Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

**COASTAL AND ESTUARINE GEOLOGY**

**FILE REPORT NO. 02-01**

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# EXECUTIVE SUMMARY

The shellfish bed sedimentation study was designed to determine if impacts to the adjacent mapped Natural Oyster Bar 8-10 (NOB 8-10) resulted from the construction of the containment dike surrounding the Poplar Island Environmental Restoration Project. The study was part of a number of efforts designed to insure that construction of the containment area resulted in minimal impacts to the surrounding areas. NOB 8-10 lies immediately to the west of the construction area adjacent to the west-northwest facing portion of the perimeter dike.

The initial study design addressed the following null hypothesis: "There is no increase in sedimentation rates on the charted oyster bar during the construction of the exterior dikes at Poplar Island when compared to sedimentation rates in reference areas unaffected by dike construction." Three sites were selected from within NOB 8-10 and compared to three reference sites located in similar water depths and located well away from the construction area.

The initial study results determined that sediment mobility within both NOB 8-10 as well as the reference sites was quite high and temporally dynamic. The high mobility prevented the direct measurement of small amounts of sediment accumulation and the comparison of the study and reference areas. As a result of these observations, the study design was altered from addressing the null hypothesis to measuring greater thicknesses of sediment accumulation on NOB 8-10 itself. Measurements were made using a depth sounder and associated data was collected with a side-scan sonar unit. The sonar data were analyzed to determine bottom type across a wide area of the oyster bar and classify the bottom as sand, mud, shell, or sand covering shell.

Pre- and post-construction bathymetry,.corrected for tidal differences, showed no distinctive patterns or trends of sediment accumulation. Had sand spread outward from the dike construction it would likely have formed a thicker layer close to the dike and thinned with increasing distance. No evidence of this was apparent when the pre- and post-construction bathymetric data were compared.

Post-construction side-scan sonar records suggested that a thin layer of sand covered limited areas of shell in close proximity to the dike. Where present, the sand was apparently a few centimeters thick. Thick enough to cover some objects interpreted as oyster shell on the pre-construction side-scan survey. Although, it cannot be definitively stated that this sand was attributable to dike construction, proximity to the dike suggests that the source of the sediment was related to construction activities.

A follow up side-scan sonar survey of NOB 8-10 conducted approximately one year later showed bottom conditions similar to those that were present in the previous surveys. There was no evidence of accumulation of additional sand over oyster shells on the bar. Nor was there evidence that the sand that was over the shell on the previous survey had been removed because of proximity to the Poplar Island Environmental Restoration Project.

# INTRODUCTION

The Poplar Island Environmental Restoration Project (PIERP) is being constructed for the acceptance of fine-grained sediments dredged from the approach channels to the Port of Baltimore. A number of monitoring studies were developed during the design phase to insure that the containment area operated as anticipated and resulted in minimal ecological and environmental impacts to the surrounding areas. These monitoring efforts include studies of sediment quality, wetland vegetation, water quality, water column turbidity, and shellfish bed sedimentation. In addition, use of the site and adjacent areas by finfish and wildlife is part of the monitoring effort.

The shellfish bed sedimentation study was designed to determine if impacts to the adjacent mapped Natural Oyster Bar 8-10 (NOB 8-10) resulted from the construction of the containment dike surrounding the island restoration site. This oyster bar lies immediately to the west of the construction area adjacent to the west-northwest facing portion of the perimeter dike (Figure 1). In general, water depths ranged from less than 12 feet adjacent to the dike to over 18 feet in the northwestern-most portion of the oyster bar. Dike construction utilized the placement of a sand containment berm behind a rock facing for shoreline erosion protection. The potential for identifying any movement of sand from the perimeter dike over NOB 8-10 during the construction phase was the object of the monitoring effort in this report.

The initial project design was modified part way through the monitoring study as a result of a reevaluation of the natural site conditions and the inability to identify any accumulation of sand on the oyster bar compared to reference sites. The stages of study are outlined in more detail in the main body of the text.

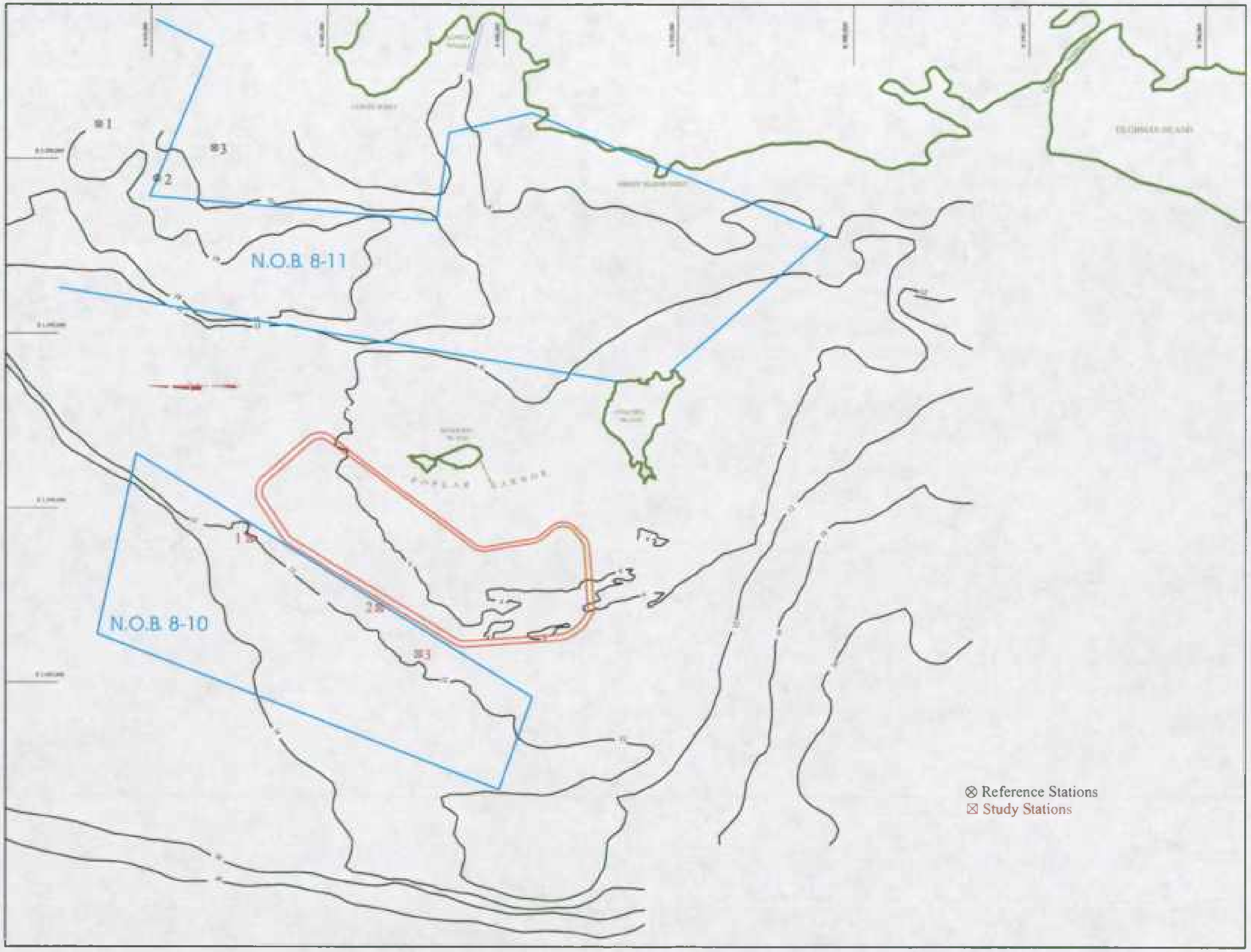


Figure 1: Natural Oyster Bar 8-10(blue boundary) and the adjacent Poplar Island Restoration Project dikes outlined in red. The initial study stations within NOB 8-10 are shown by red squares and the reference stations (in and adjacent to NOB 8-11) shown by black circles.

## BACKGROUND AND METHODOLOGY

In the initial study design, sediment accumulation within NOB 8-10 was to be compared to a reference site in an effort to address the following null hypothesis: "There is no increase in sedimentation rates on the charted oyster bar during the construction of the exterior dikes at Poplar Island when compared to sedimentation rates in reference areas unaffected by dike construction." Three sites were to be selected from within NOB 8-10 and compared to three reference sites. The reference area was to be located in waters of similar depth to the sites established within NOB 8-10, and on a shoreline with similar geomorphic characteristics and orientation. These sites were to be located well outside any zone of influence of sediment plumes emanating from the dike construction area. The selected reference area was located off Lowes Point, Talbot County, Maryland in water depths similar to those within NOB 8-10, east of the construction area and separated from it by the deeper waters of Poplar Island Narrows (Figure 1).

An initial acoustic remote sensing site survey was conducted in March 1997 over the entire extent of NOB 8-10 and the reference area using side-scan sonar and sub-bottom profiling equipment. The system utilized was a combined Edgetech Chirp Sub-Bottom Profiler and Side-scan Sonar system. The sub-bottom system operated across a frequency range of 2 kHz to 15 kHz with a pulse length of 5 milliseconds. Generally, sub-bottom records were obtained up to 2 to 6 meters below the sediment water interface. The side-scan survey system was operated at 100 kHz, and was set to survey a swath 75 meters to either side of the boat track. All equipment was interfaced to a DGPS system for navigation. The side scan results were digitally mosaiced to provide a complete image of NOB 8-10. These data were utilized in site selection for the sediment accumulation study in both the oyster bar and the reference study area.

On August 5 and 6, 1998 the locations for the sedimentation study were identified and marker horizons were established at three separate sites within NOB 8-10 and at three reference sites located northwest of Lowes Point. No construction along the western dike had occurred at that point in time and the sites were established to determine natural conditions prior to construction activities. Each site was marked with two buoys tethered to stakes driven into the bottom. Two additional stakes without buoys were driven into the bottom adjacent to the buoyed stakes to provide markers in the event that the buoys and their anchoring stakes are pulled from the bottom. At each site two flat plastic plates, 6 cm in diameter were affixed to the sediment and a thin Dacron line was stretched along the bottom between these plates. The line provided a readily observable marker for spreading 50 pounds of brightly colored sand on the bottom. Visibility was limited to between 30 cm and 130 cm, necessitating the placement of the bottom line to provide guidance in the distribution of the colored sand. The sand covered area was estimated to be 3 meters long by 1-1.5 meters wide at each site. The location of each site was established with differential GPS on the surface vessel and checked twice during the operations period. The location information and water depth for each site are noted in Table I.

**Table I:** Location and characteristics of sedimentation measurement sites.

| Site ID | Latitude (NAD 83) | Longitude (NAD 83) | Water Depth (m) | Bottom Type |
|---|---|---|---|---|
| NOB 8-10 #1 | 38° 46.986' | 76° 22.788' | 4.08 | Fine sand with some shell hash & cobbles |
| NOB 8-10 #2 | 38° 46.382' | 76° 23.212' | 2.71 | Fine sand |
| NOB 8-10 #3 | 38° 46.202' | 76° 23.488' | 3.32 | Very fine sand, some shell hash & cobbles |
| Reference #1 | 38° 47.681' | 76° 20.285' | 5.46 | Very fine sand |
| Reference #2 | 38° 47.412' | 76° 20.614' | 4.63 | Very fine sand, some shell hash |
| Reference #3 | 38° 47.142' | 76° 20.433' | 3.41 | Fine sand, some shell hash |

The original study design dictated periodic returns to the sites to collect sediment cores that could be examined to identify the location of the marker horizon. The thickness of any sediment that accumulated over the horizon could be measured to provide an indication of the rate of accumulation. In addition, the amount of sediment that accumulated on the sedimentation plates could be directly measured to provide an independent indication of the sedimentation rate.

On September 11, 1998, all the locations for the study were revisited to determine the conditions of the sites and measure sediment accumulation since the sites were established on August 5 and 6, 1988. This scheduled return one-month after site establishment was part of the original sampling plan to determine sediment accumulation under natural conditions and prior to construction of the adjacent dike.

Observations indicated that bottom sediment mobility at all of the sites was very high in the month since they were established. At all of the sites, both on NOB 8-10 and the reference area, the marker sand horizon was completely mixed into the surrounding, natural sediment and was no longer visible at the surface. A core was collected only at the first site visited (Reference Site #2) and it was observed that the marker sand was completely mixed into the upper 8 cm of the recovered sediment. The marker sand did not maintain integrity as a measurable horizon at this site. Upon visiting the remaining sites, it was determined that at none of them did the marker sand remain as a distinct horizon and no further cores were collected. Diver observations confirmed that the marker sand was completely mixed into the existing natural sediment at all the sites and had lost integrity as a marker horizon.

Measurements were made of the amount of sediment that had accumulated on the bottom plates at each of the sites. These measurements indicated that at each of the sites the amount of sediment accumulation was highly variable even though the plates were located only 3 meters apart at each site. Sediment accumulation on the plates commonly varied from 0 to 2 cm thick at any site. Bottom sediment mobility was so high that at three of the sites one of the plates was partially covered with sediment and partially left uncovered. On these three plates the sediment, where present, was up to 2 cm thick, even though the plates were only 6 cm in diameter. Thus, the variability across one plate was equivalent to the variability observed across all of the sites that were established. This precluded conducting a statistical analysis comparing sedimentation within NOB 8-10 and at the reference sites off Lowes Point.

The bottom characteristics at NOB 8-10 Study site #3 had changed completely between August and September. In August, approximately 1-2 cm of fine to very fine sand was in place at the site overlying a relatively hard light gray to white clay that was firm and immobile. This clay was determined to be mid-Pleistocene age consolidated sediment that had accumulated in a previous incarnation of the Chesapeake Bay (Owens and Denny, 1986; Colman and Halka, 1989; Colman et al., 1990). In September, all of the fine sand had been removed from the site and the underlying sediment was exposed at the surface. The normal wave and current conditions in the one-month period from August 6 to September 11 had completely removed the overlying sandy sediment.

As a result of these observations and measurements made prior to dike construction it became apparent that the assumptions under which the original study was designed were not appropriate to the conditions at the site.
Specifically:

- Sediment mobility within both NOB 8-10 as well as the reference site was quite high and temporally dynamic. This fact precluded the use of marker horizons or sedimentation plates for measuring sedimentation rates and statistically comparing the sites.

- The study design was established to determine if relatively small amounts of additional sediment (on the order of a few millimeters), attributable to the construction activities, would have an adverse effect on the oysters within NOB 8-10. The sediment mobility in both NOB 8-10 and the reference sites was an order of magnitude larger than that assumed to effect oyster viability.

Because natural sediment mobility at the sites resulted in more than a few millimeters of sediment accumulation over short time scales, the study design was altered from the attempt to measure relatively small amounts of sediment accumulation, to measuring a greater thickness of sediment accumulation. The methodology utilized was the collection of high-resolution bathymetric data at the sites as well as additional side-scan sonar data.

Additional cruises were conducted to NOB 8-10, preceding and following the construction of the westernmost dike at the Poplar Island Habitat Restoration Project. On these cruises only that portion of NOB 8-10 that was located immediately west of the dike construction area was surveyed because that portion was deemed most likely to be impacted by sediment derived from the construction. The pre- and post-construction surveys were conducted on 14 January 1999 and 10 June 1999. On these survey dates high-resolution bathymetry and side-scan sonar data were collected.

Track lines running northeast to southwest were established for bathymetric surveying. Track lines were spaced 50 m (164 ft) apart near the construction area and increased in spacing to 100 m (328 ft) apart at the westerly extent of the study area. Track lines were surveyed prior to berm construction operation in order to establish a baseline record of the bottom. The post-construction survey was scheduled as soon as possible after berm construction was completed in order to establish the initial spatial extent, thickness, and volume of any material that may have impacted the site. The location of the surveyed area within NOB 8-10 is shown by the track lines on Figures 2 and 3.

Bathymetric data were collected using a Magnavox 300 survey-grade DGPS and a Furuno FCV-598 Echo sounder. DGPS corrections broadcast by the United States Coast Guard provided a horizontal accuracy of 2-5 meters. Horizontal position was recorded in Maryland State Plane Coordinate System (MSPCS) in meters based upon the North American Datum of 1983 (NAD83). The echo sounder generated repetitive acoustic pulses, ten soundings per second, at 198 kHz for bottom recognition. The acoustic wave was reflected off the density gradient separating the water column from the bottom sediment. The reflections were then filtered and integrated within the Echo sounder to produce a measurement from the transducer to the water/sediment interface every two seconds. A data point was collected approximately every 6 meters along the survey track lines, at an average vessel speed of 6 knots. Bathymetry and positioning data were logged to a personal computer at a rate of one point every two seconds. Both the DGPS and the Echo sounder were checked against known horizontal and vertical measurements before and after each survey.

The depth data were referenced to mean lower low water (MLLW) at the Kent Point tidal gauge location for the tidal epoch of 1960-1978. This station is maintained by NOAA/NOS (station ID# 8572467). The depth data were adjusted by using tide data from the tide station, recorded at six-minute intervals, and subtracting the tide level from the bathymetric data collected during the same time interval. Incorporated into the tidal adjustments was a 20-minute offset from Poplar Island to Kent Point. The practical resolution of the post-processed bathymetric data is $\pm$ 10 cm. This resolution is sufficient only for identifying relatively thick accumulations of sediment.

The side-scan sonar system utilized in this phase of the study was an EG&G Model 260TD, operated at a 100 kHz frequency with a swath width of 25 m to each side of the vessel track. The unit was interfaced to the DGPS and the results output to a paper recorder. This unit did not have digital mosaicing capabilities. The side-scan sonar was utilized to provide ancillary information to determine if bottom sediment types changed in the surveyed areas. The side-scan results obtained in March 1997, prior to construction, demonstrated the suitability of this acoustic technique for distinguishing sand from shell bottom on NOB 8-10. A change from shell bottom prior to construction

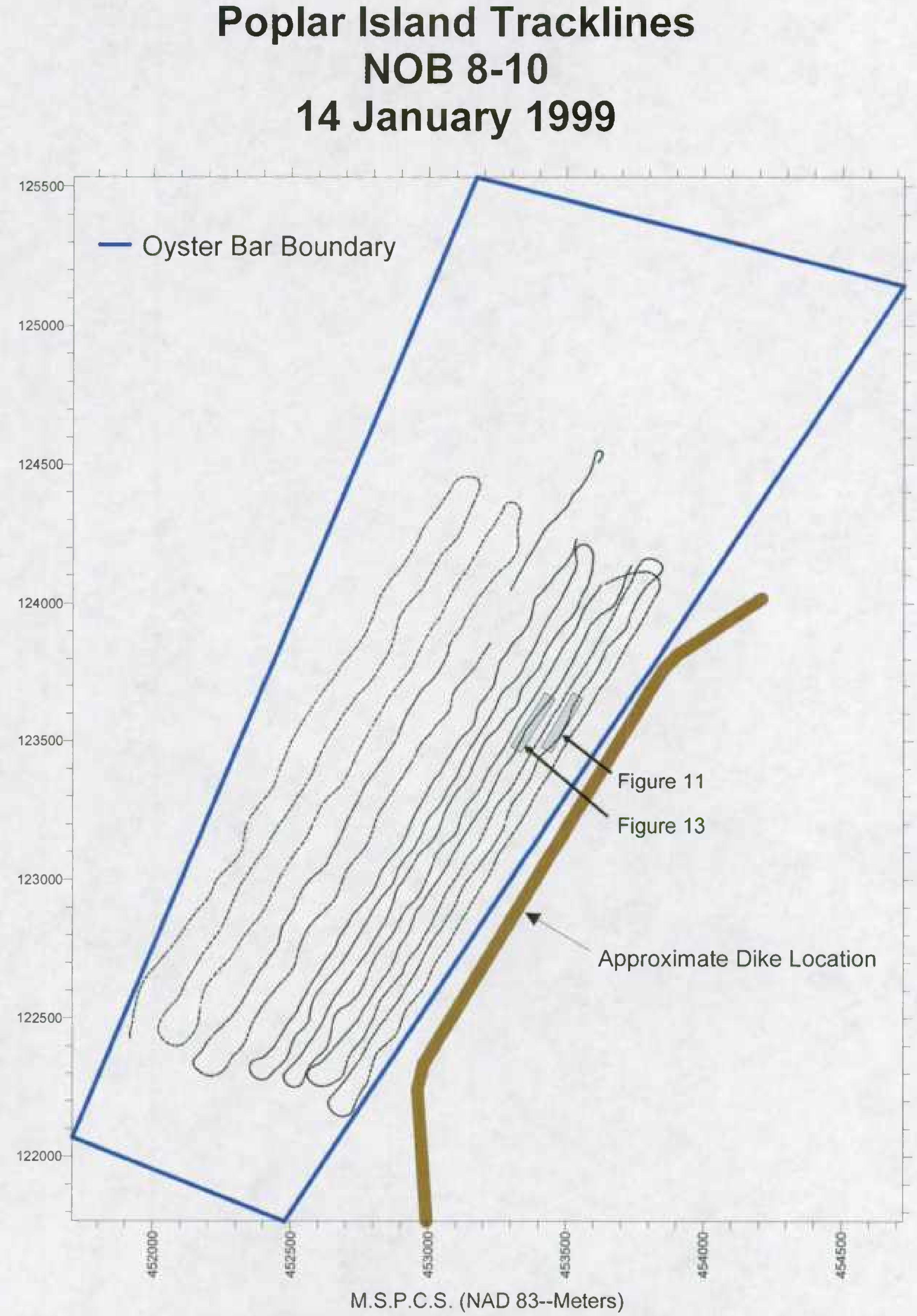


Figure 2. Data points collected during bathymetric surveying on 14 January 1999. Shaded boxes highlight the sidescan areas depicted in Figures 11 and 13. Note that the dike location is shown for reference only, survey was conducted prior to dike construction.

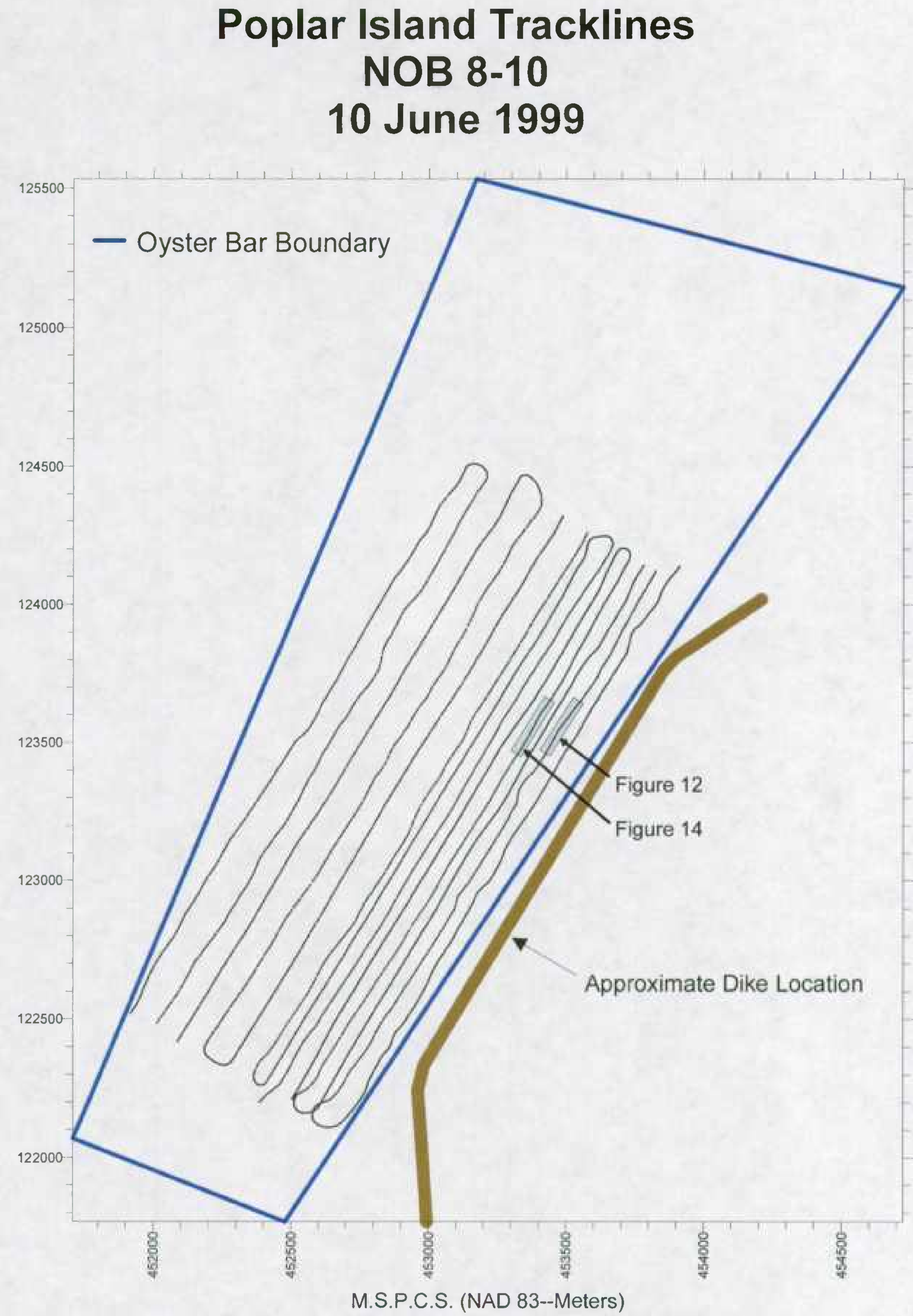


Figure 3. Data points collected during bathymetric surveying on 10 June 1999. Shaded boxes highlight the sidescan areas depicted in Figures 12 and 14.

to a sand bottom following construction would be evident on the side-scan records collected prior to and following the construction activities.

An additional side-scan sonar survey was conducted on August 15, 2000, more than one year following completion of dike construction. This survey utilized a Klein 2000 side-scan unit operating at a frequency of 100 kHz and interfaced to a DGPS, with the same basic methodologies as the previous surveys. This survey was conducted to assess if additional changes in sediment accumulation on NOB 8-10 could be detected over the one-year period following construction. All of NOB 8-10 was surveyed on this date and the results were mosaiced. Water column turbidity and surface waves resulted in acoustic data that were not as high quality as the previous survey dates.

# RESULTS

## INITIAL SIDE-SCAN SURVEY

The initial side-scan sonar survey of NOB 8-10 was conducted in March 1997 to establish bottom acoustic reflectance characteristics prior to any construction activity at the PIERP site. A full digital mosaic of the results was prepared by the U.S. Naval Research Laboratory and presented in Figure 4. One purpose of this survey was to identify sites within the mapped oyster bar that could be utilized for the placement of the marked sand horizons and the sedimentation plates. As noted previously, this initial study methodology was abandoned and replaced with pre-and post-construction bathymetric comparisons. However, examination of Figure 4 provides an overview of the variations that exist within the limits of NOB 8-10 and some indication of the natural sediment movement processes that operate on the relatively shallow platform located west of the Poplar Island Environmental Restoration Project.

The sediments on the Bay bottom west of Poplar Island consist of medium to fine grain sands (Kerhin et al., 1988), which cover a relatively shallow platform. The large fetch to the north and south combined with the prevailing westerly wind directions result in significant waves being generated over this platform. These conditions have contributed to the historical erosion rate experienced by Poplar Island (U.S. Army Corps of Engineers, 1996).

Sea level has been rising in the Chesapeake area for approximately the last 18,000 years as the major continental glaciers retreated. This rise combined with wave action is the major contributor to shoreline erosion and the associated expansion of Chesapeake Bay. As the waters rose over the lands surrounding what is now Poplar Island erosion of the unconsolidated sediments occurred to the basal level of wave activity. This erosion resulted in a sub-aqueous platform with a relatively flat, planar characteristic, dipping to the west from Poplar Island. During the process of erosion, the finer grained constituents of the eroded sediments were suspended by the wave energy and removed from the area. Left behind was a relatively coarser lag deposit consisting of sand sized materials. These sands presently form a thin sheet of sediment that overlays the surface that was eroded by wave action during sea level rise. The sands continue to be mobilized by wave action across the shallow Poplar Island platform.

On Figure 4, the limits of NOB 8-10 are shown by the blue line surrounding the mosaic image produced from the side-scan sonar survey. Significant features are identified on Figure 4. The interpretation of the bottom characteristics identified on the figure was verified by diver observations conducted in August and September 1998 during placement of the marker beds and sedimentation plates. In a side-scan record, the amount of incident acoustic energy that is reflected back to the sensor is recorded as varying shades of gray. Lighter shaded areas do not reflect much energy back to the sensors while much energy returns from darker areas on the record.

Hard sand bottom and/or the exposed underlying sediments reflect much of the acoustic energy generated by the side-scan sonar equipment. If the bottom is smooth and flat, or facing away from the side-scan unit, the record will appear lighter because much of the incident energy is reflected off the firm surface and away from the equipment sensors, much like light off a mirror. Conversely, if the sandy or hard surface faces toward the side-scan unit the more energy is reflected back toward the sensors and the surface has a darker appearance. Much of the western side of NOB 8-10, as well as the southeastern and northeastern corners, are identified as consisting of a predominantly sandy bottom. In the southern portion of the mapped oyster bar, the darker areas are identified as locations where the sandy sediments have been stripped by wave action from the erosion surface and the underlying harder sediments are exposed.

Bottom areas consisting predominantly of mud will generally reflect an intermediate amount of acoustic energy back to the side-scan sensors and will result in an intermediate gray coloration on the output print. Because muddy bottom areas are generally smooth and flat, there is generally little variation in the tonal characteristics of these areas on side-scan records. The northwestern portion of the surveyed area is interpreted to be a bottom consisting of mud or muddy sands. A number of darker narrow sinuous features are evident in this area and are interpreted to represent locations where oyster dredges were dragged across the bottom. The relatively cohesive nature of the muddy sediments served to preserve these drag marks or "scars" on the bottom.

Across much of the center of Figure 4, the bottom is relatively dark with small areas exhibiting irregular levels of reflectivity. This area was interpreted to consist predominantly of oyster shell lying on the surface. The irregular orientation of the shells on the bottom results in variable amounts of incident energy being reflected back to the side-scan sensors. This results in high variability of gray shades in areas covered by shell. No dredge marks are evident within the area. This is probably due to the fact that any dredge marks would not be distinguishable within the variable reflectively of the surrounding shell. The variable gray levels apparent over much of the area covered with shell are due to both micro scale and macro scale irregularities. On a micro scale, each shell on the bottom has a separate orientation, which results in more or less energy being reflected back to the side-scan unit. On a macro scale there is significant elevation differences across the central portion of NOB 8-10.

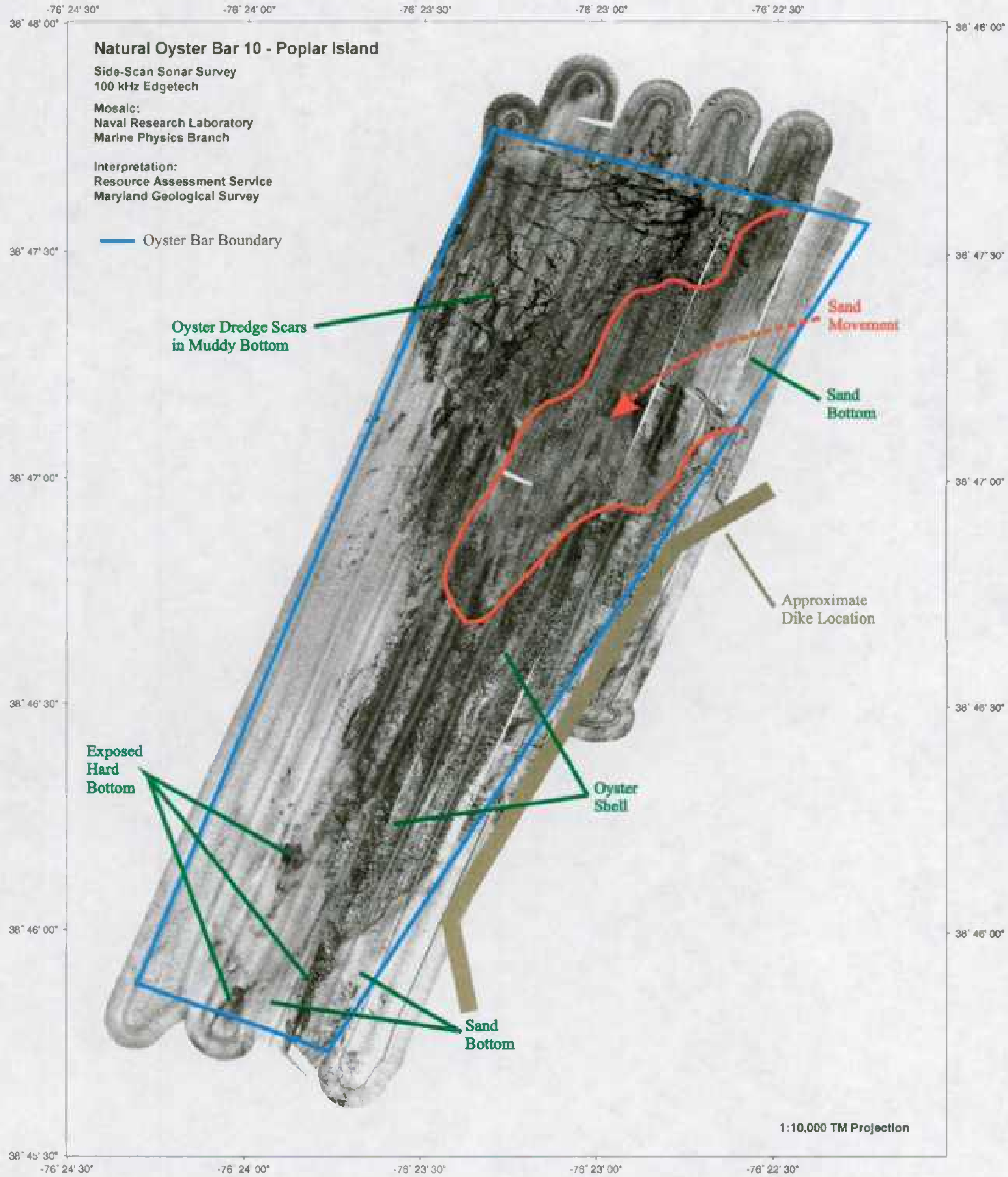


Figure 4: Side-Scan Sonar mosaic of N.O.B. 8-10 surveyed in March 1997, prior to construction activities at the Poplar Island Restoration Project. See text for details of interpretations shown. Note that the dike location is shown for reference only, survey was conducted prior to dike construction.

Figure 5 shows a bottom trace collected from the sub-bottom profiling unit in March 1997. The highly irregular bathymetry present across the center of this figure is the area covered by oyster shell. As with individual shells, areas where the slopes face the side-scan unit will return much of the incident acoustic energy and result in a darker area on the printed record. Areas that face away from the unit will return correspondingly less energy resulting in a lighter record. Some of the steep small bathymetric changes exhibited in Figure 5 may have been produced by oyster dredging activities on the oyster bar. Shell planting operations conducted by the Department of Natural Resources-Fisheries Service could have also resulted in irregular water depths (C. Judy, personal communication).

An interesting characteristic identified on Figure 4 was the relatively even shaded yet dark area located at the northeast corner of the mapped oyster bar. This area is darker than the muddy sediments in the northeastern corner, and does not show evidence of dredging activities. Tonal variations within the area are more gradual than either the muddy or the sandy areas described previously. This area was tentatively identified as an area where sands had moved across and covered oyster shell located on the bottom. Diver examination in the summer of 1998 confirmed this hypothesis. The area was relatively smooth with a 2-3 cm thick layer of sand overlying and completely covering oyster shells. This area is approximately outlined in red on Figure 4 and is labeled as "sand movement". The orientation and extent of the area suggests that the source of the sand sized sediments was located to the northeast of NOB 8-10. Apparently, waves and currents in the area were sufficiently strong to enable transport of a significant amount of sand across the oyster shells on the bottom. Whether or not this transport of sediment is continuous of intermittent, or if under some conditions the sands are removed from the bar is not known. Diver observations confirmed that the sand was still present in the area in August 1998, one and one-half years after the side-scan data shown on Figure 4 was collected. It should be noted that the movement of this sand occurred under natural conditions before any construction had begun at the Poplar Island Environmental Restoration Project.

## PRE- AND POST-CONSTRUCTION BATHYMETRIC SURVEYS

The bathymetric data collected on 14 January 1999 along the tracklines shown in Figure 2 is shown in Figure 6. As noted previously, the entire oyster bar was not surveyed during this part of the study because sandy sediment movement that directly resulted from the dike construction was anticipated to be limited to the area immediately adjacent to, and down slope from, the westernmost dike. Water depths in January were shallowest along the eastern side of NOB 8-10 where they ranged between 3 and 4 meters deep. Moving westward, depths increased relatively quickly to 5 meters and in the center of the surveyed area ranged between 5.5 and 6.0 meters deep. In the extreme northwest portion of the surveyed portion, depths were over 6 meters, as were two isolated depressions in the north and south central sections of the area. The irregular characteristic of the 5.5 meter contour in the center of the surveyed area indicates the rough nature of the bottom in the shell covered portion of the bar, as was also shown on Figure 5.

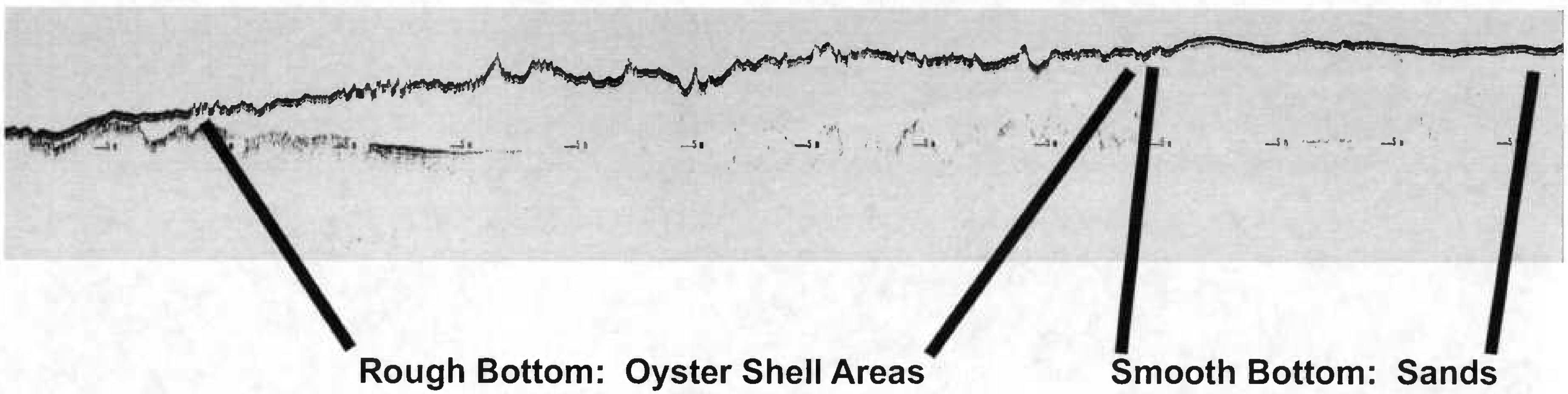


Figure 5: Example of bathymetric trace across N.O.B. 8-10 showing distinction between areas covered by oyster shells that have a rough bottom character, and areas covered by sand that exhibit a smooth character.

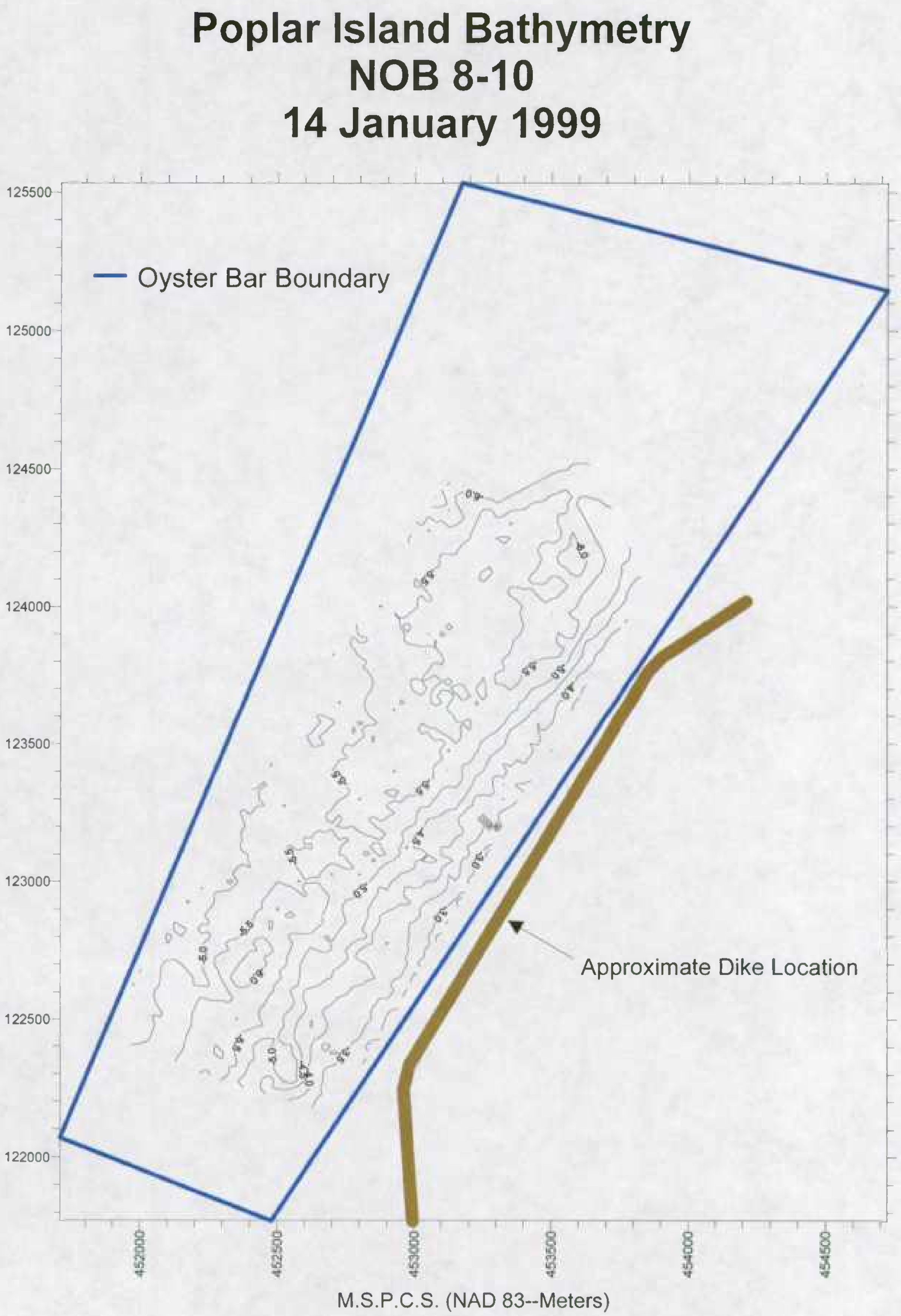


Figure 6: Bathymetry collected in the central portion of N.O.B. 8-10 on 14 January 1999. Contours in 0.5 meter intervals. Note that the dike location is shown for reference only, survey was conducted prior to dike construction.

Figure 7 shows a smoothed three-dimensional view of the area surveyed on 14 January 1999. The relatively shallower area to the east (right) side of the figure slopes quickly to the deeper area in the center of the figure. Depths are somewhat shallower on the west (left) side of the figure. The irregular nature of the bathymetry is clearly exhibited by this figure.

The post-construction survey was conducted on 10 June 1999 along the track lines shown in Figure 3. Both the resulting bathymetric contour map (Figure 8) and the smoothed 3-dimensional view (Figure 9) are similar to the pre-construction survey (Figures 6 and 7). Overall, water depths remained the same with similar morphology on both the pre- and post-construction surveys. The isolated, roughly circular "bumps" evident on the bottom on Figure 9 most likely resulted from surveying over the numerous crab pots located in the area in June. They may also have been the result of the presence of schools of fish near the bottom, or isolated construction debris or stones that were present on the bottom, but none of these possibilities was deemed likely.

A comparison of the bathymetric data collected on the two dates is shown in Figure 10. The contour interval on this figure is 20 cm, and the minimum areas of change are shown as $\pm$20 cm. Resolution of the bathymetric data was given in the Methods section as $\pm$10 cm for any one survey. The resolution between two survey dates is twice that for a single date, or $\pm$ 20 cm. It is not possible to identify differences of less than this amount between surveys. It is evident that over the entire area surveyed there is no evidence of a continuous accumulation of sediment in excess of this amount. Areas of greater change are present either as isolated mounds (positive values) or depressions (negative values). Depth changes located near the sides of the surveyed area have less credibility due to an "edge effect" that results from the fact that there is no bathymetric data present beyond the surveyed area and the gridding algorithms utilized in the data analysis add a degree of uncertainty in these areas. Most of the isolated areas with positive values shown in Figure 10 resulted from the presence of crab pots on the bottom in June. The isolated and roughly circular characteristics of most of the areas of depth range change shown on Figure 10 is partially due to the irregular bathymetry (Figure 5) that exists across much of the shell covered portions of the bar (Figure 4). Slight variations in vessel track between the two survey dates can result in quite different depth readings in areas with steep, short slopes. These areas will, however, not appear as continuous zones of depth change but as isolated features resulting from the small variations in boat track and associated depth readings between the two dates.

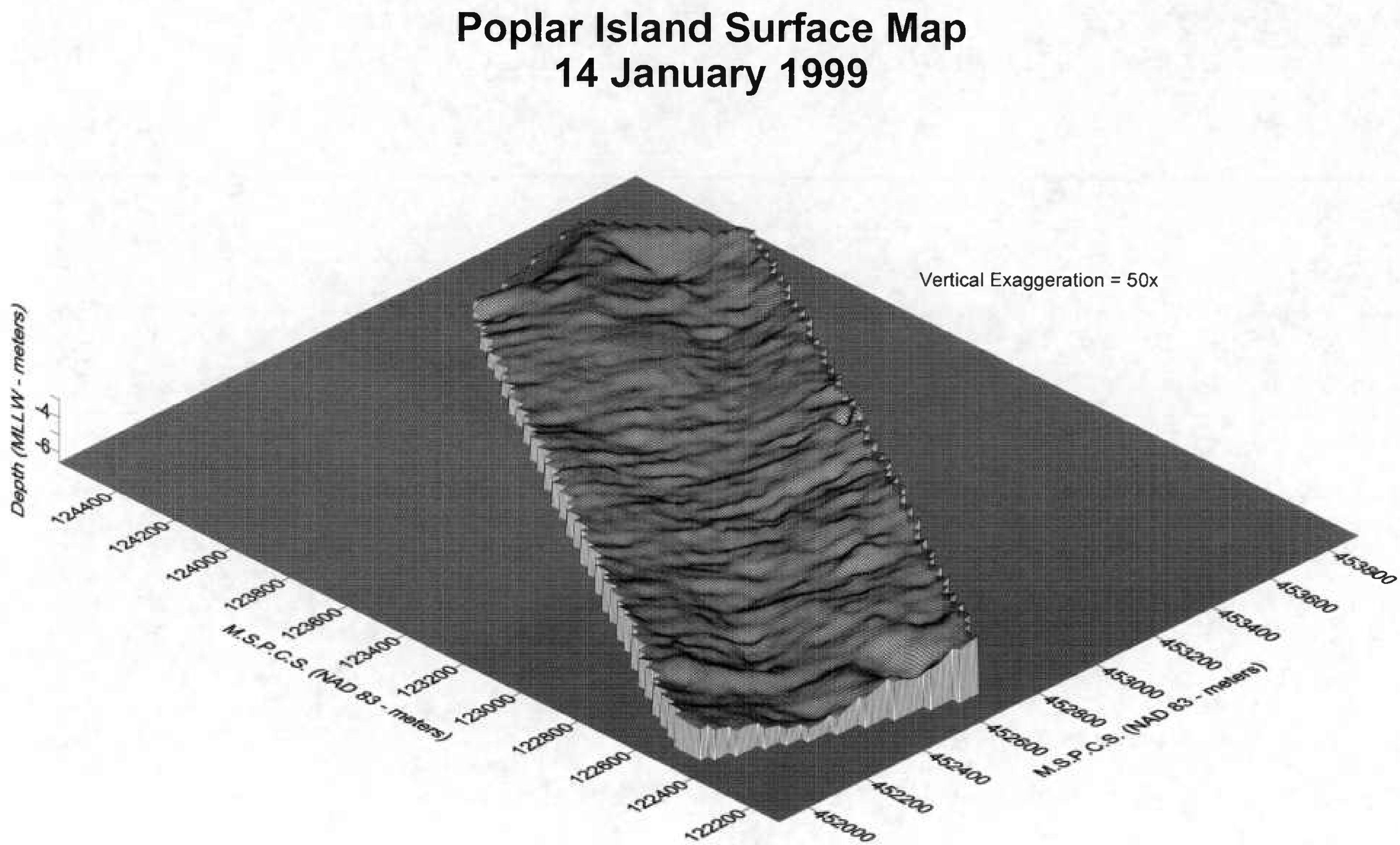


Figure 7: 3-D representation of the bathymetry in the center of NOB 8-10 prior to dike construction.

# Poplar Island Bathymetry
# NOB 8-10
# 10 June 1999

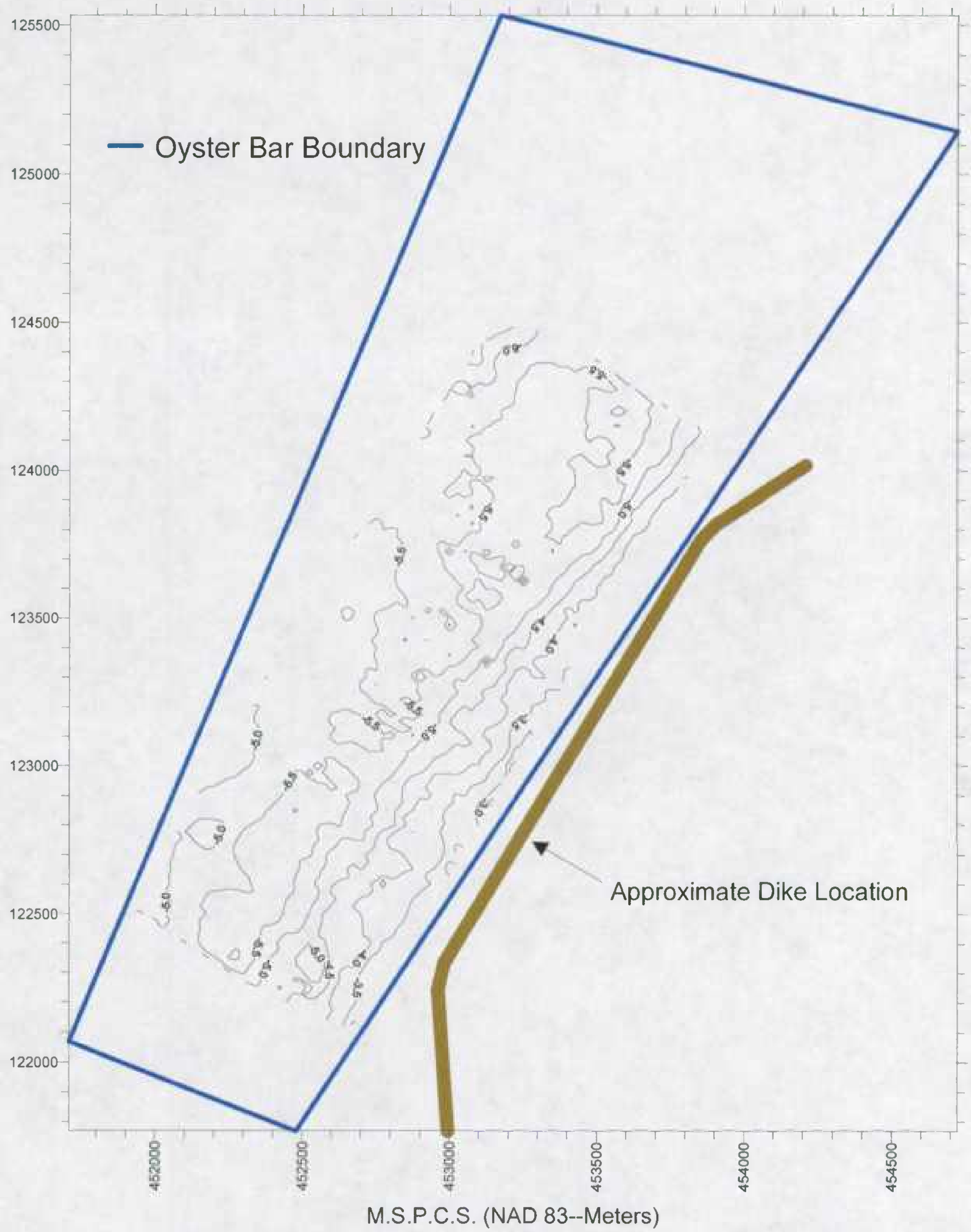


Figure 8: Bathymetry collected in the central portion of N.O.B. 8-10 on 10 June 1999. Contours in 0.5 meter intervals.

# Poplar Island Surface Map
# 10 June 1999

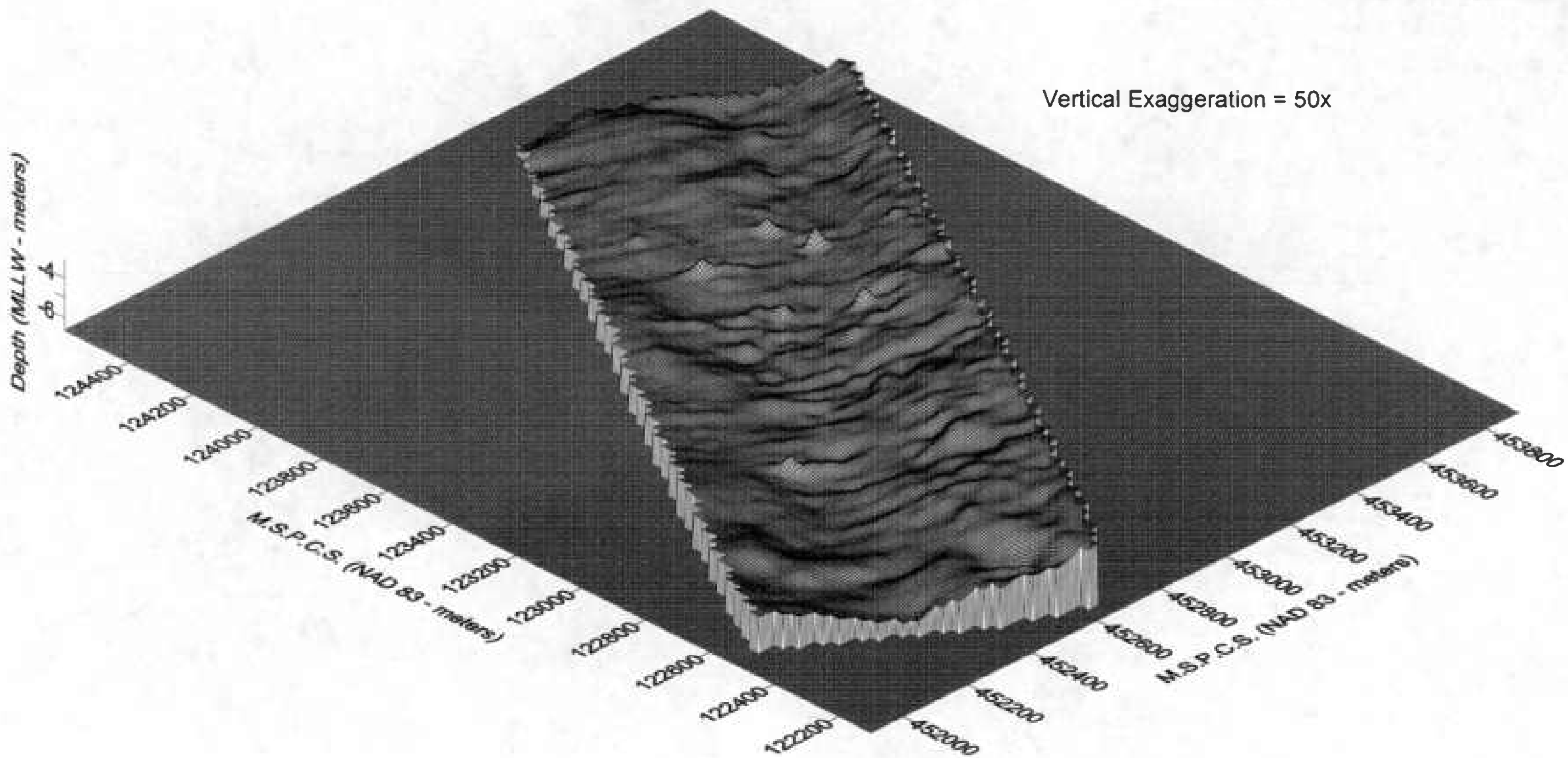


Figure 9: 3-D representation of the bathymetry in the center of NOB 8-10 following dike construction.

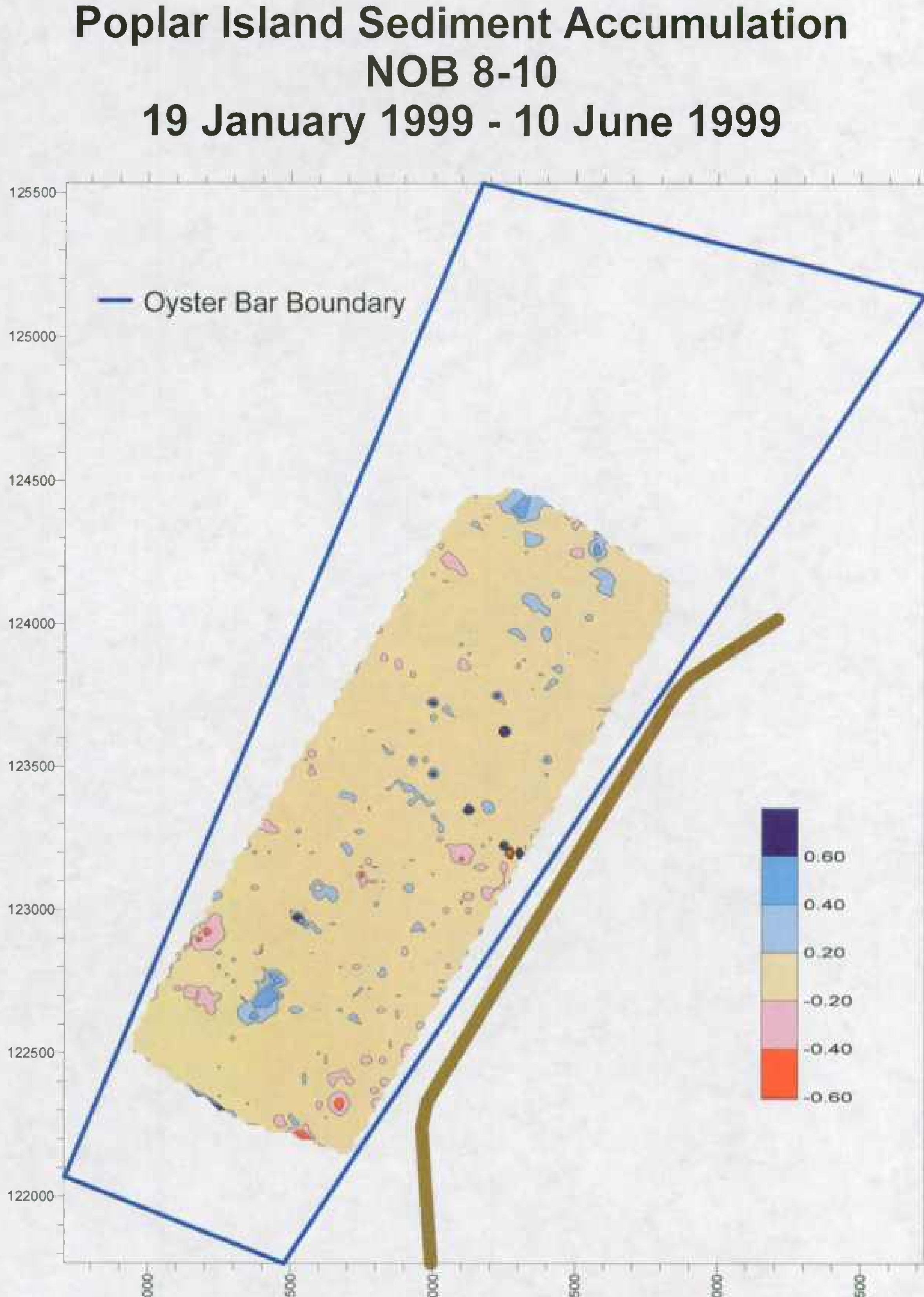


Figure 10: Changes in bathymetry in the central portion of N.O.B. 8-10 between the two survey dates. Differences less than ±20 cm are not resolvable. See text for details.

## PRE- AND POST-CONSTRUCTION SIDE-SCAN SURVEYS

The side-scan survey data were examined to determine if changes were evident, that might suggest that areas where shell was present on the bottom on the pre-construction survey were covered with sand in the post-construction survey. Figures 11 – 14 show selected areas from the survey dates. The locations of these figures are indicated on the track lines shown on Figure 2 and 3. The side-scan results from the line located closest to the dike were difficult to interpret due to excessively shallow water in that area which limited the ability to interpret the outer edges of the records. Thus, data from this line are not shown, and Figures 11-14 concentrate on lines located further from the dike.

Figure 11 shows a portion of the side-scan data collected along the second survey line west of the dike on 14 January 1999. This line was approximately 200 m (656 feet) west of the dike centerline. On this date the side-scan data shows a predominately smooth bottom with some mottled intensity changes and a very small area of variable acoustic energy return, ranging from fairly dark (high return) to very light (no return or shadow areas). These are interpreted to represent small shells or groups of shells on or very near the sediment surface. Much of the mottled tonal differences on this figure resulted from wind generated surface waves that affected the side-scan record. Wave heights on this date were near the limits that permitted collection of usable side-scan data in shallow water.

Following the construction on 10 June 1999 the bottom in this area was predominately featureless with a low intensity acoustic return suggesting a predominately sandy bottom (Figure 12). This sand, which may have resulted from the dike construction activities or from the naturally high sediment mobility in the area, appears to have covered the scattered shell located in this area prior to construction. Some other portions of this survey line showed similar differences between the two dates suggesting a change from the presence of some shell on the bottom to a smoother bottom consisting of sand sized sediments. However, these changes occurred only locally along this survey line. In other areas, the characteristics indicative of shell on the bottom remained the same on both the pre- and post-construction surveys.

Additional side-scan data located further from the dike were examined to determine if this apparent change from exposed shell to predominately sand extended much further from the construction area. The next (3$^{rd}$) line to the west showed some evidence of change, but the areas were more limited in aerial extent. Figures 13 and 14 show the records from the fourth line to the west of the dike. This line was located 300 meters (984 feet) from the dike centerline and 100 meters (328 feet) due west of the records shown in Figure 11 and 12. The quality of the records differs on the two dates due to instrument settings and weather conditions.

On 14 January 1999, (Figure 13) the major characteristic present is a rough feature extending obliquely across the survey line, and most notable on the bottom half of the figure. This feature has the characteristics of a mound of shell material on the bottom. It shows a textured surface with a varying intensity acoustic return and a shadow (light) area located on the side that faces away from the side-scan sensor. This feature is also clearly present on 10 June 1999 (Figure 14). There are scattered small reflectors located in other areas of the bottom along this track line in both Figures 13 and 14. On both survey dates the larger mound of shell noted in the bottom half of the figures has the same apparent relief and shadowing effects, suggesting that little, if any, sand moved over the shell in this area during the period between the two survey dates. Many of the scattered smaller reflectors that were present on the record in January (Figure 13) were also present on the June survey (Figure 14). In the upper right portion of Figure 14, however, a fairly extensive area of limited acoustic reflectivity was apparent in the area that was more mottled and acoustically "rough" in the Figure 13, suggesting that some sand has moved over limited areas of patchy shell in the period between the two survey dates.

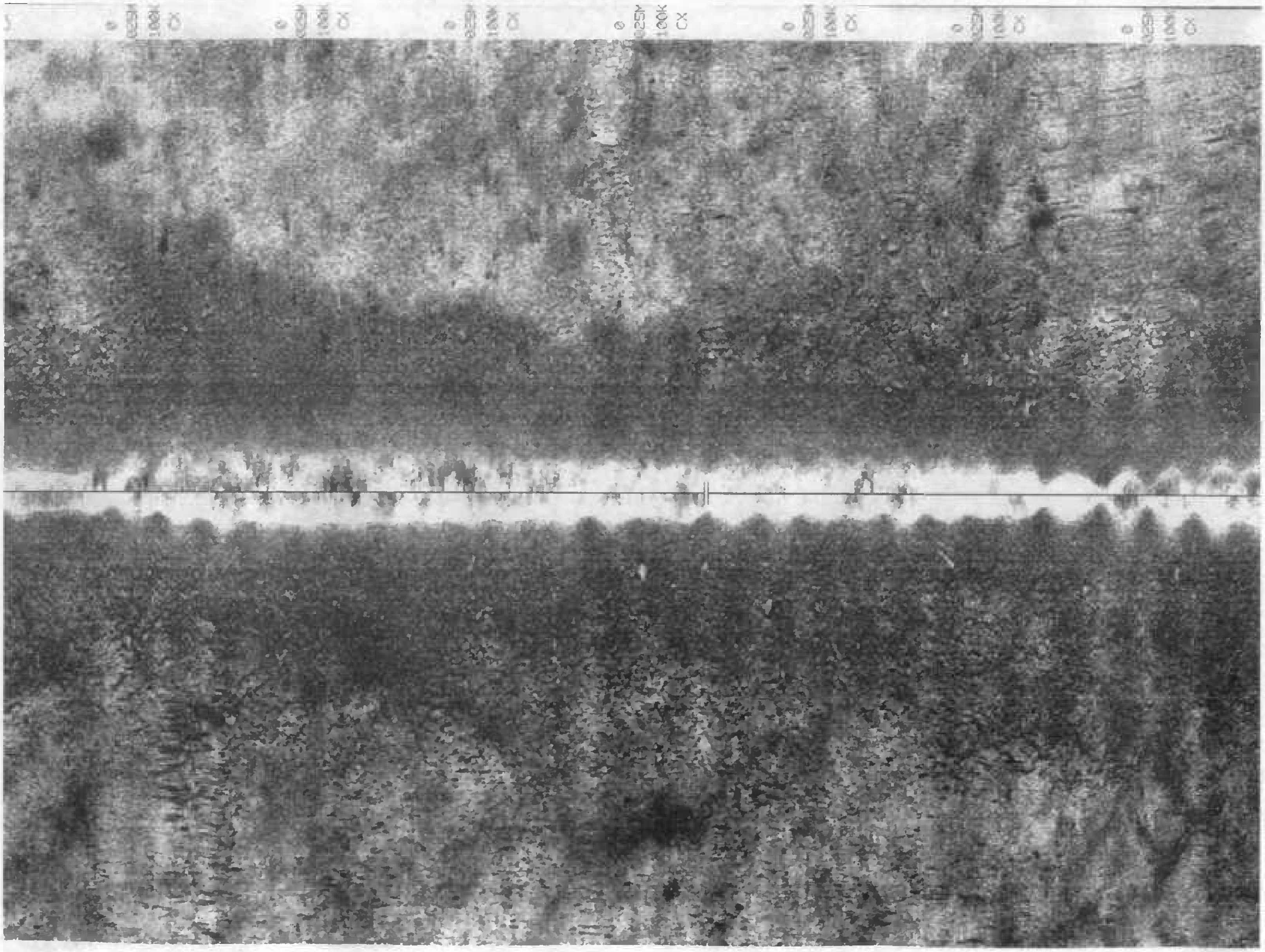

Figure 11: Side-scan sonar record collected along the portion of the trackline identified in Figure 2 on 14 January 1999. The white horizontal area across the center of the image is the vessel's trackline. Record displays the bottom 25 meters to each side of this line. See text for details.

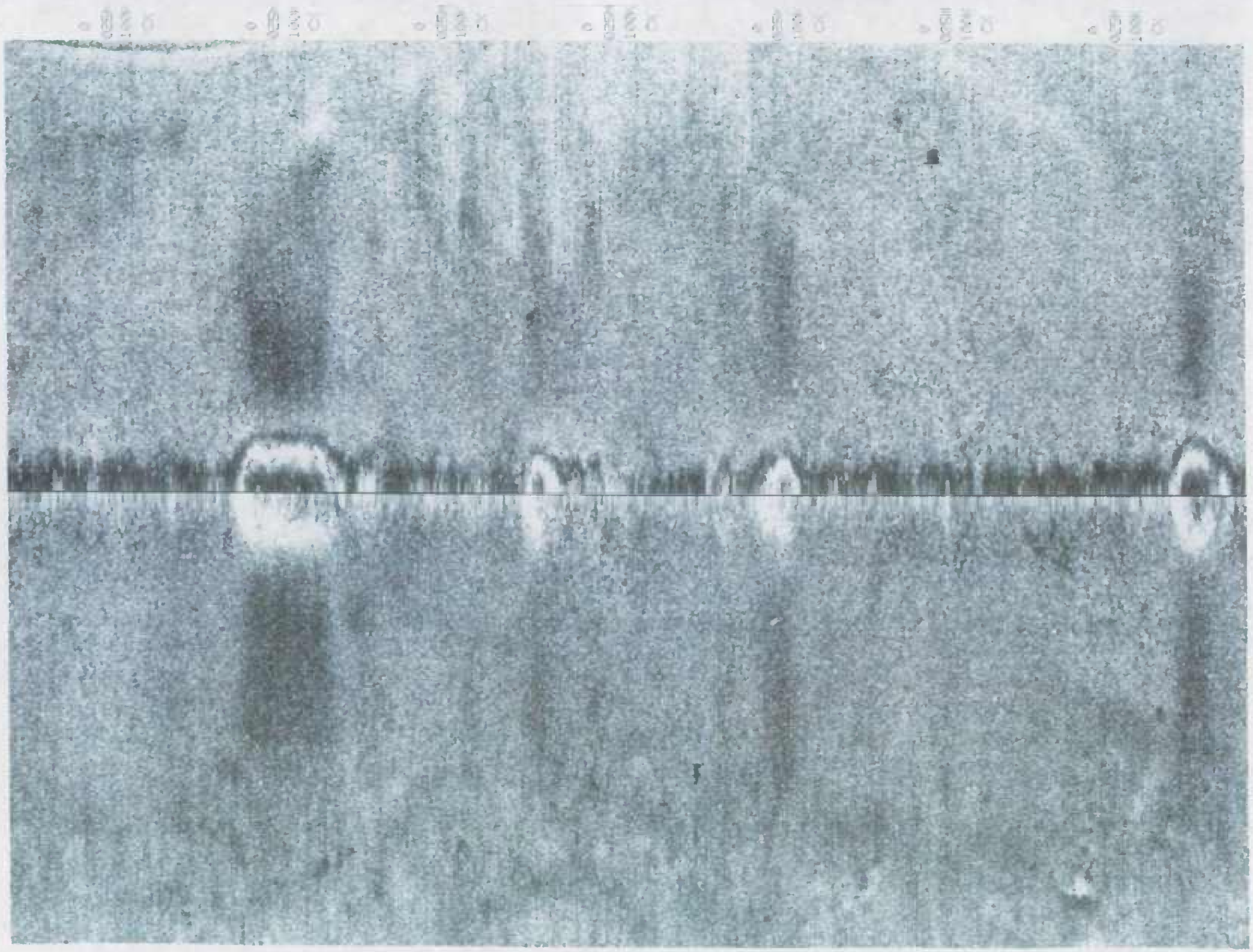

Figure 12: Side-scan sonar record collected along the portion of the trackline identified in Figure 3 on 10 June 1999. The dark horizontal area across the center of the image is the vessel's trackline. Record displays the bottom 25 meters to each side of this line. The elliptical areas located along this line and the dark zones that appear to emanate from them across the image are instrument artifacts. See text for details.

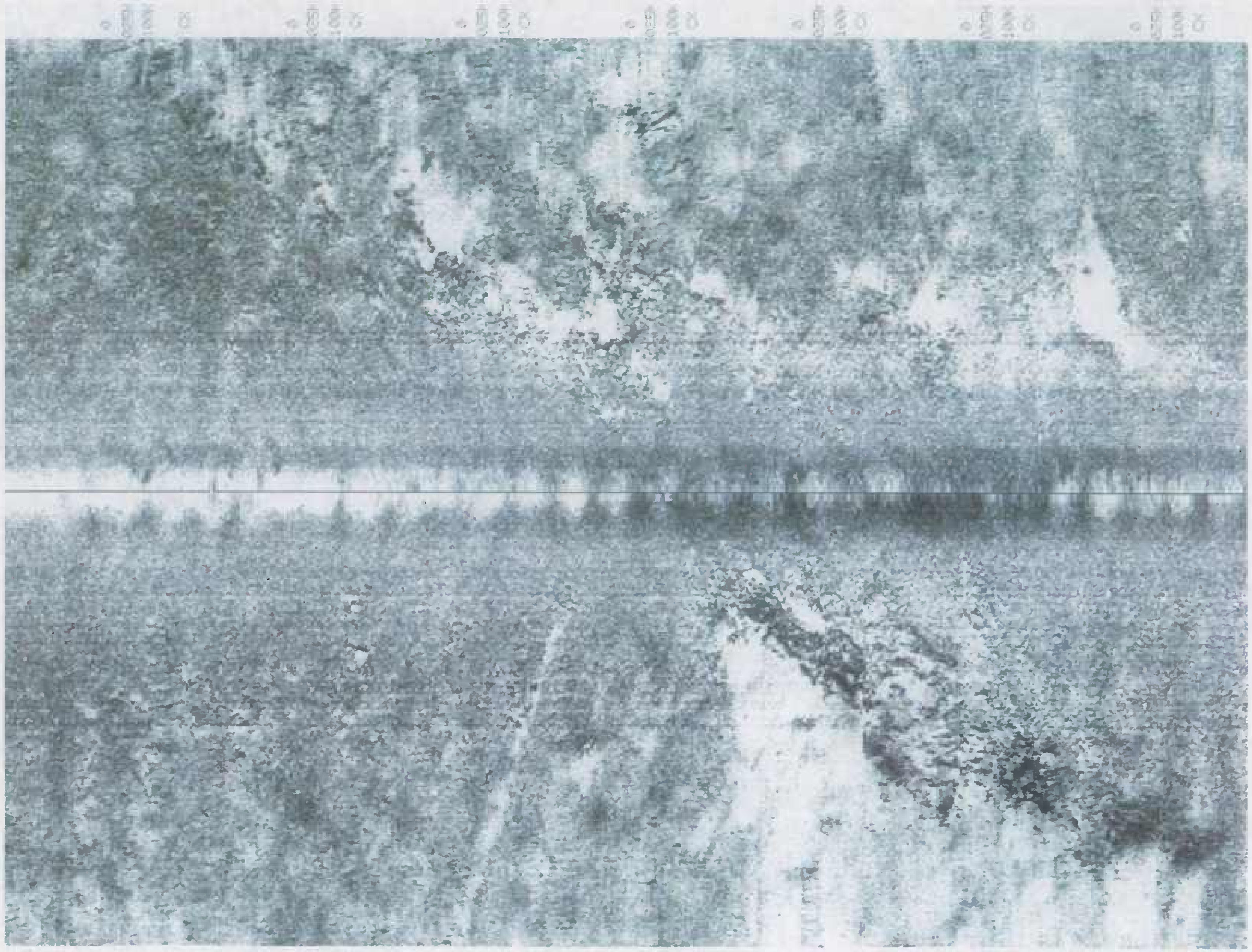

Figure 13: Side-scan sonar record collected along the portion of the trackline identified in Figure 2 on 14 January 1999. The dark horizontal area across the center of the image is the vessel's trackline. Record displays the bottom 25 meters to each side of this line. The wavy white and dark area located along the trackline is the result of instrument motion produced by surface waves. See text for details.

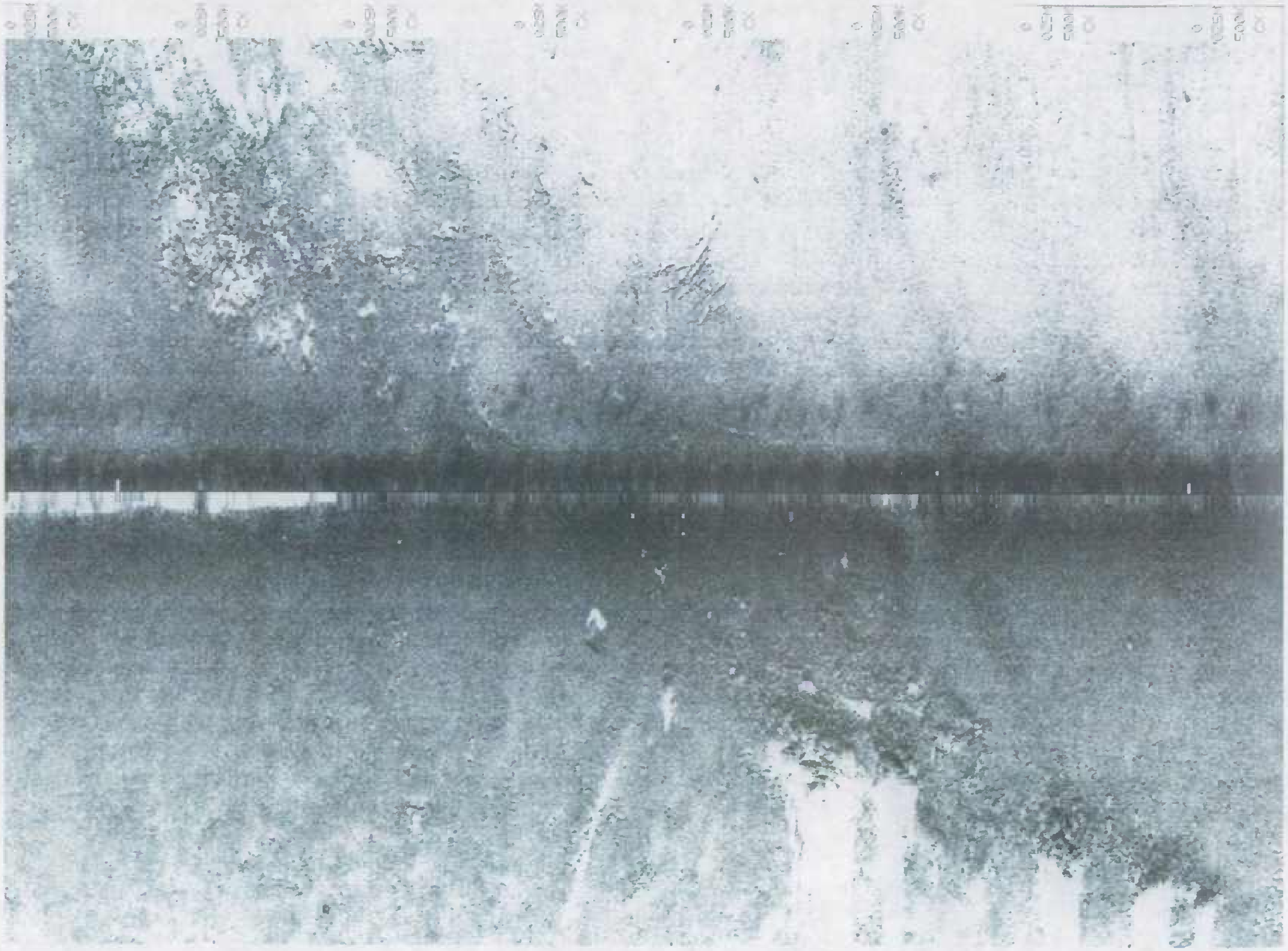

Figure 14: Side-scan sonar record collected along the portion of the trackline identified in Figure 3 on 10 June 1999. The light to dark horizontal area across the center of the image is the vessel's trackline. Record displays the bottom 25 meters to each side of this line. See text for details.

Figure 15 shows an interpretation of the overall changes that occurred on the oyster bar between the two dates. The dotted symbols reflect the track line of the survey vessel and the color-coding indicates the similarities or changes that occurred between the two survey dates. These interpretations were made by close examination of the side-scan records collected on the surveys.

A black symbol indicates that no data comparison was possible between the two survey dates. In the case of the westernmost lines no side scan data was collected in January because the weather conditions had deteriorated so much that the side-scan unit was not operated while bathymetric data continued to be collected. It was considered, at the time, that the possibility of sand moving this far from the dike area was unlikely and the side-scan data was being collected only as an information source that was ancillary to the bathymetric data. Thus, operation of the side-scan unit was discontinued. In addition, the southern half of the second line west of the dike shows no comparison because the side-scan recording paper was being changed during the June survey, so no comparison with the January survey was possible.

The blue symbols indicate areas that were interpreted to be covered with shell on both the January and the June surveys. Thus, no change occurred over the construction period. Most of the southern halves of the third through seventh lines west of the dike were characterized by oyster shells on both survey dates, as were the northern portions of the first and second lines and a few other sections of these lines.

The southern half of the first line west of the dike was sand covered with no shell on both the January and June surveys and is indicated by the red colored symbols. Areas that were interpreted to represent oyster shells covered by sand on both survey dates are shown in yellow. These essentially cover the northern portions of the third through the seventh lines west of the dike. This sand covered shell had the same acoustic characteristics as the area interpreted as "sand movement" shown in Figure 4. No change was interpreted to have occurred in this area during the construction period. It is possible that sand produced by dike construction might have been added to the sand covering the shell already in this area, but any addition would have been relatively thin as no significant change was noted in the bathymetric comparisons.

The green symbols on Figure 15 indicate areas that were interpreted to have shell on the surface in January and sand overlying the shell in June, and includes the areas shown in Figures 11 – 14. The sand that covered the shell in this area might have originated to the northeast of the oyster bar and dike construction area, and resulted from continued sand movement from this area as shown on Figure 4. However, it is likely that this change could have been attributed to dike construction activities because the area where change occurred was most extensive along the easternmost line surveyed, somewhat shorter on the second survey line to the west, and less prevalent on the third line to the west.

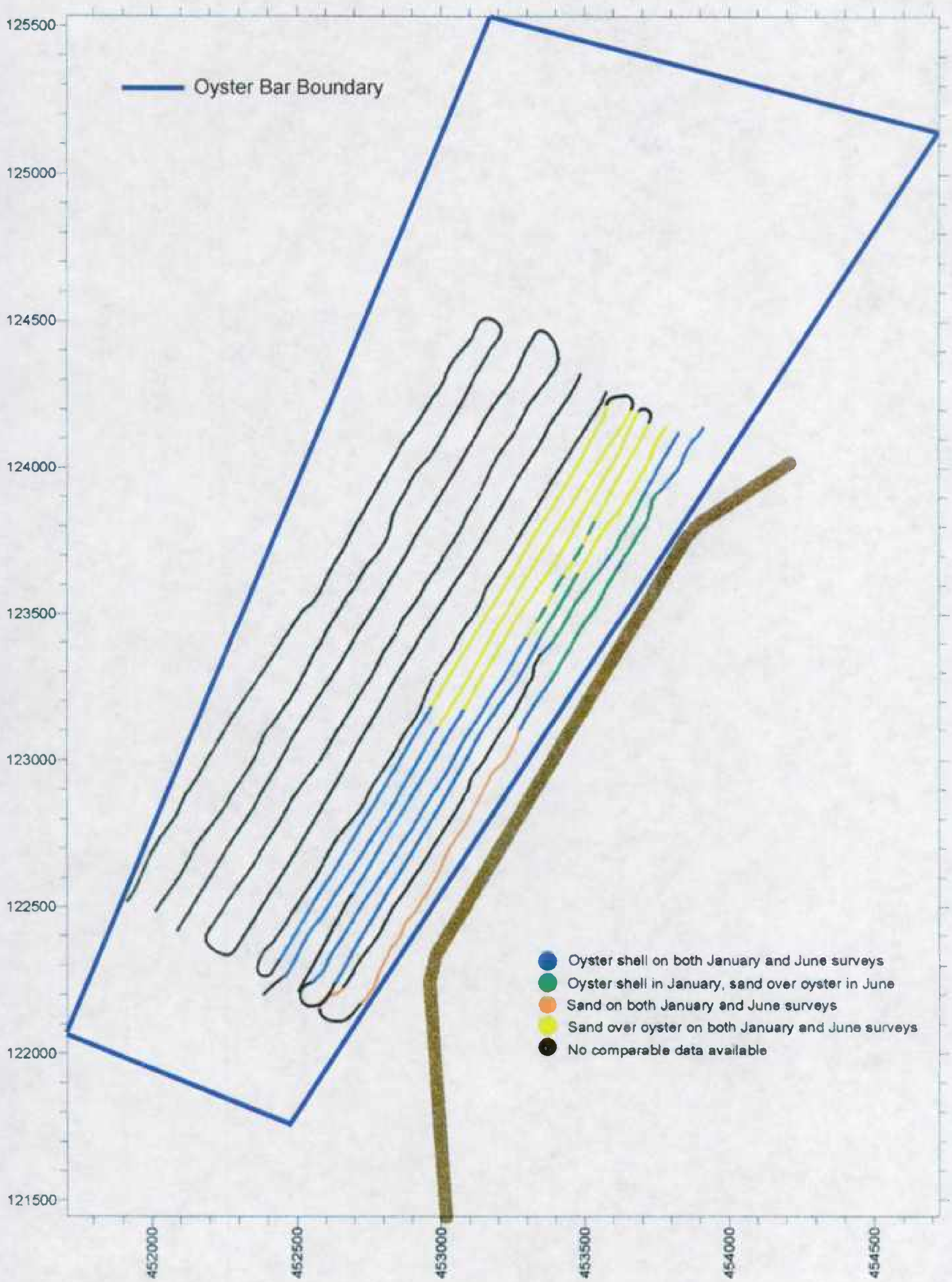


Figure 15: Interpretation of bottom characteristics along tracklines surveyed in both January and June 1999. Colored symbols indicate various sand and oyster shell combinations on these dates.

The fourth survey line west of the dike on Figure 15, shows a hachured area with alternating green and yellow colors. This line showed a mix of exposed shell and sand over shell on both the January and June surveys. Because it lies between the "yellow" and "green" zones described above it was difficult to interpret whether this portion of the surveyed area also experienced some change from shell to sand resulting directly from the construction activities or to the continued dynamic movement of sandy sediments over the shell as was apparent in the area prior to any construction activities.

Due to continued concerns over the potential impacts of sediment accumulation on NOB 8-10, an additional side-scan sonar survey was conducted on 15 August 2000. The tracklines for this survey are shown in Figure 16. The results were mosaiced and are on file at the Maryland Geological Survey, but are not included herein because the mosaic quality hinders interpretation at a page-sized scale. The general extent of the various bottom types exhibited on the three previous surveys (1997 and the pre- and post-construction surveys in 1999), were unchanged on this survey date. The quality of the record on this date precluded fine scale examination of small areas where sediment type may have changed, but the overall conditions of NOB 8-10 as revealed by the side-scan survey were unchanged. Areas that were characterized as rough and shell covered on the previous surveys did not change significantly in this post-construction survey.

# Poplar Island Tracklines
# NOB 8-10
# 15 August 2000

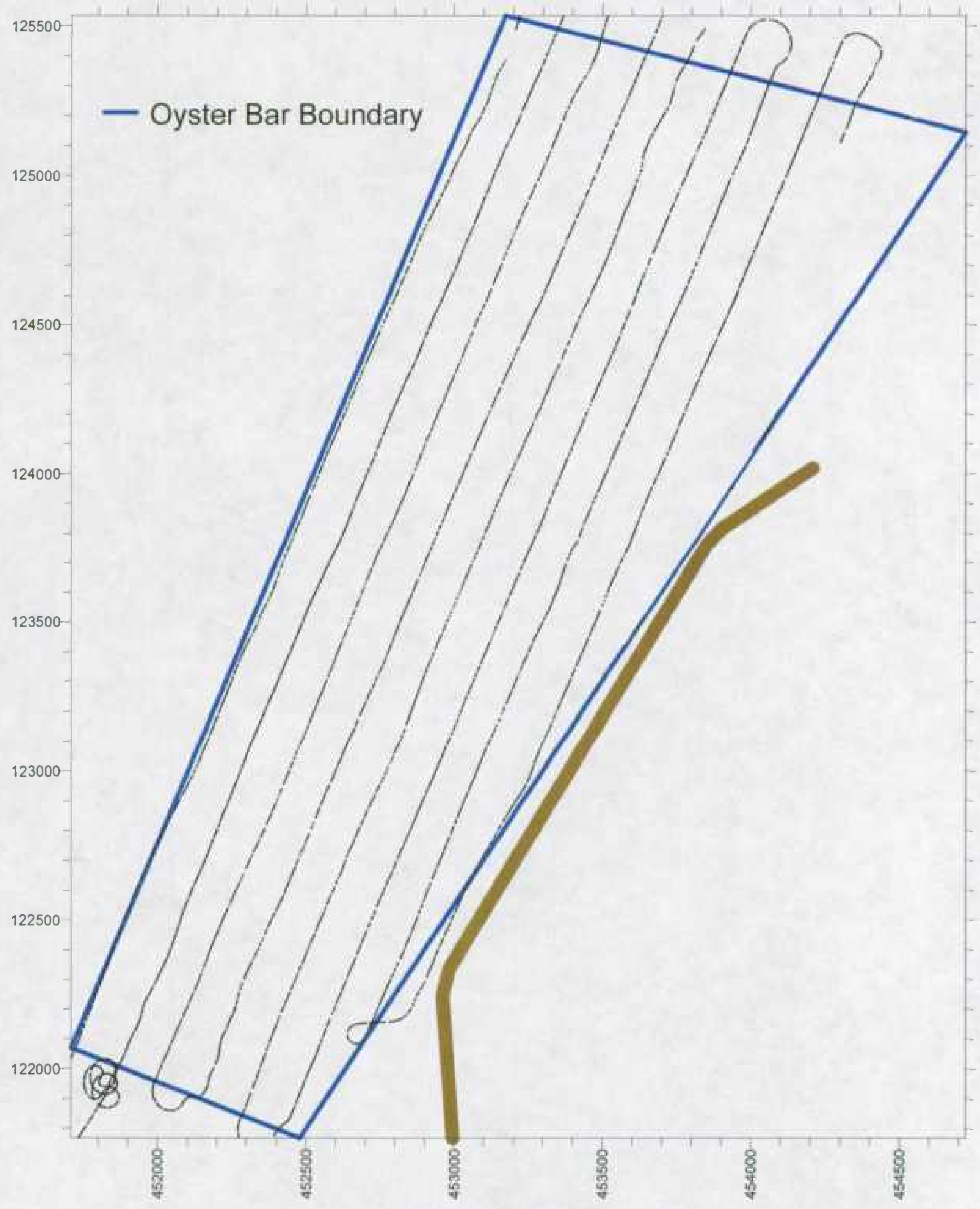


Figure 16. Tracklines for the side-scan sonar survey conducted on 15 August 2000.

# CONCLUSIONS

The pre-construction sedimentation experiments, diver observations, and side-scan survey indicated that sediment mobility within the boundary of NOB 8-10 was naturally high and that sandy sediment had completely covered some areas of shell present on the bottom. The diver observations and placement of colored marker sands and sedimentation plates in the summer immediately preceding construction confirmed the high sediment mobility under natural conditions. Approximately 2 to 3 cm of sandy sediment was observed to be covering oyster shell on much of the bar. This sediment movement was occurring naturally prior to construction activities at the Poplar Island Environmental Restoration Project site. In the month-long period that the marker sediments were on the bottom, they were heavily mixed both downward into the natural sediment and spread across the surrounding area. At one of the study sites, the marker sediment was removed as well as all of the natural sands that were present at the site. This high mobility of the natural and placed sediment was due to the wave energy that affects the bottom across the shallow platform, located west of the Poplar Island Construction site. Wave energies and the resultant sediment movement were high even during the relatively calm late summer period in 1999.

No significant bathymetric changes, that would be indicative of impacts from the construction project, occurred during the 5-month construction period for the western dike. Pre- and post-construction bathymetry, corrected for tidal differences, showed no patterns or trends of sediment accumulation within the limits of resolution. Small areas of change were noted but these could be attributed largely to the presence of crab pots present in June that were not there in January, or to edge effects at the limits of the surveyed area. If sandy sediments had spread outward from the dike construction they would likely have formed a thicker layer close to the dike and thinned with increasing distance. No evidence of this was apparent when the pre- and post-construction bathymetric data were compared (Figure 10).

Pre- and post-construction side-scan sonar records suggested that a thin layer of sandy sediment moved over and covered shell that was present on the bottom in close proximity to the dike. This occurred along some portions of the side-scan record located 250 m (820 feet) west of the constructed dike centerline. Where present, the sediment was apparently a few centimeters thick, enough to cover some objects interpreted as oyster shell on the pre-construction side-scan survey, but not thick enough to cover objects that extended much higher above the bottom. It cannot be definitively stated that any sand that migrated over this area was directly attributable to dike construction. However, no similar change in bottom characteristics were apparent on side-scan records located further than 300 meters (980 feet) from the dike, suggesting that the source of the sediment was related to construction activities. This amount of sediment accumulation was similar in thickness to that identified on portions of NOB 8-10 prior to any construction activities, confirmed by diver observations, and due to natural sediment movement over the portions of NOB 8-10.

A follow up side-scan sonar survey conducted on 15 August 2000 showed bottom conditions similar to those that were present in 1999 and 1997. Much of the central portion of NOB 8-10 exhibited a rough and irregular bottom indicative of a layer of oyster shells. Sandy bottom located in the southwest, southeast, and northeast portions of the mapped bar were still present on this date, as were the muddy sediments with dredging scars that were observed in 1997 (Figure 4). There was no evidence of much accumulation of additional sand over oyster shells on the bar, nor was there evidence that the sand that was over the shell on the previous survey had been removed because of proximity to the Poplar Island Environmental Restoration Project.

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