Monitoring Cruise at the Western Long Island
Sound Disposal Site, July 1990

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The Western Long Island Sound Disposal Site (WLIS) contains four disposal mounds formed since disposal began at the site in 1982. These mounds have remained stable over time and with the exception of the area around the most recent disposal point, have exhibited full benthic infaunal recolonization. Since the last monitoring survey at WLIS (July 1988), approximately 185,000 m^3 of dredged material has been released at the site. Locating this new dredged material, determining the stability of mounds formed prior to July 1988, and assessing the chemical and biological impact of disposal activity at the site were the objectives of the July 1990 monitoring survey.

As of August 1985 three disposal mounds existed at the site ("A," "B," and "C"). Mound "C" continued to receive dredged material during the 1985/1986 disposal season. From September 1986 to May 1988 dredged material was released at the "B" mound. During the 1989/1990 disposal season the "D" mound was formed. This disposal mound is 5.3 m high with a radius of 225 m. Comparison of the present bathymetric survey with the last survey in July 1988 showed a stable height for mounds "A" and "C" and a decrease of 1 m in height for mound "B." Since disposal was occurring at "B" just prior to the July 1988 bathymetric survey, the dredged material would have compacted between July 1988 and July 1990, possibly resulting in the 1 m decrease in height.

The center of the "D" disposal mound exhibited rapid faunal recolonization. Stage III was the predominant successional stage, and Organism Sediment Index (OSI) values were greater than +7. Many REMOTS® stations on the north and west flanks of the "D" mound exhibited only Stage I organisms and OSI values less than +6. The dark, low-reflectance of the sediments at these stations, combined with their low consolidation, are typical of newly-deposited, organic-laden sediments with high oxygen demand. This sediment is expected to reach Stage III recolonization and OSI values > +7 over time given the rapid level of recolonization at the center of the "D" mound.

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As of August 1985 three disposal mounds existed at the site ("A, "B", and "C"). Mound "C" continued to receive dredged material during the 1985/1986 disposal season. From September 1986 to May 1988 dredged material was released at the "B" mound. During the 1989/1990 disposal season the "D" mound was formed. This disposal mound is 5.3 m high with a radius of 225 m. Comparison of the present bathymetric survey with the last survey in July 1988 showed a stable height for mounds "A" and "C" (decreases in height of 0.25 m) and a decrease of 1 m in height for mound "B". Since disposal was occurring at "B" just prior to the July 1988 bathymetric survey, the dredged material would have compacted between July 1988 and July 1990, possibly resulting in the 1 m decrease in height. Since the "A" and "C" mounds have not received any new material since 1986, extensive compaction at these locations is unlikely.

The center of the "D" disposal mound exhibited rapid infaunal recolonization. Stage III was the predominant successional stage, and Organism Sediment Index (OSI) values were greater than +7. Many REMOTS® stations on the north and west flanks of the "D" mound exhibit only Stage I organisms and OSI values less than +6. The dark, low-reflectance of the sediments at these stations, combined with their low consolidation, are typical of newly-deposited, organic-laden sediments with high oxygen demand. This sediment is expected to reach Stage III recolonization and OSI values > +7 over time given the rapid level of recolonization at the center of the "D" mound.

Near-bottom dissolved oxygen (DO) concentrations measured at the reference areas and the "D" disposal mound ranged from 4.1 to 4.5 mgl^{-1}. Although significantly lower than corresponding near-surface values (9.2 - 11.8 mgl^{-1}), near-bottom DO levels remained above hypoxic levels.

1.0 INTRODUCTION

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

The disposal buoy was south of the "C" mound at coordinates 40° 59.254'N and 73° 29.095'W during the 1989 - 1990 disposal period. Barge estimates indicated that 185,044 m^3 of dredged material were disposed near the buoy during this time.

Field operations at WLIS were initiated on 12 July, 1990 to provide information on the fate of recently-disposed dredged material and to assess the environmental effects of past and recent disposal operations. Field operations included two bathymetric surveys, REMOTS® sediment-profile photography, near-bottom dissolved oxygen determination, and sediment chemistry and grain size sampling. The objectives for the 1990 monitoring cruise at WLIS were to:

- delineate the areal extent and topography of the dredged material deposited since the July 1988 survey and determine the stability of disposal mounds formed prior to the July 1988 survey;
- assess the extent of recolonization at the WLIS disposal mounds and monitor the ambient benthic infaunal successional stages present within the three reference areas;
- assess near-bottom dissolved oxygen concentrations relative to REMOTS® benthic analyses at and near the disposal site;
- provide additional baseline information on sediment chemistry and grain size at each reference station and at the disposal site; and
- provide a detailed bathymetric survey of the entire WLIS Disposal Site.

2.0 METHODS

2.1 Bathymetry and Navigation

The SAIC Integrated Navigation and Data Acquisition System (INDAS) provided the precision navigation required for all field operations. This system uses a Hewlett-Packard 9920 series computer to collect position, depth, and time data for subsequent analysis, as well as providing real-time navigation. A Del Norte Trisponder® system provided positioning to an accuracy of ±3 meters. Shore stations were established in Connecticut at known benchmarks at Greenwich Point and the Norwalk electric-generating facility. A detailed description of the navigation system and its operation can be found in the DAMOS QA/QC Plan (SAIC, 1990c).

An Odom DF3200 Echotrac® Survey Fathometer with a narrow-beam 208 kHz transducer measured individual depths to a resolution of 3.0 cm (0.1 feet). Depth values transmitted to the computer were adjusted for speed of sound and transducer depth. Prior to starting the 1990 bathymetric survey, an Applied Microsystems Model STD-12 CTD/DO probe was used to obtain a sound velocity profile. During the analysis, correction for changes in tidal height standardized the raw bathymetric data to Mean Low Water. A complete description of the bathymetric analysis technique is also given in the DAMOS QA/QC Plan (SAIC, 1990c).

A bathymetric survey of the entire site, conducted 14 and 15 July, 1990, consisted of fifty-one lanes running east and west at a 50 meter lane spacing over a 3000 x 2500 m area centered at 40° 59.408'N and 73° 28.649'W (Figure 2-1). A smaller, second bathymetric survey, conducted 15 July 1990, consisted of thirty-three lanes running east and west at a 25 meter lane spacing over an 800 x 800 m area centered approximately at the WLIS "A" mound (Figure 2-1). The previous two bathymetric surveys of the WLIS site utilized this 800 x 800 m survey grid (November 1987 and July 1988: SAIC, 1990a and 1990b, respectively). The volume of accumulated material was calculated from comparison of the 1988 and 1990 surveys.

2.2 REMOTS® Sediment-Profile Photography

REMOTS® photography detected the distribution of thin (≤20 cm) dredged material layers, mapped benthic disturbance gradients, and monitored the progress of infaunal recolonization on and adjacent to the disposal mounds. A detailed description of REMOTS® image acquisition, analysis, and interpretative rationale is given in the DAMOS QA/QC Plan (SAIC, 1990c).

REMOTS® monitoring at WLIS utilized a 25 station star grid, with 100 m spacing, centered at the buoy coordinates for the 1989 - 1990 disposal season (40° 59.254'N, 73° 29.095'W) and a 13 station cross-shaped grid centered at the "B" mound (Figure 2-2). Triplicate photographs were taken at each station. In addition, sampling at three reference areas allowed comparison of ambient versus on-site conditions (Figure 2-2). Within each reference area, triplicate REMOTS® photographs were taken at each of thirteen stations arranged in a cross-shaped pattern and spaced 100 m apart. These reference areas, also occupied during the July 1988 survey, were approximately 2000 m west (2000W), 2000 m south (2000S), and 2200 m northeast (WLIS-REF) of the "B" mound.

2.3 CTD and Dissolved Oxygen Sampling

An Applied Microsystems CTD probe (Model STD-12) obtained vertical profiles of temperature and salinity at the center of each reference area and at the center and four distal points (400N, 400E, 400W, and 400S) of the WLIS "D" REMOTS® sampling grid. The STD-12 (used to measure conductivity, temperature, and pressure) samples up to 8 scans per second and stores up to 7648 scans in 56k of internal RAM (random access memory). A Compaq Portable II microcomputer sends commands to and reads data from the instrument via an RS-232 serial interface. During deployment, the STD-12 recorded data at 2 second intervals. The microcomputer received and stored data on a floppy disk for later analysis. Salinity calculations followed the procedures described by Perkin and Lewis (1980).

A YSI Model 58 Dissolved Oxygen (DO) probe, attached to the CTD, obtained depth profiles of dissolved oxygen. The CTD was lowered slowly to the seafloor, stopping (for approximately 1 min.) at 2 m intervals to allow for equilibration of the DO probe and shipboard recording of the DO measurement.

At selected REMOTS® stations, dissolved oxygen was measured by Winkler titration. In these cases, a Niskin bottle was used to obtain water samples from approximately one meter above the bottom. A 300 mℓ subsample was drawn from the bottle, preserved, and titrated within 12 hours using a modification of the standard Winkler titration method (Strickland and Parsons, 1972; Parsons et al., 1984). The original intent of this sampling was to provide an in situ check on the YSI dissolved oxygen probe. However, during water-column profiling, the YSI probe consistently failed at depths greater than approximately 3 m and therefore only the results of the Winkler titrations were reported for the bottom oxygen concentrations. Surface oxygen values from the YSI probe were considered reliable because the sensor was calibrated to an air-saturated standard immediately prior to deployment. These values were compensated for in situ salinity using the CTD results and the algorithm of Benson and Krause (1984).

2.4 Sediment Chemistry and Grain Size

A Smith-McIntyre grab sampler (0.1 m^2) was used to collect triplicate sediment samples at the center of each reference area and at the WLIS "D" disposal point. At each station, four polycarbonate plastic core liners (6.5 cm ID) were pushed into each grab sample, extracting a minimum of 10 cm of sediment. Three of these cores were combined and placed into a sealed plastic bag for chemical analysis. The remaining cores from the triplicate grab samples were combined and sealed in plastic bags for grain size analysis. The samples were packed in ice and delivered to the NED laboratory for analysis. Analytical results were incomplete at the time of report preparation and will be included in a future report.

3.0 RESULTS

3.1 Bathymetry

The July 1988 bathymetric results indicated that minimum water depths at the "A", "B", and "C" mounds were 29.50, 29.75, and 28.00 m, respectively (Figure 3-1). In the present 800 x 800 m survey, the heights of the "A" and "C" mounds remained relatively unchanged (minimum water depths of 29.75 and 28.25 m, respectively) while the height of the "B" mound decreased approximately 1 m (minimum water depth of 30.75 m) (Figure 3-2). The depth difference plot shows that material accumulated at the active disposal point, forming the WLIS "D" mound, had an approximate height of 5.3 m (minimum water depth of 28.00 m) and a diameter of approximately 225 m.

Based on depth difference analysis comparing the July 1988 and July 1990 surveys, volume calculations indicated that an additional 101,350 m^3 of dredged material (95% confidence limits of 98,410 and 104,280 m^3) had accumulated within the 500 X 350 m area surrounding the WLIS "D" mound (Figure 3-3). This calculation incorporates decreases in depth as observed at the WLIS "D" mound and apparent increases in depth as observed at the WLIS "A" mound. Tabulation of the disposal barge logs for this same period indicated that approximately 185,000 m^3 of dredged material were deposited at or near the buoy (Figure 3-4).

The 1990 bathymetric plot of the entire WLIS Disposal Site exhibited many topographical features present in the original, 1982 survey which was conducted using 200 m lane spacing (Figures 3-5 and 3-6). In addition to enhancing the detail of the site, the 1990 survey plot delineated clearly the "A", "B", "C", and "D" mounds. A 3-D bathymetric plot provided a spatial perspective of the entire site (Figure 3-7).

3.2 REMOTS® Sediment-Profile Photography

Within the areal distribution of dredged material, as determined by the REMOTS® survey (Figure 3-8), recently-deposited dredged material exceeded the depth of camera prism penetration at several stations adjacent to the disposal point. At some of these stations (e.g., CTR, 100N, and 100E) a mottled, streaky oxidized sediment layer characterized dredged material, while at other stations (e.g., 100NE, 100SW, and 100W) dredged material had a clearly-defined apparent Redox Potential Discontinuity (RPD) boundary and high apparent sediment oxygen demand (SOD) at depth (Figures 3-9 and 3-10, respectively).

The majority of WLIS stations (WLIS "D" and "B" REMOTS® grids) exhibited a grain size major mode of ≥4 phi, with no obvious grain size anomalies differentiating the recently-deposited dredged material from ambient sediment (Figure 3-11). Some stations exhibited a slightly larger grain size major mode (4-3 phi) which, in several cases, was not attributable to the 1988 - 1990 disposal activities. As in the 1988 REMOTS® survey, stations near the "A", "B", and "C" disposal mounds had discontinuous sand layers buried at depth, representing relic dredged material (Figure 3-12). Reference area grain size data varied from station to station, with notable differences occurring in some replicate photographs at the same station (Figure 3-13). Several stations within the 2000S reference area exhibited poorly-sorted sediments with layering of sand and mud (Figure 3-14).

The frequency distribution of apparent RPD depths for WLIS and pooled reference REMOTS® stations had major modes in the 3.0 to 4.0 cm class interval, with a mean of 3.3 and 3.8 cm, respectively (Figure 3-15). This represented a significant difference in the distribution of RPD values at the two areas (Mann-Whitney U-Test, $p = 0.03$). Disposal site stations with a mean apparent RPD depth of less than 3.0 cm were primarily southwest and northeast of the "D" mound and in the vicinity of the WLIS "A" and "C" mounds (Figure 3-16). Mean apparent RPD depths near the "B" mound increased since the 1988 REMOTS® survey to greater than 3.0 cm. Numerous on-site stations (200NE, 200SE, 200S, 200SW, and 200W) and several stations within the "2000S" and "WLIS-REF" reference areas had relic RPD layers buried at depth (Figures 3-17 and 3-18).

Approximately 50% of all replicate photographs within the WLIS Disposal Site contained evidence of Stage III infaunal taxa (Figure 3-19). The majority of stations exhibited combinations of Stage I on III and Stage III seres, with the exception of a small cluster of stations to the west and north of the disposal point which exhibited exclusively Stage I infaunal taxa. Several stations located on and adjacent to the "D" mound exhibited rapid recolonization of the recently-deposited dredged material by Stage III infauna, characterized by feeding voids at depth (Figure 3-20). Approximately 63% of all reference station REMOTS® photographs ($N = 107$) provided evidence of Stage III infaunal activity, compared to 61% ($N = 36$) in the July 1988 survey. Only 6 of 39 reference stations had exclusively Stage I in all replicate photographs, whereas all other stations had combinations of Stage I on III, Stage III, and/or Stage I seres.

The frequency distribution of Organism-Sediment Index (OSI) values for the on-site stations (Figure 3-21) had major modes at the +5 and +11 class intervals. Approximately 53% of the WLIS stations had OSI values of $\leq +6$ (Figure 3-22). The majority of these stations were close to the disposal mounds, although stations on the apex of the "D" and "B" mounds had an OSI value of +11. The median OSI value for the reference stations was +9, with a major mode at the +11 class interval (Figure 3-21), and differed significantly from OSI values calculated for disposal site stations (Mann-Whitney U-Test, $p = 0.01$). OSI values calculated for the 1988 reference stations had a major mode at the +11 class interval.

3.3 CTD and Dissolved Oxygen Sampling

Winkler titration determined DO concentrations of near-bottom water samples taken at the center of each reference area and at the disposal point (Table 3-1). Dissolved oxygen concentrations ranged from 4.1 mgl^{-1} to 4.5 mgl^{-1} (2000W and 2000S reference areas, respectively). The near-bottom dissolved oxygen concentration at the disposal point was 4.3 mgl^{-1}. Surface oxygen measurements made with a YSI DO meter were significantly higher than near-bottom concentrations and ranged from 9.2 mgl^{-1} (2000W) to 11.8 mgl^{-1} (WLIS-REF) (Table 3-1).

Depth gradients of temperature, salinity, and density (as sigma-t) for each reference area and five selected disposal site REMOTS® stations are given in the Appendix. Surface salinity was approximately 27.5 ppt at each of the reference and disposal site stations, increasing slightly (ca. 0.5 ppt) at 20 - 25 m depth. Surface temperatures ranged from 19.5°C (2000W) to 21°C (disposal site stations). Each station exhibited a two-tiered thermocline at approximately 2 - 5 m and 15 - 20 m depth, with bottom temperatures averaging approximately 16.5°C.

4.0 DISCUSSION

4.1 Areal Extent, Topography, and Stability of Dredged Material

One objective of the REMOTS® sediment-profile and 800 x 800 m bathymetric surveys was to delineate the extent and topography of the dredged material deposited during the past two years' disposal activities. The results indicated a significant accumulation of dredged material at the designated disposal point. The main body of the disposal mound was a circular deposit up to 5.3 m thick with dredged material layers (ca. 5.3 - 0.1 m thick) extending approximately 225 m from the disposal buoy. Although a difference in grain size did not exist between the ambient sediments and dredged material, a relic and/or mottled RPD layer observed in conjunction with acoustically-determined changes in depth indicated the presence of dredged material. Relic oxidized layers form when a rapidly-developing redox boundary near the sediment surface is buried during subsequent disposal activities. Consistent with the results of the 1987 and 1988 REMOTS® and bathymetric surveys, several stations in the vicinity of the WLIS "A", "B", and "C" mounds had relic dredged material layers, noted principally as discontinuous sand layers at depth or as relic RPD layers. These sediments resulted from disposal operations prior to the 1989 - 1990 disposal season.

A discrepancy of 83,650 m^3 existed between the barge log estimate of 185,000 m^3 and the volume calculation of 101,350 m^3 (confidence limits of 98,410 and 104,280 m^3). The barge log volume is assumed to be an overestimate due to the significant amount of interstitial water associated with the dredged material in the barges and the self-compaction of the material after it is disposed. In a mass balance study in the New York Bight, Tavolaro (1984) determined an apparent decrease in volume of approximately 41% when comparing the barge log volume and the volume estimated by comparing pre- and postdisposal bathymetric surveys. Applying this factor to the present data results in a corrected barge log estimate of approximately 109,150 m^3 of dredged material, which is slightly greater than the upper confidence limit determined for the bathymetric volume calculations.

The height of the WLIS "A" and "C" mounds decreased 0.25 m, while the height of the "B" mound decreased approximately 1.0 m (from a minimum water depth of 29.75 m in July, 1988 to 30.75 m in July, 1990). Several factors could have contributed to the observed changes in depth. Although erosional forces can decrease mound height, previous studies have not provided evidence of significant mound erosion at WLIS (SAIC, 1990a,b), and the 1990 REMOTS® photographs did not reveal winnowing of sediments at the WLIS "B" and "C" mounds. The WLIS disposal mounds are deeper than the dynamic equilibrium between deposition and erosion forces shown to exist at water depths of 20 m (McCall, 1978). In addition, dredged material disposal at the "A" and "C" mounds has not occurred in the past five years; therefore, one would expect that the sediments are compacted, and the "A" and "C" mounds are relatively armored. Poindexter-Rollins (1990) showed that mound consolidation can continue several months after disposal (Figure 4-1) resulting in significant decreases (ca. 1.5 m) in mound height. Active disposal at the "B" mound was occurring through May 1988, less than two months prior to the July 1988 survey. Consolidation of the "B" mound was likely still in progress at the time of the 1988 survey. Further consolidation of the mound could have occurred during the two years prior to the 1990 bathymetric survey and would contribute to the observed decrease in the mound height.

Another factor affecting mound height stems from the limitations of bathymetric analysis on steep slopes and the resulting variability of recorded depths in consecutive bathymetric surveys. Smooth topographies minimize the effect of the ship's position on the recorded depth (Figure 4-2). However, the WLIS mounds have some of the steepest slopes of all mounds studied under the DAMOS monitoring program (see Table 4-1 in SAIC, 1988c). Examination of the bathymetric contour plot (Figure 3-2) revealed a 1.75 m change in depth within a 25 m distance (equivalent to the width of one bathymetric survey lane) along some regions of the WLIS "B" mound. Examination of the raw navigation data records at the peak of the "B" mound determined that the positions of the transducer during the 1990 and 1988 surveys were separated by approximately 11 m, representing a possible 0.7 m variation in recorded depth. Similar examination of raw navigation data at the "A" and "C" mounds did not reflect the same substantial changes in depth; however, changes of 0.25 m observed at WLIS "A" and "C" could be expected given the resolution limitations of the bathymetric instrumentation.

Only one photograph was obtained from each reference station during the 1988 survey (13 total per reference area), whereas triplicate photographs were analyzed during the 1990 survey (36 photos per reference area). This replication demonstrated more clearly the within-station variability which continues to exist at some stations (station W300S in the 2000W reference area, Figure 3-13). Some stations within the WLIS-REF exhibited relic oxidized layers. Located at the eastern edge of the WLIS Disposal Site and in proximity to the Eaton's Neck historic disposal site, WLIS-REF probably received some sediments during disposal operations prior to 1980. Relic oxidized layers at stations within the 2000S reference area reflected more likely the effects of wind-driven currents and storm events. In conjunction with dramatic increases in wind-driven current velocities (SAIC, 1988b), water depth at 2000S is 25 m, implying that erosional and depositional forces could be at work (McCall, 1978). Coarse-grained sediments and layering of sand and mud found within the area supported evidence of winnowing away of the fine silt/clay components of the sediment.

4.2 Recolonization Status

An objective of the REMOTS® survey was to assess the impacts of dredged material disposal on benthic recolonization. Although OSI values and RPD depths differed significantly between the WLIS reference and on-site stations, a welldeveloped RPD and Stage III infaunal taxa at the center of the "D" mound indicated that rapid recolonization of the recently-deposited dredged material had occurred. Based on the results of past REMOTS® surveys, OSI indices of +6 or less indicate chronically-stressed benthic habitats and/or those which have experienced recent disturbance, such as erosion, dredged material disposal, or hypoxia, etc. (SAIC, 1990a). Therefore, the 1990 median OSI value of +7 at the disposal site stations implied that dredged material had only a minor effect in terms of the benthic biological community.

Many stations along the fringe of the "D" mound exhibited exclusively Stage I organisms and shallow RPD depths (OSI $\leq +6$) and possibly accounted for the statistical difference of on-site versus reference station OSI and RPD parameters. The dark, low-reflectant nature of sediments at these stations was typical of newly-deposited, organic-laden sediments with a high oxygen demand. Camera overpenetrations precluded OSI and successional stage determination at stations 100E, 200E, 100SE, and 200SE, indicating the loosely-consolidated nature (high water content) of the sediments in this region of the mound. One would expect that subsequent Stage III recolonization and further development of the RPD boundary are likely to occur at these stations, given the level of recolonization at the center of the "D" mound.

Although a different survey grid and station spacing were used for the 1988 and 1990 surveys, thereby precluding direct (station versus station) statistical comparison of the 1990 and 1988 onsite REMOTS® data sets, REMOTS® parameters reflected a general improvement in the condition of the benthic habitat near the "B" mound. Mean apparent RPD depths increased to greater than 3.0 cm. In addition, OSI values near the "B" mound exhibited an increase from +3 (1988) to +11 (1990).

As in the 1988 survey, the 1990 frequency distribution of OSI values in the reference areas had a major mode of +11. Likewise, Stage III infaunal activity was apparent in 63% of all replicate reference station photographs, compared to 61% in the 1988 survey, indicating that a relatively stable and healthy benthic habitat exists within these regions.

4.3 CTD and Dissolved Oxygen Sampling

The objective of the CTD/DO sampling at WLIS was to assess near-bottom dissolved oxygen concentrations in relation to benthic habitat conditions at and near the site. Near-bottom dissolved oxygen concentrations measured at selected disposal site and reference stations were within the aerobic DO range (Table 4-1). In addition, the 1990 REMOTS® analysis suggested that a relatively healthy and stable benthic habitat persisted within the three reference areas and that infaunal recolonization of the recently-deposited dredged material was proceeding rapidly at some on-site stations. In conjunction with near-bottom DO concentrations, the 1990 REMOTS® analysis indicated that no recent or significant stress relating to near-bottom hypoxic conditions had occurred at the WLIS site. Near-surface DO concentrations were significantly greater than corresponding near-bottom values (Table 3-1); however, this difference in concentration is most likely attributable to a strong thermal stratification, as apparent in the CTD profiles. This stratification of temperature and dissolved oxygen concentration are typical for the summer months in this region of Long Island Sound (Welsh and Eller, 1991, and SAIC, 1987). Differences in near-surface DO concentrations at the disposal site and the reference areas were within the normal spatial and temporal ranges which might be expected in any estuarine area over a 6 to 8 hour sampling period.

The 1990 CTD profiles of temperature and salinity at the disposal and reference areas were similar to CTD profiles collected in 1988, while near-bottom dissolved oxygen concentrations exhibited a slight increase. The 1990 REMOTS® and CTD/DO data provided evidence of the continuing improvement in the benthic conditions observed in 1987 and 1988 following the severe and widespread hypoxia reported in 1986 in Long Island Sound (SAIC, 1988a). Conditions observed at WLIS in July 1990 may have represented the "prehypoxic" state in this region of Long Island Sound; however, the overall condition of the benthic environment suggests that any seasonal hypoxic occurrences prior to the July 1990 survey were not as severe as reported in previous years.

4.4 WLIS 3000 X 2500 Meter Bathymetric Survey

Decreasing the lane spacing of the 3000 X 2500 m bathymetric survey from 200 to 50 m enhanced the resolution of the entire WLIS Disposal Site. Many of the features observed in the 1982 survey (SAIC, 1982 and Figure 3-5) were readily apparent in the 1990 survey; however, the improved detail of the 1990 survey (Figure 3-6) will more adequately assist future disposal site management decisions.

5.0 CONCLUSIONS

Based on the results of the REMOTS® and precision bathymetric surveys, an accumulation of recently-deposited dredged material occurred where the disposal buoy had been located during the 1989 -1990 disposal season. The deposited material accumulated around the buoy in a broad, circular mound up to 5.3 m thick and had an average radius of approximately 225 m. Mound heights at the "A" and "C" mounds decreased slightly since the previous survey in July 1988, whereas the height of the WLIS "B" mound (the 1986 - 1987 and 1987 - 1988 active disposal point) decreased 1.0 m. Most likely, a combination of sediment compaction and bathymetric analysis limitations inherent to steep-sloped topographies accounts for the observed changes. No evidence, as observed with REMOTS® photography, exists to suggest significant erosion had occurred. Consistent with the results of the July 1988 survey, relic dredged material was visible in REMOTS® photographs from stations on and near the WLIS "A", "B", and "C" mounds.

REMOTS® parameters of OSI and RPD were significantly different between reference and disposal site stations, reflecting the recent disturbance in the benthic environment due to disposal activities. An on-site median OSI of +7 combined with the development of a deep RPD and Stage III infaunal recolonization at the center of the disposal mound indicated that the disturbance was primarily physical in nature. Reference station OSI and RPD values showed little change from the 1988 survey, indicating that a relatively healthy and stable benthic habitat persisted. Although direct statistical comparisons of the 1988 and 1990 on-site data could not be performed due to dramatically different sampling designs, the July 1990 results indicated a continued trend of improving benthic habitat conditions as observed during the 1987 and 1988 WLIS studies (SAIC, 1990a,b).

Conditions observed in REMOTS® photographs (e.g., a steady increase in both the apparent RPD depth and the progress of infaunal recolonization) did not provide evidence of stress related to near-bottom hypoxia. Near-bottom DO concentrations, although significantly less than near-surface concentrations, were within the aerobic range. Such decreases in DO concentration with water depth are typically found in conjunction with a highly stratified water column (as seen in the CTD profiles of selected stations in the area). Although intensified thermal stratification could foster near-bottom hypoxic conditions, no evidence of the effects of low dissolved oxygen levels was apparent in the 1990 REMOTS® photographs.

The results of the 1990 REMOTS® survey support evidence from earlier studies that conditions at WLIS are returning to the relatively undisturbed conditions seen during the August 1985 REMOTS® survey (SAIC, 1988a), prior to both Hurricane Gloria in September 1985 and the severe hypoxia which occurred in western Long Island Sound in the summer of 1986. The improved conditions in this region of the Sound have been attributed to the absence of severe hypoxic stress in recent years; therefore, the condition of the benthic environment at the WLIS

Disposal Site seems to be more sensitive to this regional phenomenon than to disposal activities.

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Table 3-1

Near-bottom and Near-surface Dissolved Oxygen Concentration at Selected Disposal Site and Reference Stations at WLIS, July 1988 and July 1990.

1988

Station	Near-Bottom[1] DO (mgl^{-1})	Near-Surface[1] DO (mgl^{-1})
7-M	4.1	7.8
7-K	4.1	7.2
7-I	4.1	7.4
7-Y	3.5	7.6
2000W	3.5	10.2
2000S	3.9	8.1
WLIS-REF	4.2	7.6

1990

Station	Near-Bottom[1] DO (mgl^{-1})	Near-Surface[2] DO (mgl^{-1})
CTR	4.3	10.0
2000W	4.1	9.2
2000S	4.5	10.5
WLIS-REF	4.5	11.8

[1] as determined by Winkler titration.

[2] as measured using the YSI DO probe.

Table 4-1

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

Dissolved Oxygen Range (mgl^{-1})	Facies
> 3.0	Aerobic
3.0 to 0.41	Hypoxic*
0.4 to 0.14	Dysaerobic
< 0.14	Anaerobic

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

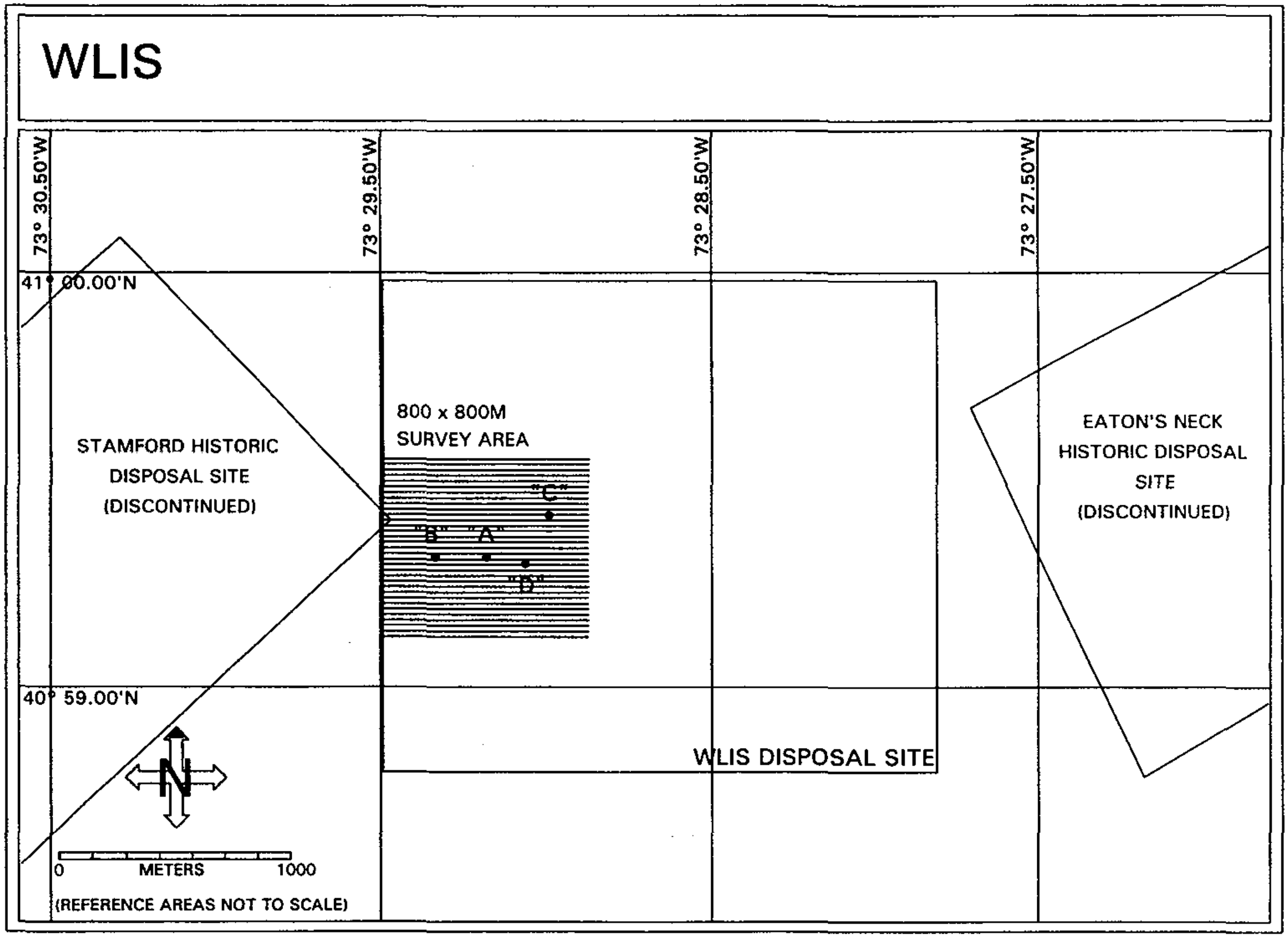


Figure 1-1. The Western Long Island Sound (WLIS) Disposal Site showing 800 X 800 bathymetric survey lanes and the location of the four disposal mounds ("A", "B", "C", and "D") near the western site boundary.

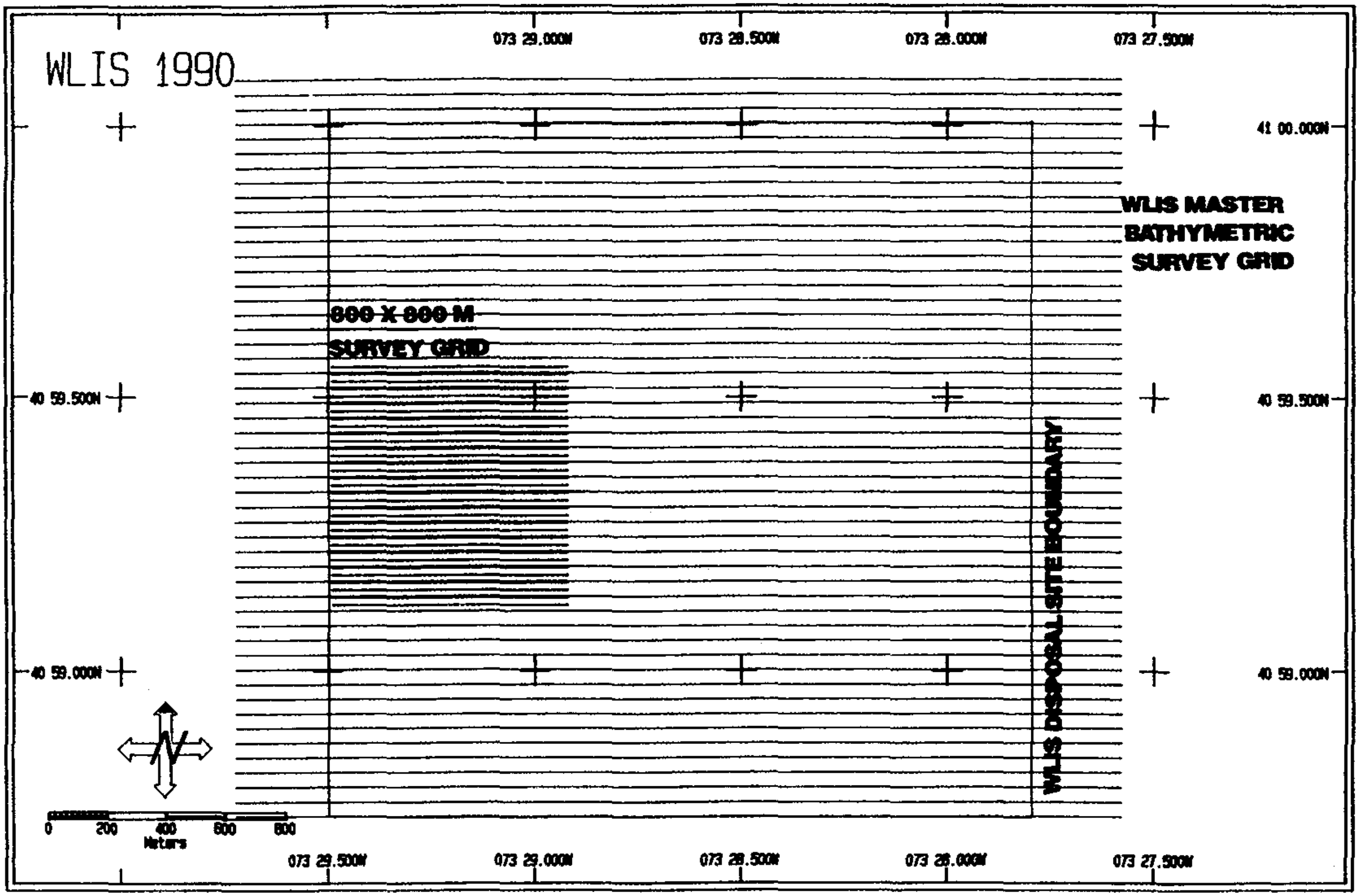


Figure 2-1. The 800 X 800 m and 3000 X 2500 m bathymetric survey lanes at WLIS, July 1990.

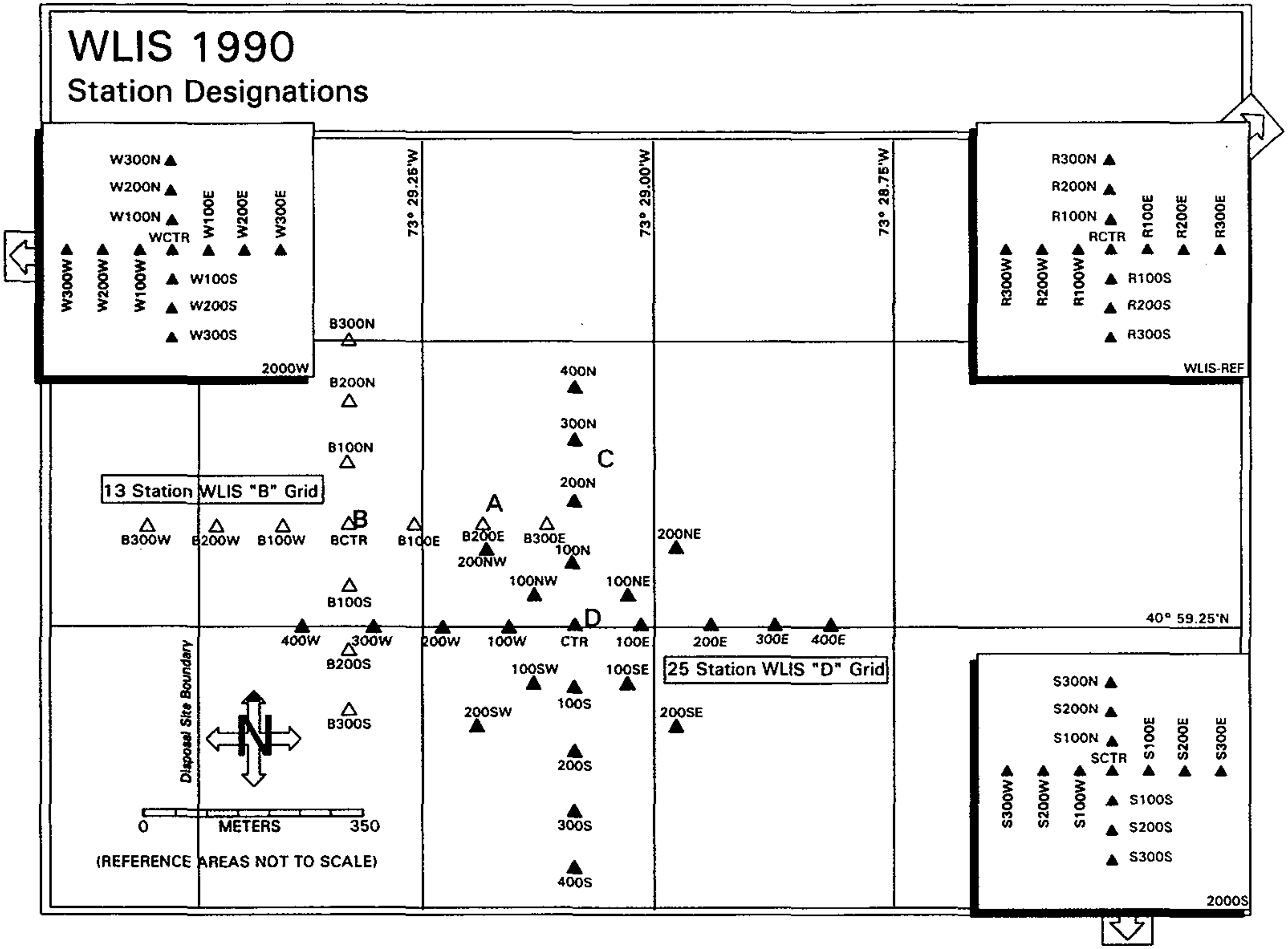


Figure 2-2. Locations and designations of the WLIS "D" and "B" REMOTS® stations at the WLIS Disposal Site, July 1990. Cross-shaped grids with 100 m spacing were used at the three outlying reference areas 2000W, 2000S, and WLIS-REF). The locations of the "A", "B", "C", and "D" mounds are also indicated.

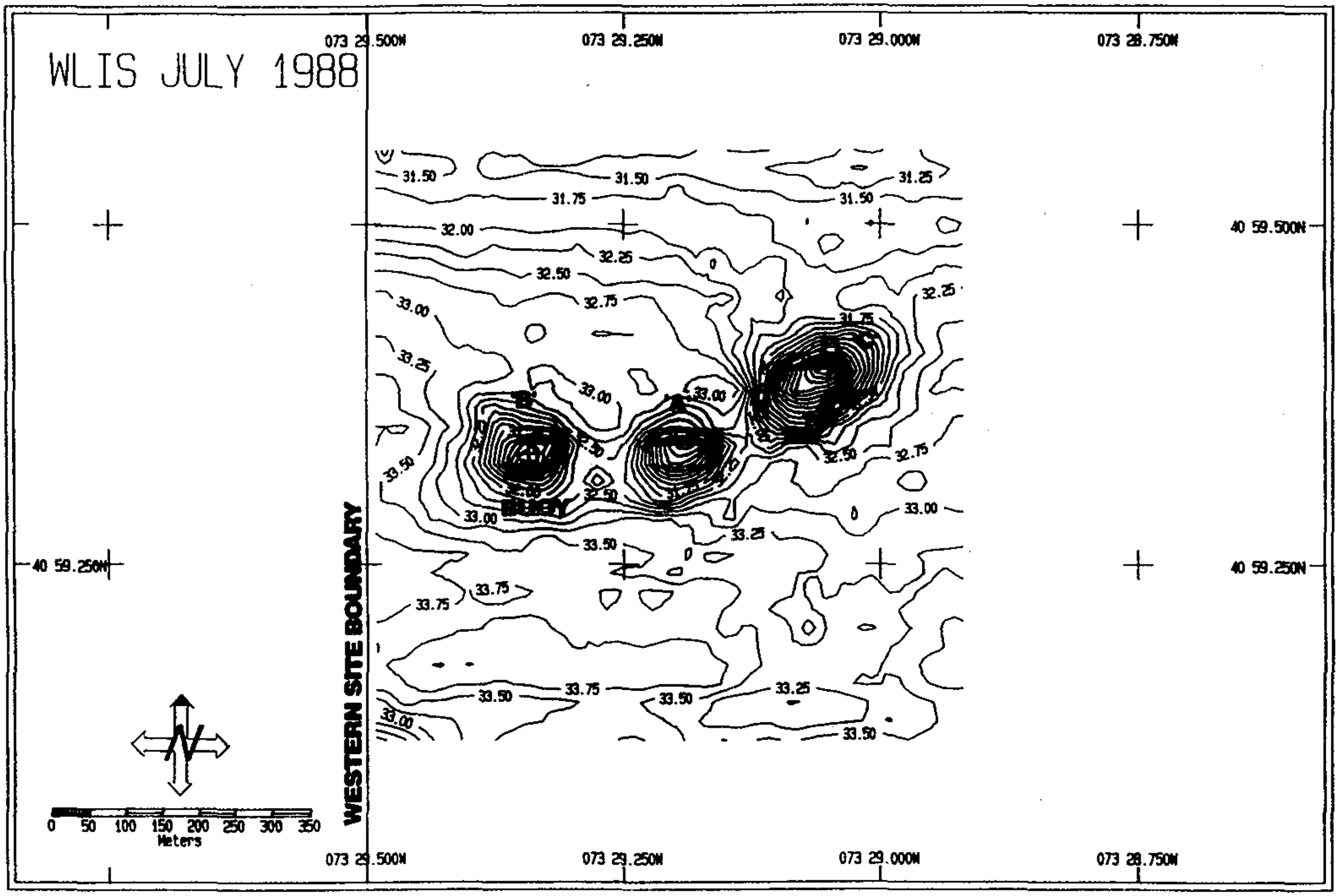


Figure 3-1. Bathymetric contour chart of the WLIS Disposal Site, July 1988, showing the "A", "B", and "C" disposal mounds. The location of the disposal buoy during the 1987 - 1988 season is also indicated. Contours at 0.25 m intervals.

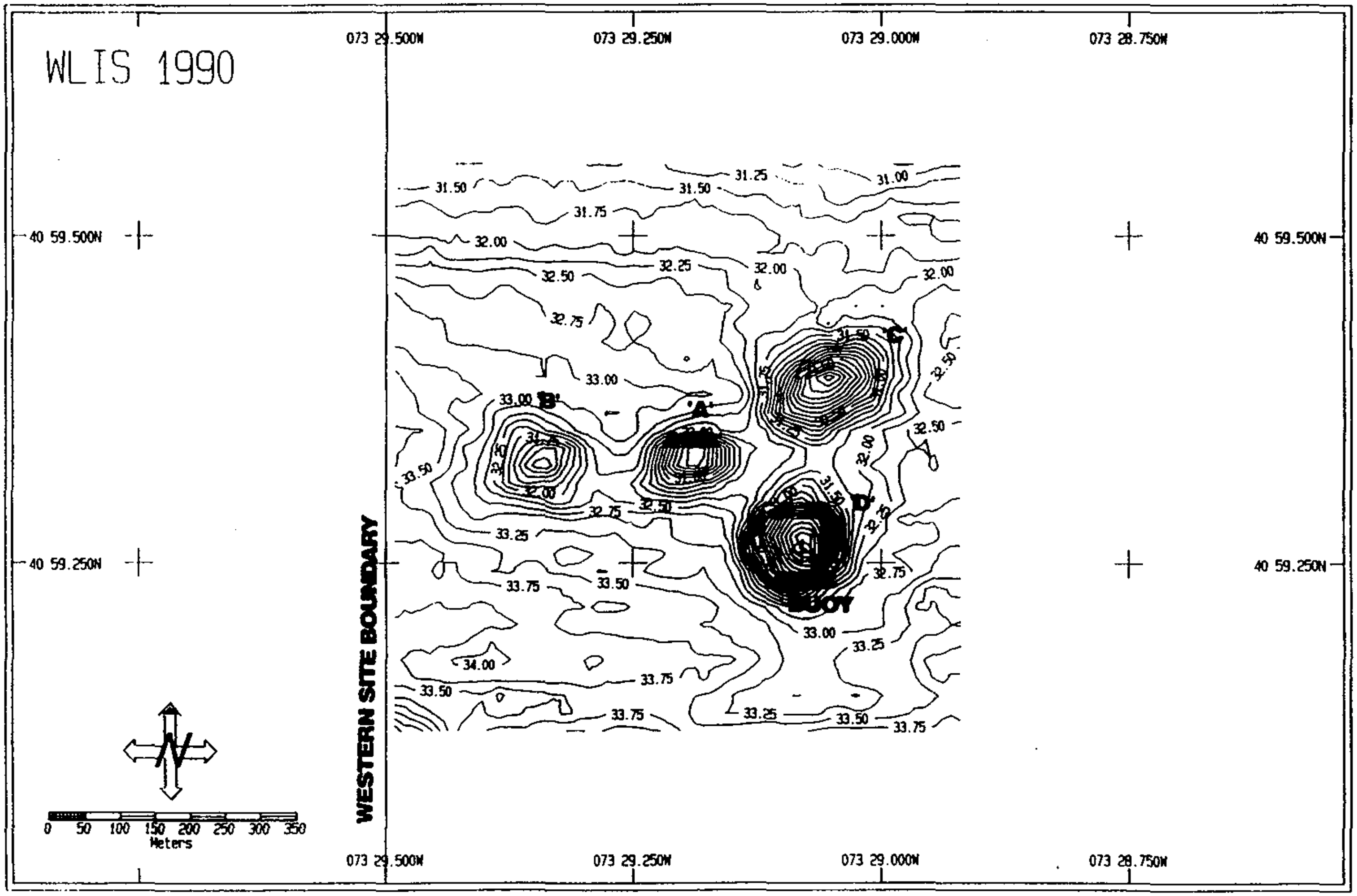


Figure 3-2. Bathymetric contour chart of the WLIS Disposal Site, July 1990, showing the "A", "B", "C", and "D" disposal mounds. The location of the disposal buoy during the 1989 - 1990 season is also indicated. Contours at 0.25 m intervals.

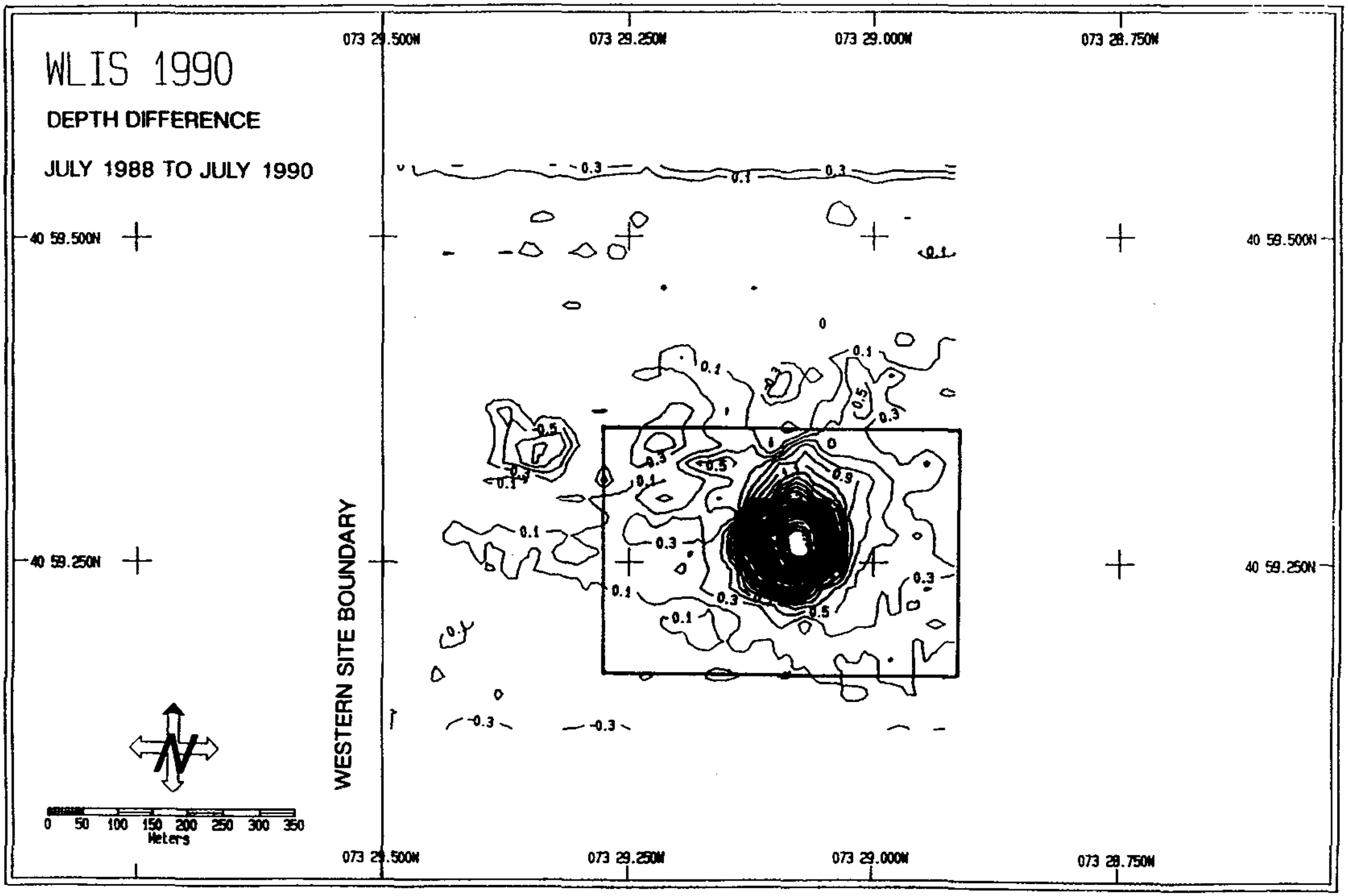


Figure 3-3. Depth difference contour plot at WLIS, July 1990. Boundaries surrounding the WLIS "D" mound delineate the 500 X 350 m region used to calculate the volume of accumulated dredged material based on depth difference analysis. Contours at 0.2 m intervals.

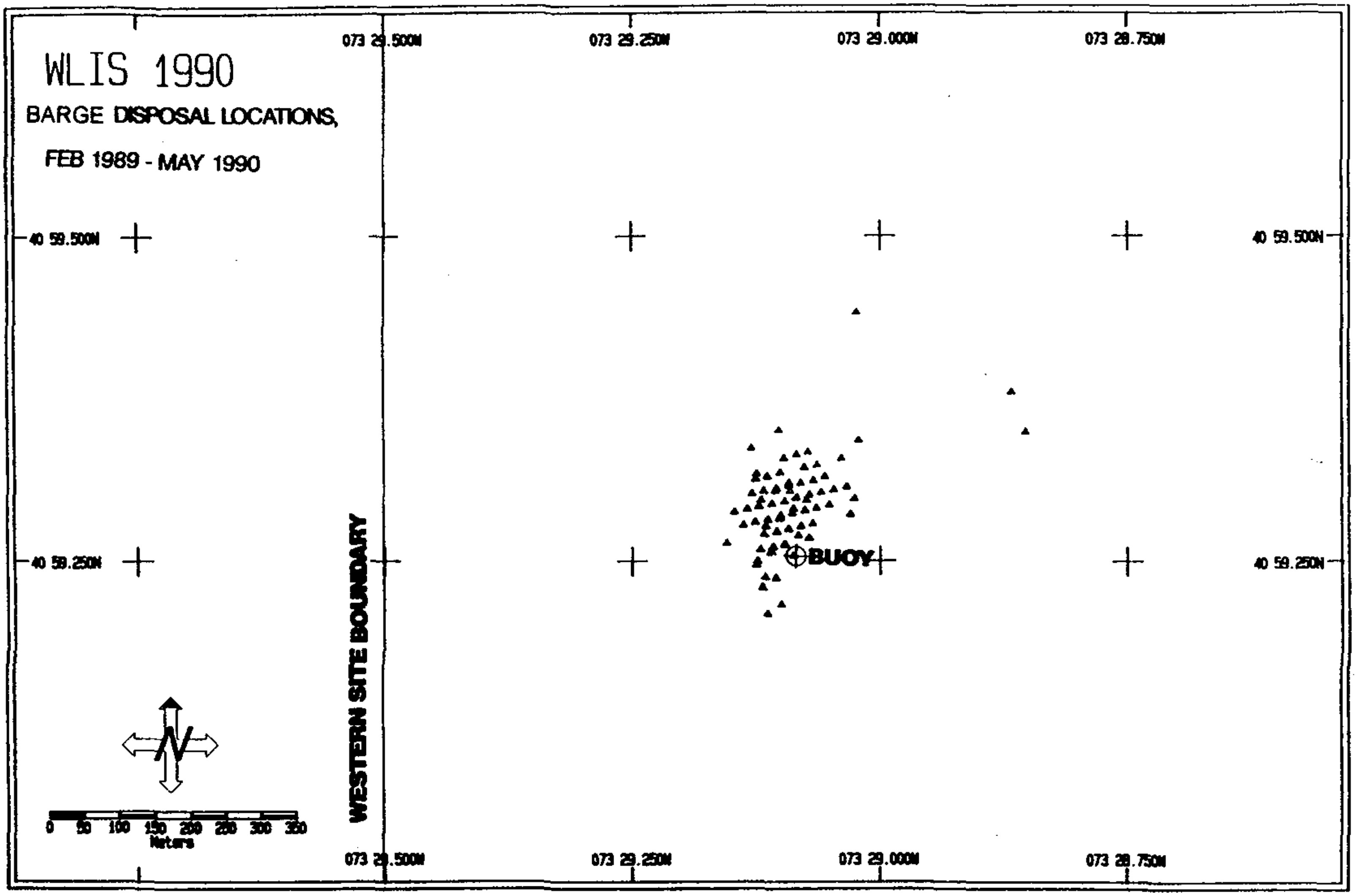


Figure 3-4. Plot of reported barge disposal locations, WLIS Disposal Site, February 1989 to May 1990. The buoy location for the 1989 - 1990 disposal season is also indicated.

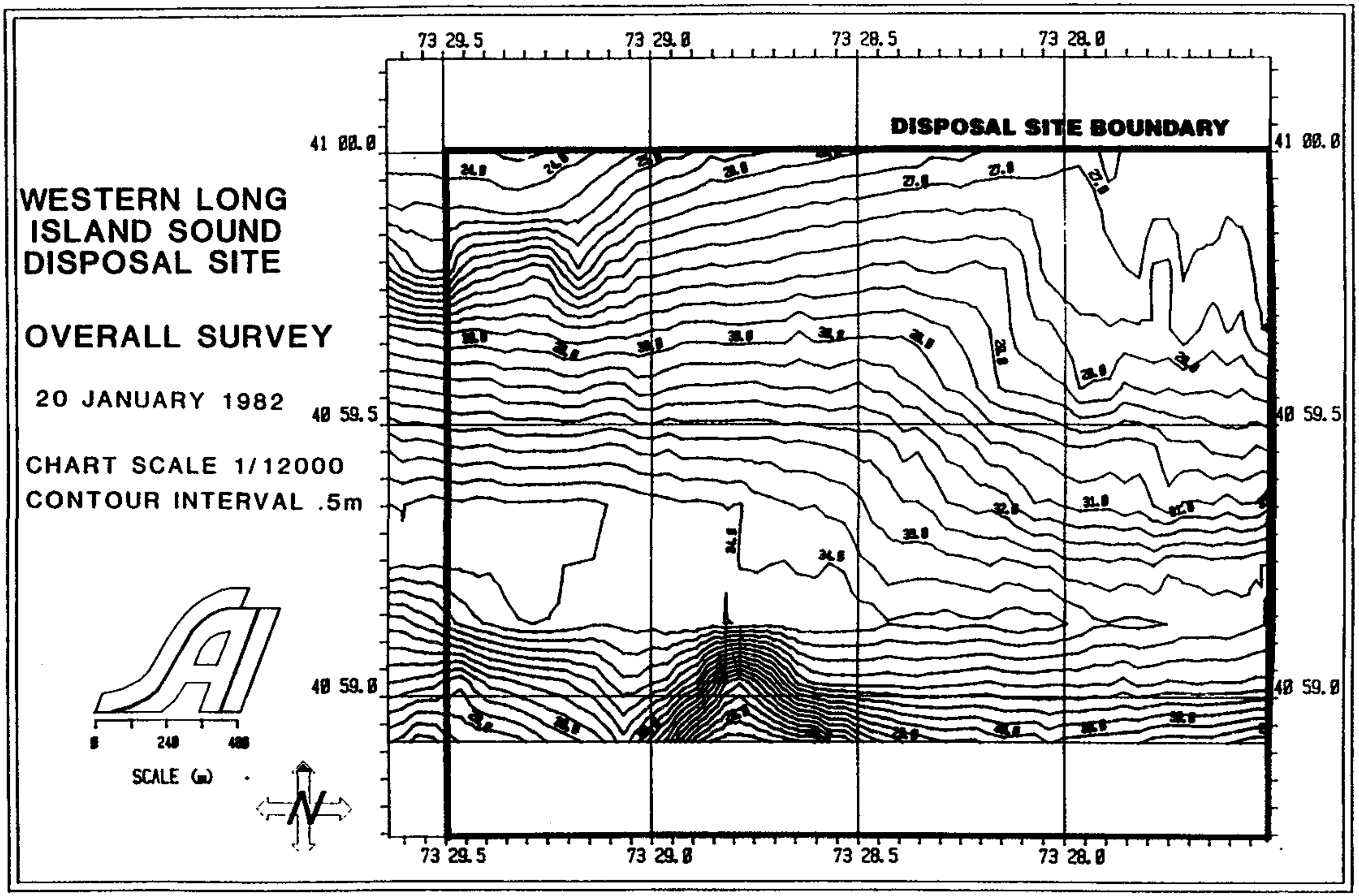


Figure 3-5. Bathymetric contour plot of the WLIS Disposal Site, January 1982. The southern site boundary extends below this plot. Contours at 0.5 m intervals.

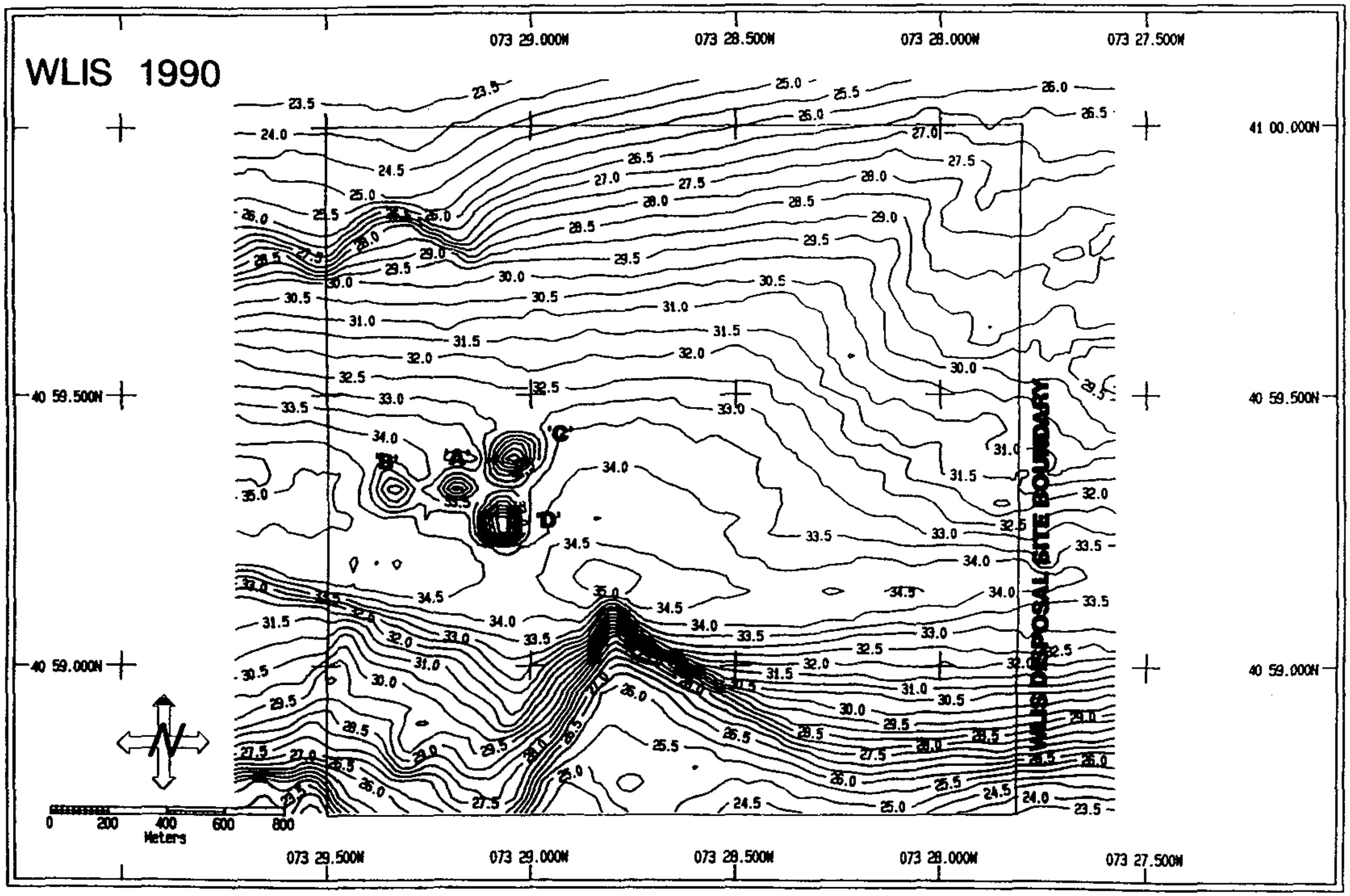


Figure 3-6. Bathymetric contour plot of the WLIS Disposal Site, July 1990. The four disposal mounds ("A", "B", "C", and "D") are clearly visible in the central, western region. The WLIS site boundary is also indicated. Contours at 0.5 m intervals.

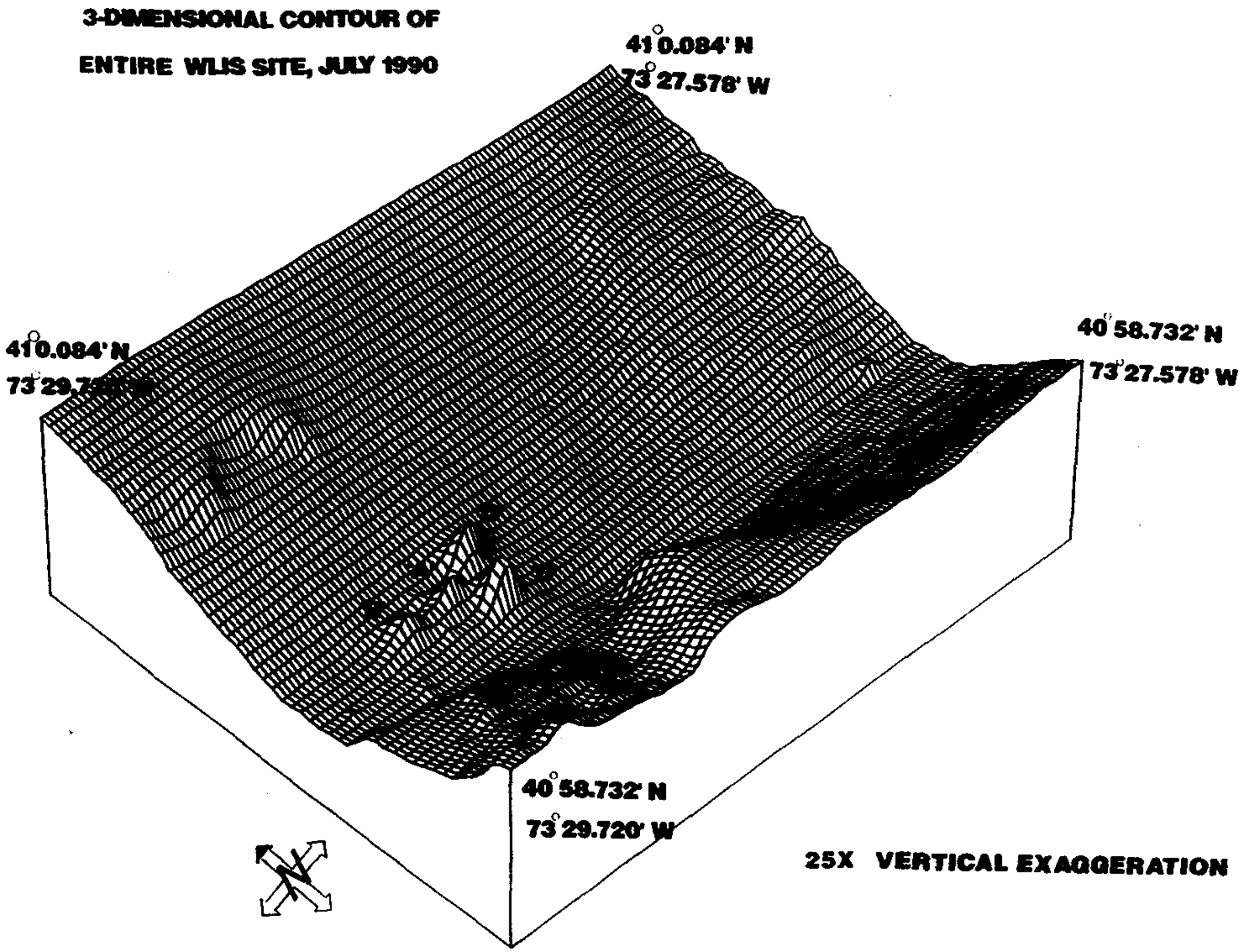


Figure 3-7. Three dimensional bathymetric plot of the WLIS Disposal Site, July 1990. The "A", "B", "C", and "D" disposal mounds are visible in the lower central portion of the plot.

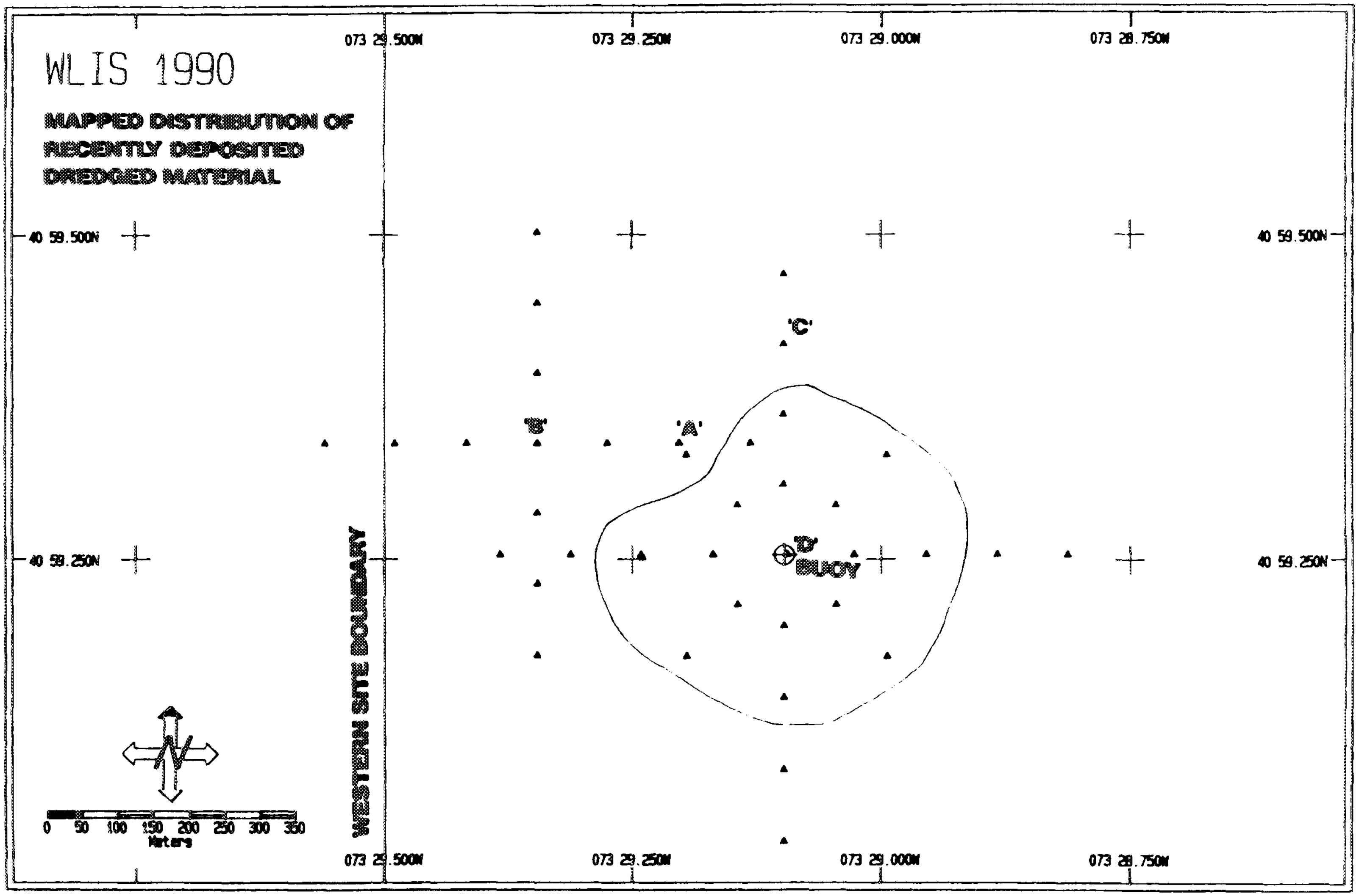
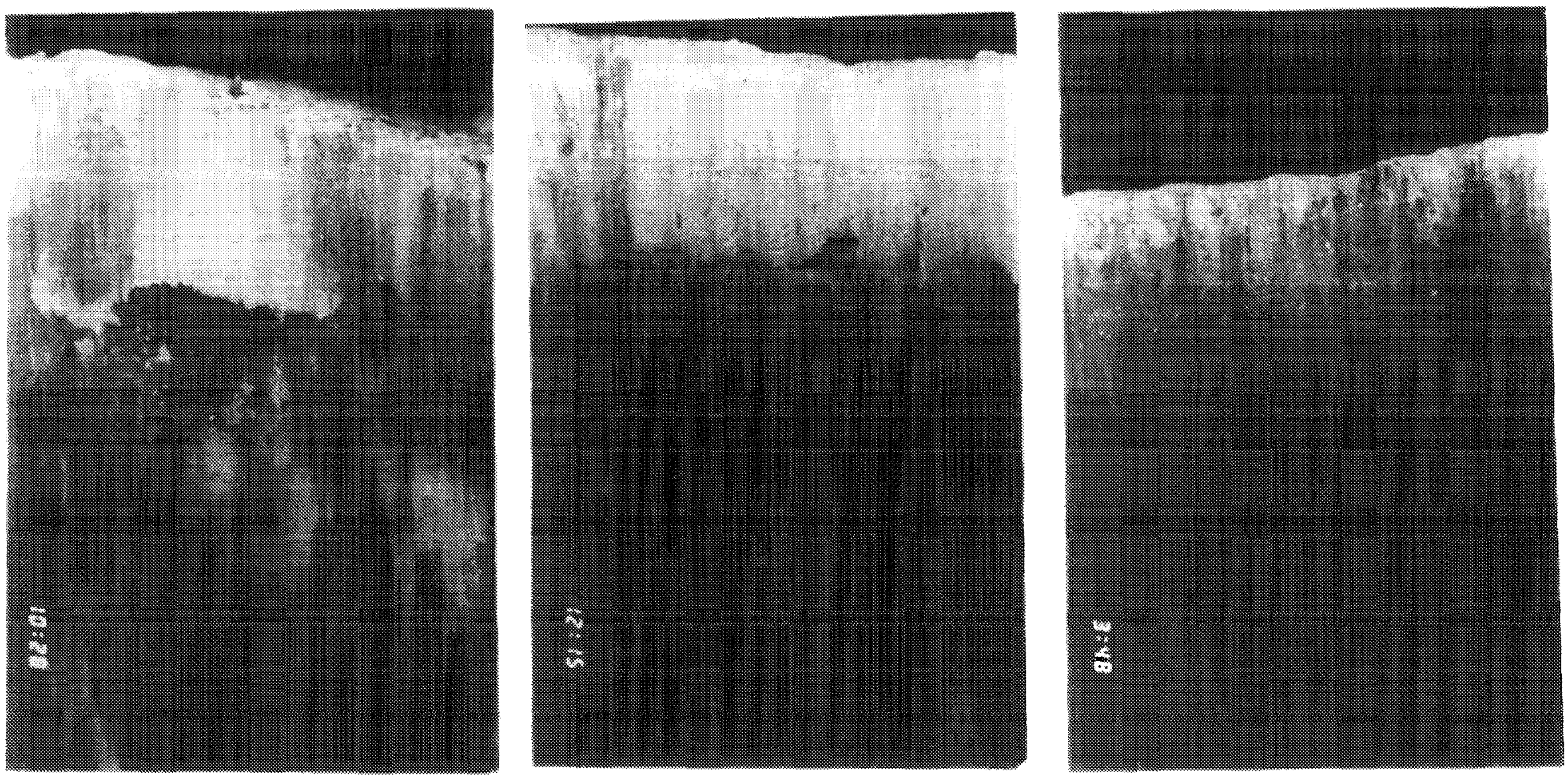
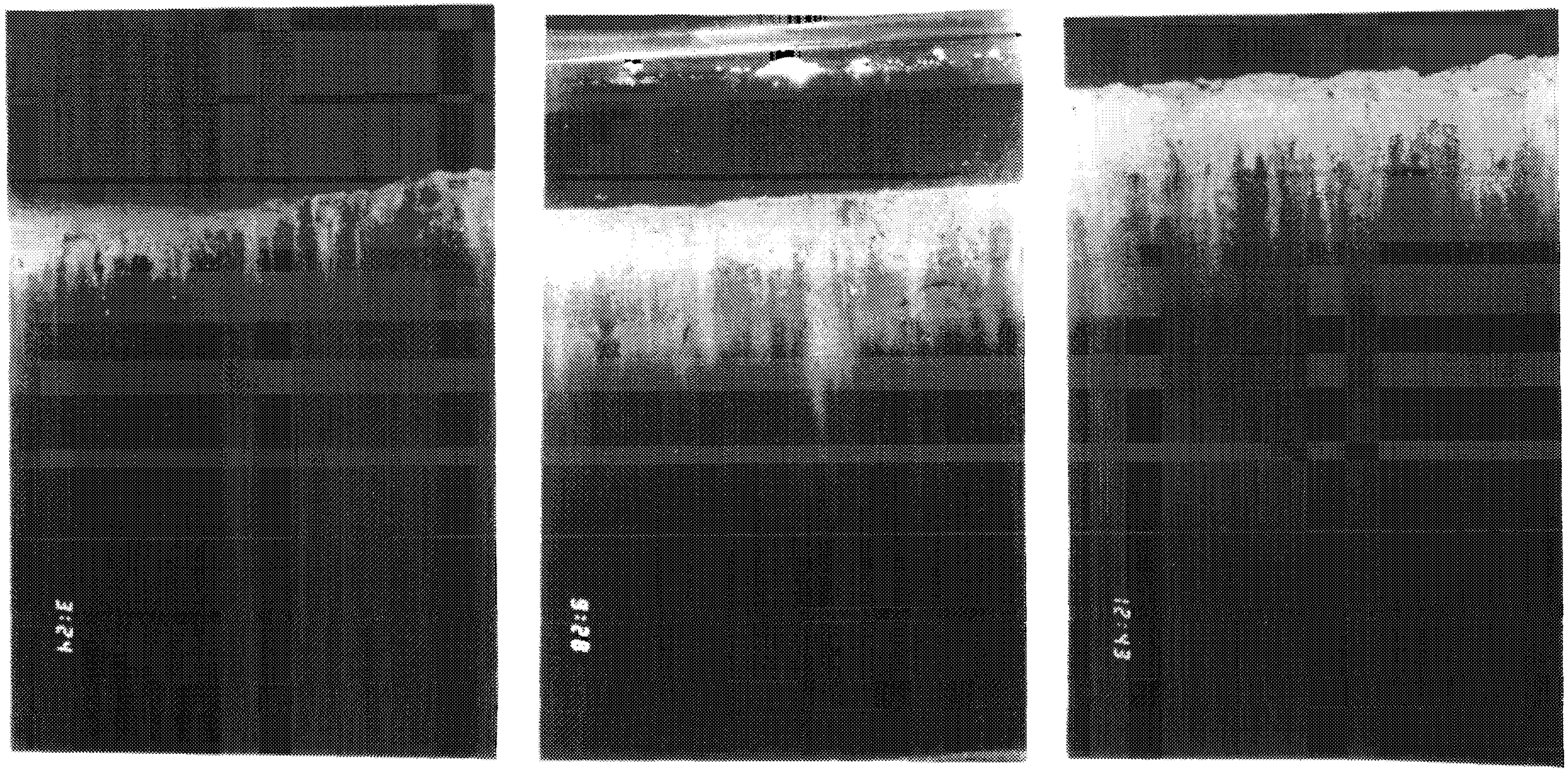


Figure 3-8. The mapped distribution of recently-deposited dredged material (between the July 1988 and July 1990 surveys) based on 1990 REMOTS® sediment-profile survey at the WLIS Disposal Site, July 1990.



A B C

Figure 3-9. Streaky and mottled RPDs observed in REMOTS® photographs from stations CTR (A), 100N (B), and 100E (C), on and in the vicinity of the "D" disposal mound. Scale = 0.5.



A B C

Figure 3-10. REMOTS® photographs revealing the well-defined apparent RPD and high sediment oxygen demand (SOD) prevalent at stations 100NE (A), 100SE (B), and 100W (C) in the vicinity of the "D" mound. Scale = 0.5 m.

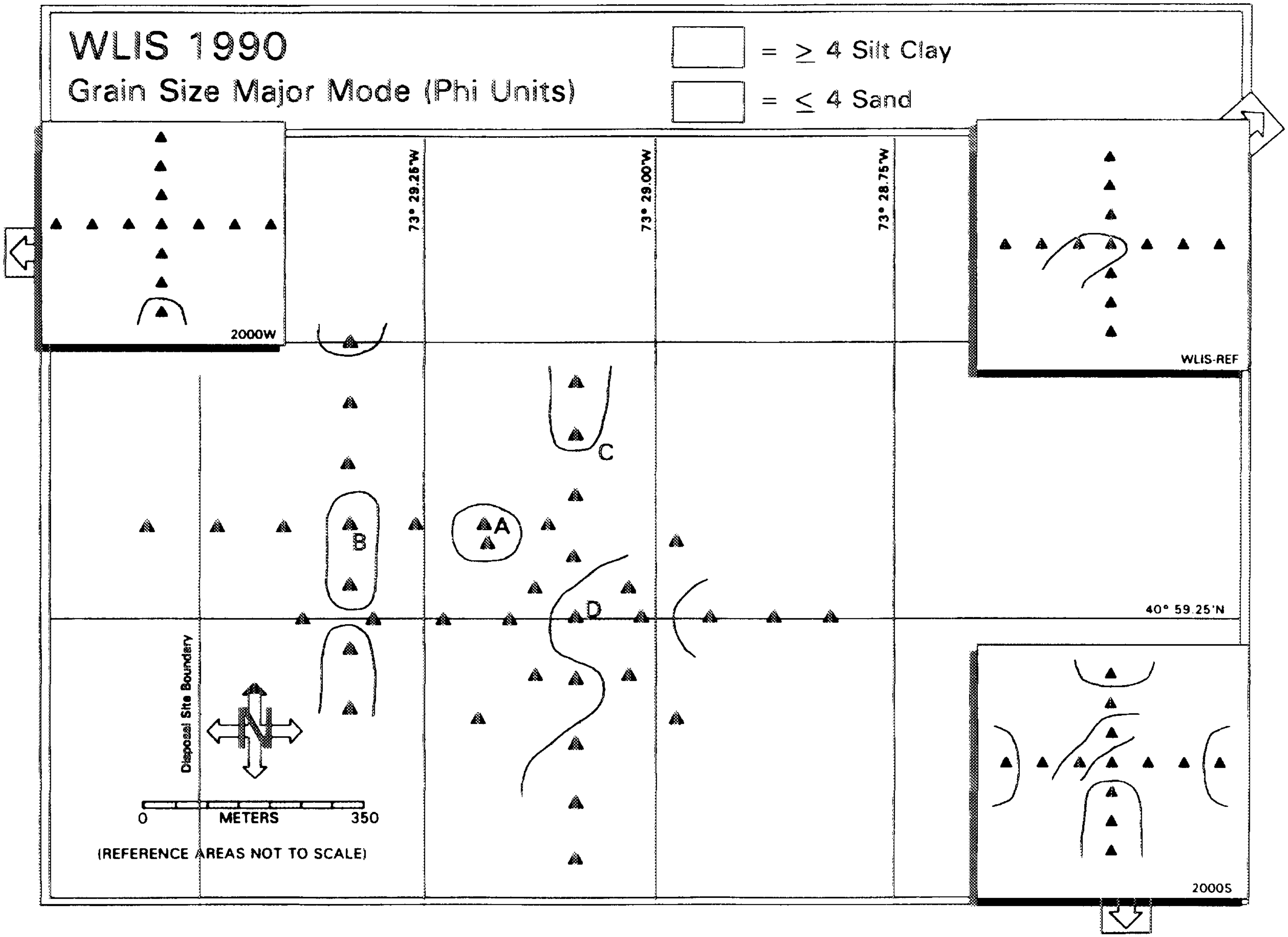
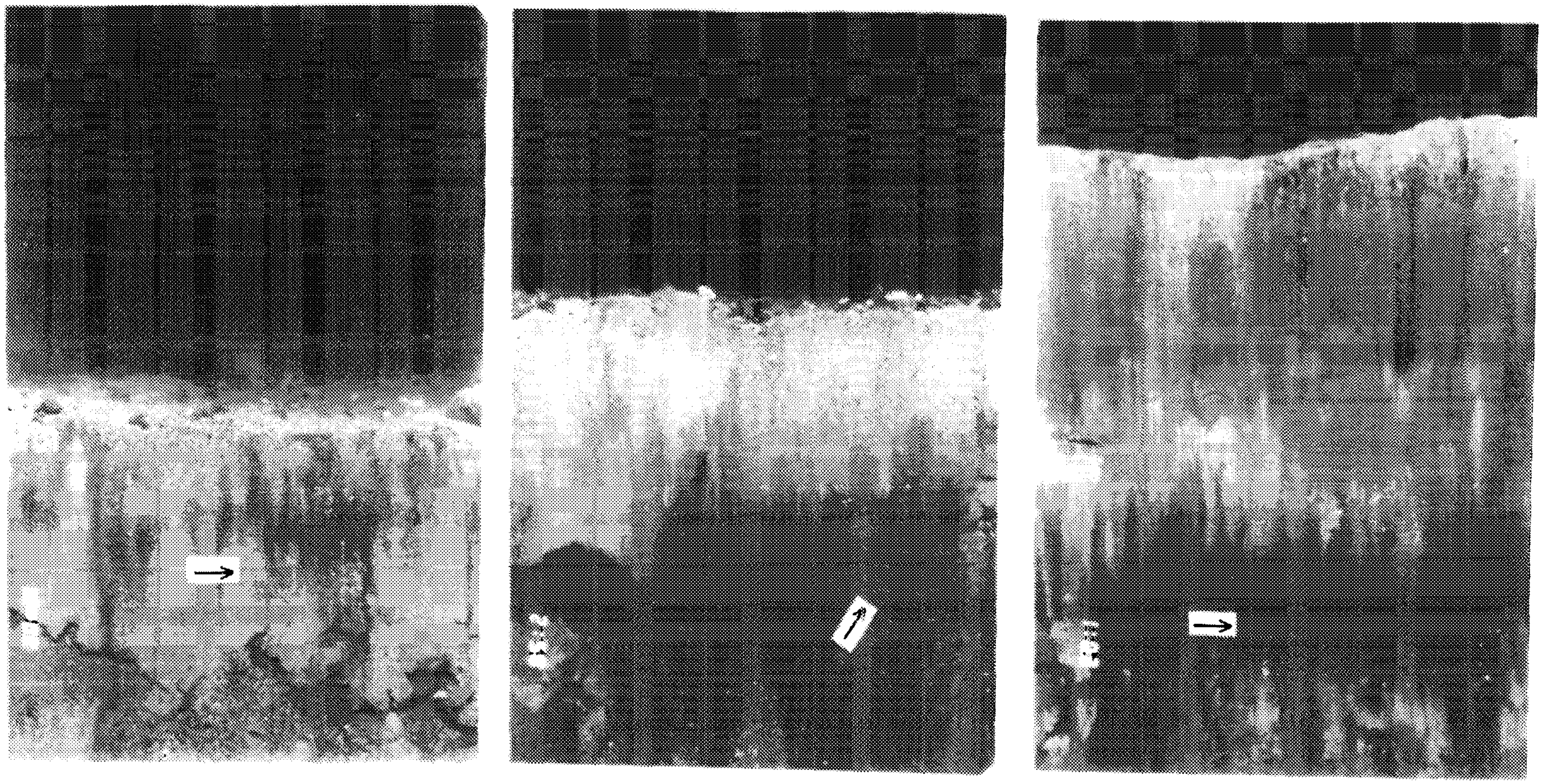


Figure 3-11. Distribution of sediment grain size major mode (phi units) at the WLIS Disposal Site and reference stations, July 1990. Contours delineate regions where grain size major mode (in phi units) was 4-3 phi or less.



A B C

Figure 3-12. REMOTS® photographs showing relic dredged material layers, characterized by discontinuous sand layers at depth (arrows) near the inactive "A" (A), "B" (B), and "C" (C) disposal mounds within the WLIS Disposal Site, July 1990. Note the production of methane gas bubbles at the "B" mound. The horizontal burrows evident in (A) and (B) may have resulted from Decapod burrowing activity.
Scale = 0.5 m.

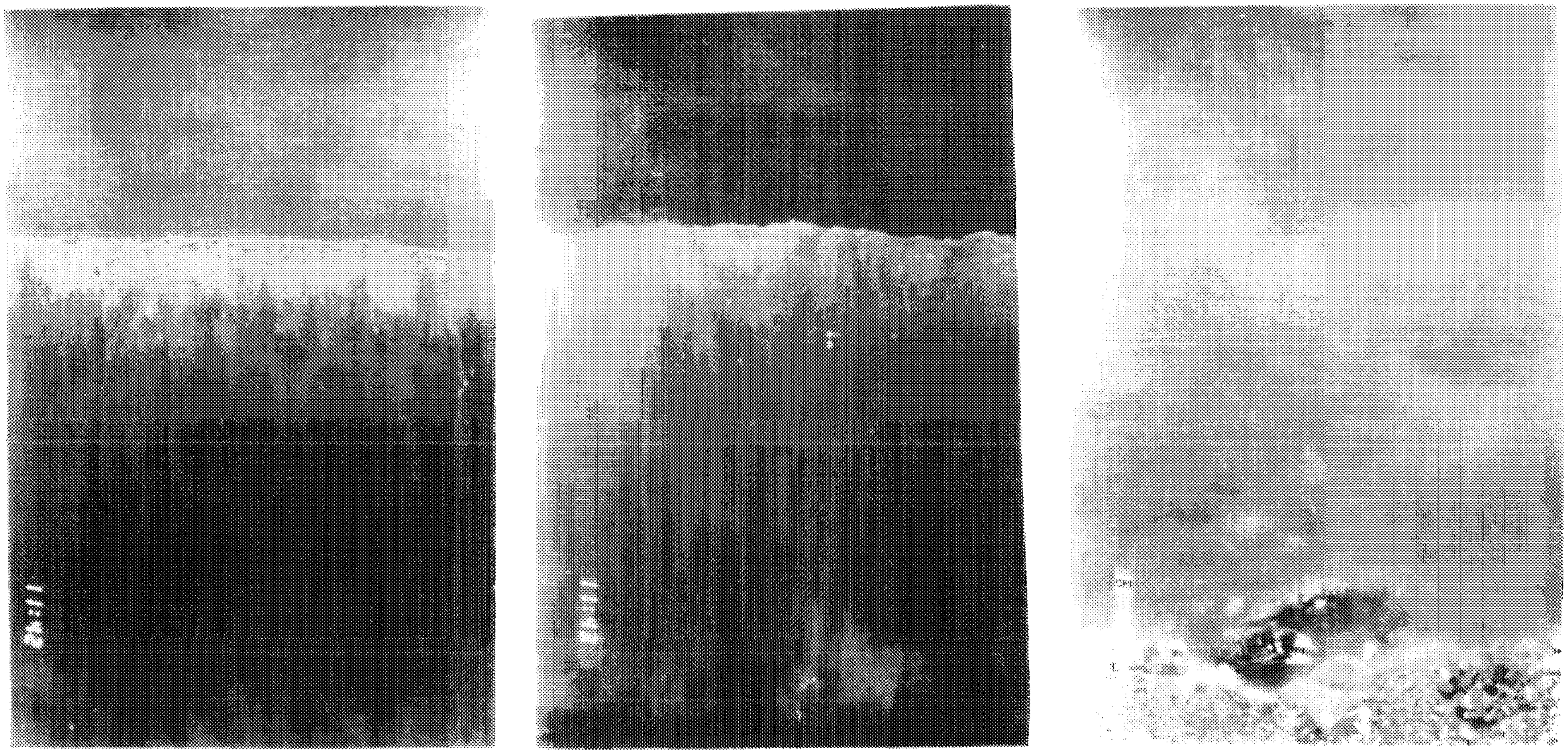
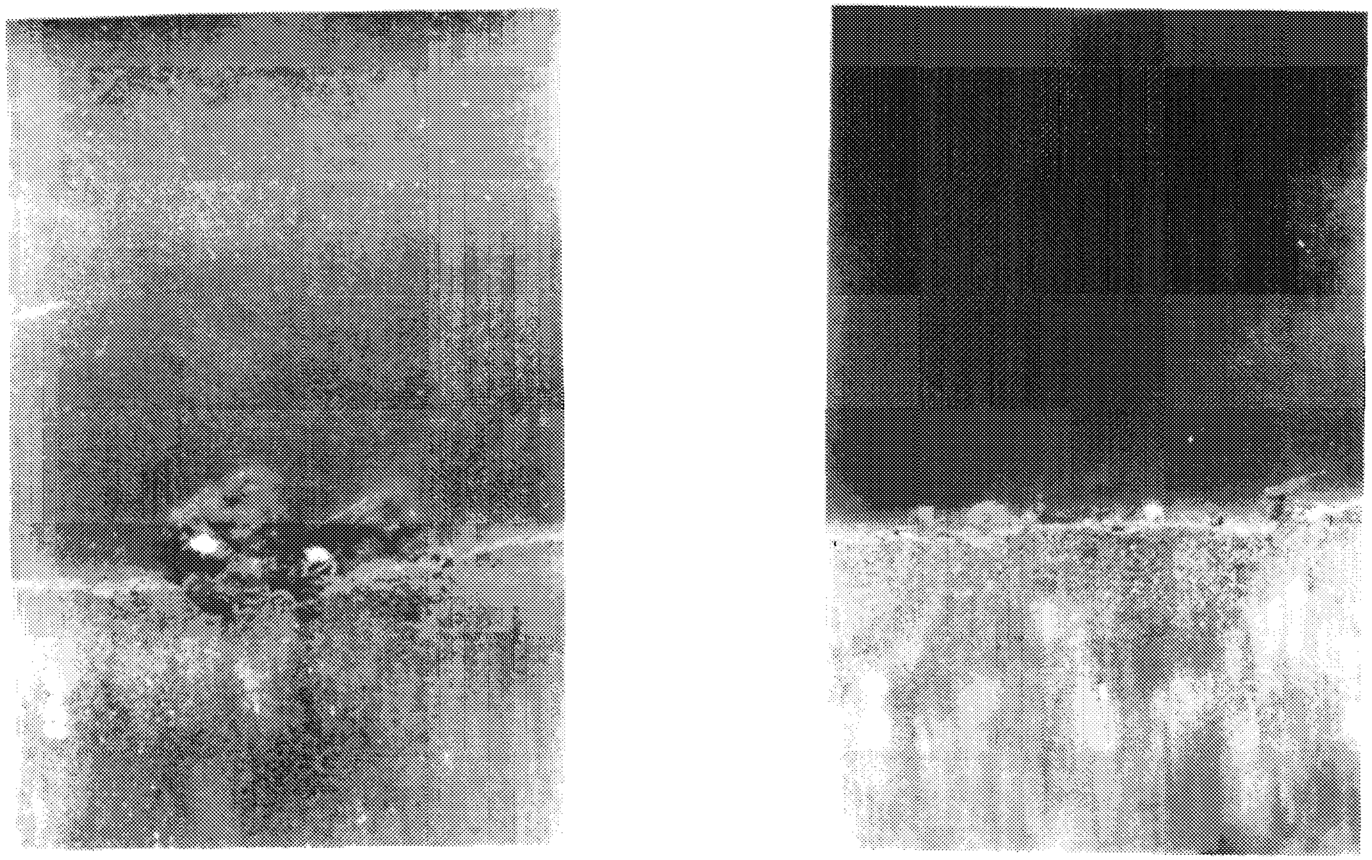


Figure 3-13. REMOTS® photographs showing within-station variability observed at station 300S of the 2000W reference area, WLIS, July 1990. Scale = 0.5 m.



S100S S200S

Figure 3-14. REMOTS® photographs showing the poorly-sorted and sandy sediments prevalent at the 2000S reference area, WLIS, July 1990. Scale = 0.5 m.

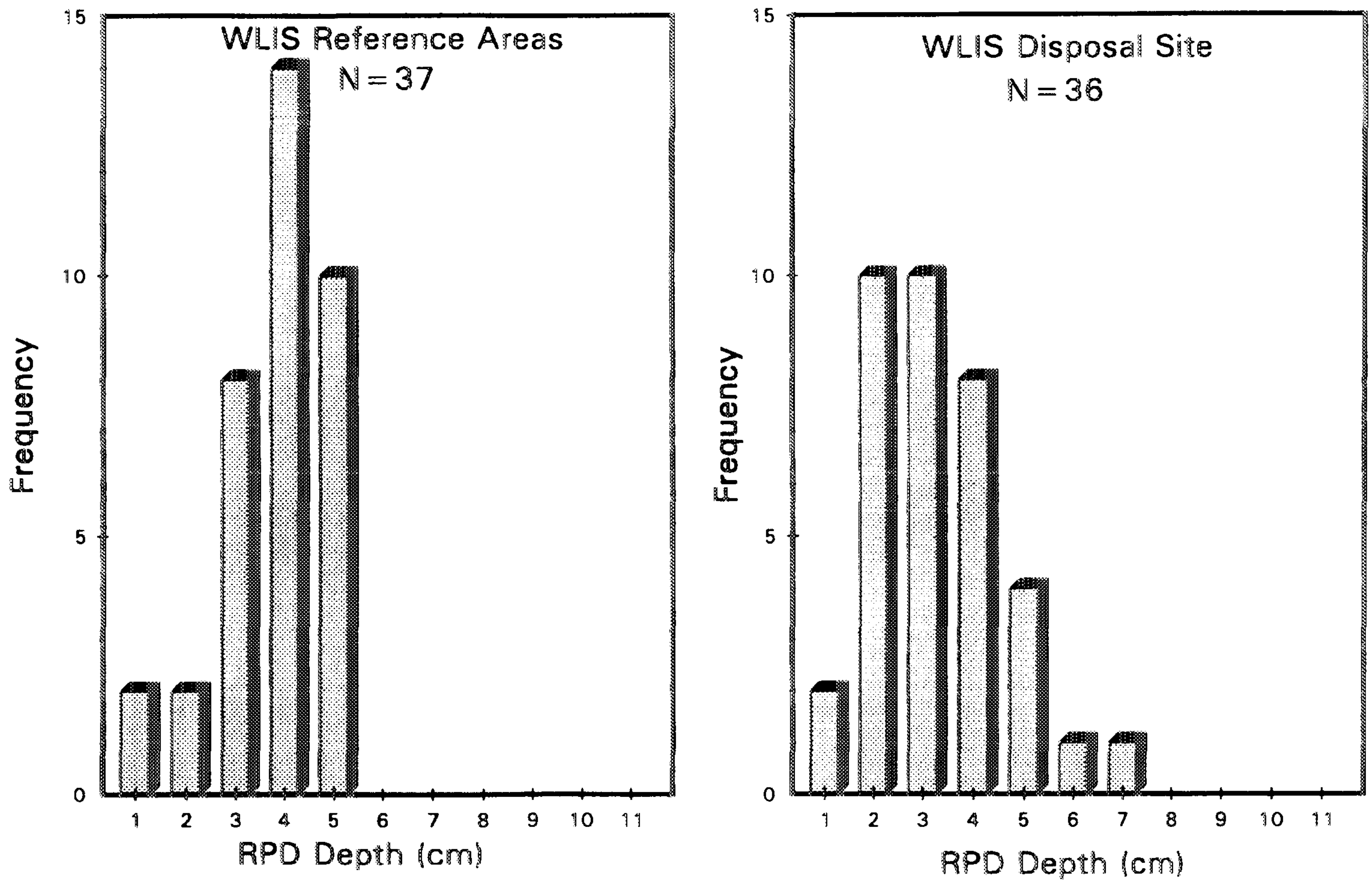


Figure 3-15. Frequency distributions of RPD depths for the on-site and pooled reference stations, WLIS Disposal Site, July 1990.

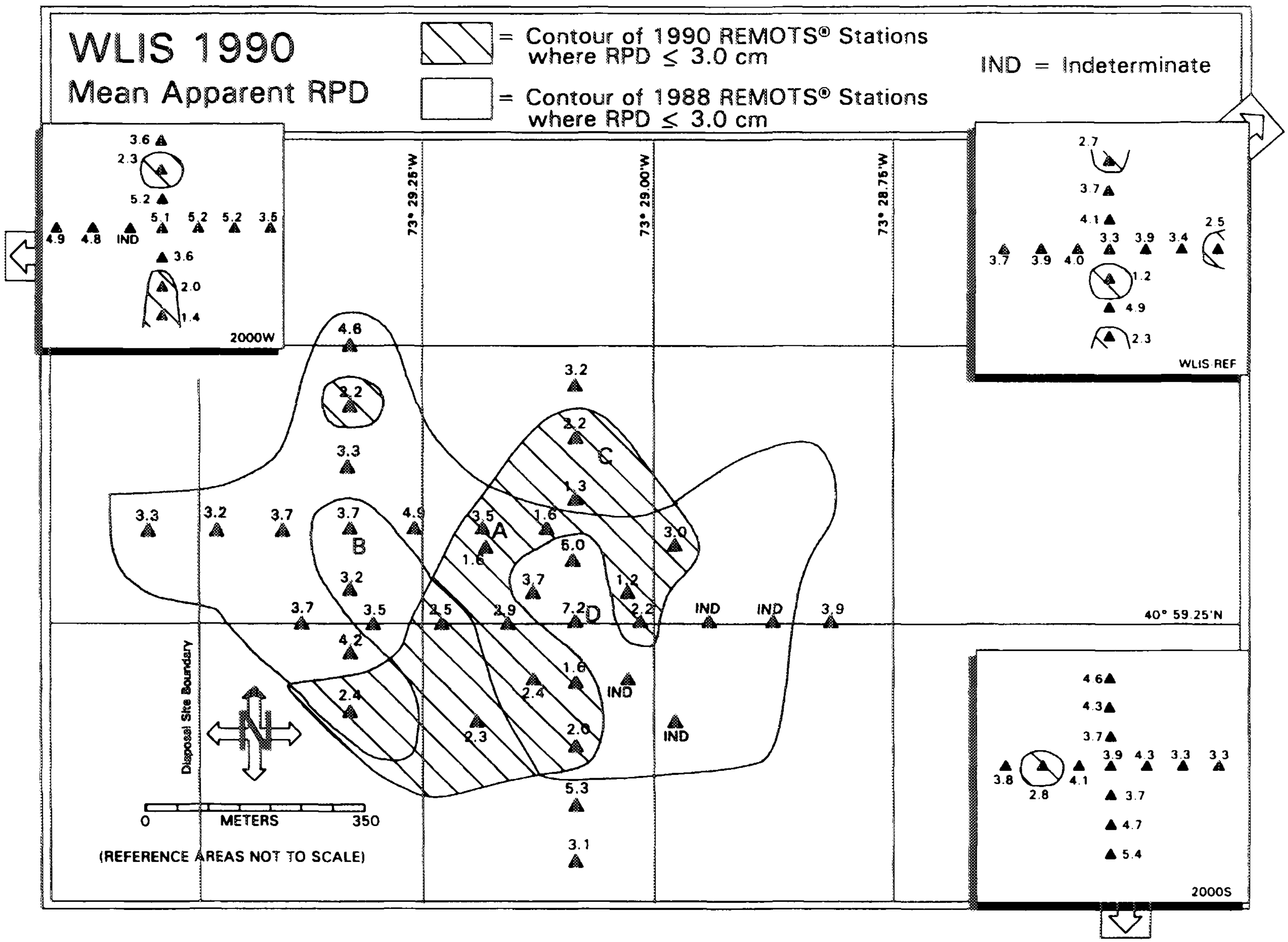
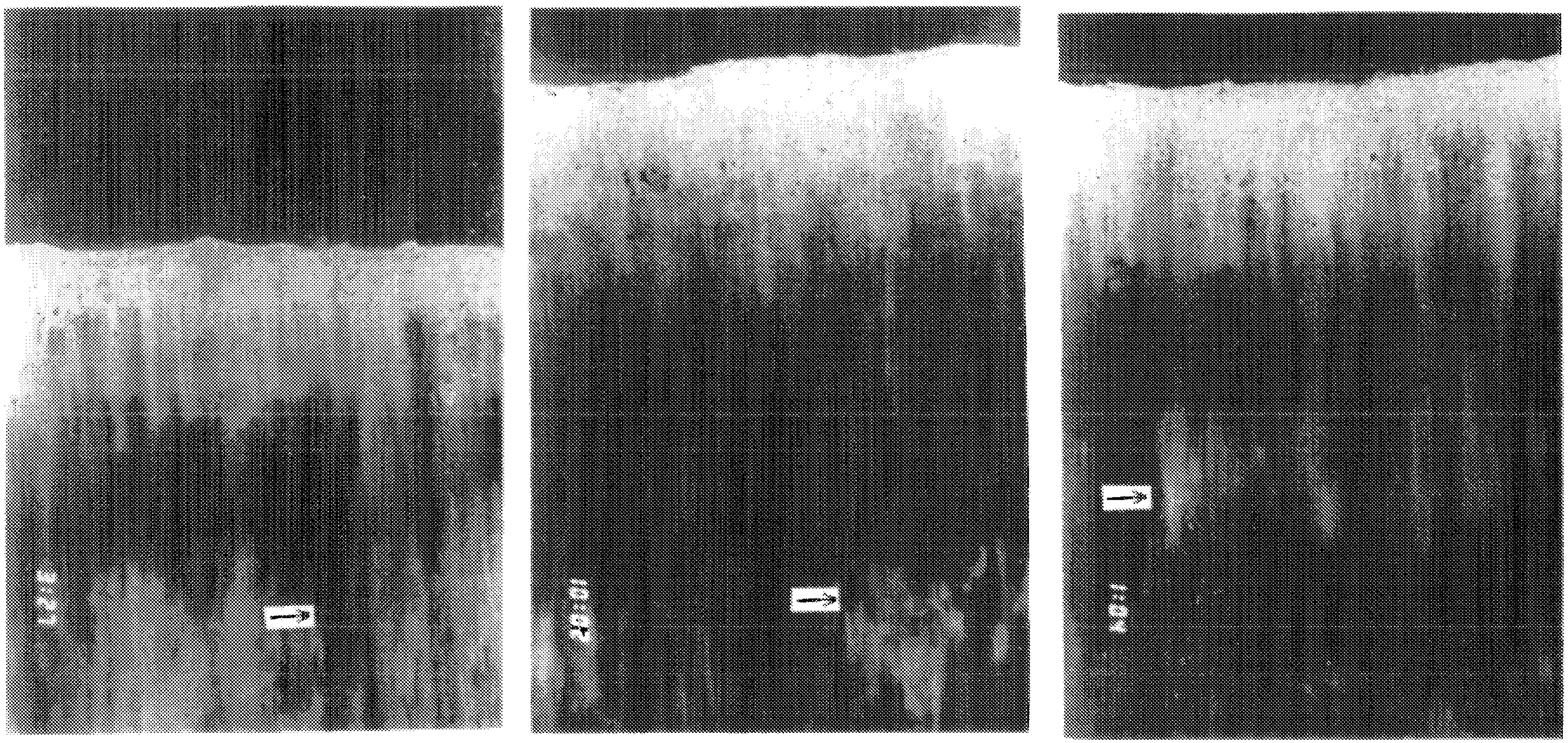
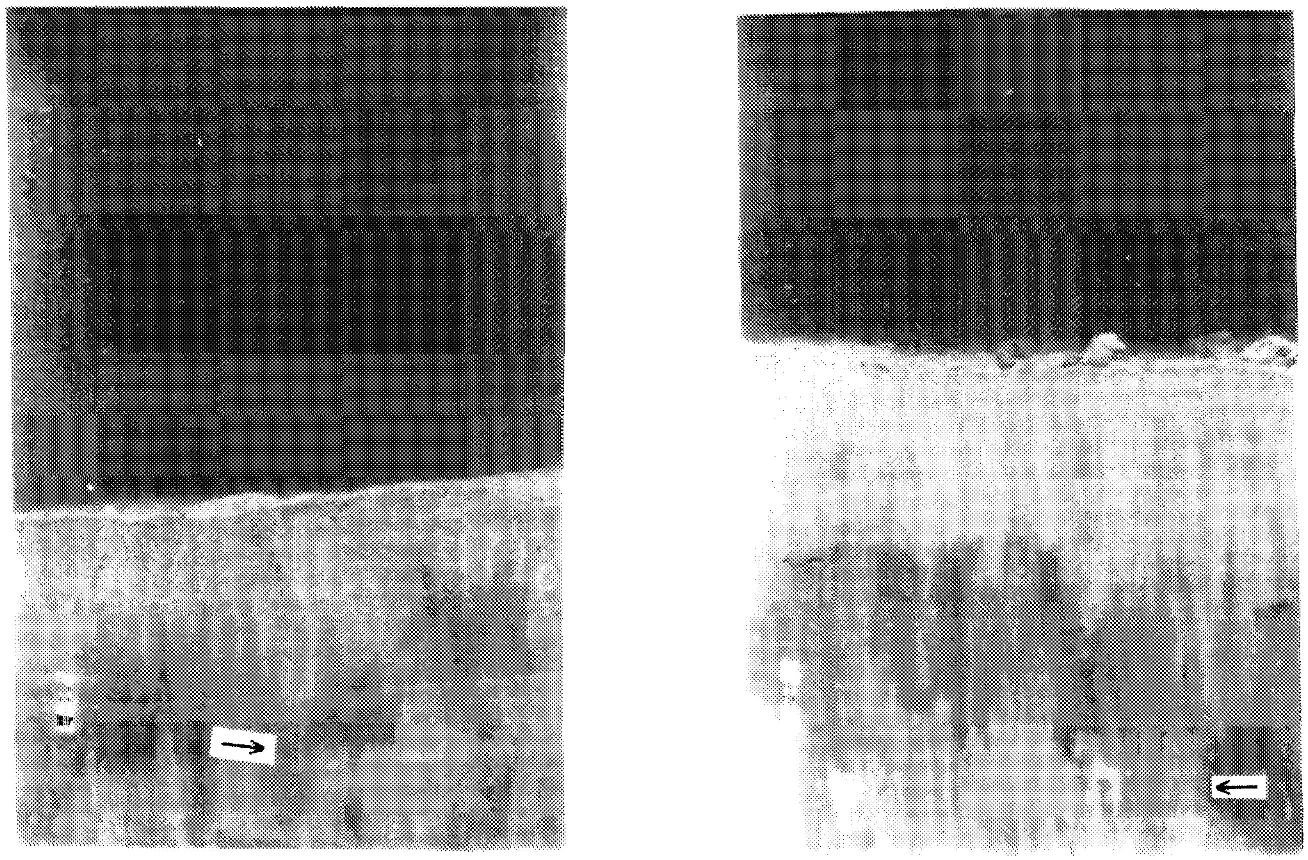


Figure 3-16. Mapped distribution of mean RPD depths at on-site and reference stations, WLIS Disposal Site, July 1990, with overlay of 1988 on-site data. Contours delineate areas where average RPD was ≤ 3.0 cm. IND = indeterminate due to camera over-penetration.



"D" "B" "C"

Figure 3-17. REMOTS® photographs showing relic RPD layers (arrows) observed at the "D", "B", and "C" disposal mounds, WLIS Disposal Site, July 1990.



A   B

Figure 3-18. REMOTS® photographs showing relic RPD layers (arrows) observed at some stations within the 2000S (A) and WLIS-REF (B) reference areas, WLIS Disposal Site, July 1990.

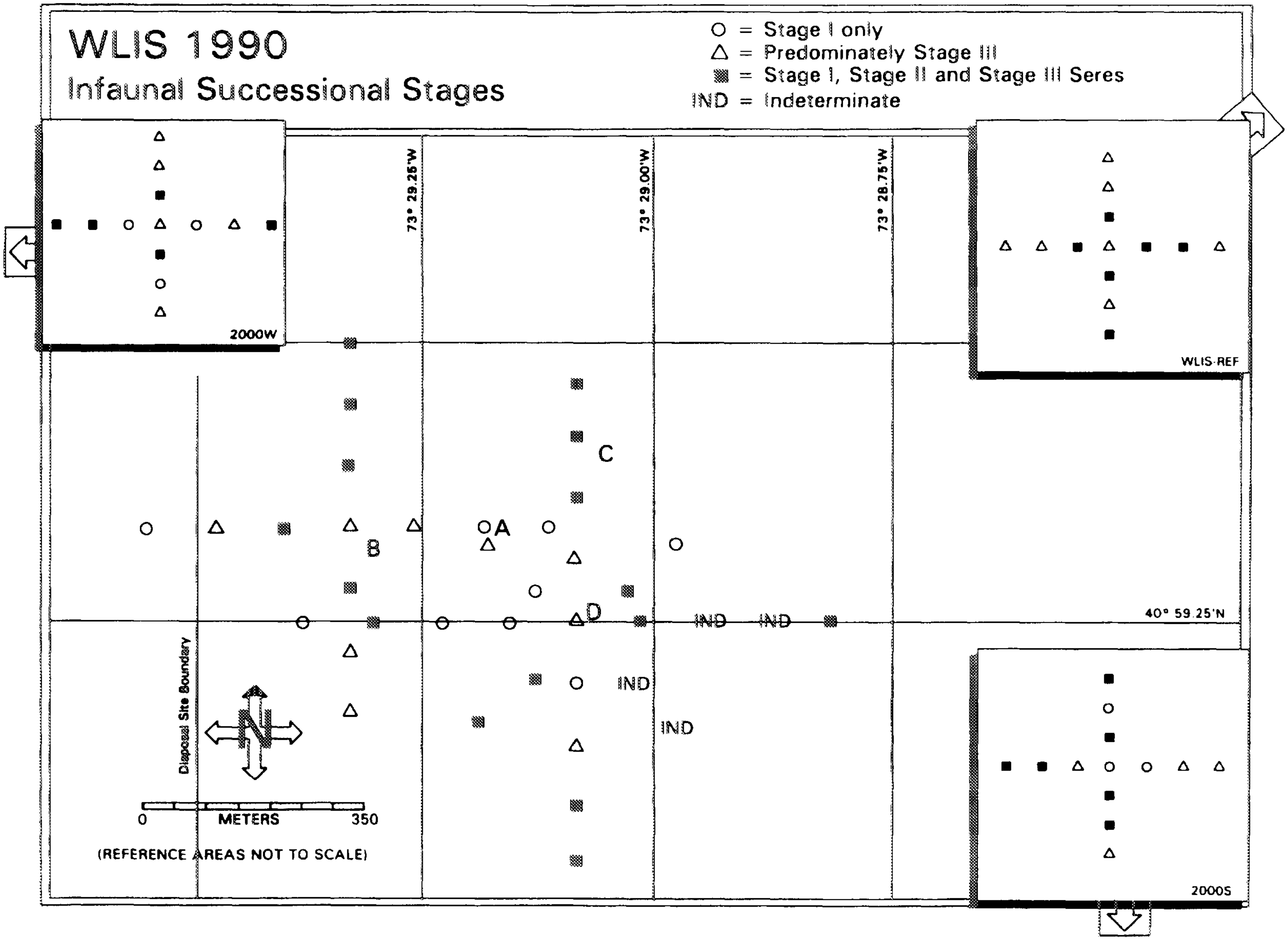
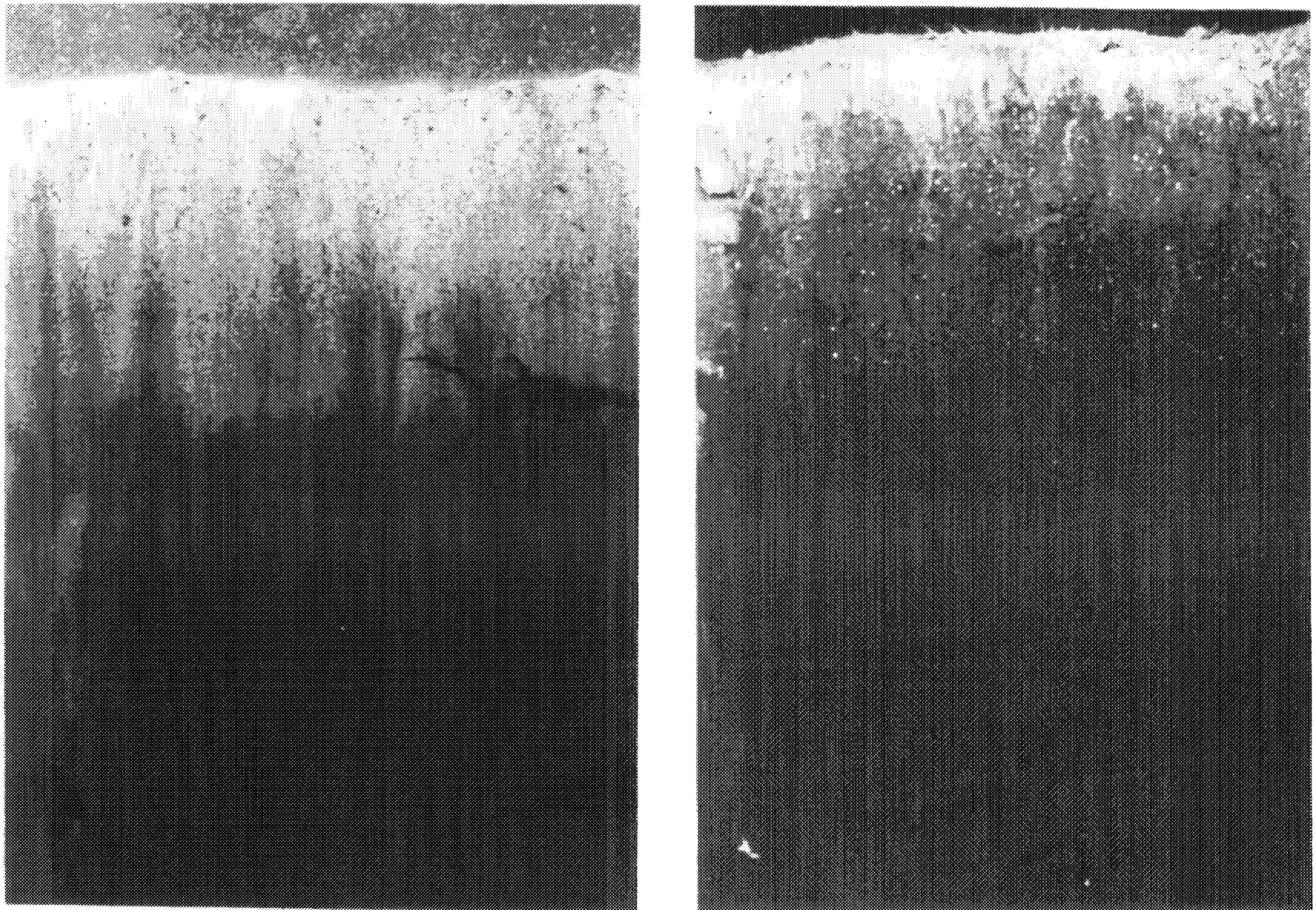


Figure 3-19. Mapped distribution of infaunal successional stages at on-site and reference stations, WLIS Disposal Site, July 1990. The locations of the disposal mounds are also indicated.



100E

200S

Figure 3-20. REMOTS® photographs showing rapid recolonization by Stage III infauna at stations 100E and 200S, in the vicinity of the "D" disposal mound, WLIS Disposal Site, July 1990. Scale = 1.0 m.

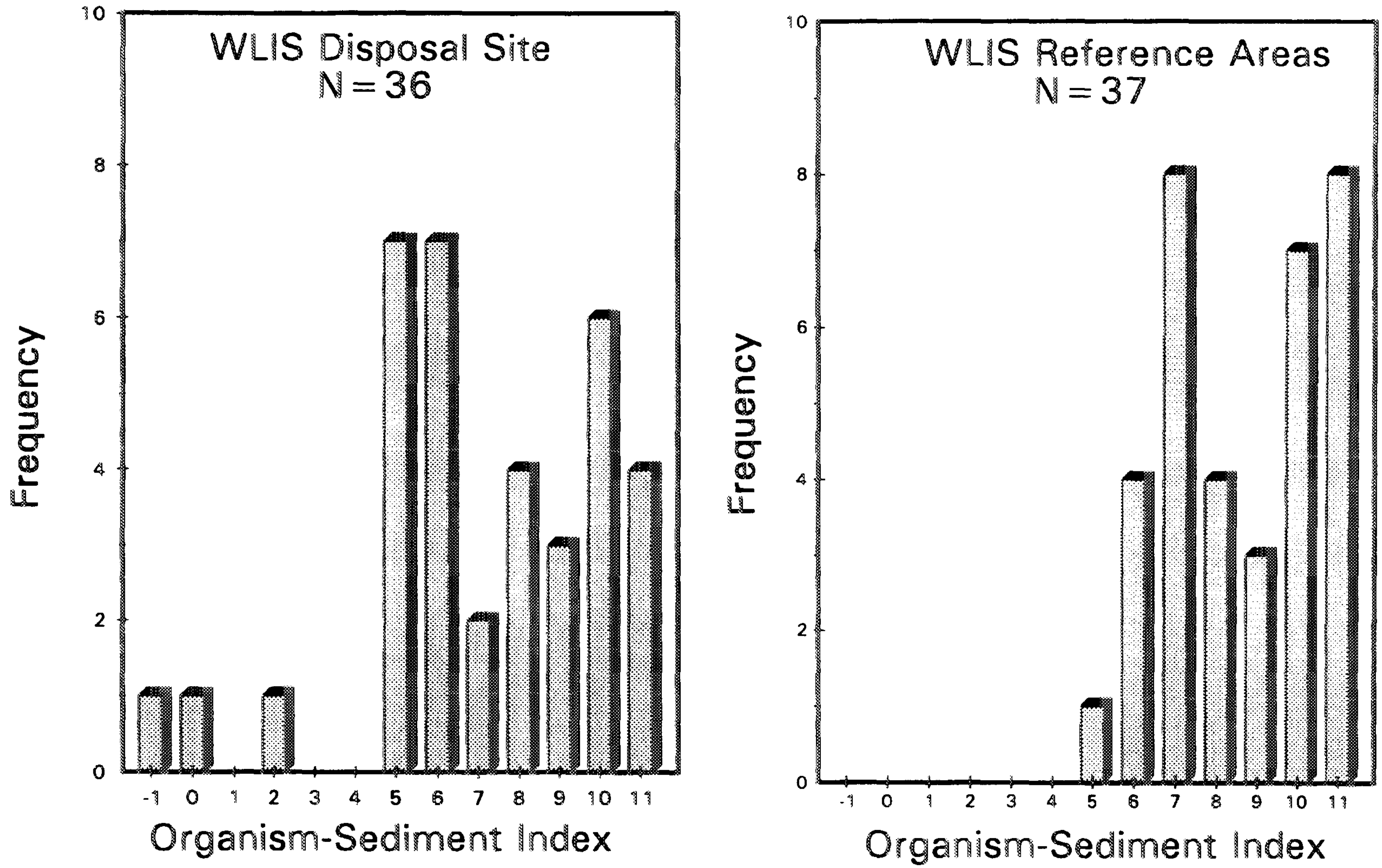


Figure 3-21. Frequency distribution of OSI values at on-site and reference stations, WLIS Disposal Site, July 1990.

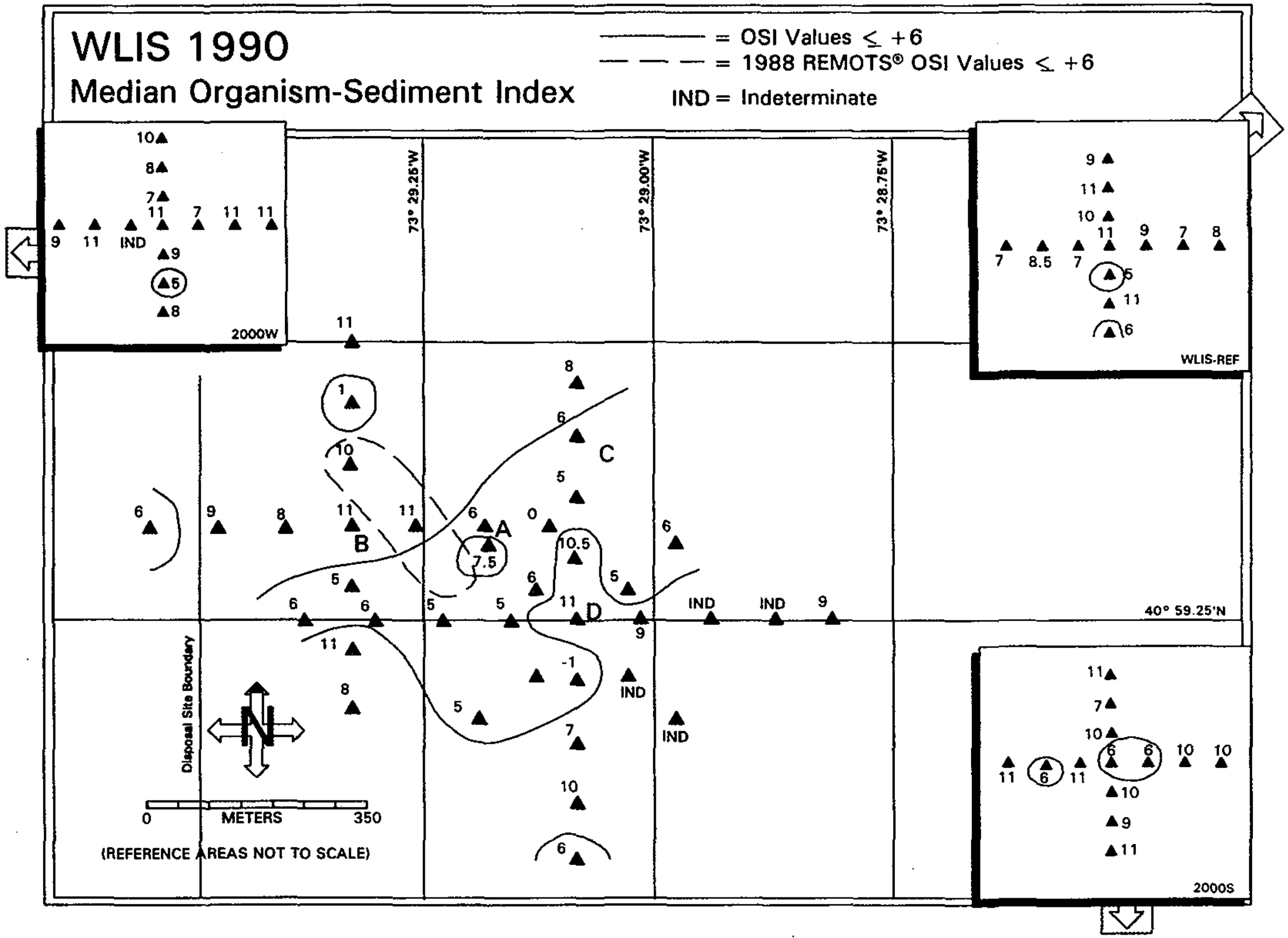


Figure 3-22. Mapped distribution of median OSI values at the WLIS Disposal Site and reference stations, July 1990. Contours delineate regions where calculated OSI values were ≤ +6. Delineation of 1988 REMOTS® stations where OSI ≤ +6 is also shown (dotted line).

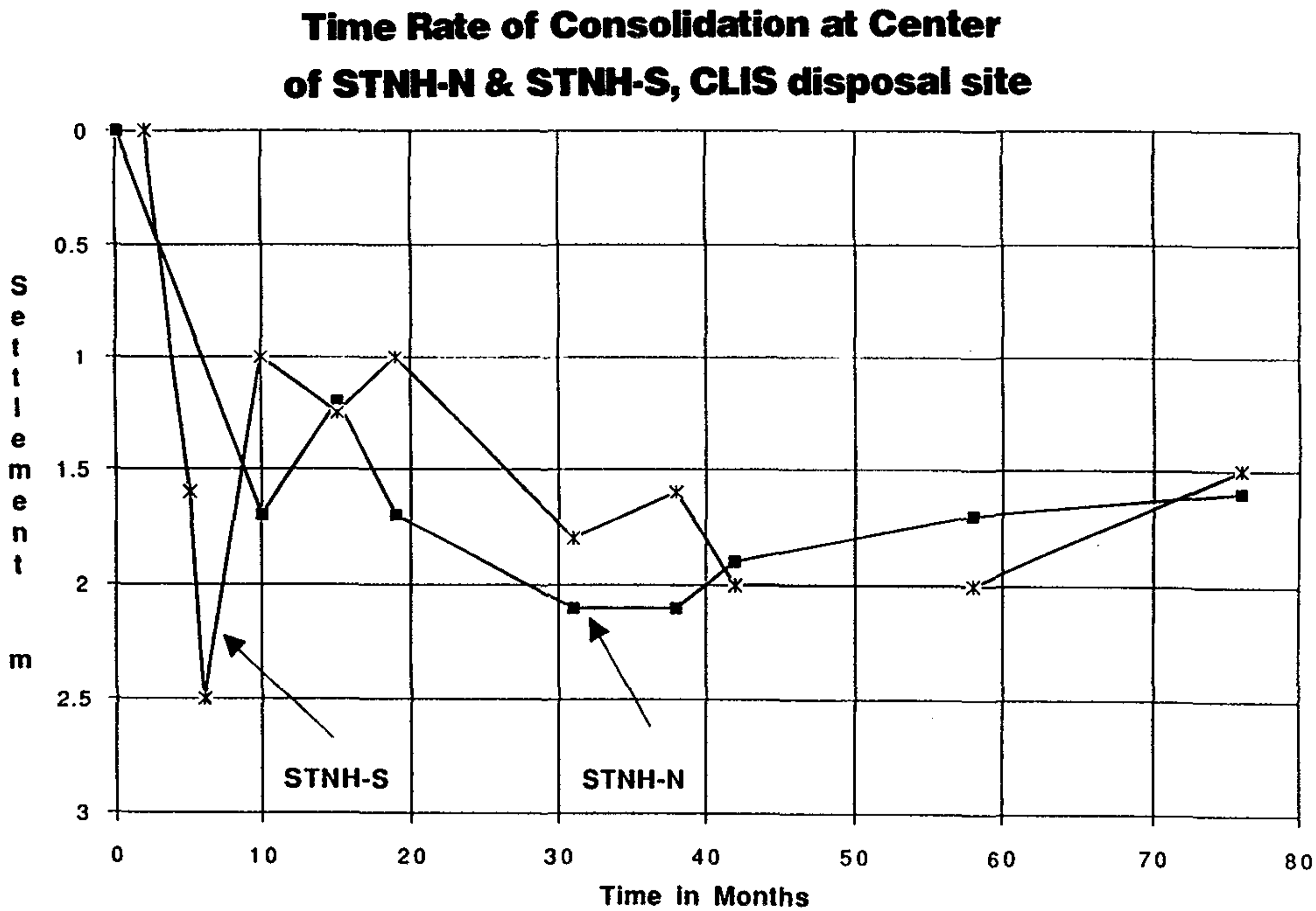


Figure 4-1. Time rate of consolidation at the center of disposal mounds located at the Central Long Island Sound (CLIS) Disposal Site. Note that substantial consolidation of sediments likely continued in the 4 - 5 months following discontinuation of disposal. (From Poindexter-Rollins, 1990).

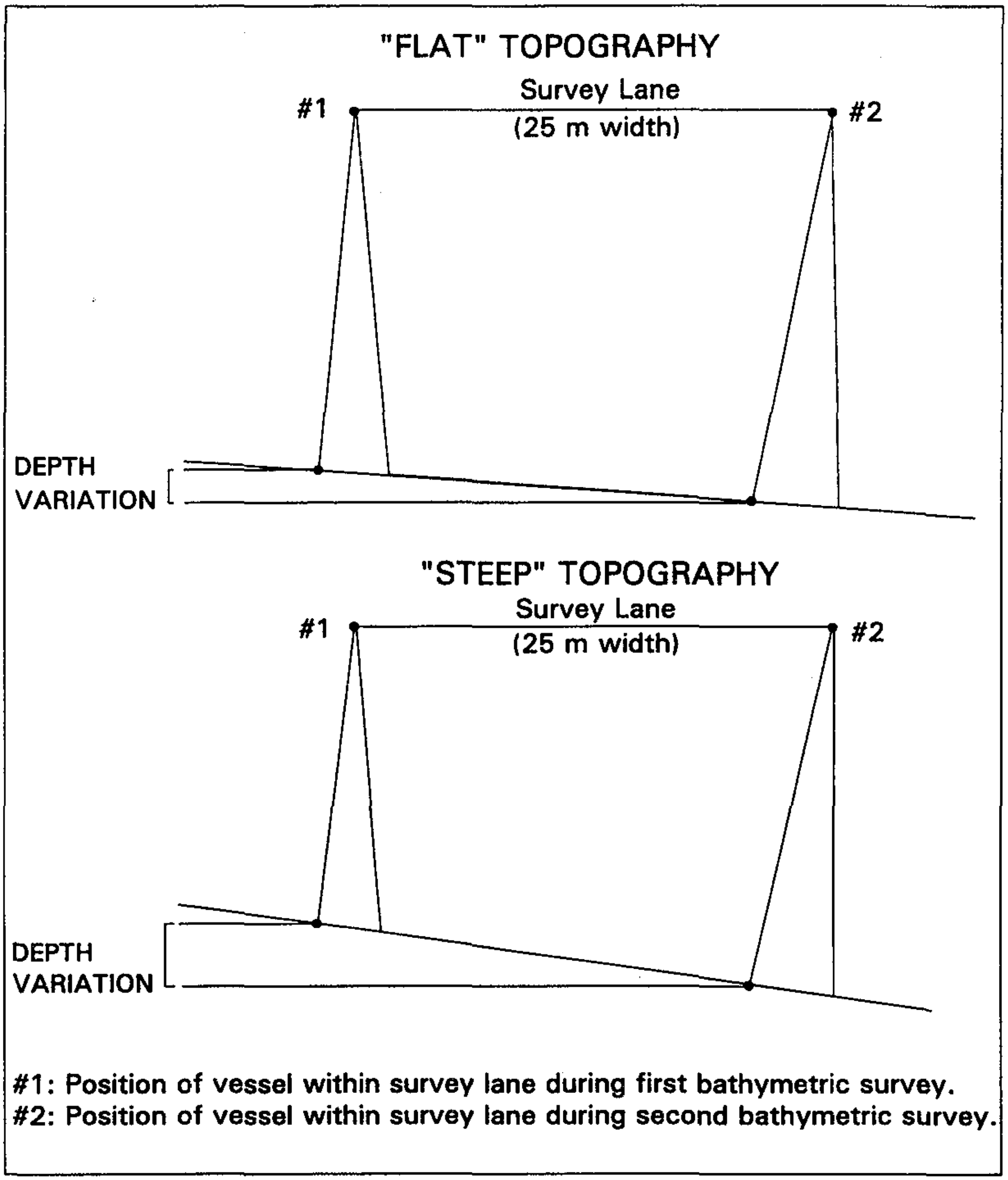
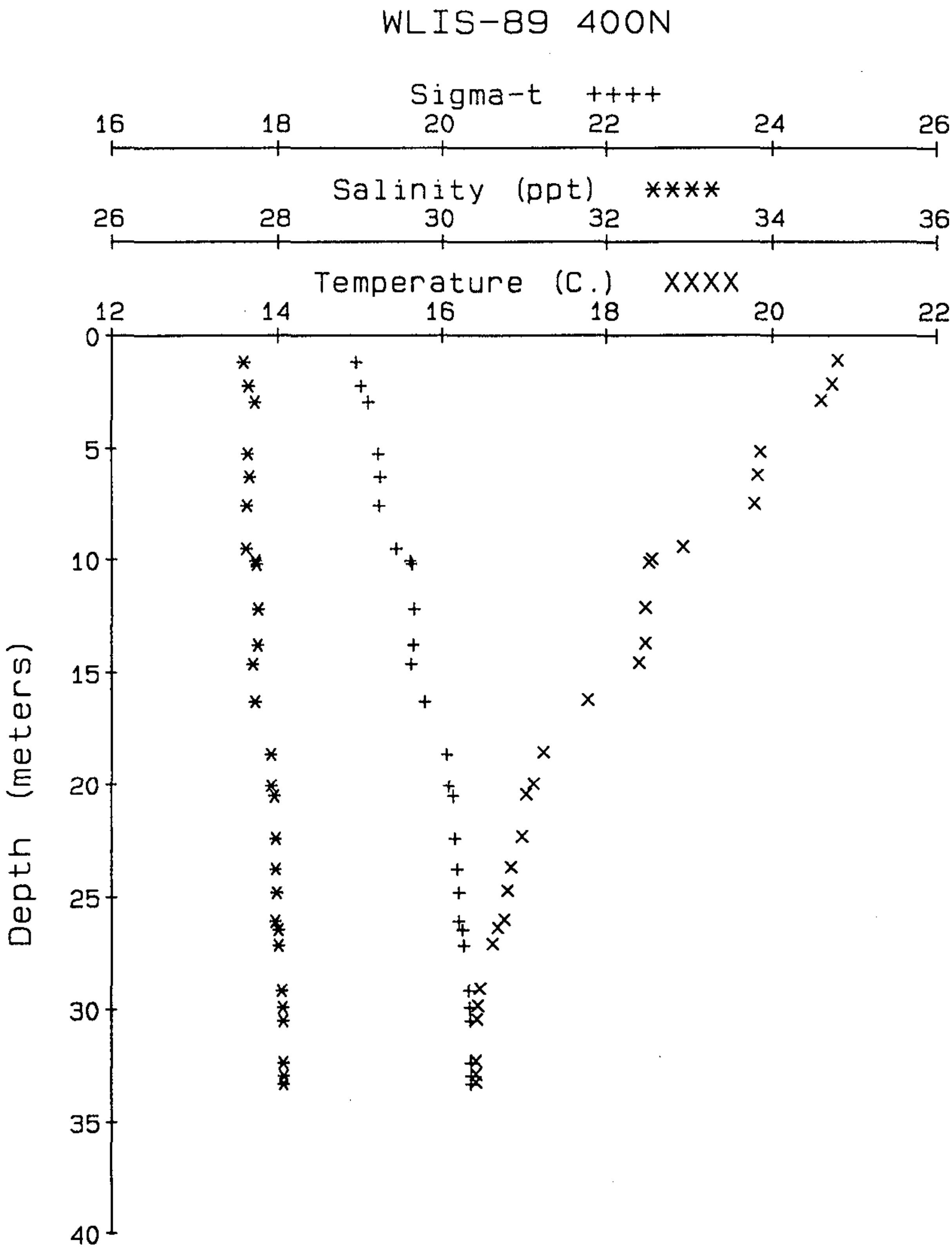
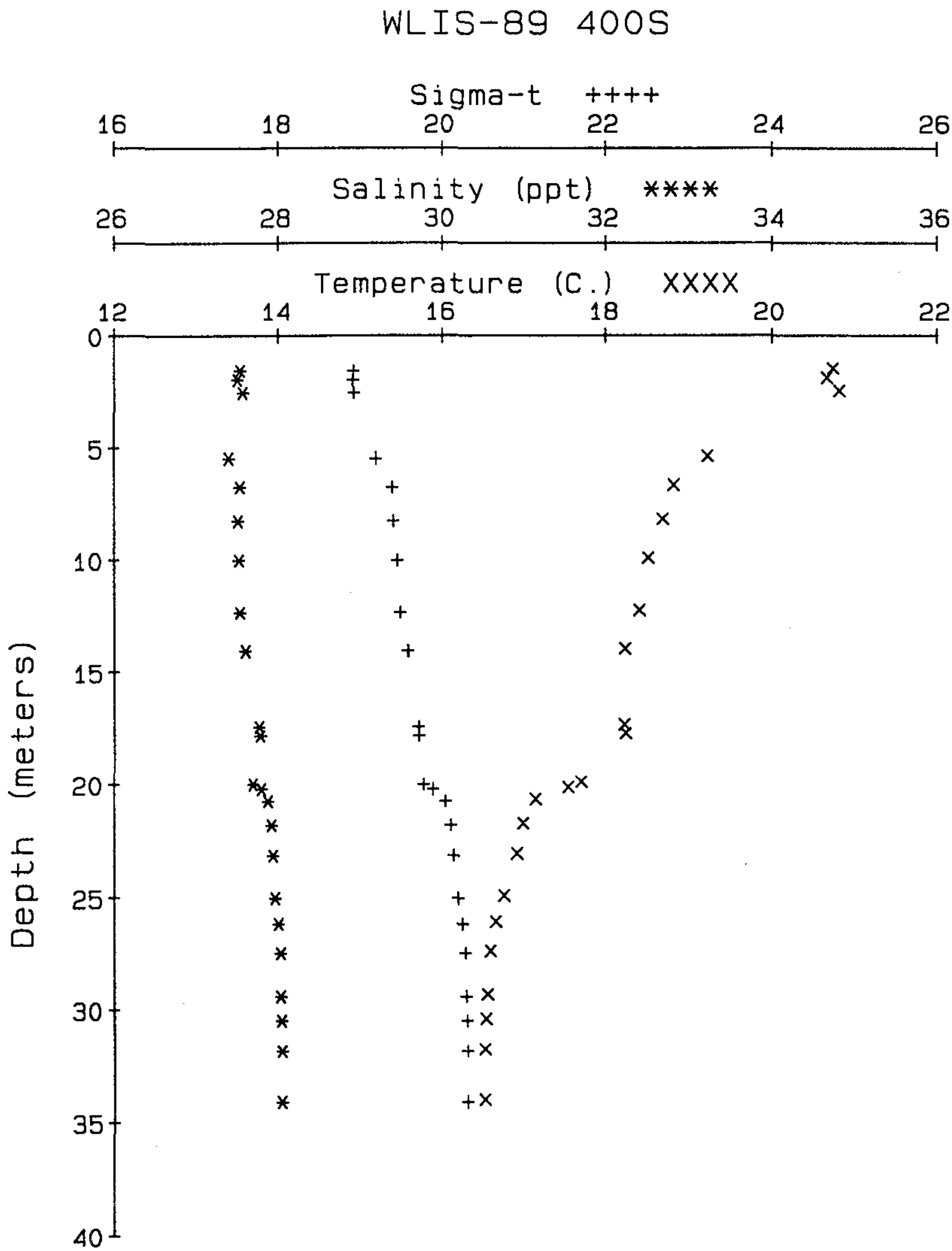
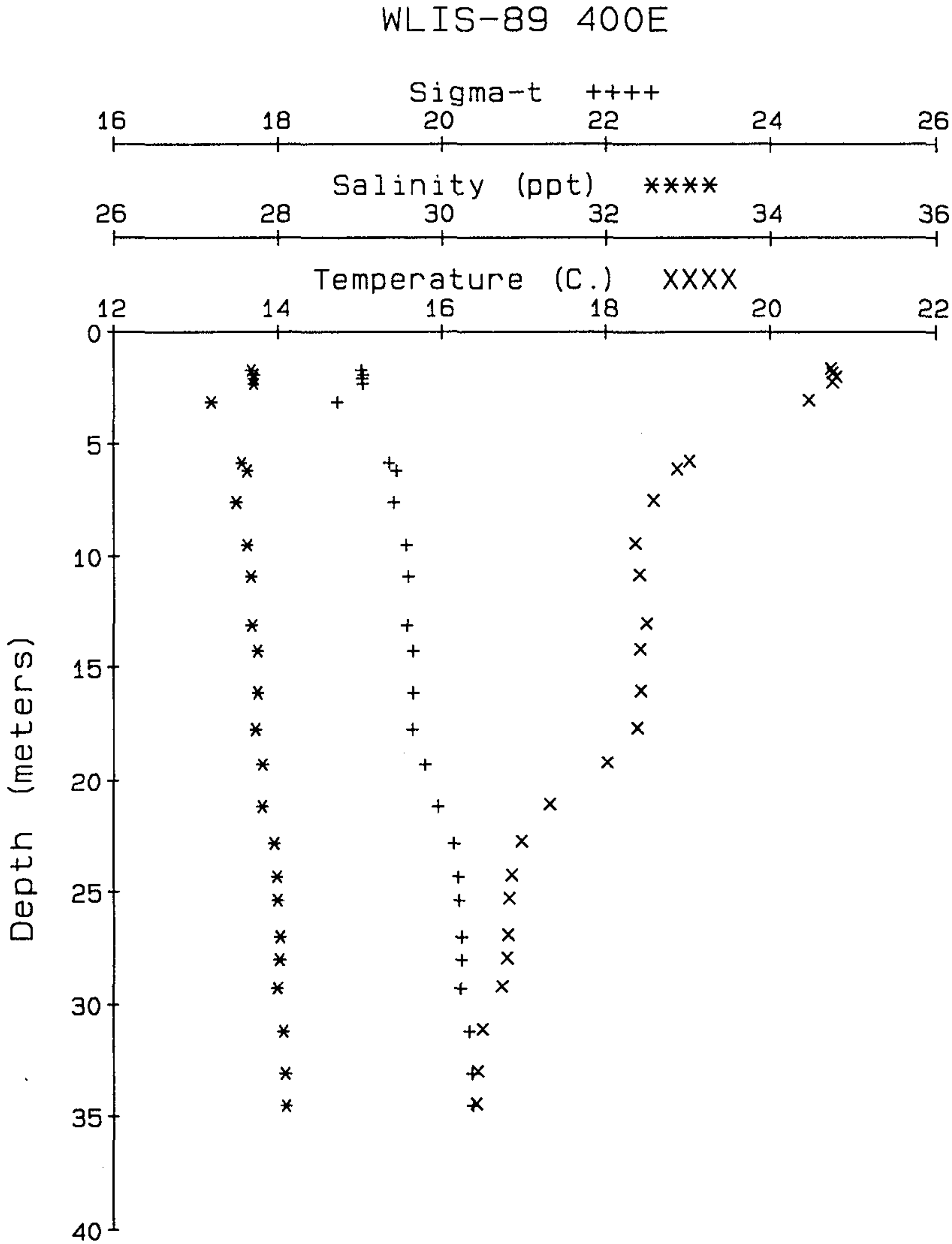


Figure 4-2. Possible variation in recorded depths within a bathymetric survey lane can increase with sloped topographies.

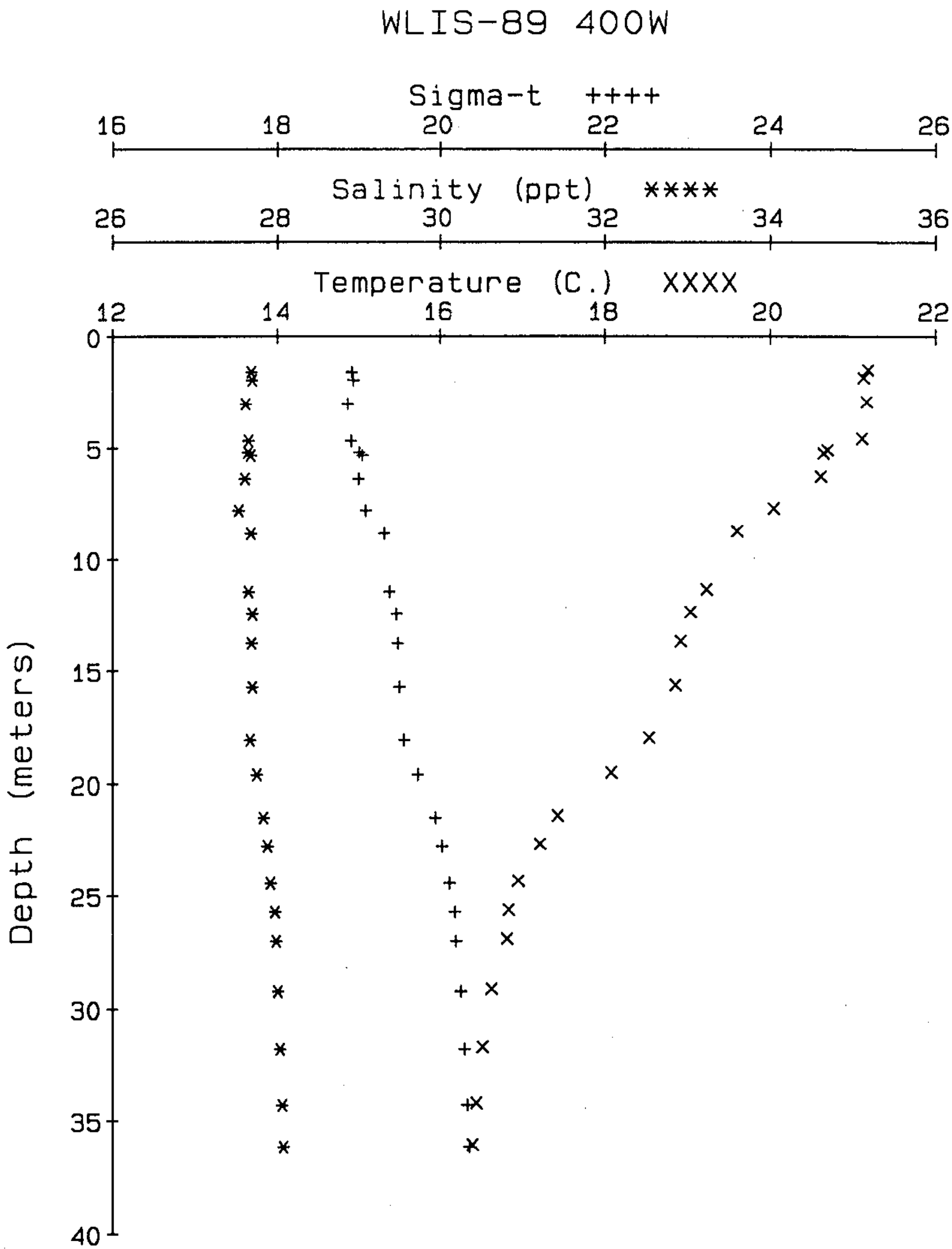
APPENDIX


WLIS-89 400N
Sigma-t ++++
16
18
20
22
24
26
Salinity (ppt) ****
26
28
30
32
34
36
Temperature (C.) XXXX
12
14
16
18
20
22
0
5
10
15
20
25
30
35
40
Depth (meters)

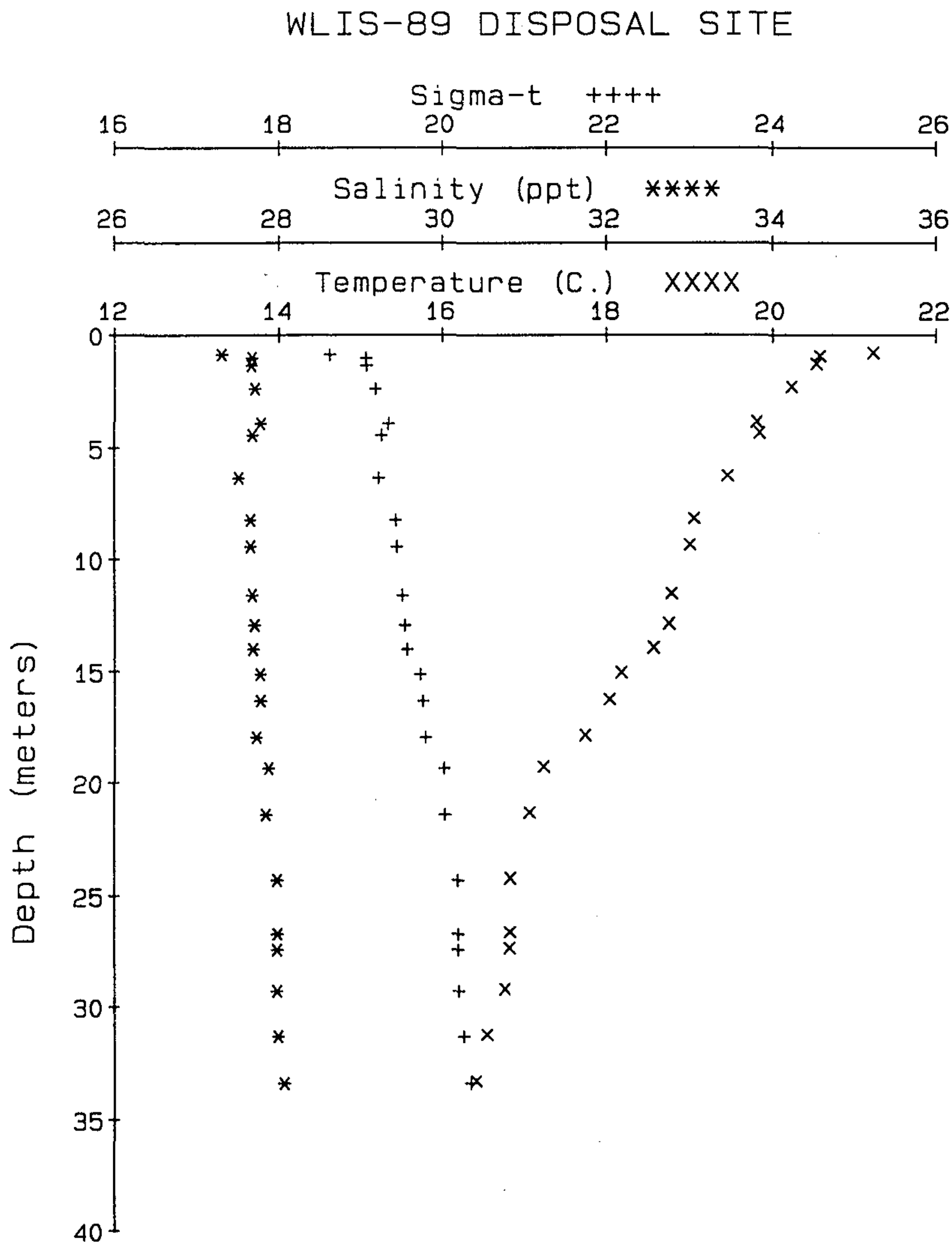

WLIS-89 400S
Sigma-t ++++
16 18 20 22 24 26
Salinity (ppt) ****
26 28 30 32 34 36
Temperature (C.) XXXX
12 14 16 18 20 22
Depth (meters)
0 5 10 15 20 25 30 35 40



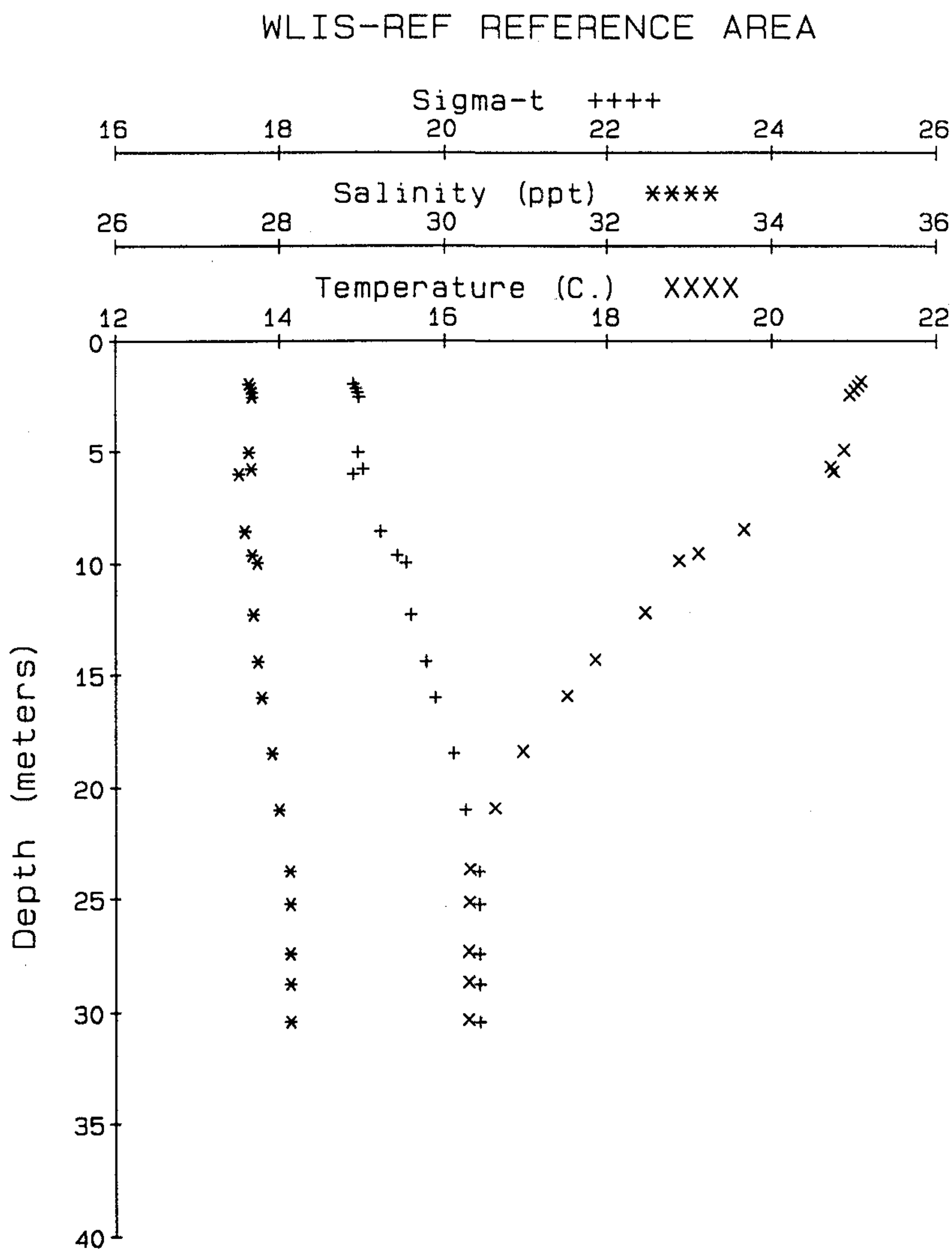
WLIS-89 400E
Sigma-t ++++
16
18
20
22
24
26
Salinity (ppt) ****
26
28
30
32
34
36
Temperature (C.) XXXX
12
14
16
18
20
22
0
5
10
15
20
25
30
35
40
Depth (meters)

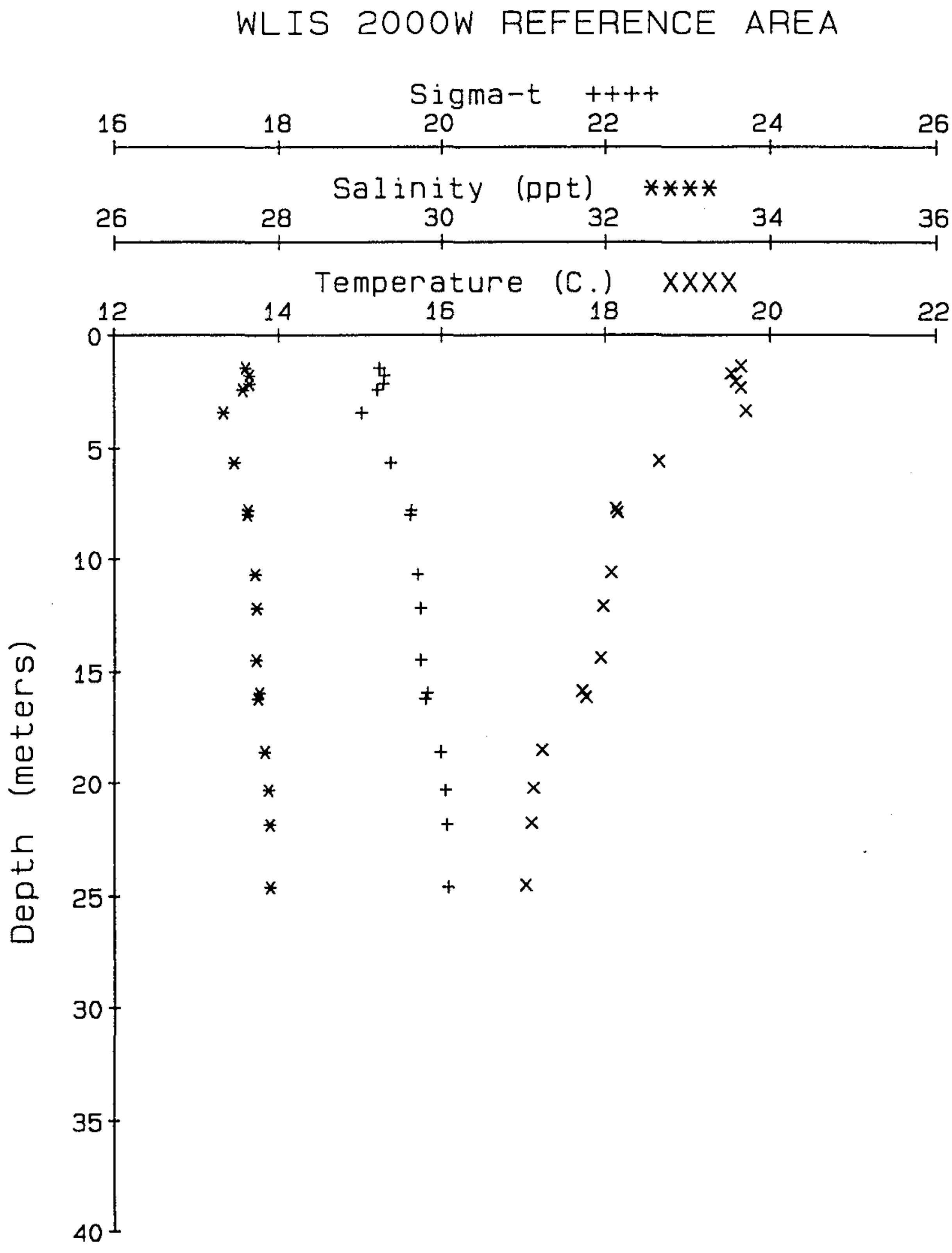


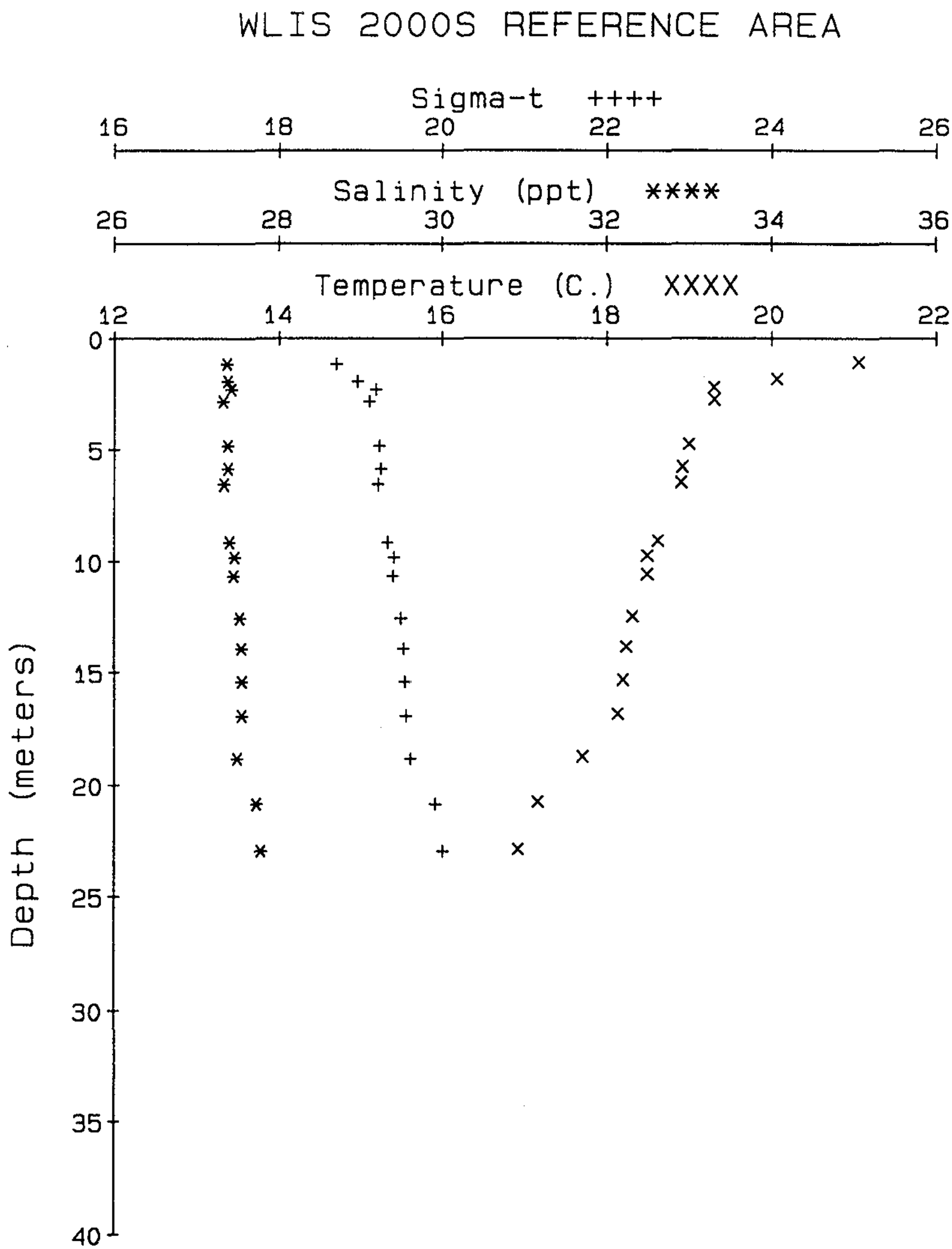
WLIS-89 400W
Sigma-t ++++
16 18 20 22 24 26
Salinity (ppt) ****
26 28 30 32 34 36
Temperature (C.) XXXX
12 14 16 18 20 22
Depth (meters)
0 5 10 15 20 25 30 35 40



WLIS-89 DISPOSAL SITE
Sigma-t ++++
16 18 20 22 24 26
Salinity (ppt) ****
26 28 30 32 34 36
Temperature (C.) XXXX
12 14 16 18 20 22
0 5 10 15 20 25 30 35 40
Depth (meters)


WLIS-REF REFERENCE AREA
Sigma-t ++++
16 18 20 22 24 26
Salinity (ppt) ****
26 28 30 32 34 36
Temperature (C.) XXXX
12 14 16 18 20 22
Depth (meters)
0 5 10 15 20 25 30 35 40


WLIS 2000W REFERENCE AREA
Sigma-t ++++
16 18 20 22 24 26
Salinity (ppt) ****
26 28 30 32 34 36
Temperature (C.) XXXX
12 14 16 18 20 22
Depth (meters)
0 5 10 15 20 25 30 35 40


WLIS 2000S REFERENCE AREA
Sigma-t ++++
16 18 20 22 24 26
Salinity (ppt) ****
26 28 30 32 34 36
Temperature (C.) XXXX
12 14 16 18 20 22
0 5 10 15 20 25 30 35 40
Depth (meters)