results illustrate the relative magnitudes of these elevations above reference levels (Figure 3-42).

Detectable levels of PCB's (as Aroclor 1254) occurred in Nephtys at both the reference and on-site stations (Table 3-7). The graph of these results indicates that the highest levels of PCB's were found in the polychaetes from station 1500W, and relatively high levels occurred in the reference animals (Figure 3-42). PCB body burdens in Nephtys at station 1500W were significantly higher than the reference levels, while body burdens at stations 400W and 1000E of FVP did not differ significantly from the reference and those at stations CTR and 400E were significantly less (Table 3-6).

## 3.5 Dissolved Oxygen

Near-bottom dissolved oxygen concentrations measured at the REMOTS® stations at the various CLIS mounds are plotted in Figures 3-43, 3-44 and 3-45. Differences among the mounds were the result of day-to-day variations in the measured DO concentrations, which showed a decreasing trend over the four days of sampling. On any given day there was relatively little variability between stations. For instance, values measured on 8/26 at the CLIS-86 and MQR mounds ranged between 3.94 and 5.46 mg/ (Figures 3-43 and 3-45), while those measured on 8/27 at NH-83 ranged from 2.39 to 3.13 mg/ (Figure 3-45). The range of values on 8/28 at STNH-S and at some FVP stations was 2.03 to 3.37 mg/ (Figures 3-44 and 3-45), while the remainder of FVP stations had a range of 2.03 to 2.36 mg/ on 9/11. At the reference stations, a DO concentration of 4.92 mg/ was measured at 2000S on 8/26 and 2.92 mg/ was measured at 2500W on 8/28, while on 9/11 stations 4500E and CLIS-REF had values of 2.36 and 2.32 mg/, respectively (Figure 3-43).

Representative plots of the depth gradients in dissolved oxygen, temperature, salinity, and density (as sigma-t) for at least half of the REMOTS® stations at each mound are given in the Appendix. Like the near-bottom DO values, these variables exhibited much more between-day than within-day variability. In the plot from CLIS-86 station 4-400SW on 8/26 (Figure 3-46), there was a subsurface temperature minimum between 5 and 10 m in depth, while salinity and density showed only a slight gradual decrease from the surface to the bottom. DO concentrations also decreased gradually from a little over 6 mg/ at the surface to about 5 mg/ at depth.

At the MQR stations sampled on 8/26 and the NH-83 stations sampled on 8/27, there was evidence of a slight halocline at a depth of about 10 m, as illustrated in the representative plot from NH-83 station 1000S (Figure 3-47). Coincident with this halocline there was a very slight temperature decrease and density increase, while DO concentration was remarkably uniform throughout the water column. A very similar pattern was seen on 8/28 at the STNH-S stations, as illustrated in the representative plot from station 200SW (Figure 3-48). A different pattern, however, was seen at the FVP stations sampled on 8/28. At these stations, the temperature, salinity, density, and DO values showed absolutely no variation with depth, as illustrated in the plot from station 150E (Figure 3-49).

There was little variation among the CTD/DO plots obtained at all stations on 9/11. The representative plot from FVP station 1000E indicated a thermocline established between 5 and 10 m and a slight, gradual increase in salinity and density with depth (Figure 3-50). As on the preceding days of sampling, there was virtually no variation in DO concentrations from surface to bottom.

The near-bottom DO concentrations and the gradients in DO, temperature, salinity, and density at the reference stations were similar to those measured at the on-site stations on any given day of sampling. The only exception to this was station CLIS-REF (Figure 3-51), where the salinity values were about 5 parts per thousand lower and there were slightly sharper vertical gradients in both salinity and temperature compared to the other stations sampled on 9/11.

## 4.0 DISCUSSION

### 4.1 Bathymetry

The objective of the bathymetric survey at the CLIS-86 mound (Figure 3-1) was to delineate the extent and topography of the dredged sediment deposit resulting from the year's disposal activities. Due to miscommunications among the dredging contractors, dredging inspectors, and NED regulatory personnel about the precise location of the disposal point at CLIS-86 following buoy redeployment, two predominant disposal locations existed. Comparison of the 1987 bathymetric contour plot (Figure 3-1) with that of July 1986 (Figure 3-2) revealed significant depth changes at both of these locations. In the vicinity of disposal location "A" (Figure 3-3), the 1986 disposal mound peak located east of the buoy grew by a maximum of 80 cm, while the new peak 75 m north of the buoy represented a mound with a maximum thickness of 2.4 m (Figure 3-1). Volume estimates derived from scow logs placed a total of 73,000 $m^3$ of dredged sediment at the buoy, including 8,462 $m^3$ representing a capping operation conducted in May of 1987.

A 20 to 40 cm reduction in depth took place between the CLIS-86 and CS-2 disposal mounds, as a result of disposal in location "B" (Figure 3-3). The disposed sediment occurred as a low, broad mound which appeared as a lobe extending up to 480 m southeast of the CS-2 mound. Patchy areas of depth change occurred east and northeast of the lobe and blended with disposal operations conducted in the vicinity of the buoy. The peaks of the CS-2 and CLIS-86 disposal points grew by a maximum of 40 cm.

The new mound located 75 m north of the buoy is attributed to the concentration of dredged sediment deposited at the buoy. The new lobe extending southeast of the CS-2 disposal mound also represents a concentration of dredged sediment, but it is not seen as a point of rapidly changing relief on the 1987 bathymetric chart. Patchy areas of depth change could be attributed to scattered disposal events occurring around the buoy, as well as around the disposal point located approximately 475 m northwest of the buoy (in Figure 3-3, locations "A" and "B", respectively).

## 4.2 REMOTS® Sediment-Profile Photography

One major objective of the August 1987 REMOTS® surveys at the CLIS disposal site was to delineate the extent of dredged material deposited during the past year at the CLIS-86 disposal mound. The results indicated that most of the disposed material was located primarily in the immediate vicinity of the disposal buoy, in agreement with the results of the bathymetric survey.

The locations of the northern, eastern and southern boundaries of the disposal mound were readily inferred based on the REMOTS® images obtained in the present survey. Determining the boundaries to the northwest, west and southwest was more difficult due to the proximity of the Cap Site 1 and 2 historical deposits. The difficulty stemmed from the inability to distinguish between "relict" and "fresh" dredged material in some of the REMOTS® photos at these locations. It appeared that patches of fresh dredged material were intermixed with relict deposits at several western flank stations, obscuring the boundary marked by the most recently deposited material. This agrees well with the results of the bathymetric survey and the scow log plots, which had shown that patchy areas of depth change attributable to scatterred dredged material deposits occurred in the area between the CS-2 and CLIS-86 mounds.

A second major objective of the 1987 REMOTS® surveys was to monitor infaunal recolonization rates at the CLIS-86, FVP, MQR, NH-83, and STNH-S disposal mounds. At FVP, the relatively high percentage of replicates showing Stage III infauna basically was unchanged from July 1986. At the CLIS-86, NH-83, and STNH-S mounds, the increase in deep-dwelling, deposit-feeding taxa indicates extensive colonization occurred since the July 1986 survey. This was particularly significant at NH-83 and STNH-S, two mounds which in the past have generally exhibited lower benthic indices than other mounds at the CLIS disposal site. It should be noted, however, that the increase in Stage III taxa may not be as dramatic as the numbers suggest, because only a single replicate image from each station at the CLIS-86, NH-83, and STNH-S mounds was analyzed in July 1986. Because of within-station patchiness in their distribution, Stage III taxa which might have been present at the time of the earlier surveys could easily have been missed.

In July 1986, Stage III taxa were noted at the MQR mound for the first time since the initial REMOTS® survey at this site in January 1983. The present survey confirms that the MQR mound, which historically has experienced the slowest rate of recolonization among CLIS mounds, continued to be colonized successfully. The significant deepening of the RPD noted at most MQR stations presumably reflects the increased bioturbation associated with a greater number of Stage III infauna.

The results of the statistical comparisons indicated that the stations at the CLIS-86 mound where dredged material was present had RPD depths which were significantly shallower and OSI values which were lower than at the reference stations. This reflects the physical disturbance of the seafloor in this area as a result of the relatively recent dredged material disposal activities. Given continued infaunal colonization of this mound once disposal activities cease, it is expected that future benthic conditions in this area will become comparable to those on the ambient seafloor. For all the stations surveyed at the other mounds, RPD depths and OSI values were not significantly different from those at the reference stations. This suggests that at the time of sampling, the benthic habitat quality at these past disposal mounds was comparable to that which existed on the ambient seafloor in this part of Long Island Sound. Table 4-1 is a summary ranking of the mean OSI values for the reference stations and for all stations sampled at each of the CLIS disposal mounds surveyed in 1986 and 1987. With the exception of CLIS-86, the ranking of the various mounds has remained unchanged compared to 1986. Although the 1986 and 1987 OSI values at CLIS-86 were not significantly different, the lower ranking in 1987 probably reflects the physical disturbance at this mound resulting from the disposal activities of the past year.

The increase in the mean OSI values at the MQR, NH-83, and STNH-S mounds is extremely noteworthy. Previous surveys have indicated unusually slow recolonization rates and low benthic indices at these three mounds. The higher OSI values reflect the general increase in Stage III infauna and deepening of the RPD which have occurred in this region since 1986.

## 4.3 Sediment Sampling and Analysis

The results of physical testing of sediments at CLIS, which show that mixtures of silt or silty sand predominated at all stations, generally agree well with the results obtained in the REMOTS® survey (Figure 3-4). This is particularly true at the stations directly on the disposal mound (i.e., CTR and 400W), where high proportions of medium and fine sand reflected inputs of dredged sediments which were predominantly sand (55-65%) with lesser amounts of silt and clay. The high sand content at off-mound stations 2000E and 1000N possibly reflects natural heterogeneity in sediment types in these areas. At 1000N, the high sand content also is possibly a result of the significant bottom disturbance (e.g., erosion of fines and/or deposition of sand) which was found to have occurred at stations shoreward of the CLIS disposal site following Hurricane Gloria in September 1985 (SAIC, 1989b).

One objective of the sediment chemical analyses was to determine if the concentrations of sediment-associated contaminants indicated evidence of any resuspension, transport, and redeposition. Concentrations of metals in surface sediments on the disposal mound (i.e., within about a 400 m radius of the buoy) typically were either below analytical detection limits, were significantly less than or did not differ significantly from those measured at the reference stations. These results are not surprising considering the fact that most of the material disposed later in the season was relatively uncontaminated, especially the clean sediments deposited at the buoy in May during the small capping operation. While Cu at station 400E was elevated compared to the reference level, this and most of the other metals occurred at Class I levels at all stations. Thus, there was little evidence in the mound surface sediments of the relatively high (i.e., Class II and III) levels of Pb, Zn, Cd, Cu, and Hg contained in the dredged material disposed earlier in the 1986-87 disposal season. Likewise, significant contamination was not observed in and around the disposal mound in terms of Fe, % total carbon, organochlorine pesticides, PHC's and PCB's. The Class II concentration of Hg at 400E was very close to the Class I upper limit and was largely due to a single and possibly outlying replicate value (Table 3-2).

At the CLIS-86 mound, the lack of a significant contaminant signature in surface sediments suggests that contaminated material disposed earlier in the year remained buried beneath the clean cap material and thus was effectively isolated from contact with the overlying water. If contaminant transport and redeposition were occurring along the east-west transect defined by stations 1500W, 400W, CTR, 400E, 2000E and 3500E (the axis of predominant current movement), it is expected that contaminants would be detected above natural background levels and would follow a decreasing concentration gradient from the mound to the outlying stations. In fact, graphs of the sediment chemistry data (Figures 3-40 and 3-41) show that in general, concentrations were slightly elevated at the outlying transect stations (1500W, 2000E, 3500E) relative to the mound transect stations (400W, CTR, 400E). However, none of the outlying stations showed elevated contaminant concentrations relative to background (i.e., reference) levels, which might be expected if contaminant transport was occurring.

Statistical tests showed that among the six transect stations, there were no significant differences in the concentrations of Hg, Pb, Zn, As, Cu, PHC's, and % total carbon (Kruskal-Wallace one-way analysis of variance, $p > 0.05$). When the transect stations were pooled, the resulting mean concentration of each of these contaminants was not significantly different from the corresponding mean reference value (Mann-Whitney U-test, $p > 0.05$). The mean Fe concentration at the reference stations was significantly higher than that at the pooled transect stations (Mann-Whitney U-test, $p = 0.0136$).

The fact that contaminant concentrations did not differ among the transect stations and in turn the mean concentration of each contaminant for the pooled transect stations was either significantly less than or not different from the mean reference station value suggests a lack of transport of contaminants from the CLIS disposal site. This is valid both in a short-term sense for contaminants from the CLIS-86 mound (the active disposal point), as well as in a long-term, cumulative sense for contaminants from any of the disposal mounds at the site. Unfortunately, the question of near-field contaminant transport could not be readily addressed given the relatively large distances (typically 1 km) between some of the transect stations. At this scale, it might be expected that contaminants transported either during disposal or as a result of resuspension of mound sediments would be substantially diluted by background material. The question of near-field transport could be explored in future monitoring efforts by using more closely-spaced transect stations.

## 4.4 Body Burden Analysis

Reflecting the general pattern of sediment contaminant levels, Nephtys body burdens at stations in and around the disposal site were generally below detection limits or were either significantly less than or not different from those at the reference stations. The only two contaminants displaying both body burdens and sediment concentrations above detection limits at all stations were Cu and Fe. In view of the objective of the body burden analyses, a nonparametric test for association (Spearman's coefficient of rank correlation) was employed to assess the degree of correlation between sediment concentrations and body burdens of Cu and Fe. This test showed that the mean body burden concentrations of Fe and Cu were not significantly associated with the mean concentrations of these metals in the sediment at the body burden stations (Spearman's rho = -0.31 for Cu and 0.14 for Pb, $p > 0.05$).

In the July 1986 survey at CLIS (SAIC, 1990), significantly elevated levels of Cr and Cu were found both in the sediment and in Nephtys at the MQR and FVP mounds, suggesting a positive correlation between sediment contamination and bioaccumulation. At the same time, however, elevated concentrations of Cr, Cu, and Zn in Nephtys at the STNH-N mound did not correspond with significantly elevated sediment concentrations of these three metals. At the New London disposal site in 1986 (SAIC, 1989a), no association was found between the elevated sediment concentrations of several contaminants and body burden levels in the bivalve Pitar sp.. Given these past results, and considering the relatively small sample sizes and the uncertain exposure history of the Nephtys collected in the present study, definitive conclusions regarding the degree of association between sediment contaminant levels and bioaccumulation are premature.

## 4.5 Dissolved Oxygen Regime

The results of the CTD/DO sampling at the CLIS disposal site indicate a significant day-to-day variation both in near-bottom DO concentrations and in the vertical distributions of DO, temperature, salinity, and density. Within-day or between-day variability in the distributions of these parameters may in part be due to tide- or wind-induced mixing of the water column which is a characteristic physical process in an estuary such as Long Island Sound. Such mixing may explain why on 8/28 the CTD plots from stations sampled in the morning at the STNH-S mound show that some vertical stratification was present (Figure 3-48), while the plots from stations sampled in the afternoon at the FVP mound suggest a very well-mixed water column (Figure 3-49). The absence of near-bottom oxygen depletion and the uniform vertical distribution of dissolved oxygen observed at nearly every station over the four sampling days further suggest that the water column was well-mixed with respect to this parameter. During the warmer summer months in some years, mixing of the water column may not occur for extended periods of time, leading to development of water column stratification which may persist. At such times, it is possible for dissolved oxygen depletion in near-bottom waters to become severe enough to cause mass mortality of bottom-dwelling organisms.

Although vertical gradients in temperature, salinity, and density are discernible in many of the CTD/DO plots in this survey, normally estuaries such as Long Island Sound are not permanently stratified. It is likely that the the CTD/DO plots reflect spatial and temporal variability in the distribution of different water masses on any given day of sampling. This may explain why on 9/11 station CLIS-REF, located at some distance from the other stations sampled on that day, had in comparision much lower salinity and slightly sharper vertical gradients in salinity and temperature.

The literature on the distribution of benthic assemblages in permanently stratified (low-oxygen) marine basins provides information on "critical" thresholds of low dissolved oxygen and infaunal distributions (Rhoads and Morse, 1971). These thresholds, shown in Table 4-2, indicate that water which could be classified as hypoxic was present from the surface to the bottom at the stations sampled on 8/27, 8/28 and 9/11. Previous sampling on 8/26 had revealed the presence of aerobic water in this vicinity. Such results reflect the estuarine nature of the CLIS disposal site, where dissolved oxygen concentrations typically may vary diurnally, tidally, and seasonally. The observed trend of decreasing DO concentrations over the four days of sampling may reflect either the in situ depletion of oxygen in this region of the Sound or an influx of low DO parcels of water originating elsewhere. In either case it is important to note that on any given day of sampling, DO concentrations at the reference stations did not appear to be different from those measured at the disposal mounds. This leads to the conclusion that the somewhat transient hypoxic conditions at the mounds were a region-wide phenomenon unrelated to disposal activity.

The main objective of the CTD/DO sampling at the CLIS disposal site was to assess both near-bottom concentrations and depth gradients in dissolved oxygen as an adjunct to interpretation of the REMOTS® benthic analyses at the various mounds. In 1986, it was hypothesized that low OSI values at the MQR, NH-83 and STNH-S mounds might be attributed in part to the Sound-wide phenomenon of hypoxia in near-bottom waters. While it is difficult to relate an instantaneous DO measurement to potential biological effects, the 1987 CTD/DO results do show that the local benthic assemblage typically experiences short-term variability in the DO regime. However, there was no evidence in the REMOTS® photos of widespread hypoxic stress in the benthos at any of the CLIS disposal mounds surveyed. Significantly higher OSI values in 1987 compared to 1986 at the MQR, NH-83, and STNH-S mounds reflect the successful infaunal recolonization which occurred at these sites in the year between the two surveys. Such successful recruitment of infaunal organisms and their continued presence at these mounds suggest an absence of chronic near-bottom hypoxia in the weeks and months preceeding the 1987 survey.

## 5.0 CONCLUSIONS

Precision bathymetric and REMOTS® surveys were carried out with three objectives. The first objective was to delineate the extent and topography of the dredged sediment deposit resulting from the year's disposal activities at the CLIS-86 mound. The results of both of these surveys verified an accumulation of dredged material in the immediate vicinity of the disposal buoy. The bathymetric results showed a mound-shaped deposit centered approximately 75 m north of the buoy, slightly northwest of the 1986 mound peak. REMOTS® photography revealed that thin layers (<20 cm) of the deposited material extended in a 600-700 meter diameter circle surrounding the buoy. The dredged material consisted of low-reflectance silt-clay having a significant sand or sand-layer component, consistent with its grain-size designation prior to disposal. Determining the extent of recently-deposited material in REMOTS® photos from stations to the northwest, west and southwest of the buoy was difficult due to the proximity of the Cap Site 1 and 2 historical deposits.

Scow logs indicated that disposal occurred both at the buoy and in an area approximately 475 m west-northwest of the buoy, leading to the prediction that the disposed sediment would occur as a low, broad mound between the CLIS-86 and CS-2 mounds. Comparisions with the 1986 bathymetric survey confirmed that a new fan-like lobe of deposited material extended 400 m southeast of the CS-2 disposal mound, just inside the northwest corner of the disposal site boundary. This deposit accounted for a 20 to 40 cm reduction in depth in the area between the CLIS-86 and CS-2 disposal mounds. At the other CLIS disposal mounds, where only REMOTS® monitoring occurred in 1987 (FVP, MQR, NH-83 and STNH-S), the apparent extent of dredged material was the same as that mapped in 1986.

The second objective of the REMOTS® surveys at the CLIS disposal site was to monitor biological conditions and document the process of infaunal recolonization at several previously-used disposal mounds. At the FVP mound, the relatively high percentage of replicate REMOTS® images showing Stage III infauna was basically unchanged from July 1986. At the CLIS-86, NH-83, and STNH-S mounds, significant increases in the number of images showing deep-dwelling, deposit-feeding taxa suggested extensive recolonization had occurred since the summer of 1986. Likewise, the increased number of Stage III taxa at the MQR mound indicated a continuation of the trend first noted in the July 1986 survey. The increase in Stage III successional seres and the concomitant increase in OSI values at the MQR, NH-83, and STNH-S mounds is particularly noteworthy, because this southern-most part of the

CLIS disposal site has historically exhibited lower benthic habitat quality than other CLIS disposal mounds.

A third objective of the 1987 field operations at the CLIS disposal site was to assess near-bottom dissolved oxygen concentrations and characterize the depth gradient in DO relative to the REMOTS® benthic analyses at the five disposal mounds surveyed. The results of the CTD/DO sampling indicated the presence of hypoxic water throughout the water column on three of the four days of sampling at the various mounds. This suggests that the local benthic assemblage was experiencing short-term variability in the DO regime at the time of sampling. However, the lack of evidence of widespread stress in the REMOTS® photos, coupled with the higher 1987 OSI values, suggest an absence of chronic near-bottom hypoxia in this region of the Sound in the weeks and months preceding the survey. The observed temporal variablity in DO concentrations suggests either gradual in situ depletion over the sampling period or influxes of low DO parcels of water originating elsewhere. In either case, it was noted that on any given day of sampling, DO concentrations at the reference stations were not different from those measured at the disposal mounds. This led to the conclusion that, as predicted, the somewhat transient hypoxic conditions at the mounds were a region-wide phenomenon unrelated to disposal activity. Variations in the vertical distribution of salinity, temperature, and density were attributed to large-scale mixing processes characteristic of the Long Island Sound estuarine environment.

The results of physical testing of sediments at the CLIS-86 mound agreed well with the REMOTS® grain-size analyses, both indicating presence of dredged material consisting of sand and silty-sand with lesser amounts of clay. The objective of the chemical analyses of sediments from the transect stations was to assess the transport of contaminants from the mound and site along the axis of predominant current movements. Chemical analyses of the surface sediments indicated the occurrence of several metals and PCB's only at Class I concentrations. Likewise, there was no significant contamination observed in and around the disposal mound in terms of Fe, % total carbon, organochlorine pesticides and PHC's. These results provide evidence that the more contaminated material (i.e., Class II and III levels of Pb, Zn, Cd, Cu, and Hg) disposed earlier in the 1986-87 disposal season was buried beneath cleaner capping material deposited during the final weeks of the season. This confirmed the prediction that the majority of sediment-associated contaminants would be deposited within the mound, limiting the potential for further resuspension and transport.

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**Table 3-1**

Results of Physical Testing of Sediment Collected at CLIS, August 1987. Station Designations are in Relation to the CLIS-86 Mound Center, Except for the Station 1000 Meters East of FVP (1000E FVP).

| Station | Visual Classification | % Coarse Material | % Medium Sand | % Fine Sand | % Fines |
|---|---|---|---|---|---|
| CTR | olive-gray silty sand | <1 | 15 | 43 | 42 |
| 400E | olive-gray silt | <1 | <1 | 8 | 92 |
| 400W | olive-gray silt with sand | 5 | 7 | 11 | 77 |
| 1500W | olive-gray silt | <1 | <1 | 3 | 97 |
| 1000E FVP | olive-gray silt | <1 | <1 | 2 | 98 |
| CLIS-REF | olive-gray silt | 1 | 1 | 3 | 93 |
| 4500E | olive-gray silt | <1 | 2 | 3 | 95 |
| 3500E | olive-gray silt | <1 | <1 | 3 | 97 |
| 2000E | olive-gray silt with sand | <1 | 5 | 11 | 84 |
| 2000S | olive-gray silt | <1 | 2 | 3 | 95 |
| 1500SW | olive-gray silt | <1 | <1 | 3 | 97 |
| 2500W | olive-gray silt | <1 | 2 | 4 | 96 |
| 1000N | olive-gray silty sand | 5 | 13 | 44 | 38 |

Table 3-2

Results of Chemical Analyses of Sediment Collected at CLIS, August 1987
(Concentrations Based on Dry Weight; PHC's = Petroleum Hydrocarbons)

| Station/Replicate | Hg ppm | Pb ppm | Zn ppm | As ppm | Fe ppm | Cd ppm | Cu ppm | PHC's ppm | % Total Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|
| REF/1 | 0.21 | 47 | 130 | 8.1 | 25,600 | Nd | 39 | 121.0 | 1.50 |
| REF/2 | 0.17 | 44 | 119 | 7.3 | 23,700 | Nd | 37 | 134.0 | 1.70 |
| REF/3 | 0.16 | 46 | 113 | 5.9 | 24,400 | Nd | 37 | 183.0 | 1.60 |
| Mean | 0.18 | 46 | 121 | 7.1 | 24,567 | - | 38 | 146.0 | 1.60 |
| ±Std. Dev. | 0.03 | 2 | 9 | 1.1 | 961 | - | 1 | 32.7 | 0.10 |
| 4500E/1 | 0.27 | 55 | 151 | 5.3 | 31,800 | Nd | 53 | 177.0 | 2.60 |
| 4500E/2 | 0.23 | 50 | 136 | 5.3 | 28,500 | Nd | 50 | 184.0 | 2.20 |
| 4500E/3 | 0.27 | 58 | 156 | 6.9 | 28,800 | Nd | 57 | 158.0 | 2.00 |
| Mean | 0.26 | 54 | 148 | 5.8 | 29,700 | - | 53 | 173.0 | 2.27 |
| ±Std. Dev. | 0.02 | 4 | 10 | 0.9 | 1,825 | - | 4 | 13.5 | 0.31 |
| 2000S/1 | 0.25 | 55 | 148 | 6.8 | 27,800 | Nd | 55 | 198.0 | 3.60 |
| 2000S/2 | 0.26 | 53 | 157 | 5.9 | 30,200 | Nd | 58 | 190.0 | 1.70 |
| 2000S/3 | 0.26 | 56 | 149 | 7.0 | 28,900 | Nd | 55 | 225.0 | 1.50 |
| Mean | 0.26 | 55 | 151 | 6.6 | 28,967 | - | 56 | 204.3 | 2.27 |
| ±Std. Dev. | 0.01 | 2 | 5 | 0.6 | 1,201 | - | 2 | 18.3 | 1.16 |
| 2500W/1 | 0.29 | 59 | 152 | 7.1 | 30,700 | Nd | 71 | 242.0 | 1.60 |
| 2500W/2 | 0.32 | 50 | 147 | 6.6 | 30,400 | Nd | 65 | 241.0 | 2.00 |
| 2500W/3 | 0.28 | 39 | 161 | 8.6 | 28,600 | 1.0 | 78 | 264.0 | 1.60 |
| Mean | 0.30 | 49 | 153 | 7.4 | 29,900 | - | 71 | 249.0 | 1.73 |
| ±Std. Dev. | 0.02 | 10 | 7 | 1.0 | 1,136 | - | 6 | 13.0 | 0.23 |

Table 3-2 continued

| Station/Replicate | Hg ppm | Pb ppm | Zn ppm | As ppm | Fe ppm | Cd ppm | Cu ppm | PHC's ppm | % Total Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|
| 1000N/1 | 0.11 | 17 | 43 | 2.5 | 9,410 | Nd | 38 | <50.0[1] | 0.46 |
| 1000N/2 | 0.05 | 10 | 28 | 1.8 | 6,410 | Nd | 14 | <50.0[1] | 0.20 |
| 1000N/3 | 0.11 | 13 | 44 | 3.0 | 9,950 | Nd | 22 | 89.4 | 0.34 |
| Mean | 0.09 | 13 | 38 | 2.4 | 8,590 | - - | 25 | 63.1 | 0.33 |
| ±Std. Dev. | 0.03 | 4 | 9 | 0.6 | 1,907 | - | 12 | 22.7 | 0.13 |

[1] Below analytical detection limits

**Table 3-2 continued**

| Station/Replicate | Hg ppm | Pb ppm | Zn ppm | As ppm | Fe ppm | Cd ppm | Cu ppm | PHC's ppm | % Total Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|
| 1000E FVP/1 | 0.30 | 63 | 165 | 7.6 | 37,300 | Nd | 72 | 183.0 | 1.80 |
| 1000E FVP/2 | 0.29 | 46 | 129 | 6.4 | 24,900 | Nd | 58 | 232.0 | 1.80 |
| 1000E FVP/3 | 0.24 | 45 | 118 | 6.5 | 23,200 | Nd | 45 | 182.0 | 1.90 |
| Mean | 0.28 | 51 | 137 | 6.8 | 28,467 | - | 58 | 199.0 | 1.83 |
| ±Std. Dev. | 0.03 | 10 | 25 | 0.7 | 7,697 | - | 13 | 28.6 | 0.06 |
| 3500E/1 | 0.27 | 59 | 149 | 7.0 | 29,600 | Nd | 56 | 180.0 | 1.90 |
| 3500E/2 | 0.28 | 56 | 138 | 6.4 | 27,400 | Nd | 56 | 165.0 | 2.00 |
| 3500E/3 | 0.34 | 56 | 138 | 6.8 | 28,300 | Nd | 56 | 242.0 | 2.40 |
| Mean | 0.30 | 57 | 142 | 6.7 | 28,433 | - | 56 | 195.7 | 2.10 |
| ±Std. Dev. | 0.04 | 2 | 6 | 0.3 | 1,106 | - | 0 | 40.8 | 0.26 |
| 2000E/1 | 0.26 | 66 | 153 | 7.2 | 25,900 | Nd | 65 | 191.0 | 1.00 |
| 2000E/2 | 0.29 | 55 | 137 | 8.0 | 25,700 | Nd | 62 | 257.0 | 2.40 |
| 2000E/3 | 0.34 | 53 | 161 | 8.3 | 28,200 | Nd | 69 | 252.0 | 1.60 |
| Mean | 0.30 | 58 | 150 | 7.8 | 26,600 | - | 65 | 233.3 | 1.67 |
| ±Std. Dev. | 0.04 | 7 | 12 | 0.6 | 1,389 | - | 4 | 36.7 | 0.70 |
| 1500SW/1 | 0.28 | 46 | 140 | 5.7 | 26,900 | Nd | 61 | 238.0 | 2.00 |
| 1500SW/2 | 0.27 | 48 | 145 | 5.6 | 29,200 | Nd | 61 | 230.0 | 2.00 |
| 1500SW/3 | 0.31 | 53 | 143 | 7.2 | 29,100 | Nd | 58 | 240.0 | 1.90 |
| Mean | 0.29 | 49 | 143 | 6.2 | 28,400 | - | 60 | 236.0 | 1.97 |
| ±Std. Dev. | 0.02 | 4 | 3 | 0.9 | 1,300 | - | 2 | 5.3 | 0.06 |

## Table 3-2 continued

| Station/Replicate | Hg ppm | Pb ppm | Zn ppm | As ppm | Fe ppm | Cd ppm | Cu ppm | PHC's ppm | % Total Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|
| CTR/1 | 0.25 | 35 | 114 | 7.7 | 18,800 | Nd | 38 | 272.0 | 3.10 |
| CTR/2 | Nd | 15 | 41 | 4.9 | 11,100 | Nd | 13 | <50.0[1] | 0.60 |
| CTR/3 | 0.48 | 61 | 164 | 7.1 | 25,600 | Nd | 104 | 140.0 | 1.90 |
| Mean | 0.36 | 37 | 106 | 6.6 | 18,500 | - | 52 | 154.0 | 1.90 |
| ±Std. Dev. | 0.16 | 23 | 62 | 1.5 | 7,255 | - | 47 | 111.7 | 1.20 |
| 400E/1 | 1.06 | 53 | 141 | 6.2 | 23,700 | Nd | 80 | 234.0 | 1.80 |
| 400E/2 | 0.31 | 41 | 160 | 9.7 | 26,900 | Nd | 85 | 254.0 | 1.70 |
| 400E/3 | 0.20 | 53 | 123 | 7.0 | 20,800 | 0.70 | 82 | 259.0 | 1.70 |
| Mean | 0.52 | 49 | 141 | 7.6 | 23,800 | - | 82 | 249.0 | 1.73 |
| ±Std. Dev. | 0.47 | 7 | 18 | 1.8 | 3,051 | - | 3 | 13.2 | 0.06 |
| 400W/1 | 0.52 | 57 | 126 | 4.5 | 18,600 | 1.30 | 94 | 1050.0 | 1.80 |
| 400W/2 | 0.19 | 36 | 60 | 2.6 | 12,700 | Nd | 3,6 | 137.0 | 0.93 |
| 400W/3 | 0.18 | 32 | 86 | 3.1 | 11,900 | 1.40 | 68 | 263.0 | 1.60 |
| Mean | 0.30 | 42 | 91 | 3.4 | 14,400 | 1.35 | 66 | 483.3 | 1.44 |
| ±Std. Dev. | 0.19 | 13 | 33 | 1.0 | 3,659 | 0.07 | 29 | 494.8 | 0.46 |
| 1500W/1 | 0.30 | 62 | 144 | 9.7 | 29,800 | Nd | 70 | 185.0 | 3.40 |
| 1500W/2 | 0.26 | 50 | 114 | 6.7 | 23,200 | Nd | 54 | 130.0 | 2.10 |
| 1500W/3 | 0.32 | 47 | 164 | 7.9 | 31,400 | 2.00 | 78 | 193.0 | 1.90 |
| Mean | 0.29 | 53 | 141 | 8.1 | 28,133 | - | 67 | 169.3 | 2.47 |
| ±Std. Dev. | 0.03 | 8 | 25 | 1.5 | 4,347 | - | 12 | 34.3 | 0.81 |

[1] Below analytical detection limits

**Table 3-3**

Results of Statistical Testing for Significant Differences in Chemical Concentrations in Sediment Collected at CLIS, August 1987

| | Variable | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Station | Hg | Pb | Zn | As | Fe | Cd | Cu | PHC's | % Total Carbon |
| CTR | ns | ns | ns | ns | - | na | ns | ns | ns |
| 400E | ns | ns | ns | ns | - | na | + | ns | ns |
| 400W | ns | ns | - | - | - | na | ns | ns | ns |
| 1500W | ns | ns | ns | ns | ns | na | ns | ns | ns |
| 1000E FVP | ns | ns | ns | ns | ns | na | ns | ns | ns |
| 3500E | ns | ns | ns | ns | ns | na | ns | ns | ns |
| 2000E | ns | ns | ns | ns | ns | na | ns | ns | ns |
| 1500SW | ns | ns | ns | ns | ns | na | ns | ns | ns |
| 1000N | - | - | - | - | - | na | - | - | - |

+ = 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)

na = statistical test not applicable because chemical concentrations were below detection limits in some or all replicates

Table 3-4

Organochlorine Pesticides and PCB's in Sediment Collected at CLIS, August 1987. Concentrations are Based on Dry Weight.

| Parameter | Detection Limits (µg/Kg) | 1000E FVP | REF | 4500E | 3500E | Station 2000E | 2000S | 1000N | 1500SW | 2500W |
|---|---|---|---|---|---|---|---|---|---|---|
| Alpha-BHC | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Beta-BHC | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Delta-BHC | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Gamma-BHC (Lindane) | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Heptachlor | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aldrin | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Heptachlor epoxide | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Endosulfan I | 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Dieldrin | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 4,4'-DDE | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Endrin | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Endosulfan II | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 4,4'-DDD | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Endosulfan sulfate | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 4,4'-DDT | 16 | ND | ND | ND | ND | 200 | ND | ND | ND | ND |
| Methoxychlor | 80 | ND | ND | ND | ND | ND | ND | 82 | ND | ND |
| Endrin ketone | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Chlordane | 80 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Toxaphene | 160 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Endrin aldehyde | 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aroclor-1016 | 80 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aroclor-1221 | 80 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aroclor-1232 | 80 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aroclor-1242 | 80 | 180 | ND | ND | 160 | ND | ND | ND | ND | ND |
| Aroclor-1248 | 80 | ND | ND | ND | ND | ND | 140 | 83 | 92 | ND |
| Aroclor-1254 | 160 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aroclor-1260 | 160 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aroclor-1262 | *** | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Aroclor-1268 | *** | ND | ND | ND | ND | ND | ND | ND | ND | ND |

ND = not detected
***The detection limits for Aroclors 1262 and 1268 are similar to that for Aroclor 1260.

Table 3-4, continued*

| Parameter | Detection Limits (µg/Kg) | 1500W | Detection Limits (µg/Kg) | CTR | 400E | 400W |
|---|---|---|---|---|---|---|
| Alpha-BHC | 16 | ND | 80 | ND | ND | ND |
| Beta-BHC | 16 | ND | 80 | ND | ND | ND |
| Delta-BHC | 16 | ND | 80 | ND | ND | ND |
| Gamma-BHC (Lindane) | 16 | ND | 80 | ND | ND | ND |
| Heptachlor | 16 | ND | 80 | ND | ND | ND |
| Aldrin | 16 | ND | 80 | ND | ND | ND |
| Heptachlor epoxide | 16 | ND | 80 | ND | ND | ND |
| Endosulfan I | 16 | ND | 80 | ND | ND | ND |
| Dieldrin | 32 | ND | 160 | ND | ND | ND |
| 4,4'-DDE | 32 | ND | 160 | ND | ND | ND |
| Endrin | 32 | ND | 160 | ND | ND | ND |
| Endosulfan II | 32 | ND | 160 | ND | ND | ND |
| 4,4'-DDD | 32 | ND | 160 | ND | ND | ND |
| Endosulfan sulfate | 32 | ND | 160 | ND | ND | ND |
| 4,4'-DDT | 32 | ND | 160 | ND | 190 | ND |
| Methoxychlor | 160 | ND | 800 | ND | ND | ND |
| Endrin ketone | 32 | ND | 160 | ND | ND | ND |
| Chlordane | 160 | ND | 800 | ND | ND | ND |
| Toxaphene | 320 | ND | 1600 | ND | ND | ND |
| Endrin aldehyde | 32 | ND | 160 | ND | ND | ND |
| Aroclor-1016 | 160 | ND | 800 | ND | ND | ND |
| Aroclor-1221 | 160 | ND | 800 | ND | ND | ND |
| Aroclor-1232 | 160 | ND | 800 | ND | ND | ND |
| Aroclor-1242 | 160 | ND | 800 | ND | ND | ND |
| Aroclor-1248 | 160 | ND | 800 | ND | ND | ND |
| Aroclor-1254 | 320 | ND | 1600 | ND | ND | ND |
| Aroclor-1260 | 320 | ND | 1600 | ND | ND | ND |
| Aroclor-1262 | *** | ND | *** | ND | ND | ND |
| Aroclor-1268 | *** | ND | *** | ND | ND | ND |

ND = not detected
* Note different detection limits for Station 1500W versus Stations CTR, 400E and 400W.
***The detection limits for Aroclors 1262 and 1268 are similar to that for Aroclor 1260.

**Table 3-5**

Trace Metals in Body Tissues (Dry Weight) in *Nephtys*
Collected at CLIS, August 1987

| Station/Replicate | Cd | Pb | Cu | Fe | Hg |
|---|---|---|---|---|---|
| | Concentration in μg/g dry weight | | | | |
| CLIS REF/1 | <0.35 | <3 | 16.3 | 749 | <0.03 |
| CLIS REF/2 | <0.35 | <3 | 16.3 | 742 | <0.03 |
| CLIS REF/3 | <0.35 | <3 | 17.7 | 756 | <0.03 |
| Mean | <0.35 | <3 | 16.8 | 749 | <0.03 |
| ±Std. Dev. | - | - | 0.8 | 7 | - |
| CTR/1 | <0.65 | <3 | 46.9 | 1081 | <0.03 |
| CTR/2 | <0.65 | <3 | 53.4 | 1173 | <0.03 |
| CTR/3 | <0.65 | <3 | 52.1 | 1160 | <0.03 |
| Mean | <0.65 | <3 | 50.8 | 1138 | <0.03 |
| ±Std. Dev. | - | - | 3.4 | 50 | - |
| 400E/1 | <0.23 | <3 | 18.0 | 473 | <0.03 |
| 400E/2 | <0.23 | <3 | 17.6 | 464 | <0.03 |
| 400E/3 | <0.23 | <3 | 17.1 | 423 | <0.03 |
| Mean | <0.23 | <3 | 17.6 | 453 | <0.03 |
| ±Std. Dev. | - | - | 0.5 | 27 | - |
| 400W/1 | <0.28 | <3 | 24.8 | 155 | <0.03 |
| 400W/2 | <0.28 | <3 | 25.4 | 147 | <0.03 |
| 400W/3 | <0.28 | <3 | 25.4 | 156 | <0.03 |
| Mean | <0.28 | <3 | 25.2 | 153 | <0.03 |
| ±Std. Dev. | - | - | 0.3 | 5 | - |
| 1500W/1 | <0.13 | <3 | 12.4 | 374 | <0.03 |
| 1500W/2 | <0.13 | <3 | 11.6 | 376 | <0.03 |
| 1500W/3 | <0.13 | <3 | 12.4 | 382 | <0.03 |
| Mean | <0.13 | <3 | 12.1 | 377 | <0.03 |
| ±Std. Dev. | - | - | 0.5 | 4 | - |
| 1000E of FVP/1 | <0.35 | <3 | 25.9 | 588 | <0.03 |
| 1000E of FVP/2 | <0.35 | <3 | 26.6 | 581 | <0.03 |
| 1000E of FVP/3 | <0.35 | <3 | 25.9 | 581 | <0.03 |
| Mean | <0.35 | <3 | 26.0 | 583 | <0.03 |
| ±Std. Dev. | - | - | 0.5 | 4 | - |

**Table 3-6**

Results of Statistical Testing for Significant Differences in Chemical Concentrations in *Nephtys* Collected at CLIS, August 1987

| Station | Cd | Pb | Cu | Fe | Hg | PCBs (as Aroclor 1254) |
|---|---|---|---|---|---|---|
| | | | Variable | | | |
| CTR | na | na | + | + | na | - |
| 400E | na | na | ns | - | na | - |
| 400W | na | na | + | - | na | ns |
| 1500W | na | na | - | - | na | + |
| 1000E FVP | na | na | + | - | na | ns |

+ = concentrations significantly higher than Reference animals ($p \leq 0.05$, Mann-Whitney U-test)

- = concentrations significantly less than Reference animals ($p \leq 0.05$, Mann-Whitney U-test)

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

na = not applicable, statistical test could not be performed because chemical concentrations in some or all replicates were below detection limits

**Table 3-7**

PCBs (as Aroclor 1254) in Body Tissues (Dry Weight) in *Nephtys* Collected at CLIS, August 1987

| | Concentration in μg/g dry weight | |
|---|---|---|
| Station/Replicate | PCBs (as Aroclor 1254) | Mean ± Std. Dev. |
| CLIS REF/1 | 0.303 | |
| CLIS REF/2 | 0.280 | |
| CLIS REF/3 | 0.195 | 0.259 ± .057 |
| CTR/1 | 0.144 | |
| CTR/2 | 0.073 | |
| CTR/3 | 0.187 | 0.135 ± .058 |
| 400E/1 | 0.030 | |
| 400E/2 | 0.025 | |
| 400E/3 | 0.017 | 0.024 ± .007 |
| 400W/1 | 0.139 | |
| 400W/2 | 0.173 | |
| 400W/3 | 0.258 | 0.190 ± .061 |
| 1500W/1 | 0.552 | |
| 1500W/2 | 0.400 | |
| 1500W/3 | 0.310 | 0.421 ± .122 |
| 1000E of FVP/1 | 0.203 | |
| 1000E of FVP/2 | 0.106 | |
| 1000E of FVP/3 | 0.112 | 0.140 ± .054 |

**Table 4-1**

Summary of Organism-Sediment Index Ranking
CLIS Disposal Mounds, 1986-87

| Area | N 1986 | N 1987 | Mean OSI 1986 | Mean OSI 1987 | 1986 Min. | 1986 Max. | 1987 Min. | 1987 Max. |
|---|---|---|---|---|---|---|---|---|
| CLIS REF | 20 | 12 | 9.55 | 9.08 | 3 | 11 | 6 | 11 |
| FVP | 60 | 63 | 9.10* | 8.62*+ | 3 | 11 | 4 | 11 |
| CLIS-86 | 17 | 110 | 7.65* | 8.18* | 4 | 11 | 3 | 11 |
| STNH-S | 15 | 55 | 7.47 | 8.22* | 4 | 11 | 3 | 11 |
| NH 83 | 16 | 54 | 6.31 | 8.22*+ | 4 | 11 | 4 | 11 |
| MQR | 48 | 59 | 5.71 | 7.92*+ | -3 | 10 | 1 | 11 |

* = Not significantly different from the CLIS Reference value (Mann-Whitney U-test, $p > 0.05$)

\+ = Significantly different from the 1986 value (Mann-Whitney U-test, $p \leq 0.05$)

**Table 4-2**

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

| Dissolved Oxygen Range (mg/l) | Facies |
|---|---|
| > 4.2 | Aerobic |
| 4.2 to 0.41 | Hypoxic* |
| 0.4 to 0.14 | Dysaerobic |
| < 0.14 | Anaerobic |

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

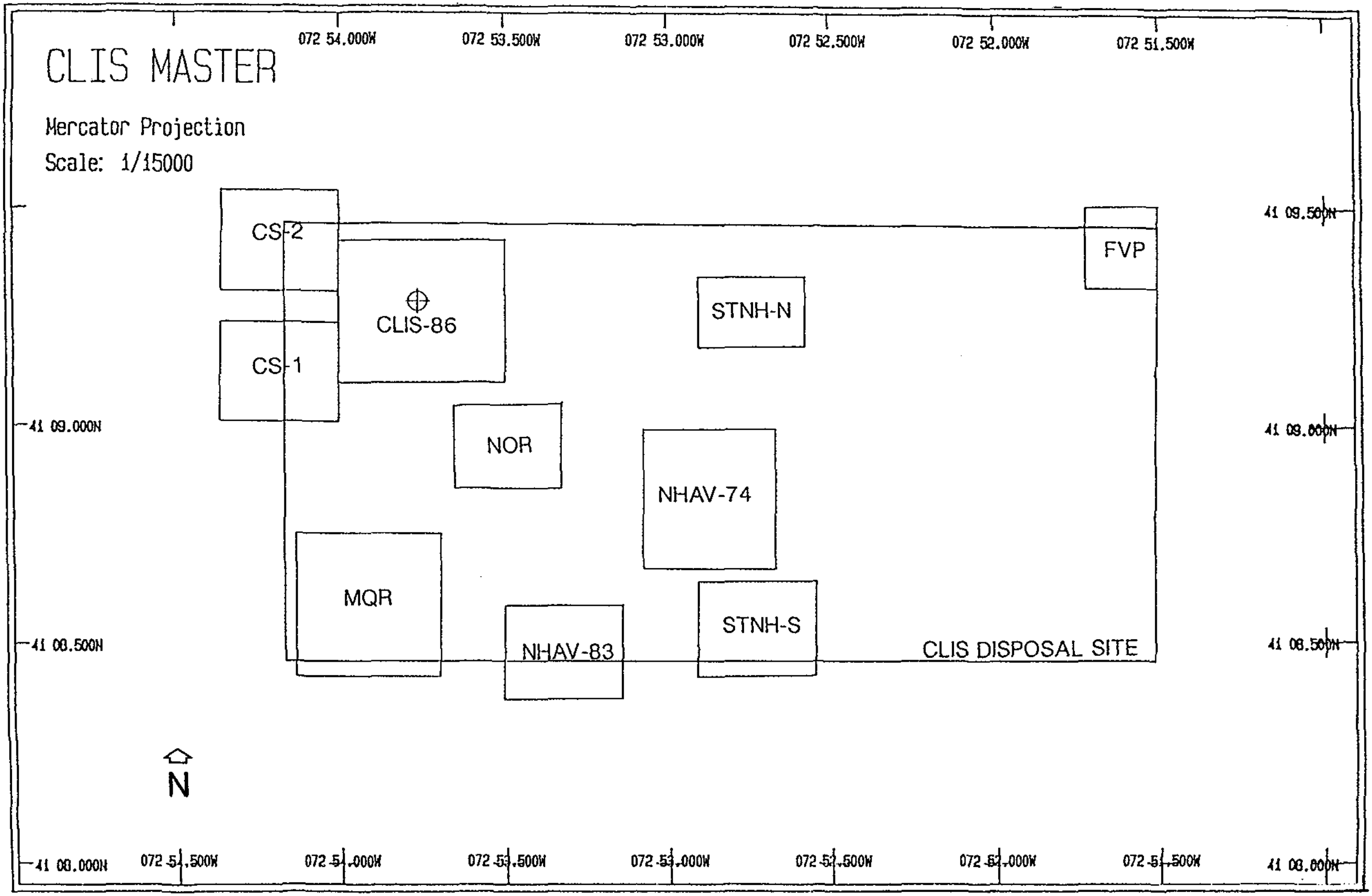



**Figure 1-1.** Map of the Central Long Island Sound (CLIS) disposal site, with boxes outlining the approximate locations of individual disposal mounds.

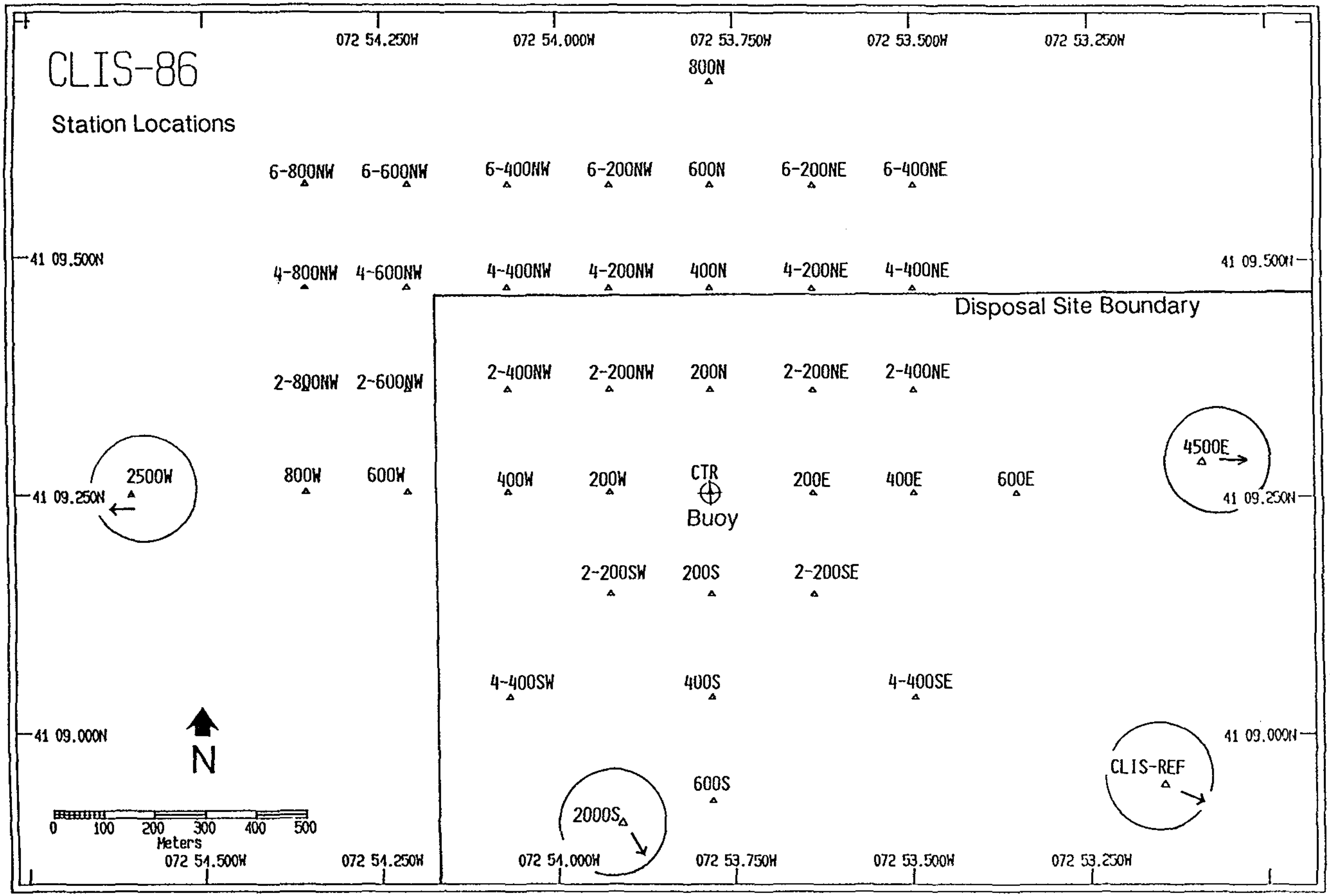



**Figure 2-1.** Locations and designations of REMOTS stations at the CLIS-86 disposal mound, August 1987. All station designations are in relation to the CLIS-86 mound center. The four outlying reference stations (CLIS-REF, 4500E, 2000S and 2500W) are circled and their locations indicated by arrows.

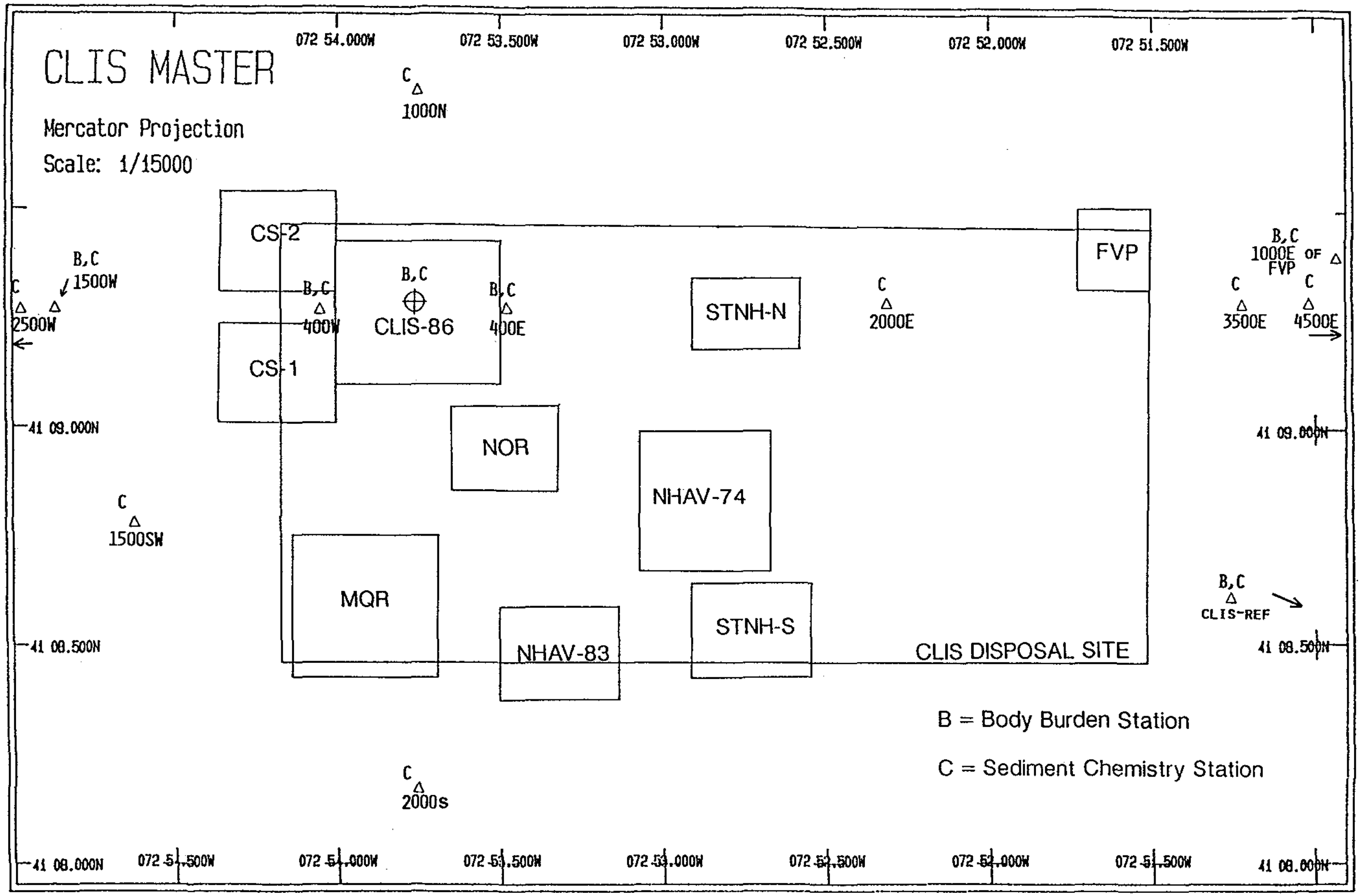



**Figure 2-2.** Locations of body burden and sediment chemistry stations (triangles) at the CLIS disposal site, August 1987. Station designations are in relation to the CLIS-86 mound center, except for the station 1000 m east of the FVP center (1000E of FVP). Station locations are roughly to scale with the exception of stations 2500W, 4500E and CLIS-REF.

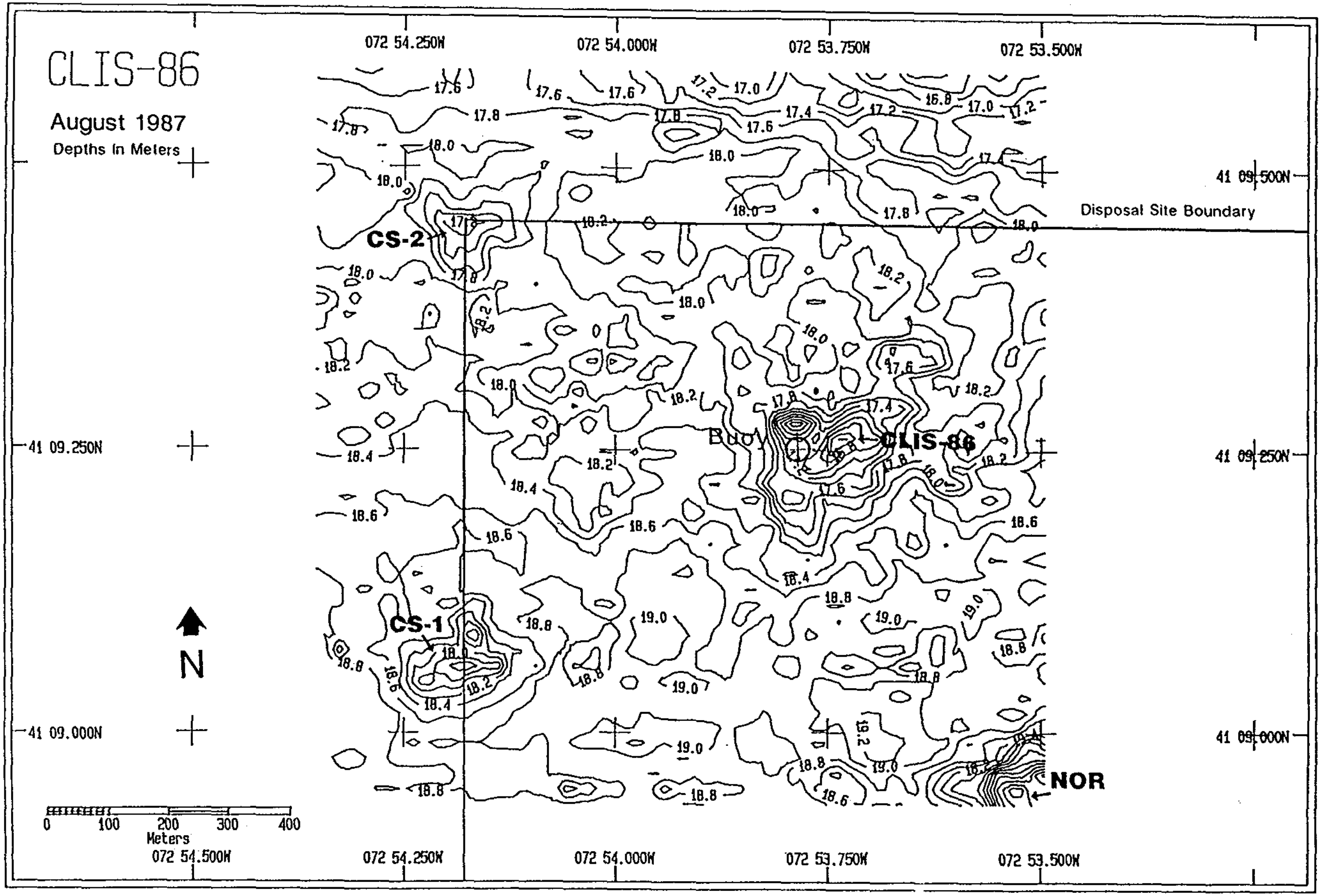



**Figure 3-1.** Bathymetric contour map of the area surveyed in the vicinity of the CLIS-86 disposal mound, August 1987.

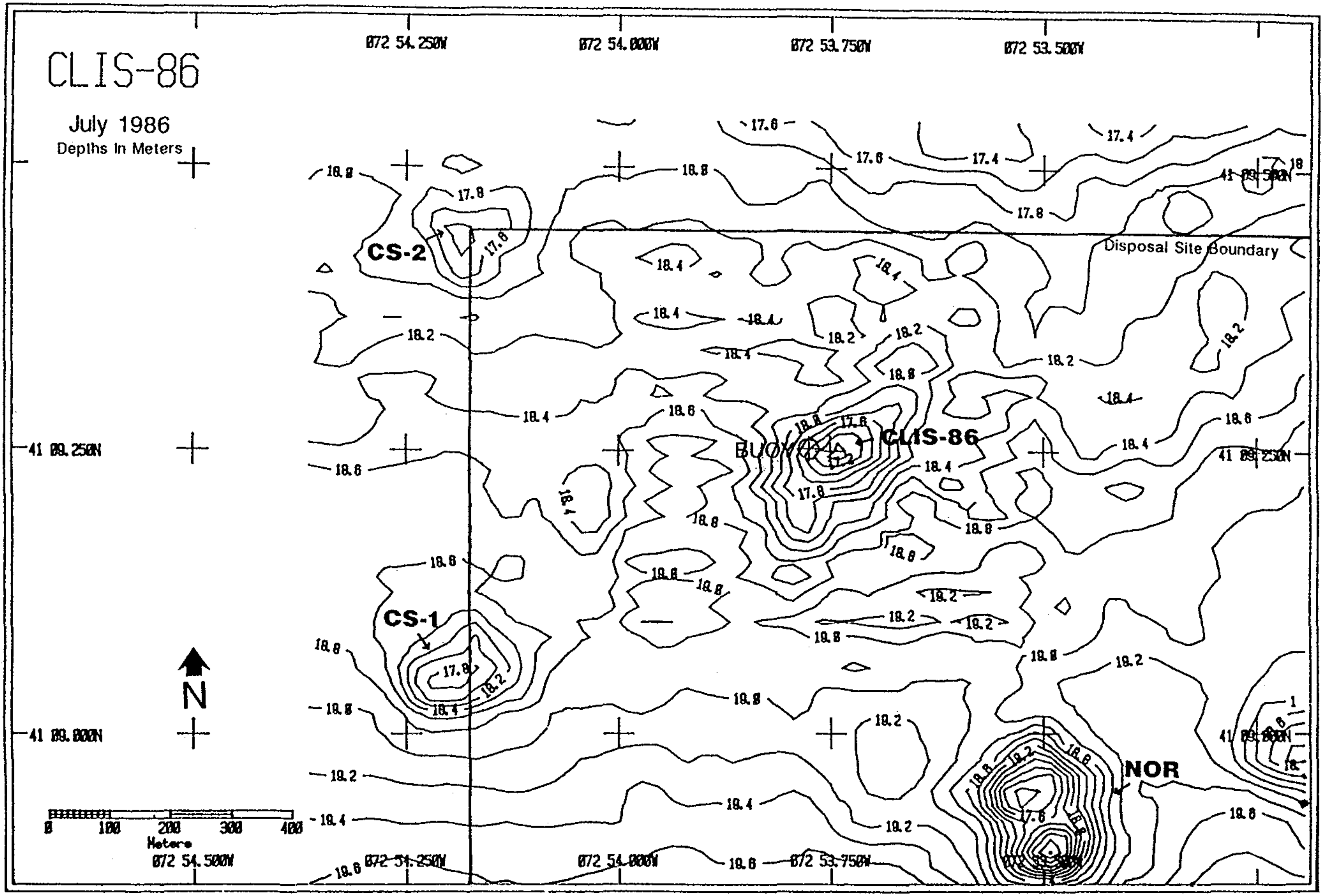



**Figure 3-2.** Bathymetric contour map of the area surveyed in the vicinity of the CLIS-86 disposal mound, July 1986.

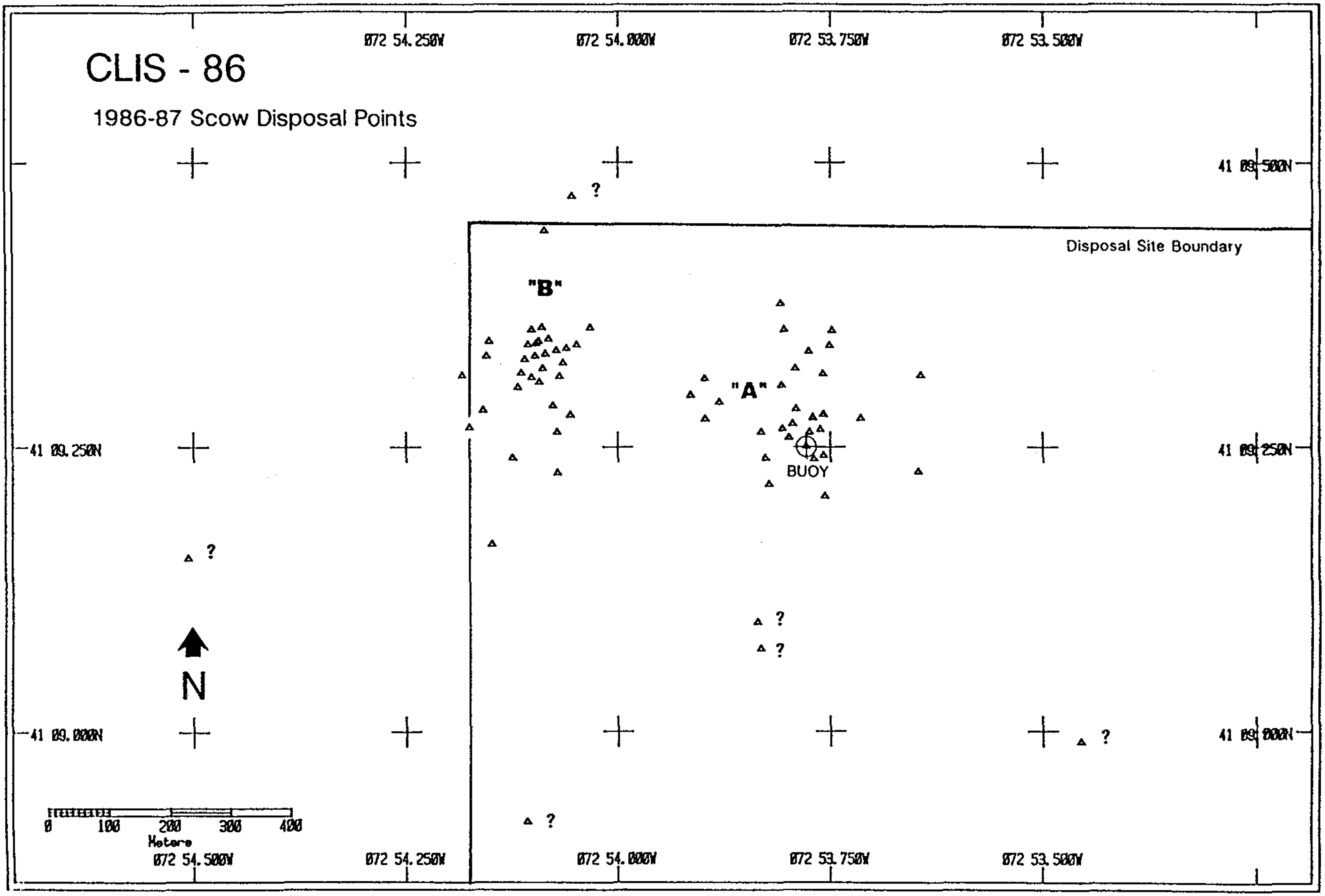



Figure 3-3. Disposal points at CLIS over the past year based on Loran coordinates taken from scow logs. "A" and "B" represent two distinct disposal loci. The symbol ▲? indicates that the Loran record from the scow logs is questionable for these points.

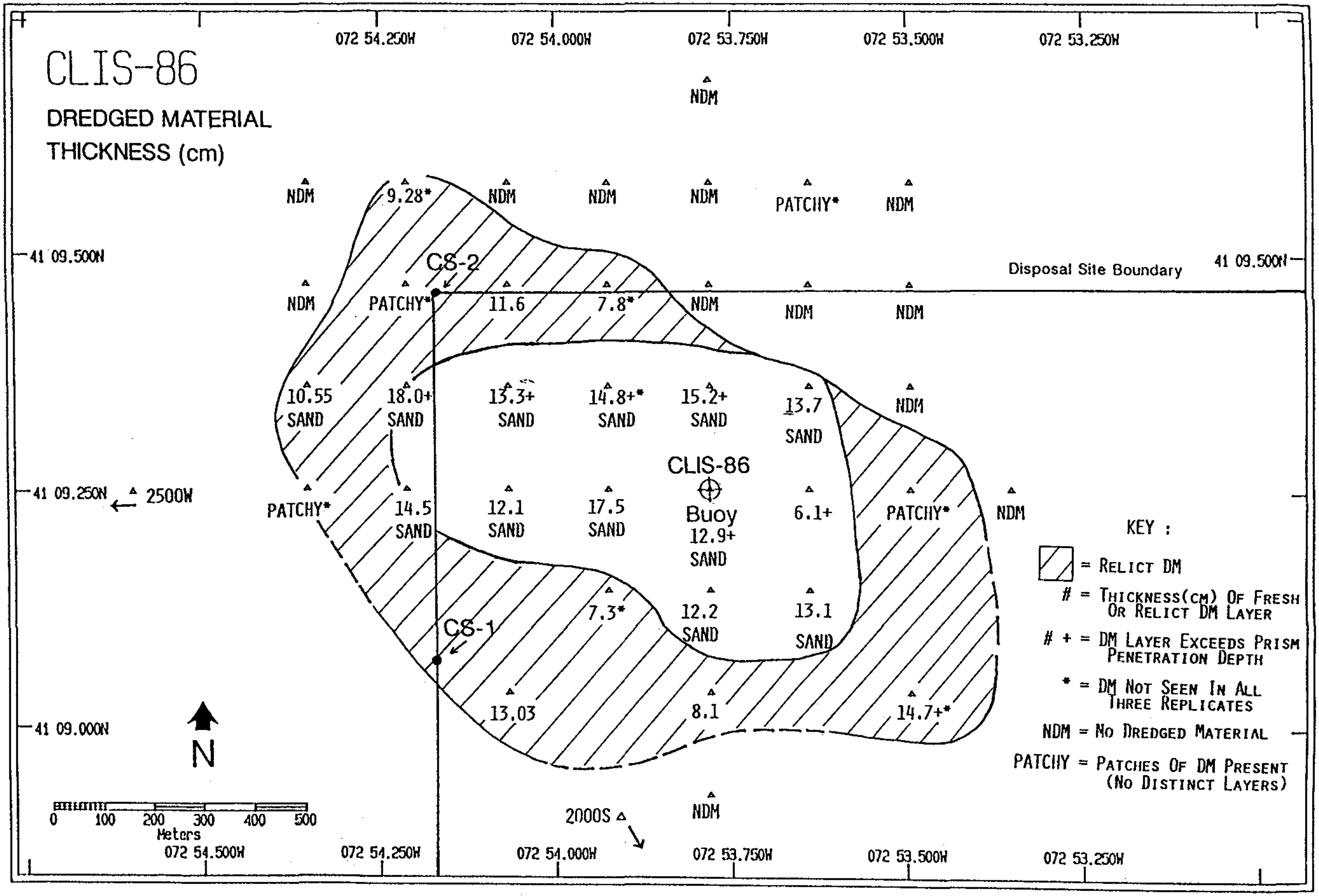



Figure 3-4. Distribution of dredged material at the northwest corner of the CLIS disposal site, August 1987. The solid line around the buoy encloses an area having recently-disposed dredged material, while the hatched area has "relict" dredged material.

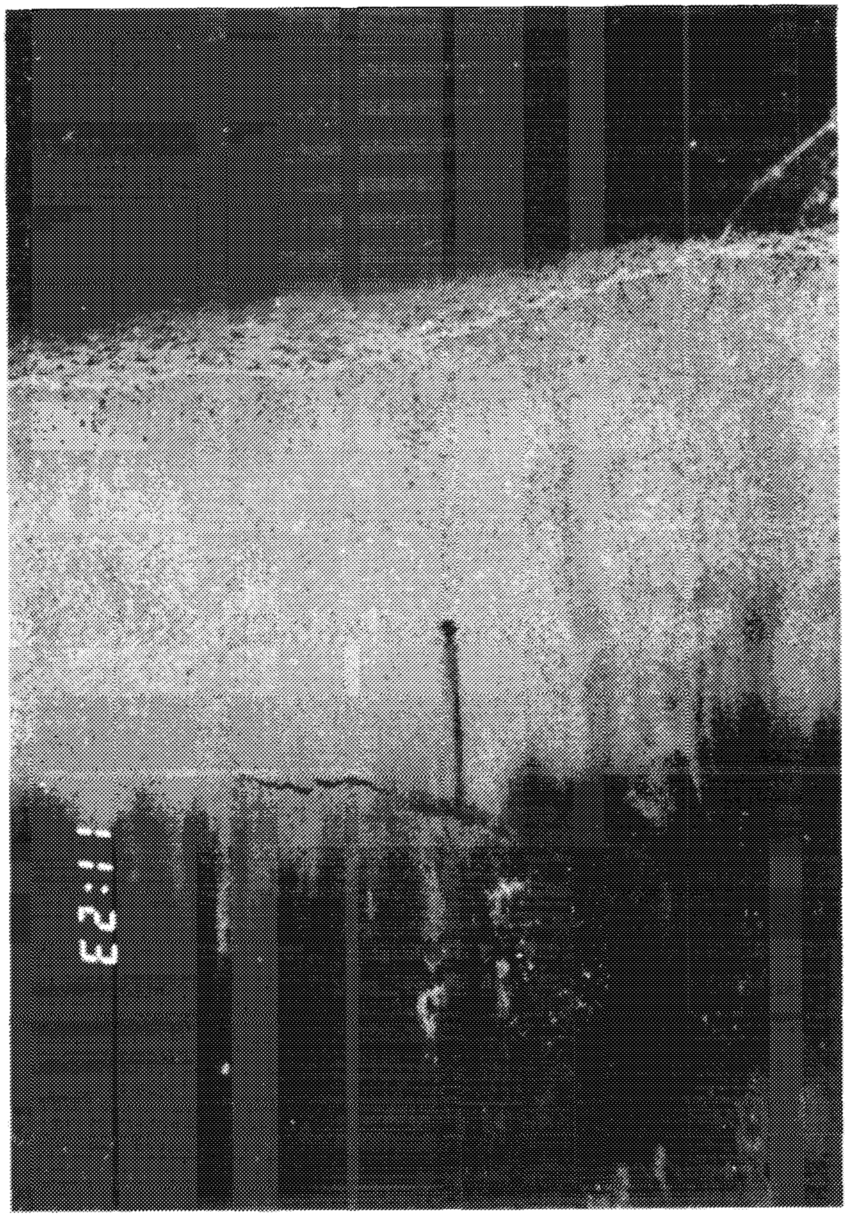


Figure 3-5. REMOTS® photo from station 2-400NW showing a typical "fresh" dredged material layer which extends beyond the depth of penetration of the camera prism. This material was characterized by a distinct redox contrast and low reflectance sediment at depth having high apparent oxygen demand. Note also the significant sand component in the high reflectance surface layer. Scale of photo = 1X.

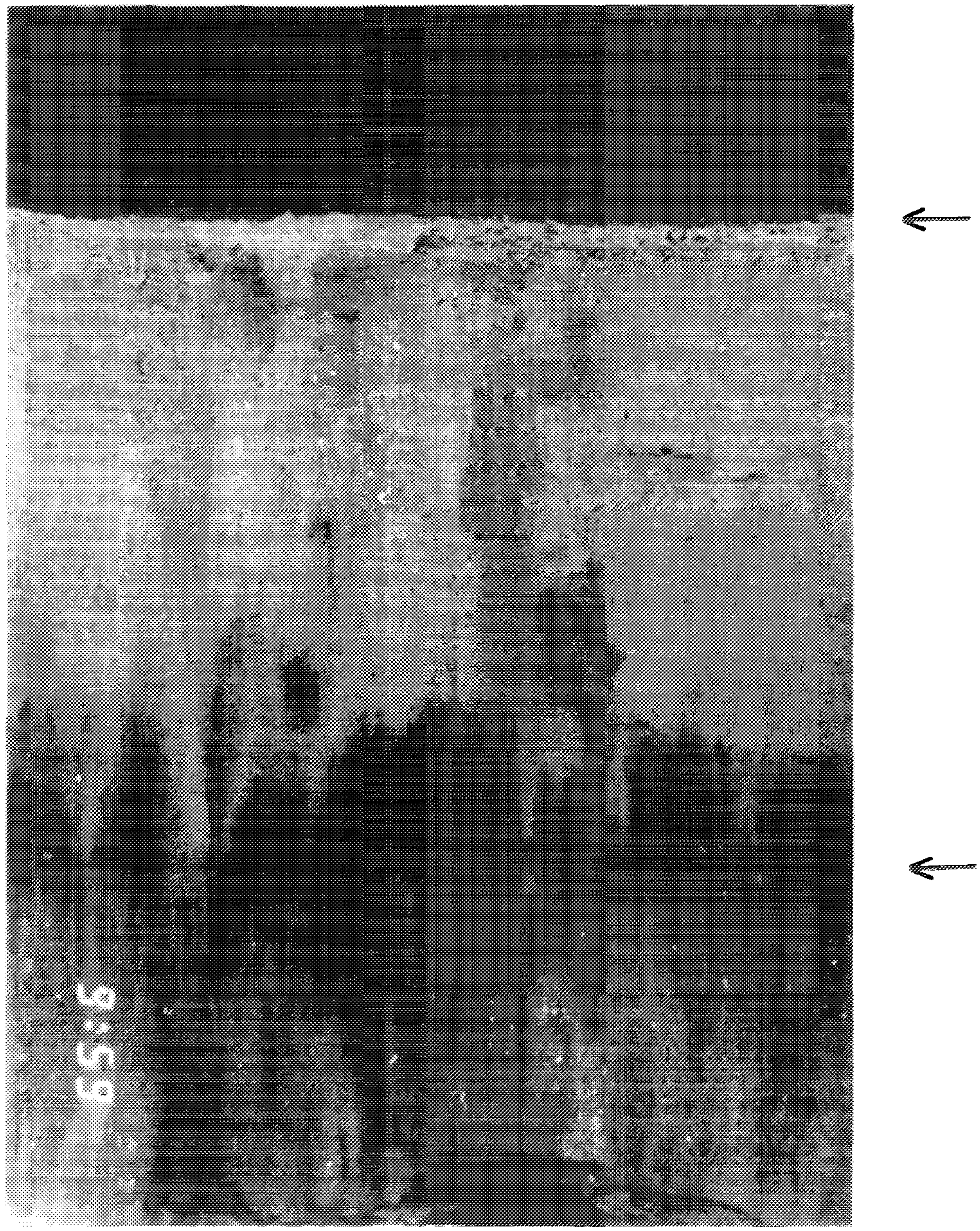


**Figure 3-6.** REMOTS® photo A (above) from station 4-400NW and photo B (following page) from station 2-800NW illustrate possible "relict" dredged material layers. The thickness of such layers is measured from the sediment surface down to the bottom of the patchy band of low reflectance sediment at depth (the distance between the arrows). Scale of both photos = 1X.

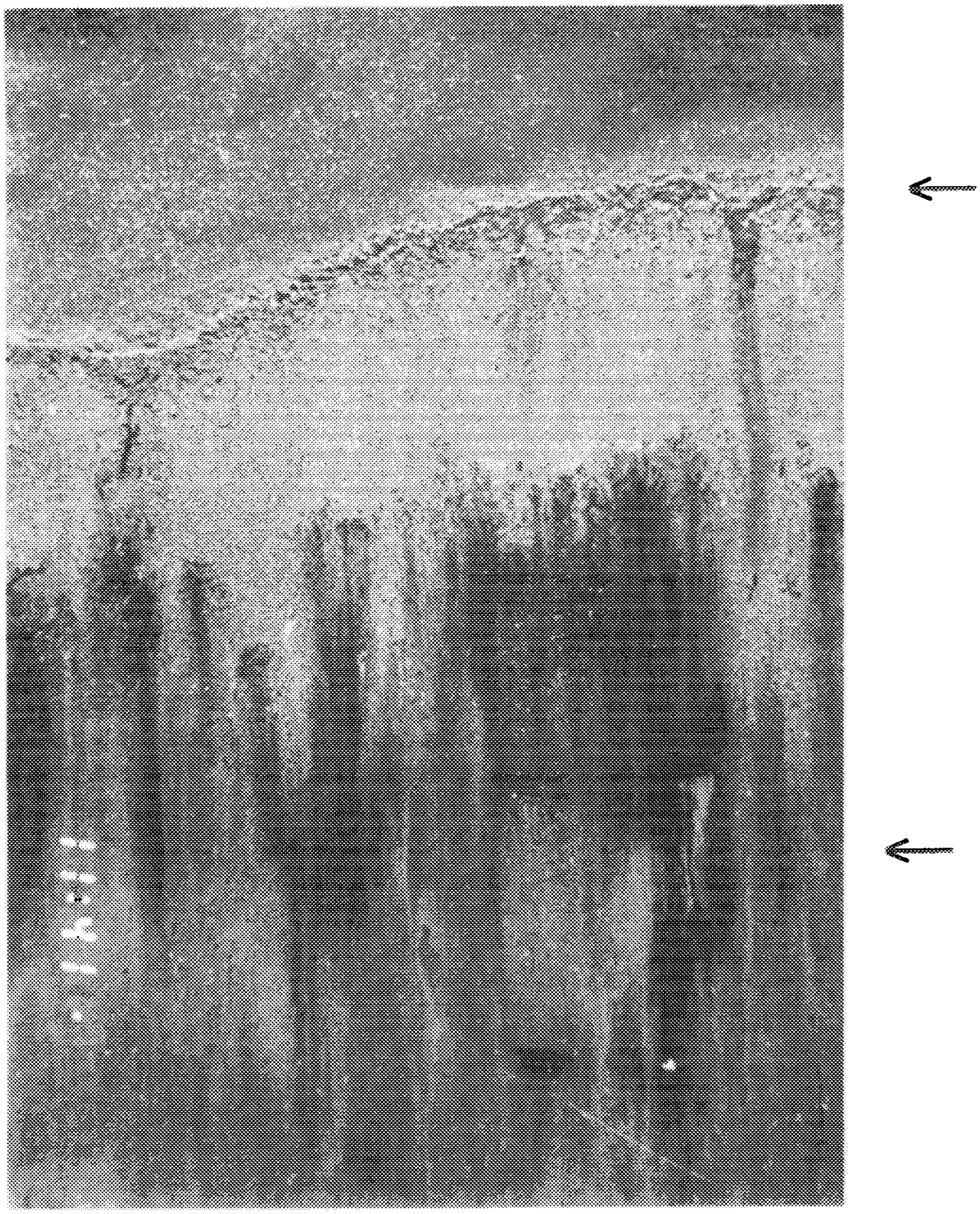


Figure 3-6, image B.

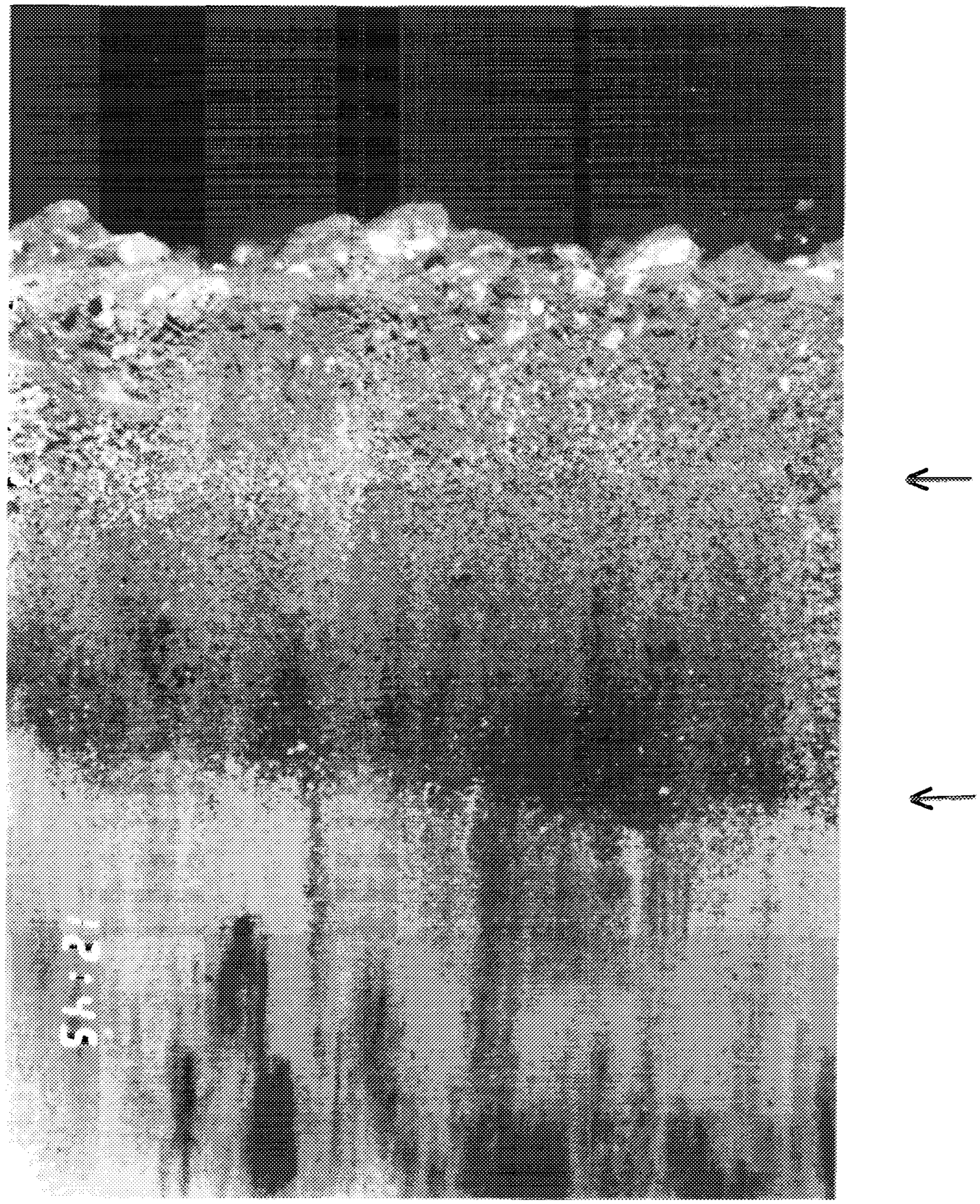


**Figure 3-7.** The points of contact between distinct depositional horizons of fine sand (3-2 phi) are indicated by arrows in this REMOTS® photo from station CTR. This stratigraphic sequence reflects a temporally-varying pattern of dredged material disposal. Scale = 1X.

**Figure 3-8.** Two replicate REMOTS® photos from station 4-400SE illustrating within-station patchiness in the distribution of dredged material. Photo A (above) shows low reflectance patches of dredged material, while no dredged material is apparent in photo B (following page). Scale of both photos = 1X.

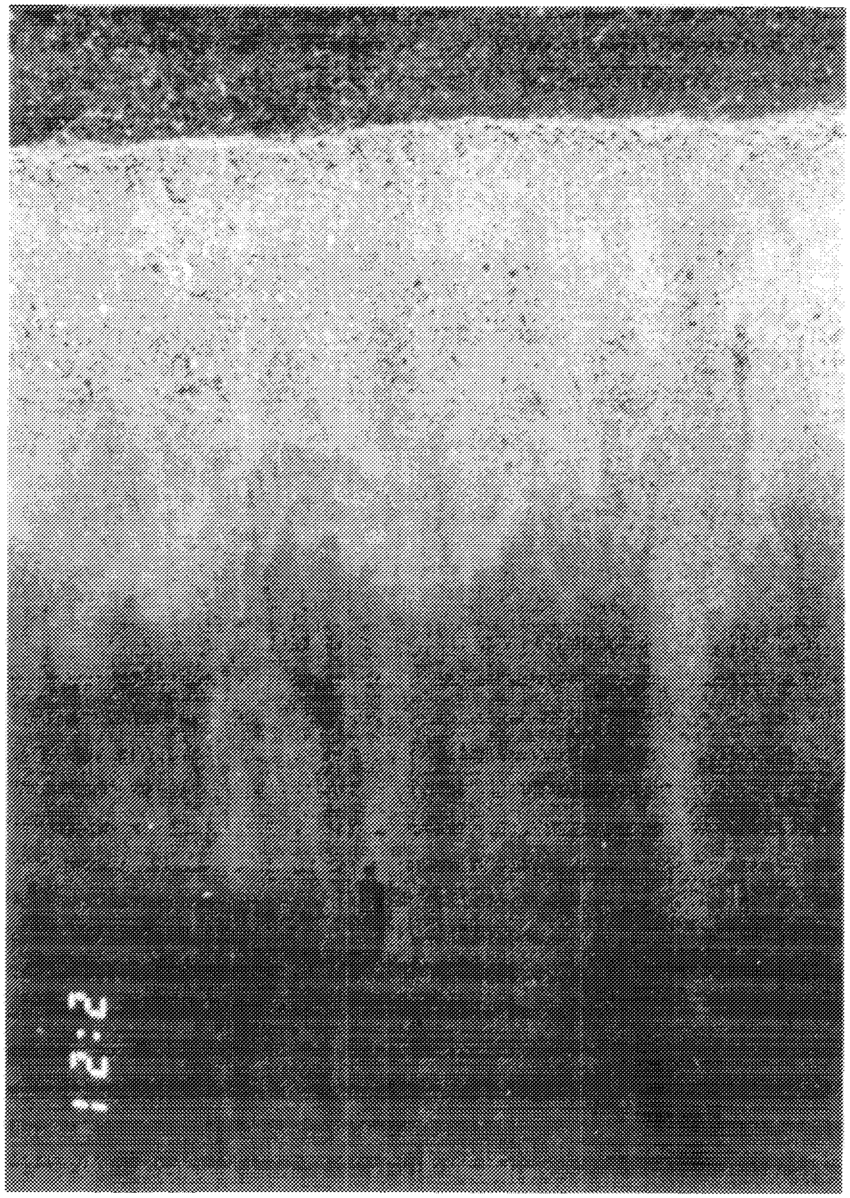
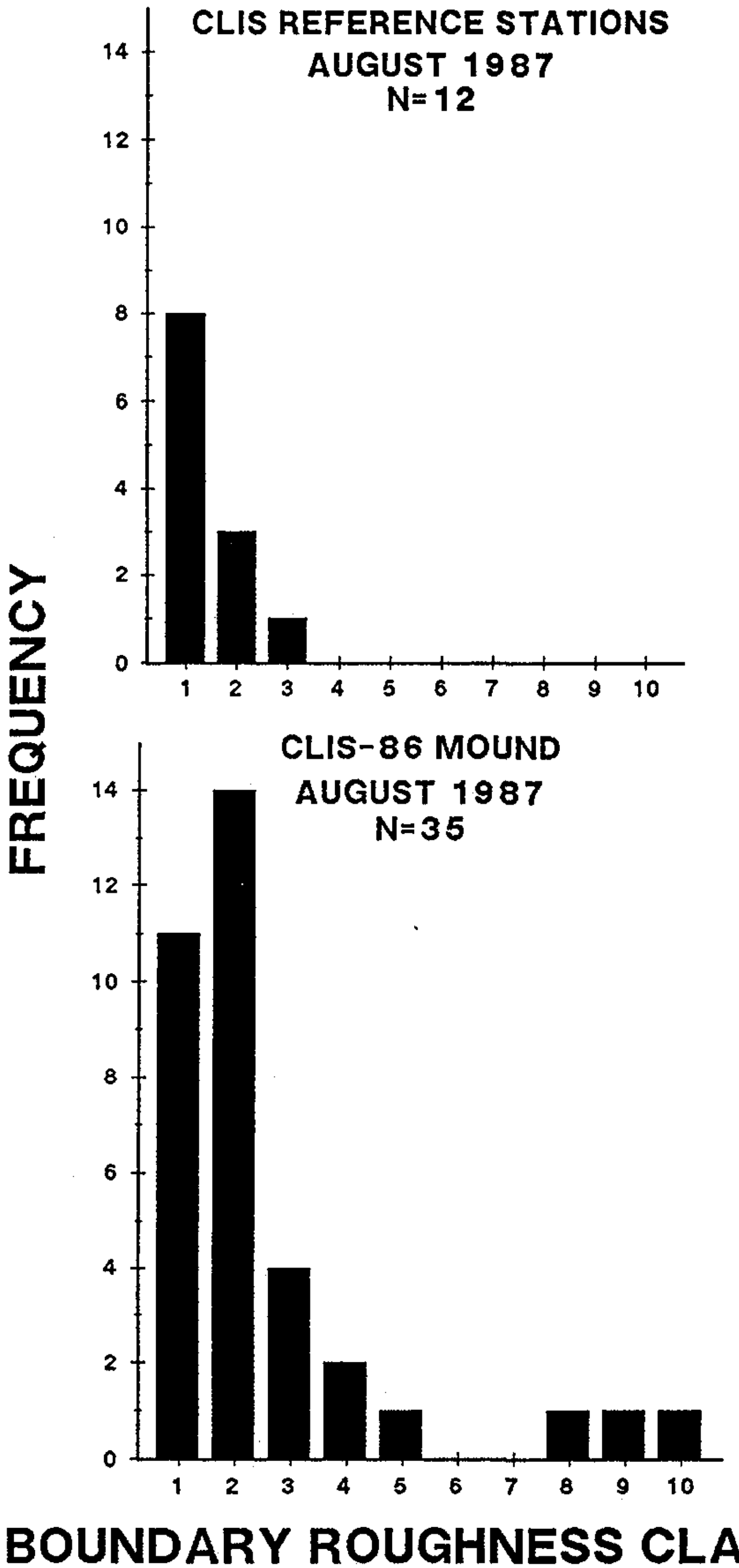


Figure 3-8, image B.




**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 |

Figure 3-9. Frequency distributions of small-scale surface boundary roughness values for all replicates at the CLIS-86 mound stations where dredged material was present and the CLIS reference stations, August 1987 (n = number of replicates).

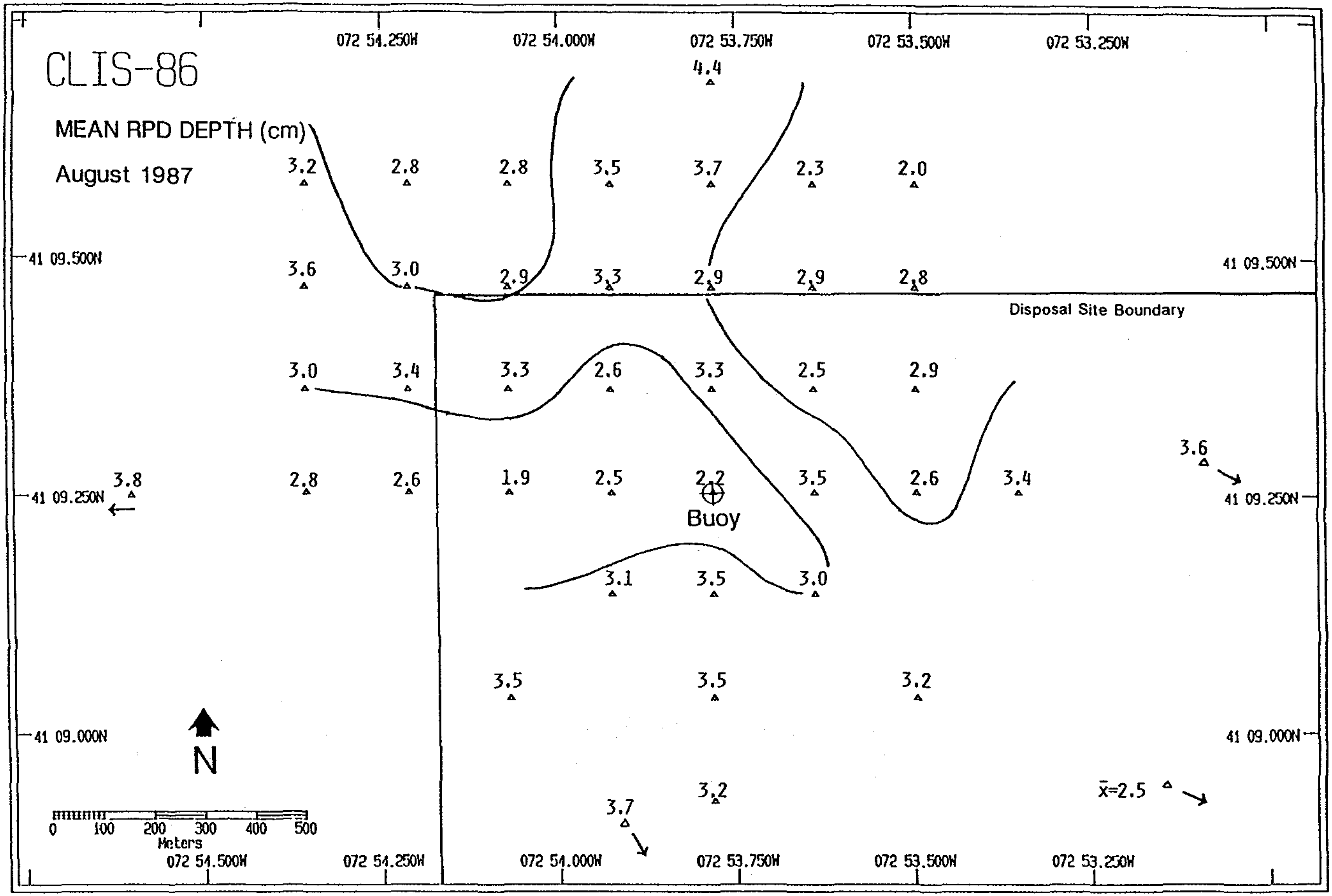



**Figure 3-10.** The distribution of apparent RPD depths, averaged by station, at the CLIS-86 mound and CLIS reference stations, August 1987. Contours delimit areas having RPD depths $\leq$ 3 cm.

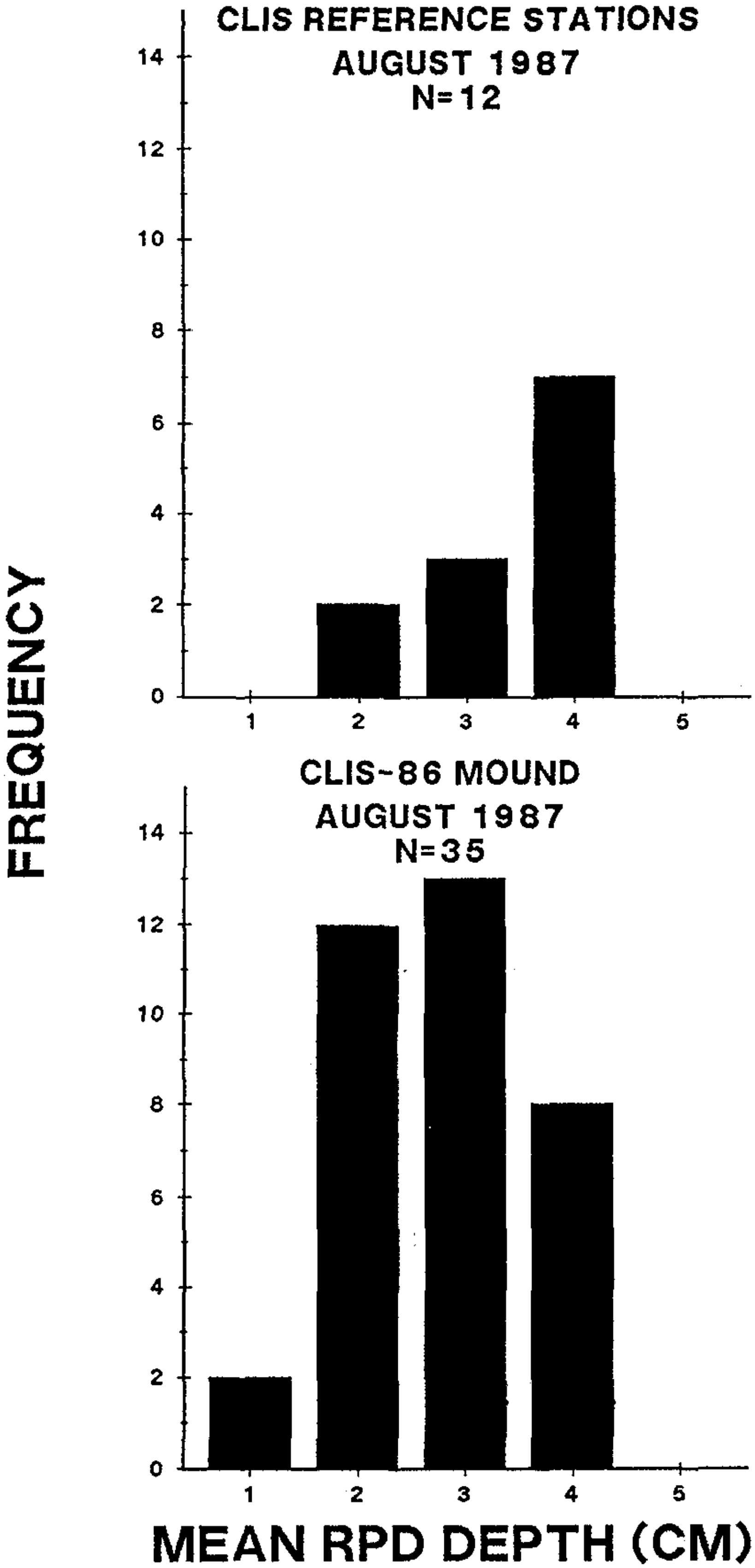



**Figure 3-11.** Frequency distributions of apparent RPD depths for all replicates at the CLIS reference stations and the CLIS-86 disposal mound stations where dredged material was present, August 1987 (n = number of replicates).

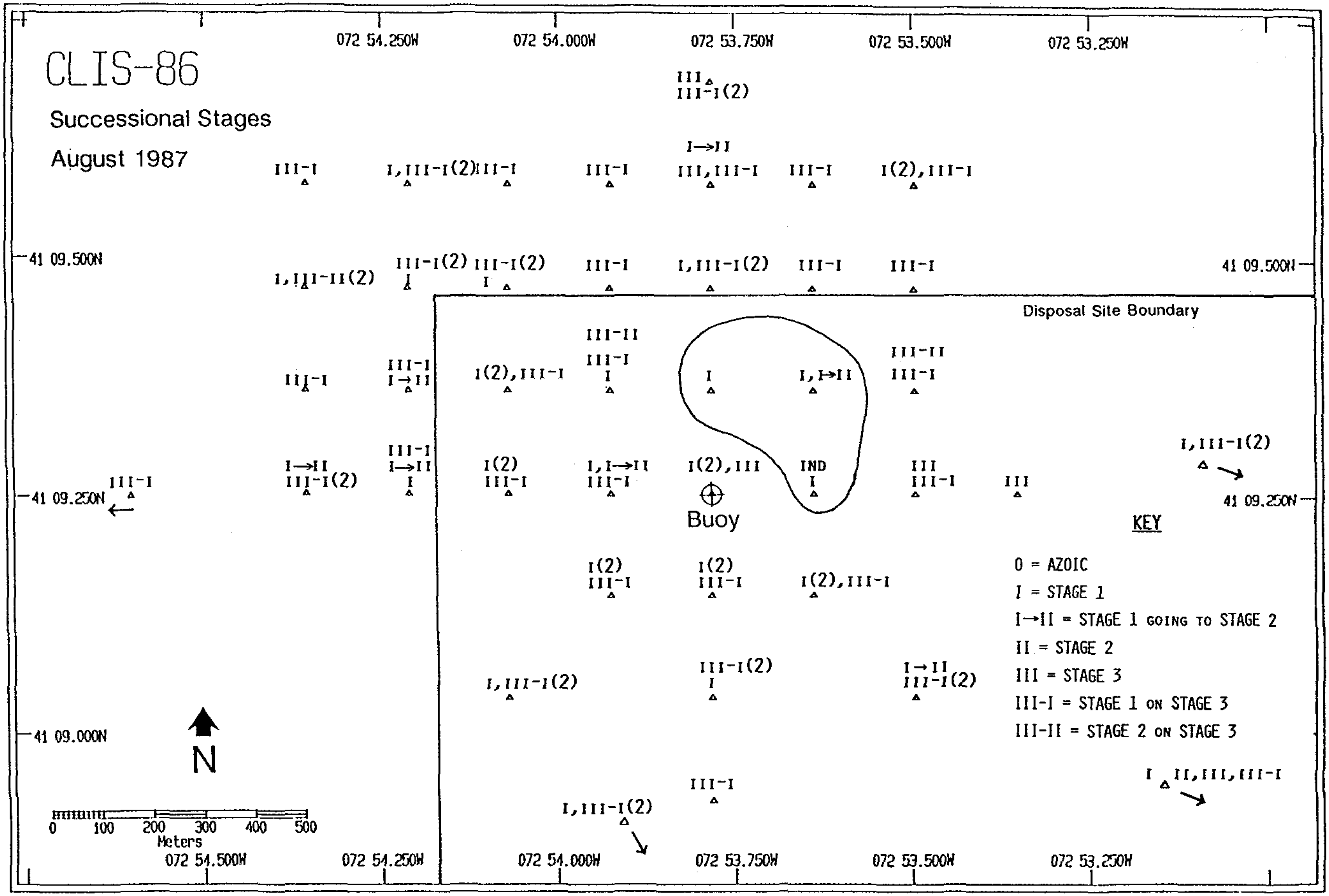



**Figure 3-12.** The distribution of infaunal successional stages at the CLIS-86 mound and CLIS reference stations in August 1987. The contoured area lacks Stage III infauna.

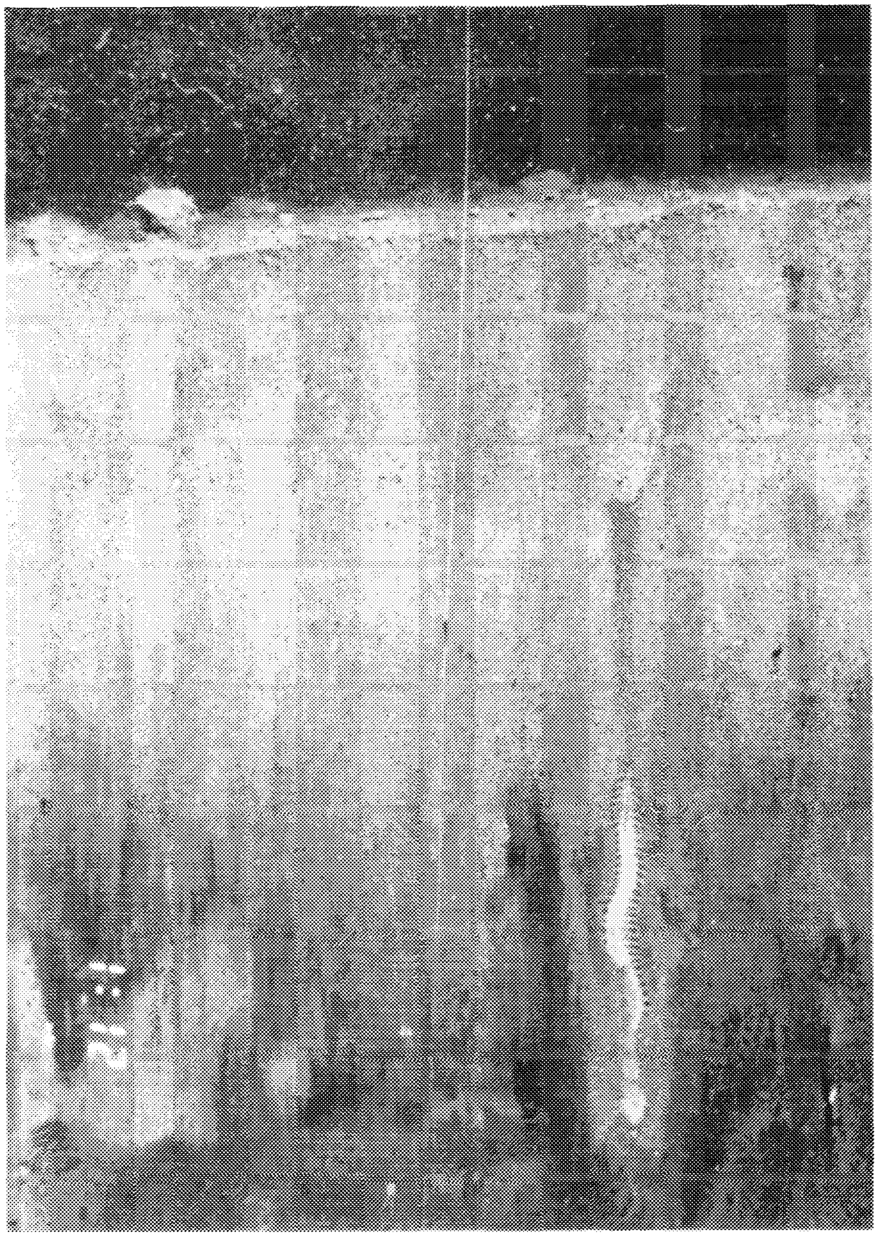


Figure 3-13. The polychaete Nephtys incisa is visible at depth in this REMOTS® photo from station 600E. This deposit-feeder is a typical Stage III organism. Small, opportunistic, tube-dwelling polychaetes are barely visible at the sediment surface, giving this station a Stage I on Stage III designation. Scale = 1X.

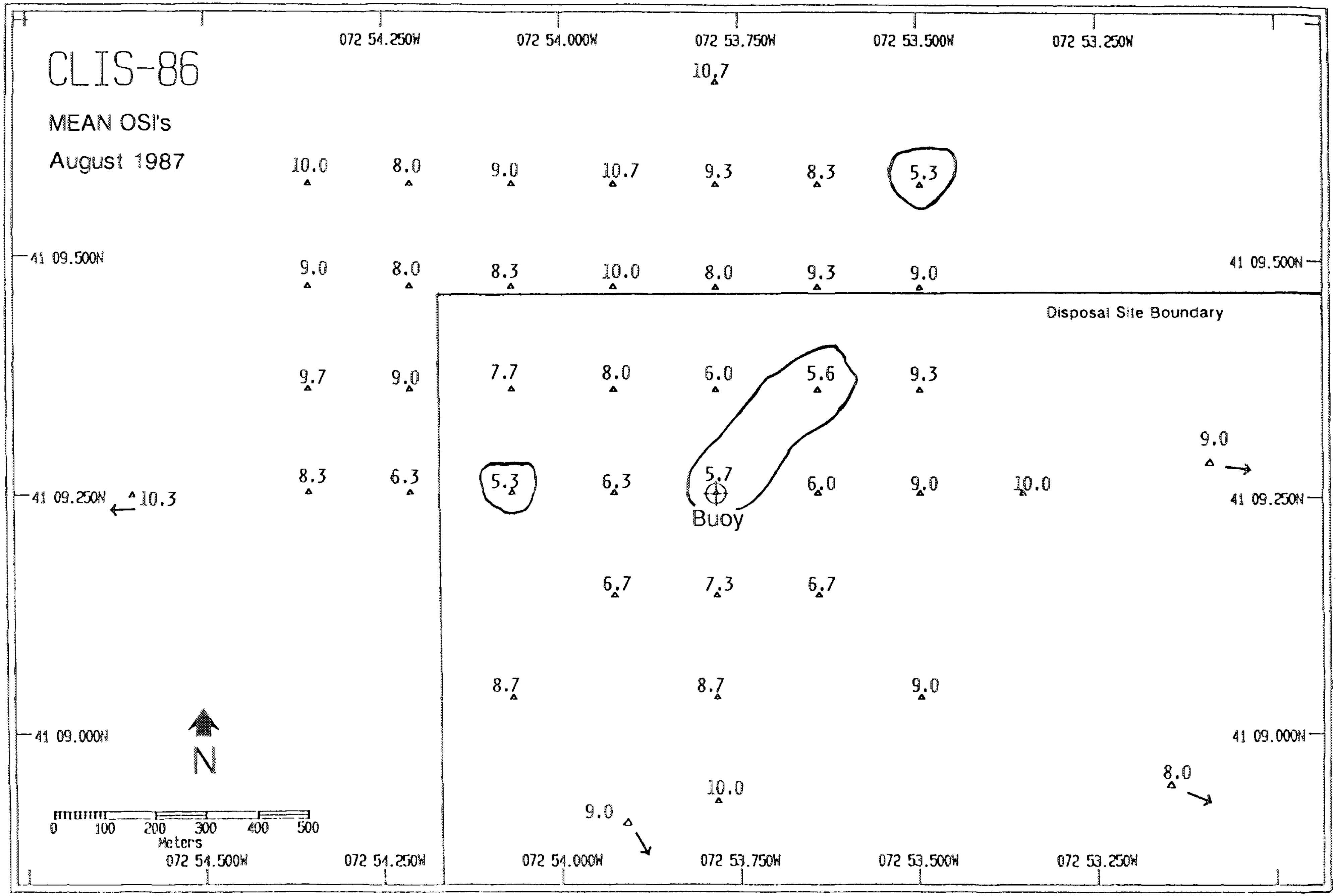



**Figure 3-14.** The distribution of Organism-Sediment Indices, averaged by station, at the CLIS-86 mound and CLIS reference stations, August 1987. The contours delimit areas having mean OSI values < +6.

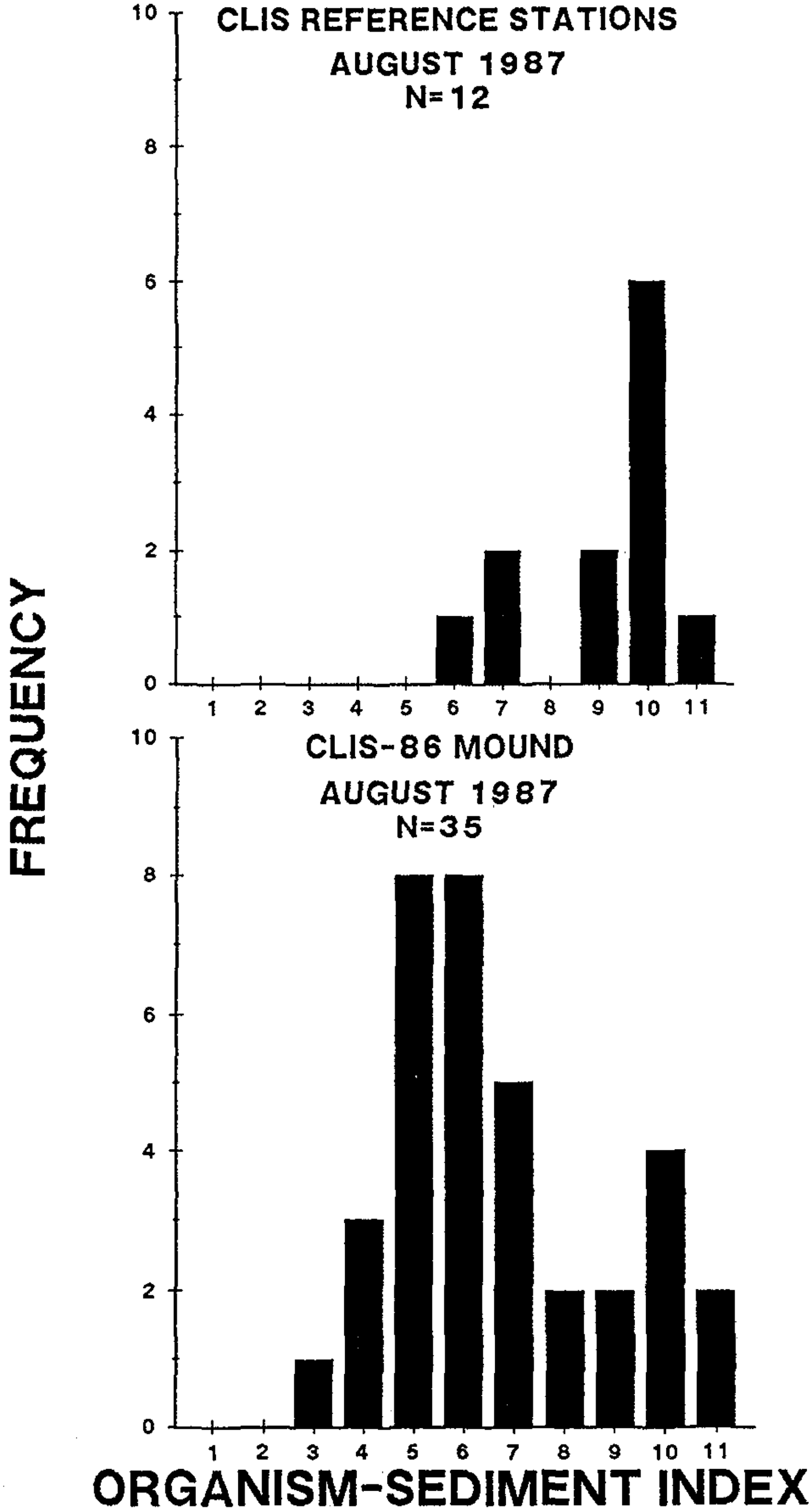



Figure 3-15. Frequency distributions of Organism-Sediment Index values for all replicates at the CLIS reference stations and the CLIS-86 mound stations where dredged material was present, August 1987 (n = number of replicates).

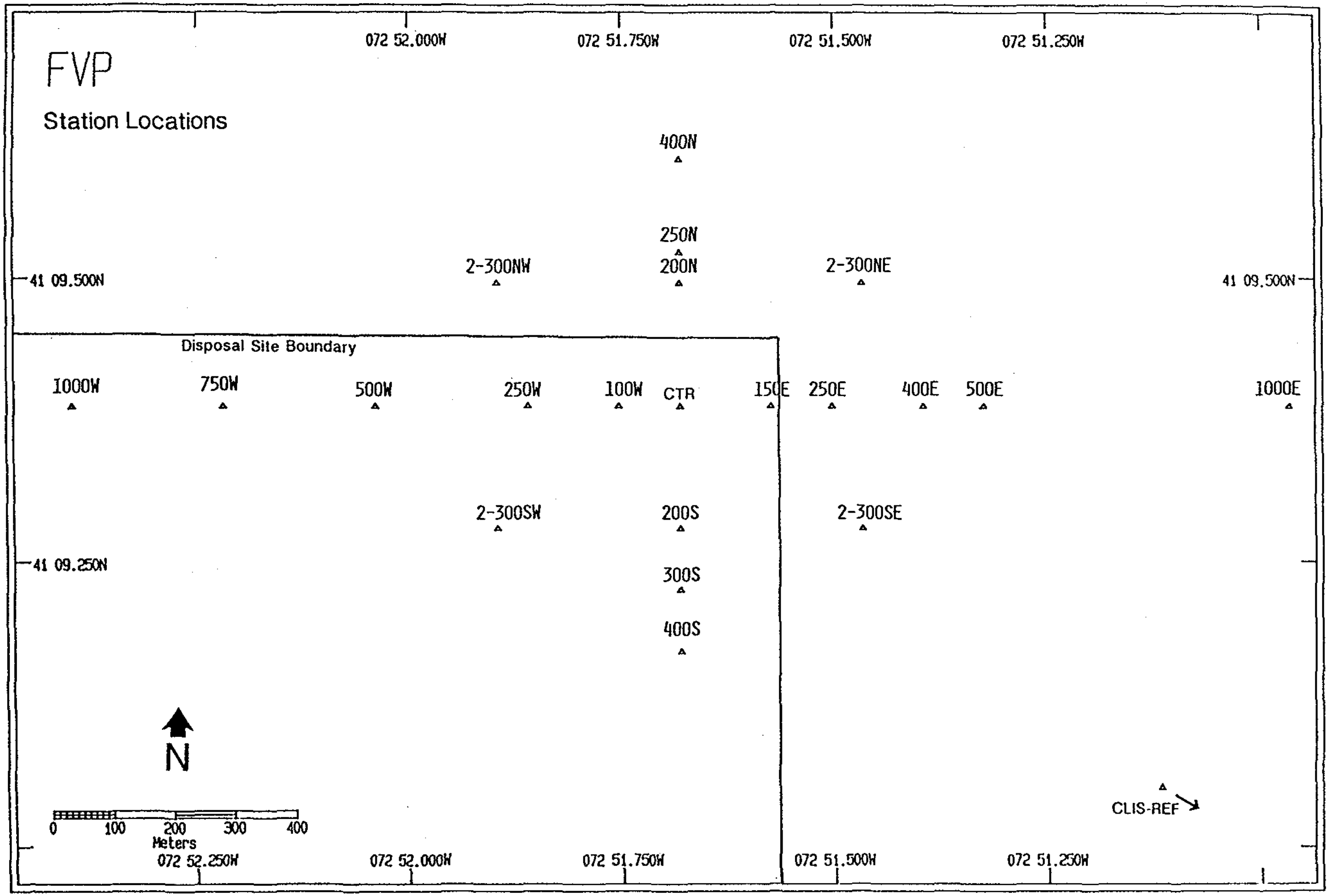



**Figure 3-16.** Locations and designations of REMOTS stations at the FVP disposal mound, August 1987. Station designations are in relation to the FVP mound center.

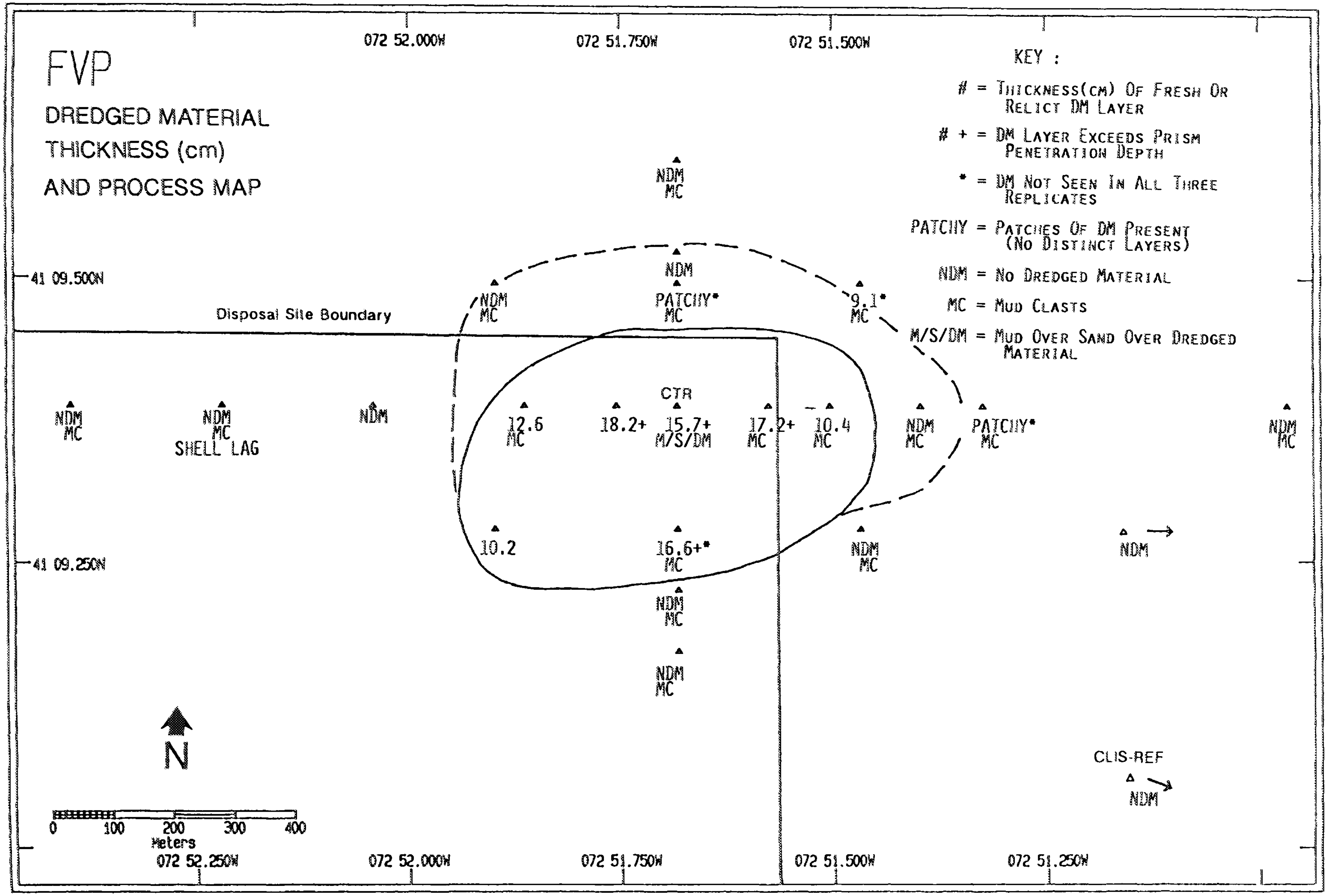



**Figure 3-17.** Distribution of dredged material and various physical features at the FVP disposal mound, August 1987. The solid line outlines the extent of dredged material as mapped in the present survey, while the broken line delimits the extent of the dredged material mound as originally mapped in May 1983.

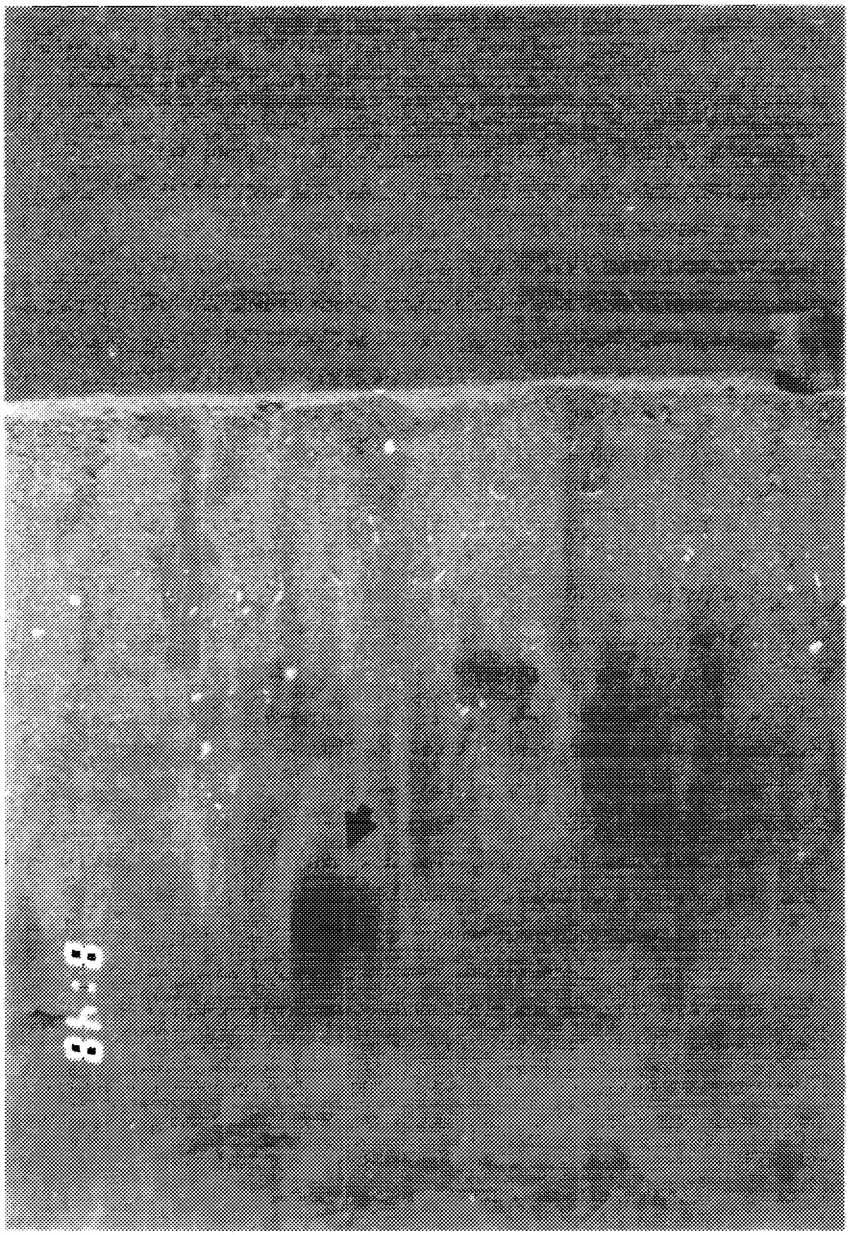


**Figure 3-18.** REMOTS® photo from station 2-300NW located on the flanks of the original FVP disposal mound. The patch of low reflectance sediment at depth (arrow) presumably represents "relict" dredged material. Scale = 1X.

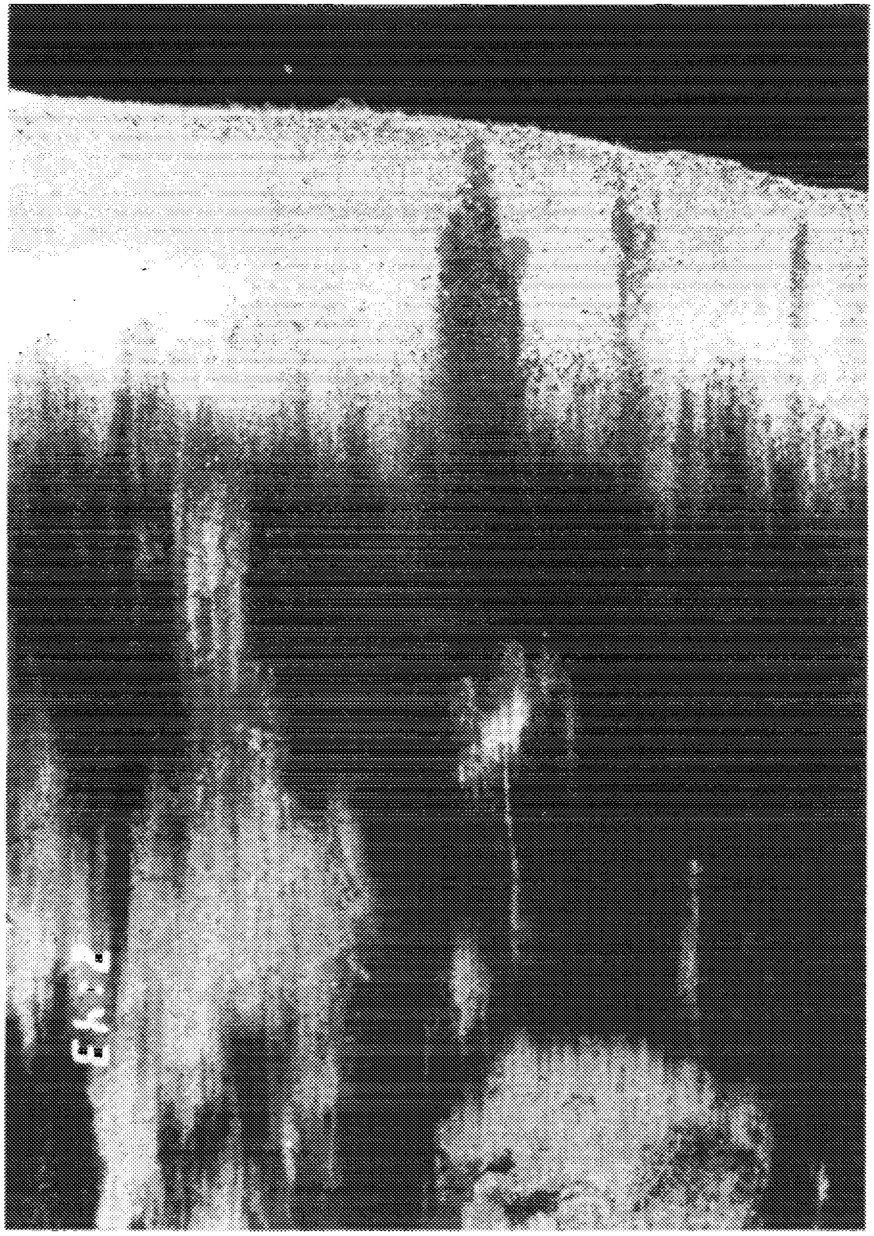


**Figure 3-19.** A distinct sand layer is evident at a depth of approximately 2-3 cm in this REMOTS® photo from FVP station CTR. Low reflectance dredged material extends beyond the penetration of the camera prism in this photo. Note also that the sediment surface at this station appears to be relatively undisturbed. Scale = 1X.

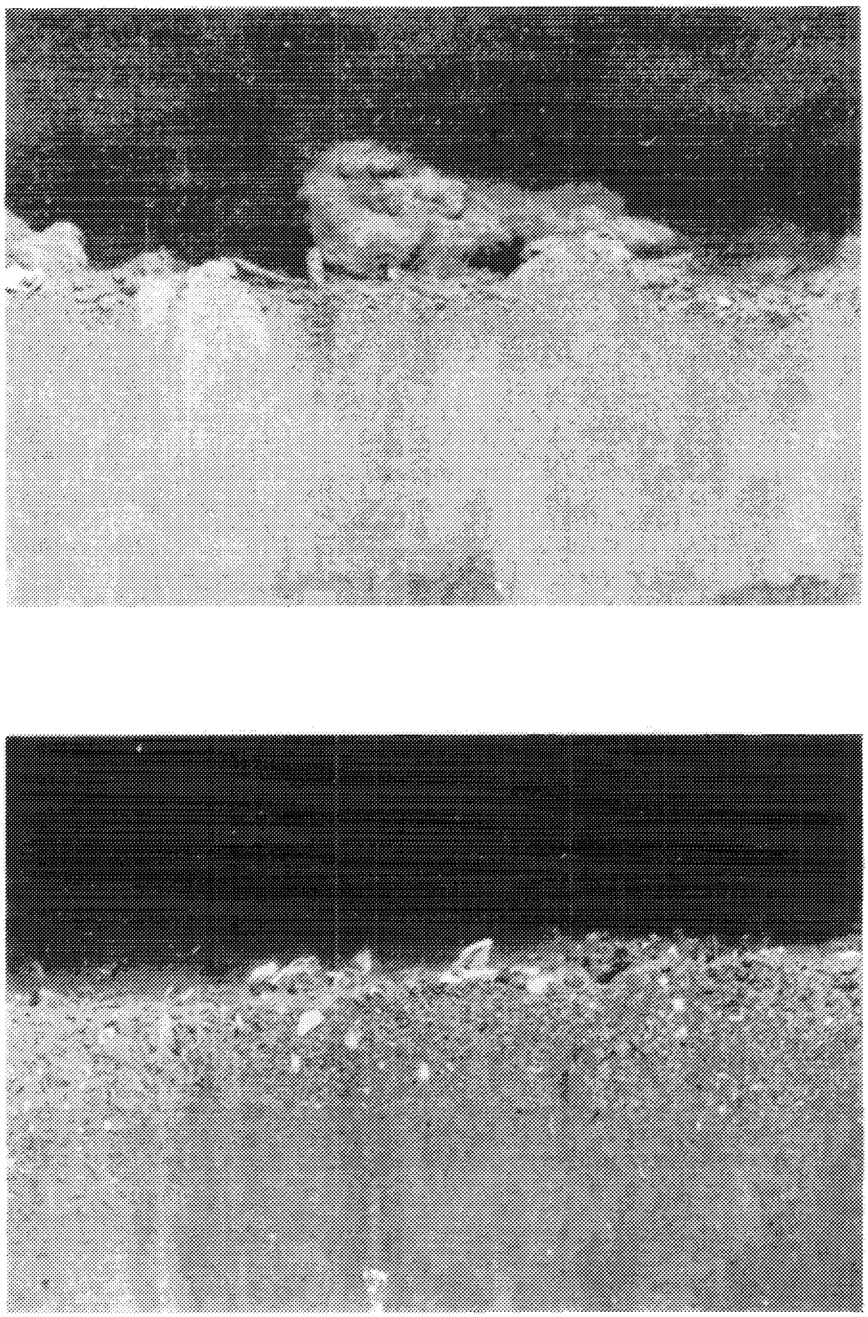


Figure 3-20. Two REMOTS® photos from the FVP mound illustrating mud clasts (top) and a shell lag deposit (bottom) at the sediment surface. Scale = 1X.

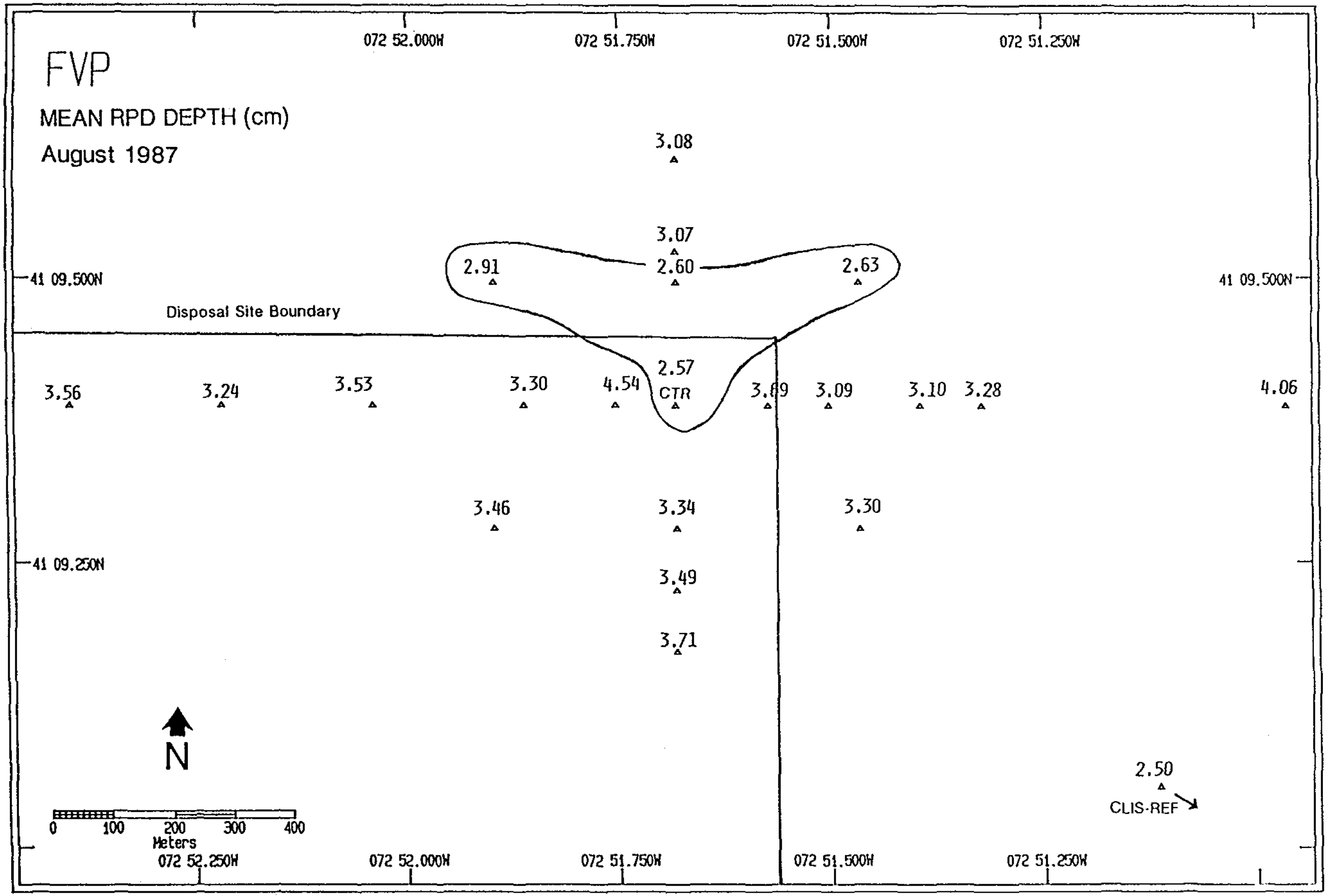



**Figure 3-21.** The distribution of apparent RPD depths, averaged by station, at the FVP mound in August 1987. The area enclosed by the contour line has mean apparent RPD depths $\leq$ 3 cm.

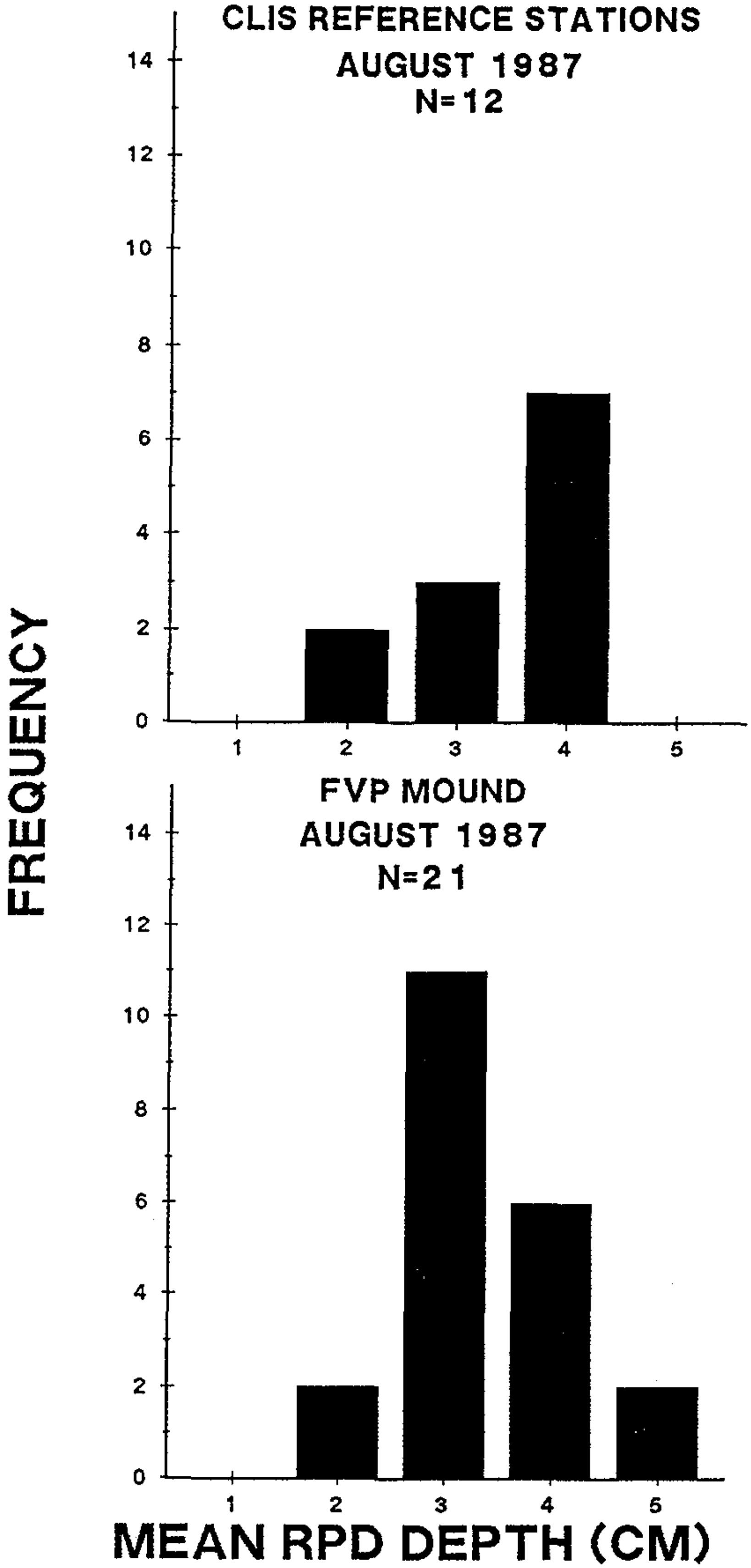



**Figure 3-22.** Frequency distributions of apparent RPD depths for all replicates at the CLIS reference stations and the FVP disposal mound stations where dredged material was present, August 1987 (n = number of replicates).

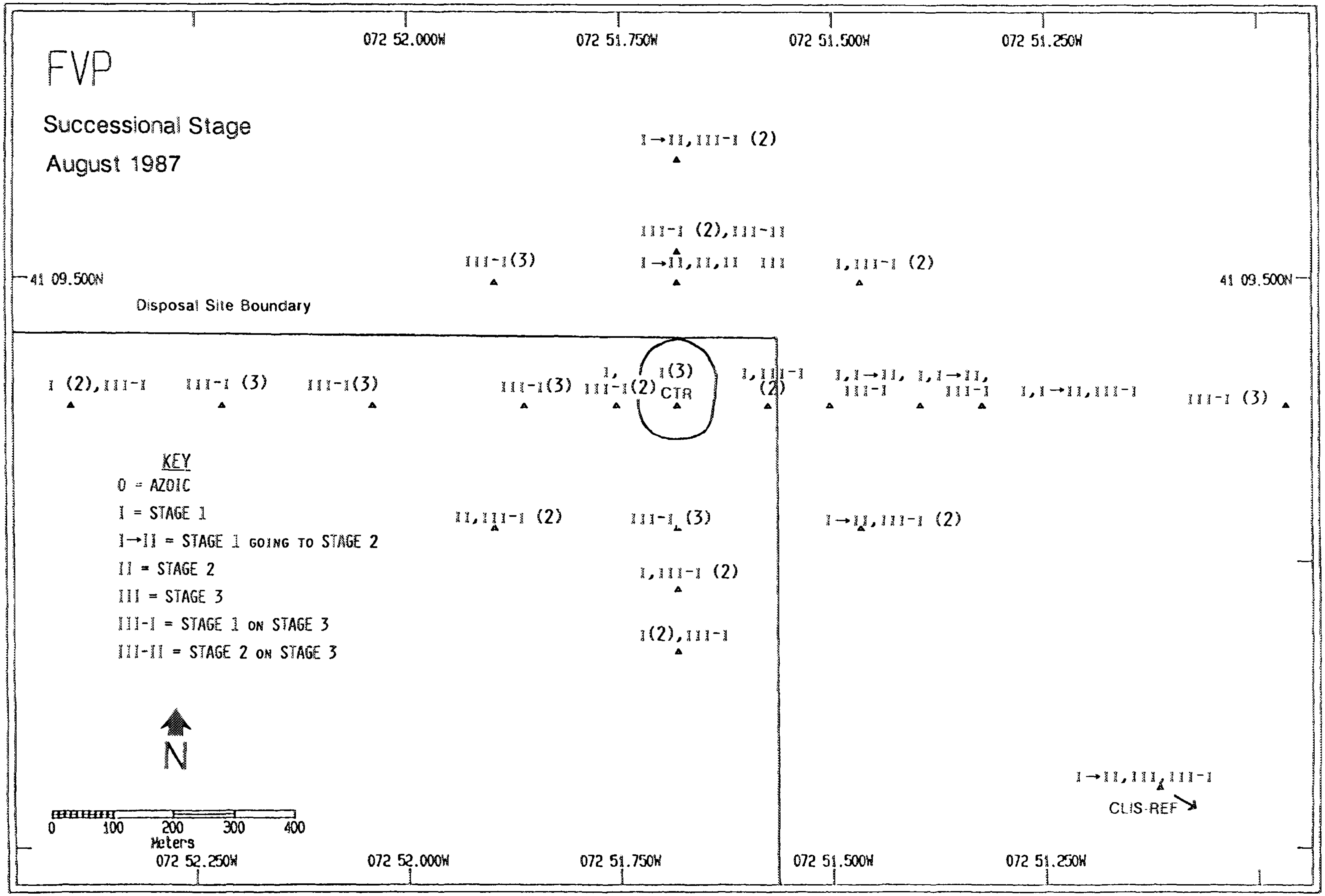



Figure 3-23. The distribution of infaunal successional stages at the FVP mound in August 1987. The contour delimits station CTR as the only one not having Stage III infauna.

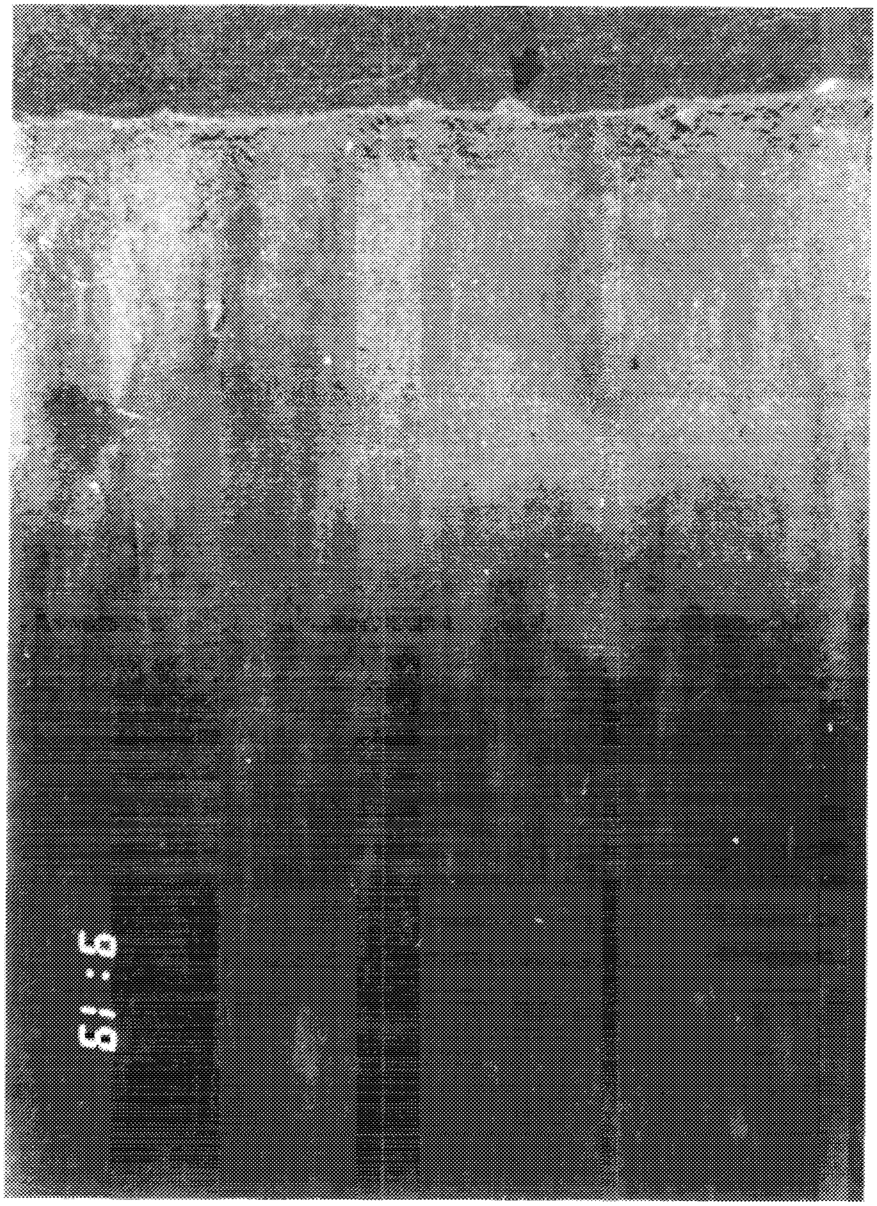


Figure 3-24. A single ampeliscid amphipod tube (arrow) is visible at the sediment surface in this REMOTS® photo from station 400E. Scale = 1X.

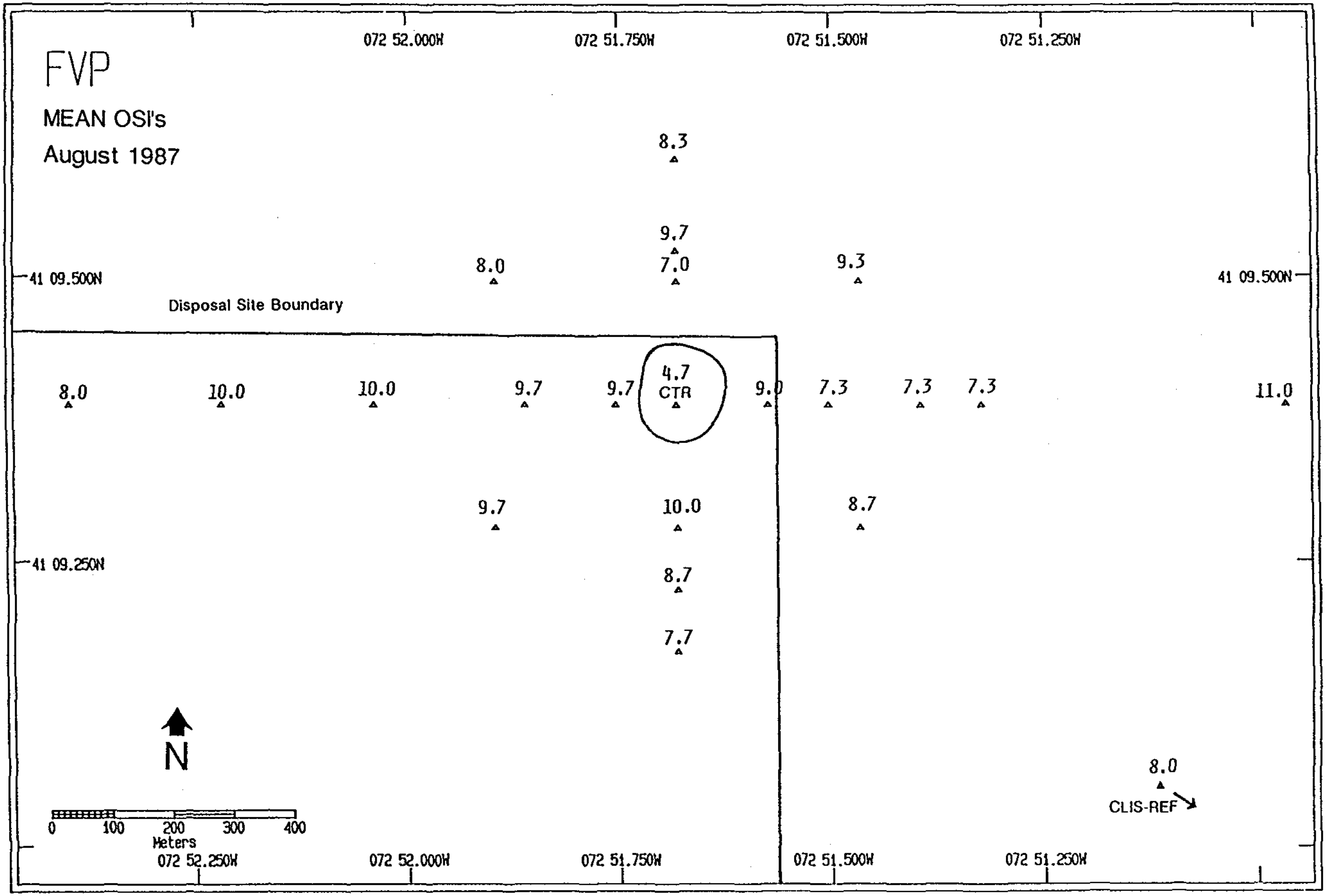



**Figure 3-25.** The distribution of Organism-Sediment Indices, averaged by station, at the FVP mound in August 1987. Station center, delimited by the contour, has an average OSI value < +6.

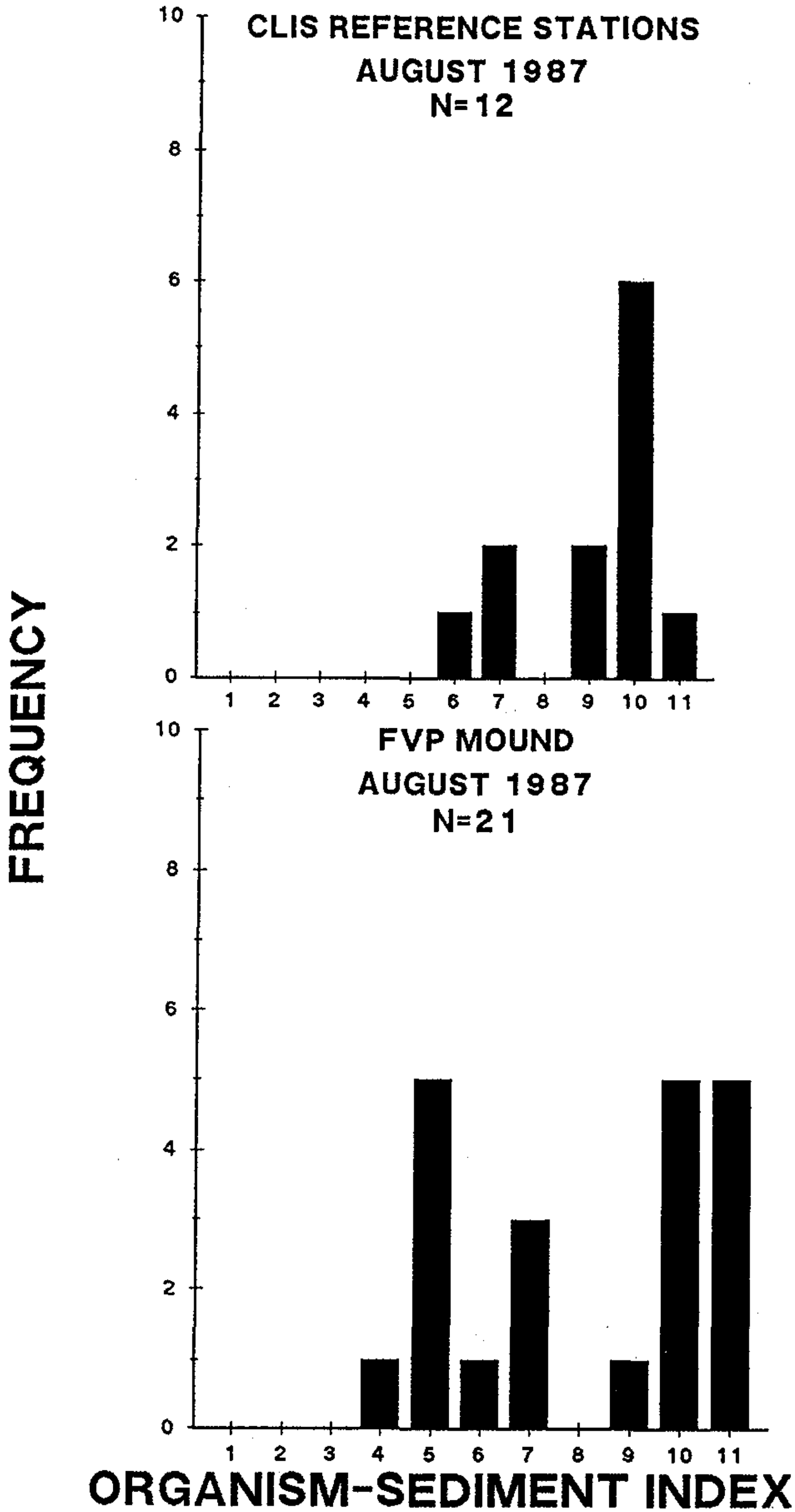



**Figure 3-26.** Frequency distributions of Organism-Sediment Index values for all replicates at the CLIS reference stations and the FVP mound stations where dredged material was present, August 1987 (n = number of replicates).

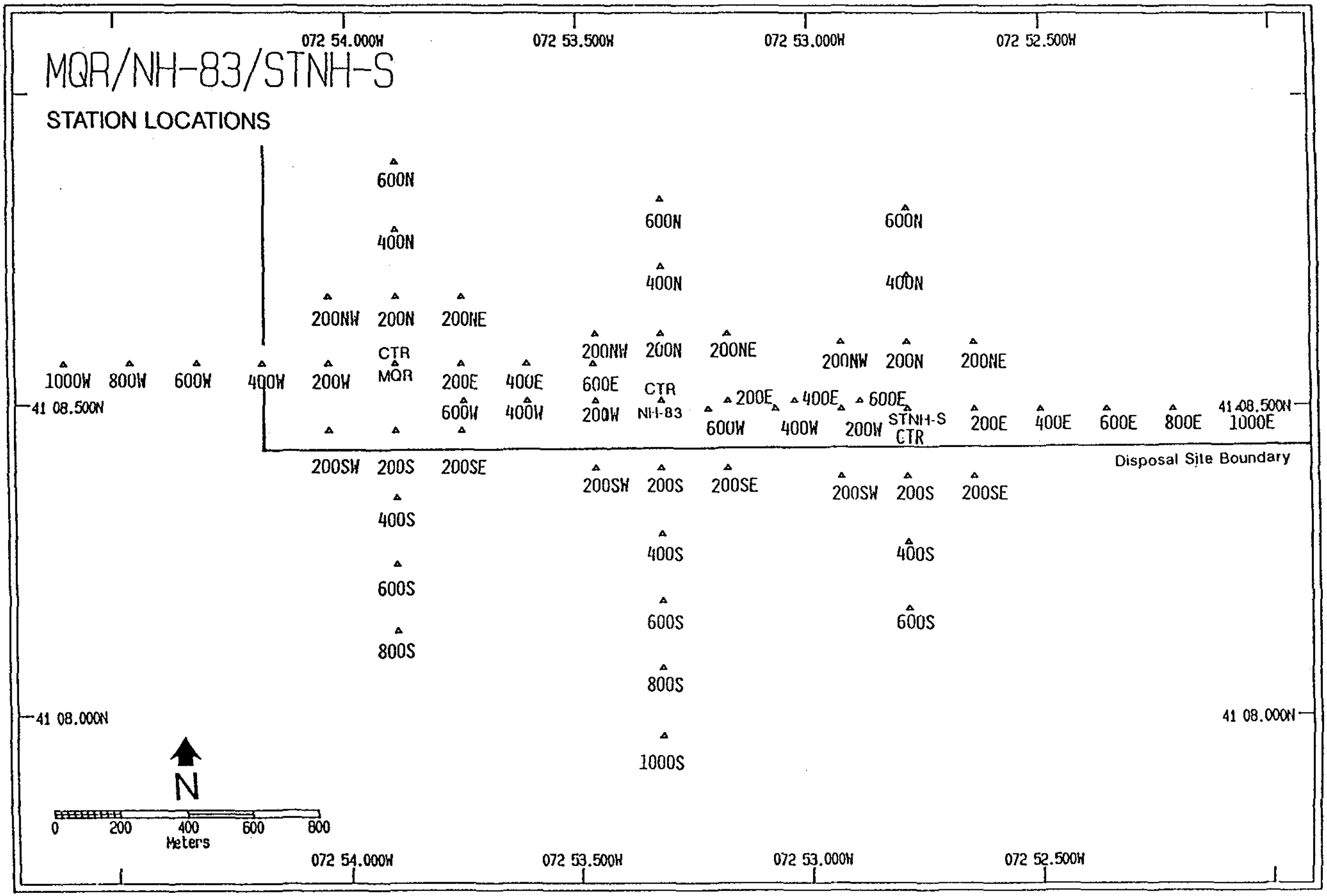



**Figure 3-27.** Locations and designations of REMOTS stations at the MQR, NH-83 and STNH-S disposal mounds, August 1987. All station designations are in relation to their respective mound's center.

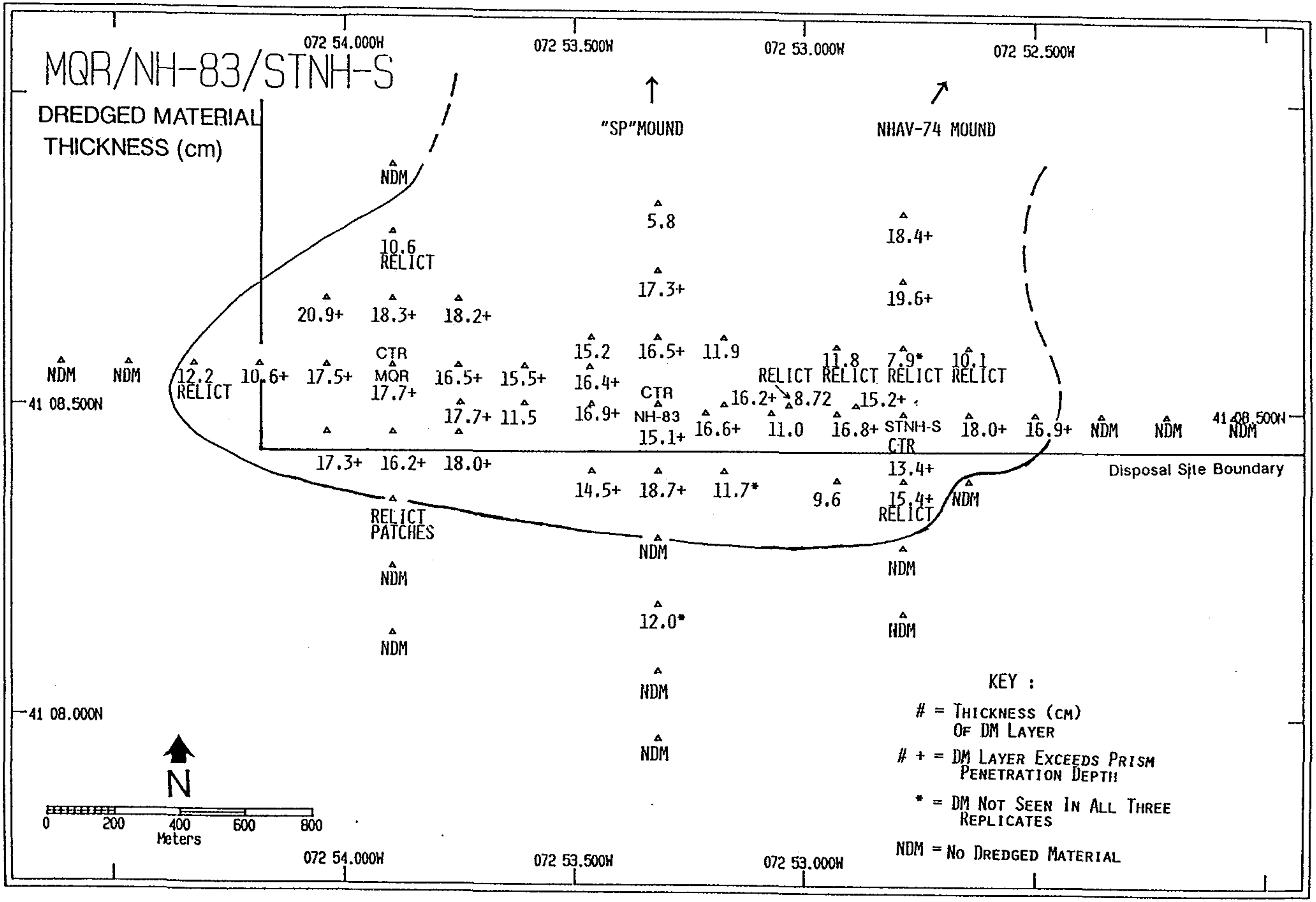



**Figure 3-28.** Approximate distribution (indicated by the contour line) of dredged material at the MQR, NH-83 and STNH-S disposal mounds, August 1987.

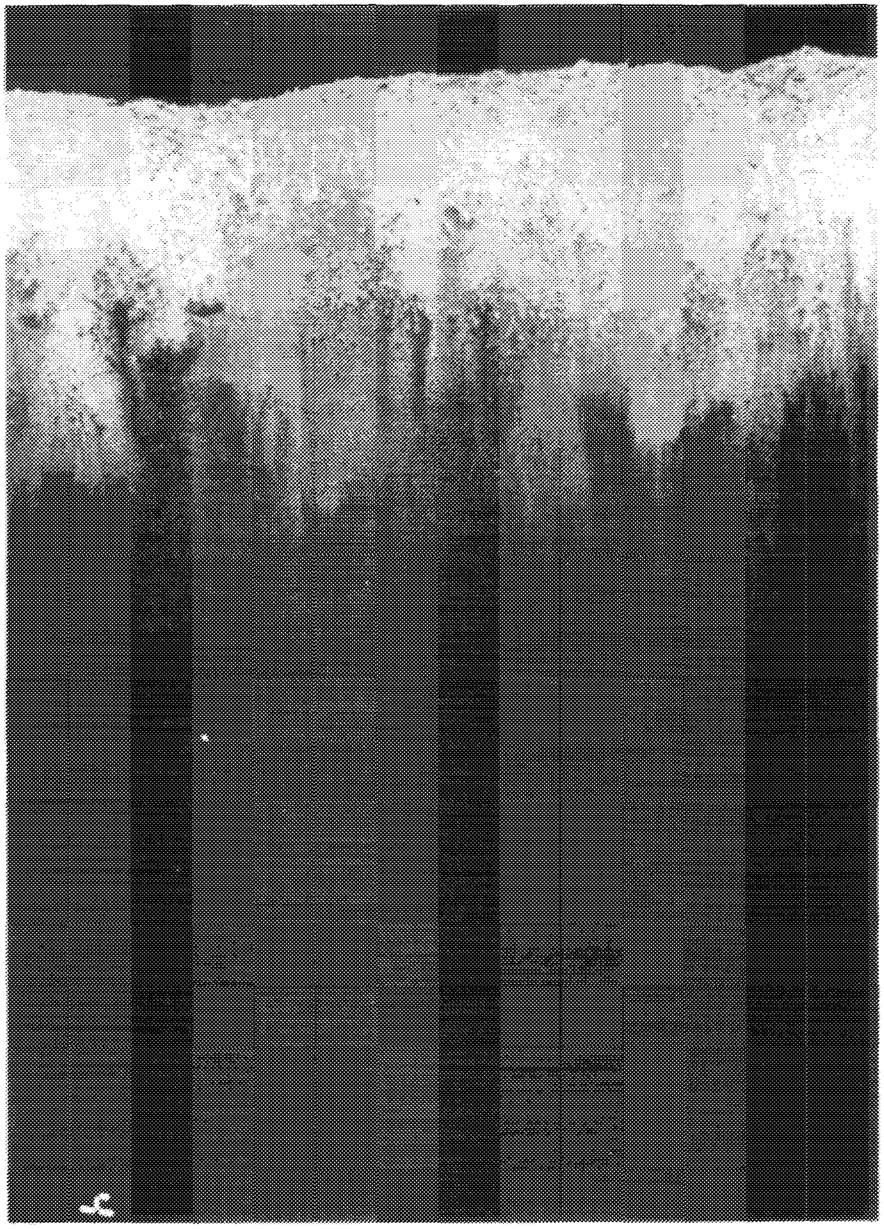


Figure 3-29. REMOTS® photo from MQR station CTR showing a typical fresh dredged material layer which extends beyond the depth of penetration of the camera prism. This material exhibits a "sand over mud" stratigraphy in which high reflectance silt-clay having a subordinate sand component overlies low reflectance fine-grained sediment having high apparent oxygen demand. Scale = 1X.

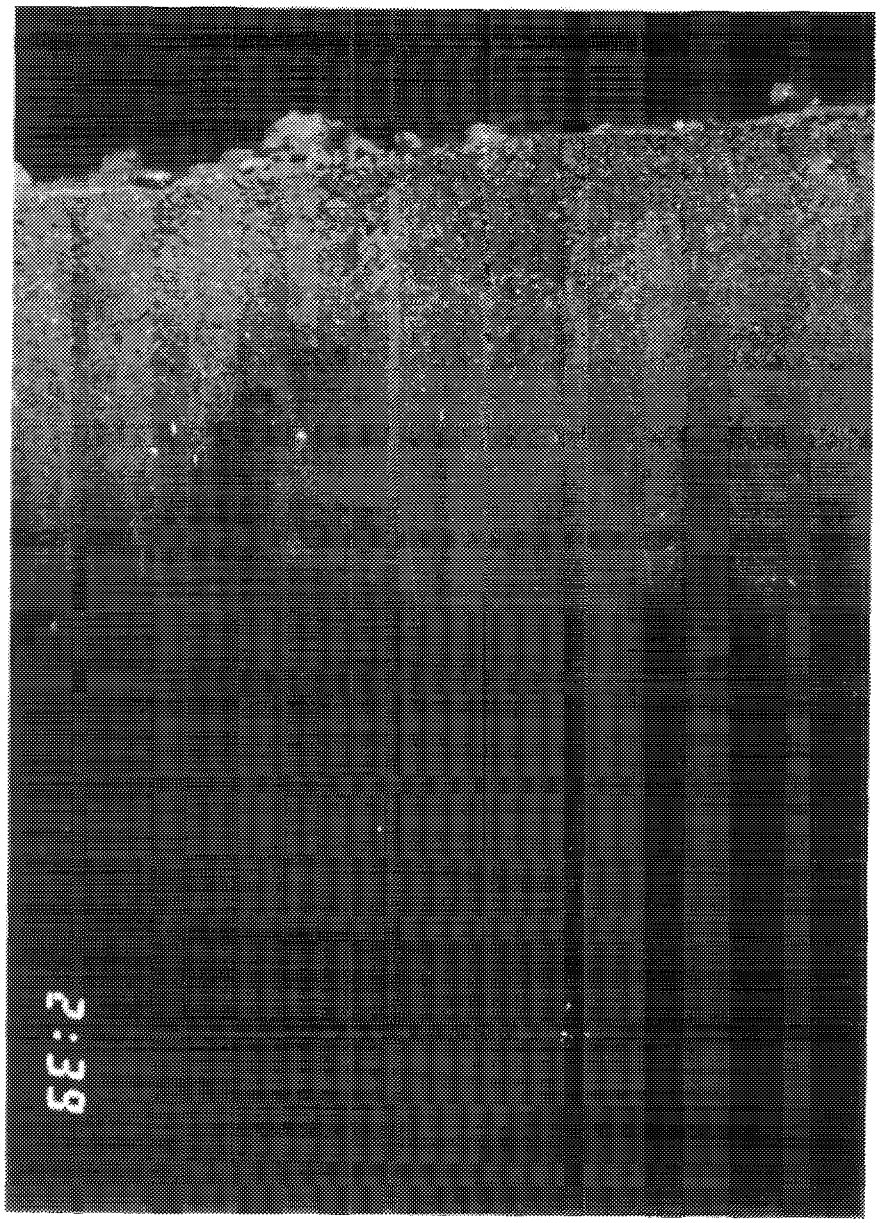



**Figure 3-30.** Two REMOTS® photos from STNH-S station 200N which illustrate the effects of sediment reworking on the optical "signature" of dredged material. Dredged material which exceeded the prism penetration depth in July 1986 (photo A, above) is visible only as a "relict" layer one year later (the layer between the arrows in photo B from August 1987, following page). Scale of both photos = 1X.

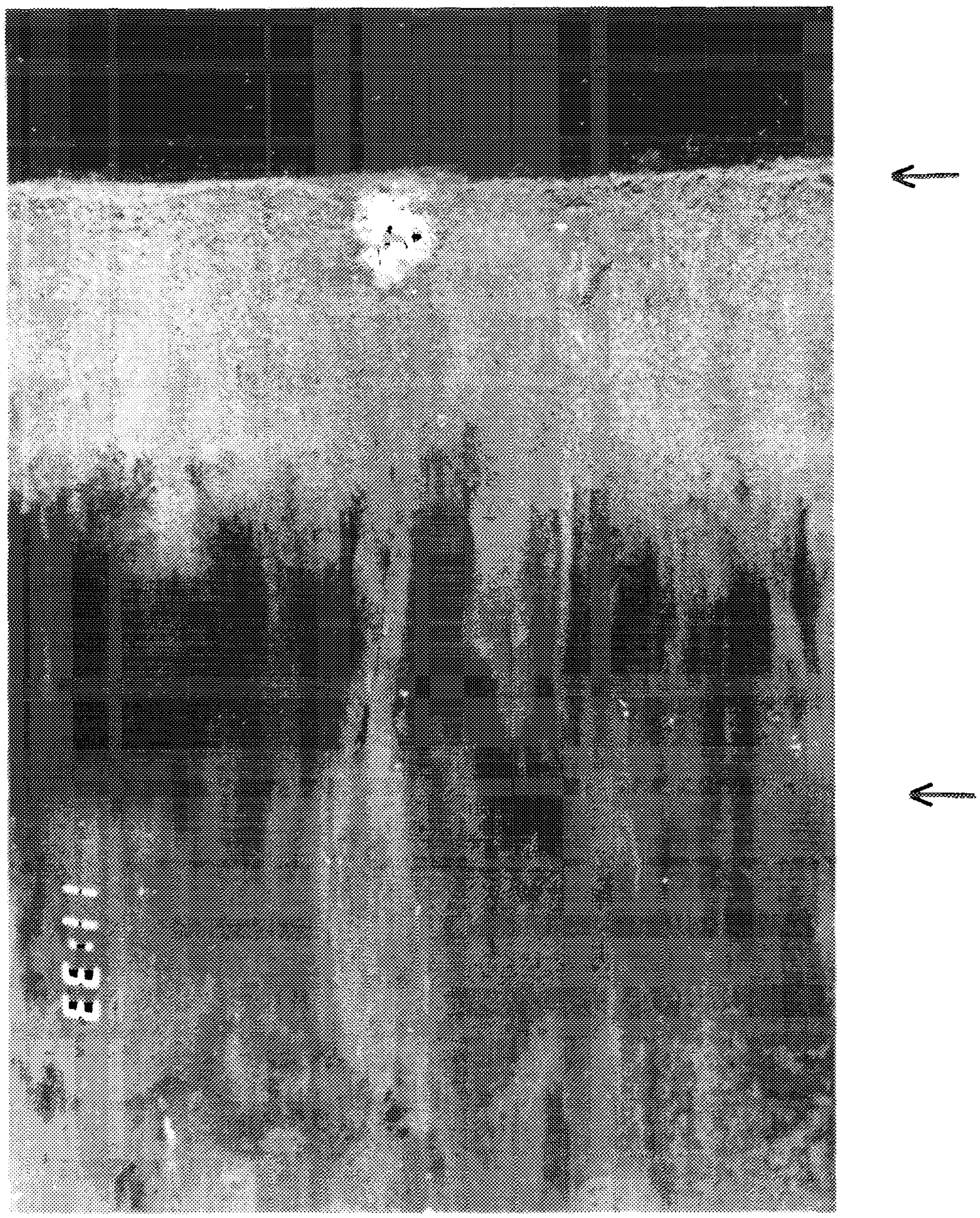


Figure 3-30, image B.

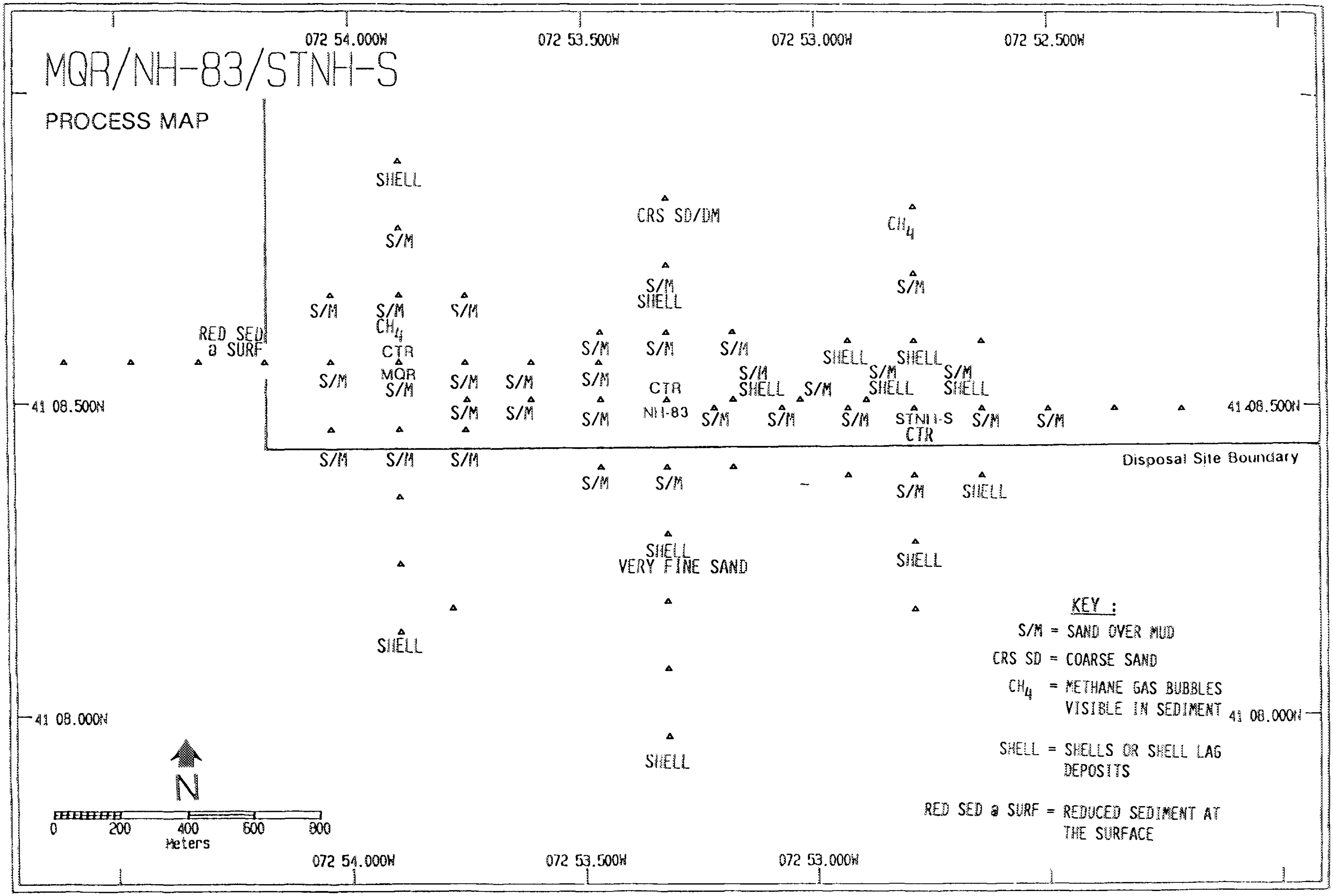



Figure 3-31. "Process" map of physical and sedimentological seafloor features at the MQR, NH-83 and STNH-S disposal mounds, August 1987.

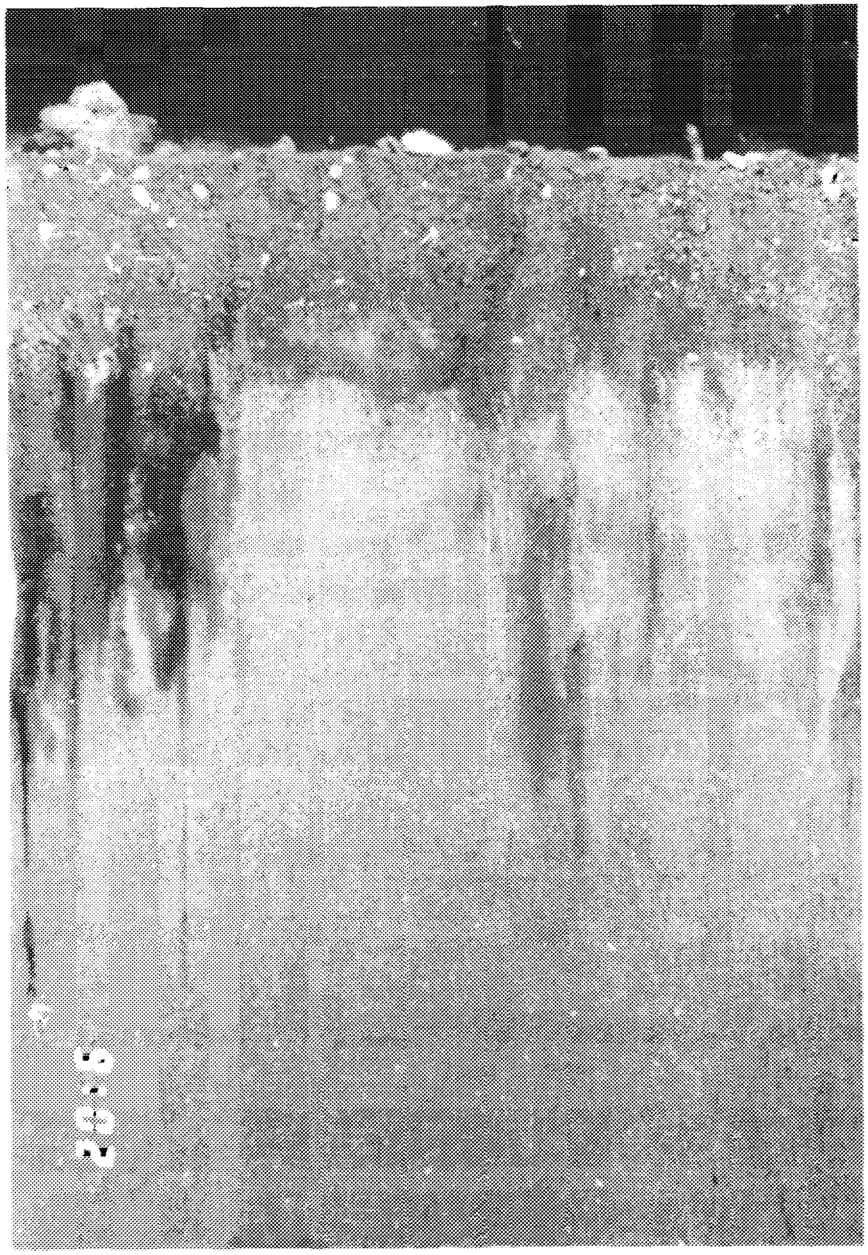


Figure 3-32. REMOTS® photo from STNH-S station 200W showing a layer of intermediate-reflectance sediment overlying high reflectance material. The underlying layer possibly may consist of cohesive clay. A shell lag deposit is present on the sediment surface, and the bivalve Mulinia lateralis is visible just below the surface (white spheres). Scale = 1X.

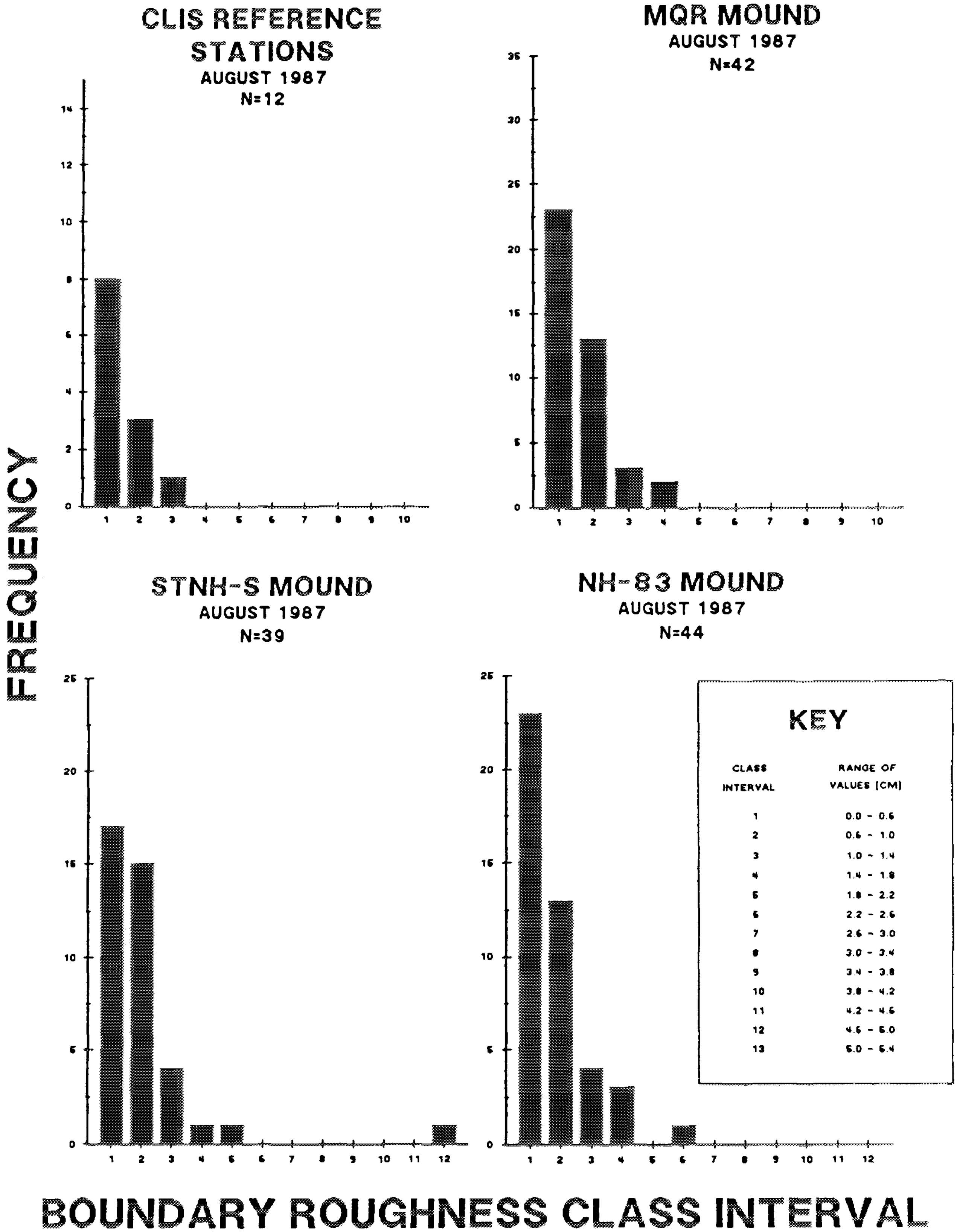



Figure 3-33. Frequency distributions of small-scale surface boundary roughness values for all replicates at the CLIS reference stations and the stations where dredged material was present at the MQR, NH-83, and STNH-S mounds, August 1987 (n = number of replicates).

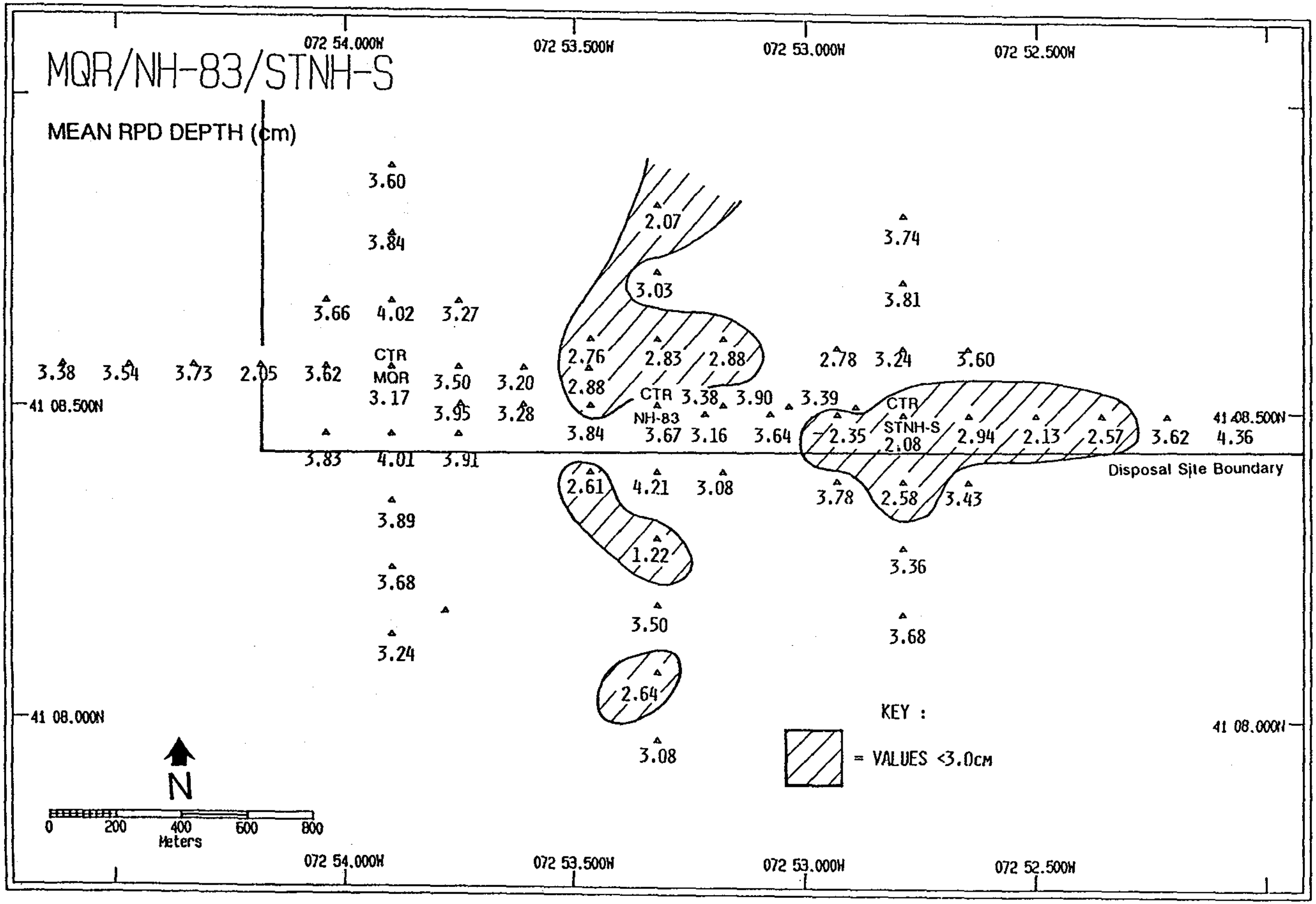



**Figure 3-34.** The distribution of apparent RPD depths, averaged by station, at the MQR, NH-83 and STNH-S mounds in August 1987.

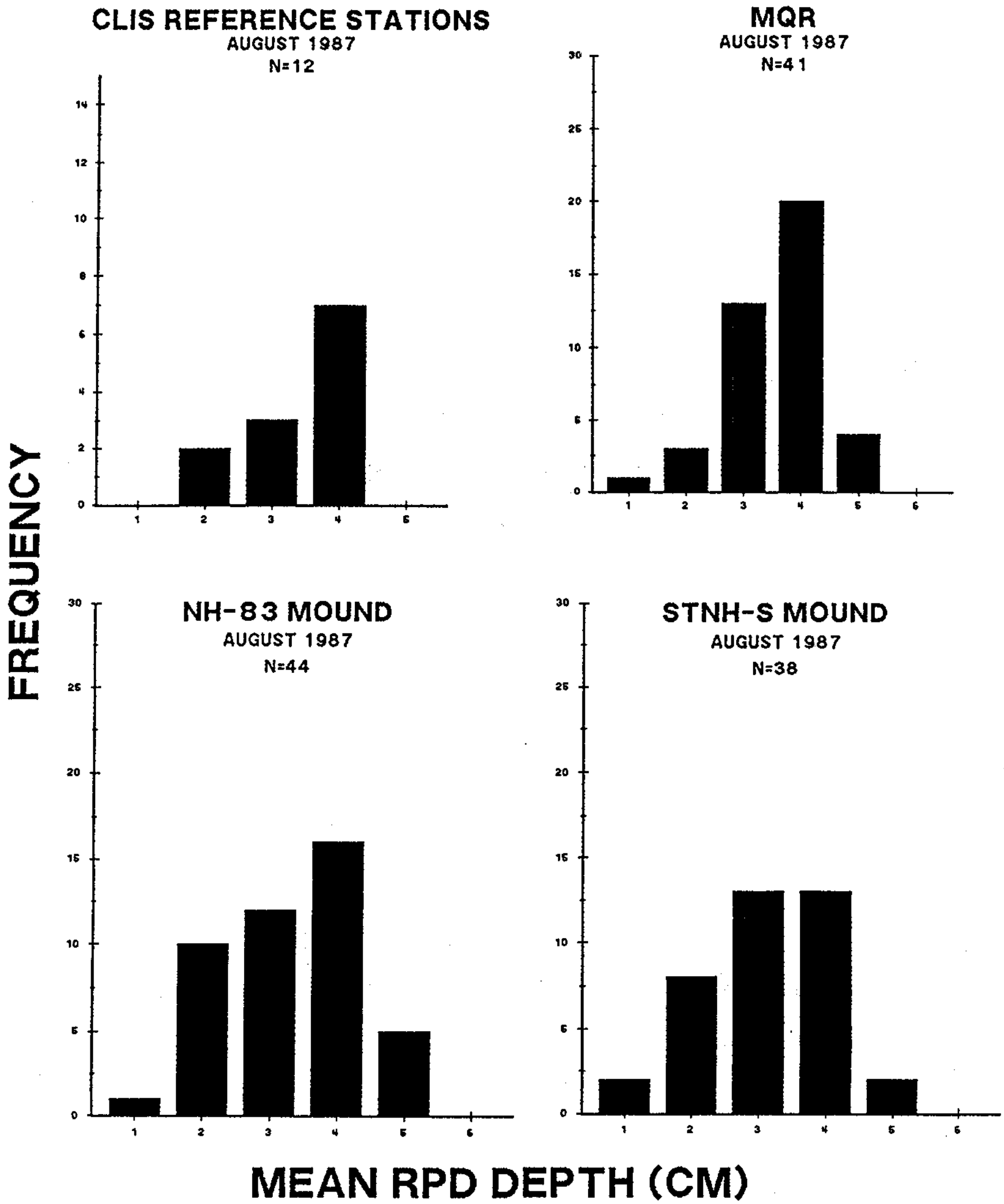



**Figure 3-35.** Frequency distributions of apparent RPD depths for all replicates at the CLIS reference stations and the stations where dredged material was present at the MQR, NH-83, and STNH-S disposal mounds, August 1987 (n = number of replicates).

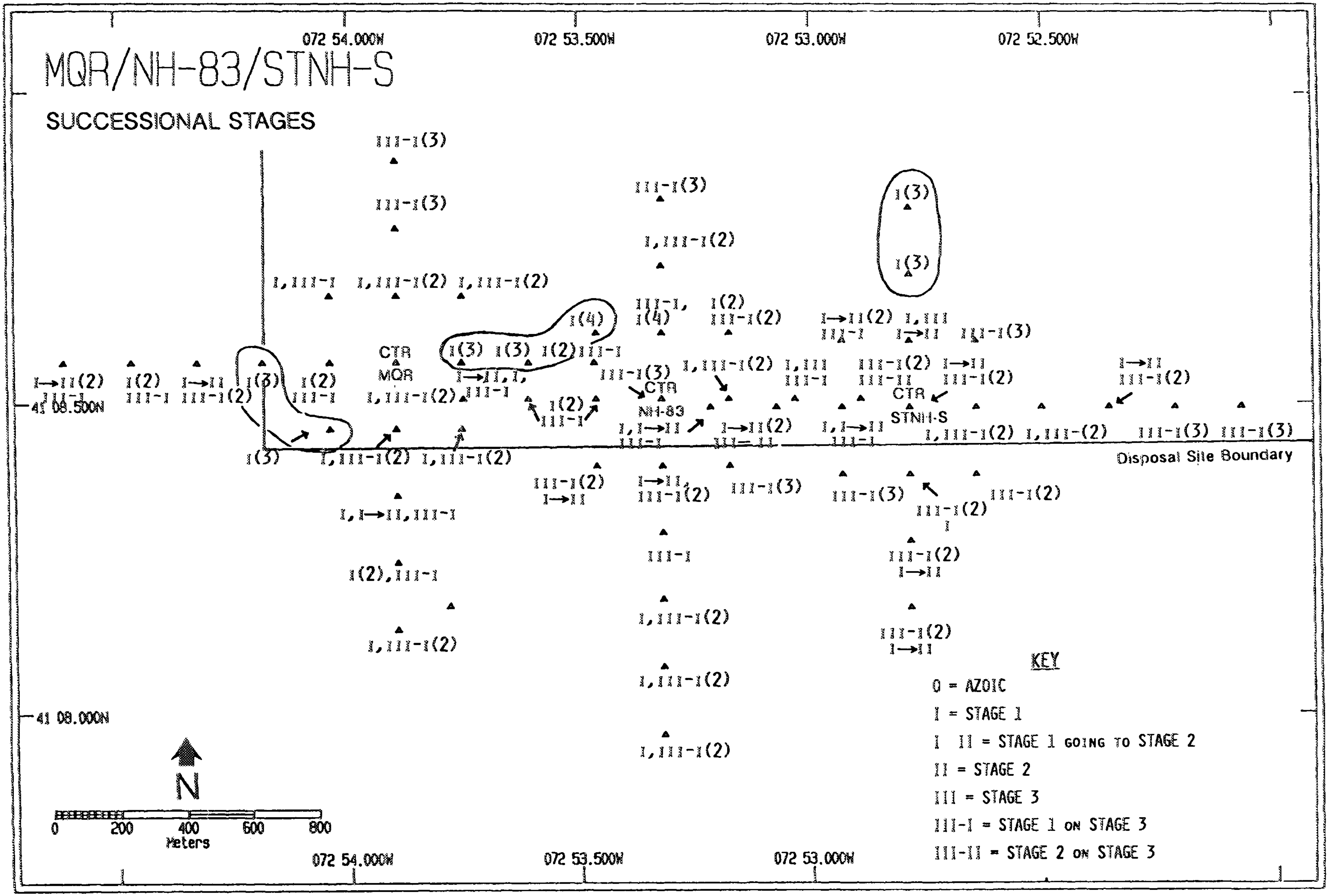



Figure 3-36. The distribution of infaunal successional stages at the MQR, NH-83 and STNH-S disposal mounds in August 1987. Contours delimit areas lacking Stage III infauna.

**Figure 3-37.** REMOTS® photo from MQR station 200W illustrating a Stage I on III successional sere. A Stage I polychaete assemblage at the sediment surface overlies the head-down deposit feeding polychaete (Stage III) visible at depth. Scale = 1X.

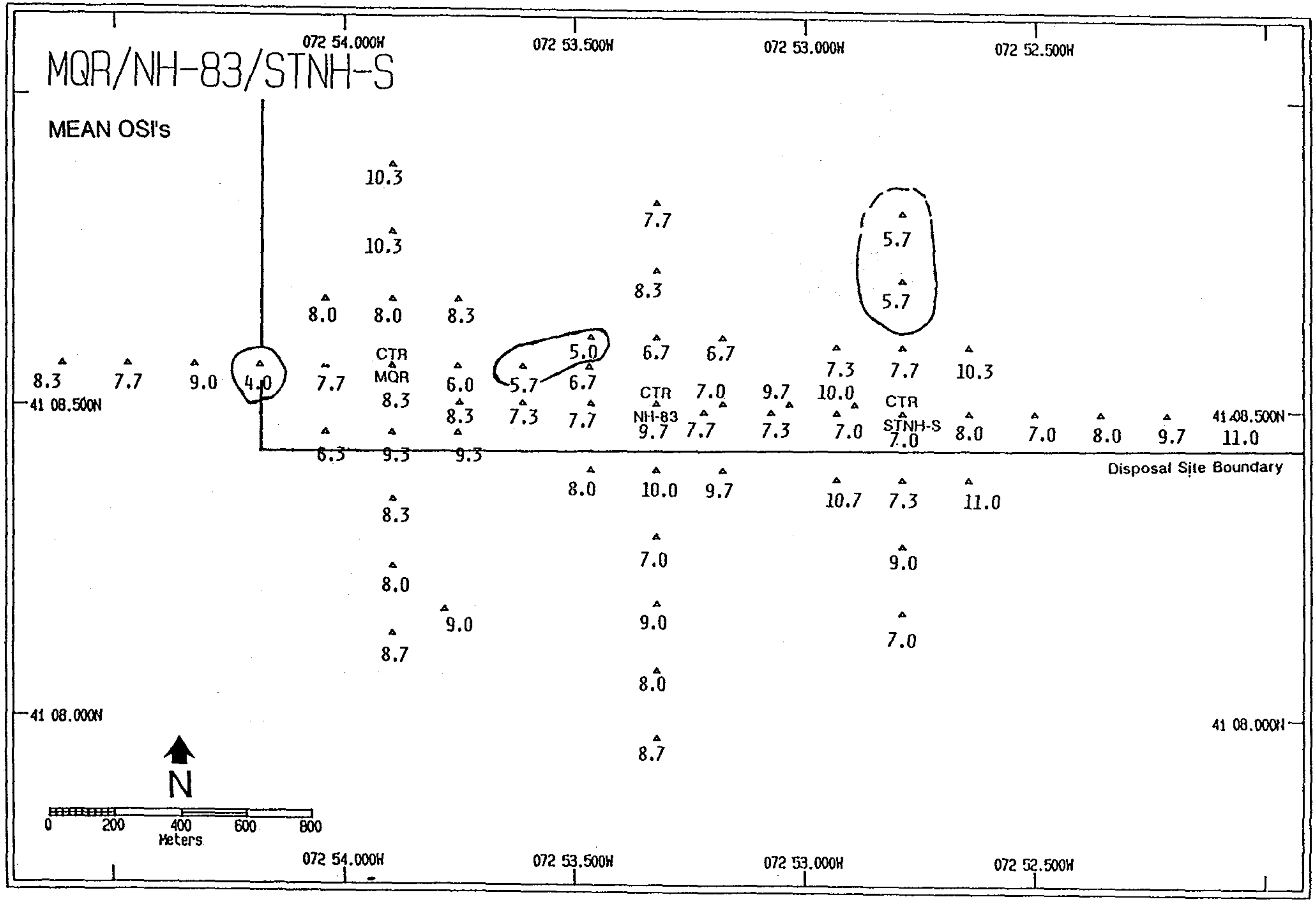



**Figure 3-38.** The distribution of Organism-Sediment Indices, averaged by station, at the MQR, NH-83 and STNH-S mounds in August 1987. Contours delimit areas having mean OSI values < +6.

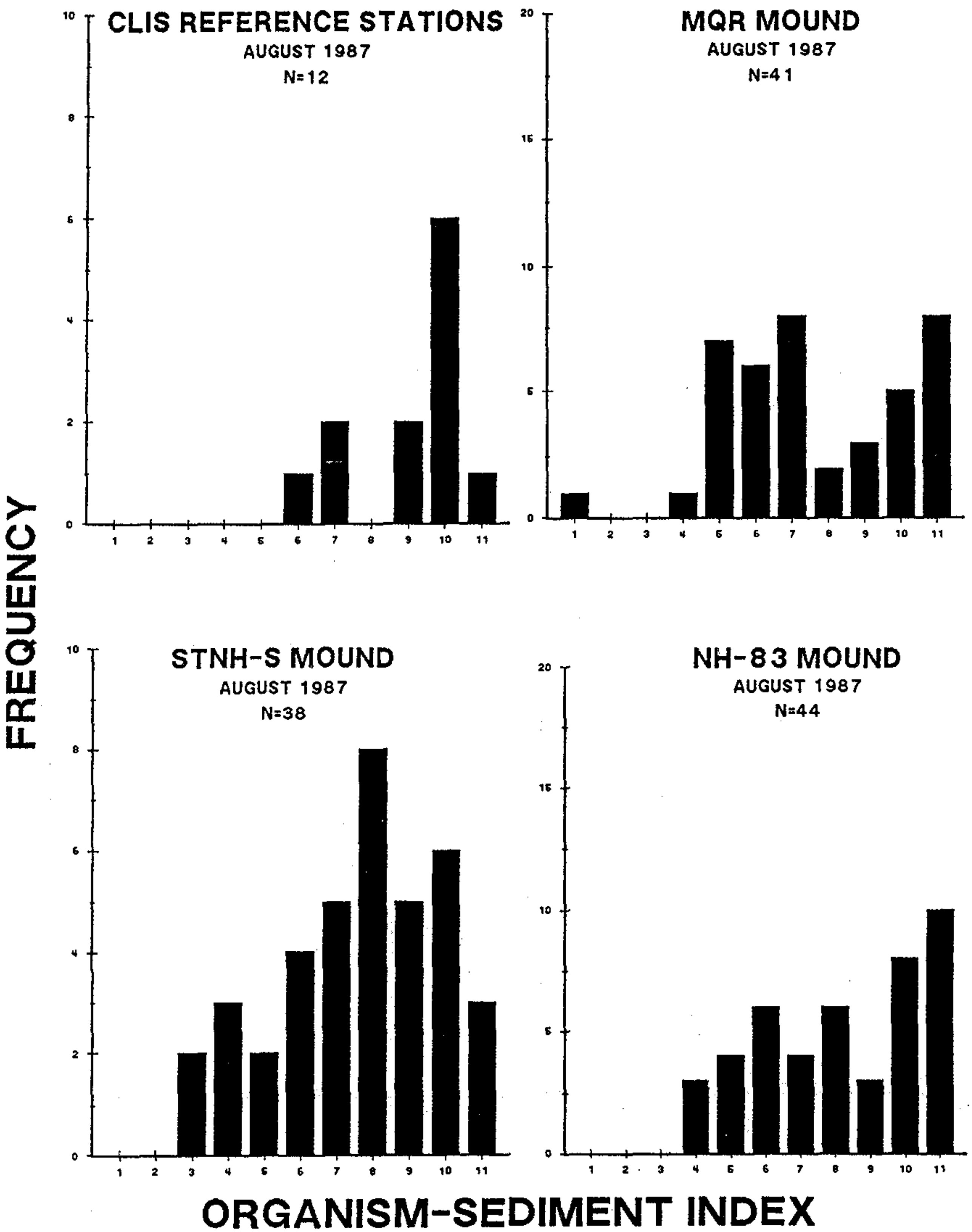



Figure 3-39. Frequency distributions of Organism-Sediment Index values for all replicates at the CLIS reference stations and the stations where dredged material was present at the MQR, NH-83, and STNH-S disposal mounds, August 1987 (n = number of replicates).

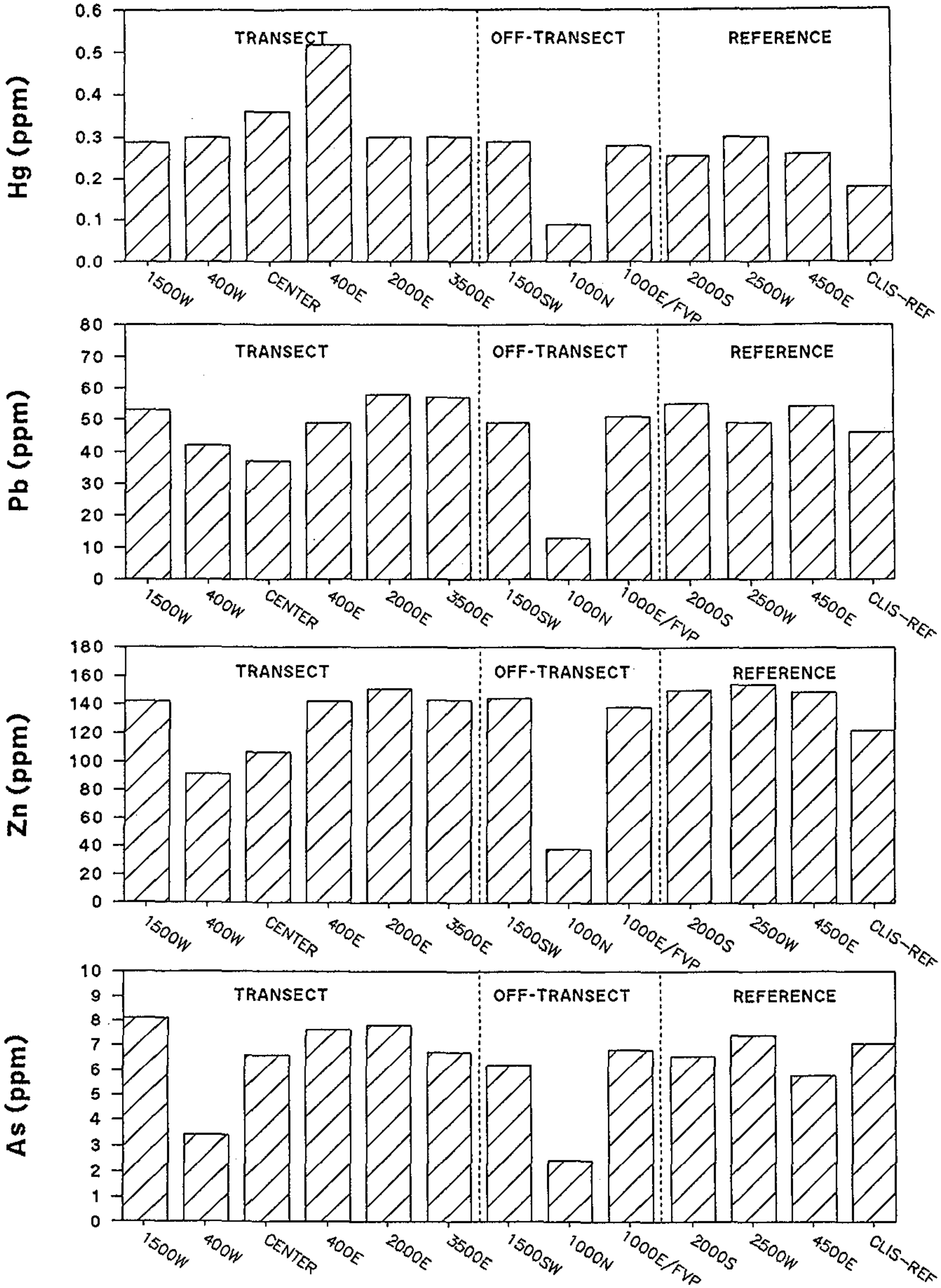



Figure 3-40. Results of chemical analyses of sediment collected at CLIS, August 1987. Concentrations are based on dry weight. Station designations are in relation to the CLIS-86 mound center, except for the station 1000 m east of the FVP mound center (1000E/FVP).

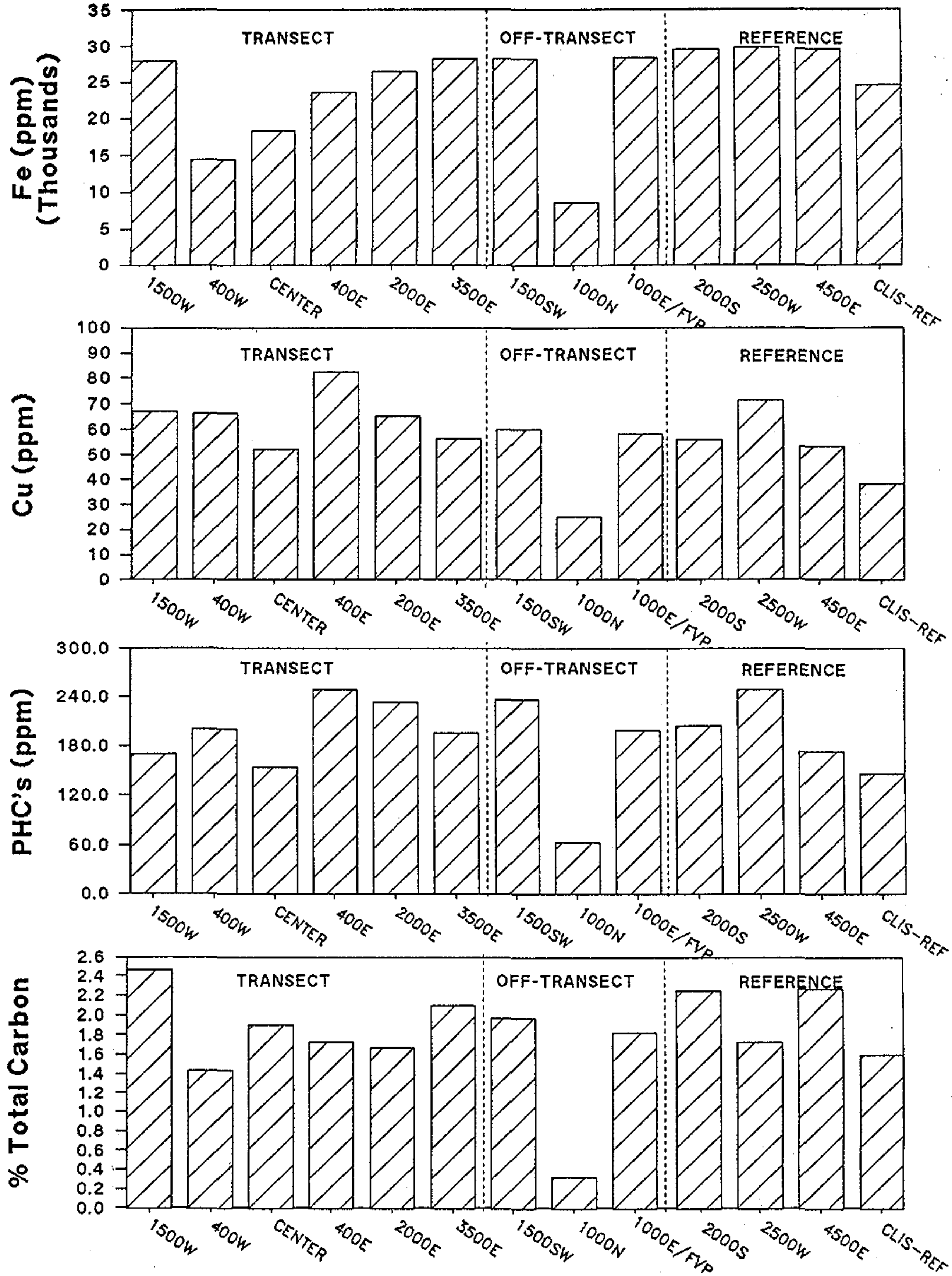



Figure 3-41. Results of chemical analyses of sediment collected at CLIS, August 1987. Concentrations are based on dry weight; PHC's = petroleum hydrocarbons. Station designations are in relation to the CLIS-86 mound center, except for the station 1000 m east of the FVP mound center (1000E/FVP).

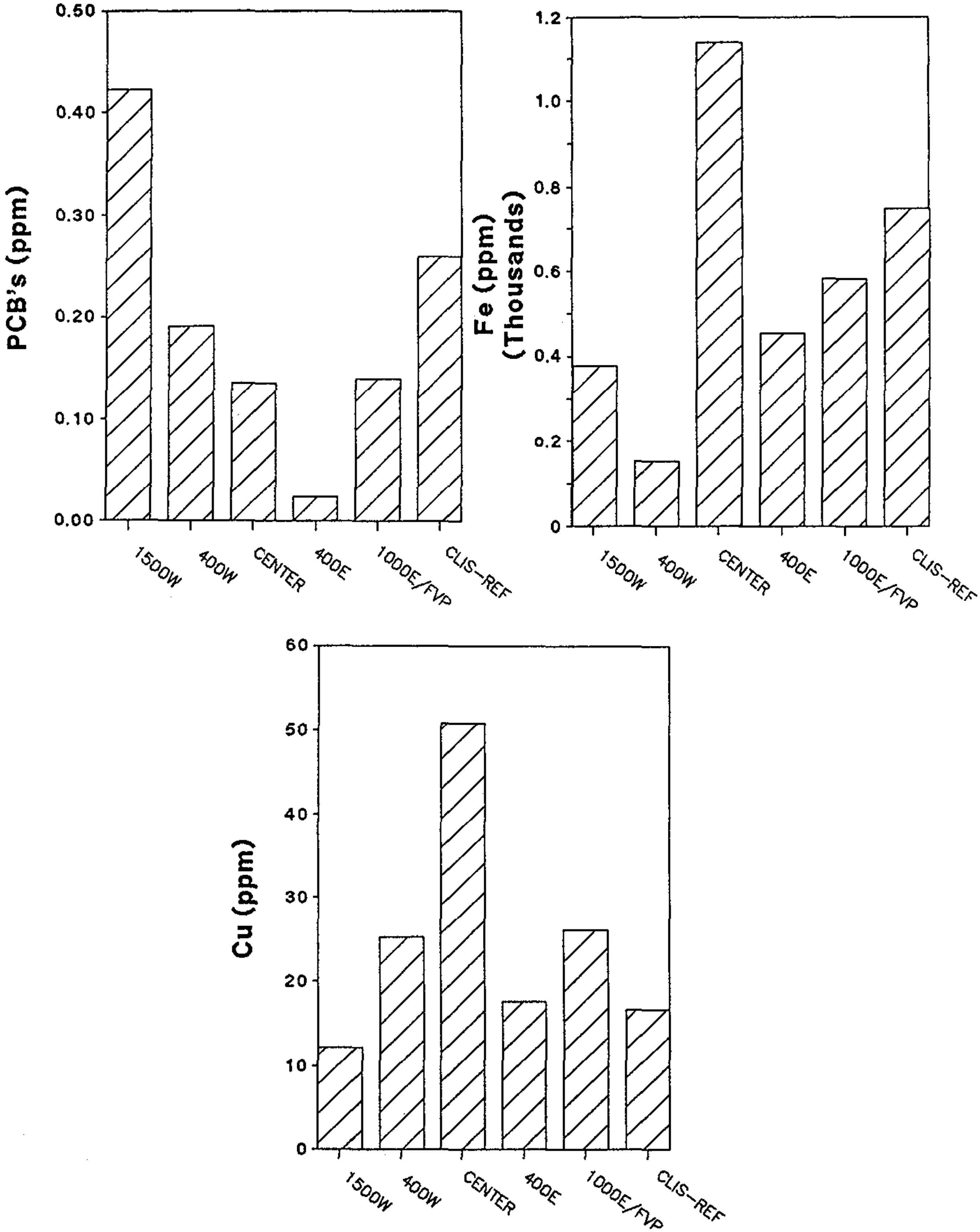



Figure 3-42. Results of body burden analyses on Nephtys collected at CLIS, August 1987. Concentrations are based on dry weight of tissue. Station designations are in relation to the CLIS-86 mound center, except for the station 1000 m east of the FVP mound center (1000E/FVP).

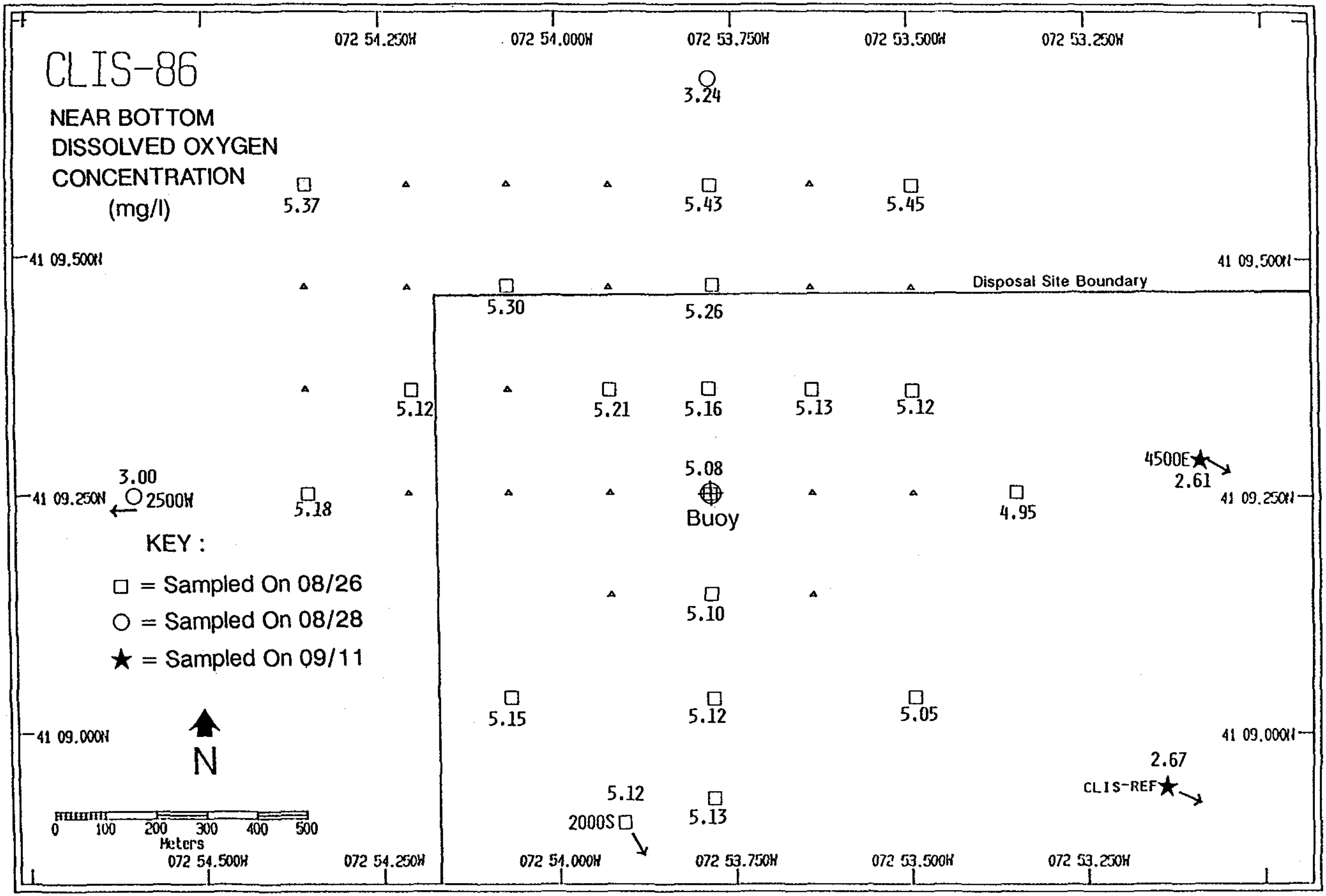



**Figure 3-43.** Near-bottom dissolved oxygen concentrations (in mg/ℓ) measured at selected REMOTS® stations at the CLIS-86 mound, August and September 1987. Dissolved oxygen measurements obtained at the four CLIS reference stations (CLIS-REF, 4500E, 2000S and 2500W) are also given.

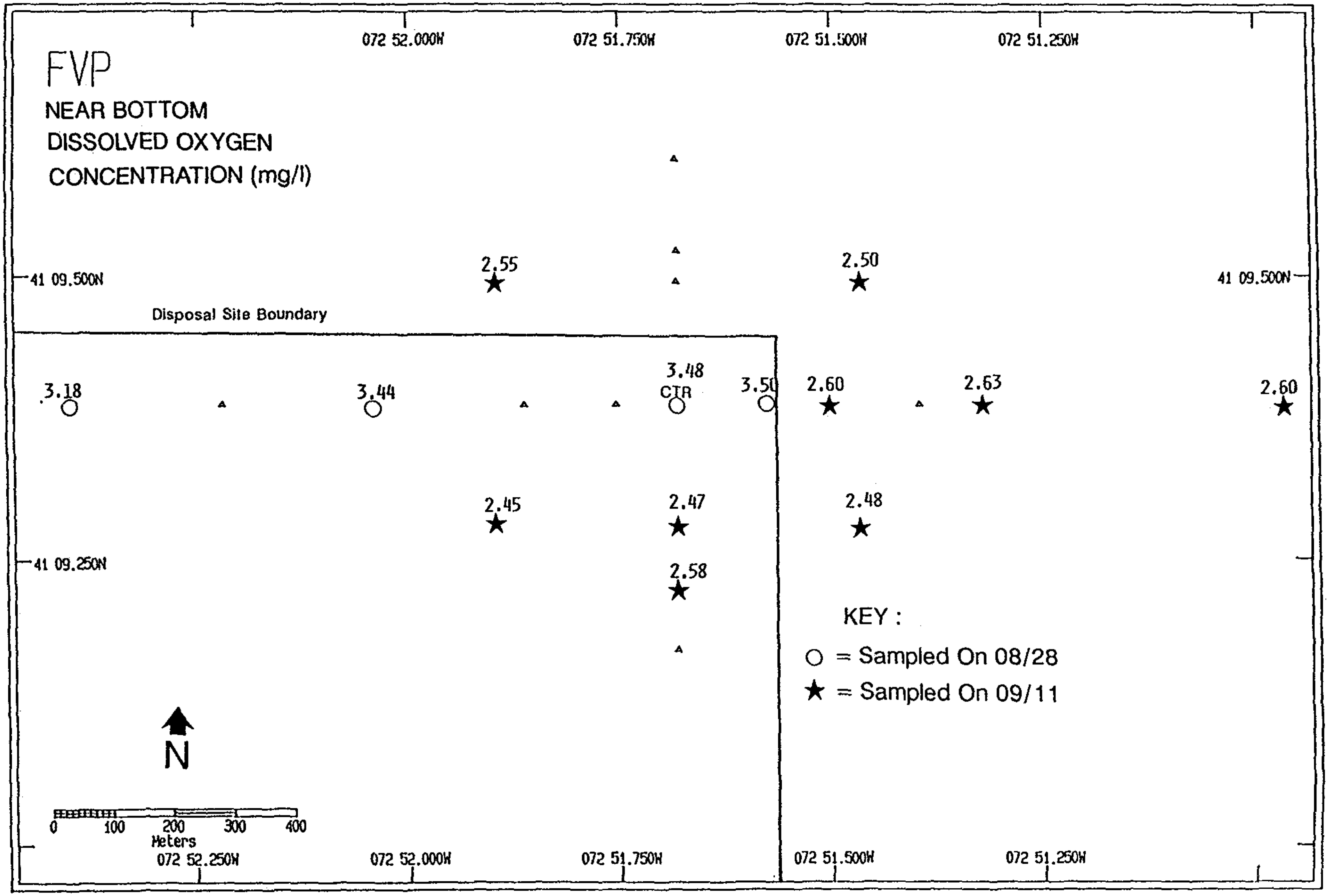



**Figure 3-44.** Near-bottom dissolved oxygen concentrations (mg/ℓ) measured at selected REMOTS® stations at the FVP mound, August and September 1987.

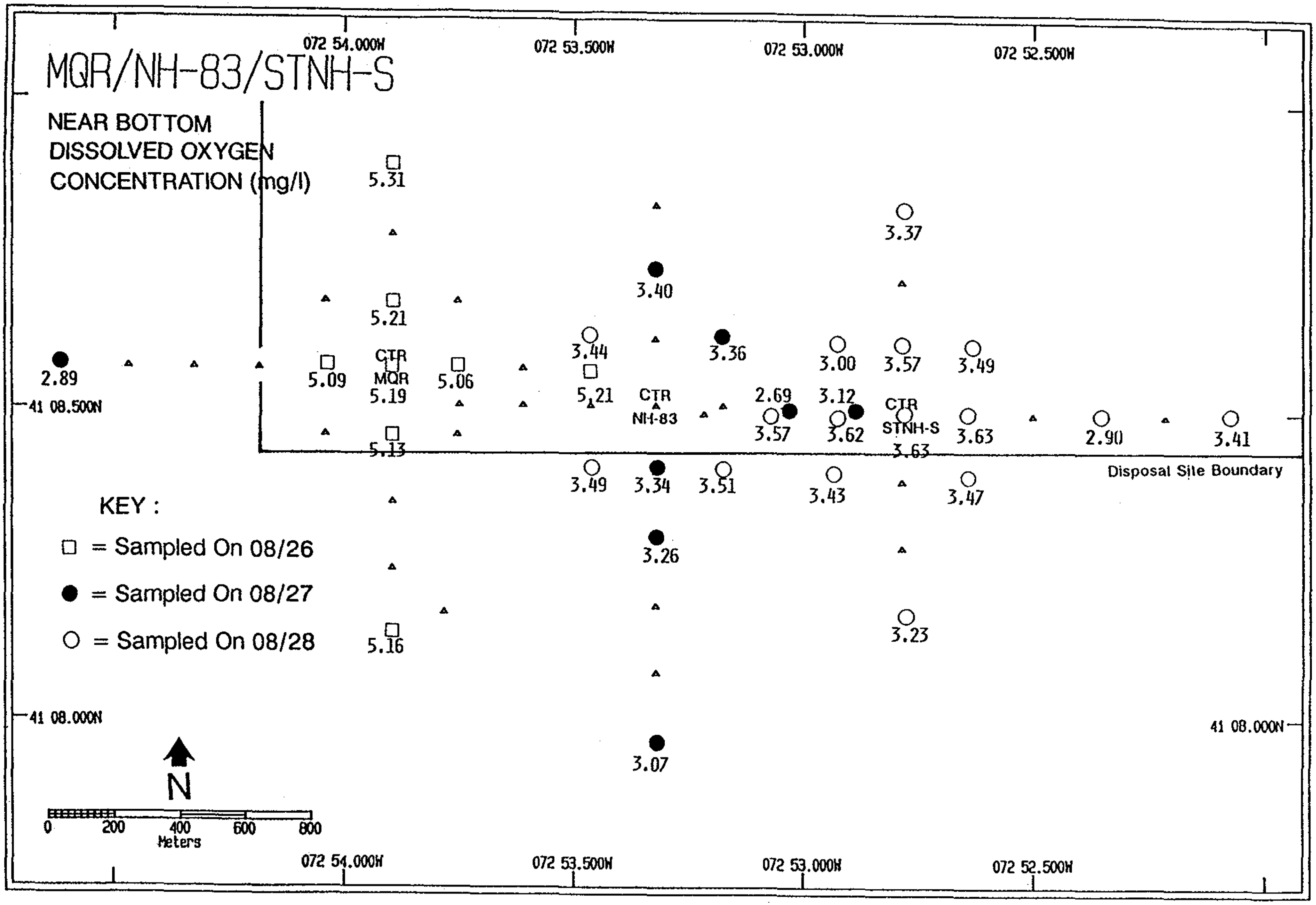



**Figure 3-45.** Near-bottom dissolved oxygen concentrations (mg/ℓ) measured at selected REMOTS® stations at the MQR, NH-83 and STNH-S mounds, August 1987.

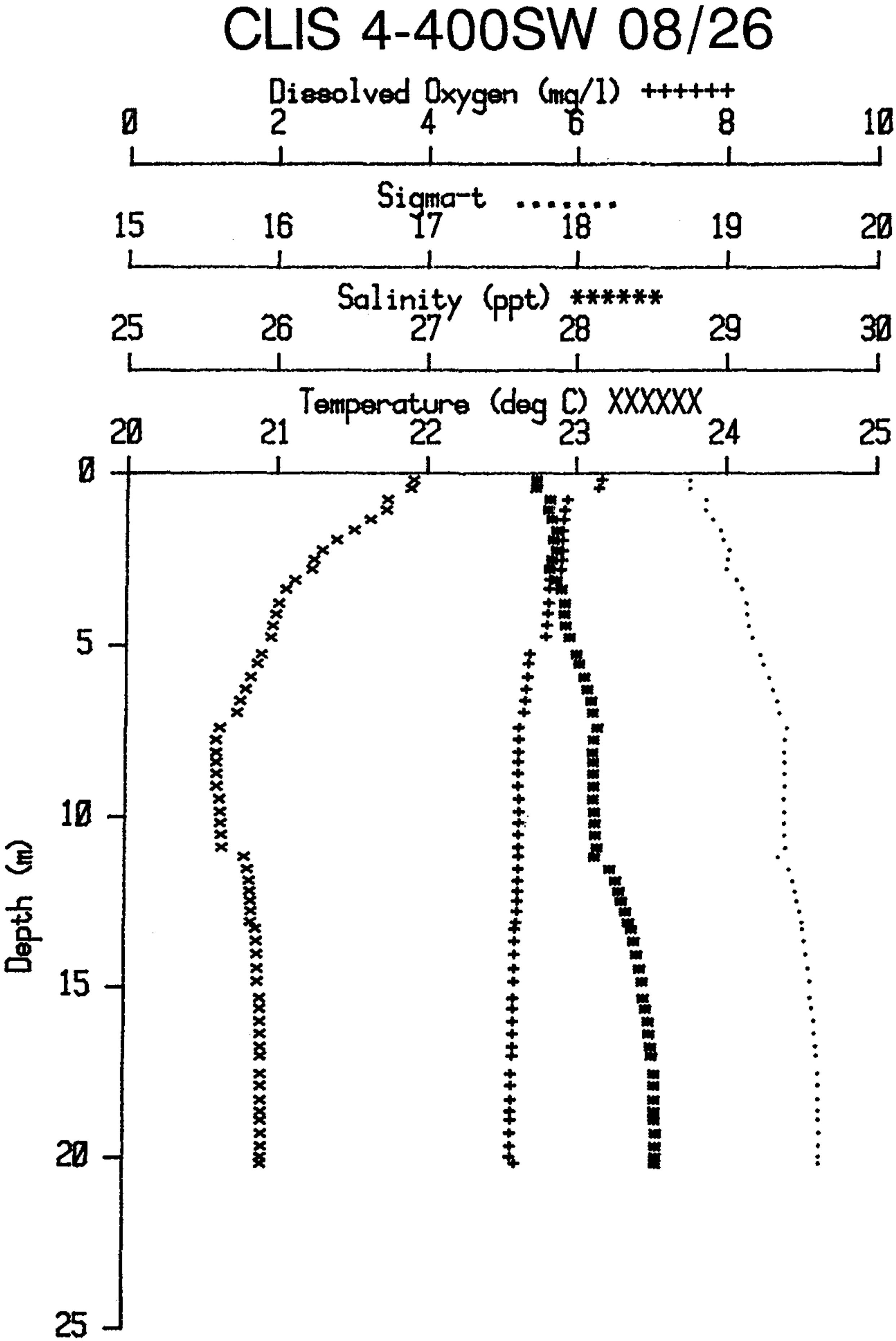



Figure 3-46. CTD/DO plot from CLIS-86 station 4-400SW on 8/26.

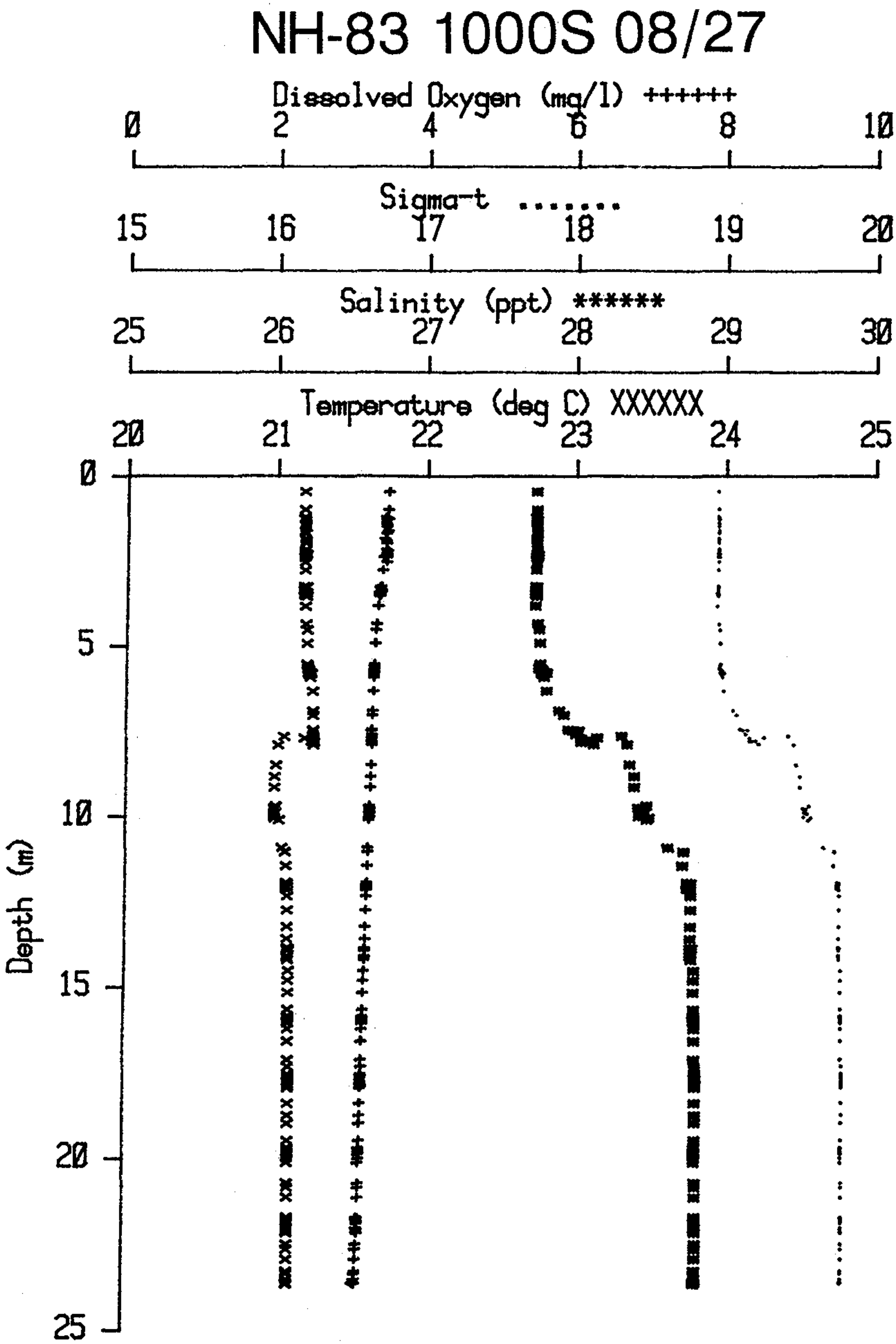



Figure 3-47. CTD/DO plot from NH-83 station 1000S on 8/27.

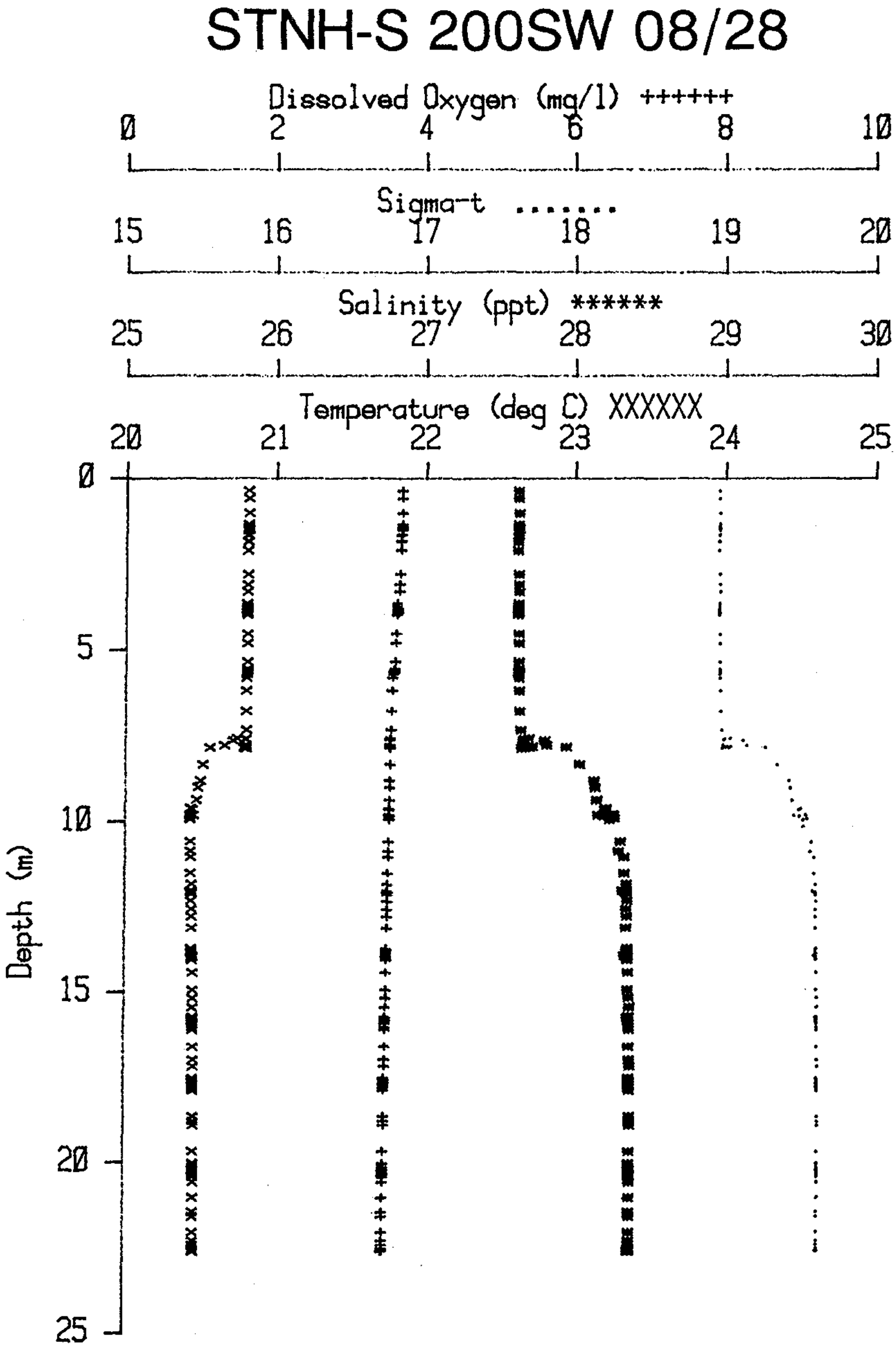



Figure 3-48. CTD/DO plot from STNH-S station 200SW on 8/28.

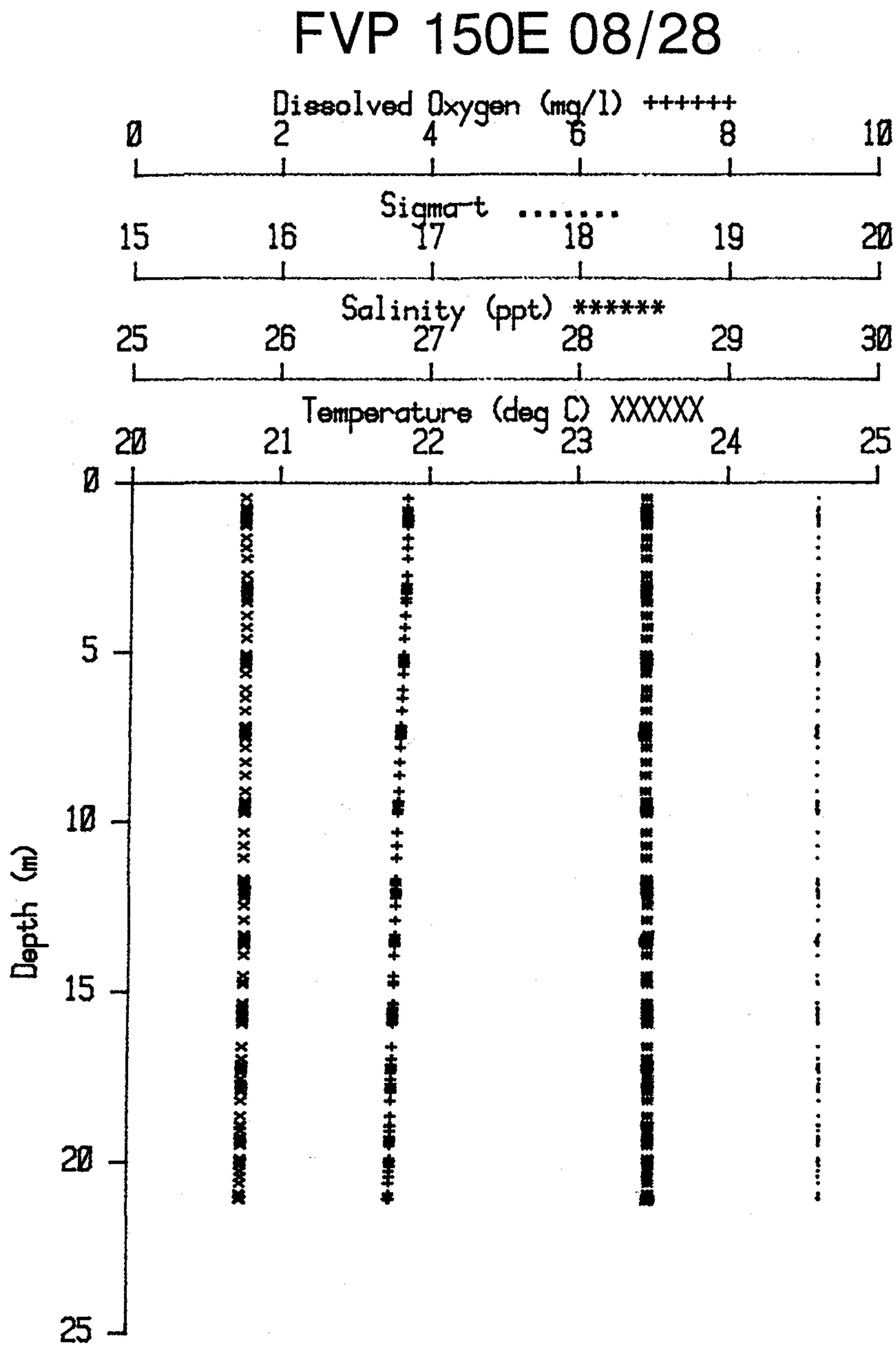



Figure 3-49. CTD/DO plot from FVP station 150E on 8/28.

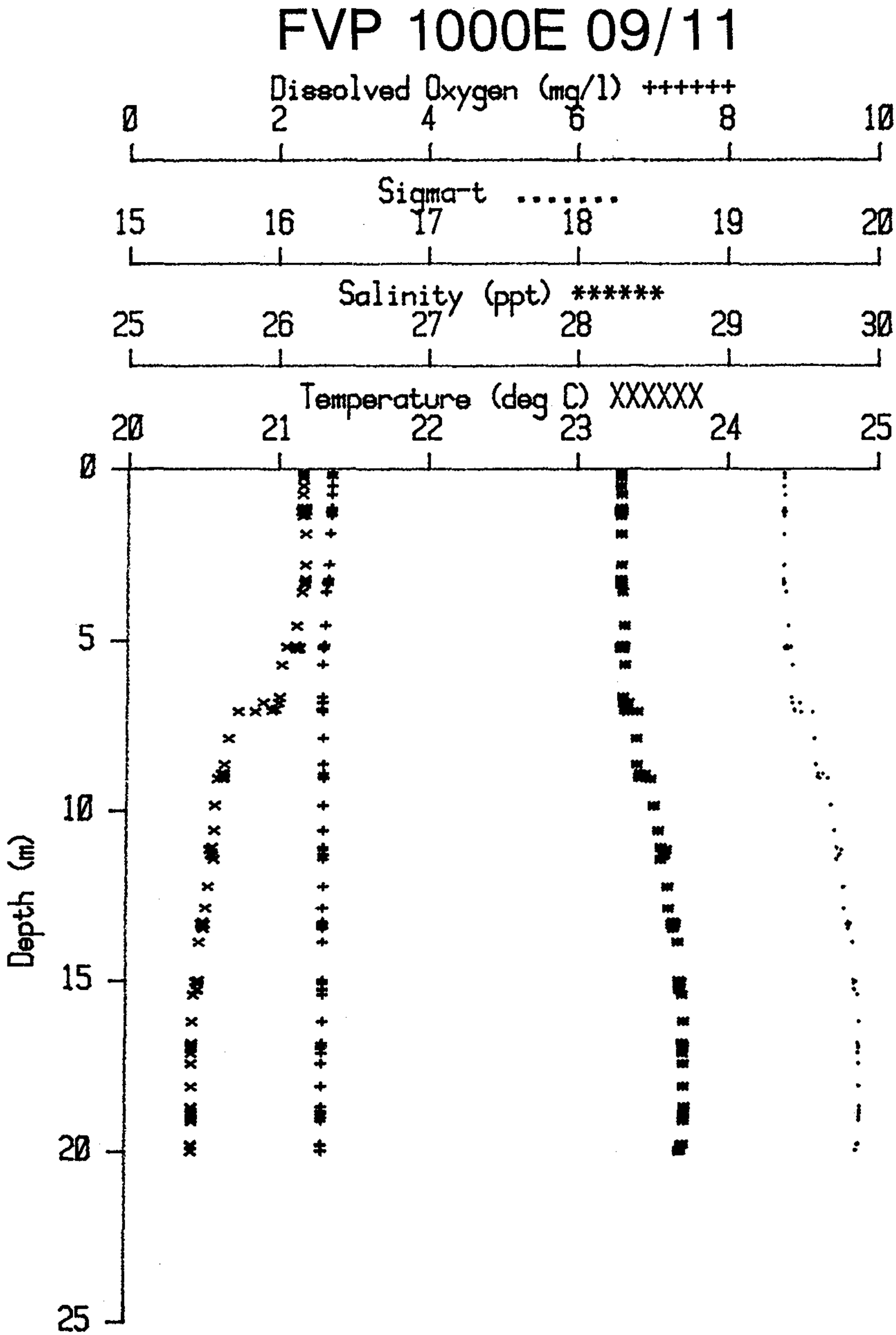



Figure 3-50. CTD/DO plot from FVP station 1000E on 9/11.

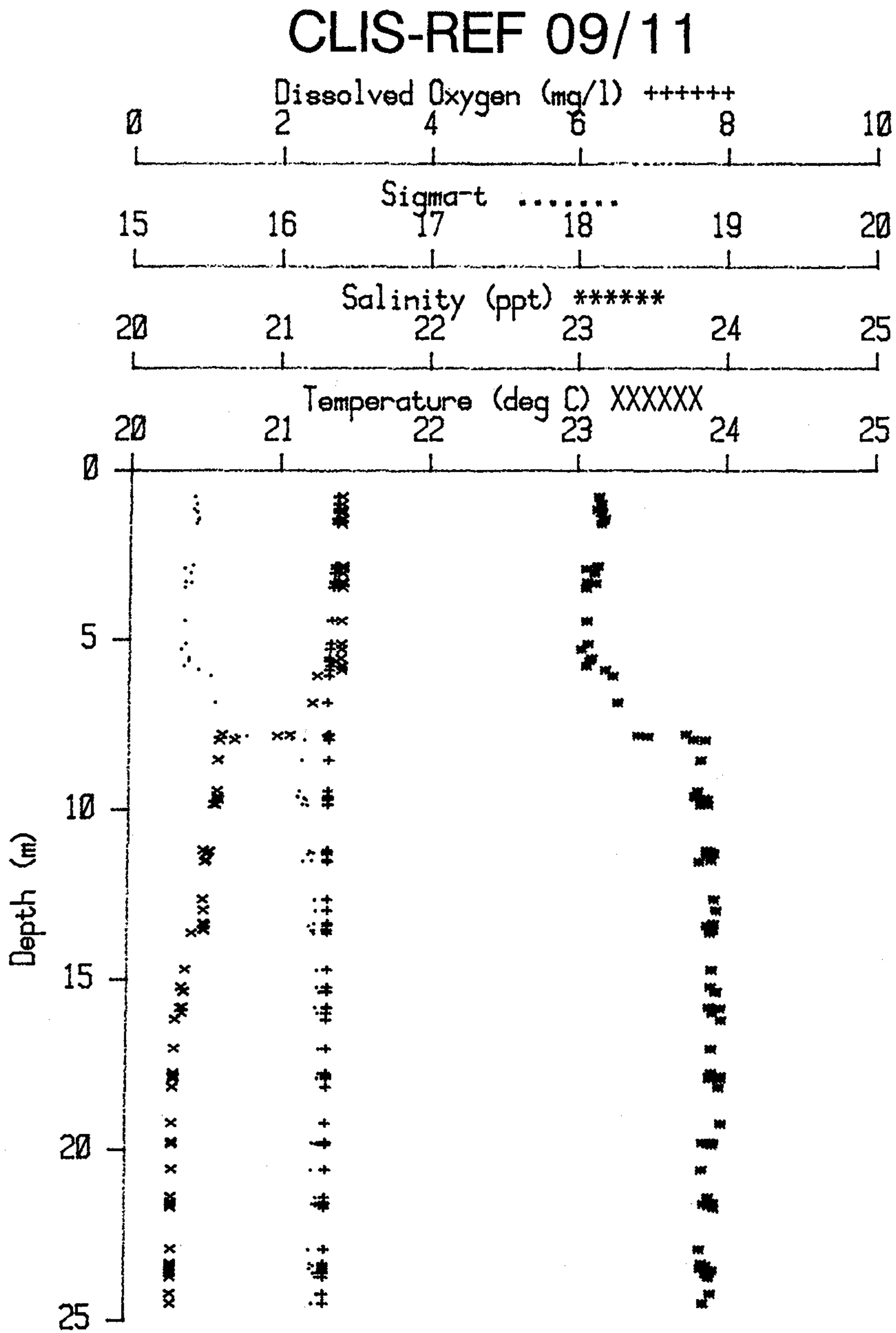
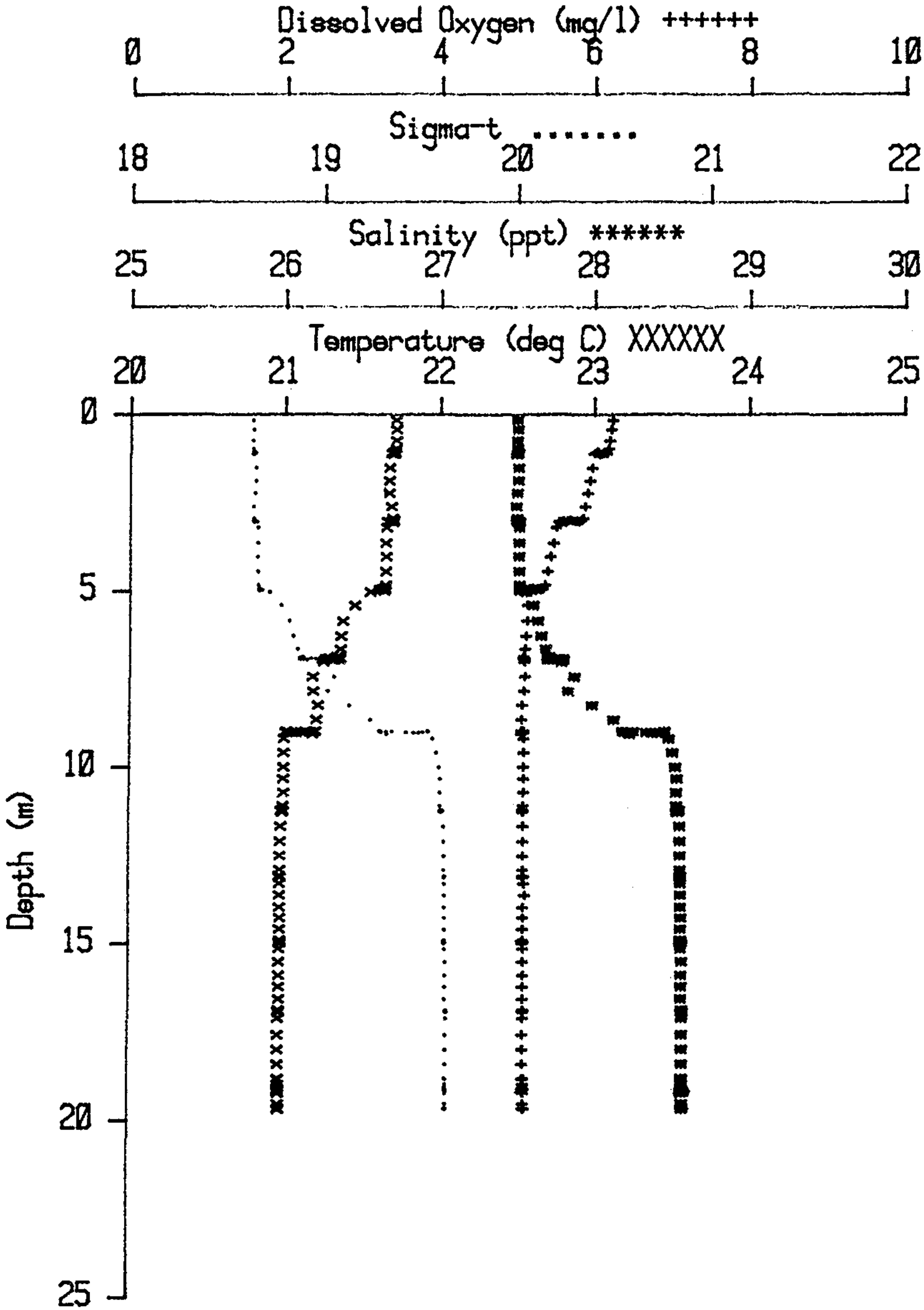


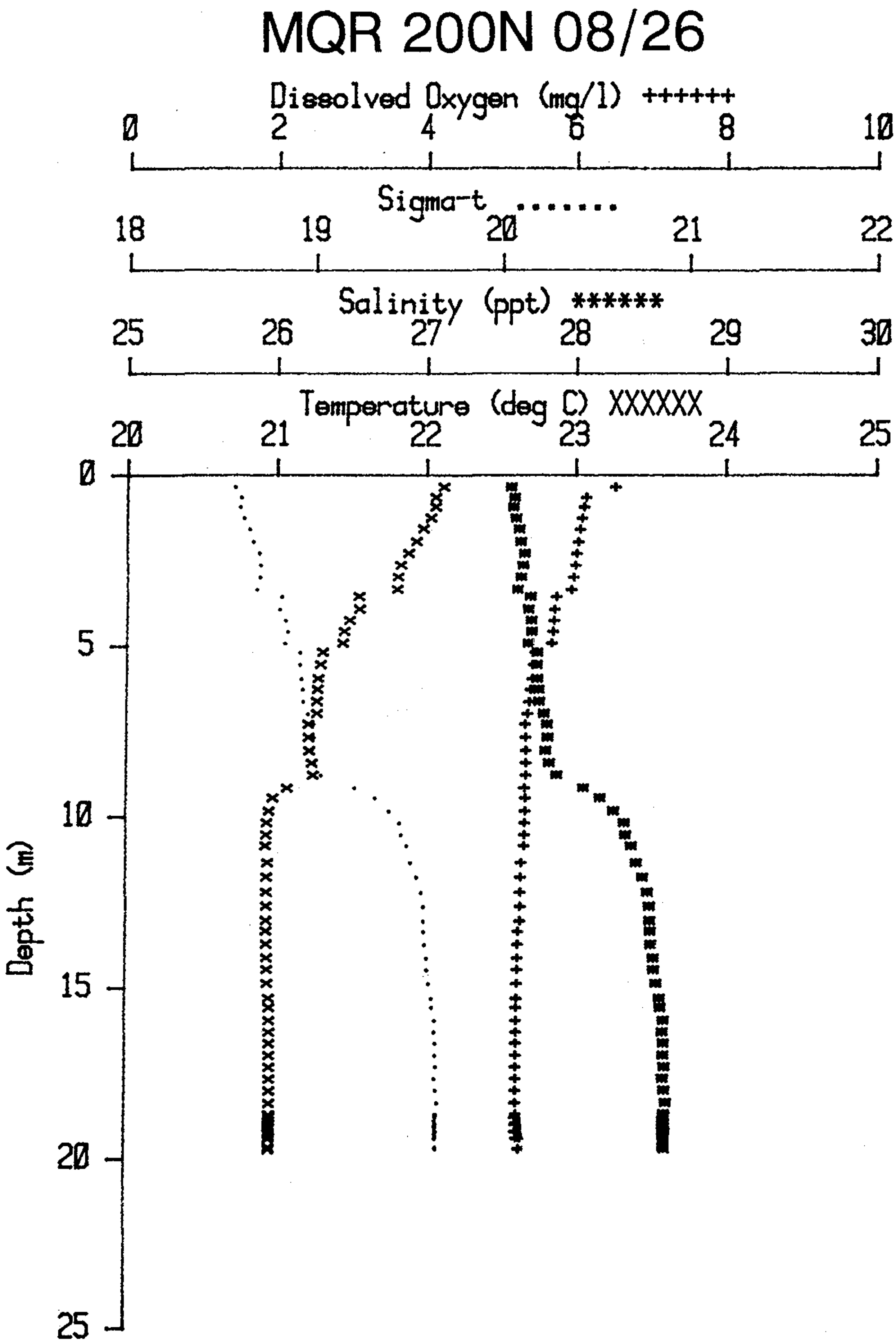

Figure 3-51. CTD/DO plot from the CLIS-REF station on 9/11.

## APPENDIX

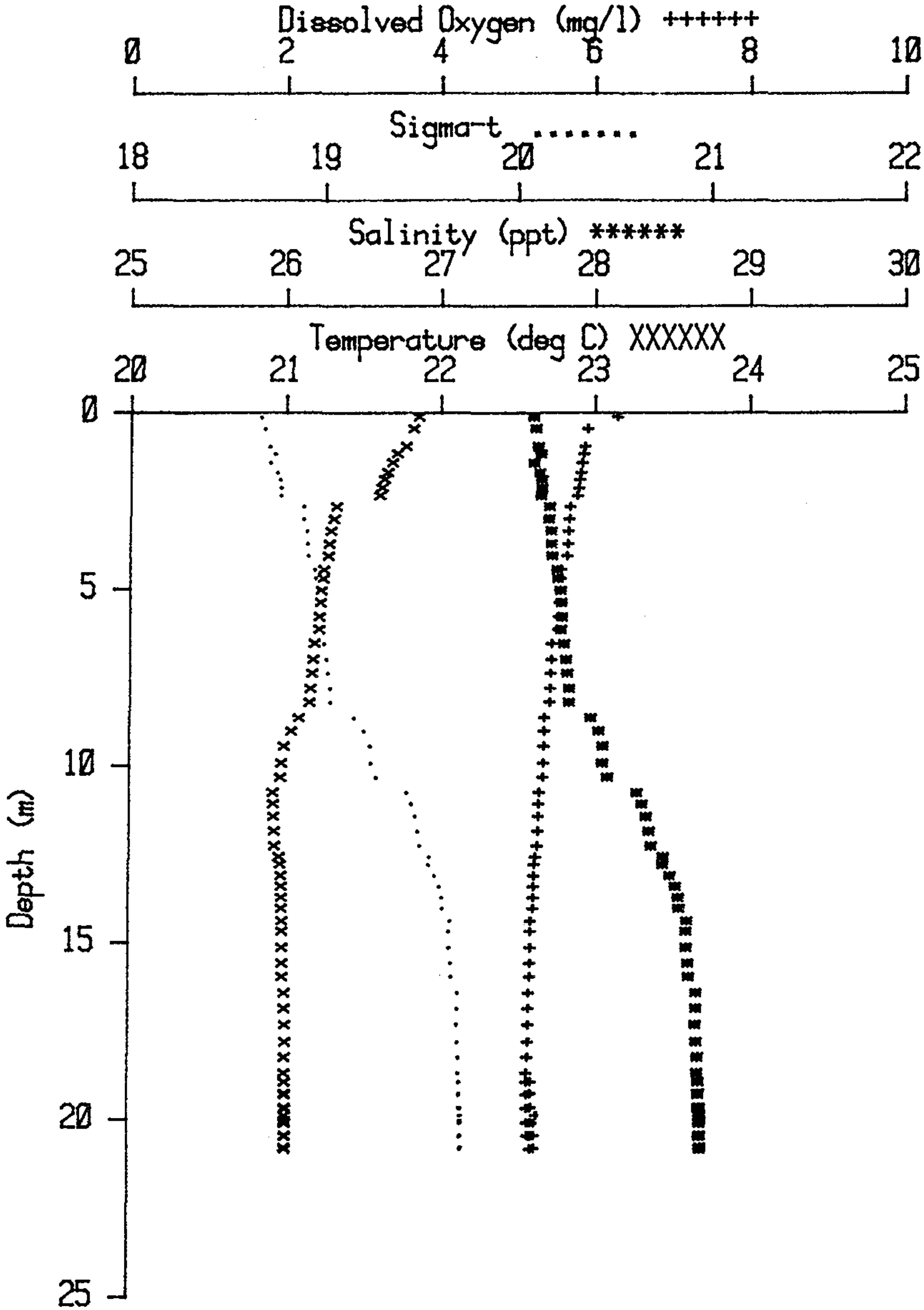
CTD/DO PLOTS FOR STATIONS SAMPLED AT CLIS,
AUGUST AND SEPTEMBER 1987

# MQR 200W 08/26

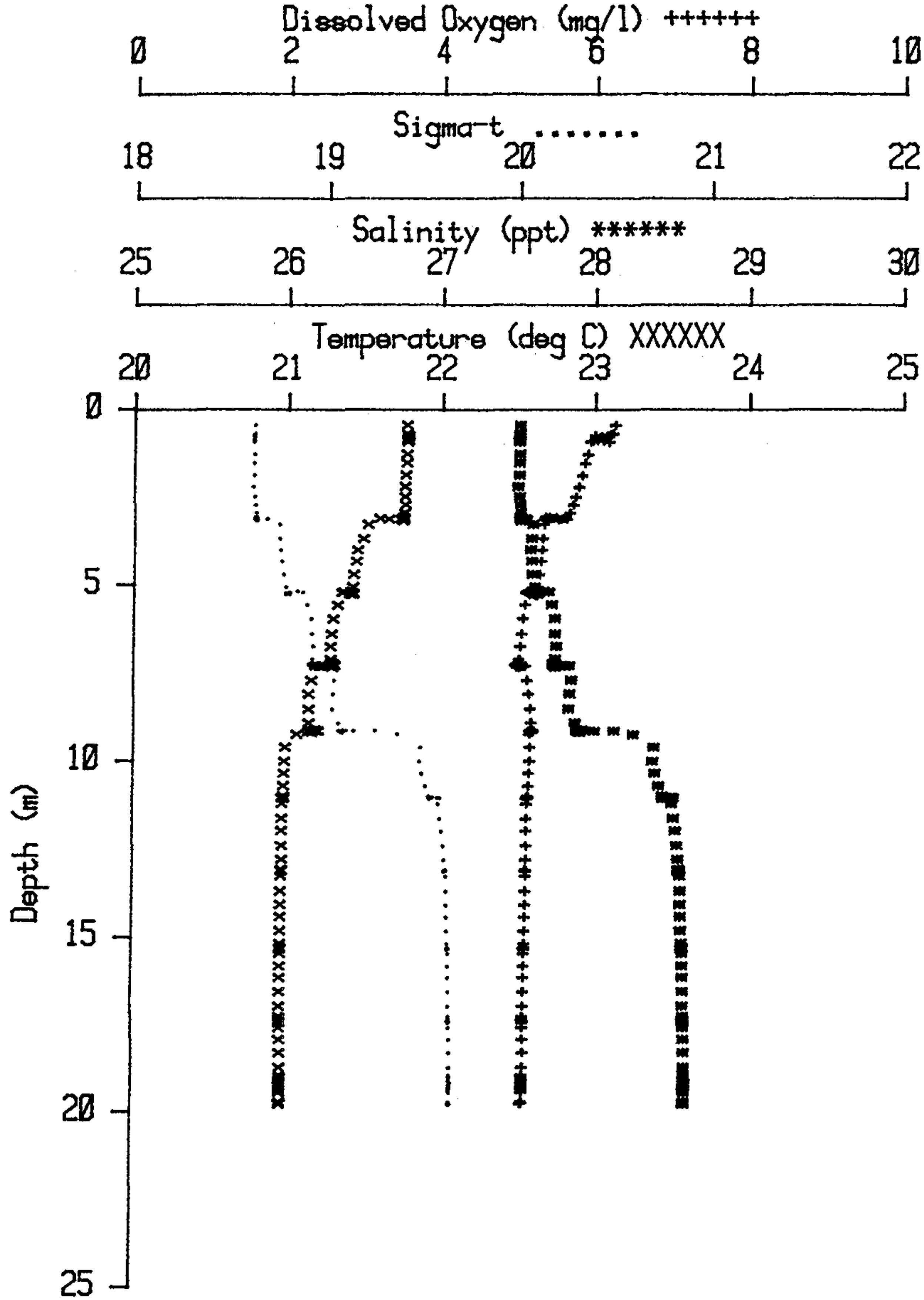


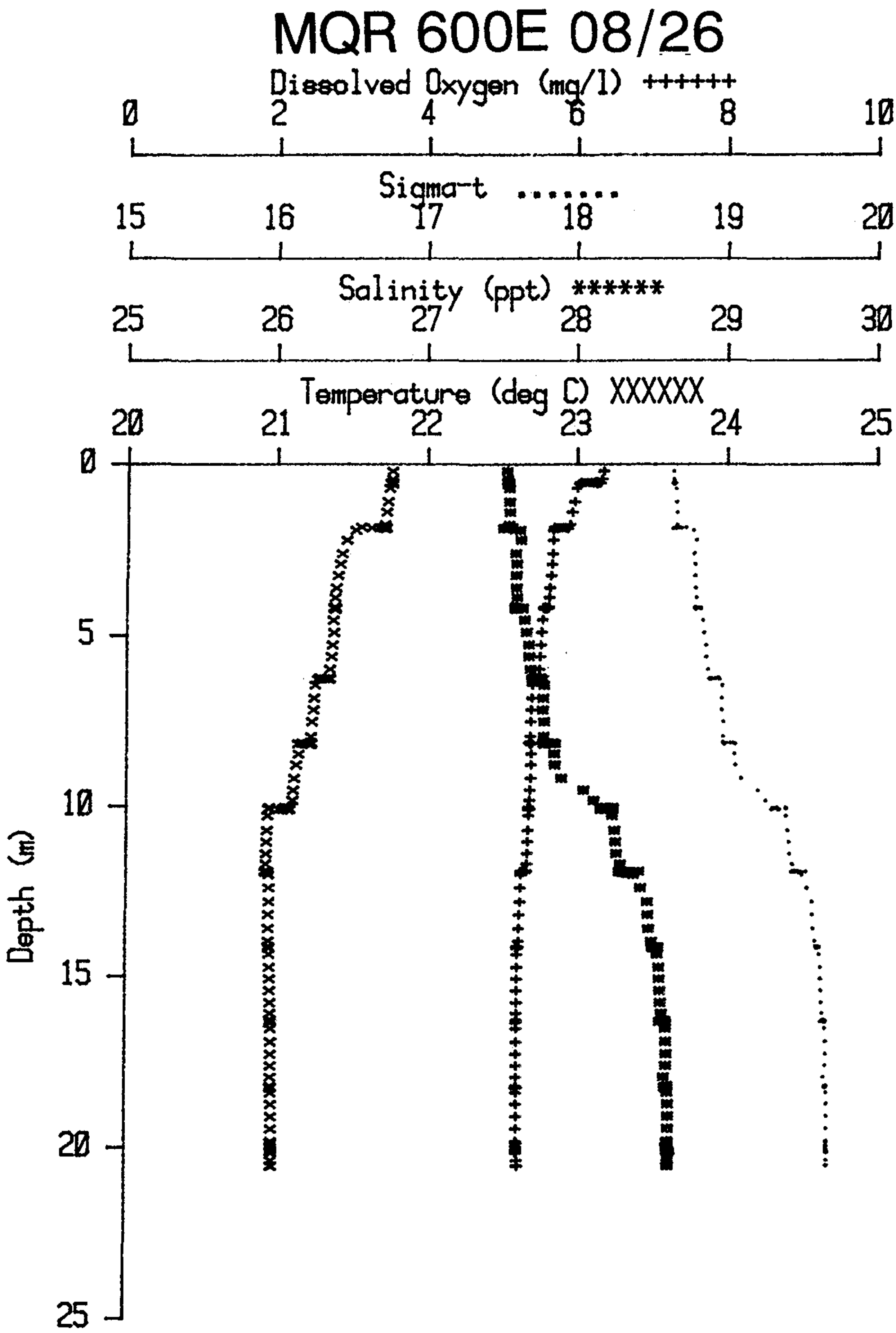

MQR 200N 08/26
Dissolved Oxygen (mg/l) ++++++
0 2 4 6 8 10
Sigma-t .......
18 19 20 21 22
Salinity (ppt) ******
25 26 27 28 29 30
Temperature (deg C) XXXXXX
20 21 22 23 24 25
Depth (m)
0 5 10 15 20 25

# MQR 200S 08/26

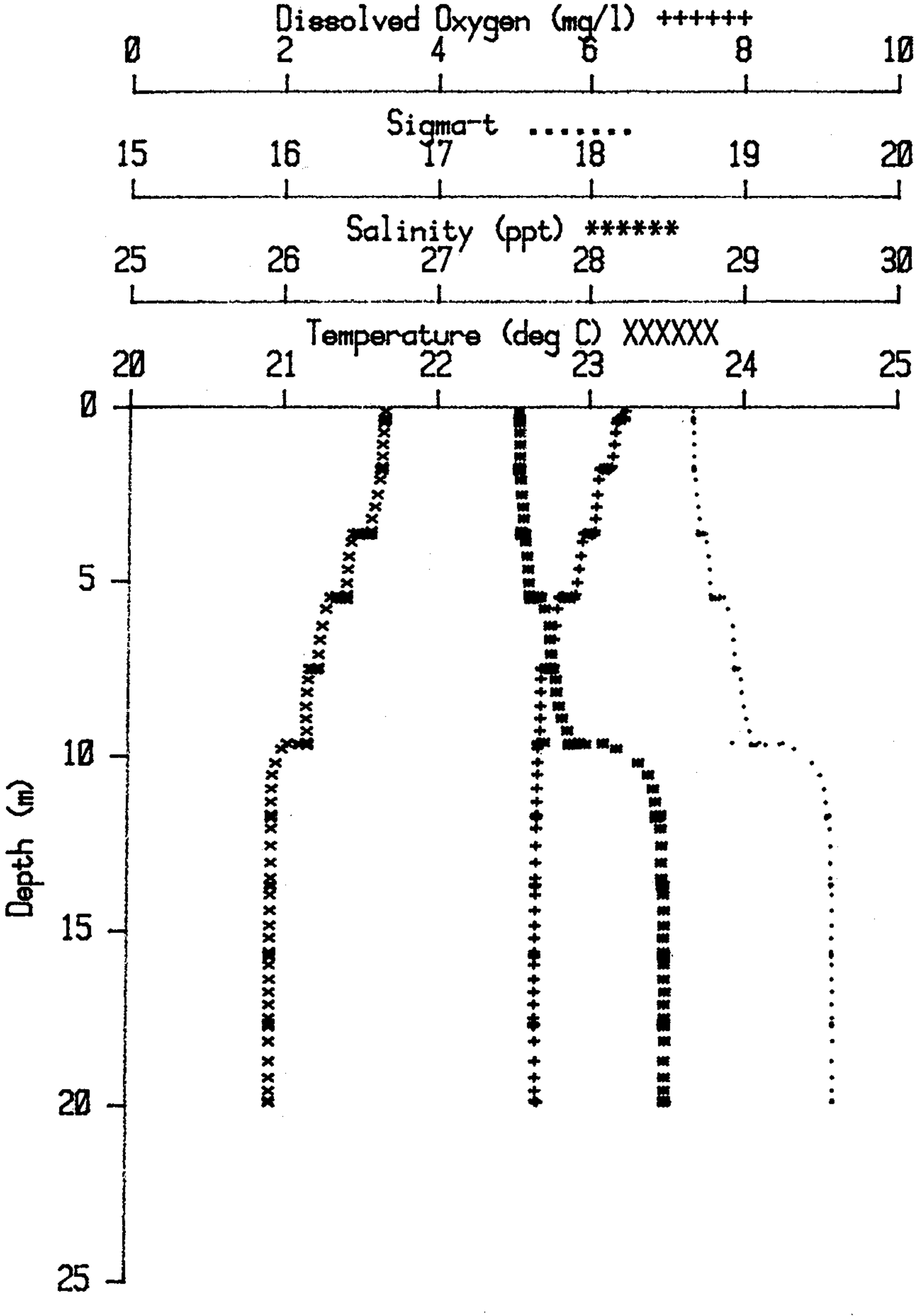


# MQR 200E 08/26

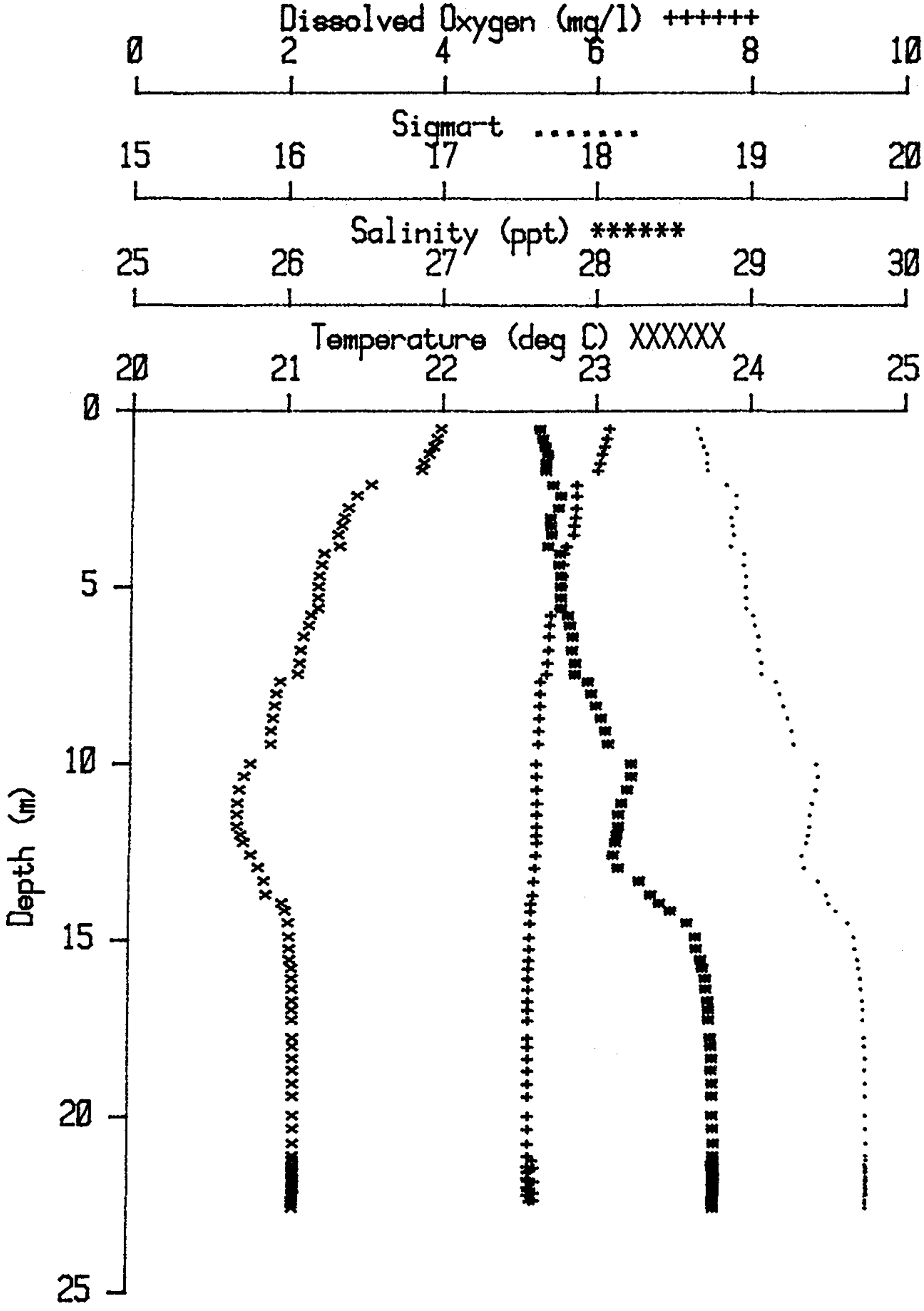


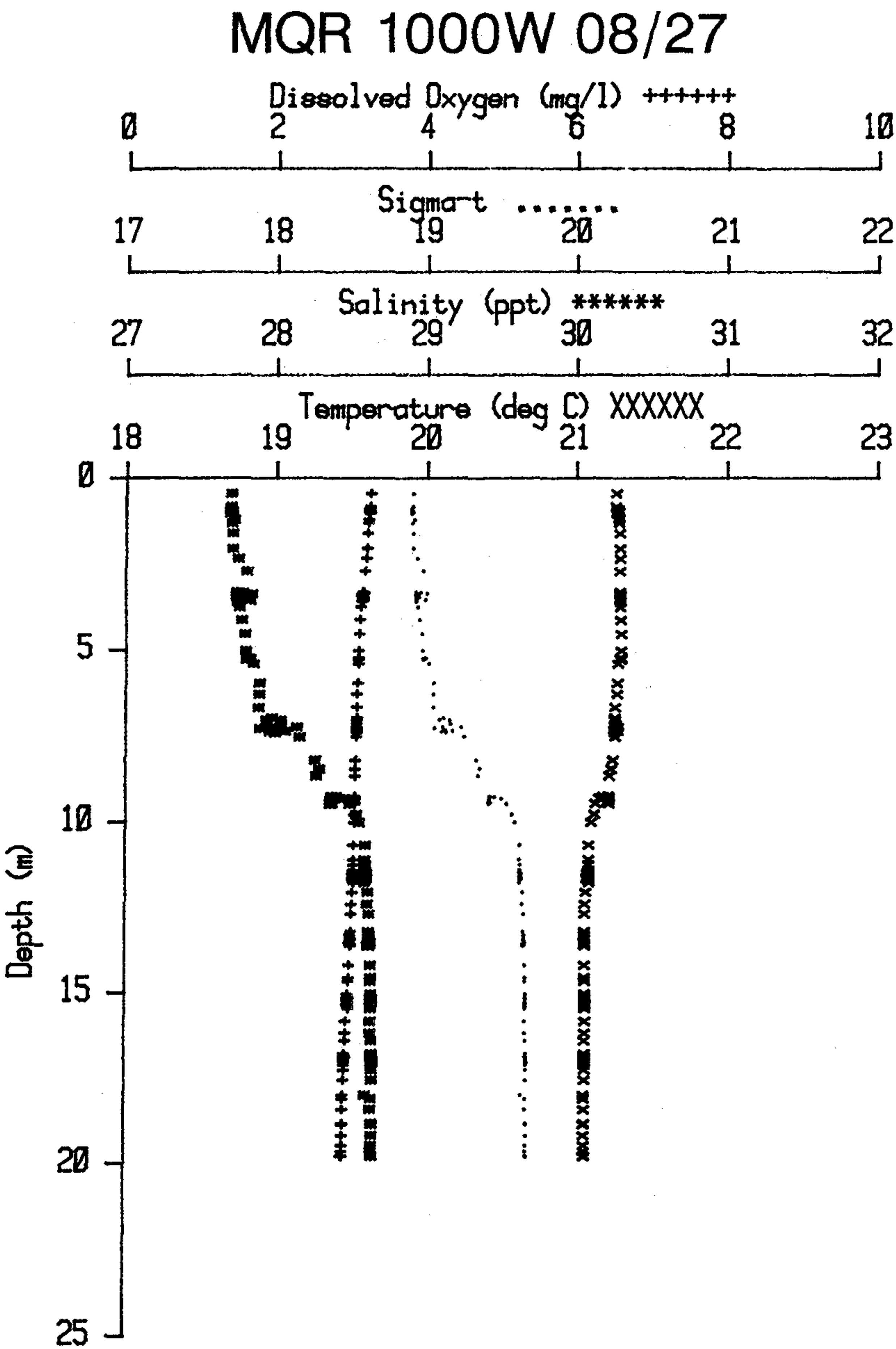

MQR 600E 08/26
Dissolved Oxygen (mg/l) ++++++
0 2 4 6 8 10
Sigma-t .......
15 16 17 18 19 20
Salinity (ppt) ******
25 26 27 28 29 30
Temperature (deg C) XXXXXX
20 21 22 23 24 25
Depth (m)
0 5 10 15 20 25

# MQR 600N 08/26



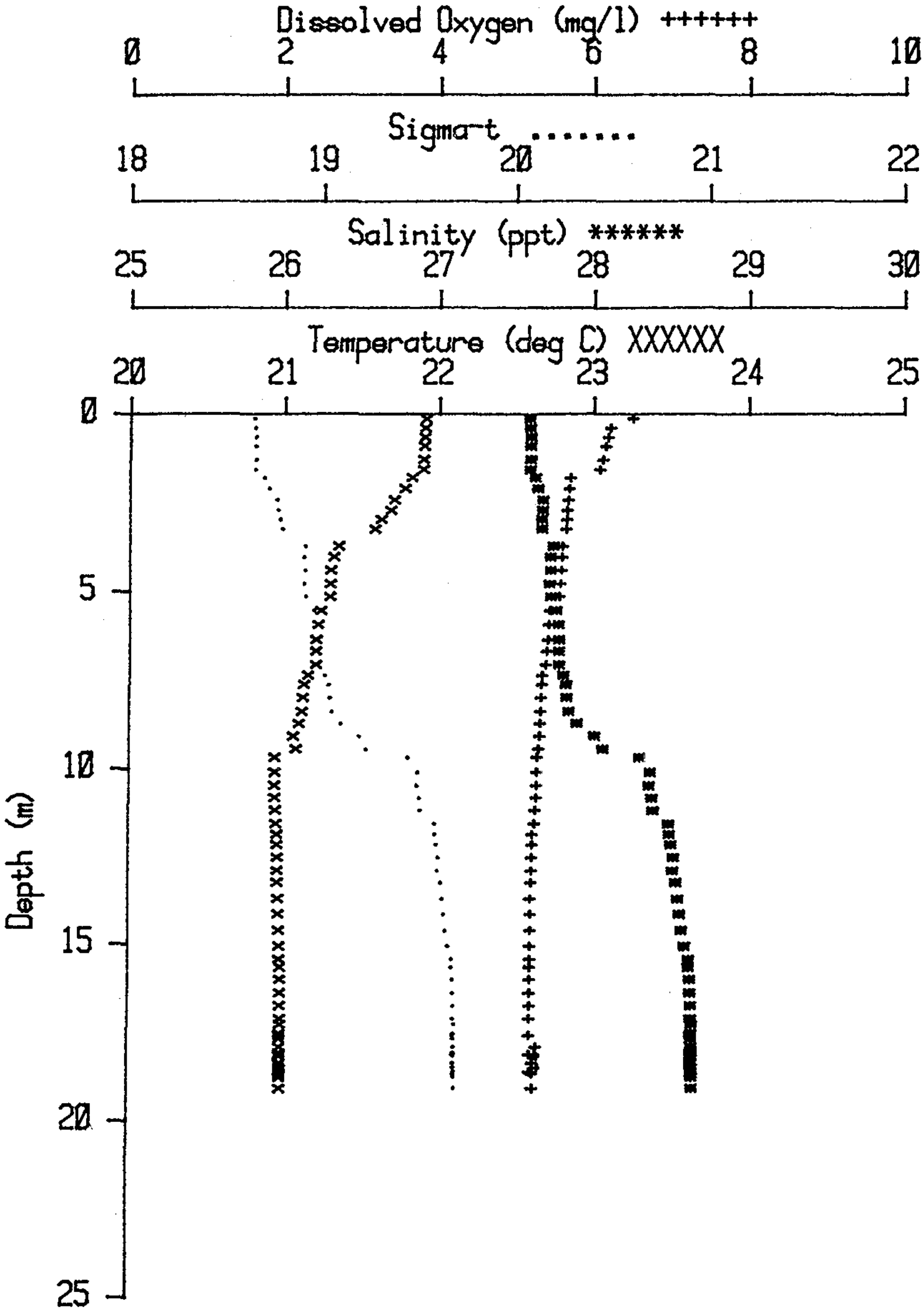
# MQR 800S 08/26



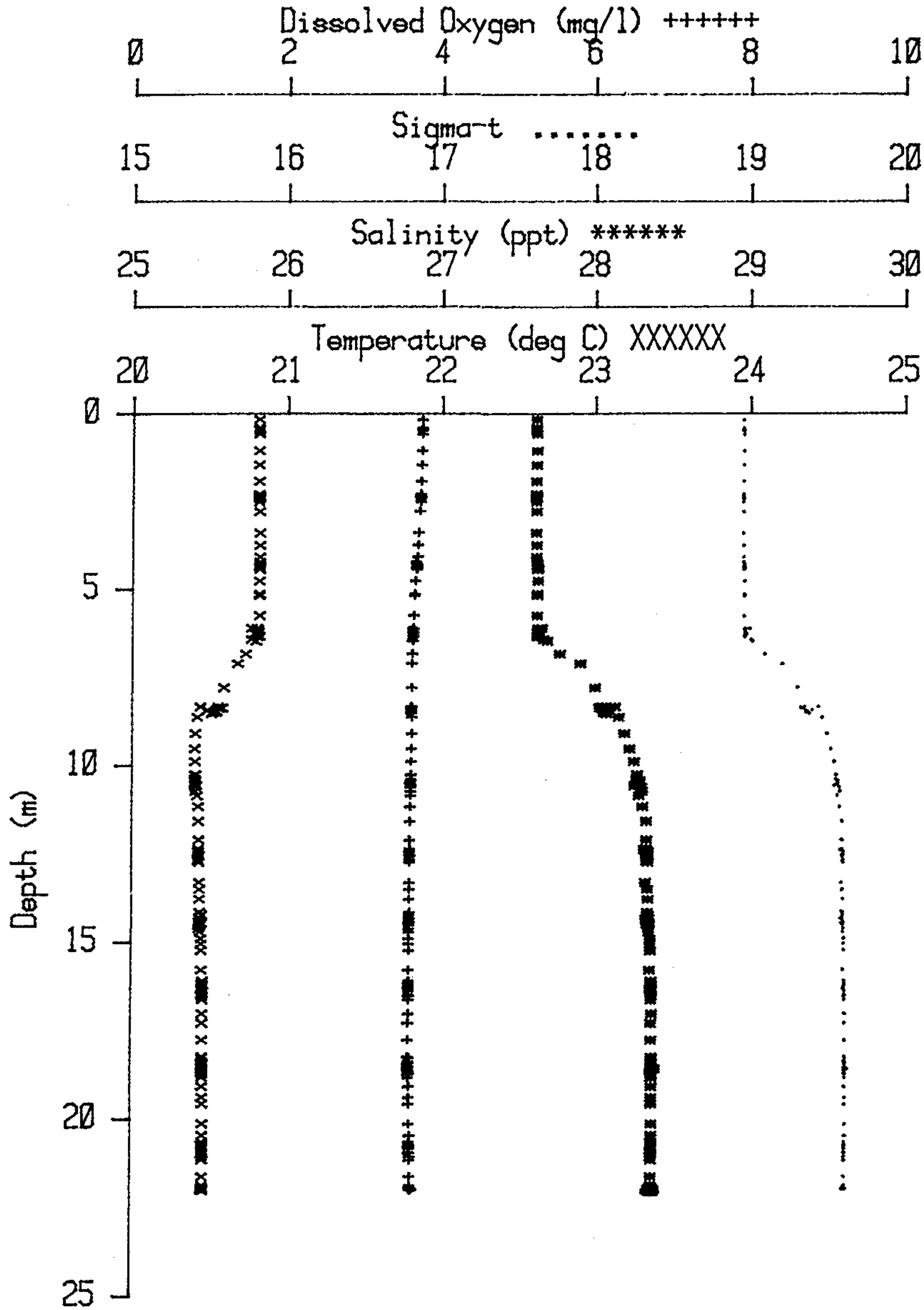


MQR 1000W 08/27
Dissolved Oxygen (mg/l) ++++++
0 2 4 6 8 10
Sigma-t .......
17 18 19 20 21 22
Salinity (ppt) ******
27 28 29 30 31 32
Temperature (deg C) XXXXXX
18 19 20 21 22 23
Depth (m)
0 5 10 15 20 25

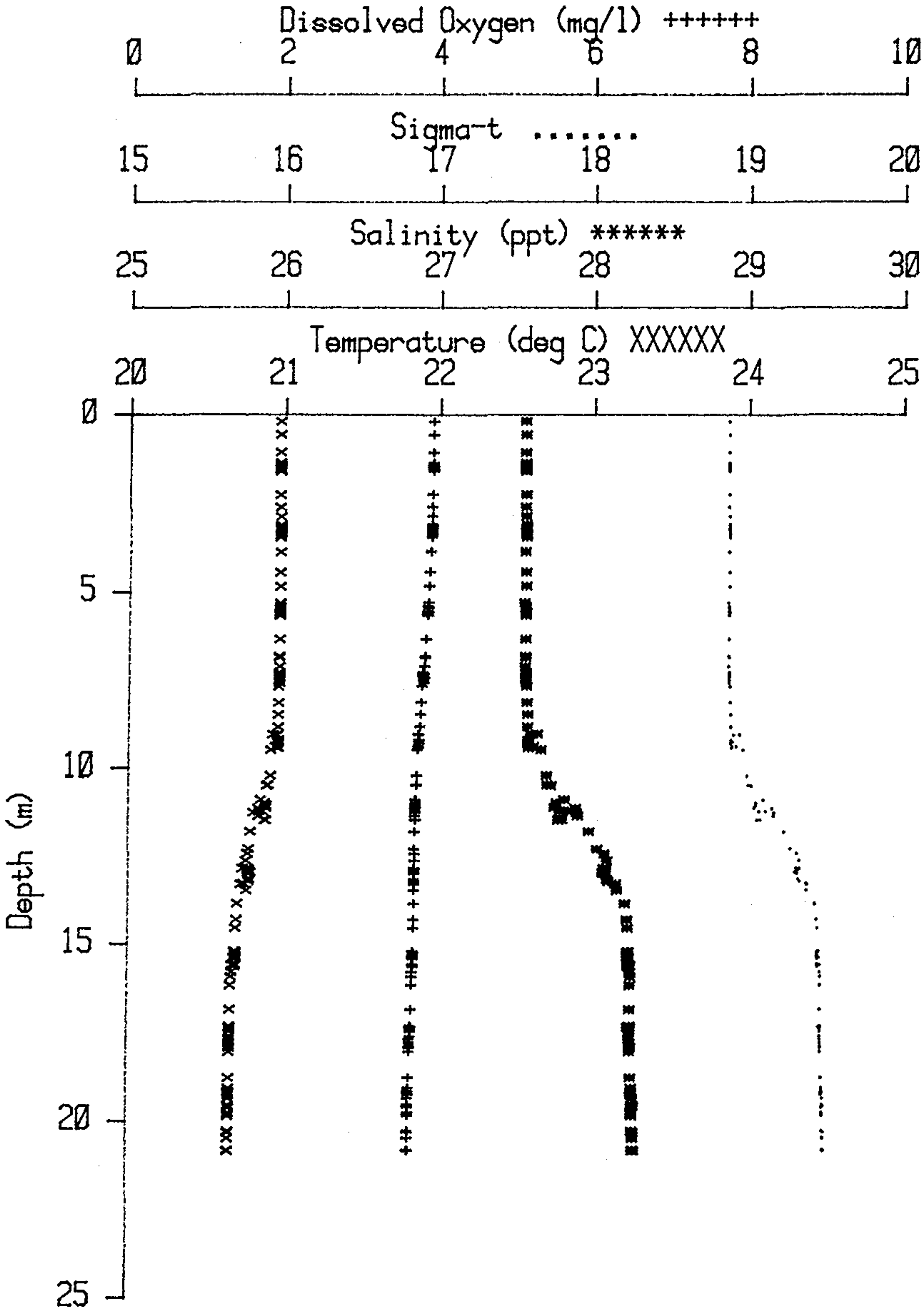
# MQR CTR 08/26


Dissolved Oxygen (mg/l) ++++++
0 2 4 6 8 10
Sigma-t .......
18 19 20 21 22
Salinity (ppt) ******
25 26 27 28 29 30
Temperature (deg C) XXXXXX
20 21 22 23 24 25
Depth (m)
0 5 10 15 20 25

# STNH-S 200N 08/28



# STNH-S 200W 08/28



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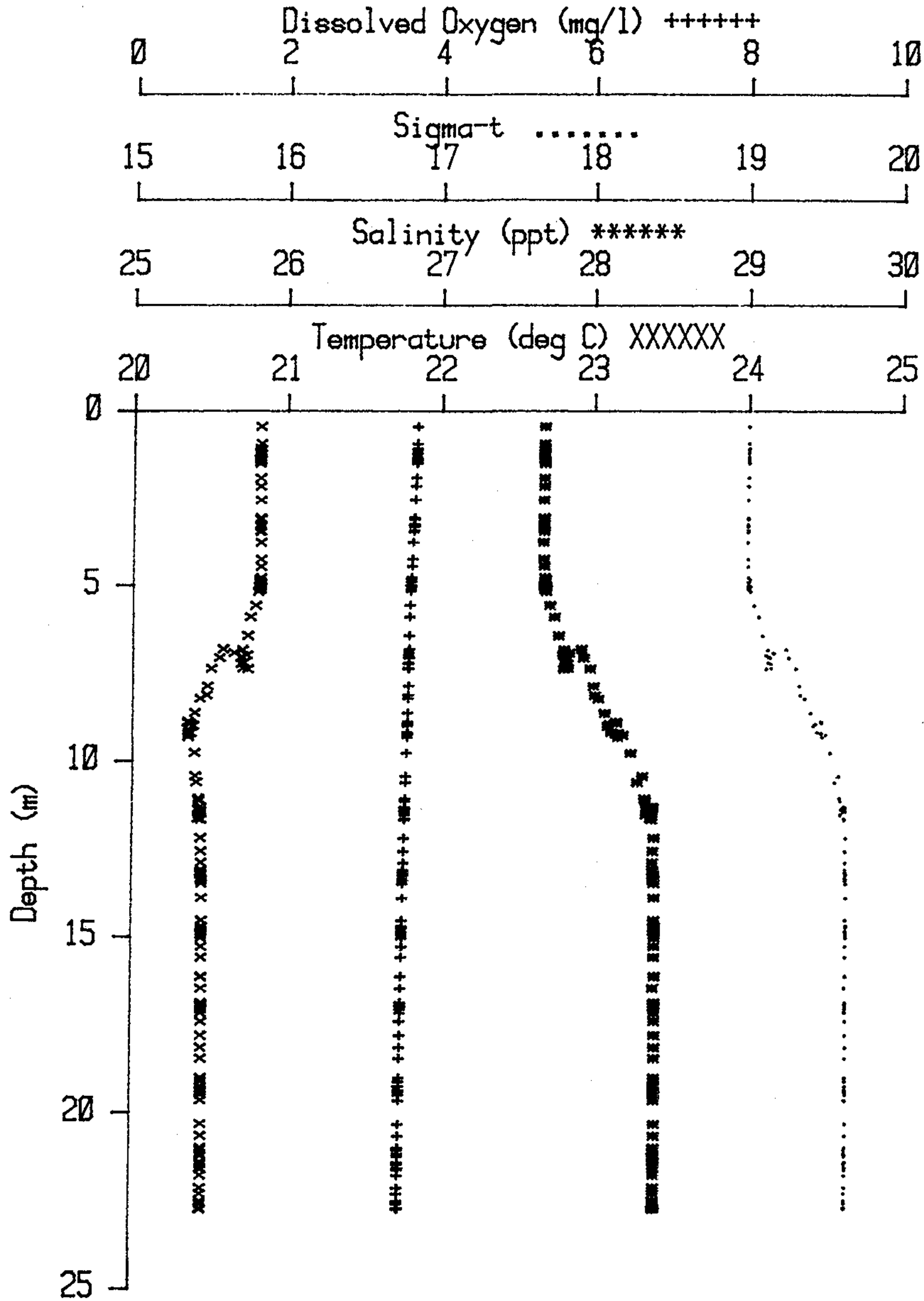

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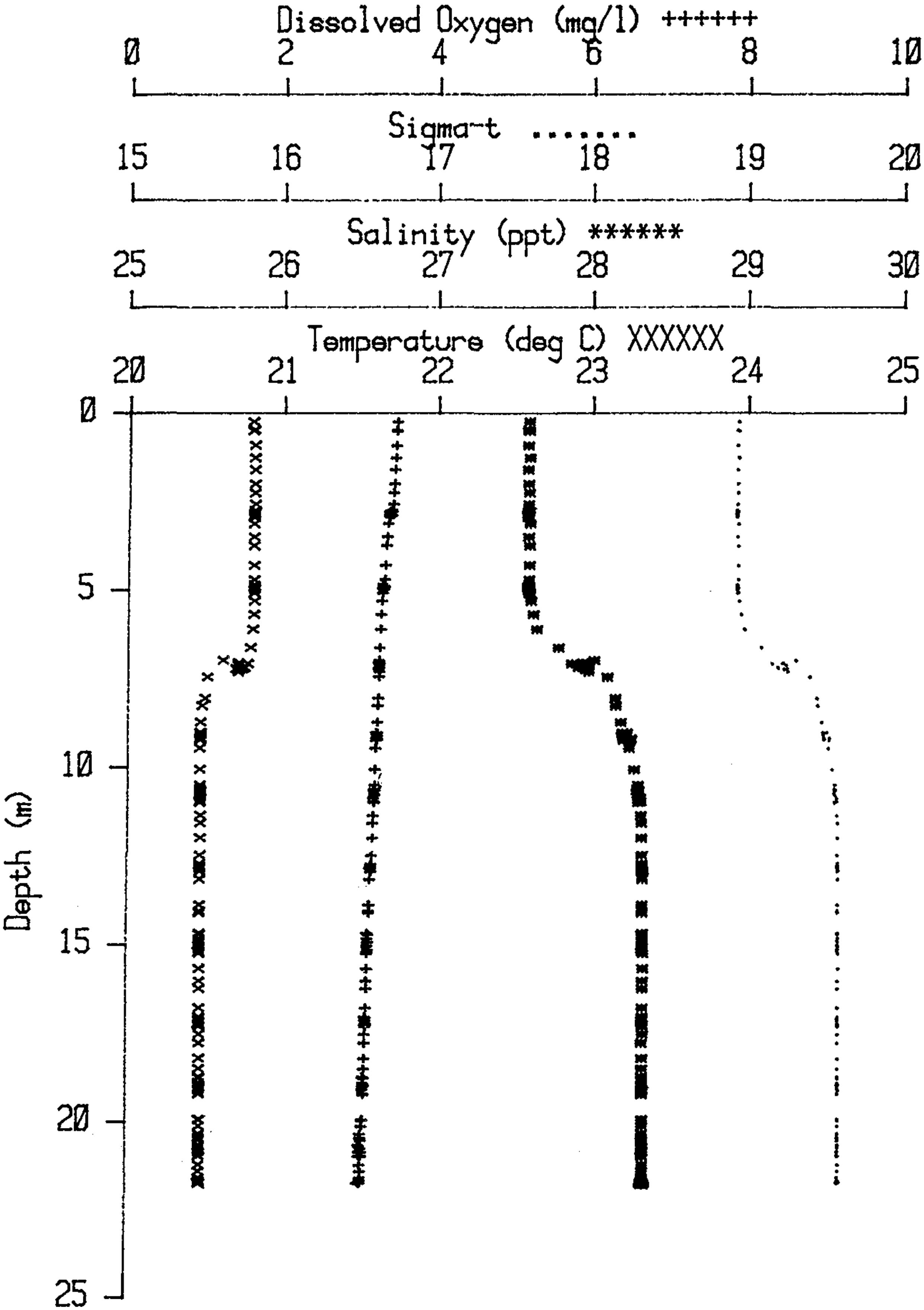

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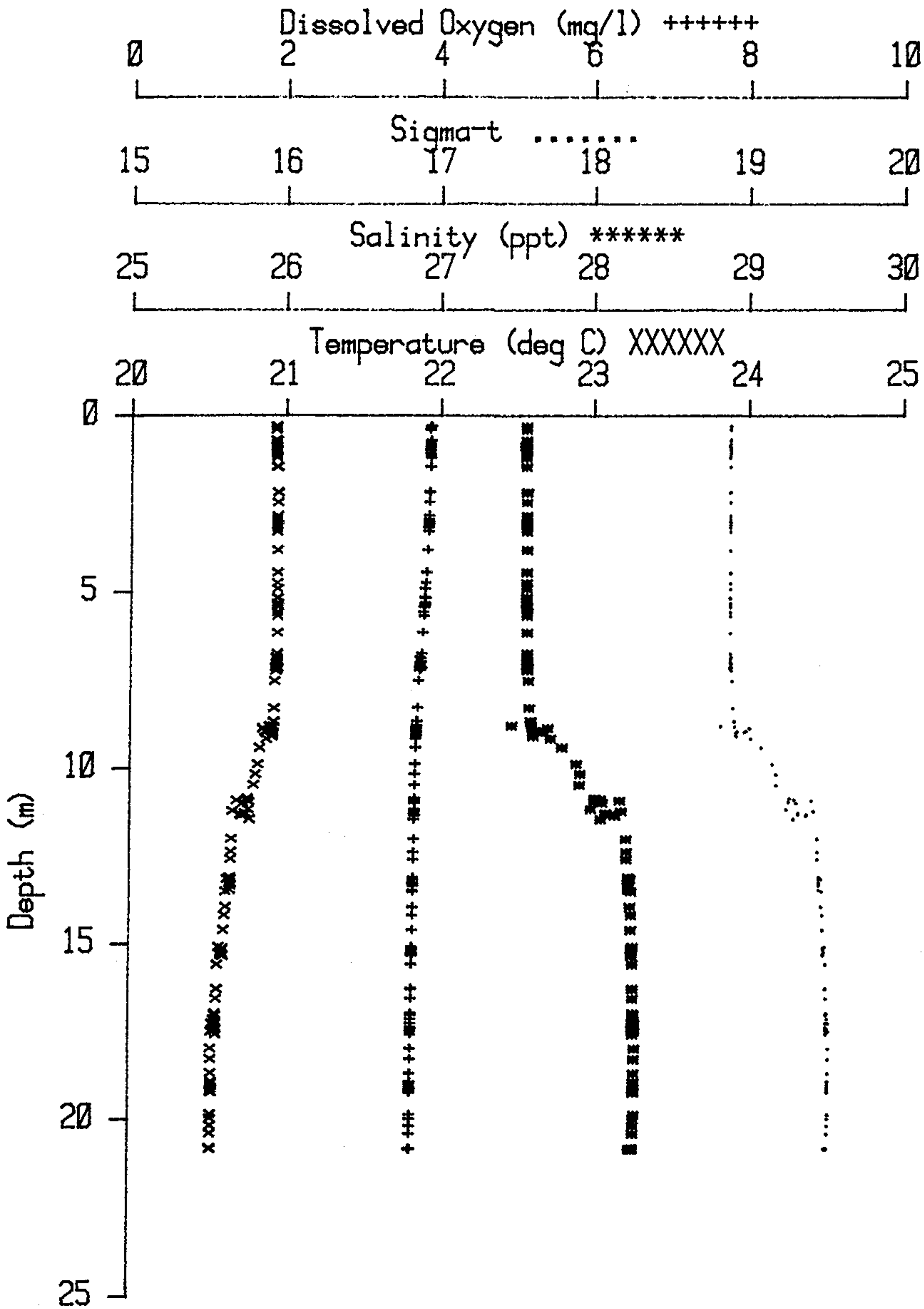

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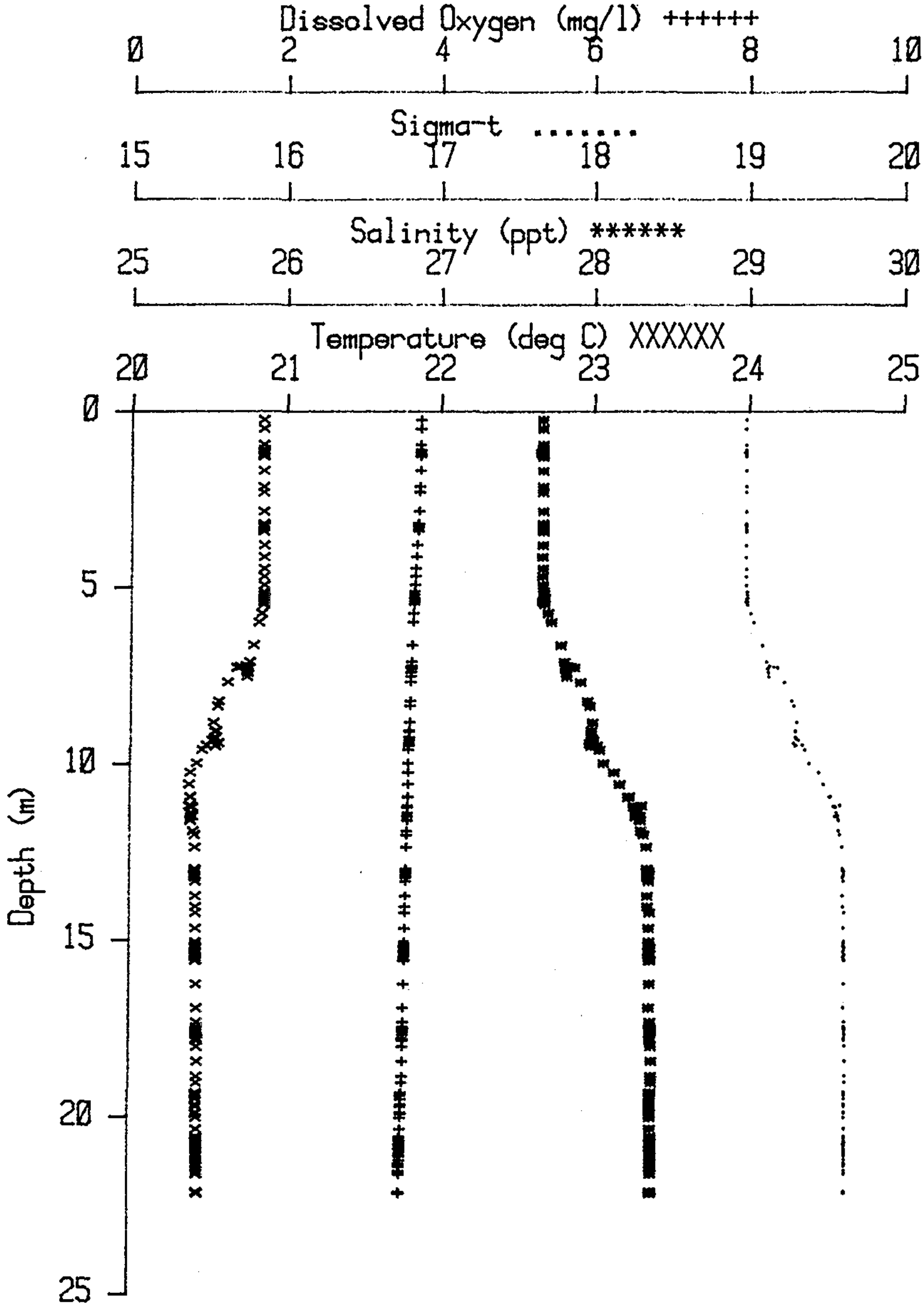

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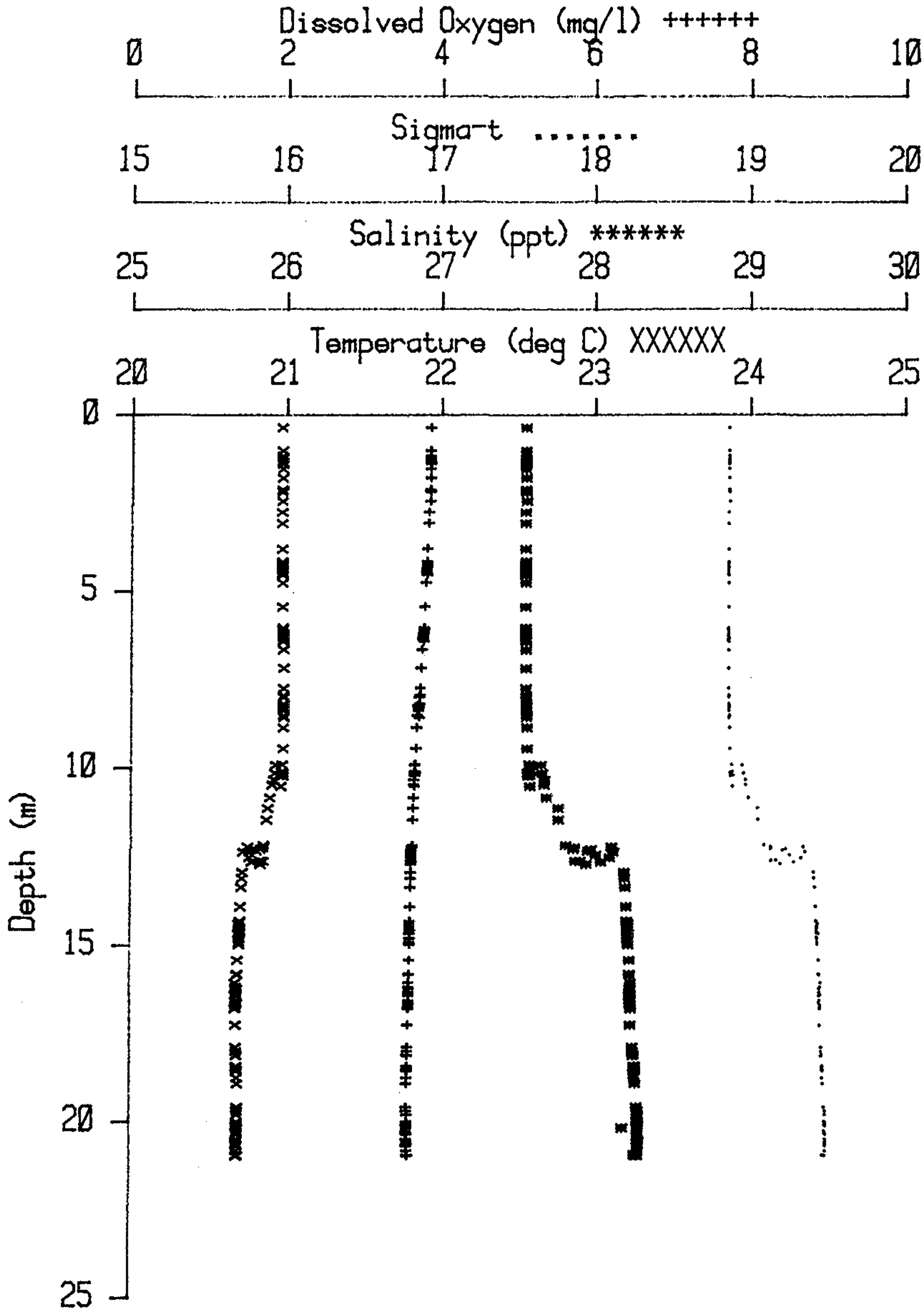
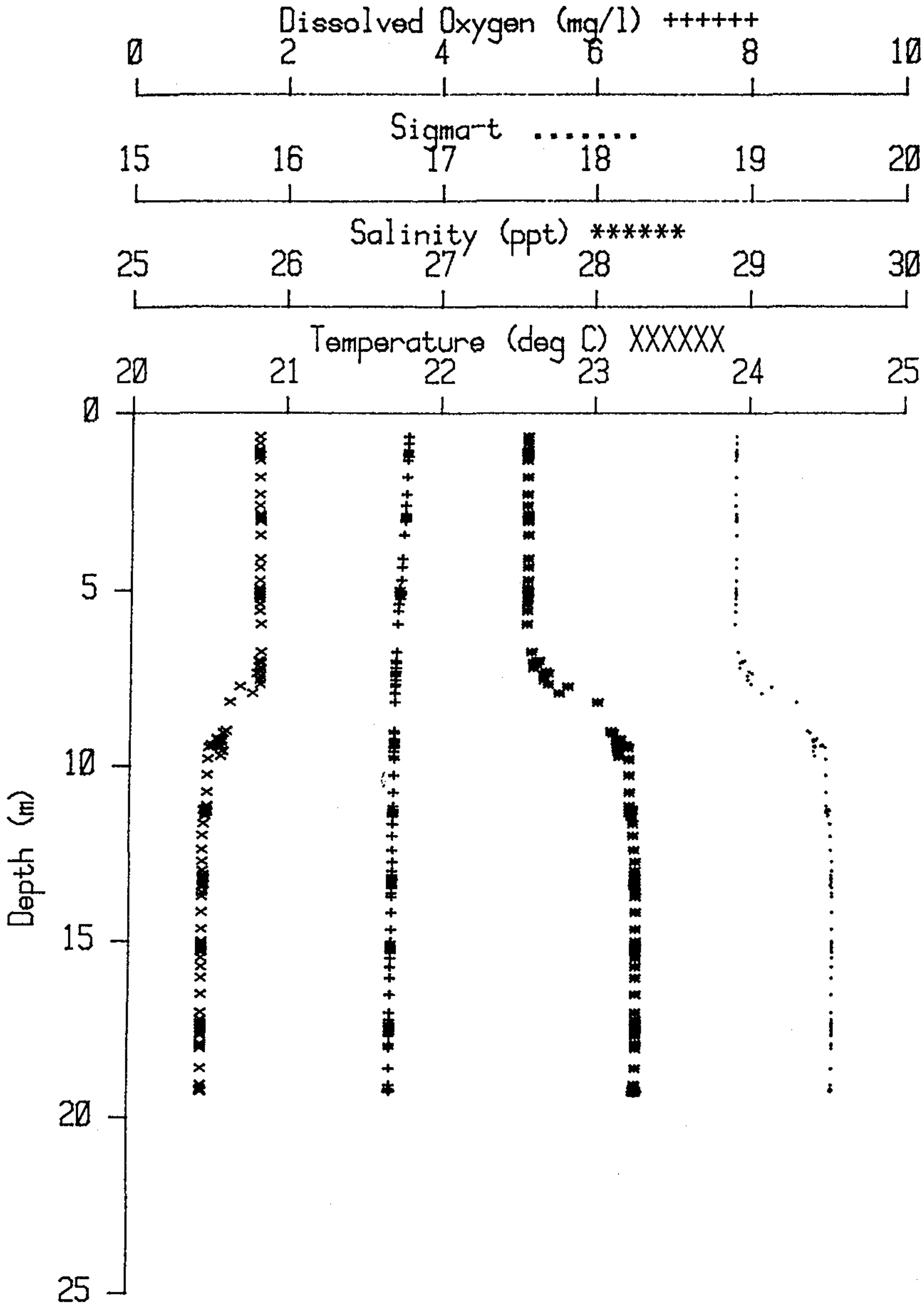


# STNH-S 600N 08/28



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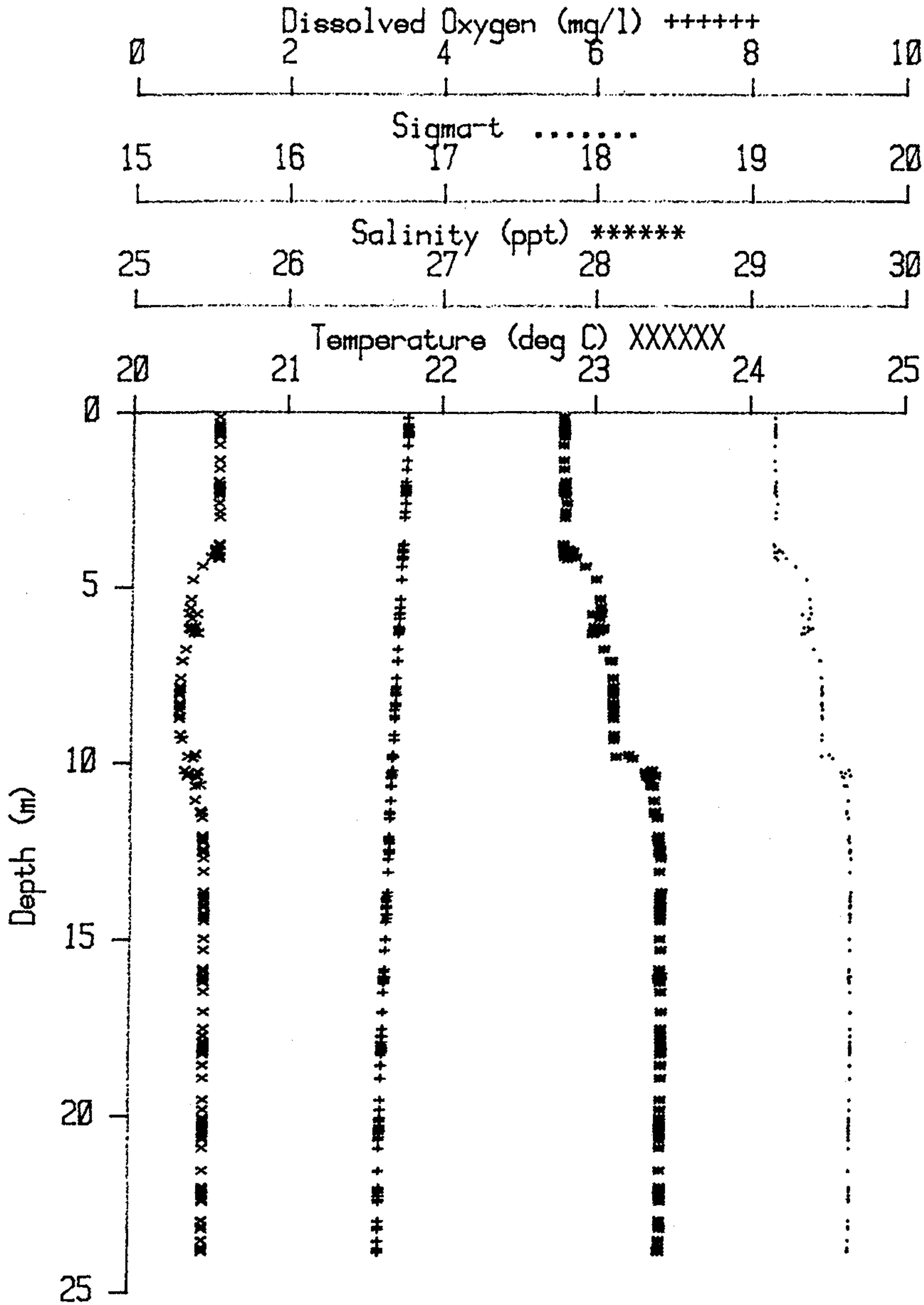
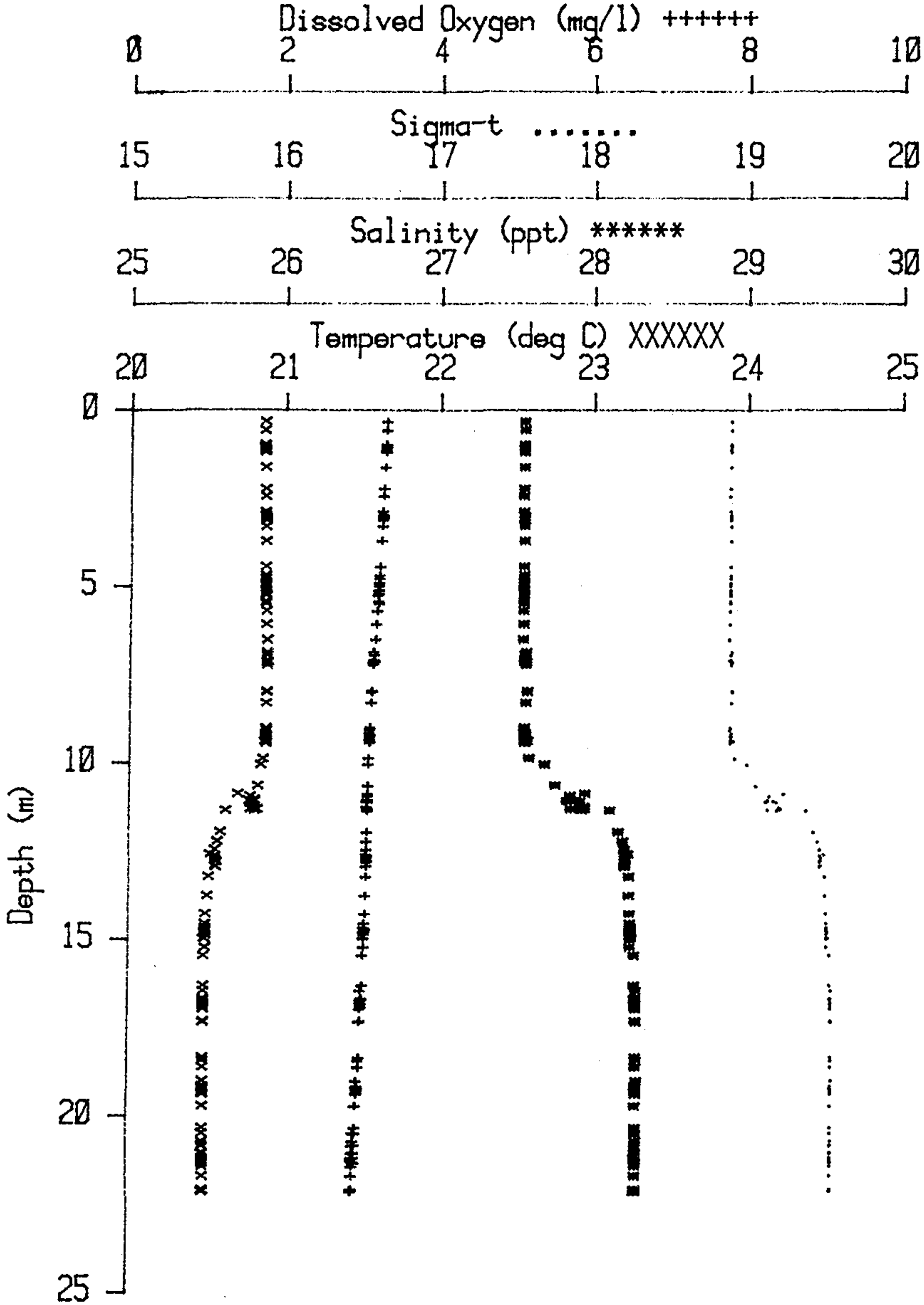


# STNH-S 600E 08/28



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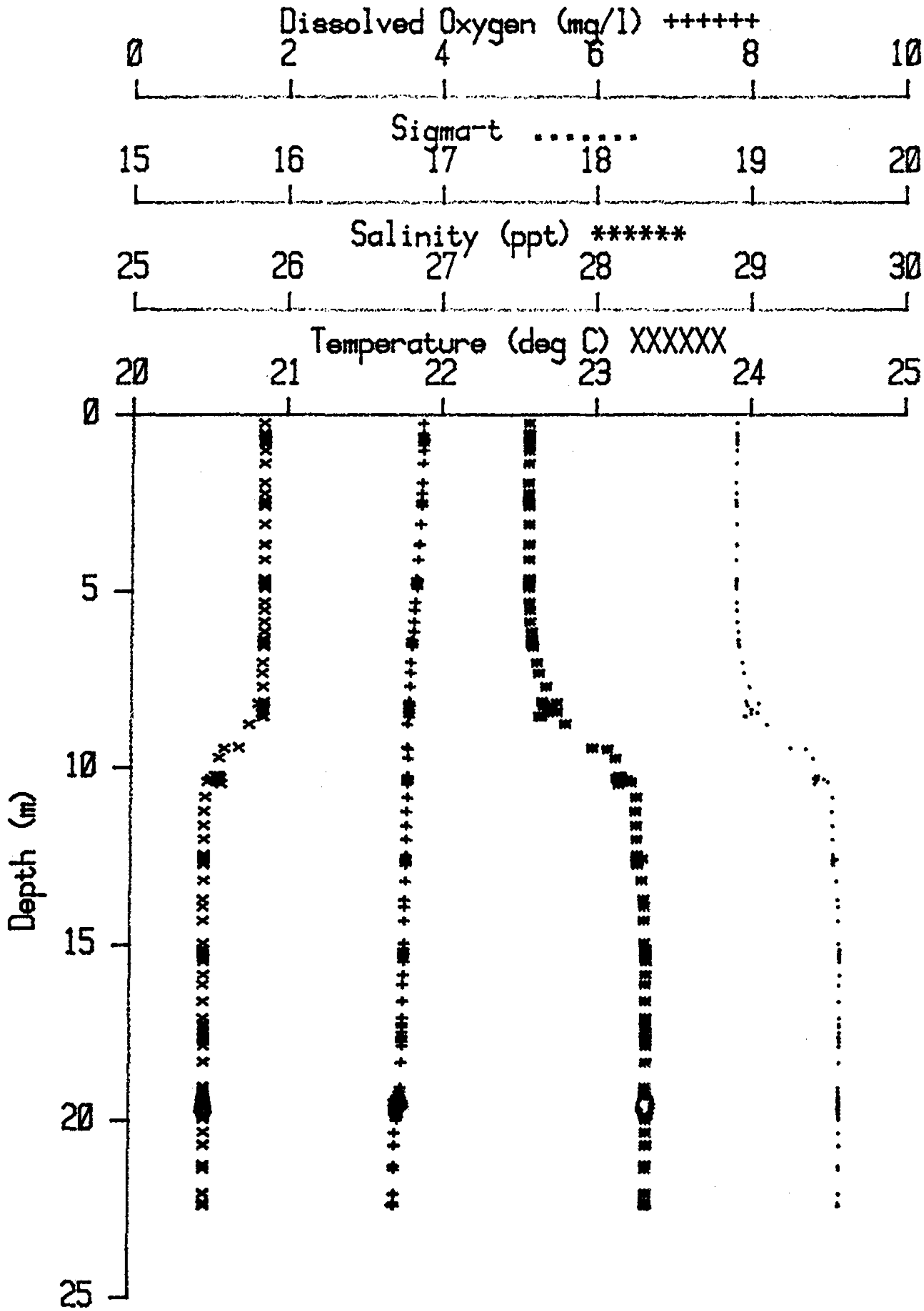

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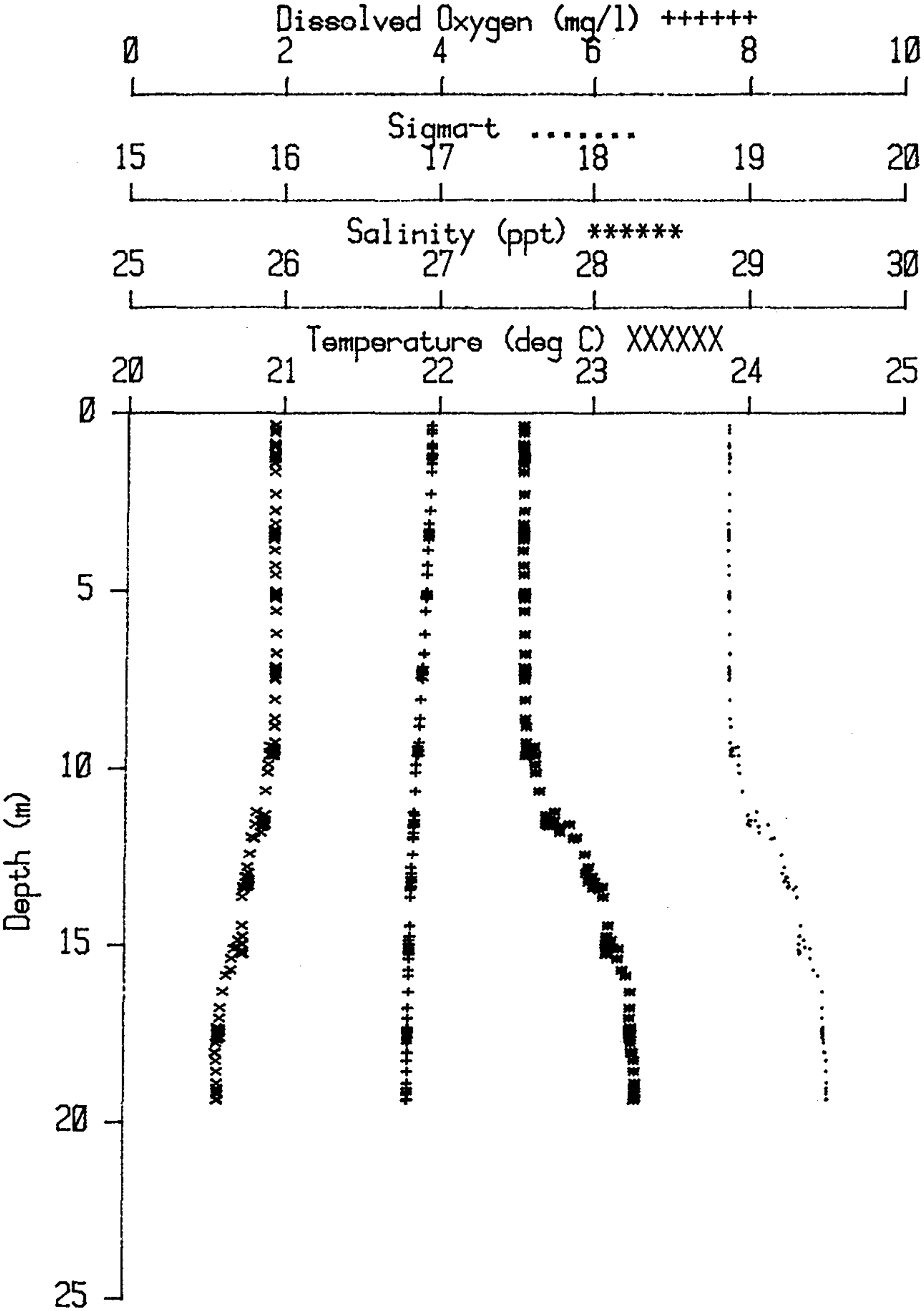
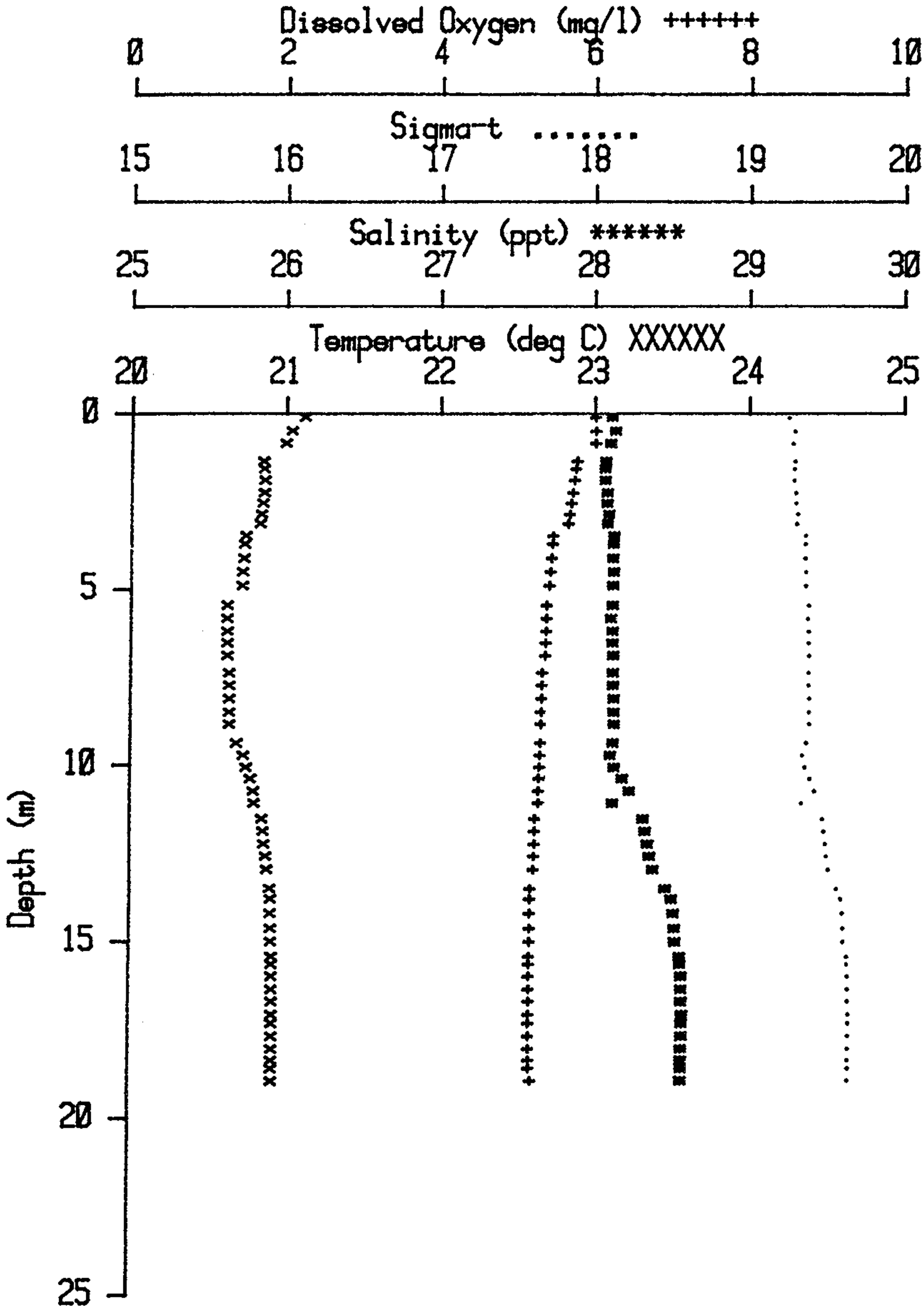


# CLIS 200N 08/26



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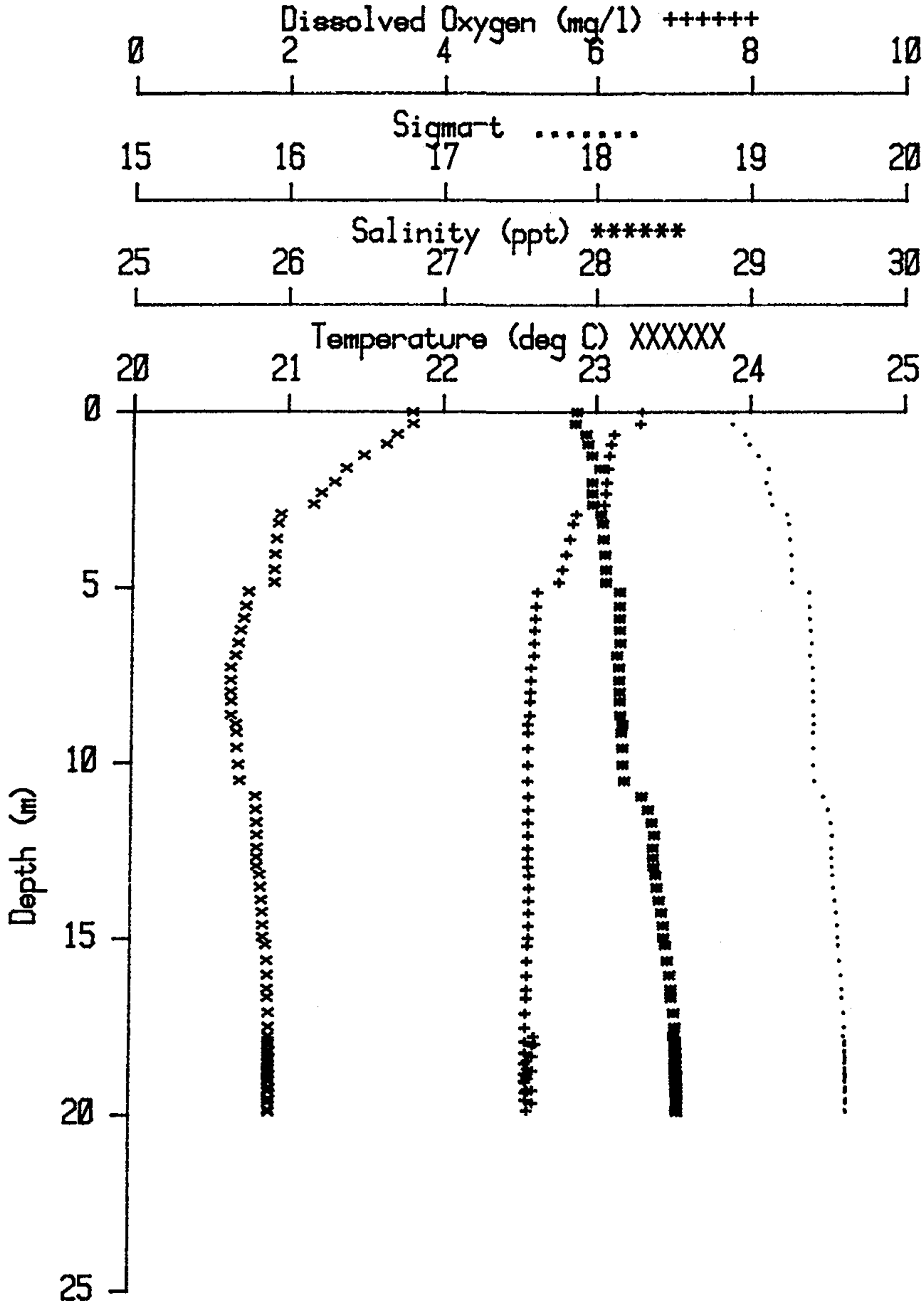
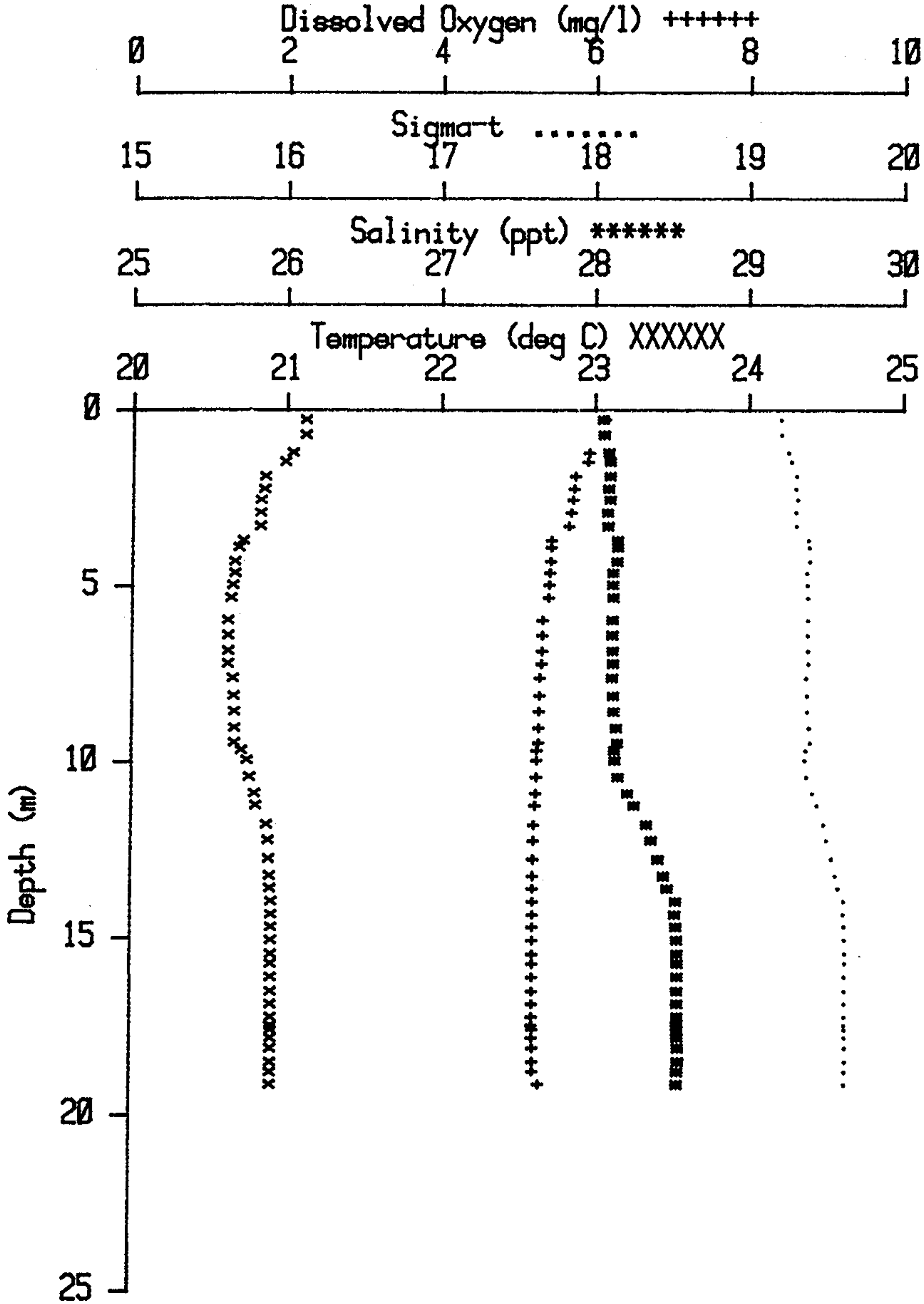


# CLIS 2-200NW 08/26



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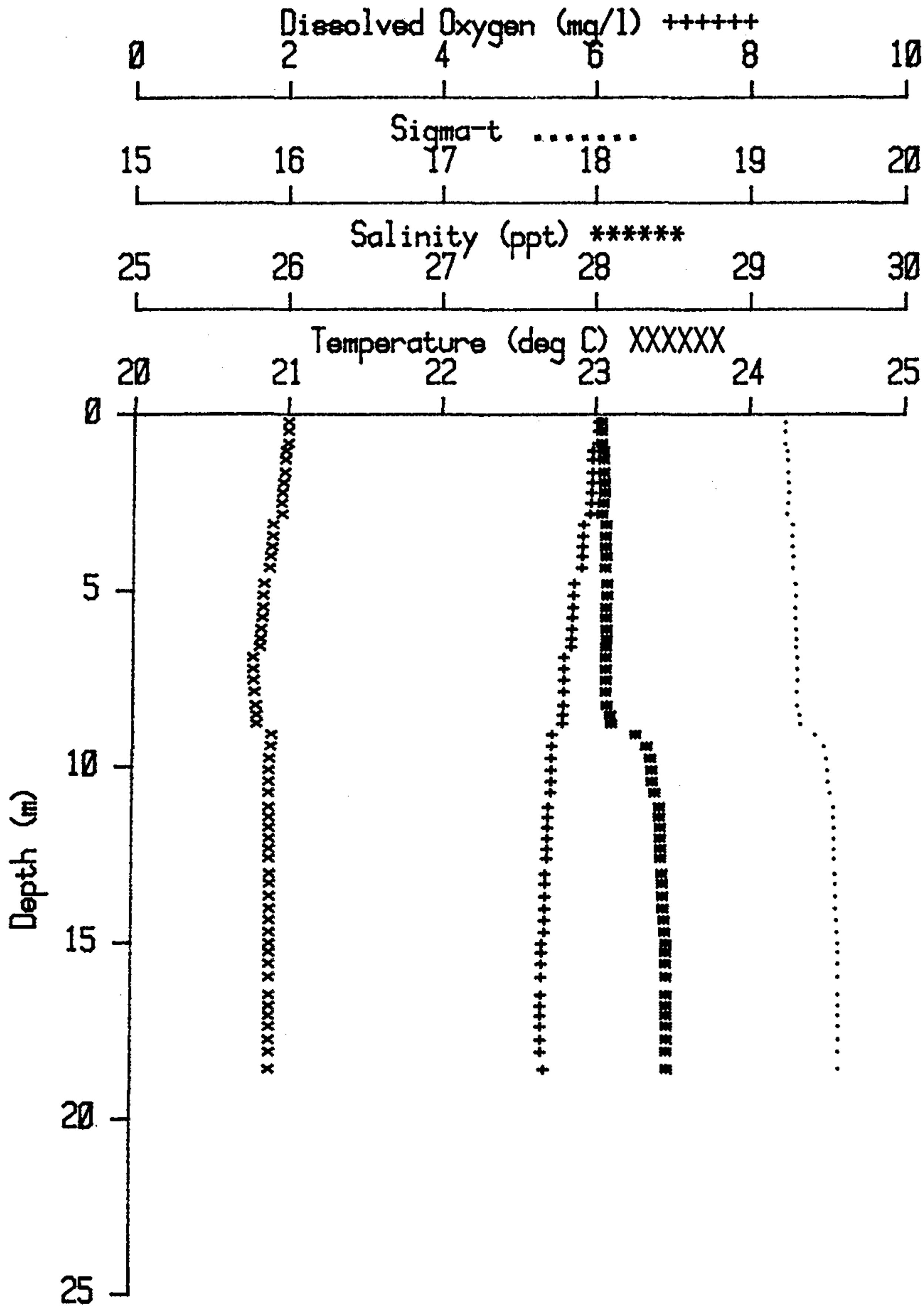

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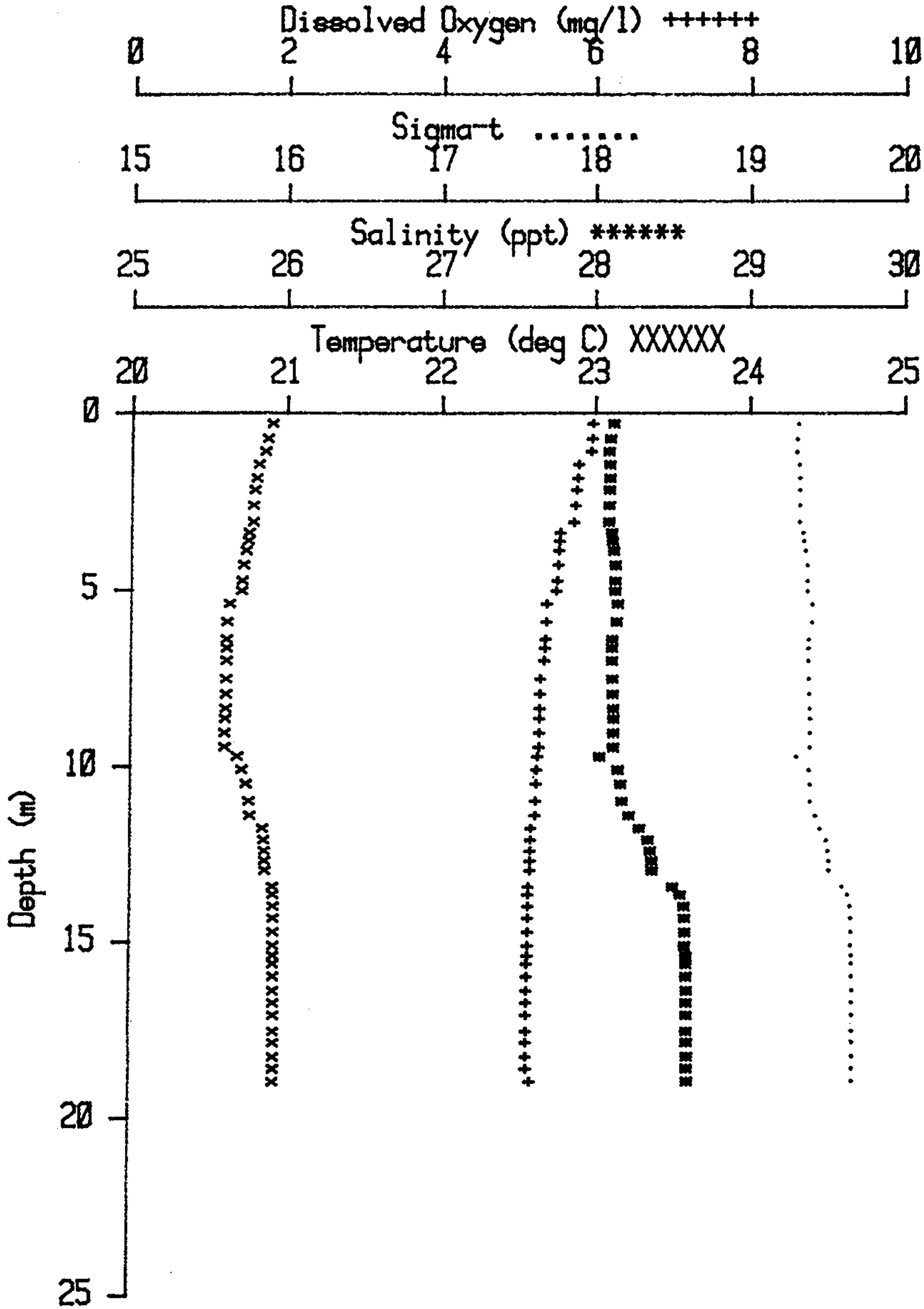

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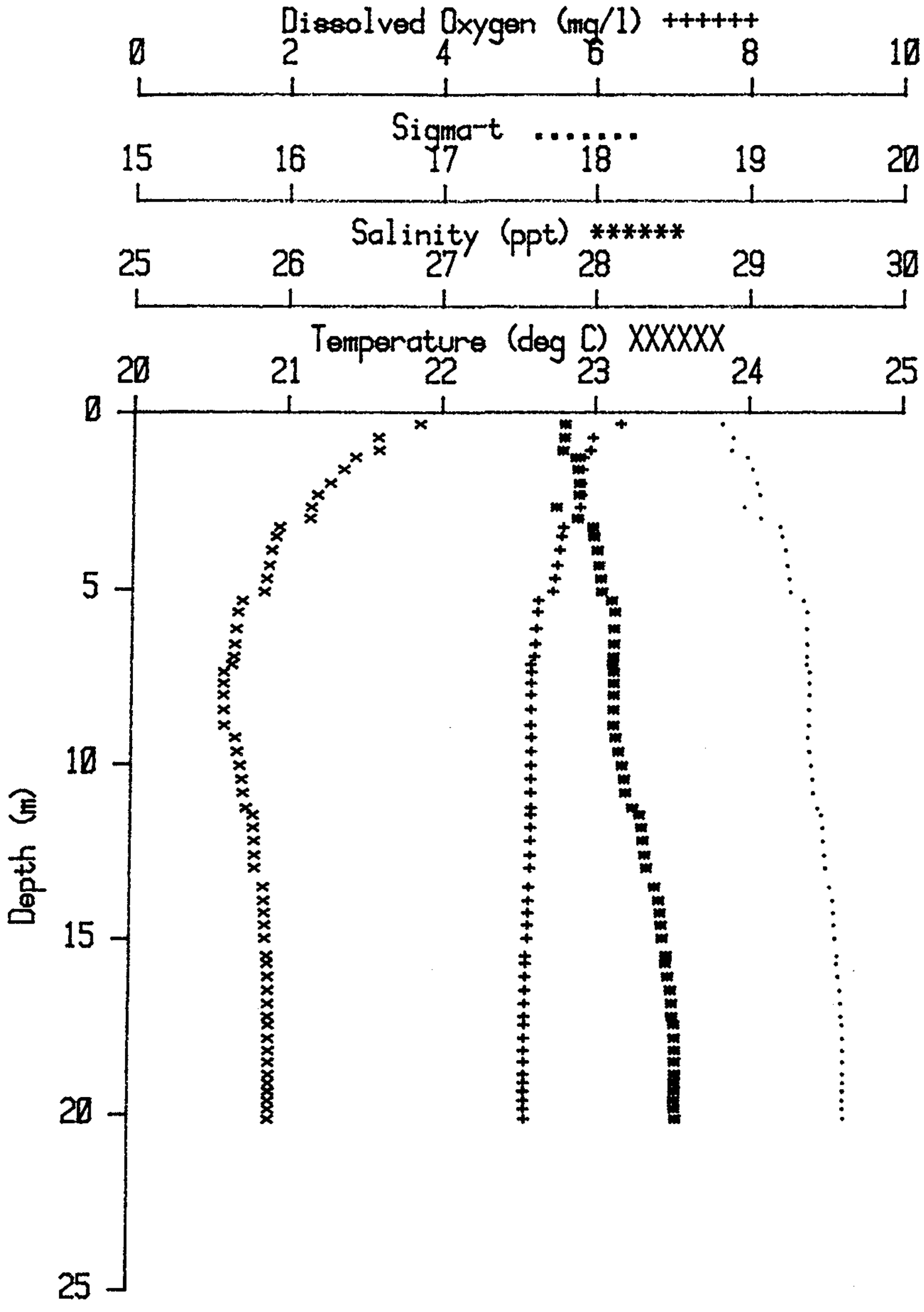

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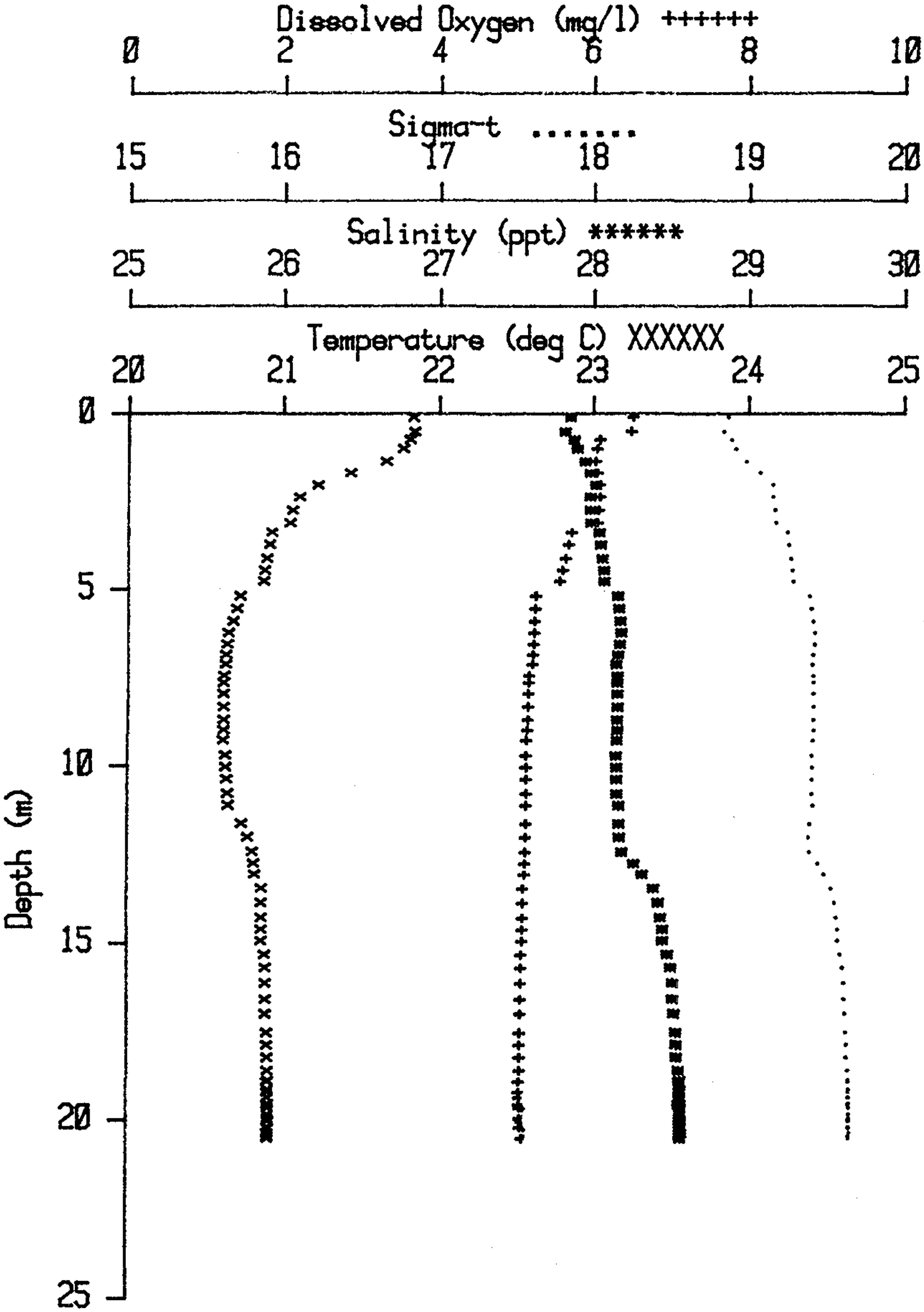

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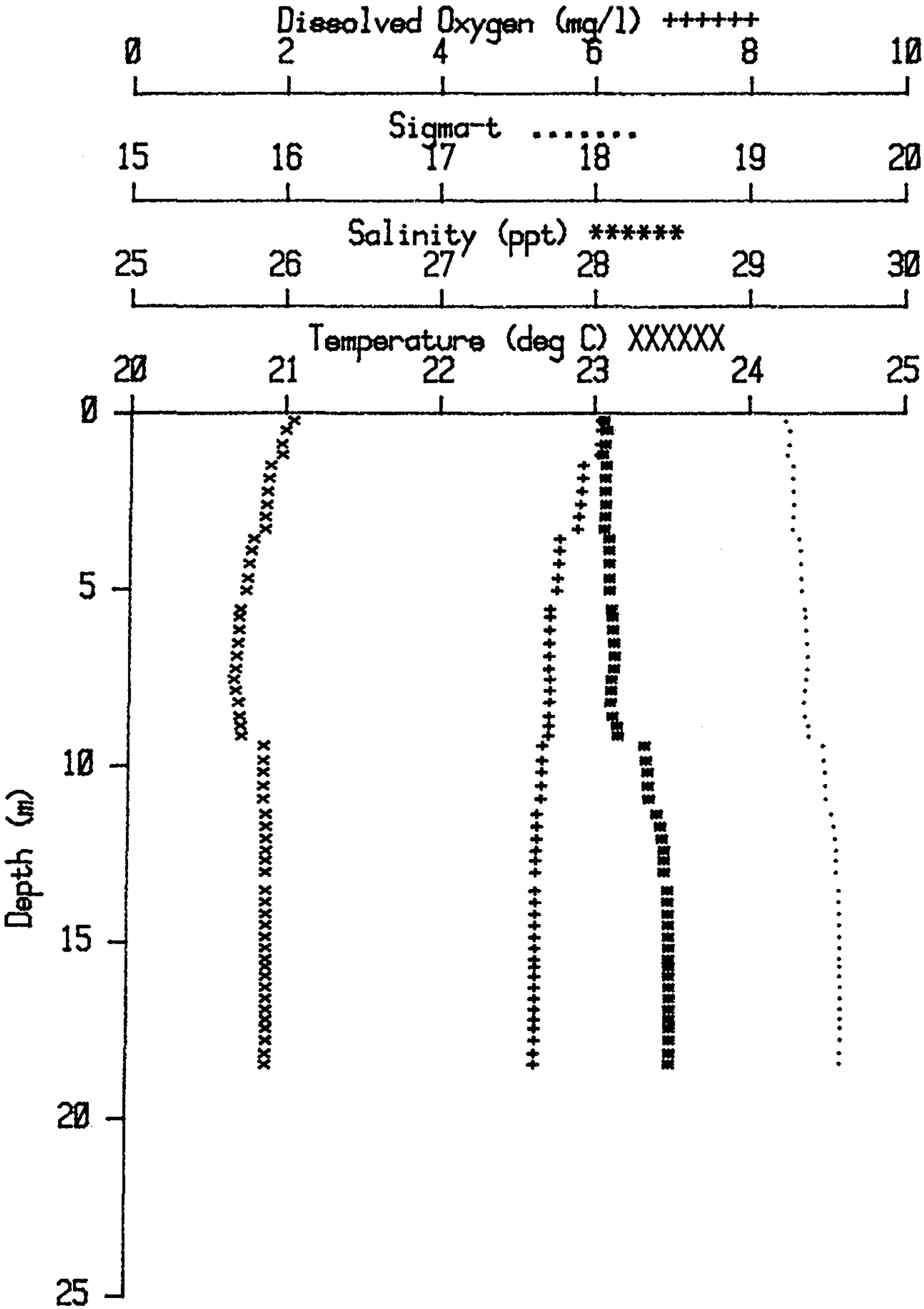

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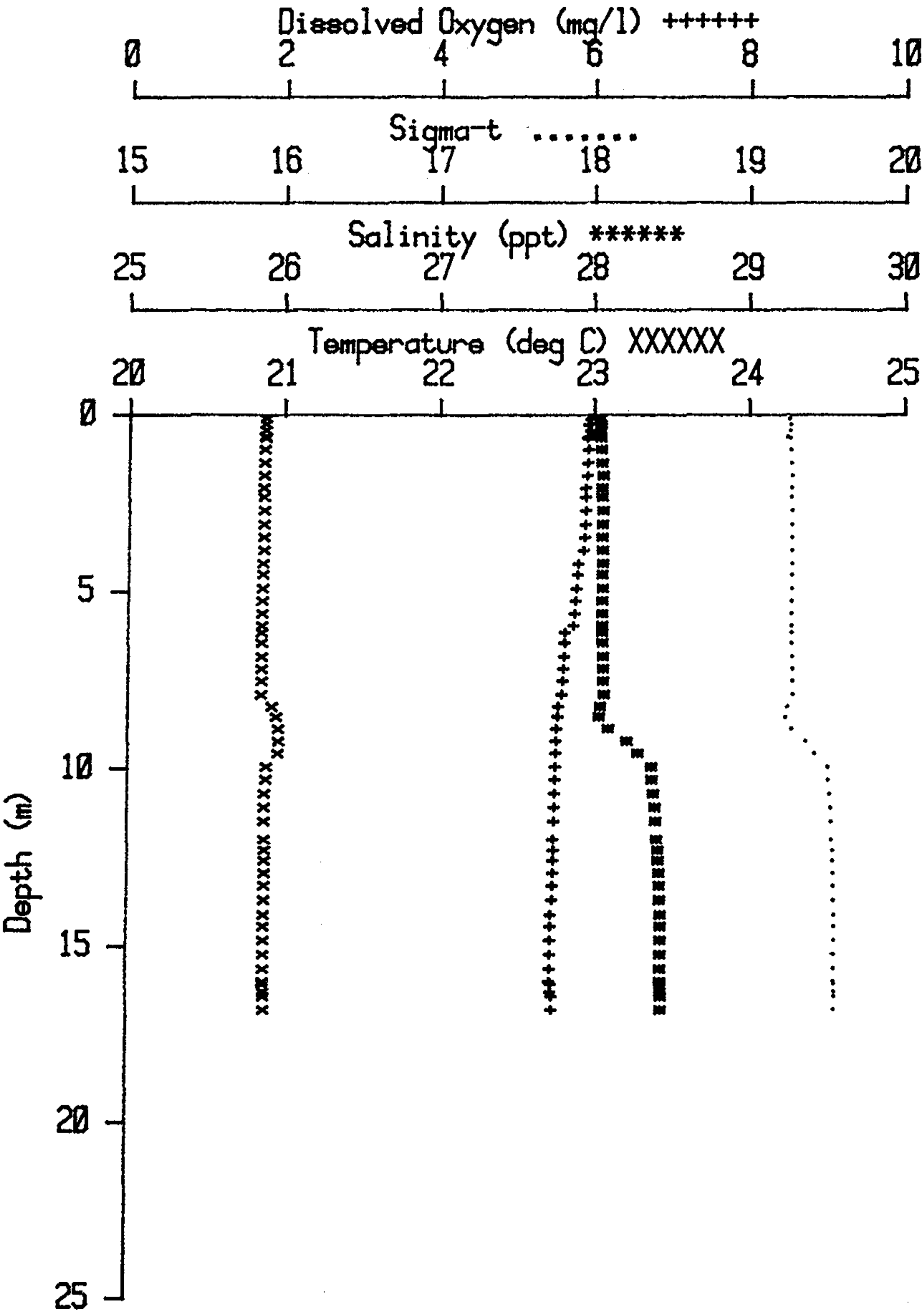
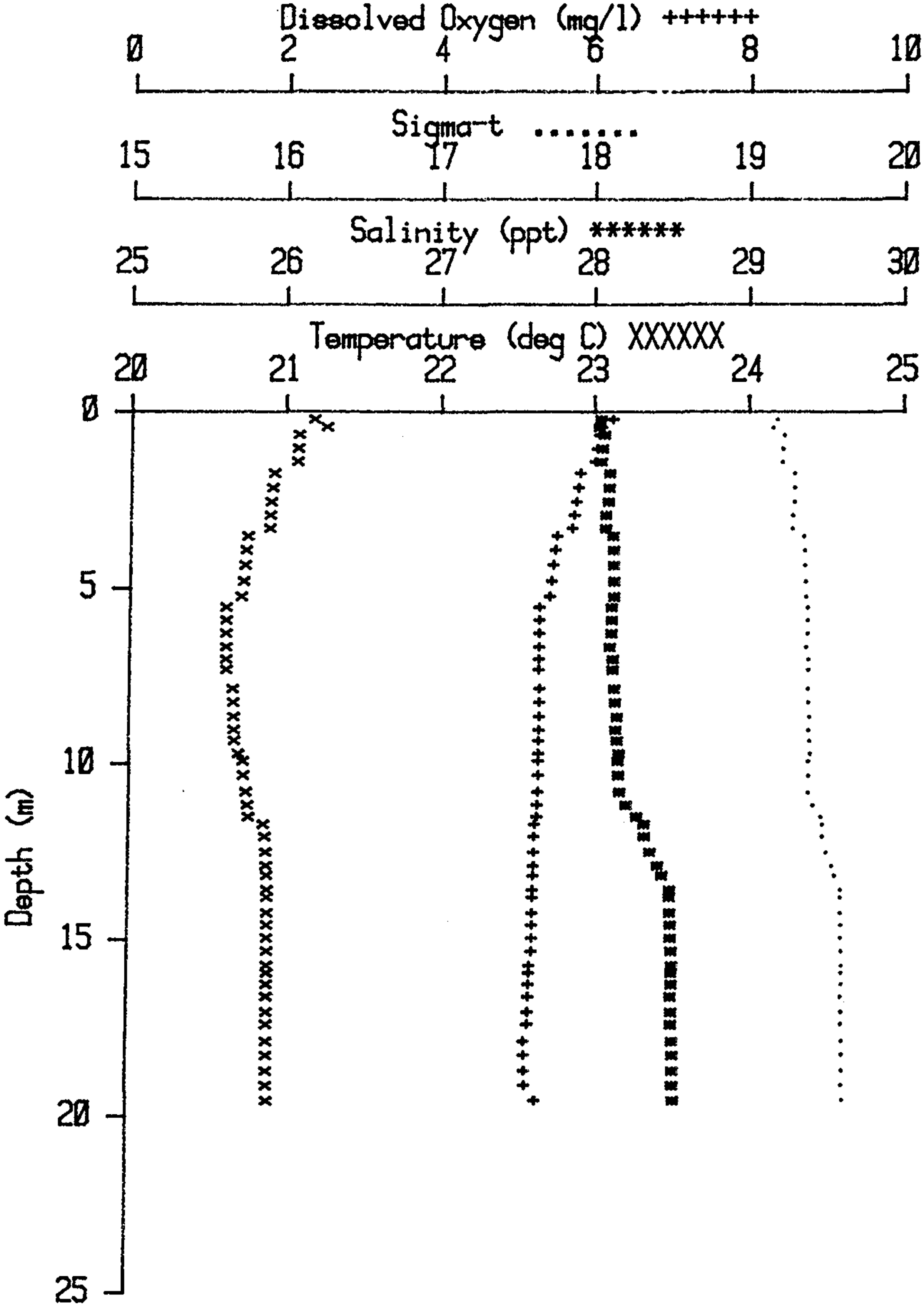


# CLIS 2-600NW 08/26



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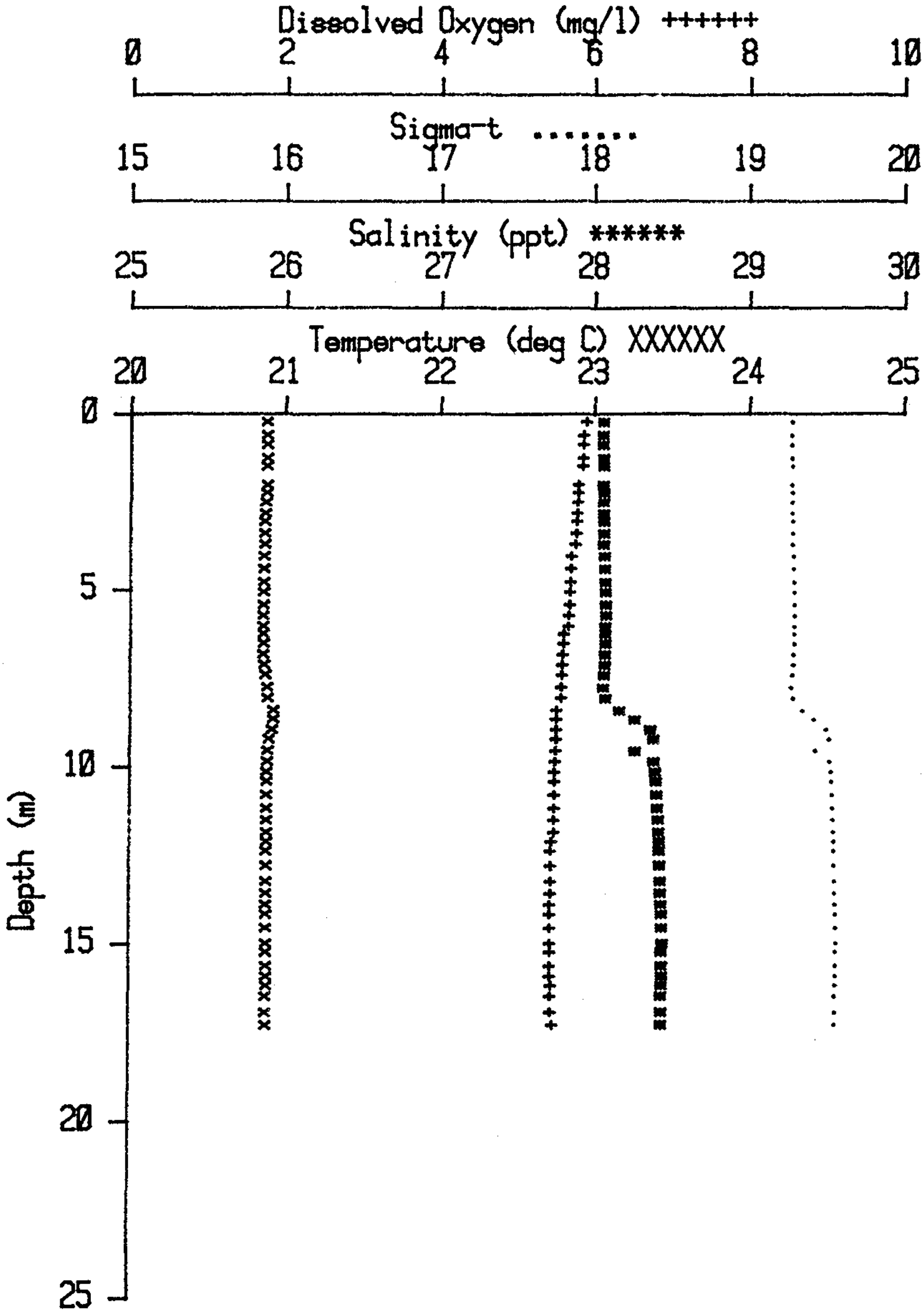

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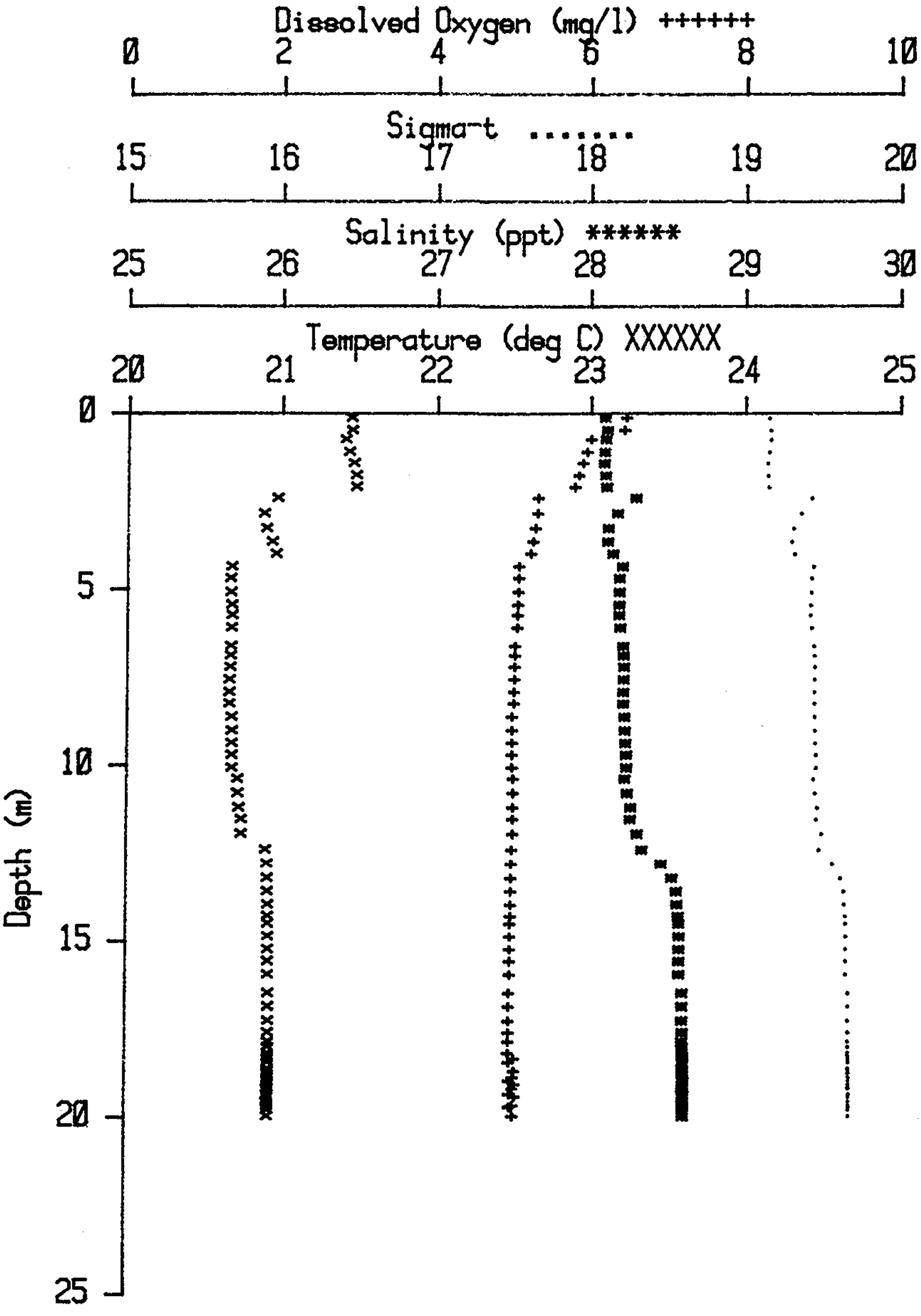

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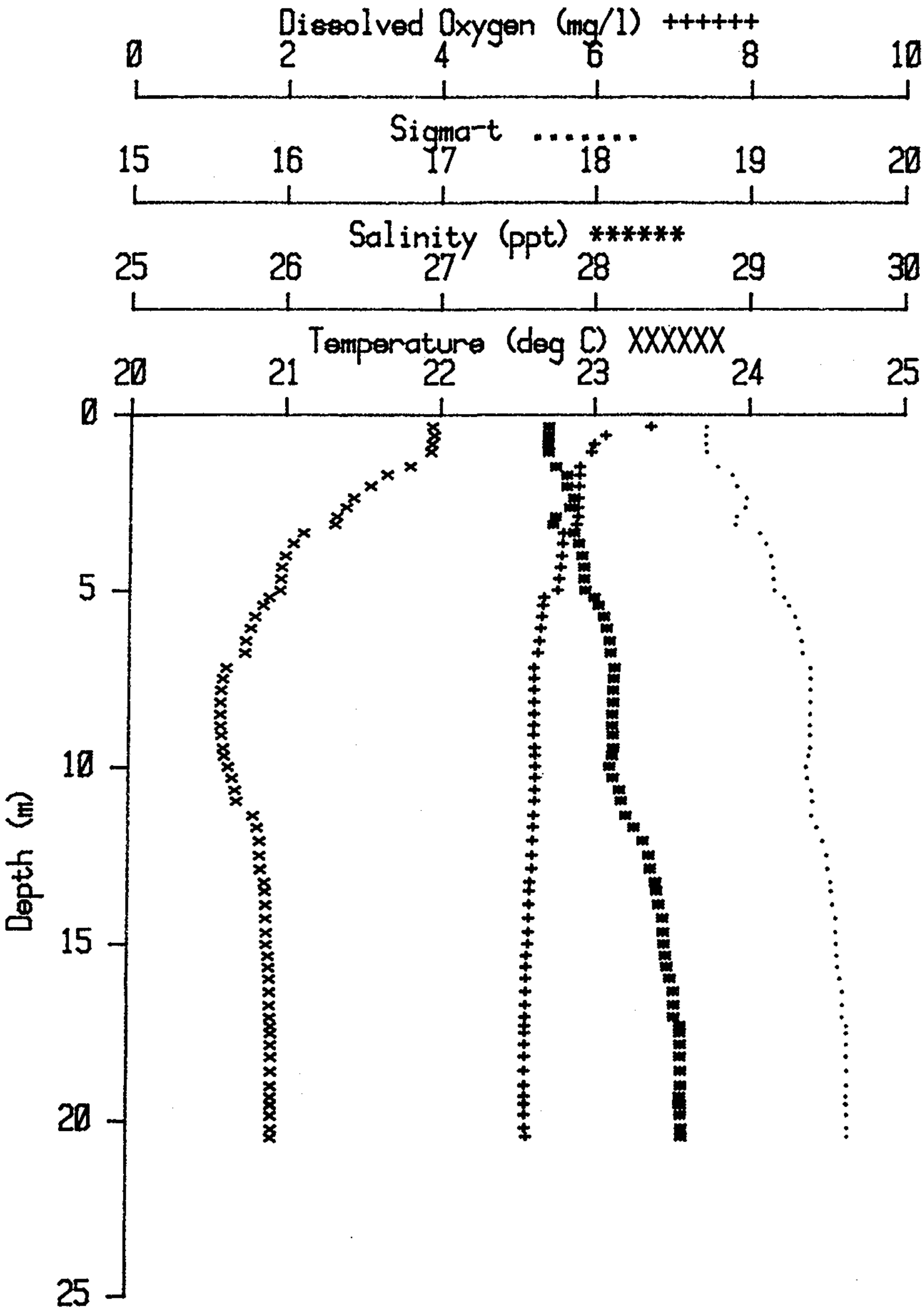

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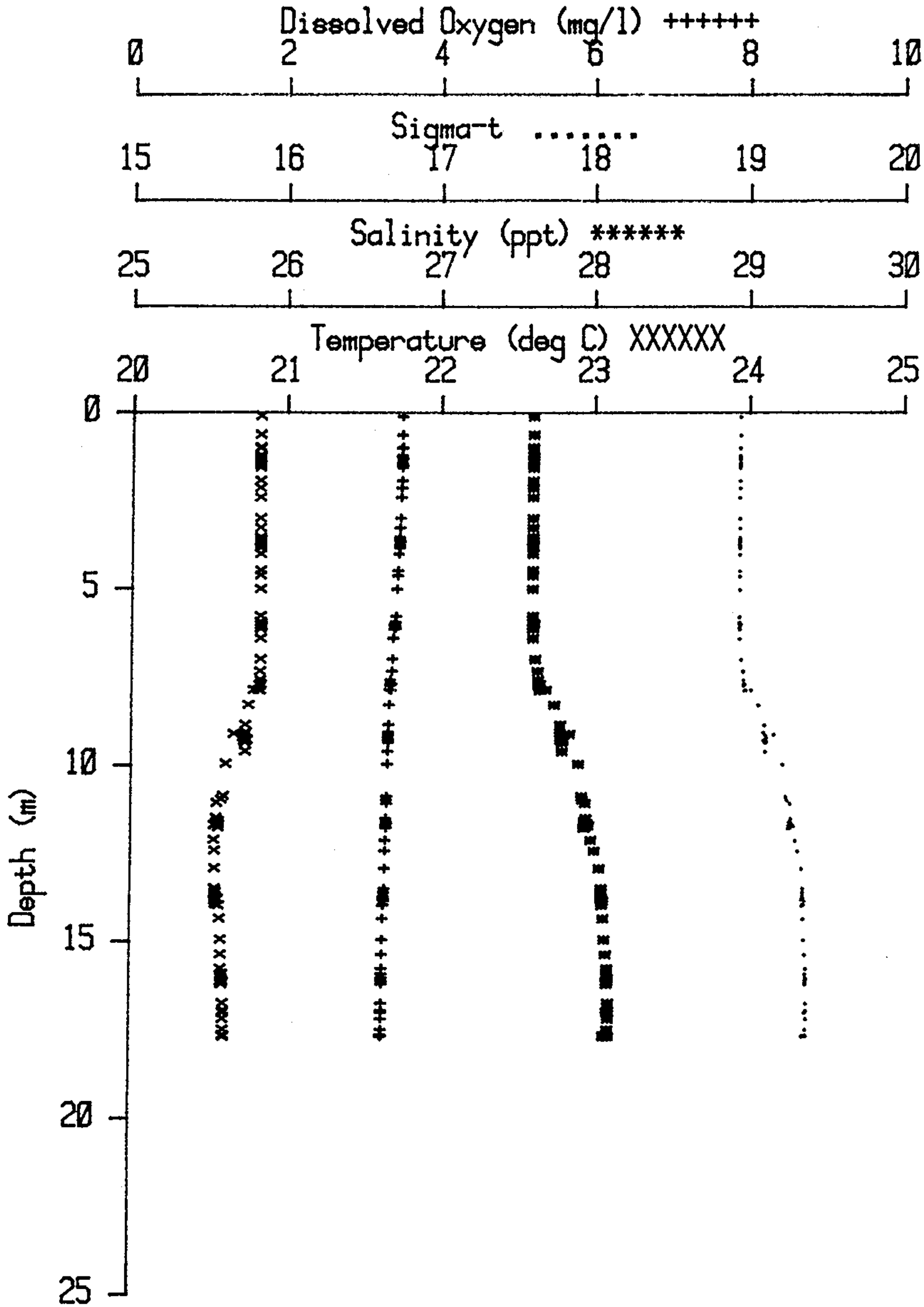
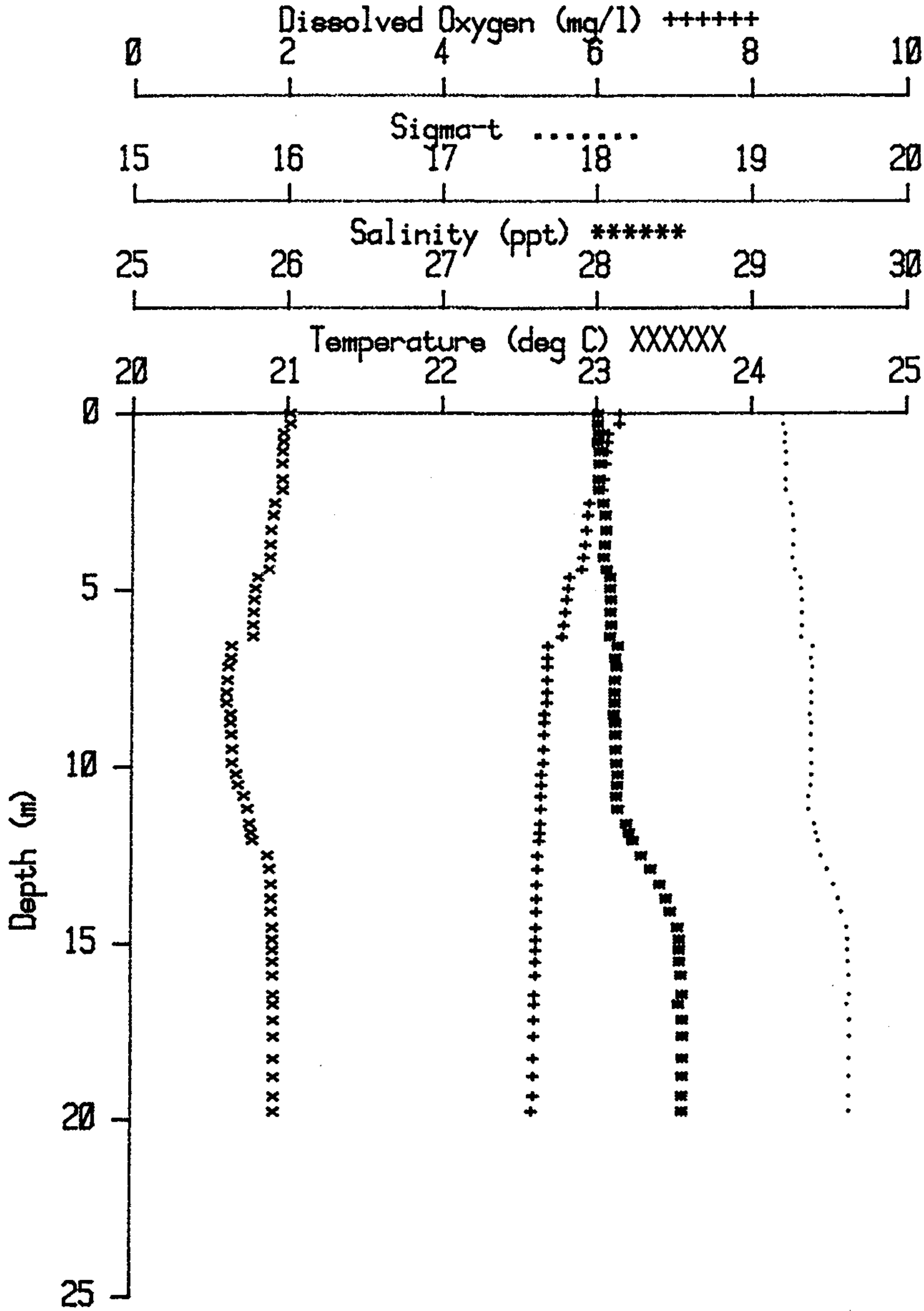


# CLIS 800W 08/26



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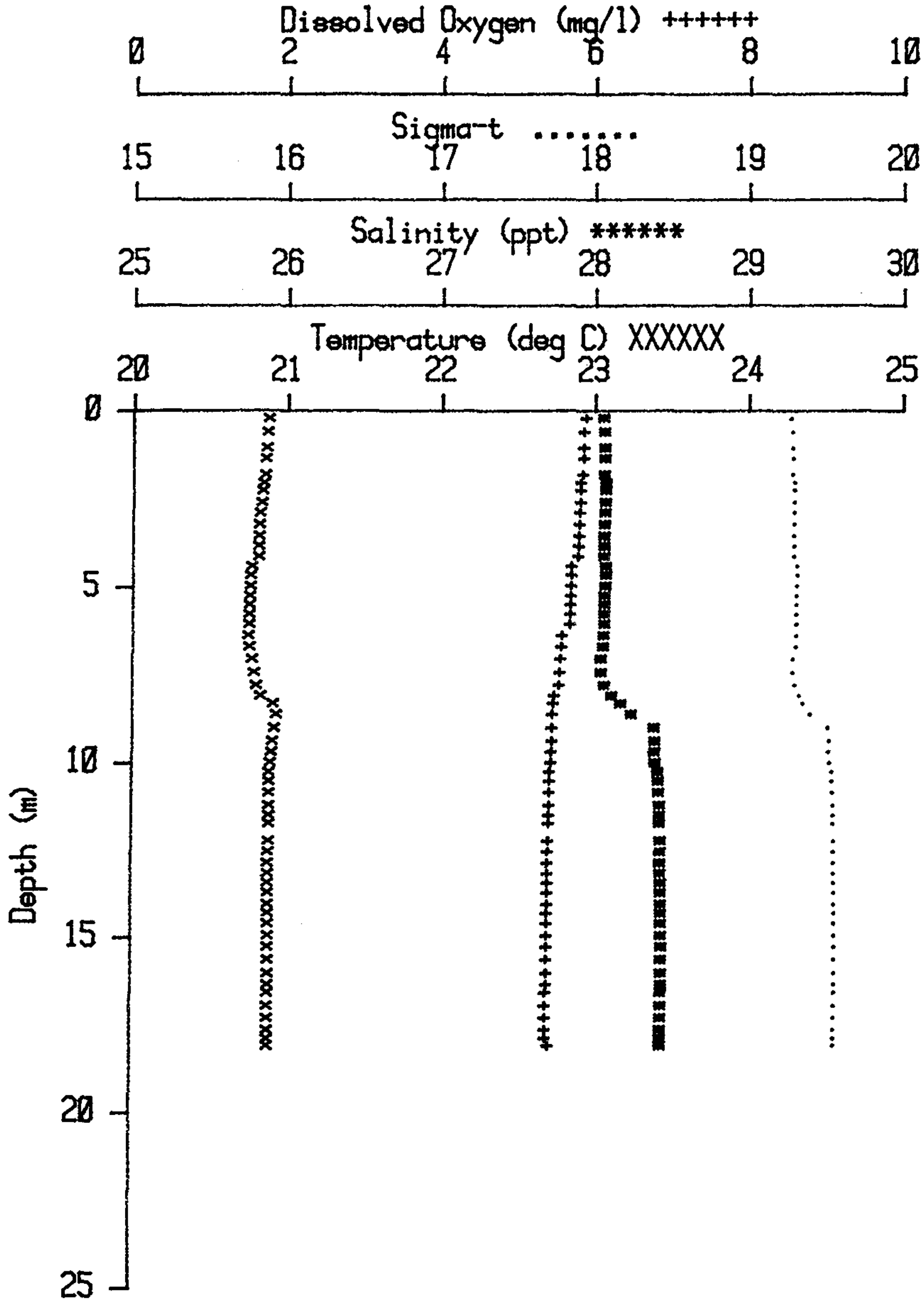
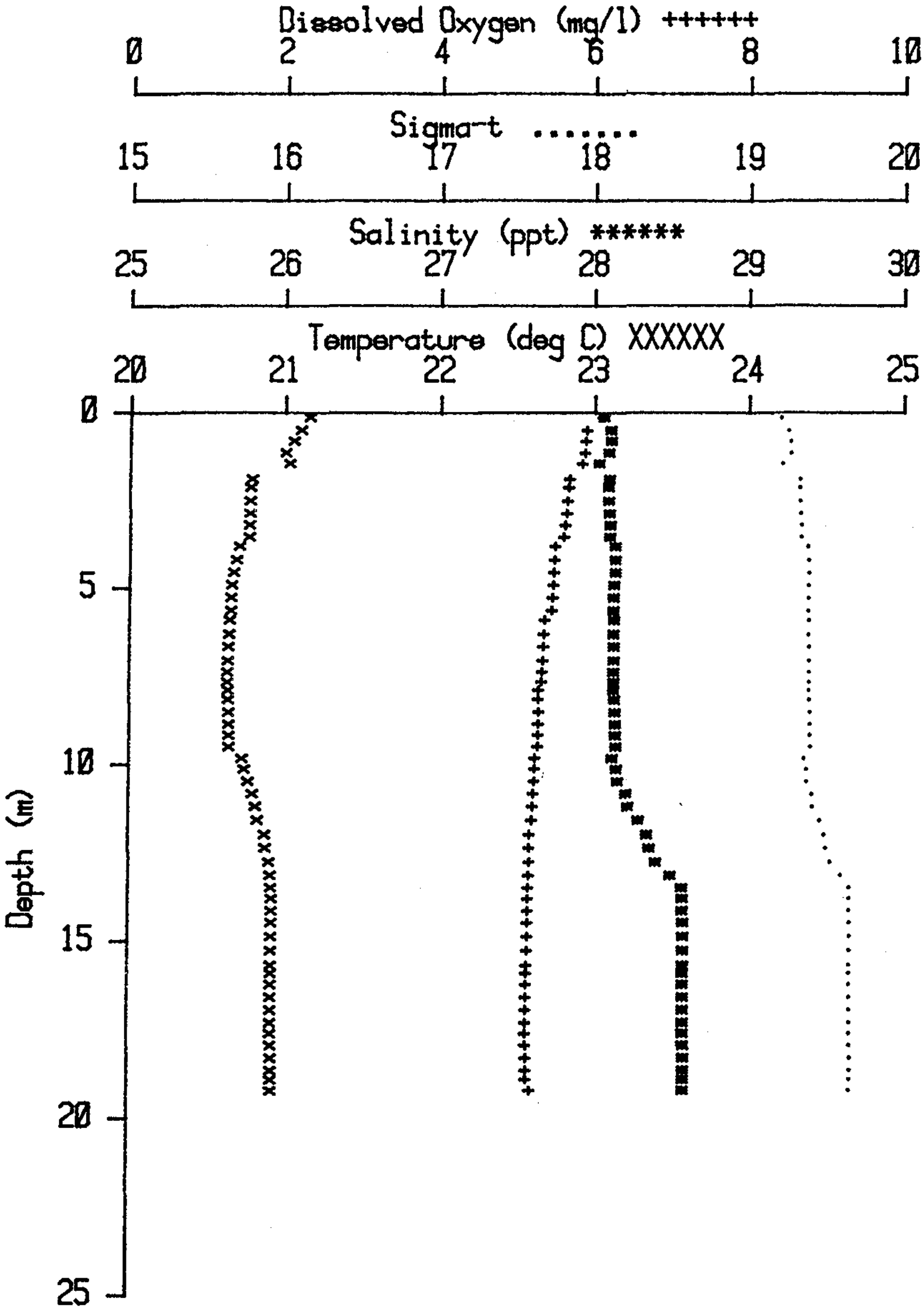


# CLIS 2-200NE 08/26



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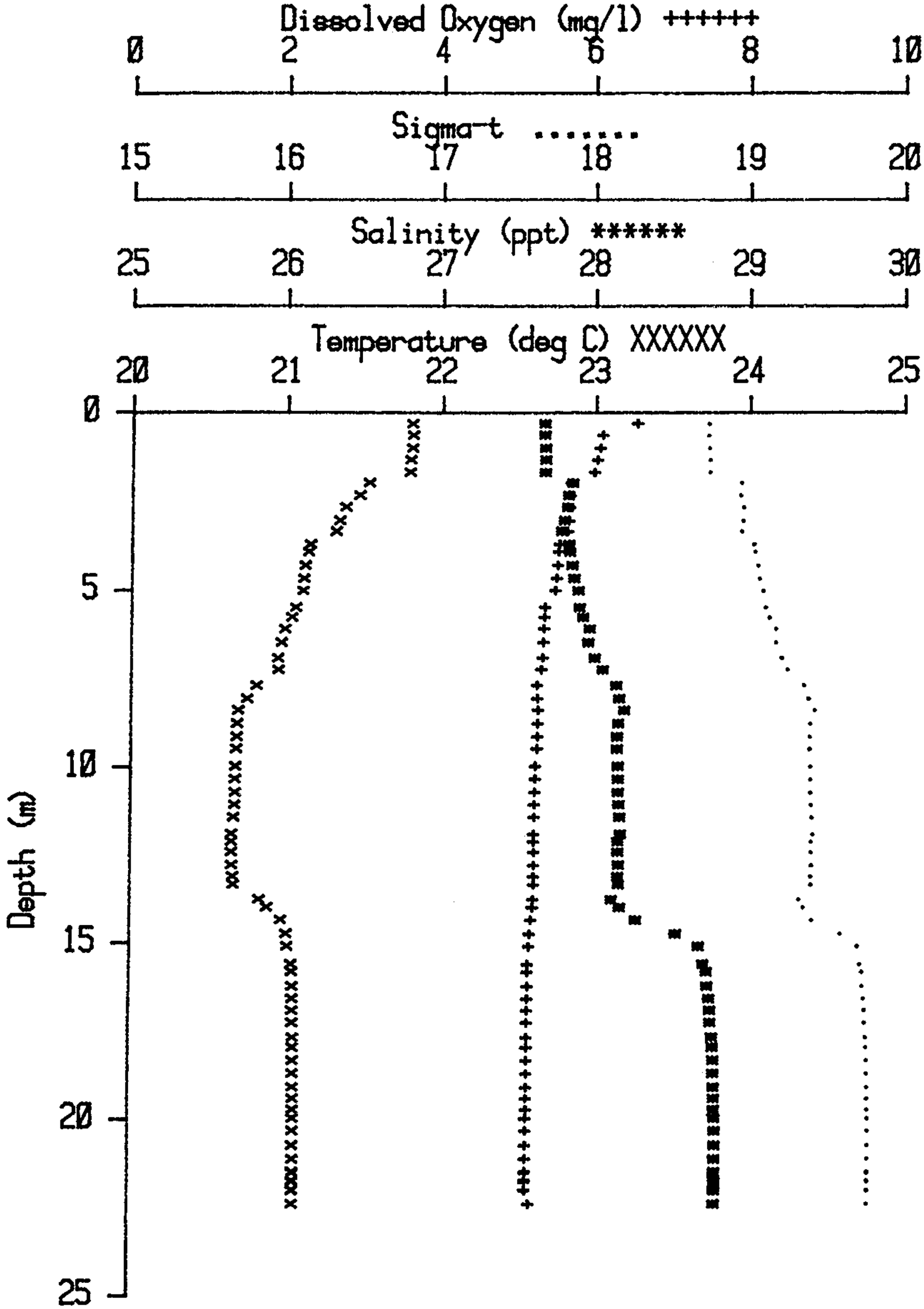

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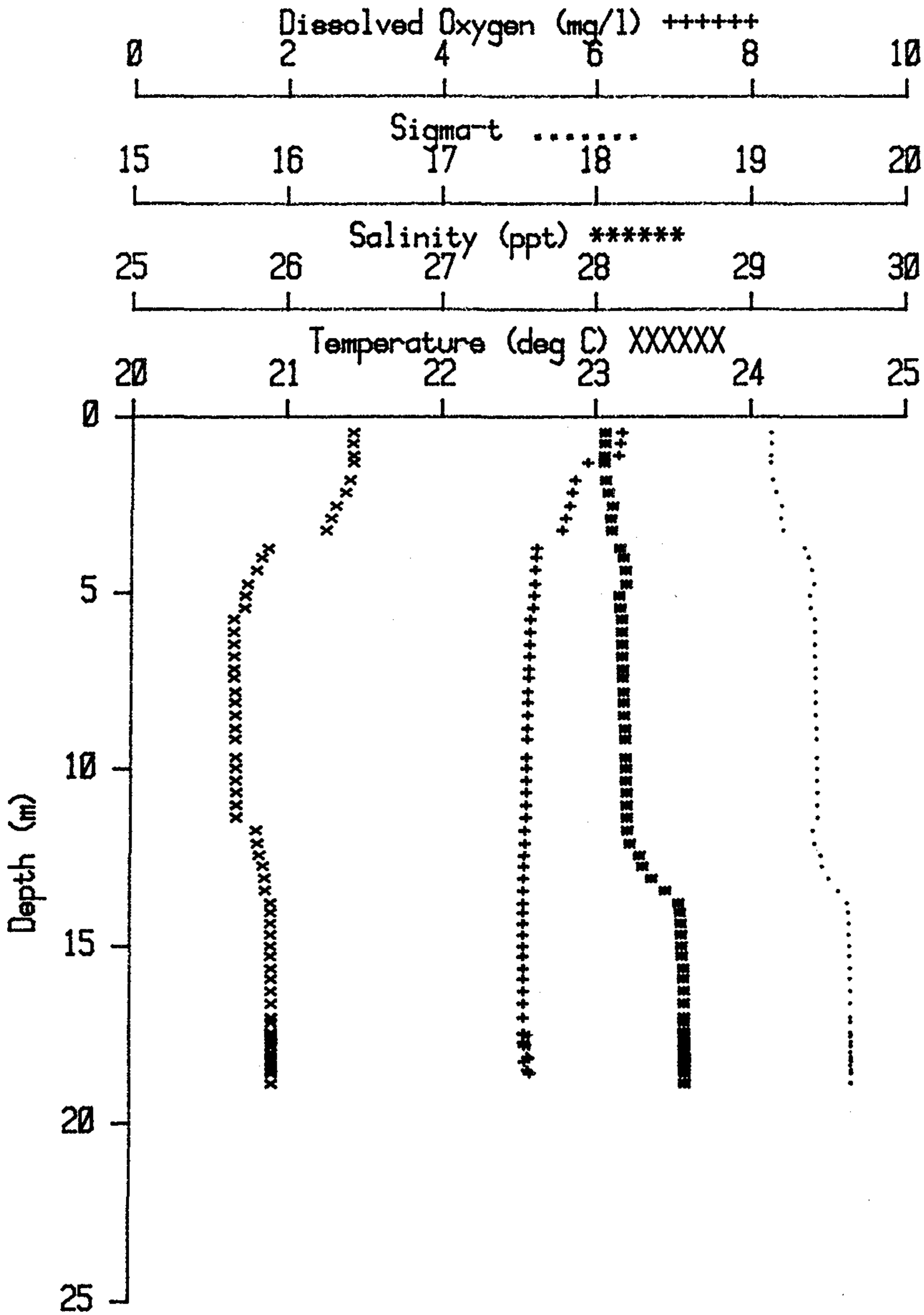
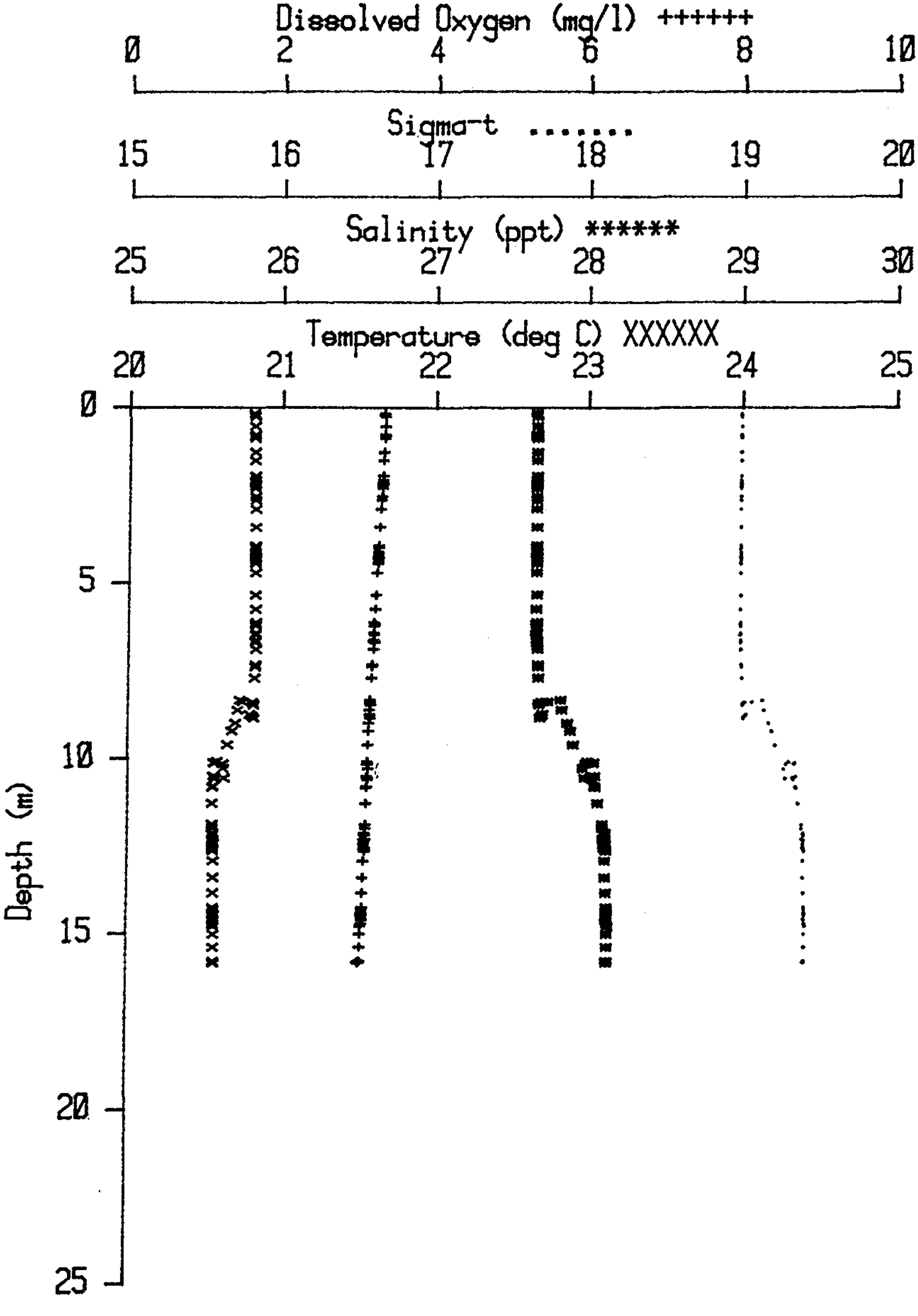


# CLIS 2500W 08/28



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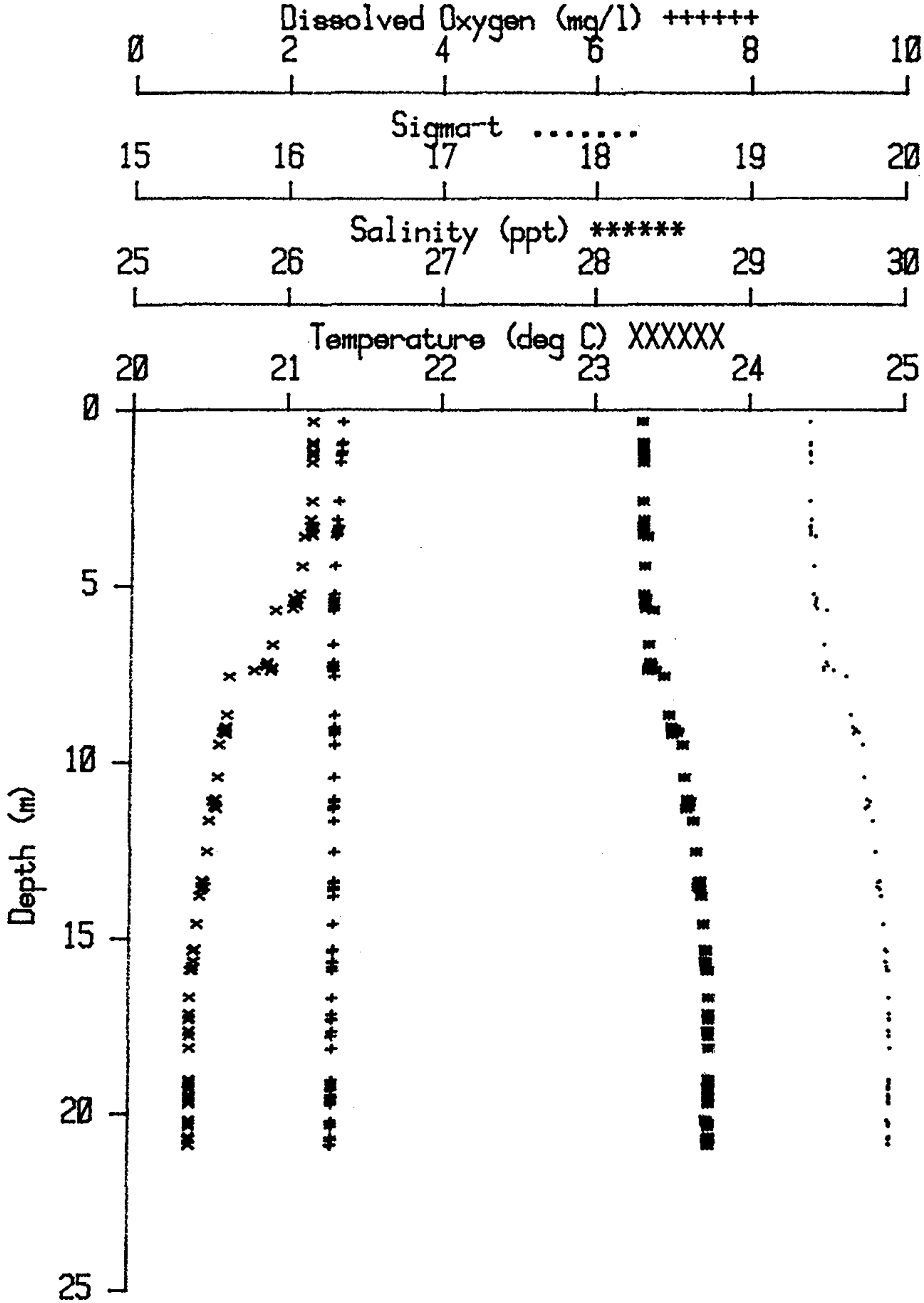

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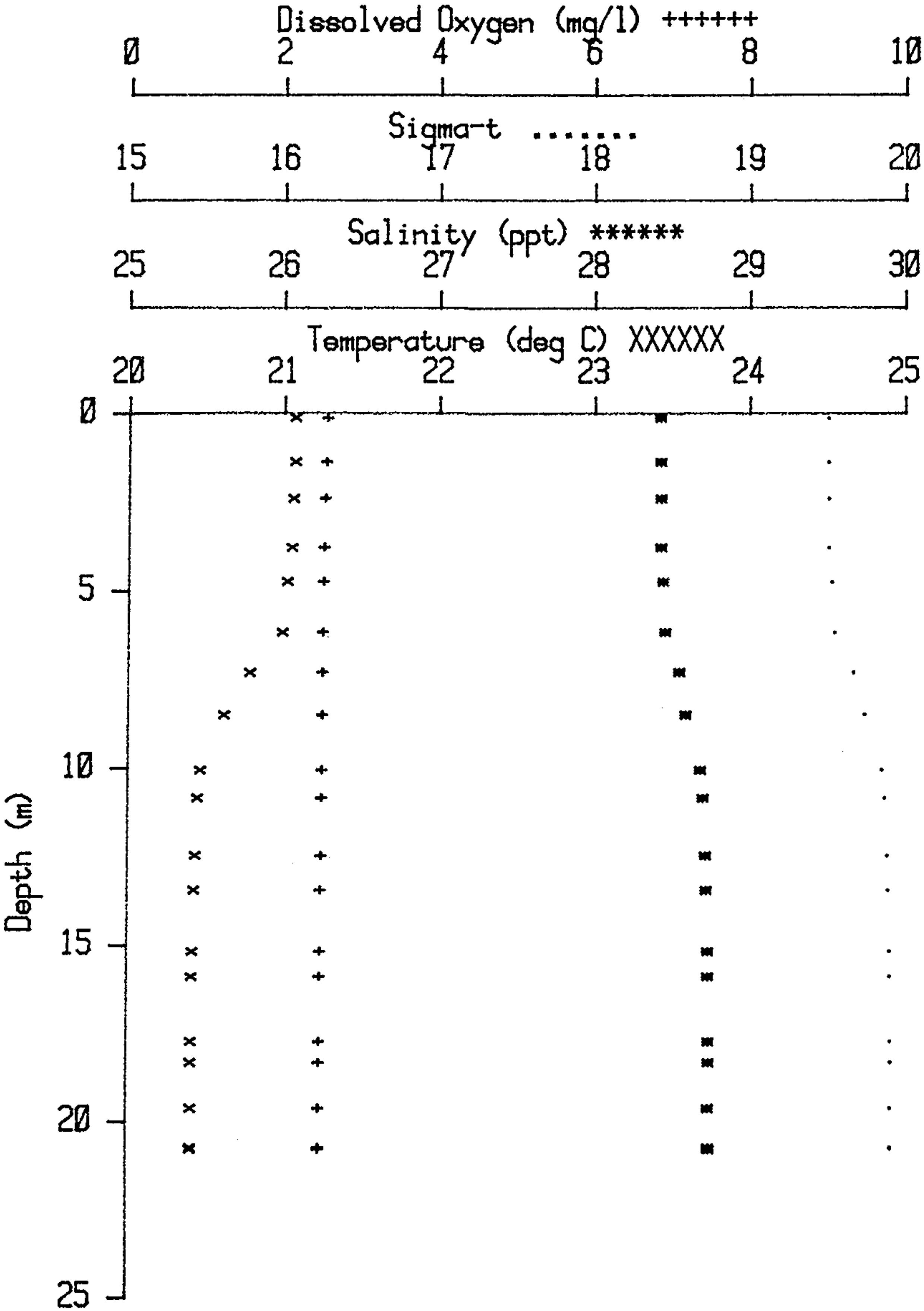

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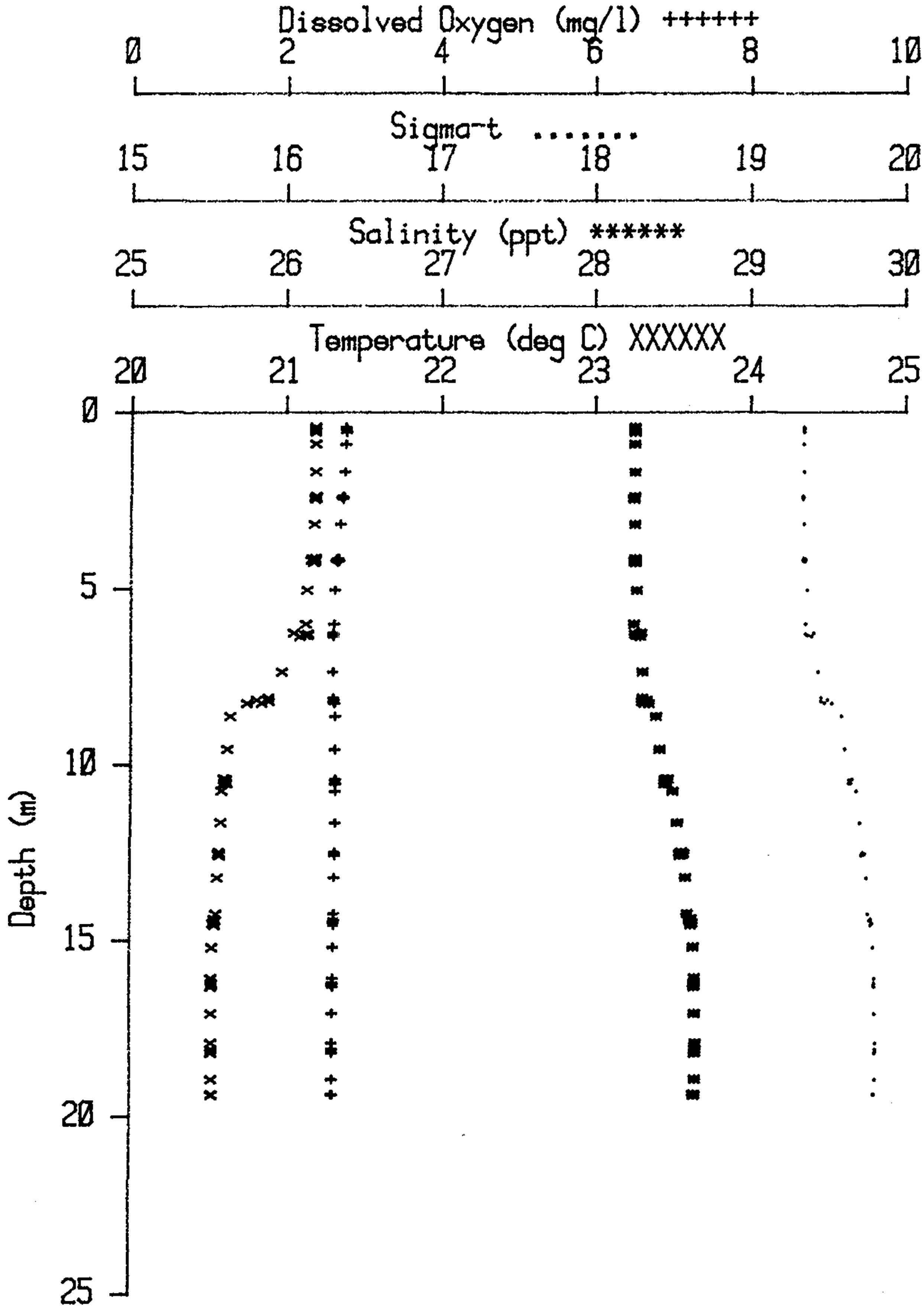

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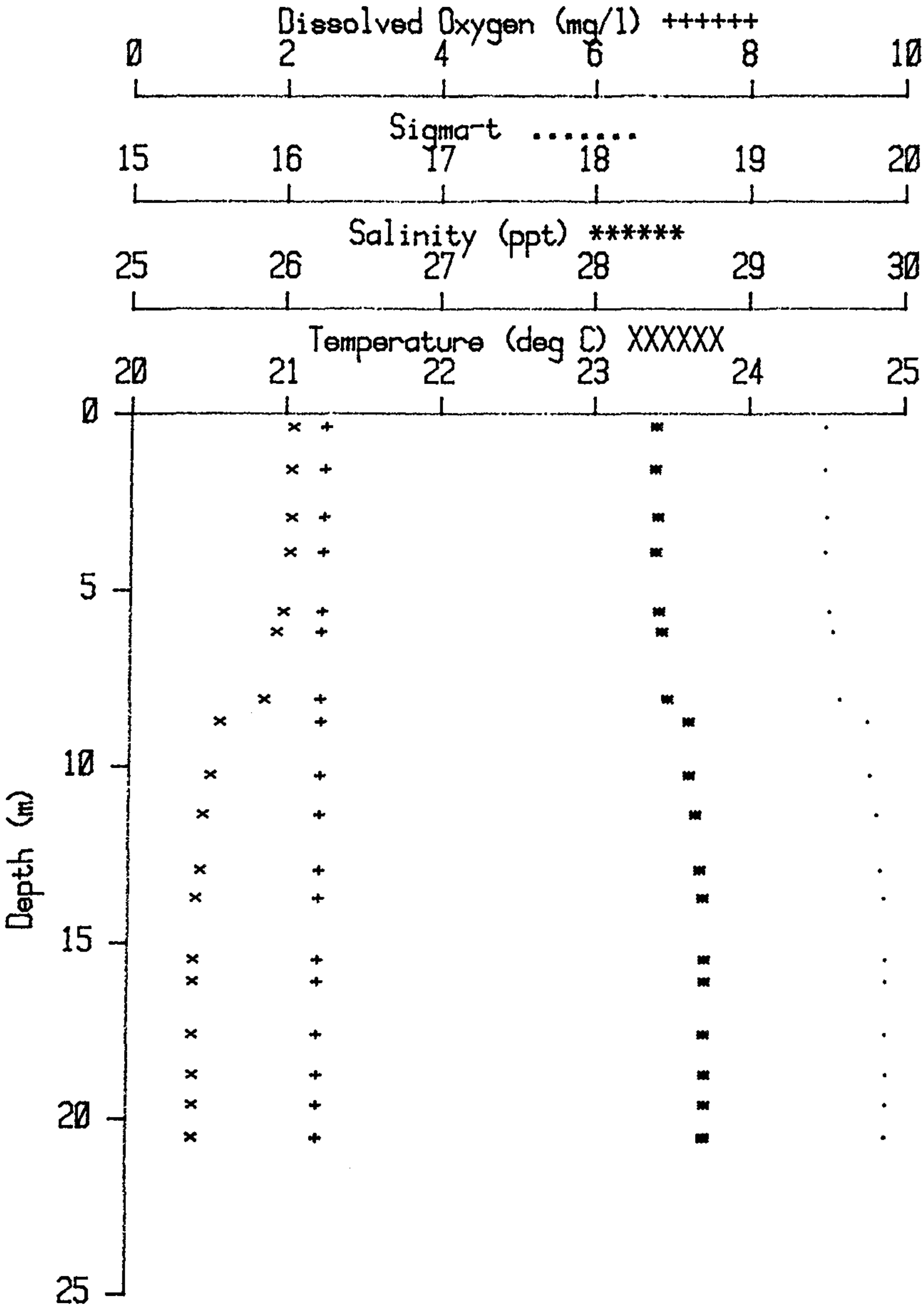

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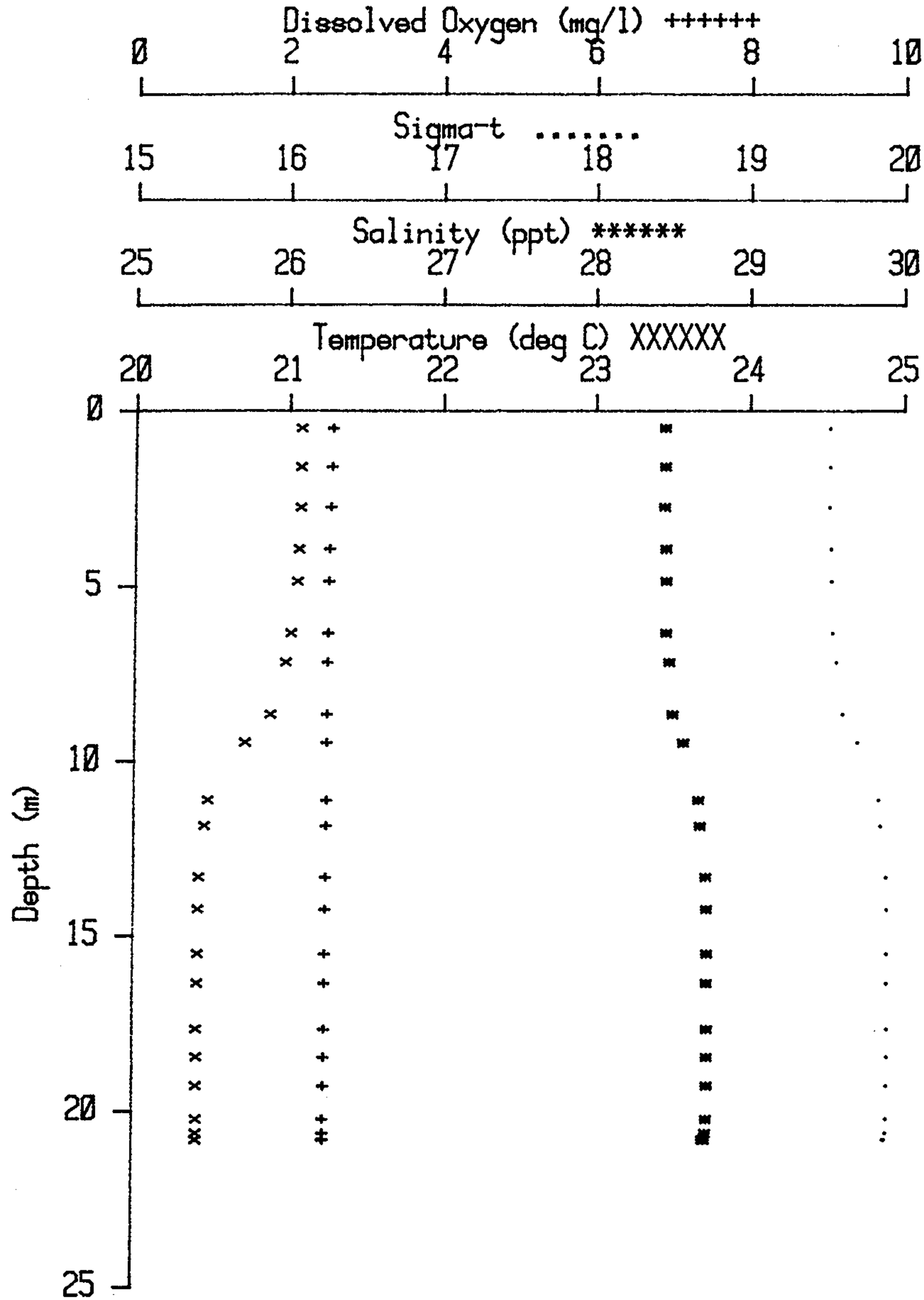

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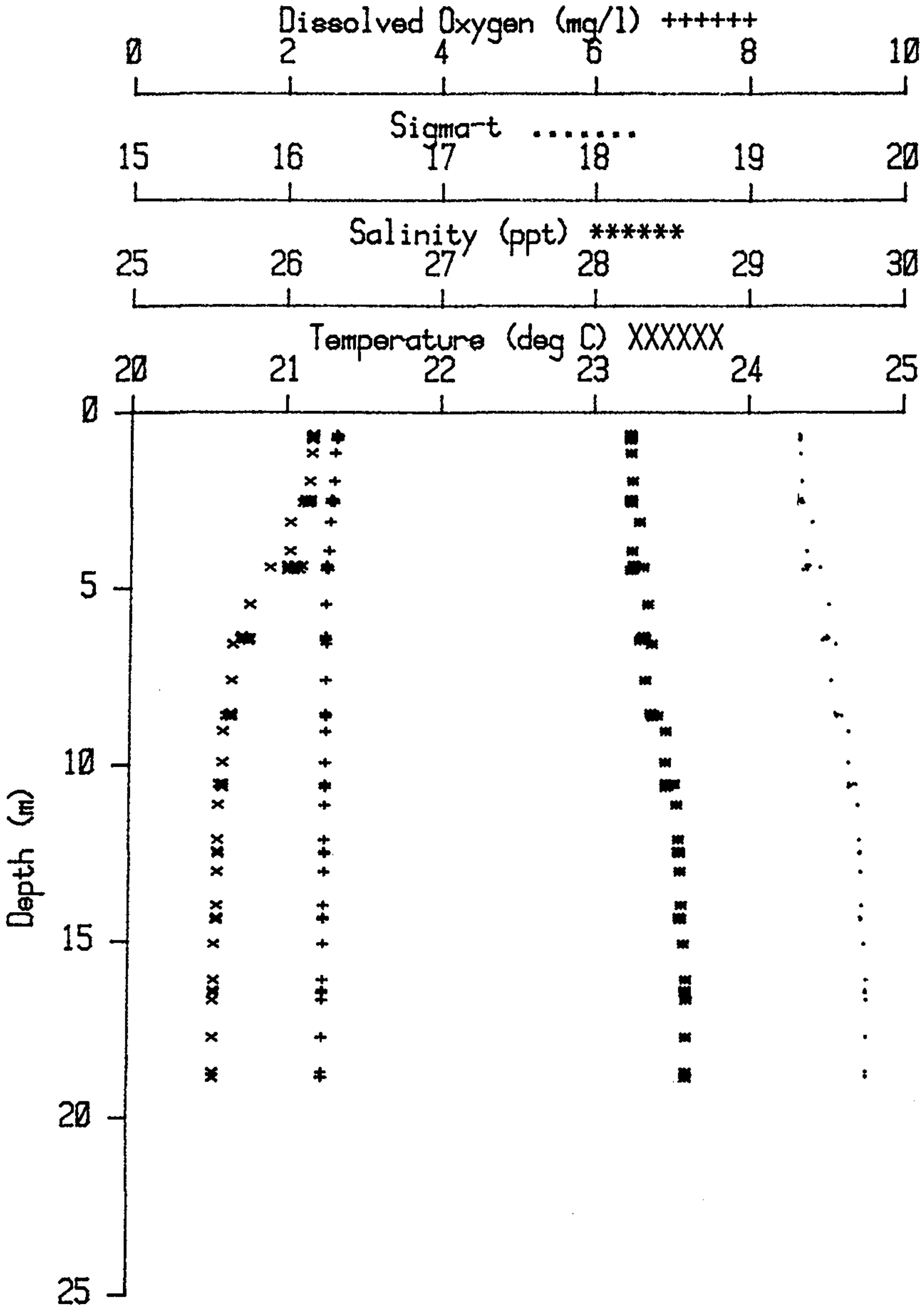

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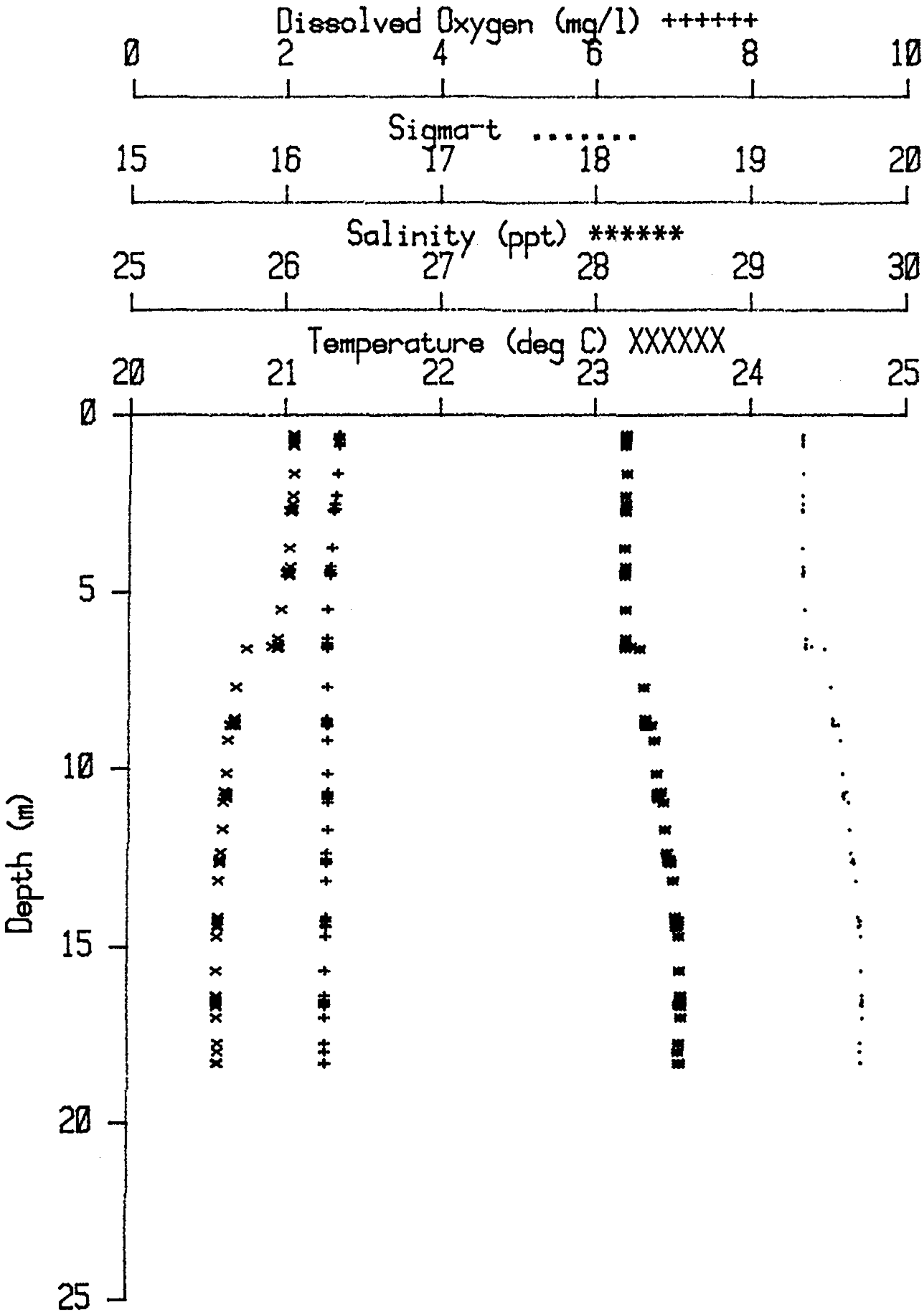

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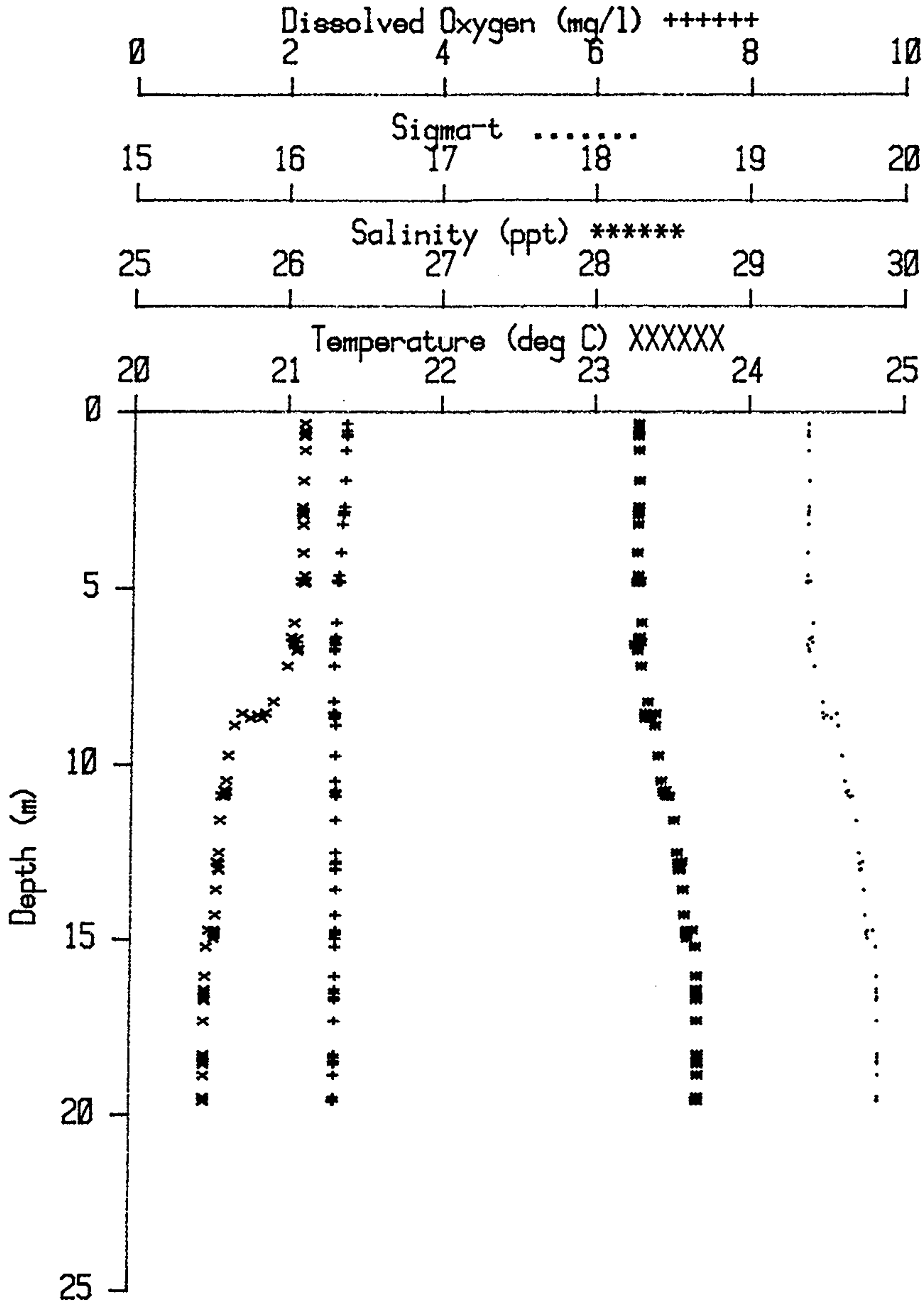

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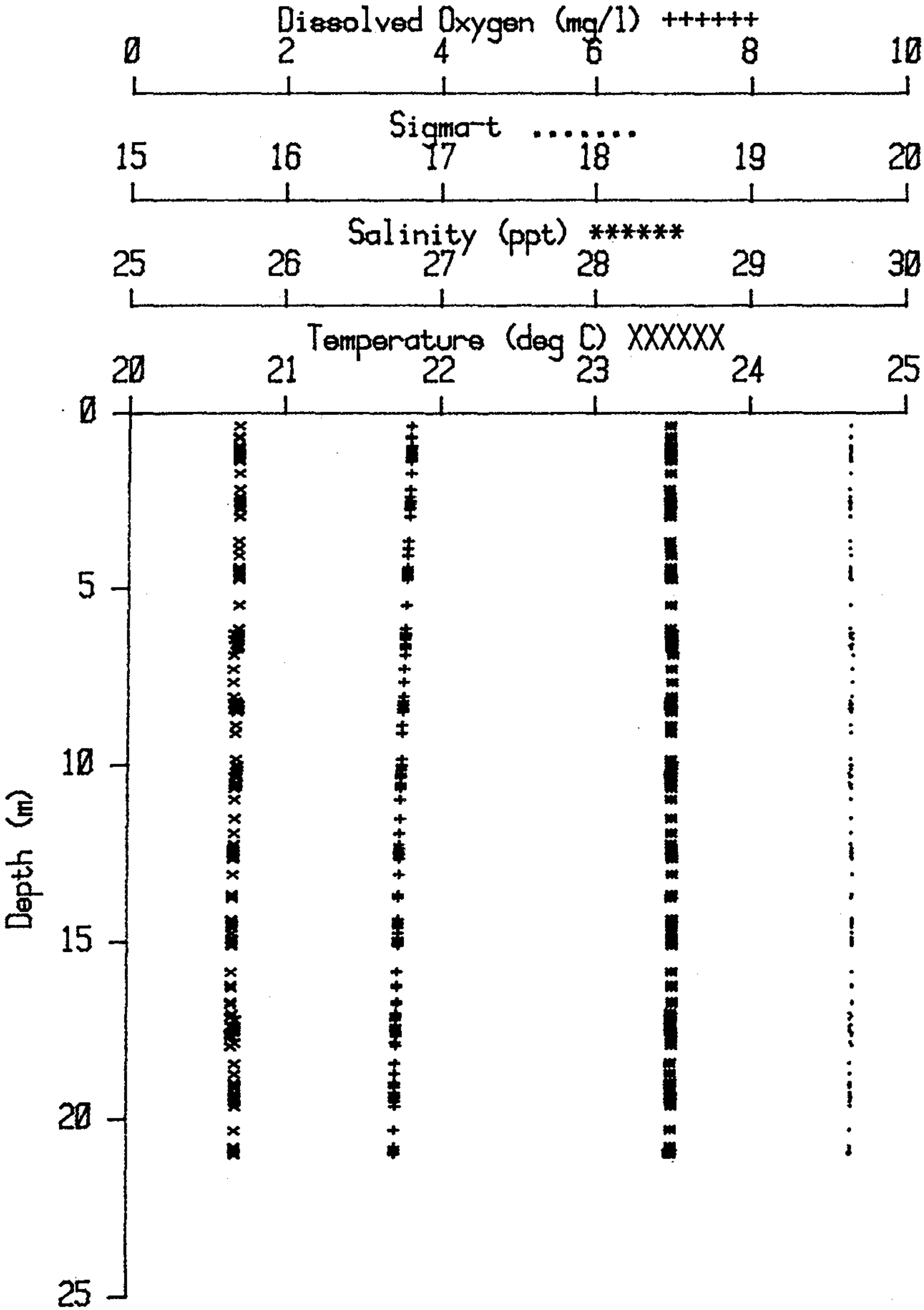
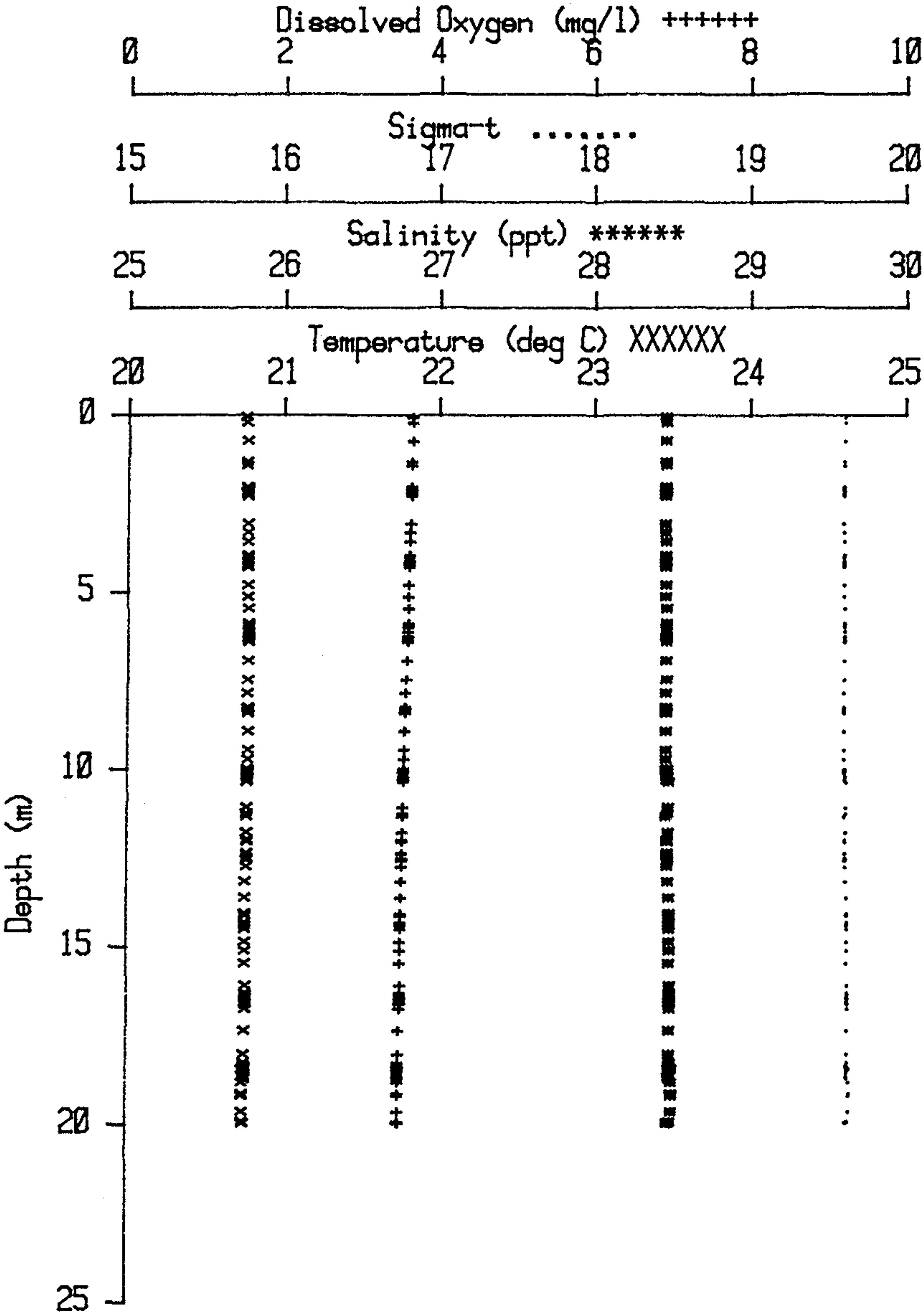
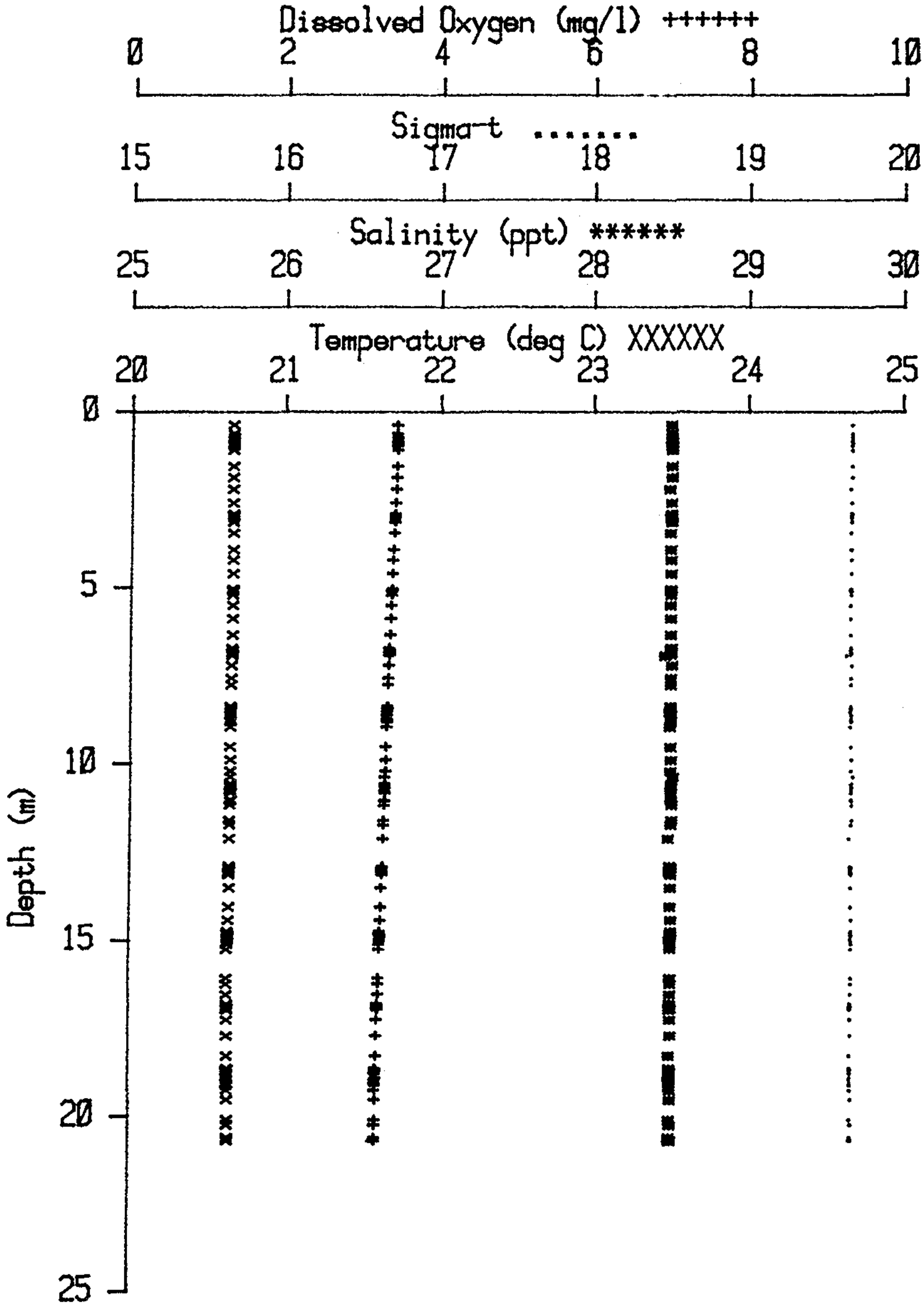


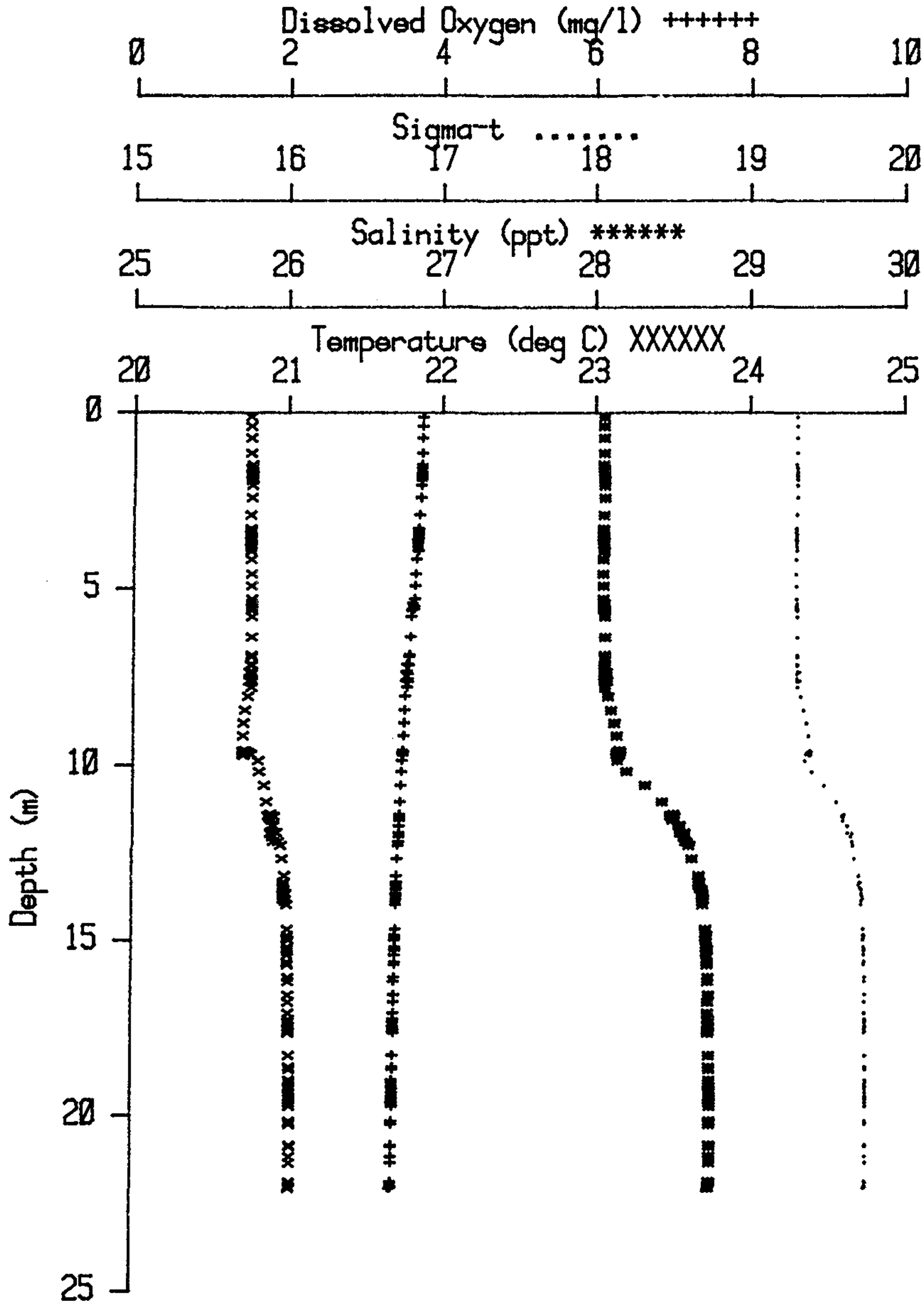
# FVP CTR 08/28


Dissolved Oxygen (mg/l) ++++++
0 2 4 6 8 10
Sigma-t .......
15 16 17 18 19 20
Salinity (ppt) ******
25 26 27 28 29 30
Temperature (deg C) XXXXXX
20 21 22 23 24 25
Depth (m)
0 5 10 15 20 25

# FVP 1000W 08/28



# NH-83 200NE 08/27



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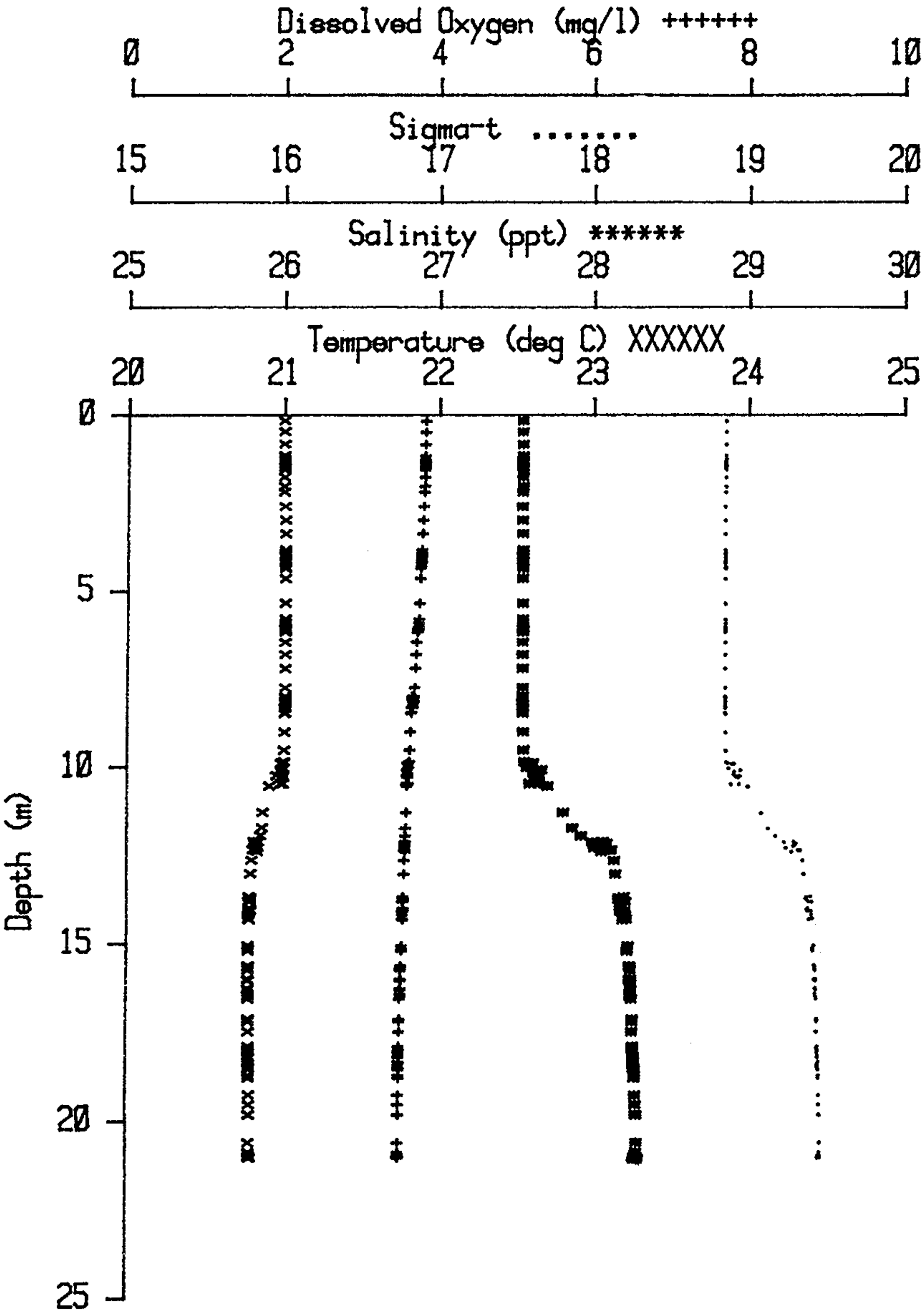
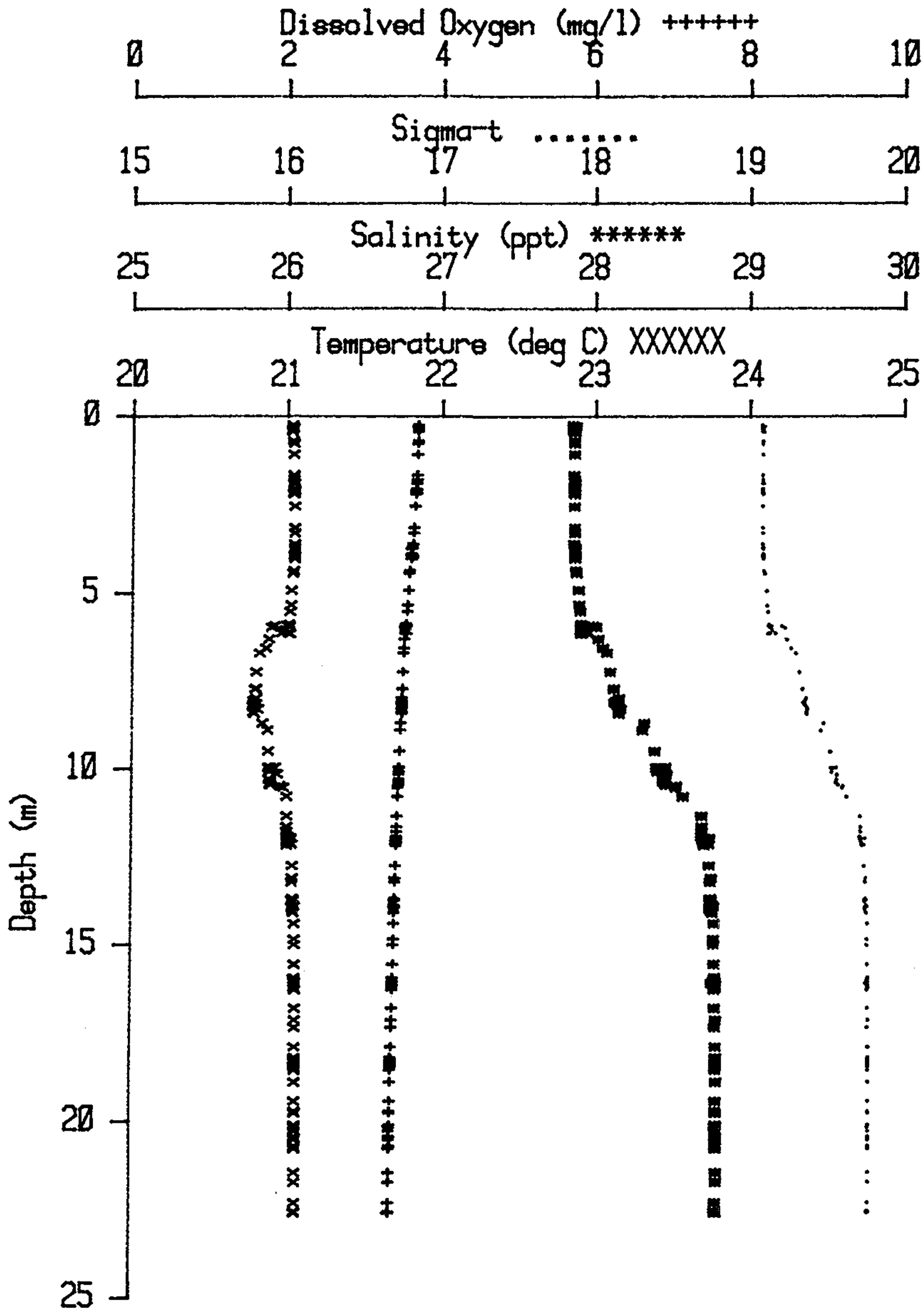
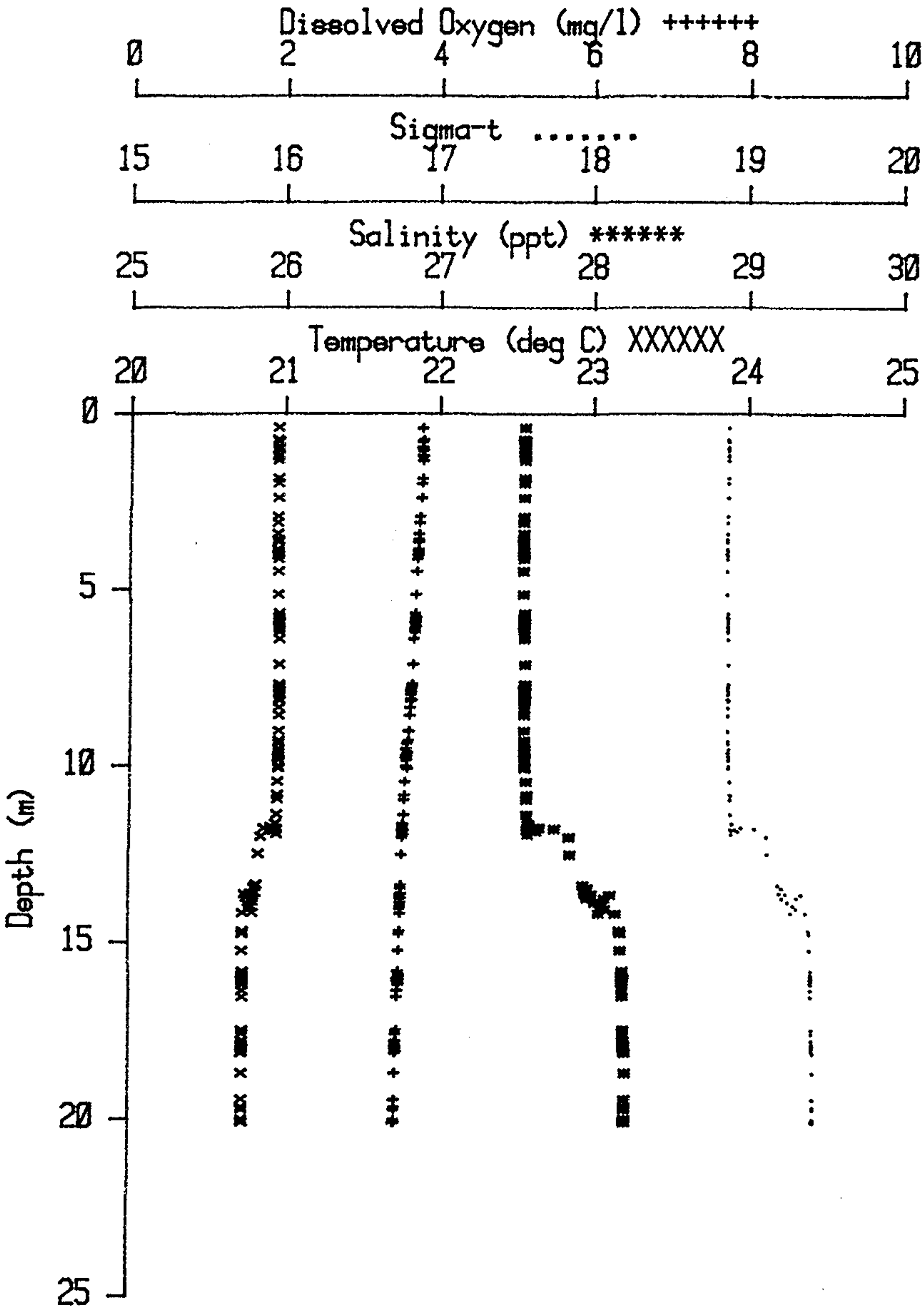
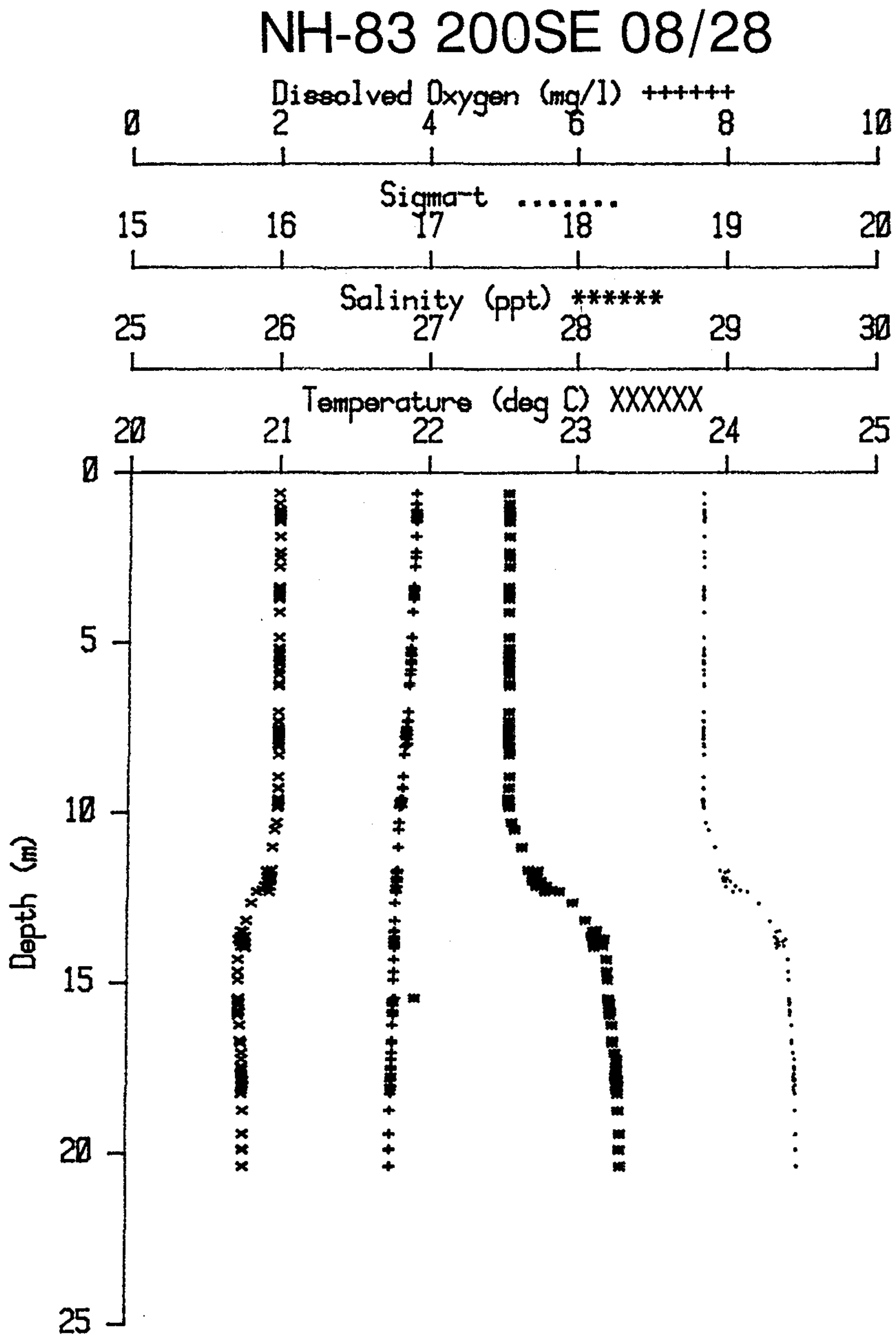


# NH-83 200S 08/27



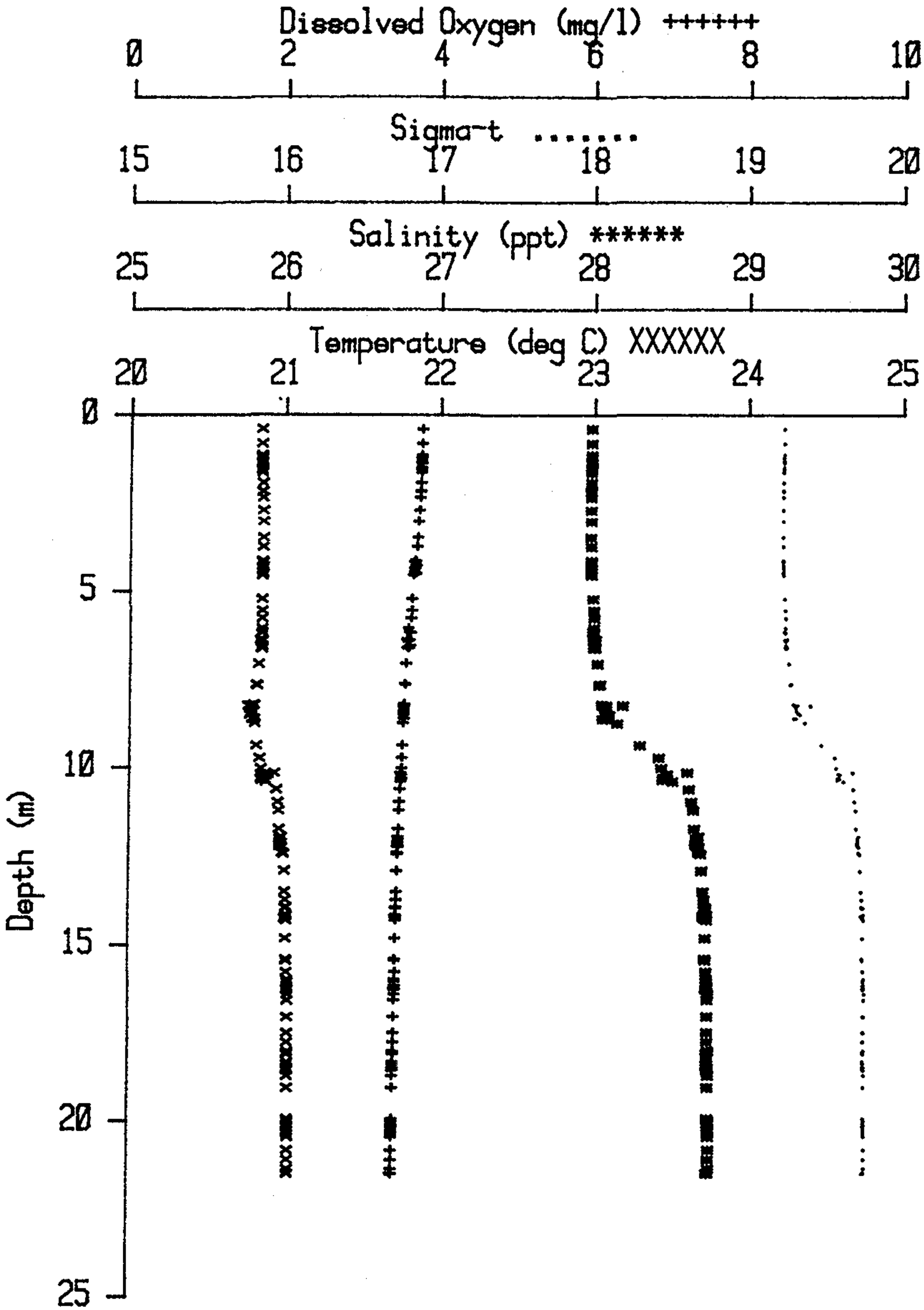
# NH-83 200NW 08/28





NH-83 200SE 08/28
Dissolved Oxygen (mg/l) ++++++
0 2 4 6 8 10
Sigma-t .......
15 16 17 18 19 20
Salinity (ppt) ******
25 26 27 28 29 30
Temperature (deg C) XXXXXX
20 21 22 23 24 25
Depth (m)
0 5 10 15 20 25

# NH-83 400N 08/27



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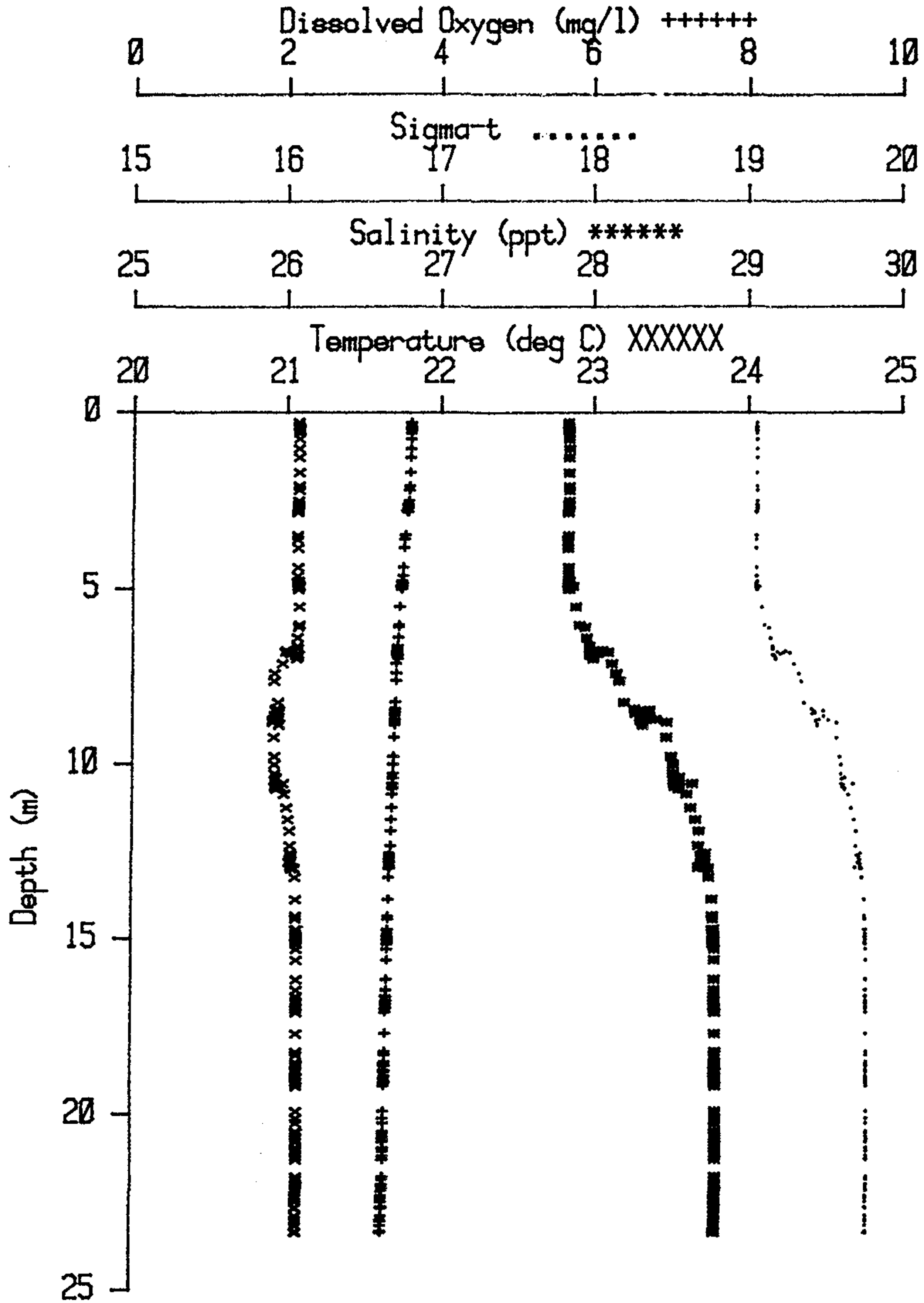
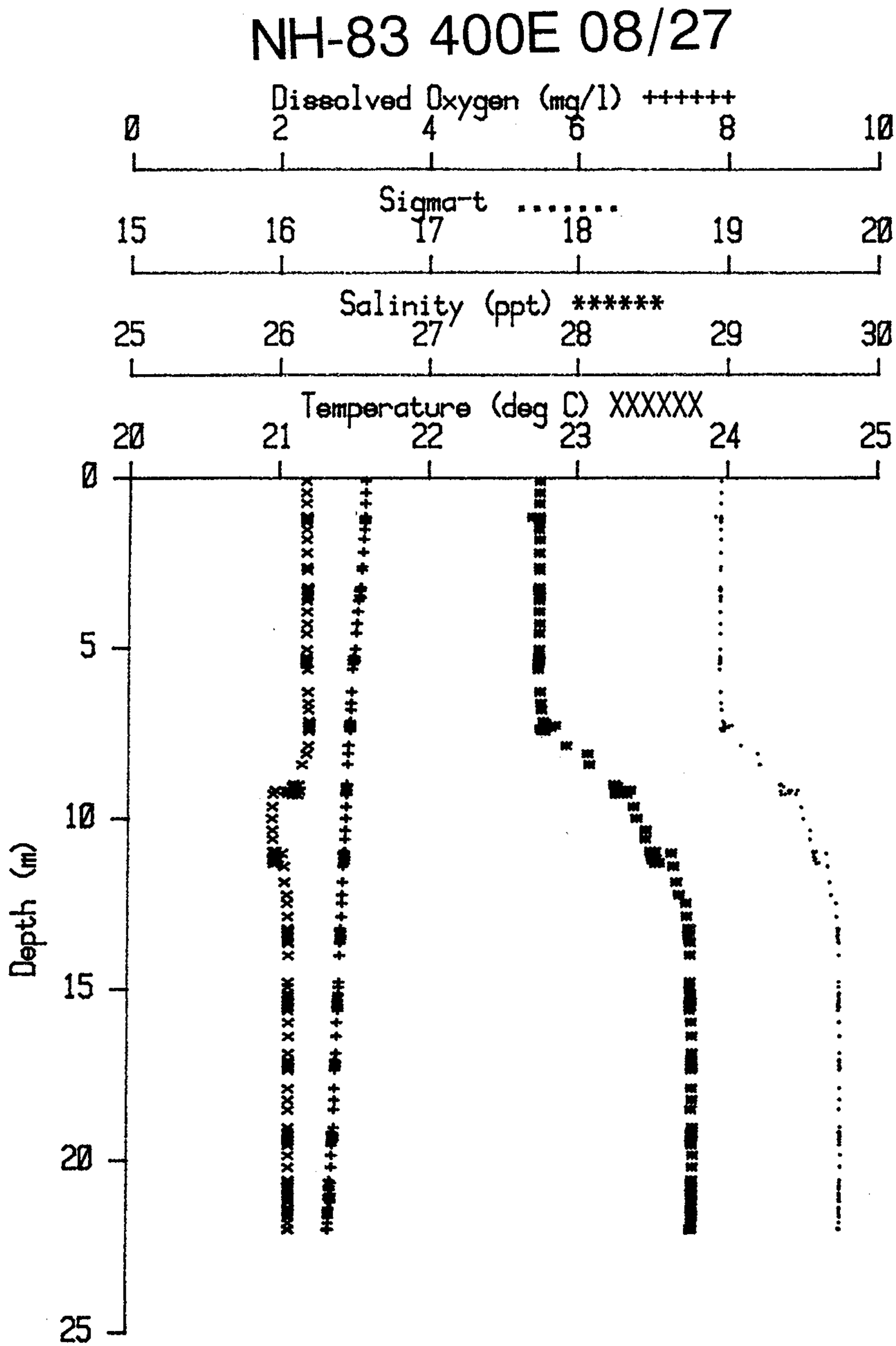
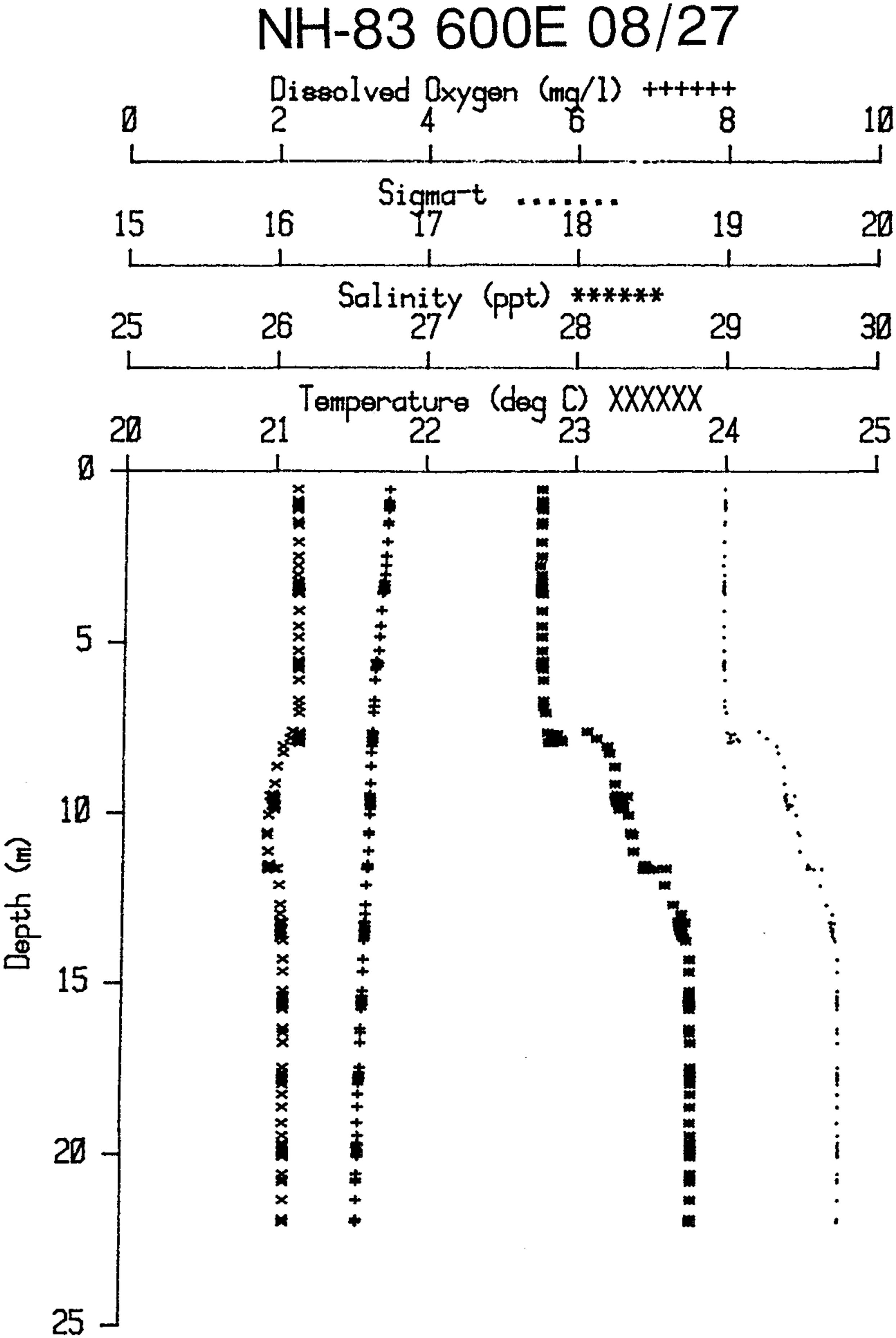



NH-83 400E 08/27
Dissolved Oxygen (mg/l) ++++++
0 2 4 6 8 10
Sigma-t .......
15 16 17 18 19 20
Salinity (ppt) ******
25 26 27 28 29 30
Temperature (deg C) XXXXXX
20 21 22 23 24 25
Depth (m)
0 5 10 15 20 25

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